Journal of Natural Science Collections

Title: The Deterioration Phenomena (DP) Method: An efficient approach to collection surveying

Author(s): Royce, K.

Source: Royce, K. (2024). The Deterioration Phenomena (DP) Method: An efficient approach to collection surveying. *Journal of Natural Science Collections*, *Volume 12*, 105 - 125.

URL: http://www.natsca.org/article/2848

The Deterioration Phenomena (DP) Method: An efficient approach to collection surveying

Kathryn Royce

School of Geography and the Environment, University of Oxford, South Parks Road, Oxford, OX1 3QY

Email: kroyce@pm.me

Received: 28th Jul 2023

Accepted: 21th Feb 2024

Citation: Royce, K. 2024. The Deterioration Phenomena (DP) Method: an efficient approach to collection surveying. *Journal of Natural Science Collections.* **12.** pp. 105-125.

Abstract

Collection assessments are a well-known and widely employed tool for examining the overall state of a collection and identifying any processes which may be causing negative changes to collection items. As such assessments can be time- and resource-intensive, a well-designed method is critical for easy and effective data capture, analysis, and replication within a reasonable timeframe. The difficulty in striking this balance has produced nearly as many methods as there are museums, but there is still a high degree of subjectivity, ambiguity, and variability in both procedure and result. The Deterioration Phenomena (DP) Method was designed in an attempt to tackle these challenges. It can be quickly performed on an entire or substantial fraction of a collection. This coverage is achieved by recording only the presence or absence of pre-defined visible 'Deterioration Phenomena' (DP). The extent and severity of these criteria are purposefully not determined in order to minimise surveying time, reduce variability due to interpretational bias, and solve the quandary of assigning quantitative values to subjective perceptions. The DP Method has been successfully applied to four mineralogical collections, and provided ample data to determine and understand local deterioration processes. As the methodology is easy to adapt - through selecting DP that are applicable for the items being surveyed - it is hoped that the DP Method will be adopted within and beyond natural history collections to monitor change over time and to elucidate deterioration causes and pathways.

Keywords: Deterioration Phenomena Method; conservation; condition assessment; collection survey; care of collections; natural history collections

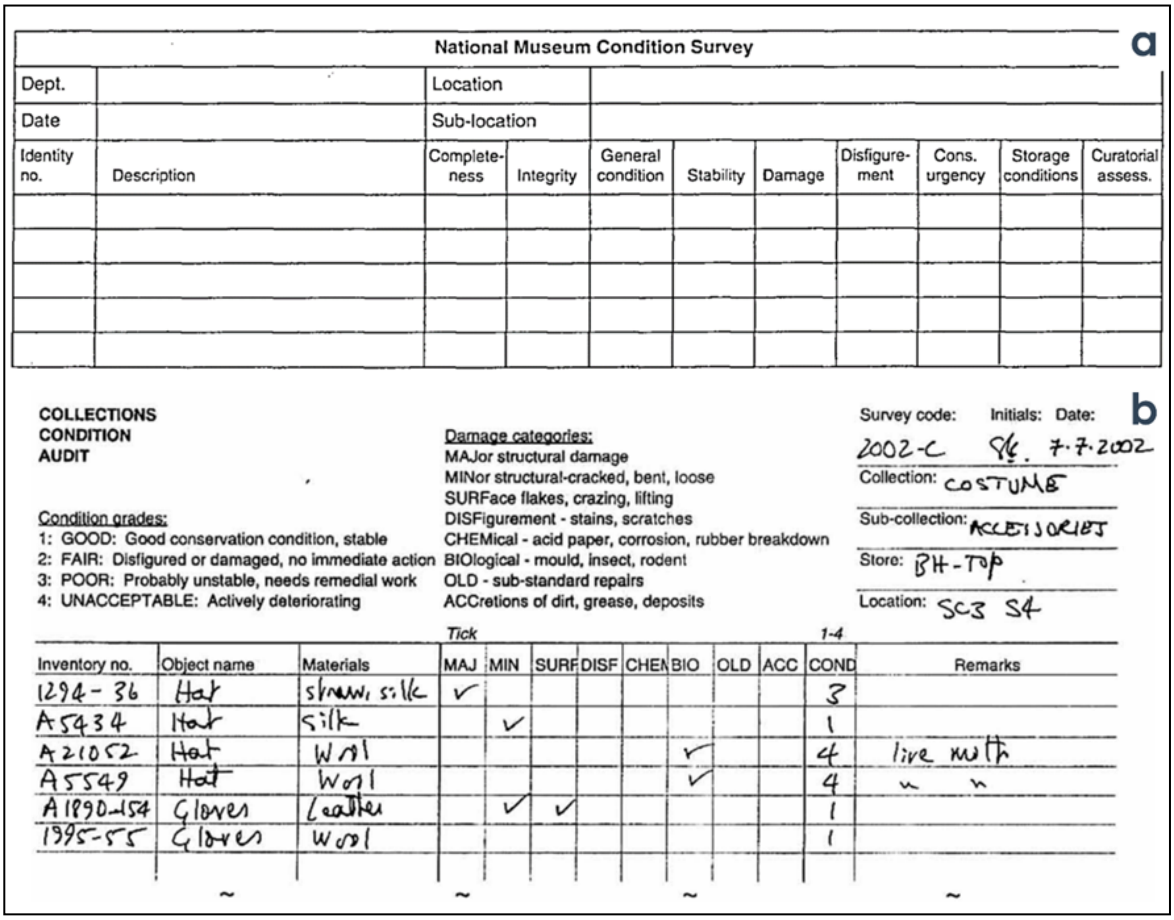
Introduction

A condition assessment is a non-invasive survey conducted to systematically examine the immediate condition of an object or collection (Taylor, 2005). Whilst there are various reasons for performing a condition assessment (see Taylor and Stevenson 1999: 20), they are most commonly employed to aid collection management, improve decision-making, and garner additional resources (Taylor and Watkinson 2003; Norris, 2015; Forleo and Francaviglia 2018; Kosek and Barry 2019). As these assessments can be time- and resource-intensive, a well-designed method is crucial for capturing as much relevant and useful data as possible. This is often easier said than done, however; variability can easily be introduced into the process by a number of factors. Be it the object, environment, surveyor, or means of documentation, each affects the reliability of the data being produced if not adequately controlled or mitigated (Taylor and Watkinson, 2007; Taylor, 2013).

Previously developed methods used generic forms (Figure 1) with broad and often ambiguous terminology in order to be applicable to multiple or mixed-media collections. However, such terminology introduces interpretational bias (Taylor and Stevenson, 1999; Taylor and Watkinson, 2003; Taylor, 2013). If criteria are broad, overlap, or are not well defined, their interpretation will vary as each person applies their own frame of reference to determine what the terms mean for a given context (Taylor, 2013). Terms such as ‘good’ and ‘bad’ - which are commonly used for ranking condition (Ashley-Smith, 1995; Taylor, 2013; Gioventù, 2018; Kosek and Barry, 2019) - are qualitative and subjective. Most may know what contributes towards ‘good’ or ‘bad’, but as there is no standardised definition for either term, each person will define them differently according to their past experiences and knowledge of the material being assessed (Taylor, 2013).

