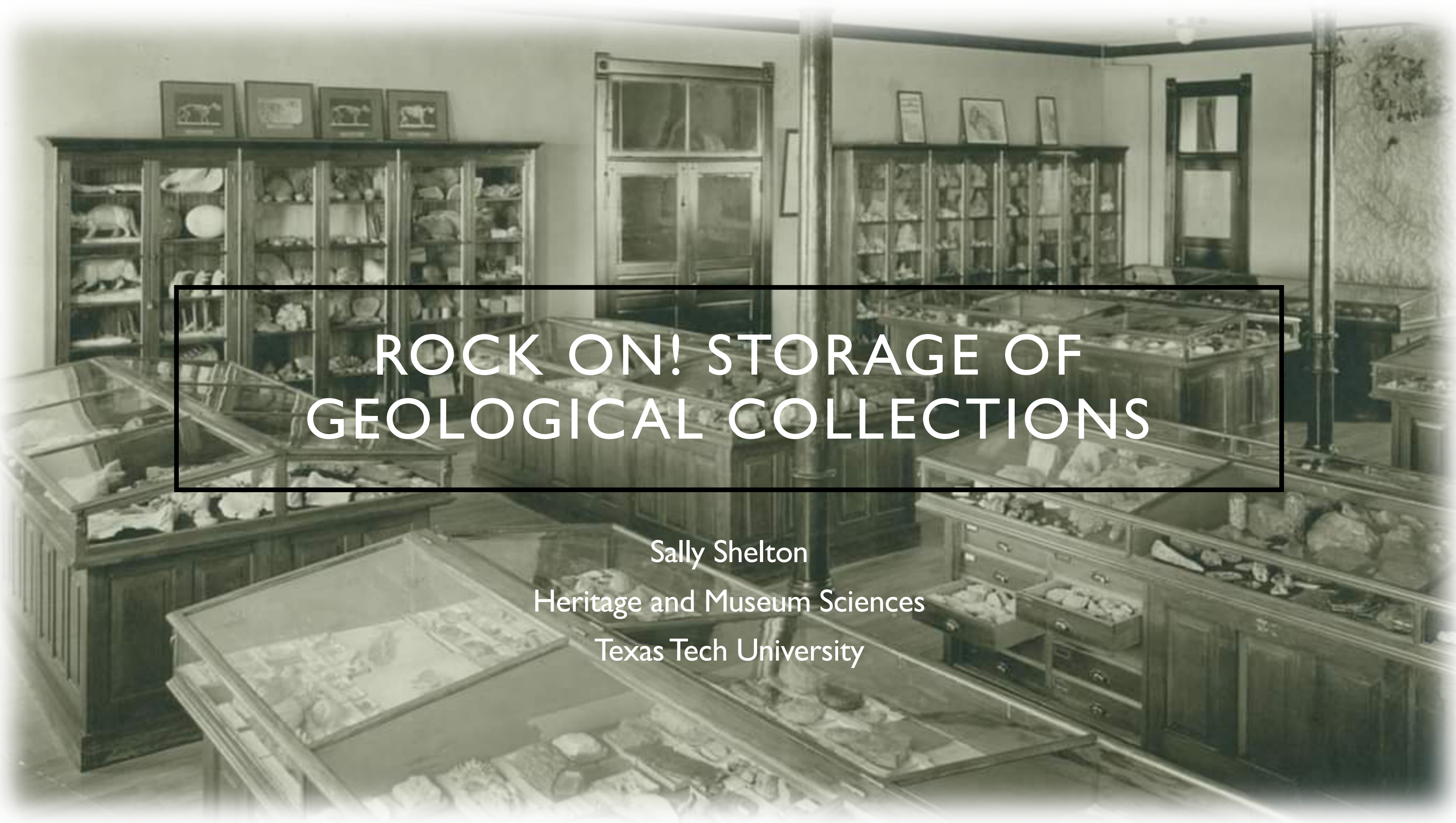

ROCK ON! STORAGE OF GEOLOGICAL COLLECTIONS

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PARAMETERS

- Our focus today will be on storage approaches in the preventive conservation of geological collections.
- There are more specific issues with archaeological lithic and fossil collections. Though there is some common ground with their basic care, these are separate areas of discussion and will not be covered today.
- Similarly, *in situ* conservation of geological materials and heritage sites, while important, will not be discussed in this presentation.

THINGS NOT TO WORRY ABOUT!

- Most of geological storage is common-sense preventive conservation; a few approaches are specialized.
- You don't necessarily have to know exactly what a geological specimen or object is in order to know how to provide good basic care.
- Knowing what you are dealing with, however, really helps with effective storage decisions.
- When in doubt about identification…. geologists love to consult!


PERCEPTIONS
Why do we have problems with geological collections?

THE "JUST ROCKS" PROBLEM

- Geological materials are often under-conserved or cared for because we assume that they are sturdy, unchanging, and not susceptible to environmental problems.
- The specimens/objects most likely to get care are those with high market value, and even then they may only get increased security without truly improved storage.
- Specimens deteriorating on exhibit or in collections are often overlooked until the damage is profound.

