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ORIGINAL RESEARCH OR TREATMENT PAPER

Standardizing Collections Record Data for Increased Understanding of Glass Collections Across the Smithsonian Institution

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ABSTRACT

The information contained in museum collections catalog databases is an invaluable resource for understanding and caring for collection items. The identification and grouping of items in a collection based on criteria such as location of manufacture, use, or materials composition allows for items at greater risk for long term preservation issues to be more appropriately monitored and cared for. However, identifying these items can be difficult, particularly when the collections data or terminology included in collections catalogs and databases vary significantly between items or across collections. This paper discusses the process and results of a data consolidation and cleaning campaign that was undertaken by the Smithsonian's Glass Deterioration Working Group. This work was done in order to develop a consistent database of glass and glass-containing collection items that is able to be effectively queried for items of particular concern or interest from a preservation standpoint.

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Data cleaning; data management; collection survey; glass; glass alteration

Glass collections at the Smithsonian Institution

The Smithsonian Institution in Washington D.C. is comprised of a network of 21 museums and the National Zoo, each with their own focus, mission, and collections care policies. Despite the vast differences between collections at each museum, one aspect all the Smithsonian museums have in common is the presence of glass and glass-containing collection items. The glass collection items at the Smithsonian are as diverse as the museums that house them, and include objects from around the globe and spanning the timeline of human civilization, ranging from ancient glass beads to space shuttle windows, from elaborate sculptures to daguerreotypes.

The Glass Deterioration Working Group (GDWG) was formed at the Smithsonian in early 2020, with the goal of conducting a sample survey aimed at assessing the condition of the glass and glass-containing collection items found across all of the Smithsonian museums in order to identify areas of strengths and weaknesses for better long-term preservation (Cobb et al. 2022). Because of its large and varied collections, the Smithsonian offers a unique opportunity to study variations in current glass condition on a broader scale than has ever been previously possible.

Prior to beginning the sample survey, it was first necessary to compile a standardized combined collection record dataset of all available collection catalog records of glass and glass-containing collection items. The present analysis and discussion are limited to items for which individual catalog records exist and are available in digital collection databases. While the full scope of glass collections at the Smithsonian will be assessed as part of the broader survey being conducted by the GDWG, including both archival glass photographic plates and glass used in natural history specimen storage, neither of these groups of items are individually cataloged and will not be discussed here.

To generate the combined collections record dataset, collections stewards from each collaborating museum and department across the Smithsonian were asked to generate a complete list of collection records of items that include glass as a component material, using available digital collection databases. The resulting combined collection record dataset contains over 100,000 individual collection item records. However, the methods used to record collection item information were found to vary between museums and departments – standards which have also changed significantly over the Smithsonian's 178 years (Turner 2015, 661–662). In many cases, more detailed information about each collection item could be found in paper catalog cards or archival accession files, however the number of collection items at the Smithsonian makes it beyond the scope of this project to attempt to supplement the digital records with non-digitized records in any widescale way. This variation in the available digitized data meant that in order for the combined collection record dataset to be effectively queried, the provided

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data first required a considerable amount of standardization and consolidation. The details of the data cleaning campaign, as well as some of the resulting insights and information that can be drawn from the cleaned and consolidated dataset are presented here.

It is important to note also that what data is or is not included in catalog databases is rooted in Western museological practices which are often divorced from the knowledge systems and contexts of the individuals or cultures who created the items (Boden 2022; Srinivasan et al. 2010; Turner 2015; Turner 2016). This means that catalog databases may lack, misrepresent, or even intentionally neglect important information about items (Turner 2015; Turner 2016, 106–107). The authors recognize that their work draws on data that is situated in colonial systems of recordkeeping, and that further cleaning and consolidating this data perpetuates those systems.

Identifying deteriorating glass collection items

In the context of museum collections, the primary driver of deterioration in glass is a process known as glass alteration (Gin 2014; Majérus et al. 2020). Glass alteration occurs when water or other hydrogen-bearing species come into contact with the surface of the glass and undergo an ion exchange reaction with the alkalis present in the glass matrix (Brill 1975; Jantzen, Brown, and Prickett 2010). As glass alteration progresses, it leads to the formation of characteristic microcracking and a frosted appearance on the glass surface, as well as the development of secondary precipitate materials (Jantzen, Brown, and Prickett 2010; Majérus et al. 2020). In advanced cases, the cracking of the glass driven by this alteration can lead to complete object loss (Koob 2006, 125). The phenomenon of glass alteration, sometimes called glass disease or glass sickness, has been noted in glass for centuries, though most work focused on understanding the phenomenon has been much more recent (Brill 1975; Koob 2006, 12–13). Figure 1 shows some examples of how glass alteration can appear in museum collections. The rate and severity of the deterioration of a glass object is directly tied to both the composition of the glass, specifically the concentration of alkali components, and the environmental conditions in which the object is stored (Kunicki-Goldfinger 2008; Koob et al. 2017).

While significant work has been, and continues to be conducted on the use of analytical characterization techniques for studying glass collection items and the mechanisms underlying their deterioration (Fischer et al. 2018; Majérus et al. 2020; Verhaar et al. 2019; Verhaar, van Bommel, and Tennent 2020) the scale and breadth of many collections, lack of access to analytical equipment and expertise, and sampling restrictions often precludes scientific analysis as a method of assessing the condition of most glass collections. Instead, collections often rely on visual condition surveys in order to approximate and understand the condition of a collection.

In recent years, a number of surveys have been conducted on prominent glass collections around the world with the intent of identifying patterns in observed instances of glass alteration of collection items. Many of these surveys have been focused on a specific type of collection item such as glass beads (Fusco and Speakman 2010; Lovell 2006; O'Hern and McHugh 2014), flutes and piccolos (Brostoff et al. 2022), magic lantern slides (Santos et al. 2021) or eighteenth century central European colorless tableware (Kunicki-Goldfinger et al. 2002; Kunicki-Goldfinger et al. 2003).

