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Identifying and managing asbestiform minerals in geological collections

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Abstract

Asbestos is widely recognised as a serious hazard, and its industrial use is now banned within the UK, and EU, and strict regulations govern the use of older manufactured materials which may contain asbestos. However, asbestos is also a natural geological material, and may occur in museum collections as minerals or constituents of rock specimens. In the UK the Control of Asbestos Regulations 2012 (CAR 2012) provides the legal framework for the safe identification, use and disposal of asbestos. However, these regulations, and other EU regulations, provide no specific guidance on dealing with potentially asbestos-containing natural materials. CAR 2012 specifies just six asbestos minerals although a number of other minerals in museum collections are known to have asbestiform structures and be hazardous, including other amphiboles, and the zeolite erionite. Despite the lack of specific guidance, museums must comply with CAR 2012, and this paper outlines the professional advice, training and procedures which may be needed for this. It provides guidance on identification of potential asbestos-bearing specimens and on procedures to document them and store them for future use, or to prepare them for professional disposal. It also makes suggestions how visitors, employees and others in a museum can be protected from asbestos as incoming donations and enquiries, managed in the event of an emergency, and safely included in displays.

Key words: Asbestos minerals; Hazardous fibrous minerals; Asbestos management; The Control of Asbestos Regulations, 2012; Health & safety

Introduction

Asbestos is a hazardous substance, and most countries now have legislation restricting and controlling the use and management of asbestos in the workplace (e.g. WHO, 2014). Asbestos is now widely understood as an issue in museum collections, and well-tested procedures to ensure legal compliance have been devised for asbestos present in social and industrial collections, where it may be a component added in the manufacture of an object or artefact. However, all forms of asbestos also occur in nature, and this is barely considered by any current legislative or regulatory frameworks.

Many geological collections will include natural specimens which meet legal definitions of asbestos, or which present similar risks, and accordingly, in the UK at least, there is a legal requirement to manage this risk. However, there is currently little formal guidance as to how this should be done, as all current UK legislation and EU directives have been drafted to deal only with the risk from asbestos in industrial use, and manufactured items and materials.

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As with the management of radioactive mineral specimens or objects, any institution which holds asbestos will need to obtain professional advice at some stage in the process of legal compliance. However, natural asbestos in collections poses a far greater challenge than radioactivity. There is no simple means of measuring or quantifying the hazard instrumentally, as can be done with radioactivity, and in the UK at least, the asbestos regulatory framework is much more specific about management and mitigation approaches.

This paper, the second in the series dealing with hazardous geological materials in museum collections, examines some issues relating to natural asbestos, and provides practical advice to ensure legal compliance, and the safe custodianship of asbestos-bearing geological specimens. The relevant UK legislation is *The Control of Asbestos Regulations* 2012 (CAR, 2012; HSE, 2012a), which provides the legal framework for working with and managing asbestos to minimise release of fibres. It is enforced by the Health and Safety Executive and local authorities. As this legislation is derived from EU directive 2009/148/EC, measures suggested in this paper should, in general, be appropriate for collections housed in other parts of the EU, subject to differences in control limits for asbestos fibres (currently in the UK 0.1 fibres/cm^3 of air measured over a continuous 4 hours).

Asbestos: what is it?

Asbestos is not a single substance but a term used to refer to commercially extracted forms of the serpentine and amphibole groups of minerals which have particular chemical compositions and textural properties. In current UK legislation (CAR 2012) 'asbestos' specifically means any of the following:

- asbestos actinolite
  CAS No 77536-66-4
- asbestos grunerite (amosite)
  CAS No 12172-73-5
- asbestos anthophyllite
  CAS No 77536-67-5
- Chrysotile
  CAS No 12001-29-5 or CAS No 132207-32-0
- crocidolite
  CAS No 12001-28-4
- asbestos tremolite
  CAS No 77536-68-6

(The codes after the mineral names refer to CAS Registry Numbers assigned to chemicals by the Chemical Abstracts Service, a division of the American Chemical Society. Although these are included in UK legal definitions, they provide no useful information of either a geological or practical nature.)

In UK law the term 'asbestos' is also used for any material containing any one of the listed minerals or mixtures of these minerals in 'more than trace amounts'. A trace amount is defined by CAR 2012 as 1 or 2 fibres being identified in a sample using a stereo microscope or scanning electron microscope after examination for ten minutes (HSE, 2005). Whilst this definition works well for the purpose of identifying industrial asbestos in a wide range of commercial products and construction materials, it is of very limited use when applied to natural rocks and minerals.

One major problem is that the UK Control of Asbestos Regulations 2012 provides no definition of 'fibrous'. The term is used by mineralogists in a wide range of subjective ways, most of which are certainly distinct from what they would regard as asbestiform (e.g. Clinkenbeard, 2002). Asbestos fibres are defined under US guidance (EPA/600/R-93-116, Appendix A) as showing all of the following criteria:

Length	A mean aspect ratio from 20:1 to 100:1 or higher for fibres longer than 5 µm
Width	Very thin fibrils (individual components of fibre bundles), usually less than 0.5 µm in width
Form	Two or more of the following criteria: Parallel fibres occurring in bundles; Fibre bundles displaying splayed ends; Matted masses of individual fibres and/or fibres showing curvature.