"REQUIRING LESS ATTENTION, THEY GOT IT"

- D.A. Allan, Director of the Free Public Museums, Liverpool, suggested that the perceived durability of geological materials works against the interests of these collections.
- "**Requiring less attention, they got it**, and, while the passage of time saw new material and new methods of preparation and exhibition introduced into other natural history departments, the rocks and the fossils remained intact and inert, sometimes almost invisible beneath the gently accumulating layers of dust."
- https://simonknell.com/the-roller-coaster-of-museum-geology/

THERE IS NO SUCH THING AS "JUST ROCKS"

- Geological collections include huge ranges of materials, values, rationales for collecting, risks, values, and environmental sensitivities.
- Storage solutions need to be planned around the unique factors of each collection.

STORAGE CONCERNS

- **Storage**: what best protects the collections and minimizes risks, both to the collections and to the users?
- **Documentation**: how do your documentation and your storage enhance each other so that no information linkages are lost?
- **Handling/Access**: what concerns do you have about access to valuable, fragile, and/or hazardous collections, and how do your storage and security approaches mitigate some of these?

CONSERVATION CONCERNS

- Material types (know what you are dealing with)
- Size of collection (physical dimensions of objects, from microscopic to entire building structures)
- Weight of collections (can be extremely high)
- Size of collection (numbers can be large)
- Preservation of one-to-many relations of originals and samples
- Environmental sensitivities (can be very damaging)
- Risks to the collections (can be extremely vulnerable)
- Risks from the collections (can be extremely hazardous)
- High financial values (both legitimate and black market)

MATERIALS TERMINOLOGY

- Mineral: naturally occurring inorganic material with a defined composition and structure.
- Rock: aggregate of one or more minerals.
- Gems: minerals, rocks, or fossils prepared (often cut and polished) to attractive forms.
- Meteorites: rocks of extraterrestrial origin.

- (Waller, 2019)

RANGE OF MATERIAL TYPES

- Mineral/mineraloid
- Rock/stone
- Ores and precious metals
- Gem (worked as jewelry and other adornments)
- Extraterrestrial (meteorites, tektites, lunar samples)
- Biogenic/anthropogenic (including artificial materials)
- Worked as art/cultural objects (sculpture, etc.)
- Cores (large scientific samples of sediments, rock, or ice)
- Building materials (from samples to structures)

A NOTE ON MINERALS

- Mineralogists recognize anywhere from ~5000 to ~10,000 minerals. About 350 are known to be unstable.
- Accurate identification may involve hand lens viewing, sampling, testing, and microscopy.
- So….if you have unidentified specimens, try to locate any contextual information (collector, site of collection, date, other materials in the same accession, etc.).
- The best strategy for dealing with identification of unknowns is consulting a geologist.

NOTE ON ROCK/STONE

- Q: What is the difference between rock and stone?
- A: They are the same thing.
- **Rocks** are naturally occurring solid aggregates or masses of minerals, mineraloids, and/or organic material.
- **Stone** in our field is a term of art used for rock materials that are worked or otherwise encountered in a cultural context

SMALL SPECIMENS AND PREPARATIONS: MICROSLIDES

- Any of a number of small specimens or preparations may be permanently mounted on microslides for microscope use.
- Mount: glass microslide + mounting media + specimen + coverslip
- Problems: the older the mounting medium, the more likely that it is one of the problematic adhesives or resins once in common use.
  - Also, the section, the slide, and the cover slip are fragile and brittle.

MICROSLIDE STORAGE

- There is a wide range of microslide storage cabinets available that provide efficient, secure storage and protection for these complex and fragile items.
- Some of these are small enough to fit into a larger storage drawer or case; others are designed to be stand-alone.
- Given the choice, select a steel microslide storage cabinet over a wooden one.
- Make sure that all slides are labeled directly on the glass (not a glue-on label) with the parent specimen number.

SMALL SPECIMENS AND PREPARATIONS: THIN SECTIONS

A thin section is literally a slice of a larger specimen, thinner than a sheet of paper in most instances, which is mounted on a microslide for examination under magnification and specialized lighting (e.g. polarized light).

Thin sections may be mounted on any of a number of sizes of microslides.

SMALL SPECIMENS AND PREPARATIONS: MICROMOUNTS

- A micromount is a small specimen, often a single mineral crystal, showing the key characteristics of that mineral type under magnification.
- Micromounts are highly popular in mineral collector communities, because they are easy to prepare and are often sold inexpensively or traded.
- Most micromounts are permanently housed in small, clear, lidded acrylic boxes (~4 cm^3). There may be a magnifying lens in the top to facilitate viewing without removing the specimen.
- There is no standardized documentation or preparation set of standards in the community. These are often donated to museums as is.
- Problems: adhesives and consolidants, old repairs, lack of information.