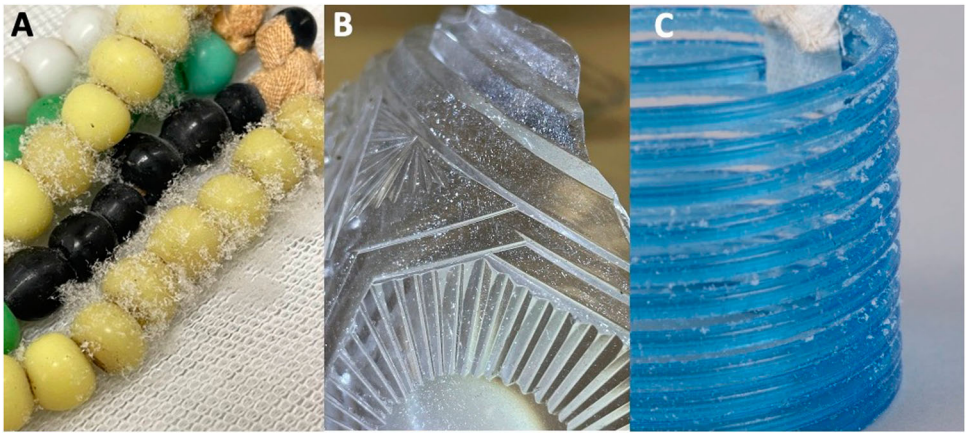

Figure 1. Examples of altered glass collection items: A. Detail of beads on a stole (E358123, Department of Anthropology, National Museum of Natural History, Smithsonian Institution, photograph by author) with significant secondary precipitate formation; B. Detail of a fragment of a glass decanter with extensive crizzling and microcracking (1983.0539.01, Division of Home and Community Life, National Museum of American History, Smithsonian Institution, photograph by author); and C. Glass coil (E410538, Department of Anthropology, National Museum of Natural History, Smithsonian Institution, photograph by author) with secondary precipitate formation.

Other surveys have focused on assessing the condition of items from a particular period of glass such as Cabo del Arco's survey of European and British glass at the National Museum of Scotland (Cabo del Arco 1999), Tay's survey of glass plate negatives from the late nineteenth and early twentieth century (Tay 2013), McCabe's survey of nineteenth-century glass negatives (McCabe 1991), Brostoff et al.'s review of nineteenth century photographic glass (Brostoff et al. 2020), or Melin and Franzon's assessment of the National Museum's collection of glass dating from between 1500 and 1800 (Melin and Franzon 2019). Still other surveys have focused on assessing how glass alteration impacts or is impacted by other materials that are present on an item such as Schorpp et al.'s assessment of collection items exhibiting adverse interactions between glass and metal (Schorpp et al. 2019).

Each of these studies has added insight into the likely prevalence of visible alteration in different kinds of glass collection items and allows for easier identification of collection items at greater risk of this type of deterioration. However, the broad range of collection focuses across the different Smithsonian museums means that collection items that may fall into some of the higher risk categories identified in the literature are often spread over many different museums or department collections. Identifying all collection items belonging to these disparate groups and making comparisons between them can be difficult. By creating a combined collection record dataset of cataloged glass at the Smithsonian it is now possible to query this dataset in order to effectively identify these specific groups of interest based on item type, material components, age, or location of manufacture.

Inherent vice: material classes of interest

Understanding trends in glass alteration becomes significantly more complex when the glass components of an item are deteriorating in proximity to other constituent materials of that item or neighboring items. This phenomenon, known as 'inherent vice,' plays a critical role in the long-term stability of cultural heritage collections (Van der Reyden 2010). For glass alteration, recent literature points to a number of materials classes which are of particular concern when considering the long-term stability of glass and glass-containing collection items.

Metal alloys

The increased alkalinity of glass surfaces that can result from the presence of secondary precipitate materials formed during glass alteration has been observed to drive localized corrosion in some metal alloys that are in direct contact with the altering glass surface

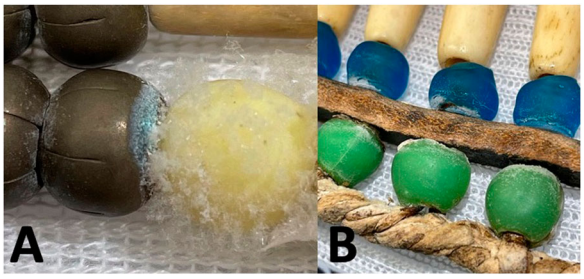

Figure 2. Examples of material interactions on altering glass: (A) Detail of a stole (E358123, Department of Anthropology, National Museum of Natural History, Smithsonian Institution, photograph by author) which shows an instance of glass-induced metal corrosion where the alteration of the glass bead is causing corrosion on the metal bead directly next to it; and (B) Detail of a breastplate (E364518, Department of Anthropology, National Museum of Natural History, Smithsonian Institution, photograph by author) which shows the development of a soapy secondary precipitate layer forming on the glass beads at their interface with the hide component of the item.

(Eggert 2010). This phenomenon, known as glass-induced metal corrosion, has been the subject of considerable study in the last two decades (Eggert 2010; Eggert et al. 2010; Eggert et al. 2011; Eggert and Fischer 2022; Fischer et al. 2019). For metal components, localized corrosion related to contact with the glass is likely to appear as a band of friable corrosion products, flaking, or discoloration along the border of the metal edge that is immediately in contact with the glass component of the item as seen in Figure 2(A) (Eggert 2010; Eggert et al. 2010; Eggert et al. 2011; Eggert and Fischer 2022; Fischer et al. 2018). While this phenomenon has primarily been observed on copper-containing metal alloys such as bronze and brass, other common metals and their alloys, such as lead and zinc, have also been observed to undergo glass-induced metal corrosion (Eggert 2010; Fischer et al. 2019). In addition, some other commonly used metal alloys with minority copper components, such as most silver, can also be affected by this phenomenon (Eggert 2010).