As illustrated in Figure 1b, commonly used criteria do not directly convey what forms of material change can be seen in the object, but rather focus on the potential causes of the change (e.g. chemical or biological agents). This approach introduces interpretational bias (Taylor and Stevenson, 1999), as one is not just recording what is seen, but rather determining what caused the effects and then translating it into the categories of the form. Causes are often difficult to determine as they necessitate inferences and assumptions. This multi-step thought process introduces variability by requiring additional information - such as knowledge of environmental conditions, housing materials, and how these react with objects - that is often not readily available (Taylor and Stevenson, 1999; Taylor and Watkinson, 2003) or is only known to a select group. The surveyor may not fully or correctly understand the potential causes of damage or may only search for the specific causes that confirm their suspicions (Taylor and Stevenson, 1999; Taylor and Watkinson, 2003), resulting in attribution error and false data.

Even if the cause of material change is obvious when looking at the object, others may interpret it differently at a later stage if the cause is not



a

National Museum Condition Survey

Dept.		Location	
Date		Sub-location	

Identity no.	Description	Complete-ness	Integrity	General condition	Stability	Damage	Disfigure-ment	Cons. urgency	Storage conditions	Curatorial assess.

b

COLLECTIONS CONDITION AUDIT

Condition grades:
1: GOOD: Good conservation condition, stable
2: FAIR: Disfigured or damaged, no immediate action
3: POOR: Probably unstable, needs remedial work
4: UNACCEPTABLE: Actively deteriorating

Damage categories:
MAJor structural damage
MINor structural-cracked, bent, loose
SURFace flakes, crazing, lifting
DISFigurement - stains, scratches
CHEMical - acid paper, corrosion, rubber breakdown
BIOlogical - mould, insect, rodent
OLD - sub-standard repairs
ACCretions of dirt, grease, deposits

Survey code: 2002-C Initials: [illegible] Date: 7.7.2002
Collection: COSTUME
Sub-collection: ACCESSORIES
Store: BH-TOP
Location: SC3 S4

Tick / 1-4

Inventory no.	Object name	Materials	MAJ	MIN	SURF	DISF	CHEM	BIO	OLD	ACC	COND	Remarks
1294-36	Hat	straw, silk	✓								3	
A5434	Hat	silk		✓							1	
A21052	Hat	Wool						✓			4	live moth
A5549	Hat	Wool						✓			4	" "
A1890-154	Gloves	Leather		✓	✓						1	
1395-55	Gloves	Wool									1	

Figure 1. Examples of forms used for condition assessments. One form (a.) uses subjective, value-based terminology (from Taylor and Watkinson 2003), whilst another (b.) uses terms more aligned with possible types of material change, but there is still some uncertainty and overlap between the categories (from Taylor 2013).

accurately reflected in the form (Taylor and Stevenson, 1999). An example seen both in Figure 1b (the two wool hats) and Keene (2002) is biological deterioration: "combined with condition grade 4 [it] implies pest infestation or active mould growth" (ibid. 148). Keene (2002) here admits that there are two possible ways to interpret the same results. In the case of the two hats, we only know that they are being affected by an active pest infestation because of the notes. These notes can easily be divorced from the main data (that of condition grade and damage type) during bulk analysis of one or more collections. Thus the urgency of an active infestation becomes invisible beyond the form.

This example evidences that there should be no implied meaning in the survey form, and that specific types of material change need to be clearly differentiated. Thus, the selected criteria should allow for the surveyor to clearly record what is seen in order to avoid false impressions and misunderstandings in subsequent review of the results.

Perhaps the simplest way to ensure clarity is to record the effects of material change, rather than the causes, as effects are easier to identify and document (Taylor, 2013). This can be done by selecting phenomenological (i.e., visually observable) criteria applicable for the collection being surveyed (for examples, see Sully and Suenson-Taylor, 1996; Kosek and Barry, 2019). Although the exact number and terms used may vary between collection or material types, criteria should be specific, mutually exclusive, comprehensive, and well-defined to minimise subjectivity and accurately record condition without collecting redundant information (Sully and Suenson-Taylor, 1996; Taylor and Stevenson, 1999; Taylor, 2013; DeMouthe, 2017; Kosek and Barry, 2019).

A Different Approach

One may wonder whether it is truly possible to objectively evaluate condition, given the difficulty in constructing and performing assessments. However, as the problem of condition is akin to that of damage (Royce *et al.*, 2023) - due to the difficulty in quantifying the subjective - arguably the solution is the same: decouple the tangible from the intangible and focus solely on material changes. This is achievable through approaching collection assessments as a bottom-up process (Figure 2), and introducing a state survey as the initial step within the process in order to more holistically understand a collection.

The first step is a state survey which collects information about the collection's current state via a physical examination. This can be supplemented with analytical tests and imaging, and or a review of surrounding infrastructure (including environmental conditions and housing materials) if any concerns are raised during examination. As Figure 2 illustrates, this survey is the foundation upon which the rest of the assessment is built. It is during this stage that one collects arguably the most critical information, as lacking a clear understanding of the collection's present situation will fail to provide any effective actions. For example, if one sees evidence of a pest problem, but does not investigate whether it is active, what pest species are involved, and what parts of the collection are being attacked, any actions taken could result in a misestimation or waste of resources, all at the collection's expense. Thus it is critical to know collection state to move forward into the other parts of the assessment.

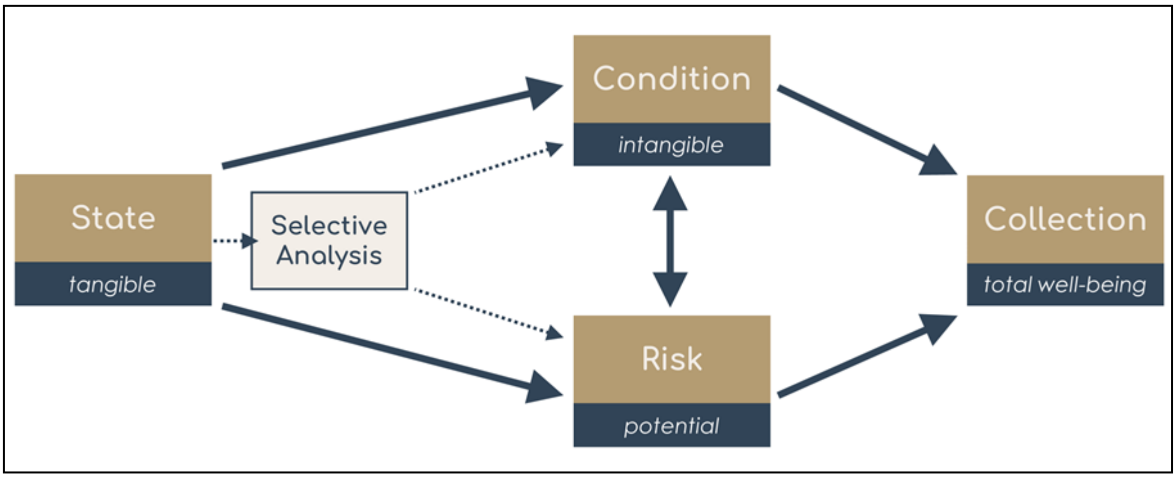


Figure 2. Flow chart illustrating a collection assessment approach.

Separating state from condition not only addresses many concerns regarding subjectivity, but also facilitates data analysis. Whilst data relevant to object state can be recorded in previous assessment methods, the state data may not be extractable or statistically assessable. Having an analysable data set at this stage helps to identify key areas of concern and deploy immediate actions to address urgent hazards (like a pest infestation) and stabilise the collection, if necessary.