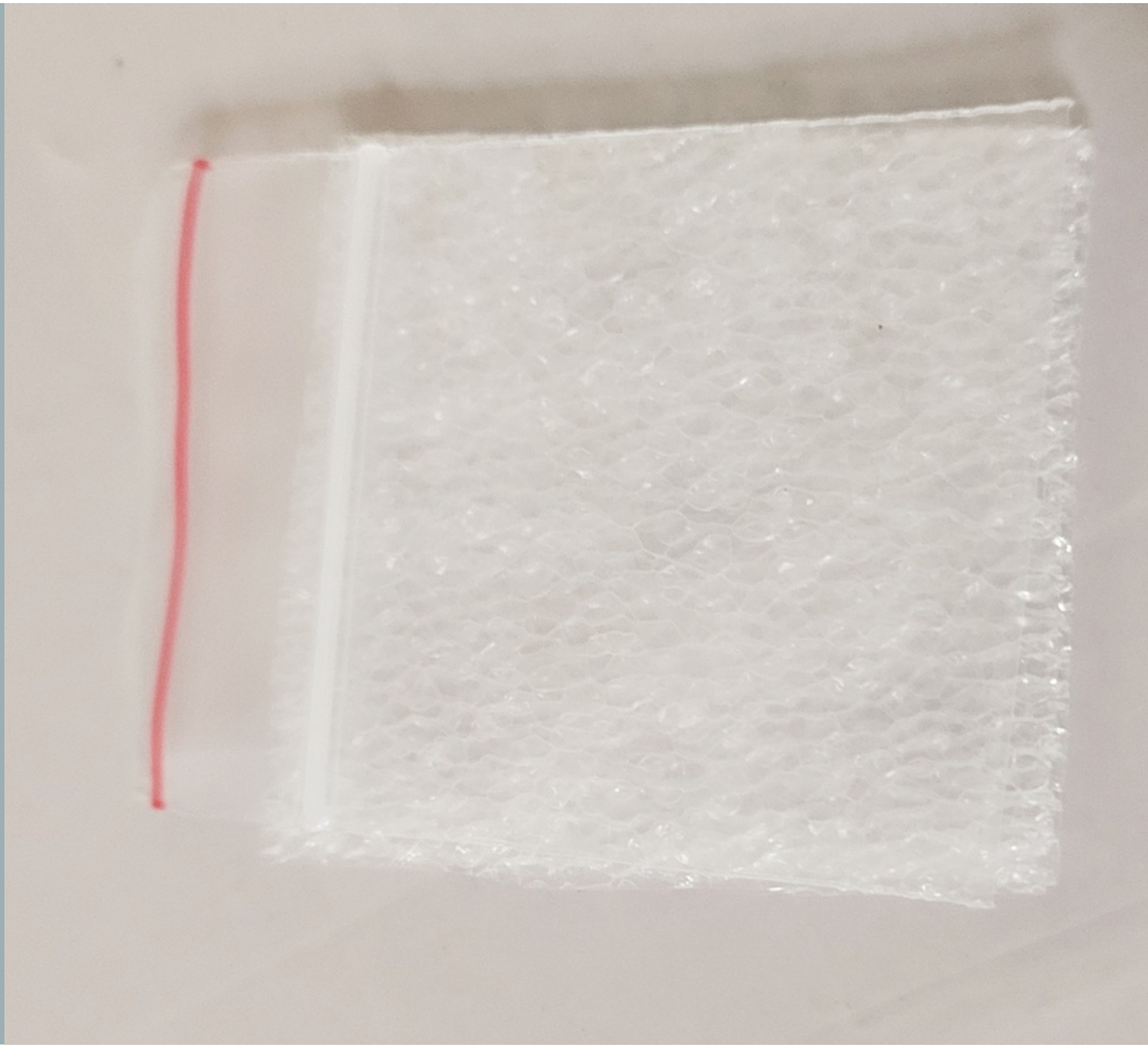
BASIC STORAGE: PAD, BAG OR BOX, TAG

All geological specimens benefit from padding with closed-cell archival foam materials.

Drawers, trays, and boxes should all be padded.