Wood

Recent research focused on the presence of wooden components used in the construction of collection storage furniture has indicated that the off-gassing of volatile organic compounds such as formaldehyde and acetic acid from these materials drives an increased rate of observed glass alteration in glass collection items stored in the same space (Eggert and Fischer 2022; Koob 2006, 127; Palomar, García-Patrón, and Pastor 2021; Robinet et al. 2009; Thicket and Ling 2022). However, it is not just wooden components used in collection storage that can have this effect on glass collection items. Cultural heritage items

containing wooden components can also themselves be a source of volatile organic compounds that can be detrimental to the long-term stability of glass components on these same items or on neighboring glass items (Grøntoft 2012; Smedemark, Ryhl-Svendsen, and Schieweck 2020). In these instances, the glass components nearest to the off-gassing wood will typically exhibit localized crizzling or microcracking which appears as increased opacity in the glass. For the purposes of this study, wood was defined as the hard or soft wood of a tree, and does not include leaves or seeds.

Plastic

Like wood, some plastic compositions, particularly early plastics such as acetate or cellulose nitrate, are known to release volatile organic compounds such as acetic acid from the former polymer as they age and deteriorate (Lazzari and Reggio 2021). The presence of these compounds in the local environment have been observed to accelerate the visible alteration of nearby glass surfaces (Budu and Sandu 2015; Cid and Palomar 2022; Hatchfield 2004; Martellini et al. 2020; Whitman, Chen, and Osterman 2007, 94).

Leather and hide

Glass components, usually beads, that are in direct contact with a piece of hide, skin, or leather onto which they are sewn, have been observed to form a unique presentation of secondary precipitate products as the glass surfaces alter, as can be seen in Figure 2(B). In some cases, the hide substrate has been observed to darken in the areas that are in contact with the deteriorating glass (Lougheed and Shaw 1985, 11). Analysis of these secondary precipitate compounds has indicated that the alkalis coming from the glass bulk are reacting with the oils and fats present in the hide to form a soap on the surface of the glass (Fenn 1987, 195). This phenomenon is further complicated by the fact that leather and hide can vary considerably in pH, tanning process, and the application of pesticides and other applied materials. Further research is needed to identify what characteristics of leather or hide might be responsible for producing this adverse interaction.

Methodology

Gathering glass collection item records

In order to compile a full combined collection record dataset of all the recorded glass collection items across Smithsonian museums, representatives from each collecting museum or department were asked to provide a spreadsheet of the available catalog data for all of the glass and glass-containing item records in each collection's digital database. The museums and departments across the Smithsonian make use of a number of different database management software packages to manage their collection information (e.g. The Museum System (TMS) and Electronic Museum (EMu)). Within these databases, the level of information included about each collection item can vary from incredibly detailed to extremely sparse. As a result, glass-containing collection items could not always be reliably identified by a search for the term 'glass' as a material component.

Various strategies were used to query the available databases to ensure that as many glass and glass-containing items as possible were captured. For collections with robust digital records including thorough and accurate material-level information, gathering data was as simple as using keywords that are known synonyms for glass to search that collection's digital catalog. These keywords included but were not necessarily limited to: glass, crystal, paste stone, Pyrex, and mirror.

For collections with more sparsely populated digital catalog records, or for instances where the presence of glass on an item had been frequently overlooked when entering the component materials of a given item type, the collections representative was asked to perform additional catalog searches using terms for items that typically include glass (e.g. goblet, eyeglasses, camera, beads/beadwork, collodion positive, lantern slide, ambrotype etc.) in order to gather a more complete list of glass-containing items in that collection. This project relied heavily on the expertise of the collections representatives in determining what search terms were most likely to yield the most complete list possible of glass collection items for each museum or department.

Non-glass and excluded glass

While this project is interested in capturing as full and complete a picture of the condition of glass and glass-containing items as possible across the institution, to maintain logistical simplicity and focus on the most pertinent issues facing glass collection items, several different types of glass and glassy materials were actively excluded from consideration.

Vitreous coatings

While technically glass, vitreous coating materials such as ceramic glazes or enamels generally have different compositions from those found in solid glass, which allow them to adhere to the supporting material to which they are applied (Rhodes 1975, 55). In most cases, these different compositions and distinct functions result in deterioration phenomena that differ significantly from items comprised of solid glass bodies

(Baricza et al. 2016; Coutinho, Miller, and Macedo 2015; Schalm et al. 2009; Smith, Carlson, and Newman 1987). As such, they were determined to not be assessable under the same criteria that this project uses to evaluate the condition of glass items and were therefore excluded from the project dataset.

Faience

This material, often found in ancient Egyptian collections, is better classified as a ceramic than a glass and was excluded from the project dataset (Tite, Manti, and Shortland 2007).

High surface area glass

High surface area glasses such as fiber glass or glass fabric, as well as techniques that make use of powdered glass, such as frit or *pâte de verre*, were excluded from the dataset as it was determined that it would be impossible to adequately assess the condition of these material types using the same criteria as items comprised of solid glass bodies.

Architectural glass

The logistics of accessing and assessing pieces of installed architectural glass rendered the inclusion of these items impractical.

Modern replaceable glass

The largest category of glass to be excluded from the project dataset is modern glass that is used to hold or protect an item, but that is not part of the item itself and would be discarded and replaced in the event of deterioration or fracture. This includes glass used in modern frames to protect and show the actual collection item in question underneath. This also includes the bottles, cases, and Riker boxes that might be used to store items in some collections. We relied on the expertise of the collections representatives to determine what constituted replaceable glass versus glass that was considered a relevant component of an item.