Clearly these criteria require use of microscopy. However they do not address the broader issue of initial risk assessment, and deciding on thresholds where such resource-intensive techniques may be required.

To comply with legislation and safeguard those in the vicinity of or working with collections, it is important to be able to establish which specimens present a risk. Paraphrased, Regulation 5 of CAR 2012 states that if there is any doubt as to whether asbestos is present there is an obligation to assume that it is. This either means being able to differentiate between asbestos and non-asbestiform varieties of the minerals listed in the legislation, or erring on the side of caution and including specimens which might not prove to be asbestiform.

An additional complexity is that although asbestos is always fibrous by definition, geological 'asbestos' specimens will often be texturally variable, and it may be hard or impossible to provide a definitive statement as to how much, if any, material in natural specimens meets legal definitions of asbestos.

Who can identify asbestos?
UK legislation specifies that only a United Kingdom Accredited Service (UKAS) accredited specialist laboratory can provide a legally sound opinion as to whether asbestos is present or not. Such laboratories follow strict protocols for the handling and analysis of the standard industrial asbestos materials as defined in UK law. However, there are no protocols for the assessment of asbestos in natural geological materials, and in any case the potential mineralogical diversity of natural materials means that the methods used in asbestos labs will not uniquely or reliably distinguish asbestos from non-asbestos minerals.

It is also important to note that, in the UK, most specialist mineralogists, academic or curatorial, would not be considered legally competent to identify materials as being asbestos or not, unless they have UKAS accreditation and follow the appropriate protocols, even though these have not been designed to work with natural materials. This obviously leaves something of a "Catch-22" situation for those wishing to accurately assess and manage risk associated with natural rocks and minerals.

Identifying asbestos in geological collections
Many asbestos specimens will be labelled or recorded as such in museum records, and examination of registers and catalogues should always be an early stage of risk assessment. By looking for the word 'asbestos', or a variety of other trigger terms (see Table 1) it is possible to remotely identify parts of a collection which are likely to present significant risk.

However, in addition to the asbestos minerals listed in the legislation (Figs 1-6) there will be specimens which present a risk, but may not be labelled as containing these minerals. Examples include nemalite, a highly fibrous form of brucite, which although not hazardous, is intimately associated with chrysotile (Berman, 1932); garnets from Valmalenco, Italy and Asbestos, Quebec, Canada which are commonly associated with chrysotile; and epidote from a number of Alpine localities which may occur with actinolite asbestos. Many other possible associations with asbestos minerals exist, and routine curatorial training should include ensuring awareness that asbestos present in rock and mineral specimens may not be recorded in associated documentation. Asbestos minerals usually occur in low to medium grade metamorphic rocks, and ultrabasic or basic rocks. This means rock names such as serpentinite and metagabbro should also be regarded as potential asbestos trigger terms.

There is also debate surrounding the status of elongate cleavage fragments of the tremolite-actinolite group of minerals, but which do not meet the criteria for asbestiform fibres as shown on page 52. This includes the variety byssolite. Bailey *et al*. (2003) provide a synopsis of published research to suggest that these should not be considered an asbestos hazard. This somewhat conflicts with the NIOS (US National Institute for Occupation Safety)

Table 1. The main synonyms and variety names for asbestos and other hazardous asbestiform minerals, and other trigger terms.

General:	asbestos, asbestus, amianthus, asbestiform
Actinolite:	attinoto, byssolite, ferro-tremolite, manganactinolite, silbölite, Strahlstein, stralite, zillerthite/zillertite
Anthophyllite:	antholite, antholith, anthogrammite, anthophylline, grey asbestos, kupfferite, magnesio-anthophyllite strelite, thalacerite
Chrysotile:	asbophite, bastite, bostonite, clinochrysotile, faserserpentine, karystiolite, kuphoite/ kupholite, lefkasbestos, marmolite, metaxite, orthochrysotile, parachrysotile, picrosmine/Pikrosmin, pyroidesine, retinalite, schweizerite, serpentine, serpentinite, thermophyllite, vorhauserite, white asbestos Other serpentine group minerals that are very commonly mixed with chrysotile are: alumoantigorite, antigorite, Blätterserpentin, ferrolizardite, lizardite, picrolite, porcellophite, zermattite
Erionite:	no known synonyms but was once thought (erroneously) to be identical to offretite so check entries under this mineral
Grunerite:	amosite, brown asbestos
Richterite:	astochite, astorite, isabellite, kalio-magnesio-katophorite, magnophorite, mangan-tremolite, marmairolite, natronrichterite, Natrongrammatit, richterite-asbestos riebeckrichterite, simpsonite, soda richterite, soda tremolite, Szechenyiit/Szechenyit, tremolite-glaucophane-richterite, waldheimite
Riebeckite:	abriachanite, blue asbestos, blue ironstone, cape blue, crocidolite, mangan-crocidolite, Mangan-krokidolith, orthoriebeckite, osannite
Tremolite:	abkhazite, calamite, grammatite, Grammatit-Strahlstein, hoepfnerite, kalamite, nordenskiöldite, peponite, raphilite, sebesiteraphilite, smaragditic, Strahlstein, Tonerdehaltiger
Winchite:	eckrite

This list has been compiled mainly from Clark (1993) and is not comprehensive. A few of the names have also been used for other mineral species.