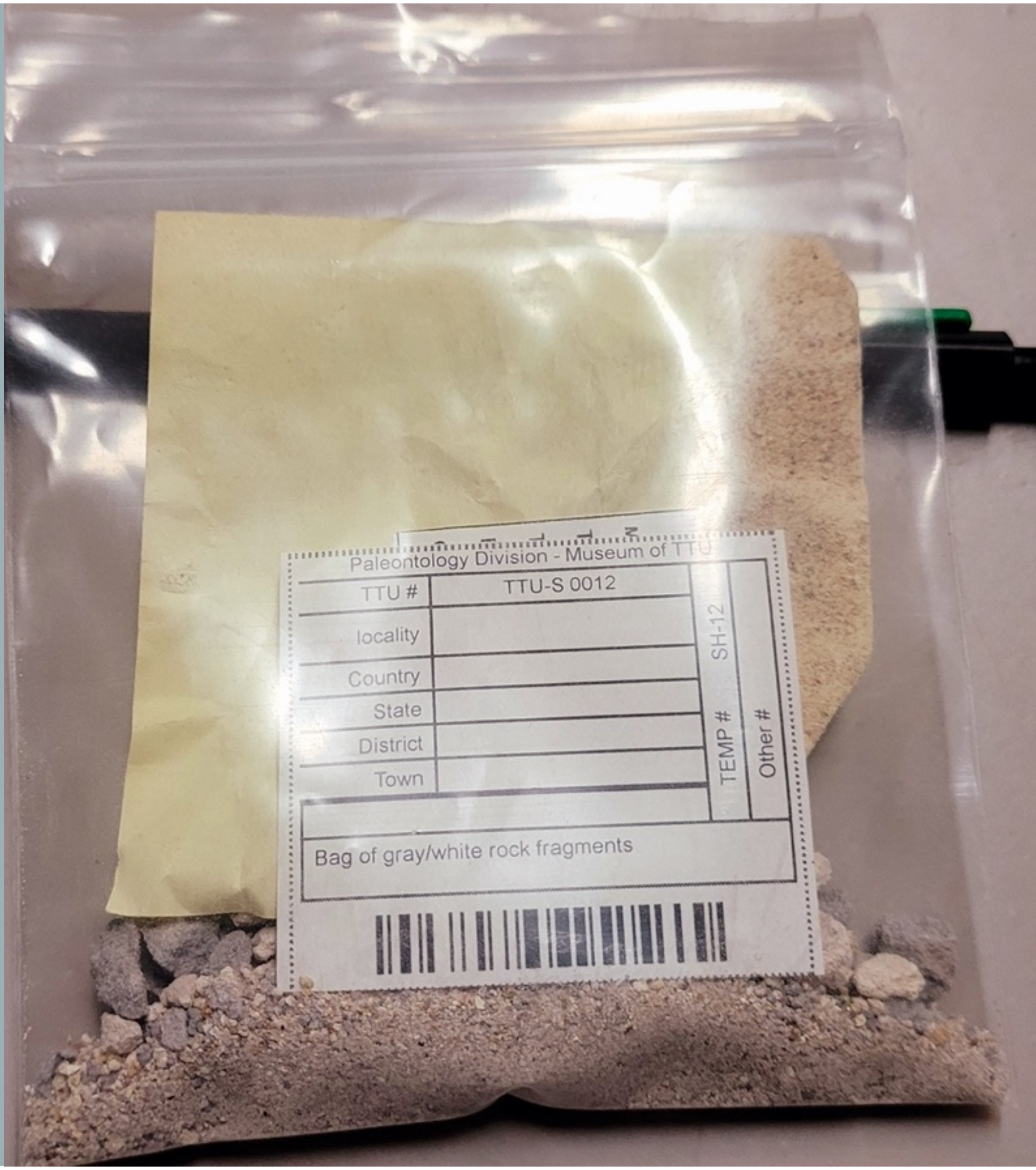
Archival bags serve as a second layer of protection for small- to medium-sized specimens. The padding serves as a sandwich layer between the specimen and its label.

This also facilitates vertical storage of smaller specimens. And minimizes abrasion.



FRAGMENTS

Bags also help with the containment of powdered or fragmentary materials.



CUSTOM PADDING

Foam padding can also act as a support. Starting with a base layer of foam, more layers are added with cutouts to encase the edges of the specimen. This works best with boxes and trays.

Lidded boxes are always preferable.

STORAGE CONCERNS: WEIGHT OF COLLECTIONS

- Geological collections may be exceptionally heavy, and require reinforced cases, drawers, and shelves. Regular steel shelves have been bent and even broken by overloading.
- Geological collections objects should not be stacked or piled on other objects in storage.
- Heavy objects are often still very brittle, and need to be protected from physical damage (dropping/breaking, abrasion, etc.)
- Even the heaviest objects should never be stored directly on the floor.

STORAGE OF HEAVY MATERIALS

- All heavy geological collections objects require padded supports in storage to distribute weight, prevent slipping and falling, and ensure safe handling.
- Heavy and oversized objects need to be both securely supported and palletized in order to facilitate moving, shelving, and unshelving by pallet jacks or forklifts.
- Heavy objects should never be stacked on each other, and should never support their own weight.

MACRO STORAGE SOLUTIONS

- Open storage shelves with protection
- Pallets and palletizing, plus pallet jacks and forklifts
- Padding and support
- Dust and light protection
- Labels: specimen, support, pallet

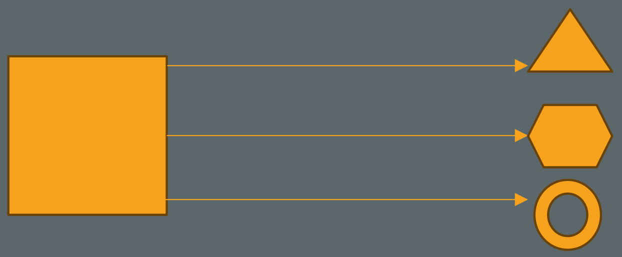
SIZE OF COLLECTION (NUMBERS)

- As with many other natural history collections, geological collections are often quite large in order to establish a statistically significant research base.
- Field collections in particular often have hundreds, even thousands, of specimens, depending on the research base that is needed and the likelihood (or lack of it) of being able to return to the collection site.

PROBLEMS WITH STACKING

When specimens are stored two or three deep, abrasion and weight are the main problems. Specimens should be spread out and no more than one deep.

Abrasion will destroy numbers and labels on specimens.



CONNECTIONS AND ASSOCIATIONS

How do we manage information linkages in storage?

ONE-TO-MANY CONNECTIONS

- One-to-many connections: the documentation (both labeling and database decisions) must preserve the relationship between the parent specimen and all derivative preparations, because sometimes the storage does not.
  - It's common to have many different samples and preparation types from the same parent specimen.