Materials commonly confused for glass

In addition to the glass types that were excluded from this project, it was also found that a number of non-glass material terms that contain the word 'glass' were unintentionally included in searches of the digital catalogs. These include Plexiglas, glassine, and isinglass (a polymer, a coated paper, and adhesive respectively). Care was taken to locate and remove items with these materials from the dataset.

It is also likely that in some small number of cases catalogers misidentified materials such as Plexiglas or other plastic components of an item as glass, when no glass is actually present. Identifying and removing these collection items was not possible without a detailed item-by-item evaluation, which was outside the scope of this project. Therefore, these items are considered to be within the inherent error of processing data on this scale.

Finally, it is also important to note that, though the materials listed here were excluded from evaluation as part of this project, it was only these materials that were excluded, not necessarily the items that they might be part of. For example, an item that contained both enameled elements along with glass beads or jewels was kept in the dataset.

Cleaning and standardizing the collections spreadsheets

The datasets obtained from each museum or department contained considerable variability in formatting, term use, and level of detail. Each spreadsheet was cleaned and standardized using the data cleaning software package OpenRefine (OpenRefine v3.7.4 2023). OpenRefine is a free, open-source program that allows for the sorting and grouping of items within a spreadsheet to simplify the identification and cleaning of messy data (e.g. spelling errors or duplicate terms) (OpenRefine 2023). This project utilized OpenRefine v3.5.2 through v3.7.4 over the course of several months. The majority of the cleaning work performed on these spreadsheets was focused on two of the data fields that were present in every single collection spreadsheet: item terms and materials.

Item terms

The terms used to describe specific item types were found to vary considerably from collection to collection. In order to meaningfully categorize and group the thousands of different items found in the combined collection record dataset, it was determined that the item terms would first need to be consolidated to a single dictionary from an external database. The Getty Research Institute's *Arts and Architecture Thesaurus* (AAT) (The J. Paul Getty Trust 2023) was selected for this purpose.

Using the data reconciliation feature of OpenRefine, it was possible to electronically link the provided item term for each item in a museum or department's spreadsheet with a defined term from the AAT. The AAT has almost half a million defined item terms, which allowed for most items to be easily matched with an AAT entry (Harpring 2010). In instances where no direct match for a given item term was found in the AAT, the term for a similar item, or the term for the more general grouping of items under which the item of interest would be found was used instead. For example, 'hydraulic pressure indicator' was matched to the term 'pressure gauges' while 'ship model' was standardized to 'models (representations).'

A challenge that was encountered during item term standardization was that for many common item types, a variety of terms or combination of terms may be used to describe the same item. Each defined term in the AAT contains a list of possible alternate terms for the same item type, making it easier to standardize these terms across collections. For example, 'glass, cordial,' 'glass, schnapps,' 'cordials, coin,' 'cordial glass,' 'schnapps glass,' and '*bitterglazen*' were all standardized to the term 'cordials.' Another particularly important benefit of the AAT is that the terms included and defined are each grouped within broader object hierarchies which allow for multiple terms to be associated with one another under larger categories. For example, all distinct cup or drinking glass types (e.g. tumblers, goblets, cups, wine glasses etc.) could be easily grouped into one category termed 'drinking vessels.'

However, one notable drawback to this process was that in many Smithsonian collections, a single catalog record may be used to describe an item with multiple pieces, or to describe a grouping of items. For example, a dagger and its sheath will often be listed together under a single catalog record. However, the AAT does not have a defined term for these types of groupings. Instead, it contains individual terms to describe each piece. In these cases, a judgement had to be made about which component was most likely to contain glass, and that term was used in the standardization.

Material components

In addition to item terms, every item's material constituents were also included in the collections data provided by each museum and department. There was considerable variation in the formatting of these materials lists. While most spreadsheets contained only a brief list of the materials comprising each item, some collections contained detailed, multi-sentence descriptions. In these cases, care was taken to isolate any material terms from the rest of the description prior to term cleaning and consolidation. Other collections presented materials information in the form of complex material hierarchies. For these spreadsheets, the material term of interest was located at the end of each hierarchy string, and each string had to be separated and then simplified on an individual basis. For example, the terms 'Hide/leather > Caribou hide/skin,' 'Beads > Glass bead/beads' and 'cloth/fabric > wool cloth' were standardized to 'hide,' 'glass,' and 'wool.'

OpenRefine was used to check the materials data in each spreadsheet for spelling errors and duplicate terminology. However, unlike item terms, it was decided that linking the materials terms to an external dictionary was not the most appropriate way to categorize this data. Instead, a standardized list of materials terms was generated directly from the terms found in the collections datasets. For material terms which were determined to fall within one of the four previously identified material classes of interest (metal alloy, wood, plastic, and leather/hide) the specific names used to refer to each of these materials were cleaned as minimally as possible in order to preserve any potentially relevant information. However, in order to reduce the overall number of individual material terms in the combined collection record dataset, some terms for materials outside of the four classes of interest were, where possible, refined and grouped together under a broader material term. For example, 'diamonds,' 'emeralds,' and 'garnets' were all grouped under the term 'semi-precious/precious stone,' while 'china,' 'porcelain,' and 'bisque' were all grouped under the term 'ceramic'. The final list of materials terms found across all collections can be found in the Appendix. Additionally, it was noted that in many cases, the photographic emulsion on glass supported and glass cased photographs was not listed as a component material. This material was added to the dataset consistently throughout all of the collections.

Results and discussion

Calculating the total number of glass collection items

Following data cleaning and standardization, the collections record data provided by each museum and department was compiled into a complete dataset containing 119,797 glass and glass-containing individual collection item records across all Smithsonian museums and departments. It is important to note that this value represents the sum of all individual collection records obtained from each museum or department – it is not representative of the total number of individual collection items. In many instances, a single catalog record will be used to identify a group of items and the specific item count for these groups is not always known or reliably recorded in the collection databases. Due to this, the combined collection record dataset is almost certainly an undercount of the true number of glass-containing collection items at the Smithsonian. The discussion of the compiled data set presented here, therefore, focuses on analyzing trends in available collection records, not necessarily individual collection items. It is expected that the total number of records that might be included in this dataset would fluctuate based on when the catalog data was collected, as items frequently move into and out of collections. The analyses presented here are based on the data available to the GDWG at the time of publication.