Fig. 1. Asbestiform actinolite from Austria (OUMNH-Min9250, specimen c.90 x 80mm).

publication of 2011, which presents an agenda for research to provide more robust evidence supporting or disproving this claim.

The volume of asbestos specimens in mineral collections will obviously vary from one museum to another, but is likely to be small. For example the National Museum of Wales mineral collection (34,000 registered specimens) contains just 0.5% asbestos minerals, whereas the Oxford University Museum of Natural History, which has similar sized total holdings, includes a substantial asbestos mineral research collection so contains 1.7%.

Fig. 3. Single packaged specimen of anthophyllite (OUMNH-Min22006, specimen c.95 x 50mm). Scandinavia, particularly Finland, is the main producer of commercial anthophyllite.

Fig. 2. Single packaged specimen of grunerite from South Africa (OUMNH-Min21564, specimen c.150 x 135mm). This mineral is known commercially as brown asbestos or amosite (from the acronym for the 'Asbestos Mines of South Africa').

Outside the law: hazardous fibrous minerals not covered by legislation

Discussion so far has focused on the fibrous minerals covered by legislation. Bailey *et al.* (2003) suggest that there may be as many as 100 mineral species capable of being fibrous, although such habits are typically quite rare. Unlike the six minerals listed in CAR 2012, evidence of detrimental health effect for these other minerals is generally lacking, or the data equivocal. Bailey *et al.* (2003) suggest that there is no compelling evidence that the fibrous nature of these minerals alone makes them hazardous and that factors such as biodurabilities (retention of the fibres in the body), bioactivity, and bioavailability can influence how active, and therefore hazardous, they are. Of the minerals for which data from mortality studies or laboratory experiments exist, they concluded that, asbestiform richterite, asbestiform winchite, and the zeolite group mineral erionite present a hazard equal to that of industrial asbestos. Research suggests that erionite may present a greater hazard than gruner-

Fig. 4. Chrysotile vein (NMS G.1908.36.5). Chrysotile, also referred to as white asbestos, is the most commonly used asbestos mineral.

Fig. 5. Crocidolite, also known as blue asbestos, is a variety of the amphibole riebeckite. (top: OUMNH-Min16130, specimen c.60 x 32mm; bottom: OUMNH-Min26175 from Australia, 53mm high tube).

ite (commercially known as brown asbestos) (Wagner *et al.,* 1985) and this may be a product of voids in the crystal lattice in addition to its fibrous nature (Coffin & Ghio, 1991). At present these minerals are not included within legislation. Erionite was original identified as a hazard in altered volcanic rocks in the Cappadocia region of Turkey but has been identified by the US Geological Survey in twelve US States (Sheppard, 1996). Wollastonite, palygorskite (referred to as attapulgite in the text) and sepiolite are also mentioned in the literature (WHO, 1986), and implicated as potentially hazardous, but Bailey *et al*. (2003) suggest that this status is unfounded. Once again until established as safe, the best approach is to treat all fibrous minerals with care to prevent fibre release.

Managing asbestos specimens in collections

The Control of Asbestos Regulations 2012 (CAR 2012) provides the legal framework which dictates how asbestos is managed, and general guidance on compliance is provided by the HSE document *Managing and working with asbestos* 2013. Although they are not listed, we would recommend including erionite, finely fibrous winchite, and finely fibrous richterite, in any work carried out to comply with this legislation.

There are several steps in the process of ensuring that asbestos specimens in collections are well managed. These comprise:

- Training and background research
- A desk study to scope the occurrence or likelihood of asbestos minerals in the collection

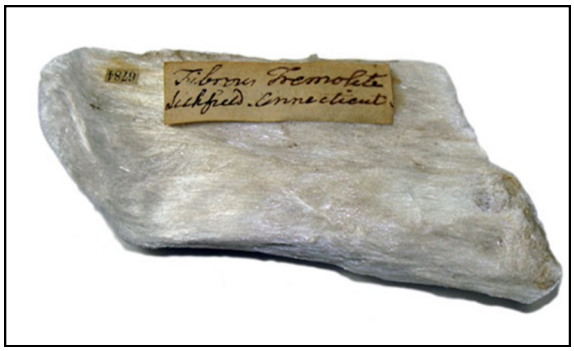


Fig. 6. Fibrous tremolite from the USA (OUMNH-Min6784, specimen c.93 x 40mm).