Whilst the state survey deals with the physical aspects of a collection, the condition assessment addresses the intangible. This is where aspects such as the object's history and environment and stakeholders' experiences, perceptions, and positions (Royce, 2023) are used to contextualise the collection's state and identify its current values and uses. Information acquired during this phase would be derived from collection documentation (e.g., collection registries, environmental data), institutional documents (e.g., policies, mission statement, exhibition plans), and stakeholder opinions (collected via polls, interviews, social media, etc.).

Whilst state and condition are useful in assessing the current status of a collection, they cannot predict potential future changes. As such, it is critical to include a risk assessment (such as those outlined in Taylor 2005, Waller 2013, and Pedersoli, *et al.* 2016), which uses both the tangible and intangible to make evidence-based predictions of what would happen to the collection were varying scenarios to occur. The data from the state survey is used to identify probable agents of change, likely exposure and outcomes, and any potential synergies between agents. This is again contextualised by the information from the condition assessment, which is used to accurately characterise the magnitude of risk and loss. The results of the risk assessment can then be fed back into the condition assessment - hence the two-way arrow in Figure 2 - to determine how values and uses would change if damage were to occur.

This approach in and of itself is not truly novel; previous collection assessment methods all include the determination of state, condition, and risk to some degree. However, by consciously dividing a collection assessment into these three discrete parts (Figure 2), one can collect the correct information at the right time, and each part can be allocated to different individuals or teams (if the resources are available). When the information from the three parts is united, a holistic understanding of the collection emerges, which facilitates identifying efficacious targeted actions that address priority concerns, be they major revisions to infrastructure or maintenance of current procedures. As this new approach contains a relatively novel element (the state survey), an equally novel method needed to be developed.

The Deterioration Phenomena (DP) State Survey Method

The Deterioration Phenomena (DP) State Survey Method was intentionally designed to collect semi-quantitative and statistically robust data pertaining to the state of collection items whilst avoiding or mitigating the aforementioned biases and short-comings of pre-existing methods. This was achieved chiefly through its signature feature: the use of phenomenological criteria, named 'Deterioration Phenomena'.

Deterioration Phenomena

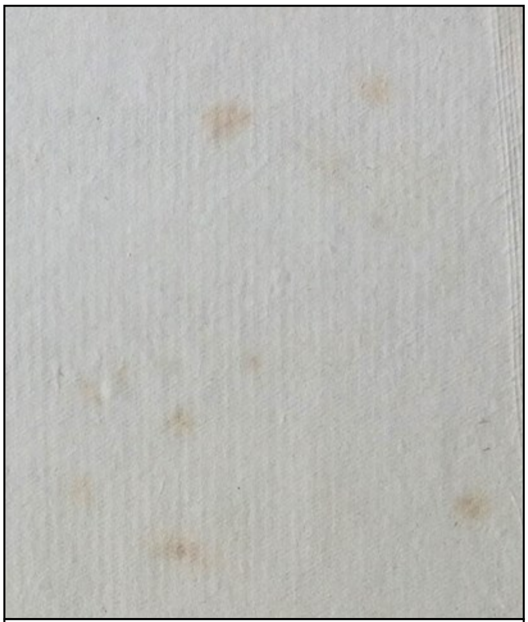
Deterioration Phenomena (DP) are criteria that are visual indicators of material change and are specific to the collection being examined. By selecting DP that are applicable for the items being surveyed, the DP Method can easily be adopted to other collection types, even those beyond natural history.

Some general examples of DP found on a wide range of materials are 'cracking' and 'colour change'. These are important visual changes that one could anticipate to find in most, if not all, collection types. More specific examples include 'dimpled' for minerals, or 'foxing' for paper. Be they specific or general, it is critical that the chosen DP are simply and explicitly defined both verbally and pictorially (Figure 3). This ensures that all parties involved, both in the present and future, have as similar of an understanding of the criteria as possible.

Only the presence (1) or absence (0) of DP is noted. There is no grading, scaling, or determination of the extent or severity of a given DP. This is a very deliberate part of the method's design, first and foremost to maintain one's focus on state, rather than condition. It also essentially simplifies the process to a series of yes or no questions (i.e., Is this DP present; yes or no?), thus avoiding the variability inherent to categorisation. Because categorisation it is a two-step thought process (Taylor, 2013), it necessitates drawing upon external information to classify the observed changes, be in abstract terms (e.g., good, poor, unacceptable) or numerical ('on a scale from 1 to 5').

Categorisation also takes substantially more time than spotting the changes themselves because of

Dimpled
Shallow divots in the mineral surface



Foxing
Orange to brown discolouration of paper, usually away from foredges and present as discrete spots or blotches.

Figure 3. Example DP definitions, each with an image that visualises how the change is exhibited within the select material type.

the degree of thinking involved. This results in spending more time per object, which significantly increases both the total time required to complete the survey and the data's accuracy due to the increased likelihood of questioning one's perceptions and judgements.

Even if the extent or severity of criteria were measured quantitatively, collecting these measurements would still take a significant amount of time and arguably provides too much information. Whilst such information may be important to know for an individual object, it would be superfluous at a collection-scale, bogging down both data collection and analysis. Further information regarding specific material changes can be collected at a later date for selected objects which have been determined to be of concern.

Simplifying the surveying process also allows for it to be completed by non-experts, including volunteers, who may never have seen specific types of objects before and lack the contextual information necessary to determine condition. Thus, a lack of personal familiarity would not necessarily hamper data collection.

Applications and DP Used

For the author's doctoral research (Royce, 2023), the DP State Survey Method was employed on the mineral collections held at four UK museums (Table 1): Oxford University Museum of Natural History (OUMNH), National Museum Cardiff (NMC), National Museums Liverpool (NML), and the Sedgwick Museum of Earth Science (Sedgwick).

A pilot was first performed on 22 of the Minescan Reserve specimens at NMC to confirm that the chosen DP were applicable and sufficiently defined. The specimens surveyed - and those of the Minescan project more generally - are ore body samples from mines across Wales, and were collected as physical records of the local geology. In addition to pyrite, the Minescan specimens are largely comprised of various ore (e.g., arsenopyrite, chalcopyrite, sphalerite) and gangue minerals (e.g., quartz, calcite).

Study 1 was conducted with the systematic mineral collection held at OUMNH with the purpose of corroborating the Mineral Susceptibility Database (Royce *et al.*, 2023) to a museum collection. Study 2 was then performed on the pyrite specimens held at the four aforementioned museums in order to elucidate how pyrite oxidises in the museum context. Preliminary results from both of these studies can be found in the author's doctoral thesis (Royce, 2023); detailed findings are to be published at a later date.

Table 1. Summary of the studies conducted, including details of the collections and the length of the surveys.

Study Number	Specimen Type	Museum	Number of Specimens	Percent of Collection	Time Taken (hr)	Average Rate (spec./hr)
P	sulfide ore bodies	NMC	22	0.7–1.2%	—	—
1	systematic collection	OUMNH	13,716	40%	181	79
2	pyrite	OUMNH	358	63%	6	61
		NMC	482	72%	11	54
		NML	135	52%	3	45
		Sedgwick	298	82%	8	44

Table 2. The evolution of DP applied to subsequent studies.