The majority (~82%) of all glass collection records are found in three of the larger Smithsonian museums: the National Museum of American History (51,303), the National Museum of the American Indian (32,326), and the National Museum of Natural History (14,050). However, glass collection records were found in every museum and department, with the smallest number of records found to be 109 glass items held at the Anacostia Community Museum.

Collection record analysis by item type

In addition to the composition of the glass components of an item and the environmental conditions in which it is being stored, the rate of observable glass deterioration has been shown to be influenced by both the type and shape of the glass-containing items in question. For example, daguerreotypes, bottles, vases, and decanters have been observed to display a higher degree of visible glass alteration on their internal surfaces, potentially due to the presence of the higher humidity micro-environments that can develop in these restricted or enclosed spaces (Barger, Smith, and White 1989, 146; Hunter 2017; Koob 2006, 122; van Giffen and Astrid 2017).

Additionally, while it is impossible to know the history and use of every item in Smithsonian collections, in many cases an item's type may provide some reasonable insight into how an item may have been used and what types of conditions it may have been exposed to prior to acquisition. Being able to categorize the collections by item type allows for some of these potential trends in use to be considered.

The built-in hierarchies of item terms within the Getty's AAT allow for similar item types to be grouped into larger categories. Figure 3 shows the most common item categories found across Smithsonian collections. The single biggest category is 'furnishings and equipment', however, it is clear that the Smithsonian's glass-containing collections span a wide range of forms and uses.

Within each of these larger categories it is possible to identify particular groupings of item types which, based on evidence in the literature or observations by collection stewards, may be more susceptible to glass alteration or other condition issues. For example, within the 'containers' subcategory, it is possible to differentiate between 'culinary containers' (e.g. champagne flutes and casserole dishes) and 'containers for personal use' (e.g. perfume bottles and makeup cases). Items within the 'costume' subcategory can be distinguished between accessories that were worn – and therefore potentially in contact with the moisture and salts present in perspiration – and accessories that were carried. Within 'tools and equipment,' the AAT terms make it possible to group things by 'labware,' 'animal equipment,' and more.

The combined collection record dataset can also be queried for information about how the population of a particular item type or larger category of glass item is distributed across the Smithsonian. Individually cataloged photographic glass provides a good example of this potential. There are almost 25,000 individually cataloged glass plate negatives in the Smithsonian collections spread over seven museums. Lantern slides are held at eight museums, while ambrotypes are only found at five. Most of the other glass-supported photographic types in the Smithsonian collection are found in significantly smaller numbers (less than 700 items) and are typically spread across only one to two museums.

Collection record analysis by material

While there has been an increasing number of studies in recent years focused on surveying and analyzing glass collections at cultural heritage institutions globally, the majority of this work has centered on items that are composed either primarily or entirely of glass. However, using the consolidated materials data found for each item in the combined collection record dataset, it was found that collection records which list glass as their sole component material represent only a small proportion, approximately 21%, of the total number of glass collection records. This suggests that the glass and glass-containing collections at the Smithsonian are considerably more materially complex than collections which contain a majority of items made only of glass.

The greatest proportion (~42%) of item records in the combined collection record dataset were found to contain two listed materials, primarily due to the large number of glass-supported photographic negatives, which are comprised of glass and a photographic emulsion, and which are found across Smithsonian collections. The average number of materials in each collection record across Smithsonian collections was found to be slightly higher at 2.5 (± 1.2) materials per collection record. Figure 4 shows the proportion of the total glass collection records that indicate a given number of distinct component materials terms.

Another method for assessing the material complexity of glass collections across the Smithsonian is through determining the total number of distinct materials found across the glass and glass-containing collections records in each museum or department. There were found to be as many as 172 distinct materials terms listed as components of glass collection items across each museum and department, with an average number of 73 distinct materials terms listed per collection. Understanding the material complexity of glass collections and the ways in which additional component materials can interact with