Storage by preparation type: provides specialized environment, aids research needs, provides storage systems based on common concerns (e.g. size, value)

- ➔linkages to original specimen/data may be lost

Storage by specimen parent::child linkages: preserves the physical association

- ➔specialized storage needs may be overlooked

PRESERVATION OF ONE-TO-MANY RELATIONS OF ORIGINALS AND SAMPLES

- As noted, the accurate identification of geological specimens often involves some degree of sampling and testing.
- This results in a parent::child relationship of the original specimen and the samples derived from it.
- Samples need to be preserved as vouchers and validations for identification and publication.
- Depending on the method used, derived samples can have very different storage and conservation needs from the parent specimen.

DISSOCIATION

- Dissociation is the loss of specimen information, or the loss of the intellectual value added through collection and research.
- The one-to-many connection is very often lost, with the result that samples cannot be linked to the original specimen and its collecting/obtaining information.
- Storage of collections includes storage of information, both physical and virtual.

CONNECTIONS: STORAGE BY SAMPLE TYPE

- It may be more advantageous to store all similar preparations (e.g. all microscope slides, all thin sections, all powdered samples) together to facilitate specialized storage as needed.
- This makes good documentation critically important to preserve in storage systems, so that the one-to-many relationship between the original (parent) specimen and the resultant (child) preparations is not lost.

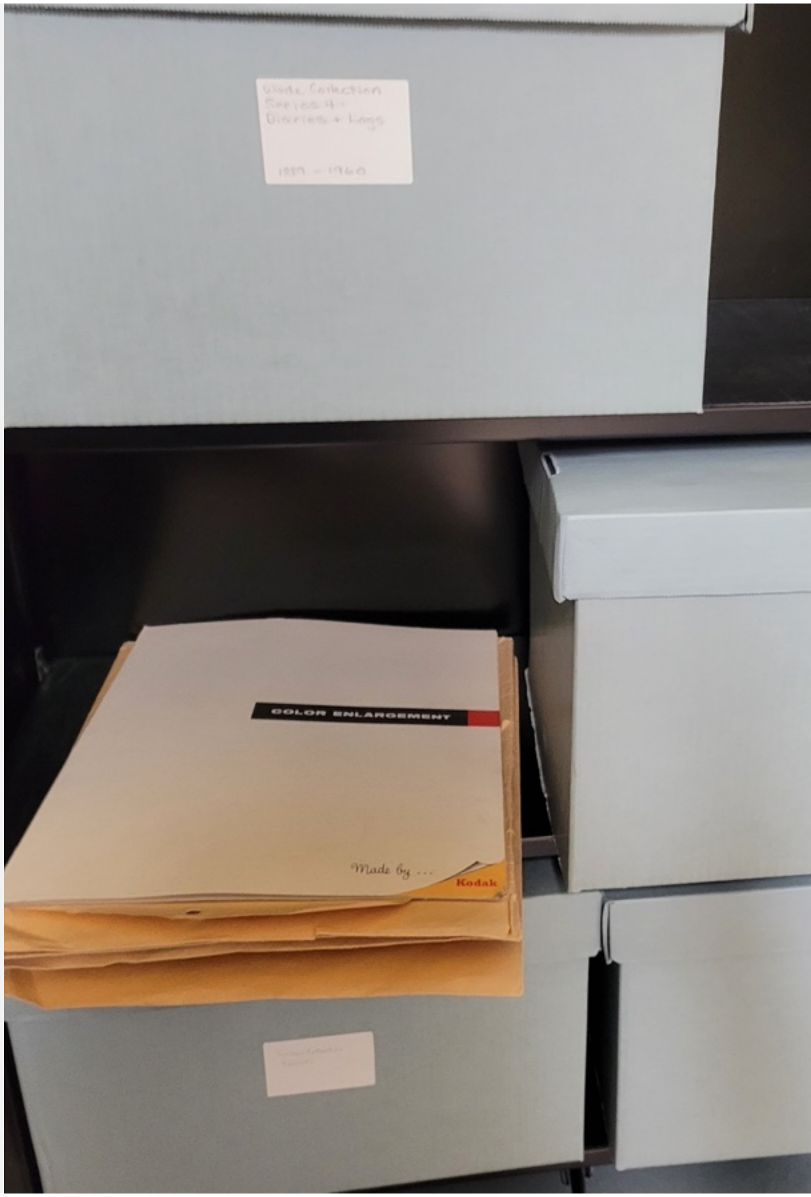
CONNECTIONS: STORAGE BY ASSOCIATION

- Alternatively, it may be preferable to store the parent specimen and the resultant preparations together so that the intellectual association is not lost and is also part of the physical storage.
- In this instance, there is a risk if any of the specimens or resultant preparations have specialized storage needs that are not being met in general storage.

THIN SECTION AND PARENT SAMPLE

DOCUMENTATION STORAGE

- Things to store separately from the objects/specimens:
- Locality information: maps, GPS coordinates, exploration plans
- Field collection: collectors' field notes and catalogs, photographs, permits/letters of permission
- Purchase information: receipts, paper trail/chain of custody, IRS documents
- Donation information: deed of gift, donor information
- Institutional: accession/deaccession and catalog records
- Results of sampling and analytical tests



RISKS TO GEOLOGICAL COLLECTIONS

What are the best storage solutions for collections at risk?