X = Discarded
X → = Redefined
→ = Retained

Pilot		Study 1		Study 2
Wet	X →	Dimpled	→	Dimpled
		Slumped	→	Rounded
Corrosion	→	Corrosion	→	Corrosion
Tarnish	→	Tarnish	→	Tarnish
Efflorescence	→	Efflorescence	→	Efflorescence
Powdery	→	Powder	→	Powder
Crumbling	→	Crumbling	→	Crumbling
Flaking	→	Flaking	→	Flaking
Pitting	→	Pits	X	
Breakages	→	Breakages	→	Breakages
Cracking	→	Cracking	→	Cracking
Abrasion	X			
Delamination	X			
Porosity	X			
		Dull	→	Dull
		Dark	→	Dark
		Pale	→	Pale
		Opacity	→	Opacity
		Colour Change	→	Colour Change

During the pilot, a preliminary set of 13 DP were trialled (Table 2). Four DP - 'wet', 'abrasion', 'delamination', and 'porosity' - were then discarded as they were not frequently seen in specimens or were difficult to define or identify. This however resulted in no DP to capture specimens which are hygroscopic or prone to deliquescence. 'Wet' was then redefined as 'slumped' (which was later rephrased as 'rounded') and 'dimpled' to capture these specimens. Whist pitting was maintained from the pilot, it was eventually dropped as pits were very rarely seen.

The main difference between the sets of DP used for the pilot and the subsequent surveys is the addition of colour criteria. Although colour is perhaps the most variable and qualitative of an object's properties, it plays a significant role in our visual experience. Changes in colour also often correlate with other changes in an object, especially in minerals (Royce *et al.*, 2023). Thus, it was determined that colour-based criteria would be included, but greater focus would be placed on changes in lightness ('dark', 'pale', and even 'dull') than in hue ('colour change'). This is because lightness is a universally recognised attribute of colour (Kuehni 2003), and changes in lightness are easier to identify and describe than those in hue (or chroma) regardless of one's chromatic vision (i.e., whether one is colour blind or not).

Pre-Survey

The three parts to the DP Method are pre-survey, surveying, and post-survey (Figure 4).

The pre-survey is crucial. It is a time of preparation: of identifying aims and objectives and collecting any pre-existing information in order for surveying to go as quickly and smoothly as possible. The first step is to identify what collections are to be surveyed and why, as these decisions shape how one approaches data collection and analysis. Using Study 2 as an example, pyrite specimens at OUMNH, NMC, NML, and the Sedgwick were surveyed to identify:

1. the state of the specimens,
2. any museum-specific deterioration patterns, and
3. any trends in deterioration which may elucidate how pyrite deteriorates in the museum environment.

Included in this first step is identifying which parts of a collection will **not** be surveyed. For Study 2, only specimens that were recorded to be primarily or exclusively composed of pyrite were surveyed. Specimens which contained pyrite as a secondary or associated mineral (be it with fossils, rocks, or other mineral specimens) were excluded. Additionally, only the specimens housed within the main sequence of drawers were surveyed; (extra)

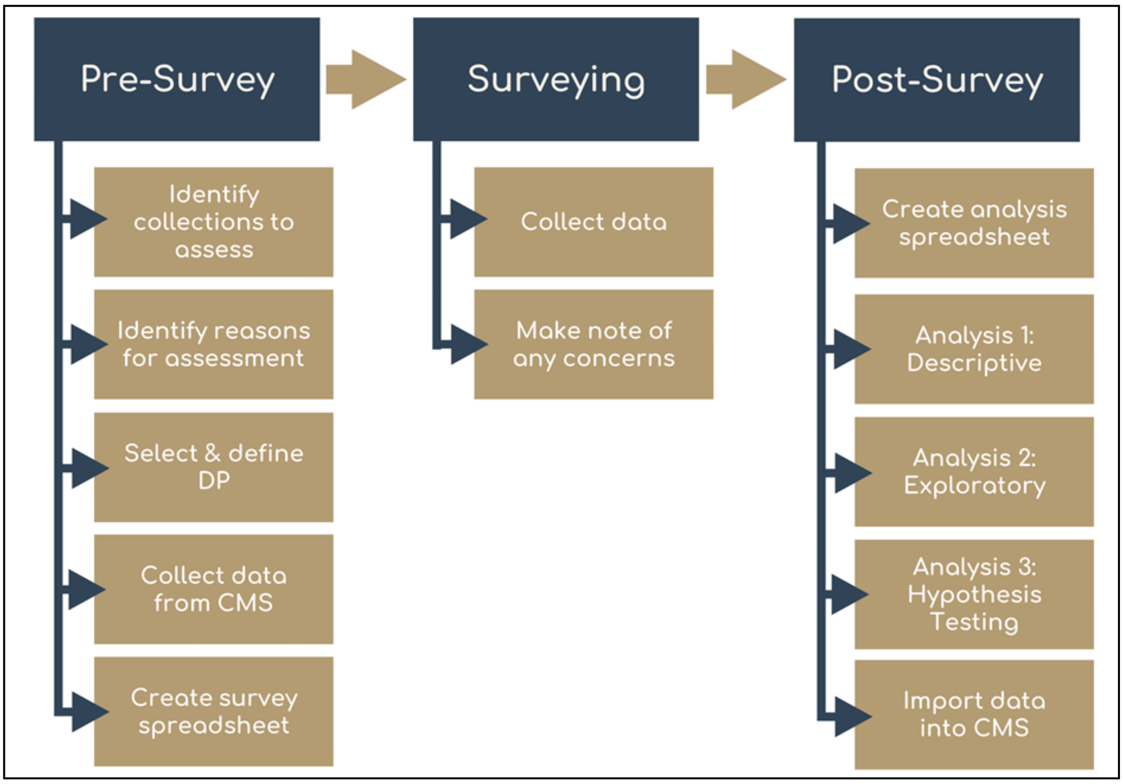


Figure 4. The three phases of surveying and the actions taken during each.

large and prepared specimens (e.g., slides, micro-mounts) were excluded. These choices were made primarily because excluded specimens were often stored elsewhere and would require significantly more time and effort to access.

Once the targeted collections are determined, DP are selected to reflect how the component objects deteriorate. A glossary of the chosen DP (Appendix 1) is then made, consisting of definitions and images like those seen in Figure 3. After this, relevant pre-existing information pertaining to each collection is retrieved from the institution's collection management system (CMS). What is deemed relevant depends on the overall purpose of the collection assessment, but should always include 1.) accession or object numbers, and 2.) the basic name or identifier of the targeted objects (e.g., pyrite, pheasant, platter). These two bits of information are key to ensuring that all subsequent information, including the survey data, is attached to the correct object. For both Studies 1 and 2, the following information was requested:

- accession/object number,
- primary mineral,
- associated mineralogy,
- locality, and
- accession/collection date.

The CMS data is then used to structure and populate the survey spreadsheet, which is divided into 6 main components (Figure 5).

1. **Worksheets** are used to divide the collection into its component groups (e.g., main mineral groups). This avoids having tens of thousands of objects in one worksheet.

2. The **Organisational columns** act as a means of sorting items by how they are found in the store and within the component groups. This allows for one to anticipate what is coming next.
   For example, minerals are often arranged by an organisational system (i.e., Hey, Dana, Strunz), which functions similarly to the Dewey Decimal System used in libraries. In these organisational systems, the main mineral groups are subdivided, either according to chemistry or crystal structure, and each mineral species is assigned a (alpha)numeric identifier. If a collection is arranged by such a system, one can sort the survey spreadsheet by the species identifier and then accession/object number. This allows for specimens that are stored together in the drawer to appear together in the spreadsheet, speeding up data entry.