- Verifying the desk study through a specimen survey
- Establishing if areas where minerals have been stored or displayed are contaminated by asbestos fibres
- Decontamination of contaminated areas
- Controlling the release of fibres
  - Encapsulation of asbestos specimens OR
  - Disposal of asbestos specimens
  - Enclosing the specimen in airtight Perspex type boxes
- Establishing procedures for safe working with actual specimens

Training

Before any attempt is made to access specimens, or undertake any work related to the possible presence of asbestos specimens in collections, it is essential that staff receive appropriate training. It is a legal requirement (regulation 10, CAR, 2012) that employers provide adequate training for anyone who may be exposed to asbestos fibres, which includes asbestos-containing materials (ACMs) or asbestos-containing objects (ACOs), so they are aware of these substances and the risks they present. There are two UK levels of training that are relevant to those dealing with geological collections:

- *Asbestos awareness*
- *Non-licensable work with asbestos*

Asbestos awareness training covers the legal definition of asbestos, the health effects of exposure to asbestos, and key aspects of managing asbestos-bearing specimens (e.g. labelling and packaging). It also outlines the emergency procedures to follow should asbestos fibres be released accidentally, and how to avoid the risk from exposure to asbestos. An overview of the relevant legislation (CAR, 2012 and REACH, 2013 - see page 60) is included along with the different categories of asbestos work (e.g. licensed and non-licensed), and what level of training is required to undertake them. This training provides no specific mention of museum collections, but is essential for any museum staff, or vol-

unteers who may come across asbestos, natural or otherwise (see HSE, 2015a for further information).

Further training in *non-licensable work with asbestos* may be needed for specialist staff who carry out work on asbestos specimens where fibres could be released. These would typically be curatorial, conservation, or academic users of geological asbestos specimens. Again, this training may not currently include any specific mention of asbestos in natural or geological materials, but it does provide essential background to safe working. *Non-licensable work with asbestos* includes a more detailed understanding of the legislation, how to work safely with asbestos specimens (e.g. drafting plans of work and emergency procedures), the correct selection and use of personal protective equipment (PPE) and respiratory protective equipment (RPE), and dealing with asbestos waste. The training also covers completing risk assessments for work involving asbestos, writing plans of work to specify how this should be undertaken, and the writing of emergency procedures to deal with the accidental release of fibres. This training must cover the specific tasks that trainees will be undertaking, e.g. surveying mineral specimens during completion of a risk assessment, packaging asbestos specimens in a negative pressure air unit, and disposing of asbestos contaminated packaging. As with *asbestos awareness,* it must be refreshed yearly and the training customized to cover any new procedures or tasks included within the trainee's work.

Do we have a problem? Scoping the Risk

All organisations are required to hold and keep up to date an Asbestos Management Plan (AMP) for all known asbestos-containing materials/objects to help manage the risks. If exposure cannot be prevented, an Asbestos Management Policy should be implemented to indicate the safe working procedures that will be adopted and the documentation that must be kept up-to-date. Organisations should already have this in place for the fabric of the building so that any asbestos is documented, identified and managed (not necessarily removed). The AMP also applies to collections, and where social and industrial collections are also held by the museum, this may have already been initiated. For the sake of clarity it is preferable to have separate plans for collections and buildings.

The first stage in developing an AMP is to scope what specimens within the collections are are known or suspected to be either asbestos or asbestos-containing, and document these in an Asbestos Risk Register. The specimen registration or reference number, the storage location and the mineral or rock name should be listed in the register, so that the nature and location of all suspected material is recorded (an Excel spreadsheet is ideal). This is undertaken through a desk study using existing collection information. Care should be taken to include any unregistered specimens; minerals where asbestos is present but not the main constituent; and all relevant rock types and specimens from known asbestos localities. It is probably impossible to adequately complete this exercise without the involvement of a mineralogist or petrologist, so you may need to get outside help.