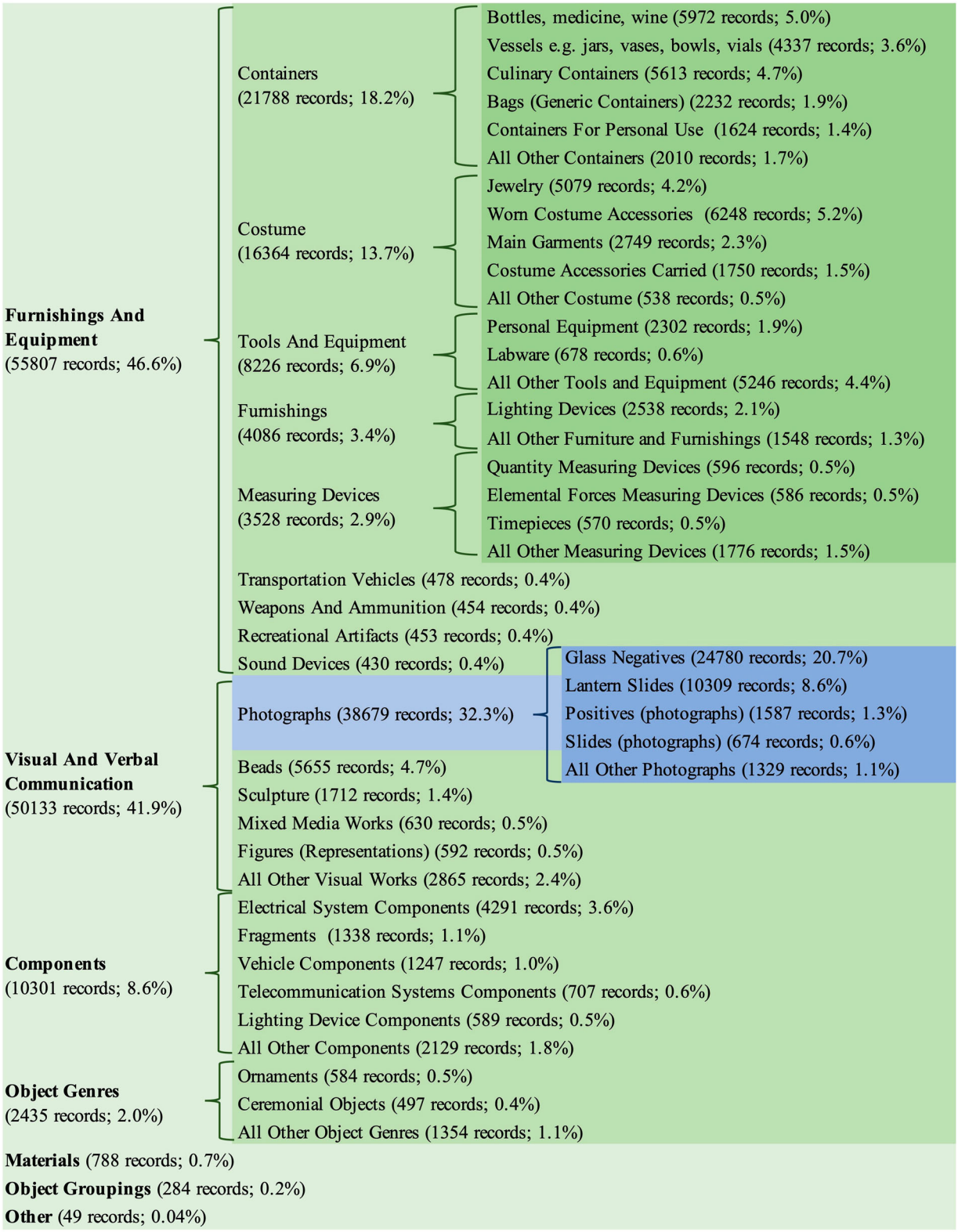

Figure 3. One potential set of hierarchy groupings of Smithsonian glass and glass-containing collections using the Getty Research Institute's *Art and Architecture Thesaurus* hierarchies. Item counts are included along with age of the total population of glass and glass-containing collections. The groupings of photographic items are shown in blue while non-photographic item groups are shown in green.

and impact the glass (or be impacted by it) is important for effective long-term preservation of glass-containing collection items.

In order to gain a better understanding of the potential role of adverse materials interactions in glass collections, the combined collection record dataset was queried for all collection records that included materials which were determined to fall within the four previously identified material classes of interest (metal alloy, wood, plastic, and leather/

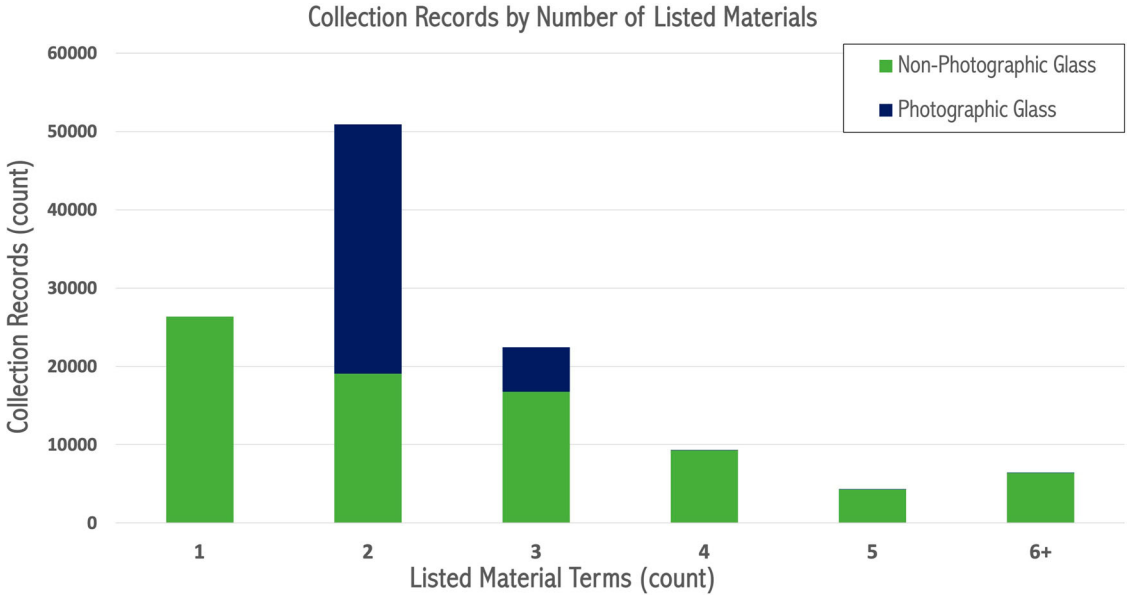

Figure 4. Count of overall glass collection records which indicate a given number of distinct component material terms. Photographic items are indicated in blue while non-photographic item groups are shown in green.

hide). Figure 5 shows the total number of collection records which were found to indicate the presence of a material in each identified class, as well as the overall number of collection records which list glass as the only material, for comparison. It is important to note that many individual collection records contain materials belonging to more than one of these four material categories. In addition, as can be seen in Figure 5, there are also many items which are composed of materials besides glass, but which did not fall within the material categories of interest identified by this project, such as photographic emulsion which is found on a large number of items. These photographic items are represented in blue.