MOST COMMON SOURCES OF ENVIRONMENTAL DAMAGE TO GEOLOGICAL COLLECTIONS

- Temperature
- RH
- Oxidation
- Light
- Water
- Physical forces
- Theft
- Dissociation

TEMPERATURE

- In general: stable ambient temperatures around 21°C (~70°F) with minimized fluctuation provide acceptable thermal storage conditions
- Temperature fluctuations can cause crazing and breakage

Examples of special concerns:

- Sulfur minerals will crack if the ambient temperature is too high
  - Normal human body temperatures may be too high, which affects handling
- Opals and any specimens with water inclusions cannot be frozen or overheated

RH

- Many, if not most, geological specimens are stable in RH conditions of ~50%. Sustained or repeated fluctuations above 15% in both directions can cause problems.
- Special cases:
  - Gypsum dehydrates to anhydrite in sustained low RH.
  - Halite begins to deliquesce and dissolve in sustained high RH.
  - Pyrite is notoriously unstable in high RH.

STORAGE SOLUTIONS FOR RH ISSUES

- The reactions described are irreversible.
- A stable RH of 50% will help keep most geological materials stable. Closed steel cases are the best strategy if at all possible.
- Minerals known to be adversely affected by RH highs and lows may need specialized cases or enclosures to provide appropriate controlled conditions.
- Geological specimens and artifacts that have already undergone RH-related reactions are often weakened structurally, and are thus more fragile and vulnerable to future reactions.

OXIDATION: IT'S NOT JUST RUST

- Oxidation is the reaction of minerals with oxygen, changing the mineral composition of the affected materials and causing a loss of the object's surface.
- Oxidation leaves the specimen more susceptible to weathering and breakdown.

OXIDATION

- Specimens vulnerable to oxidation include many rocks and minerals containing iron and other reactive components.
- Reactive specimens may require a microclimate with an artificial atmosphere containing no oxygen (=anoxia). This may be nitrogen, carbon dioxide, argon, or other inert gases.
- Microclimates require steady monitoring to ensure that the micro-atmosphere continues to protect the specimen from further deterioration.

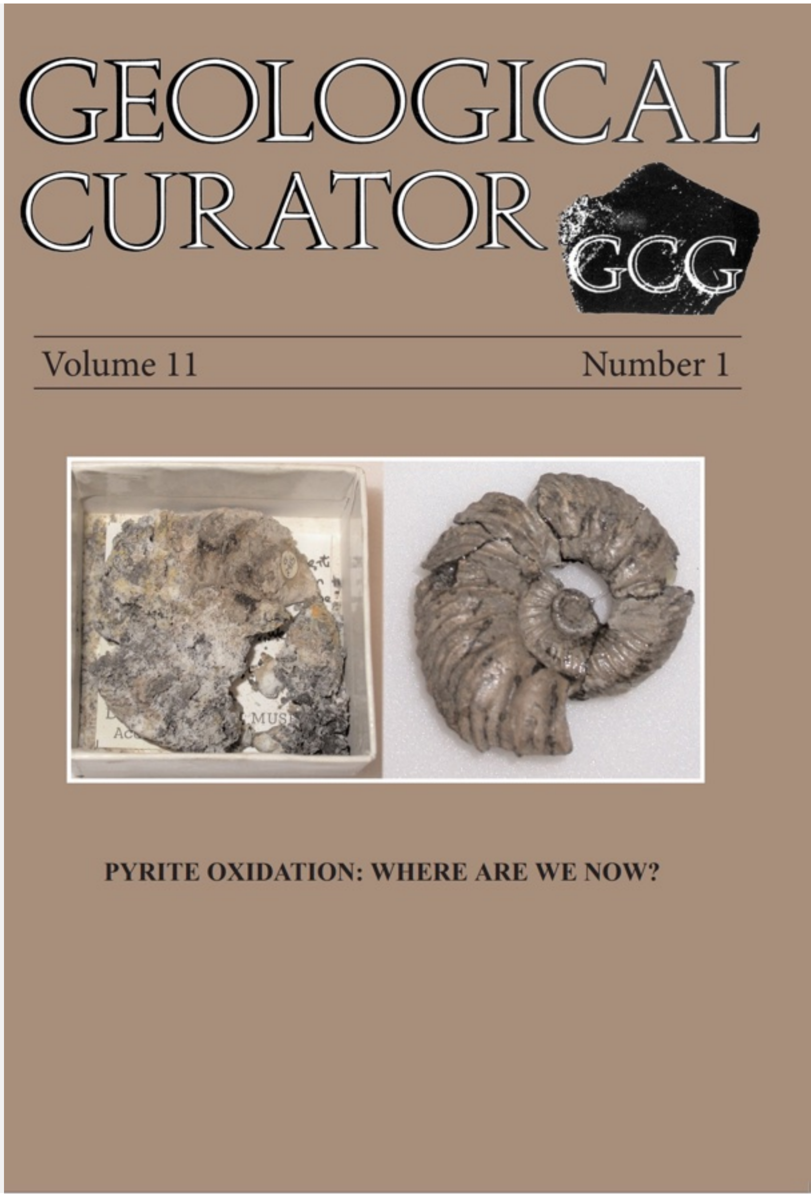
PYRITE OXIDATION

Pyrite (FeS_2, iron sulphide) occurs in many morphologies. Minerals in this group include marcasite, chalcopyrite, and arsenopyrite.