3. The **Location columns** contain information pertaining to the objects' exact location in the store (i.e., cabinet, drawer, and or shelf).
   If this information is not already known, collecting it during the survey will prove beneficial and time-saving when searching for a specific object in the future. Recording the exact location may also be required for hazardous objects (i.e. asbestiform, radioactive).

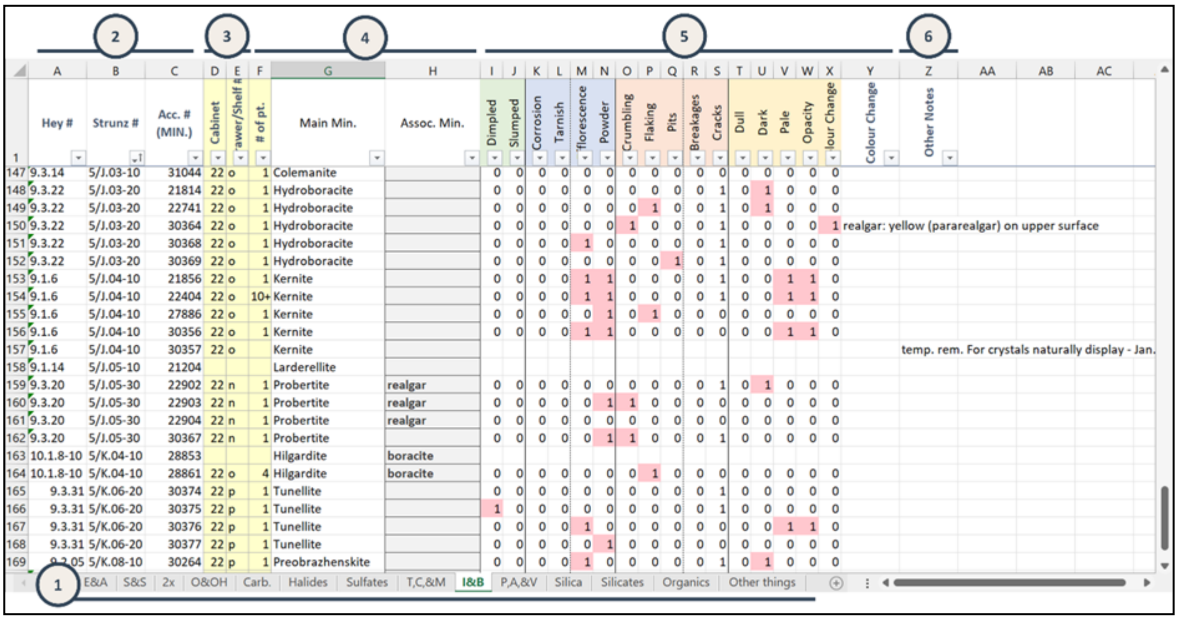


Figure 5. The six components of a (completed) DP survey spreadsheet.

4. The **Identification columns** correlate to immediately obvious visual characteristics (i.e., species, associated materials, colour). These aid surveying by providing visual clues that ensures one is attributing data to the correct object in case of a mix-up in the accession/object number.

5. The **DP columns** are the main data collection fields. Here, one enters either a 0 or 1 depending on whether the DP is absent or present.

6. **Additional notes columns** can be included to document any curatorial or conservation actions that may need to occur. This may include missing labels, specimens, or parts; need for repair or treatment; temporary removal; and the presence of hazardous material. An example column one may wish to included is a 'To Action' or 'Priority' column; a field for the rapid identification of objects needing immediate actioning. Ideally, this should be a binary (0/1) field like the DP columns, but institutional gradings can be applied for consistency. These notes columns can be used to identify key areas of concern within the collection and later facilitate resource allocation for collection care and development.

Surveying

Surveying itself is fairly straightforward: examine the object for the presence/absence of the chosen DP then type in the corresponding series of 1s and 0s. It took the author on average about a minute to examine and enter the data for each specimen (Table 1). Whilst there are no true time restrictions for examining an object, one should spend only as much time as necessary to identify DP in order to mitigate questioning one's perceptions.

Whilst the DP Method was designed so that one could survey every object in a collection, doing so is not always feasible or necessary. For both Studies 1 and 2, certain specimens were not examined; namely those stored in microenvironments (both bagged and boxed), bagged for asbestos, or were part of well-represented species (e.g., quartz, calcite, fluorite) that comprised hundreds (and sometimes thousands) of specimens. Microenvironments were not disturbed in order to maintain their climate, assuming they were still as conditioned. Asbestiform specimens and those in anoxia were often double bagged and difficult to examine. The bags often reflected the overhead lights or were not entirely transparent, obscuring detail. The anoxic bags were also only transparent on one side, limiting how much of the specimen could be viewed. As for the well-represented species, the author's personal skipping method was as follows:

If a species contained more than 50 specimens, a minimum of 50 were surveyed in order to use parametric statistical methods. At least 25% (but no more than 200) of each species' specimens were surveyed to ensure sufficient statistical representation. When skipping occurred, whole drawers were skipped. These were selected by a quick scan of all of the drawers and their contents. Those that contained other species were always surveyed. Those which contained many obviously 'worse-for-wear' specimens were flagged, and most (if not all) of these drawers were surveyed. If these accounted for 25% or more of that species' specimens, no further drawers were surveyed. If they did not, additional drawers were included. These were usually those that either contained one or two 'worse-for-wear' specimens, held fewer specimens than the rest, or were not high enough to require using the step-ladder to access.

Post Survey: Analysis

The primary purpose of analysis is the identification of deterioration; chiefly, what types of deterioration are occurring and to which specimens. This is achieved through examining the deterioration phenomena that are recorded as being present. Whether the deterioration is active, however, cannot be determined by visual observations alone and is out of the scope for the survey.

Descriptive Analysis

Analysis begins by identifying how to collapse the data into meaningful subsets in order to identify trends. Subsets can be defined in various ways, but perhaps the most useful for initial analysis is defining the subsets by 1.) species, 2.) object type, or 3.) component group. For both Studies 1 and 2, subsets were defined by the primary mineral species, for which five descriptive statistics were calculated (Table 3). The 20 entries of Table 4 will be used as a worked example to explain this phase of analysis.

After importing the survey data into a new workbook for analysis, the first metric to be calculated is the Total DP ($\sum$DP). The $\sum$DP is the sum of all DP observed in a singular object (i.e., the sum of all the 1s and 0s in a given row). For example, specimen 00201 (sulfur; Table 4) has a $\sum$DP of 2 because two DP ('powder' and 'cracks') were observed. The $\sum$DP are then used to calculate the Average DP ($\bar{x}$DP): the average $\sum$DP of all the specimens being examined. In other words, the $\bar{x}$DP represents the average number of DP seen in a (sub)set of specimens. The $\bar{x}$DP for the ten sulfur specimens listed in Table 4 is 2.

Table 3. The five descriptive statistics and how they are calculated in Excel.