Using collections data to identify items at risk of deterioration

In addition to identifying collection records that contain additional material components that could potentially be involved in adverse interactions with the glass using the combined collection record dataset, it was also possible to determine what types of items are most commonly found to contain any of these potentially problematic materials. Table 1

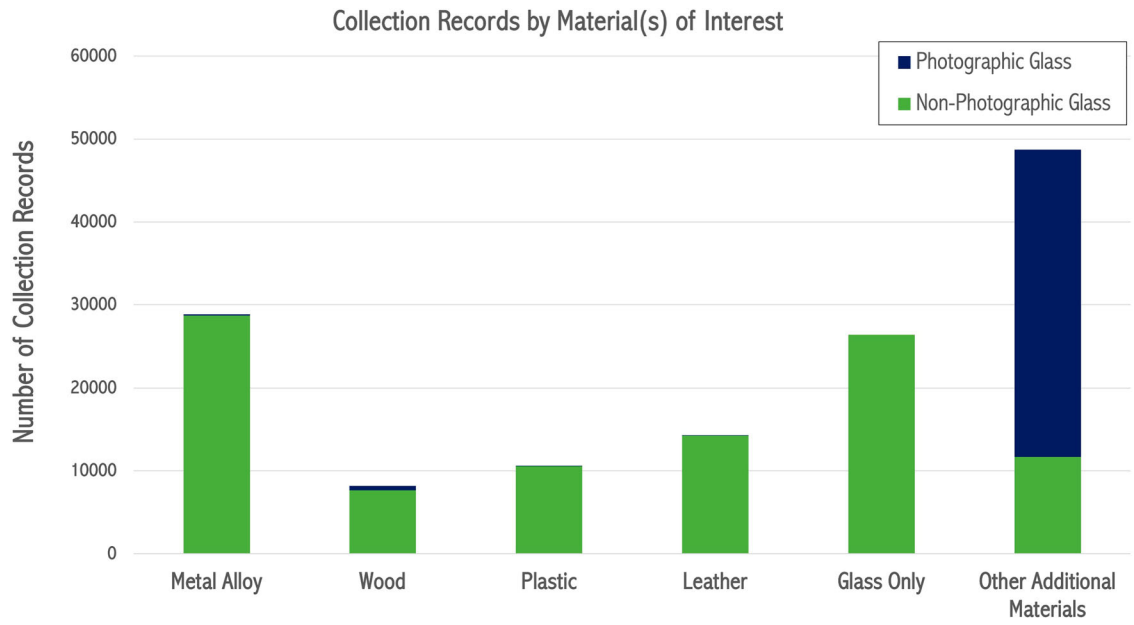

Figure 5. Total number of collection records which are reported to contain each of the identified material classes of interest. Photographic items are indicated in blue while non-photographic item groups are shown in green.

Table 1. The number of item records for each of the ten most frequently occurring item types that are reported as containing a material which has been identified as having a potential for an adverse interaction with an item's glass components.

Material	Item types (number of collection records)
Metal alloy	Diodes (1737); lamps (lighting devices) (1497); spectacles (eyeglasses) (776); daguerreotypes (photographs) (761); necklaces (566); photographs (565); airspeed indicators (438); bags (generic containers) (425); vacuum tubes (420); pressure gauges (403)
Wood	Figures (representations) (370); lantern slides (365); medicine bottles (216); jars (211); dolls (figurines) (204); bottles (193); pipes (smoking equipment) (177); mixed media works (156); radio receivers (138); mirrors (129)
Plastic	Diodes (910); bottles (327); vacuum tubes (297); airspeed indicators (272); radio receivers (241); phonograph records (239); pressure gauges (225); instruments (218); cathode ray tubes (207); spectacles (eyeglasses) (188)
Leather/ hide	Moccasins (2331); bags (generic containers) (1423); leggings (795); dolls (figurines) (518); necklaces (497); pipe bags (470); sheaths (cases) (353); shirts (main garments) (255); belt bags (243); belts (costume accessories) (222)

shows the ten most frequently identified collection item types, using the reconciled item type names from the Getty's *Arts and Architecture Thesaurus*, which are reported in the combined collection record dataset as containing each of the four potentially problematic materials.

It is also possible to use the material type and item type information contained in the combined collection record dataset to identify specific item types which have been identified in the literature as more likely to display glass alteration-related deterioration and to generate a list of items at greatest risk. The data shown in Table 2 provides an example.

A recent publication by Eggert and Fischer (2022) identified a number of specific categories of collection types that are known to display higher rates of glass-induced metal corrosion. Based on the list of item types identified in Eggert and Fischer's work, it is possible to query the combined collection record dataset to determine how many of those particular items are present in the overall collection, and in which museums they are primarily held. The combined collection record dataset can then also be used to query this selected item subset by component materials in order to identify items that are known to contain metal. While not all metals and metal alloys react with deteriorating glass to form glass-induced metal corrosion, being able to search the dataset for items which are known to contain metal allows for the identification of items which may be at increased risk of developing this form of deterioration.

Table 2. The number of collection records associated with item types that have been previously identified as having a greater risk of developing glass-induced metal corrosion, and the number and proportion of those items that also list metal, as well as specifically copper alloy, as a component material.

Items with known risk of glass induced metal corrosion (Eggert and Fischer 2022)	Total identified items	No. with metal	With metal (%)	No. with copper alloy	With copper alloy (%)
Lamps and lanterns	2348	2045	87.1	995	42.4
Eyeglasses	1125	1058	94.0	119	10.6
Daguerreotypes	762	761	99.9	646	84.8
Lightbulbs	847	487	57.5	135	15.9
Optical instruments	508	452	88.9	191	37.7
Clocks and watches	444	407	91.7	131	29.6
Ornaments	248	221	89.1	1	0.4
Beads on wire	109	109	100	25	22.9
Levels (tools)	41	37	90.2	33	80.4
Hat pins	8	6	75.0	1	12.5

It is also possible to use the data available in the combined collection record dataset to refine the list of potentially at-risk items even further. In their work, Eggert and Fischer identify copper alloys as the most common alloys to display evidence of glass-induced metal corrosion. Using the alloy-specific terminology that was preserved during data cleaning of the materials component information, it is possible to identify the potentially at-risk items that specifically list a copper alloy as a component material, as shown in Table 2. However, it is important to note that alloy-level information was not available for every item included in the combined collection dataset. This example illustrates the importance of generating and maintaining robust collections catalog data in order to be able to search the combined collections dataset for items of specific concern or interest using multiple identifying factors. This capability, even with limited available data can be used to guide targeted assessments of condition issues and directly impact decisions about collection environment parameters.