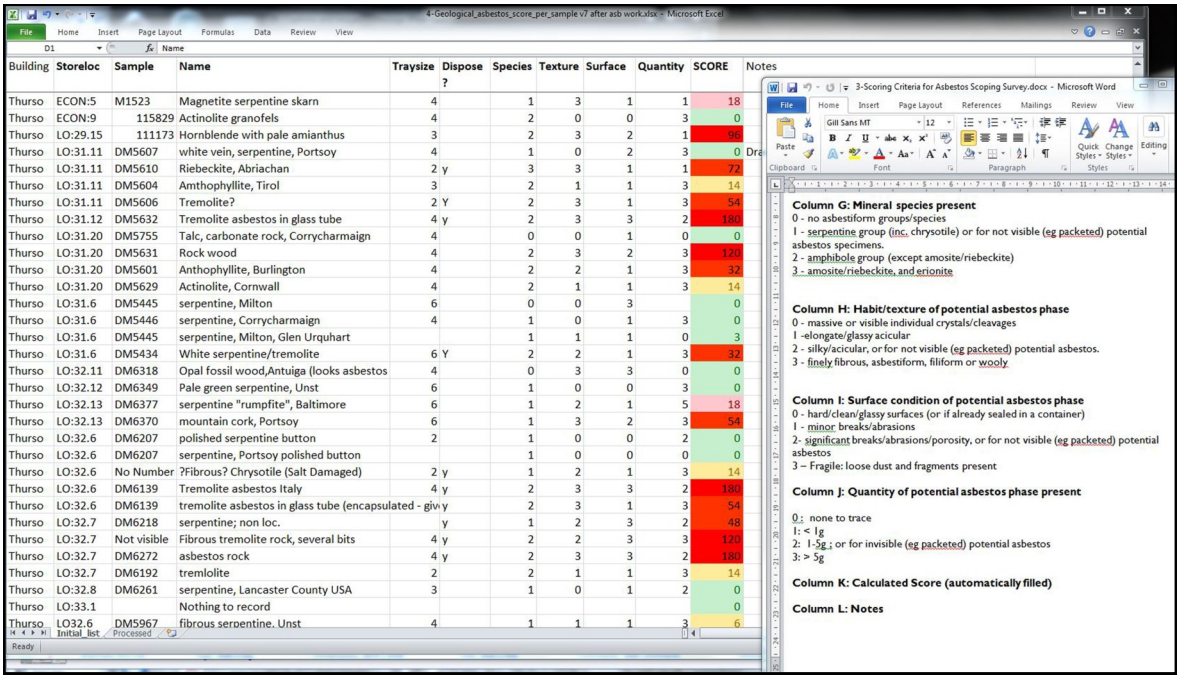
As mineral collections almost always contain historic specimens curated prior to standardisation of nomenclature, Table 1 provides a list of mineral names to check in addition to those listed in CAR 2012 and the three additional minerals mentioned above. This list is for guidance and is not exhaustive.

If no specimens are identified at the desk study stage as being asbestos or potentially asbestos, then no further action need be taken. However there should be continued vigilance and awareness of ACOs in case undocumented material is located subsequently, or specimens are presented as enquiries. Appropriate procedures should be developed for such situations (see page 60).

Identification/assessment of asbestos specimens

Once actual or potential asbestos specimens have been identified, you need to establish whether it is safe to work in the area containing these materials. If current building asbestos monitoring has not already shown that these areas are free of airborne and surface asbestos contamination, you must restrict access until a sampling program, carried out by an accredited asbestos laboratory, has demonstrated that the area is safe. Your organisation's health and safety officer will be able to advise on contractors to undertake sampling and analysis.

You should label any storage units with warning signs to indicate asbestos hazard and lock or secure them so that they cannot be opened accidentally (for details and examples see HSE, 2013, p110). These actions should be reported to the relevant managers and those with a specific responsibility for health and safety. Only those who have completed *non-licensable work with asbestos* training within the last 12 months, who are wearing appropriate PPE and PRE, and who follow the correct control measures may enter an area containing asbestos minerals, unless it has been certified as safe. In some instances air monitoring must be undertaken to enable a person's fibre exposure levels to be recorded, such records to be retained for a minimum of 40 years. An asbestos consultant will advise on this. The correct control measures include a risk assessment and plan of work (also known as a Method Statement). Personal protective equipment must be of the correct grade (specifications are covered in *non-licensable work with asbestos* training), including masks for which users have been face-fit tested and certified to use. Cabinets or storage units containing potential or actual asbestos specimens within an area identified as (or suspected of being) contaminated by asbes-



Building	Storeloc	Sample	Name	Traysize	Dispose ?	Species	Texture	Surface	Quantity	SCORE
Thurso	ECON:5	M1523	Magnetite serpentine skarn	4		1	3	1	1	18
Thurso	ECON:9	115829	Actinolite granofels	4		2	0	0	3	0
Thurso	LO:29.15	111173	Hornblende with pale amianthus	3		2	3	2	1	96
Thurso	LO:31.11	DM5607	white vein, serpentine, Portsoy	4		1	0	2	3	0
Thurso	LO:31.11	DM5610	Riebeckite, Abriachan	2	y	3	3	1	1	72
Thurso	LO:31.11	DM5604	Amthophyllite, Tirol	3		2	1	1	3	14
Thurso	LO:31.11	DM5606	Tremolite?	2	Y	2	3	1	3	54
Thurso	LO:31.12	DM5632	Tremolite asbestos in glass tube	4	y	2	3	3	2	180
Thurso	LO:31.20	DM5755	Talc, carbonate rock, Corrycharmaign	4		0	0	1	0	0
Thurso	LO:31.20	DM5631	Rock wood	4		2	3	2	3	120
Thurso	LO:31.20	DM5601	Anthophyllite, Burlington	4		2	2	1	3	32
Thurso	LO:31.20	DM5629	Actinolite, Cornwall	4		2	1	1	3	14
Thurso	LO:31.6	DM5445	serpentine, Milton	6		0	0	3		0
Thurso	LO:31.6	DM5446	serpentine, Corrycharmaign	4		1	0	1	3	0
Thurso	LO:31.6	DM5445	serpentine, Milton, Glen Urquhart			1	1	1	0	3
Thurso	LO:31.6	DM5434	White serpentine/tremolite	6	Y	2	2	1	3	32
Thurso	LO:32.11	DM6318	Opal fossil wood,Antuiga (looks asbestos	4		0	3	3	0	0
Thurso	LO:32.12	DM6349	Pale green serpentine, Unst	6		1	0	0	3	0
Thurso	LO:32.13	DM6377	serpentine "rumpfite", Baltimore	6		1	2	1	5	18
Thurso	LO:32.13	DM6370	mountain cork, Portsoy	6		1	3	2	3	54
Thurso	LO:32.6	DM6207	polished serpentine button	2		1	0	0	2	0
Thurso	LO:32.6	DM6207	serpentine, Portsoy polished button			1	0	0	0	0
Thurso	LO:32.6	No Number	?Fibrous? Chrysotile (Salt Damaged)	2	y	1	2	1	3	14
Thurso	LO:32.6	DM6139	Tremolite asbestos Italy	4	y	2	3	3	2	180
Thurso	LO:32.6	DM6139	tremolite asbestos in glass tube (encapsulated - giv		y	2	3	1	3	54
Thurso	LO:32.7	DM6218	serpentine; non loc.		y	1	2	3	2	48
Thurso	LO:32.7	Not visible	Fibrous tremolite rock, several bits	4	y	2	2	3	3	120
Thurso	LO:32.7	DM6272	asbestos rock	4	y	2	3	3	2	180
Thurso	LO:32.7	DM6192	tremlolite	2		2	1	1	3	14
Thurso	LO:32.8	DM6261	serpentine, Lancaster County USA	3		1	0	1	2	0
Thurso	LO:33.1		Nothing to record							0
Thurso	LO32.6	DM5967	fibrous serpentine. Unst	4		1	1	1	3	6