How Data is Being Examined	**Descriptive Statistic**	**Abbreviation**	**What it is**	**How to Calculate**
Individually	Total DP	∑DP	Sum of DP seen in 1 object *Row Summary*	Formula: SUM
Collection-wide OR *Grouped into Subsets*	Average DP	x̄DP	Average DP seen in all objects *Column Summary*	Formula: AVERAGE or Pivot Table, 'Values' *Value Field: Average*
	Number of specimens	# of sp.	Number of objects in a (sub)set *Column Summary*	Pivot Table, 'Values' *Value Field: Count*
	Percent DP	%DP	Percentage of objects displaying each DP *Column Summaries*	Pivot Table, 'Values' *Value Field: Average*
	%DP Patterning	—	Colour coding of %DP to facilitate data examination	Conditional Formatting *Highlight Cell Rules: 'Greater Than' &/or 'Between'*

Table 4. Survey and descriptive analysis results for 20 select specimens (ten each for sulfur and galena). Five DP (Dimpled, Rounded, Pits, Opacity, and Colour Change) were omitted here as they were absent from these specimens.

Mineral	Accession #	Corrosion	Tarnish	Efflorescence	Powder	Crumbling	Flaking	Breakages	Cracks	Dull	Dark	Pale	Total (∑DP)
Sulfur	00201	0	0	0	1	0	0	0	1	0	0	0	2
	00202	0	0	0	0	0	0	0	0	0	0	0	0
	04533	0	0	0	0	0	0	0	0	0	0	0	0
	04549	0	0	0	1	0	0	0	0	0	0	0	1
	04591	0	0	1	0	0	0	0	0	0	0	0	1
	04594	0	0	1	0	1	0	1	1	0	0	0	4
	08345	0	0	1	0	1	0	1	1	0	1	0	5
	10284	0	0	0	0	1	0	1	0	0	0	0	2
	10285	0	0	0	1	0	0	0	0	0	0	0	1
	10286	0	0	0	0	0	0	0	0	0	0	0	0
	%DP	**0%**	**0%**	**30%**	**30%**	**30%**	**0%**	**30%**	**30%**	**0%**	**10%**	**0%**	**x̄DP: 2**
Galena	04965	0	0	0	0	0	0	0	0	1	0	0	1
	11059	0	1	0	0	1	0	0	0	1	1	0	4
	11071	0	1	0	0	0	0	0	1	1	1	0	4
	12827	0	1	1	0	1	0	1	1	1	1	1	8
	15289	0	1	0	0	0	1	0	1	1	1	0	5
	15427	0	1	0	0	0	0	0	0	1	0	0	2
	18712	0	1	0	0	0	0	0	1	1	0	0	3
	18922	0	1	1	0	0	0	0	0	1	1	0	4
	19281	0	1	0	0	0	0	0	0	1	0	0	2
	21516	1	1	0	0	1	0	0	1	1	0	0	5
	%DP	**10%**	**90%**	**20%**	**0%**	**30%**	**10%**	**10%**	**50%**	**100%**	**50%**	**10%**	**x̄DP: 4**
Colour Code		0–24%	25–49%	50–74%	75–100%								

∑DP and x̄DP are useful in summarising the state of specimens, but they must be used with caution, for they are **NOT** indicators of the extent or severity of deterioration. A higher ∑DP or x̄DP does not always correlate with concerning deterioration.

Both specimens shown in Figure 6 have a ∑DP of 5, but display different DP. The DP seen in the sulfur specimen (Figure 6a) largely correspond to the siliceous sinter matrix in which the sulfur crystals are imbedded, and indicate the matrix's friable nature and susceptibility to physical forces (e.g., poor handling, vibration). The DP of the galena specimen (Figure 6b & c), however, are much more concerning as they are suggestive of surficial oxidation. This oxidation occurs when the relative humidity is greater than 65% (at 20°C) and may potentially lead to efflorescence as the mineral alters to the lead sulfate, anglesite ($PbSO_4$) (Swartzlow, 1933; Howie, 1992). Thus the nature of one's response to change is not governed by a single value but by the "patterns of change" (Kosek & Barry, 2019: 202) formed by the DP.

When reviewing multiple objects of the same type, one determines areas of concern by examining the patterns formed by the Percent DP (%DP). Each %DP is the percent average of the DP's occurrence within the subset being studied; it is the sum of the 1s and 0s of a given DP column (e.g., 'cracks') divided by the total number of specimens being examined, and displayed as a percentage. Three of the ten sulfur specimens in Table 4 were recorded to have displayed a crack of some kind, thus the %DP for 'cracks' would be 30%.

%DP patterning is produced by colour coding the %DP and is used to determine potential reaction types based on the DP observed. For mineral specimens, reaction types may include surficial oxidation, oxidation at depth, pollutant-induced oxidation, efflorescence, surface wetting, and physical forces. These reaction types are then categorised as first or second order depending on the percentage of specimens that exhibit these patterns. First order is a reaction that generally affects greater than 50% of specimens, whilst second order is that which affects less than 50%.

Determining which reaction types may be affecting the collection does require some knowledge of

Figure 6. ***A.*** *Sulfur specimen OUMHN.MIN.08345 is in multiple parts and displays noticeable cracks and crumbs. Efflorescence and a dark soot-like coating is also visible upon close examination.*
B and C. *Galena specimen OUMNH.MIN.15289 exhibits b.) a distinct dull and dark tarnish on all crystal faces, as well as c.) cracking and flaking on the bottom of one large crystal.*
Images used with permission courtesy Oxford University Museum of Natural History.

the material's deterioration, but the reading required to identify which DP to use for the survey may often provide sufficient understanding for correlating signs of change to potential causes. Even simply categorising potential reaction types into 'physical forces' and 'other' is extremely useful and can result in targeted action to address sources of the former.

Exploratory Analysis

During the second round of analysis, supplemental information is included to contextualise the survey data by determining how the peculiarities of an object are related to its present state. Supplemental information may include additional object data (e.g., locality, habit, age), environmental data, results from analytical techniques (e.g., colorimetry), and details of the housing materials. Numerical data can be studied alongside the DP columns, and categorical data can be used to categorise or filter further subsets.

This round of analysis can be classified into two categories: 1.) mapping, and 2.) comparison and correlation (Table 5). The latter can manifest in a variety of ways due to the type of additional information used. Yet both can be considered as preliminary bivariate analysis; the relationship between object state and another variable - such as location - is being explored.

Supplementary Statistical Analysis

The data produced by the DP Method is amenable to statistical methods used to examine intervariable relationships and to test hypotheses. Such examination augments descriptive and exploratory analysis, and can be used to investigate how and why certain changes occur. The exact statistical method chosen will depend upon the question posed. For instance, Student's *t*-test could be used to examine whether there is a statistically significant difference in the state between two similar collections stored in separate locations, whereas Principal Component Analysis (PCA) could be used to examine whether situational variables (e.g., museum, habit, locality) affect specimen state (Royce, 2023). Whether there are indeed any questions, however, will depend on the survey's goals (as identified in the pre-survey; Figure 4) and or the findings of the descriptive and exploratory analysis.

Discussion

Many have asserted (Drott, 1969; Glud and Johnsen, 2002; Xavier-Rowe and Fry, 2011) that - given the lack of staff and other resources - the best way to extract meaningful condition data from large collections is by randomly sampling and surveying no more than 10% of its objects. Yet often forgotten is the fact that sampling is "a compromise measure" (Drott, 1969: 119) that provides at best an approximation, and that it is critical for a sample "to be as representative as possible of the entire population" (ibid., 120). Even though the number of objects surveyed are often in the hundreds when following this approach (Table 6), there remains the question of whether the results are truly representative of what is occurring in the collection, especially when the collection in question is highly heterogenous or mixed-media (e.g., social history and anthropology). Also often omitted from reports is the substantial planning and effort required to not only determine an adequate sample size but also to randomly select and then find the objects to survey (Drott, 1969).