The pyrite form is used in jewelry, even though it is often called marcasite.

FeS_2 reacts with high RH levels and breaks down to ferrous sulphate ($FeSO_4$) and sulphur dioxide (SO_2), which converts to sulphuric acid (H_2SO_4) in the presence of water.

High T increases the speed of this reaction.



ANOXIC STORAGE OF A PYRITIC SPECIMEN

Pro: highly effective in slowing the breakdown reaction

Cons: cost and supply intensive; must be monitored and renewed

LIGHT SENSITIVITY

- Many minerals are sensitive to both visible light and UV radiation. You can see where coloration in this amethyst specimen has deteriorated from purple to brown. This is irreversible damage.
- Similarly, orpiment will degrade to realgar after prolonged light exposure.
- This is one of many reasons why exhibits cases should not be used as long-term storage for geological materials.

HYDROLYSIS

- Hydrolysis is a chemical reaction caused by water.
- Hydration: Anhydrite ($CaSO_4$) will convert to gypsum ($CaSO_4.2H_2O$) in high RH conditions.
- Dehydration: Limonite ($Fe_2O_3.H_2O$) will convert to hematite (Fe_2O_3) in low RH conditions.

DELIQUESCENCE

Deliquescence is the absorption of water into water-soluble minerals.

Atmospheric water in high RH conditions will cause water-soluble minerals to weaken and dissolve.

Liquid water can be absorbed in pooling or flooding situations.

Halite is especially vulnerable.

EFFLORESCENCE

- Efflorescence is caused by the evaporation of water from a mineral in solution.
- This is often seen in situations in which water-soluble salts rise to a surface and then dehydrate.
- This can lead to crystals of salts (sometimes called whiskering) on the surface of porous rock/stone materials.
- Because the efflorescence results from the breakdown of structural minerals, efflorescence can greatly weaken geological materials.

PHYSICAL FORCES

- Breakage: most geological specimens can and will break/shatter. Brittleness is a problem with all sizes and weights of geological specimens or objects.
- Abrasion: large collections stored together in a single drawer or box frequently exhibit abrasion damage.
- Storage solutions:
  - Bag, pad, and tag specimens in large collections
  - Separate, pad, and support large and/or brittle objects
  - Don't store geological materials directly on the floor

FRAGILE CRYSTALS AND OTHER FEATURES

Fragile materials require base padding and support.

Fine and delicate features such as these crystals should not be in direct contact with any materials which will become entangled and cause breakage.

THEFT AND HIGH FINANCIAL VALUES (BOTH LEGITIMATE AND BLACK MARKET)

- This is one of the top concerns with many geological materials, and often must be factored into your storage decisions.
- High market value is predictable with gems, precious metals, showy minerals, ores, extraterrestrial specimens, fossils, worked archaeological materials, and artistically/culturally worked objects.
- There is also high market value for specimens prized by collectors, which can be a moving target. There are many fads and trends in the collecting world.
  - If you have good connections with private collectors, whether professional or amateur, you may be able to get accurate information on which specimens currently command high prices.

STORAGE SOLUTIONS FOR HIGH-VALUE OBJECTS AND SPECIMENS

- Separate high-value geological collections from the general collection.
- If possible, provide a separate room or vault.
  - You may want to have this offsite in a secure facility.
- Assign access on a limited basis.
- Use locking steel cases at a minimum.
- Do not use interchangeable keys on case locks.
- Do not label the cases and drawers with easily read identifying information.
- Look into alarms and cameras.
- Look into specialized access and double-key locking systems such as those used for forensic and evidentiary holdings.

SPECIALIZED CONCERN: EXTRATERRESTRIAL

- Many collections include specimens of cosmic dust, meteorites, tektites, and other materials formed outside Earth.
- Storage concerns: RH sensitivity of iron-based specimens in particular; high market value; security and access.

MOON ROCK SAGA

- Of the 270 Apollo 11 Moon rocks and the Apollo 17 Goodwill Moon Rocks that were given to the nations of the world by the Nixon Administration, approximately 180 are unaccounted for.
- The only safe moon rocks are the ones that have been in locked, secure storage.
- Black market values ranged up to $5 million.

RISKS FROM THE COLLECTIONS

Which geological materials put people at risk?

SOURCES OF RISK FROM GEOLOGICAL COLLECTIONS

- Toxicity: materials containing hazardous substances (e.g. arsenic, lead, mercury)
- Offgassing: toxic gaseous emissions (cinnabar/mercury, radon)
- Contact risks: exposure by skin contact
- Radioactivity
- Inhalation risks: exposure by inhalation of tiny particles

PROTECTION OPTIONS

- All geological materials known to pose risks of any kind should be clearly labelled, both in storage and on exhibit. Cases should also have warning signs.
- Contain: Material posing risks should be boxed or contained to minimize chances of any accidental contact or exposure.
- PPE: Work with health and safety experts to determine which personal protective equipment is require for access to hazardous specimens. Follow their guidelines.
- Isolate: Store hazardous collections apart from the main collections.
- Remove completely: if you cannot provide adequate protection, find an institution that can.

RADIOACTIVITY RISKS

Radioactivity refers to the release of particles and radiation by unstable atomic nuclei.