Column G: Mineral species present
0 - no asbestiform groups/species
1 - serpentine group (inc. chrysotile) or for not visible (eg packeted) potential asbestos specimens.
2 - amphibole group (except amosite/riebeckite)
3 - amosite/riebeckite, and erionite

Column H: Habit/texture of potential asbestos phase
0 - massive or visible individual crystals/cleavages
1 -elongate/glassy acicular
2 - silky/acicular, or for not visible (eg packeted) potential asbestos.
3 - finely fibrous, asbestiform, filiform or wooly

Column I: Surface condition of potential asbestos phase
0 - hard/clean/glassy surfaces (or if already sealed in a container)
1 - minor breaks/abrasions
2- significant breaks/abrasions/porosity, or for not visible (eg packeted) potential asbestos
3 – Fragile: loose dust and fragments present

Column J: Quantity of potential asbestos phase present

0: none to trace
1: < 1g
2: 1-5g; or for invisible (eg packeted) potential asbestos
3: > 5g

Column K: Calculated Score (automatically filled)

Column L: Notes

Fig. 7. The Hunterian geological asbestos Risk assessment.

tos can also only be opened by staff complying with these training and health and safety requirements.

Specimen Surveys

Anyone accessing specimens known to be, or suspected of being, asbestos must have completed *non-licensable work with asbestos* training and be wearing the correct personal protective clothing (PPE) and respiratory protective equipment (RPE) during survey work. Specimen and locations on the Asbestos Risk Register should be examined to establish their potential to release asbestos fibres. In the current absence of robust guidelines or protocols for assessing asbestos risk in natural materials, a simple visual risk assessment for asbestos minerals has been devised by the Hunterian Museum, and calibrated against results from an accredited asbestos lab. This scores the mineral species present, the mineral habit, the surface condition (representing the susceptibility to release fibres), and an estimate of the quantity of potential asbestos material (Fig 7). These data are then weighted to produce a risk assessment score used to decide how the specimen should be managed. Note that any assessment scheme such as this should be carried out by an experienced mineralogist/ petrologist.

Processing of specimens for storage or disposal

Once the scale and scope of the geological asbestos issue has been established, and confirmed, any hazards need to be addressed and mitigated. There are two basic approaches: encapsulation, where specimens are enclosed in a manner which will prevent exposure to respirable fibres; and disposal, where suspect specimens are treated as asbestos waste.

In general, it will usually be best to employ a specialist Licenced Asbestos Contractor to carry out either encapsulation or disposal work, as the logistics of implementing a safe, legally-compliant programme, and subsequent decontamination and disposal, are very onerous. However small scale work could be carried out in-house if the staff are trained in *non-licensable work with asbestos* and have access to a correctly filtered negative pressure unit. However, guidance will be required from an asbestos consultant to ensure the risk assessments and Plans of Work meet legal requirements. Specific details of how this work should be carried out are outside the scope of this paper. Where contractors are used, curatorial staff will need to be involved in the preparation of plans of work/method statements, to ensure that the security and safe handling of the collections are fully considered.

Space preparation and project planning

Any intensive asbestos handling must take place within an air-tight enclosure using negative pressure units to control air flow, typically a temporary polythene structure erected within the store or adjacent area (Fig 8). Such enclosures include a transparent viewing panel or have CCTV installed, so that curatorial staff can see, photograph and advise on specimens being processed within, and update the asbestos register to record encapsulation or disposal (Fig 9). The contractors will advise on the design and location of the work enclosure, and on

Fig. 8. Asbestos enclosure erected within storage area at National Museum Scotland.

the location and access route to their decontamination unit (Fig 10), which they will need for changing and disposing of contaminated personal protective equipment (PPE).