Table 5. Types of exploratory analysis conducted post-survey.

Category of Analysis	**Descriptive Statistic**	**Types Additional Information**	**Purpose**
Mapping	$\bar{x}$DP	Drawer & cabinet numbers	- $\bar{x}$DP are mapped onto the room's cabinets and drawers - Used to reveal hot spots that may indicate sources of deterioration (e.g., leaks, pests)
Comparison & Correlation	- $\bar{x}$DP - %DP Patterning	- Locality - Habit - Housing material - Associated material - Collection or accession date - Analytical data - etc.	- Comparison of %DP patterns according to additional info - Examining relationship between $\bar{x}$DP/%DP & additional info - Used to determine difference in stability &/or reaction types

Table 6. Examples of surveys and the percentage of the collections covered.
** (Exact) values not provided by authors*
† Calculated estimation based on values provided by Kosek & Barry 2019 and the British Museum 2023. The reported survey was a pilot study; assumedly subsequent work will survey a greater proportion.

Collection Type	Number of Objects	Percentage of Collection	Citation
Freeze-dried Leather	660	17%	Sully & Suenson-Taylor 1996
Still Photographs	656	< 10% *	Glud & Johnsen 2002
Homogeneous Objects/Materials	*	2%	Xavier-Rowe & Fry 2011
Mixed Materials	*	5%	
Iron Gall Ink Drawings	100	~ 0.09 – 0.13% †	Kosek & Barry 2019

The DP State Survey Method foregoes the need for such "tedious" (Drott, 1969: 125) sampling procedures due its ability to quickly provide data for large proportions of a collection, regardless of size and variability. As Table 1 demonstrated, 40% or more of a collection can be surveyed in a reasonable timeframe utilising this approach. The DP Method thus ensures greater sampler presentation and provides a firm, rigorous statistical foundation for any subsequent decisions and actions.

The use of phenomenological criteria is what allows for the surveyor to cover more ground. Newey and co-authors (1993) found that surveyors required about a minute to determine and record the condition score of an object (a single criterion). With the DP Method, one can capture the presence/absence of 15 criteria in the same amount of time (Table 1). This evidences that it is possible to collect more data by forgoing the time-intensive thought processes required to determine condition.

The data produced by the DP Method is more descriptive and quantitative than a condition score as well. As previously discussed, condition scores are highly subjective and can imply multiple types of material change. The DP Method results are far less ambiguous; the string of 1s and 0s convey exactly what is and is not present, allowing one to visualise an object's appearance. This greater clarity of object state facilitates:

- analysis of change over time,
- interpersonal review and communication of results, and
- Locating the object at a later date.

This does not mean, however, that subjectivity is completely removed. All survey methods will contain some degree of subjectivity and variability, as survey data is primarily collected via human observation (Royce, 2023). While using the presence/absence binary with visual criteria does mitigate variation induced by categorisation, variability may still occur depending on whether surveyors can see the selected criteria on a given object. Many factors influence vision; having adequate lighting and an unobstructed view can aid observation, but cannot compensate for physiological variation (e.g., colour blindness, astigmatism). Increasing the number of objects surveyed is a means of accounting for this variation; the larger the dataset, the less of an affect an individual observation has. Thus, surveying large portions of a collection has an additional benefit of reducing variability.

Further investigations and developments are still necessary to confirm that the DP Method is indeed more efficacious and advantageous than pre-existing collection surveying methods. In particular, work addressing reproducibility and inter-surveyor variability ought to be conducted (Table 7). Potential studies may include:

- a multivariate analysis of results conducted by multiple surveyors to examine the effects of knowledge, training, or even visual perception, and
- the determination of a minimal percentage required for surveying to adequately characterise collection state.

Table 7. Currently identified areas requiring further development and suggestions for addressing them. From such research, suitable means for the routine usage of the DP Method for collection monitoring could be established.

Areas for Development	**Suggestions for Future Work**
Surveyor Variability and Subjectivity	Comparison of results produced by multiple surveyors with different levels of: - knowledge of the collection (i.e., conditions, history) - knowledge of object/material and its deterioration - training - vision (i.e., focusing powers, colour normal v. colour blind)
Confirming Adequate Characterisation of Collection State	Test of sampling procedures, comparing results for: - different percentages of a collection surveyed (e.g., 10% v. 25%) - variations in what is decided to be omitted from surveying
Reproducibility and Efficacy in Monitoring Changes over Time	Comparison of results produced: - by multiple surveyors - at various intervals in time (e.g., 6 months, 1 year, 5 years)

Conclusion

The DP State Survey Method was developed to produce semi-quantitative, statistically robust data pertaining to object state via the use of phenomenological criteria. The presence or absence of these visual criteria, and the patterns that are produced, are used to characterise collection state and determine any potential reactions occurring within it. By simplifying the process to a series of 'yes or no' questions, greater portions of collections can be surveyed in same amount of time as other methods. This benefits the data in three ways - improved collection representation, increased statistical rigor, and decreased variability - resulting in a better characterisation of collection state.

The DP Method can thus provide greater familiarity of a collection and an improved understanding of a collection's composition, inherent properties, and most common forms of material change. Such insights contextualise survey data, facilitate analysis, and ultimately lead to more informed decisions.

References

Ashley-Smith, J., 1995. Definitions of Damage [online]. *Annual Meeting of the Association of Art Historians*. Available from: https://cool.conservation-us.org/byauth/ashley-smith/damage.html [Accessed 8 Oct 2018].

DeMouthe, J.F., 2017. *Care and Documentation of Mineral Collections*. Chantilly, VA: Mineralogical Society of America.

Drott, M.C., 1969. Random Sampling: a Tool for Library Research. *College & Research Libraries*, 30 (1), 119–125.

Forleo, D. & Francaviglia, N., 2018. Condition Assessment of Historic House Collections: Testing Different Statistical Methods at the Château de Versailles. *Studies in Conservation*, 63 (sup 1), 76–80.

Gioventù, E., 2018. Comparison of Three Methods for Evaluating the Condition of the Collection in the Royal Apartments of the Pitti Palace, Florence. *Studies in Conservation*, 63 (sup 1), 355–358.

Glud, K.R. & Johnsen, J.S., 2002. Survey of the Still Photograph Collection At the Danish Film Institute. *Studies in Conservation*, 47 (sup 3), 74–77.

Howie, F.M.P., 1992. Sulphides and allied minerals in collections. *In*: F.M.P. Howie, ed. *The Care and Conservation of Geological Materials: Minerals, Rocks, Meteorites and Lunar Finds*. Oxford: Butterworth-Heinemann, 56–69.

Keene, S., 2002. *Managing Conservation in Museums*. 2nd ed. Oxford: Butterworth-Heinemann.

Kosek, J. & Barry, C., 2019. Investigating the condition of iron gall ink drawings: developing an assessment survey. *Journal of the Institute of Conservation*, 42 (3), 191–209.