Conclusions

The full data consolidation and cleaning campaign to support the broader survey project goals of the Glass Deterioration Working Group at the Smithsonian Institution required considerable effort and time to accomplish. However, the benefits of this process to the work of the GDWG and to the broader museum community justify this investment. The ability to sort and group collection items based on several different parameters potentially affecting their long-term stability provides the project and Smithsonian collection stewards with a new tool to better understand and preserve glass and glass-containing collections. This information will also be used to enrich and add essential context to the survey results in the next phase of the GDWG's work. Using the data contained in the combined

collection data set in conjunction with the survey results, it will be possible to identify categories of glass items that are at a statistically higher risk of exhibiting glass deterioration. This information will be used by the Smithsonian's collection stewards to better preserve the items in their care and will be shared with the broader global museum community where it will hopefully add insight and context for understanding other collections as well.

It is also hoped that the results of this work will draw further attention to the importance of collection records in collections care and preservation. The results that can be drawn from the dataset are only as detailed and complete as the information which was put into it. Having complete and detailed collection records data is vital to being able to understand broader trends in collection make-up and condition in individual collections and across institutions.

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Appendix

Comprehensive list of materials terms in cleaned combined collection record dataset.

acetate
acrylic
acrylic paint
adhesive
adhesive label
alder
alm (wood)
aluminum
aluminum alloy
aluminum plate
amber
animal component
animal protein
antimony
antimony alloy
antler
ash (wood)
bakelite
balsawood
bamboo
bark
bark cloth
basswood
batting
beechwood
beryllium
beryllium alloy
beta cloth
birch
board
bone
boxwood
brass
brass alloy
brass plate
briar (wood)
brick
brocade
bronze
bronze plate
buckram
burlap
cadmium
cadmium alloy
cadmium plate
metal
mirror glass
mother-of-pearl
mulberry
muslin
mutton cloth
mylar
natural fiber
neon
neoprene
net
newsprint
nickel
nickel alloy
nickel plate
niobium
nitrocellulose lacquer
nylon
oak
oil paint
organic material (unspecified)
organza (fabric)
paduak (wood)
paint
palm (wood)
paper
paper pulp
paperboard
calico
camwood
canvas
carbon fiber
carbon paper
cardboard
catalin (plastic)
cedar
cellophane
celluloid
cellulose
cellulose acetate
cellulose nitrate
cement
ceramic
cesium alloy
chamois
chem/pharm
chenille
cherry (wood)
chestnut
chiffon
chrome
chrome plate
clay
cloth
coating material
cobalt alloy
cocobolo
concrete
copper
copper alloy
copper plate
coral
cord
corduroy
cork
cotton
cottonwood
crayon
crepe
crepe paper
crewel
cypress
damask
photographic emulsion
photoluminescent paint
pigment
pine
pitch
plant fiber
plaster
plastic
platinum
plexiglass
plywood
poinciana
polycarbonate
polyester
polyethylene
polymer clay
polypropylene
polystyrene
polyurethane
polyvinyl chloride
poplar
porcelain
pot metal
putty
quill
rawhide
rayon
reed
resin
denim
driftwood
drywall
dye
ebony
eggshell
elastic
electronic component
enamel
fabric
fabricoid
faience
feather
felt
fiber
fiberboard
fiberglass
film
flannel
fleece
flock
foam
foil
foodstuff
formica
fungus
fur/skin
gauze
gesso
gilding
glass
glass paste
glass powder
glassine
glitter
glue
gold
gold alloy
gold plate
gouache
gourd
graphite
gum
gut
hair
sealant
seeds
semi-precious/precious stone
sequins
sequoia (wood)
shagreen
shedua (wood)
shell
shellac
silica
silicon
silicone
silk
silver
silver alloy
silver plate
sinew
slate
soft-paste
soil
solder
spandex
sponge
steel
stone/mineral
stoneware
straw
string
hard-paste
hide
horn
human remains*
imbuya (wood)
imitation fur
imitation leather
imitation pearl
imitation tortoiseshell
indium
ink
inorganic material (unspecified)
insect
insulation
iron
iron alloy
ironwood
ivory
jersey
kapton
kevlar
kidskin
lace
lacquer
latex
laurel (wood)
lead
lead alloy
leather
leatherette
linden
linen
logwood
lucite
magnesium
magnesium alloy
mahogany
maple
marble
marker
masonite
matboard
mesh
mesquite
thermoplastic
thorium
thread
tin
tin plate
tissue
titanium
titanium alloy
tortoiseshell
tungsten
tungsten alloy
twill
twine
varnish
velcro
vellum
velour
willow
wire
wood
wood shavings
wool
yarn
zinc
zinc alloy
zinc plate

paperboard	rhodium plate	styrofoam
papier mache	ribbon	suede
parchment	rickrack	synthetic material
paste	root	taffeta
pasteboard	rope	tape
pastel	rosaline	tar
Pau amarello (wood)	rosewood	taxidermy
pearl	rubber	teeth
pearwood	sand	teflon
pen	satin	tempera paint
pencil	sawdust	terracotta
pewter	scots pine	textile

*Glass-containing collection items that include human remains were excluded from the survey being conducted as part of this project, following recommendations by the Smithsonian's Task Force on Human Remains, while an institutional policy on human remains is under development.