Not all radioactivity risks are the same.

- Radon (gas)
- Alpha particles
- Beta particles
- Gamma waves

COMMON RADIOACTIVE MINERALS

- Autunite: calcium uranium phosphate
- Brannerite: contains uranium; often found with gold deposits
- Carnotite: secondary ore containing uranium and vanadinite
- Monazite: rare earth mineral containing thorium
- Thorianite: thorium dioxide
- Trinitite: radioactive fulgurite
- Uraninite: primary uranium ore mineral

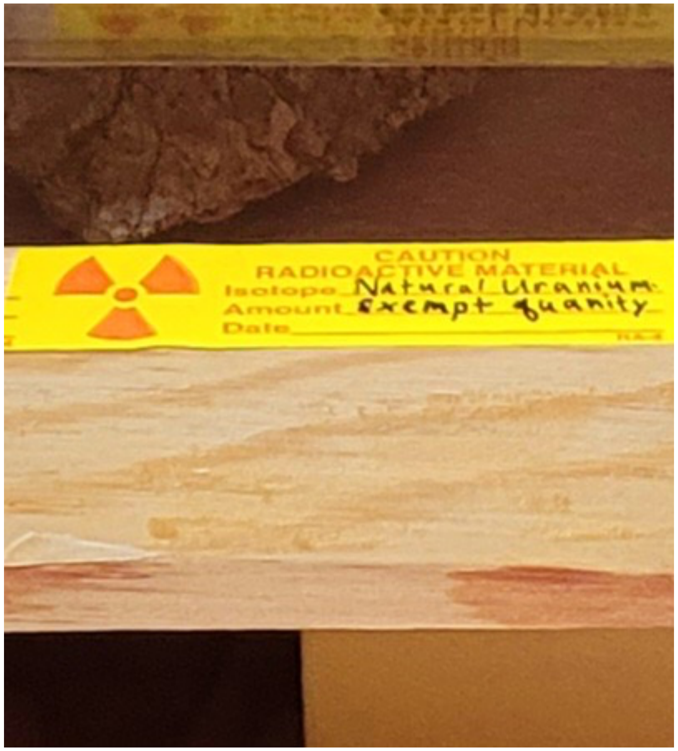
TRINITITE

- Trinitite is a fulgurite (a natural rough glass created when sand is struck by lightning, or, as in this case, other extreme high-heat events) from the Trinity test site at White Sands, New Mexico.
- Even though the site was heavily restricted after the test, local residents were able to obtain pieces and make them into jewelry and other souvenirs.

STORAGE PROTOCOL

Work with a health and safety expert to determine exactly what radioactive levels and risks are in your collection.

Also determine what enclosure and exposure requirements must be met.



INHALATION RISKS

- Asbestos/asbestiform minerals/chrysotile ➔ asbestosis
- Erionite ➔ mesothelioma
- Quartz particles ➔ silicosis
- Fluorspar and fluorite ➔ fluorosis

GENERAL PROTOCOLS FOR GEOLOGICAL COLLECTIONS STORAGE

- Many of the problems described take a long time to develop. The most powerful preventive conservation tool you have is regular visual inspection of collections and exhibits, at least once a year, combined with ongoing monitoring and recording of T, RH, and light/UV levels.
- Most geological materials do well in stable environments with well-managed environmental conditions.
- Known unstable materials should be targeted for specialized storage as soon as possible.
- Materials posing known risks should also be targeted for specialized storage.

EXHIBIT CONCERNS

- Environmental damage from higher fluctuations in T, RH, visible light, UV.
- Physical damage from moving objects on and off exhibit, inappropriate visitor access, and exhibit case damage or breakage.
- Vandalism/theft: precious metals, gems, ores, extraterrestrial objects, and collectibles are visible and attractive.
- Hazardous specimens (e.g. radioactive, inhalation risk, toxic compounds) not sufficiently secured to prevent exposure.
- Loss of associated information if labels are separated from specimens.

GUIDELINES FOR GEOLOGICAL EXHIBITS

- Don't use exhibits as visible storage for your geological collections!
- Support and pad all objects on exhibit.
- For highly valuable/theftable objects, consider reinforced cases and barriers, as well as short-term exhibition and rotation.
- Keep the key environmental parameters (T, RH, and light/UV) to the most acceptable and steadiest levels possible.
- Make sure that cases for hazardous specimens will prevent exposure. Objects posing risks should not be on open exhibit, and exhibit cases should be selected to provide good isolation and barriers
  - Either label specimens with their hazard information, or do not put them on exhibit.

STORAGE CHECKLIST

- Select cabinets and shelves that can handle the weight of geological collections.
- Provide padding and appropriate support.
- Do not stack geological objects/specimens.
- Manage environmental conditions inside and outside storage systems so that T, RH, and light, in particular, are kept at appropriate levels.
- Most collections are best stored in dark or low-light conditions when not in use or on exhibit.
- For geological collections with exceptional environmental sensitivities, consider microclimate storage approaches.

STORAGE CHECKLIST

- For collections with high market value or other theft or vandalism risks, implement high security systems.
- For hazardous specimens, implement appropriate isolation systems.
- For all limited-access collections, restrict the information posted on the cabinets and shelves.
- Maintain information links with all associated materials and data in all storage situations.

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