Kuehni, R.G., 2003. *Color Space and Its Divisions: Color Order from Antiquity to the Present*. Hoboken, New Jersey: Wiley and Sons.

Newey, H.M., Bradley, S.M., & Leese, M.N., 1993. Assessing the condition of archaeological iron: an intercomparison. *In*: *ICOM Committee for Conservation 10th triennial meeting: Washington, DC, 22-27 August 1993: preprints*. 786–791.

Norris, D., 2015. Chinese painted enamels: A condition survey of the collection at the Ashmolean Museum of Art and Archaeology. *Journal of the Institute of Conservation*, 38 (2), 146–158.

Pedersoli, J.L.J., Antomarchi, C., & Michalski, S., 2016. *A Guide to Risk Management of Cultural Heritage*. Sharjah.

Royce, K., 2023. Assessing the Stability of Mineralogical Collections in Museums. University of Oxford. DOI: 10.5287/ora-d5dagxd4g

Royce, K., Baars, C., & Viles, H., 2023. Defining Damage and Susceptibility, with Implications for Mineral Specimens and Objects: Introducing the Mineral Susceptibility Database. *Studies in Conservation*, 68 (3), 298–317.

Sully, D. & Suenson-Taylor, K., 1996. A condition survey of glycerol treated freeze-dried leather in long-term storage. *Studies in Conservation*, 41 (sup 1), 177–181.

Swartzlow, C., 1933. Note on the alteration of galena to anglesite to cerussite. *American Mineralogist*, 18 (4), 174–175.

Taylor, J., 2005. An Integrated Approach to Risk Assessments and Condition Surveys. *Journal of the American Institute for Conservation*, 44 (2), 127–141.

Taylor, J., 2013. Causes and extent of variation in collection condition survey data. *Studies in Conservation*, 58 (2), 95–106.

Taylor, J. & Stevenson, S., 1999. Investigating subjectivity within collection condition surveys. *Museum Management and Curatorship*, 18 (1), 19–42.

Taylor, J. & Watkinson, D., 2003. Using multiple hypotheses in collection condition surveys. *The Conservator*, 27 (1), 13–22.

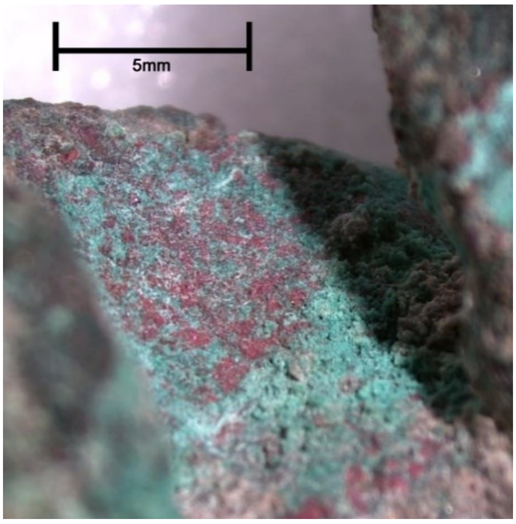
Taylor, J. & Watkinson, D., 2007. Indexing reliability for condition survey data. *The Conservator*, 30 (1), 49–62.

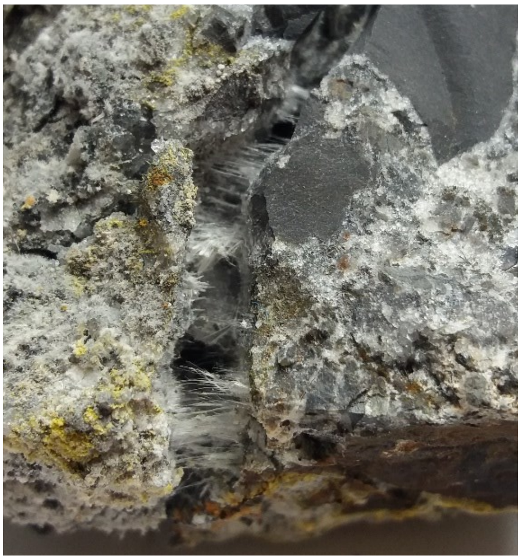
the British Museum, 2023. Two million prints online for all [online]. Available from: https://www.britishmuseum.org/exhibitions/two-million-prints-online-all [Accessed 28 Jul 2023].

Waller, R., 2013. Cultural Property Risk Analysis Model (CPRAM): A very brief introduction to key concepts What is a risk ?

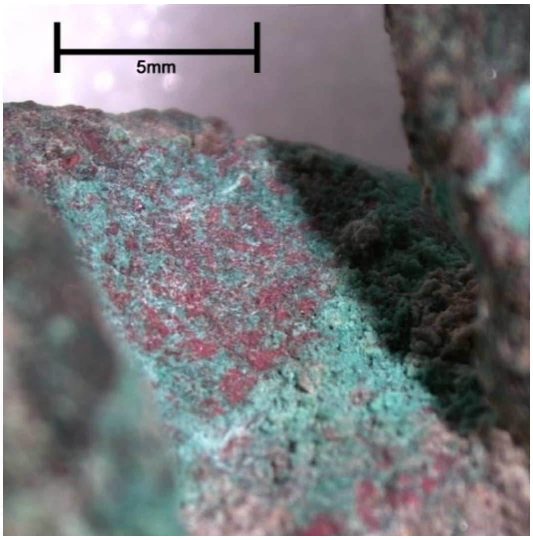
Xavier-Rowe, A. & Fry, C., 2011. Heritage collections at risk: English Heritage collections risk and condition audit. *ICOM-CC 16th triennial conference Lisbon 19-23 September 2011: preprints*, 1–11.

Appendix 1. Phenomenological criteria used during the state survey, with definitions and photographic examples.

Criteria Definition	**Example Images**
Dimpled Shallow divots in the mineral surface	
Rounded Mineral appears 'melted' with smooth edges	
Corrosion Voluminous amorphous products on mineral surface May be localised or extend across a wide surface area	

Criteria Definition	**Example Images**
Tarnish A coating on the mineral surface Coating may be darker, metallic, iridescent, or different colour than the original colour of mineral	
Efflorescence Crystalline growth on surface and or within cracks of the mineral	
Powder Amorphous grit covers the mineral surface Often comes away on glove with touch	

Criteria Definition	**Example Images**
Crumbling Mineral falling apart into many round, distinct pieces, usually of various sizes	
Flaking Mineral surface removed in distinct, angular pieces Denotes flakes free from or loosely attached to the mineral body	
Breaks Distinct pieces have come away from the main body Differs from *flaking* in that the pieces are thicker and more three-dimensional Differs from *crumbling* in that the breaks are usually clean and sharp	

Criteria Definition	**Example Images**
Corrosion Voluminous amorphous products on mineral surface May be localised or extend across a wide surface area	
Cracks Splits in the mineral surface Can be of various length, widths, and depths, but does not go completely through the specimen (depth-wise)	
Dull Lustre of a mineral has changed or become absent (i.e., no shine) e.g., the finish of a metallic mineral has become sub-metallic or is no longer shiny	

Criteria Definition	**Example Images**
Dark Coloured mineral is a darker shade of that colour or black	
Pale Coloured mineral is a lighter shade of that colour or white/colourless	
Opacity Mineral has become 'clouded', translucent, or opaque	
Colour Change Mineral colour altered from one distinct colour to another distinct colour that is not white or black (e.g., blue to yellow), or has developed an iridescence