If licenced asbestos contractors are carrying out encapsulation, you will need to brief them on your documentation and specimen-handling protocols. It is very useful to go through the proposed workflow in advance with the individuals who will be carrying out the work, using dummy (i.e. non-asbestos) specimens.

It is important that no specimens should be removed from a drawer or container that houses samples requiring encapsulation or wrapping prior to disposal. The drawer or container with its entire contents should be sealed in air tight containers or asbestos waste bags before being taken into the enclosure for processing. By this method any fibres contaminating surrounding specimens and storage materials can be safely removed when the asbestos-bearing samples are encapsulated.

Decontamination and re-use of drawers may be possible, especially if samples were contained in card trays that restricted the spread of contamination. However, the trays, and any heavily contaminated drawers would usually need to be disposed of as asbestos waste. The contractor or trained staff member carrying out the work will carry out tests for contamination to ensure any remaining containers are safe for re-use.

Requirements for encapsulation

If specimens are to be encapsulated, the minimum standard for containment which will enable safe handling by staff without use of personal protective equipment, is to seal the material in two layers of transparent protective covering. The encapsulated specimens can then be stored as normal, in new, clean card trays, and managed within normal storage furniture. Double-bagging in sealable polyethylene bags is quick, cheap and effective for basic storage as long as food/conservation grade bags are used. Alternatively inner containers could be heat-sealed polyethylene tubing, or polystyrene tubes or jars. If the sample is already contained in

Fig. 9. View through large inspection window in enclosure (frame of window visible on right of photo) at the National Museum of Wales. There was inadequate space to fit the unit in the store area, so part of a corridor was used.

Fig. 10. Typical trailer-style decontamination unit used by asbestos contractors. This may be placed inside a storage area if space allows, although here it is show placed external to the building. National Museum of Wales decontamination work 2013.

this way it need not be removed. Enclosure in a polyethylene sealed bag will ensure that if the inner container should break, the contents will be contained. Glass containers are not recommended for repackaging. If specimens are already contained in this way it is better to retain the glass container and double-bag using and outer layer of a heavier gauge (e.g. 300µm) to provide protection in case the glass breaks.

Whatever containment is selected, contaminated labels which have been in contact with suspect specimens will also need to be encapsulated with the specimen. The container must to be marked with a standard asbestos hazard tag, and the specimen number will need to be visible, or marked on the outside of the container. Any drawers or boxes housing asbestos specimens, and any storage units containing them will also need to be marked with standard asbestos hazard stickers.

Requirements for disposal

Where asbestos specimens lack accompanying data or have no potential for use, it is recommended that they are disposed of. Because of the potential hazard that this material presents, the usual procedures for deaccessioning specimens as specified in the Museum's development (acquisition and disposal) policy will not be applicable unless specimens have particular scientific or cultural value. It is consequently important that managers are made aware of and approve the proposed work at planning stage so that all disposals can be fast-tracked.

Specimens for disposal must be treated according to Hazardous Waste Regulations 2005, along with any contaminated card trays, and other waste materials arising from the work. Such waste must be doubled bagged with a red inner bag and clear outer bag, and stored in a dedicated, lockable, labeled asbestos waste container until removed from site by a licensed waste carrier. If you employ a licensed contractor, they will normally include disposal in their work programme. It is essential that the waste consignment notes are filed for a minimum of three years to ensure the traceability of the material. Disposals should be properly recorded in specimen documentation according to SPECTRUM standards.

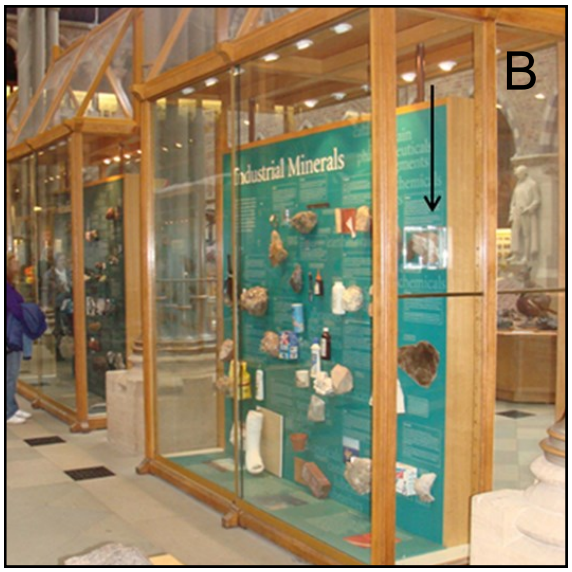


Fig. 11. An example of a hermetically sealed asbestos specimen on display at the Oxford University Museum of Natural History. 11b. The location of the specimen in the display case is indicated by the arrow.

Other things to consider

Emergency Procedures

Reference has been made in previous sections to Emergency Procedures to deal with the accidental release of asbestos fibres. Both *asbestos awareness* and *non-licensable work with asbestos* training emphasise the importance of procedures to deal with this, should it occur. The HSE document *EM1 - What to do if you uncover or damage materials that may contain asbestos* (HSE, 2012b) provides a useful checklist of actions to take. The Procedures must identify the person who will take control of any incident and document all actions that need to be undertaken following initial evacuation of the area suspected of being contaminated. This includes identification of those potentially exposed to asbestos and reporting this through RIDDOR (Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013). Those responsible for both health and safety and human resources in the organisation will be able to provide assistance with this task.

Loan and movement of asbestos specimens

The European Union regulation, *Registration, Evaluation, Authorisation & restriction of CHemicals*, more commonly referred to as REACH, controls the movement of, and prevents the sale of, 'articles to which asbestos fibres have been intentionally added' (for further details see HSE, 2015b). The Health and Safety Executive (HSE) has granted a class exemption to the museum sector solely to enable the loan or transfer of such asbestos-containing artefacts as WWII gas masks, for exhibition, subject to a number of conditions. However this exemption does not apply to geological specimens because of the technicality that the asbestos present is not an 'added' constituent.

Provided specimens are encapsulated they can be moved between sites within an organisation and also moved between organisations for the purposes of research or analysis, as this is allowed under REACH. The weight of material must not exceed 1 tonne - an ample amount for most research projects!

A grey area surrounds the movement of asbestos specimens for other purposes such as education or display, as this is technically not covered directly by REACH or the exemption. The safest approach to take is therefore to ensure that use or movement of any asbestos specimens complies with CAR 2012 (prevention of the release of fibres) and the Health and Safety at Work Act 1974. To underpin this a risk assessment and plan of work should be in place before any movement or preparation activity is undertaken, and all personal involved are aware of the Emergency Procedures, so they know what actions to take should fibres be released. Further advice as to the legitimacy of any movement of specimens should be sought from the airborne fibres team at the Health and Safety Executive.

Asbestos specimens on display

Legislation does not preclude asbestos specimens being included within displays, provided they are suitably contained to prevent any release of fibres. Specimens can be hermetically sealed into an acrylic Perspex container (or similar) provided an approved plan of work is followed and work carried out in a negative pressure unit by someone trained in n*on-licensable work with asbestos*. The encapsulated specimens can then be placed in the display case (Fig 11). This should still enable unimpeded observation of the specimens.

Specimens entering the museum through donations and public enquiries

Regardless of whether a museum's collection holds asbestos specimens, curatorial staff need to be aware that asbestos could enter the museum through donations and public enquiry services. It would be very unusual that either the public or museum staff would confuse a fossil with an asbestos-bearing geological specimen, so the main areas of concern are minerals, rocks, and collections of mixed geological material.

Possible hazards associated with these materials include radioactivity and toxicity as well as the presence of asbestos fibres, and the museum may also have concerns about the introduction of any pests or vermin with incoming material. On all fronts, it is essential to have robust procedures and well-trained front of house staff to interface with the public. They may receive *Asbestos Awareness* training, which can be undertaken in-house (see *Managing and working with asbestos* 2013).

It is important that public enquiries are never unwrapped by the enquirer or museum staff in a public area. Accidental shedding of fibres could mean the temporary closure of that area and incur the cost of decontamination. Museums can help by requesting that enquiry specimens should already be enclosed in clear seal polythene bags. If other wrappings are used, a supply of large grip-seal bags should be available to front of house staff, in which to place the fully wrapped enquiry material and then mark with the enquiry/entry number. The fact that the enquiry has been accepted unseen and uncounted should be stated on the enquiry form and enquirer's receipt.

All such enquiries should then be quarantined in a secure location away from both public and staff, and only unpacked by staff member who is trained for *non-licensable work with asbestos.* The sealed bag should be opened in the negative pressure unit so that the contents can be unwrapped and inspected by a suitably qualified person. If the museum does not have appropriate staff or facilities, then consideration should be given to refusing to carry out identifications of minerals and rocks.

Research and preparation activities: the Geological Asbestos Working Group (GAWG)

Rocks and minerals containing asbestos are retained in collections because they have value for use in research and education at a wide range of levels. If the encapsulation is opened and the specimen is sampled, sawn, ground, polished or undergoes any other geological preparation procedure, then new hazards will be introduced the nature and extent of which is currently poorly understood.

A working group was formed in 2015, to attempt to address this and some of the other hazards outlined in this paper associated with geological asbestos specimens. The group comprises university researchers, curators with responsibility for petrology and mineralogy research collections, those managing geological preparation laboratories, commercial asbestos consultants, and health and safety representatives from the university sector, the UK Health and Safety Executive and UK Health and Safety Laboratories. The main aim of the group is to develop a research programme to investigate the risks associated with the preparation of asbestos-bearing geological materials. The ultimate aim is to provide guidelines for best practice in this area. Further details of the activity of the Geological Asbestos Working Group (GAWG) will be reported through the NatSCA Journal and similar publications.

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