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Author(s): Robin O'Hern, Kelly McHugh
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RED, BLUE, AND WOUND ALL OVER: EVALUATING CONDITION CHANGE AND CLEANING OF GLASS DISEASE ON BEADS

ROBIN O'HERN, KELLY McHUGH

ABSTRACT

This article presents the results of two surveys focused on the condition and treatment of deteriorated glass beads in the collection of the National Museum of the American Indian (NMAI). Glass deterioration occurs when hygroscopic alkali components of the glass migrate to the surface and form salts. The leaching of alkali components leaves a silica enriched surface layer, which is vulnerable to further deterioration. Environmental parameters, glass composition and manufacturing processes, contact with other materials, and previous use of the object can all affect the deterioration process. Because of the large number of beaded objects at the NMAI, glass disease is a collection-wide condition issue.

Two targeted collections surveys were, therefore, carried out to monitor condition change and treatment results for at-risk beads. To assess changes in condition over time, a selection of objects originally surveyed in 1999 were re-surveyed in 2013. Ninety percent of the beads had no visible change to the deteriorated glass over 14 years. A second survey was conducted to evaluate whether treatment options used for blue and red beads—cleaning with deionized or distilled water, ethanol, 1:1 deionized or distilled water: ethanol, or mechanical cleaning—had different long-term results. Approximately 50% of the beads cleaned with water or 1:1 water: ethanol and 47% of beads cleaned with ethanol redeveloped glass deterioration; however, if the results for beads cleaned with 1:1 water: ethanol and ethanol alone are compared over the same time period, the rate of return for beads cleaned with ethanol drops to 42%. The identification of beads most likely to have or develop glass deterioration and the long-term success of treatment will help prioritize conservation resources.

1. INTRODUCTION

Glass disease is an important issue for museums with Native American Collections, and at the National Museum of the American Indian (NMAI), it is one of the most pervasive preservation problems. Of the non-archaeological object records in the NMAI's collection database, approximately 10% (11,000) contain glass beads. Not all of the objects at the NMAI have conservation records; however, for those that do, 25% of objects with glass beads have records of unstable glass. Because objects with conservation records tend to be those in the best condition that were chosen for exhibition, it is likely that the actual percentage of objects with glass deterioration is much higher. Developing greater understanding regarding how the unstable glass is deteriorating will help with long-term preservation (fig. 1).

Additionally, evaluating the effectiveness of different cleaning techniques over several years may help develop better protocols for treating glass beads. This article describes an ongoing project to assess glass disease on ethnographic beadwork in the collection of the National Museum of the American Indian.

The NMAI has its roots in New York's Heye Foundation's Museum of the American Indian (MAI), established in 1961 by financier George Gustave Heye. The Smithsonian Institution took over the extensive MAI holdings in 1989, establishing the National Museum of the American Indian. As part of the Smithsonian Institution, a new museum was built on the National Mall and the collection moved from a storage facility in New York to the Cultural Resources Center in Suitland, Maryland. In preparation for the move, which took place from 1999 to 2004, the ethnographic portion of the collection underwent a detailed, item-specific conservation survey. All cases of glass disease visible to the naked eye were noted in the survey. The items surveyed in 1999 became the foundation for this project's initial stage.

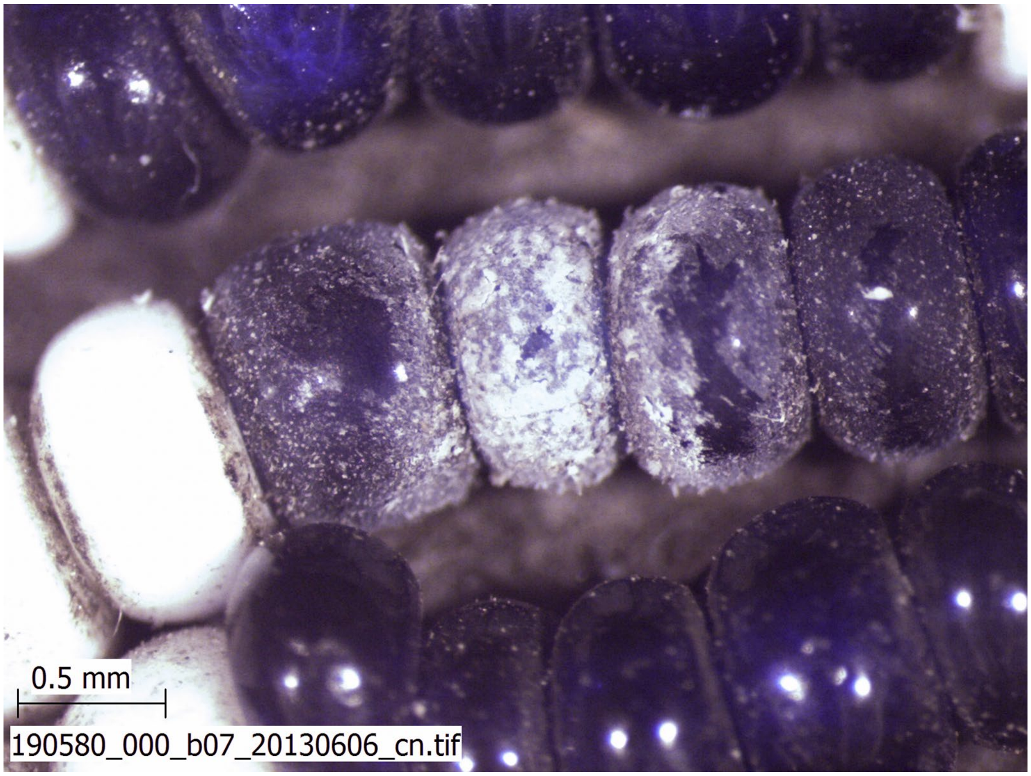

Fig. 1. Image of blue seed beads with unstable glass on a Potawatomi Bag (Courtesy of Robin O'Hern, National Museum of the American Indian, Smithsonian Institution, 19/0580)

1.1 HISTORY OF GLASS TRADE BEADS IN NORTH AMERICA

The history of non-Native-made glass beads in North America requires a brief introduction about countries of origin, colorants, manufacturing techniques, shapes, and significant historical events. Glass beads imported to North America came from Venice, Bohemia (now the Czech Republic), Holland, England, France, China, and other countries. The earliest glass beads likely came from Venice, with increased production by Holland in the 17th century and by the Czech Republic in the 19th century. Beads also entered North America from China in the 19th century (Karklins 1974, 2012; Francis 1986, 1988, 2008, 68–70; Ross 1990, 2000; Burgess and Dussubieux 2007).

Glass beads are made using several different techniques, including but not limited to drawn, wound, mold-pressed, and hollow blown (Sprague 1985). Beads made by each of these techniques can be identified by manufacturing marks such as the direction of air bubbles and the presence of seam lines. By the late 15th century, the Venetians developed a technique for making large numbers of drawn beads, the technique used for pony and seed beads (Francis 2008, 68). Pony beads are larger than an eighth of an inch and seed beads range from 1/16th of an inch to 3/16ths of an inch (Lyford 1997). Later in the 18th century, seed beads were exported to North America (Francis 2008, 71) and they began to be used in the Great Plains region in the 1840s (Francis 2008, 71).

1.2 USE OF BEADS ON NATIVE AMERICAN OBJECTS

Beads made from locally sourced or traded natural materials, such as bone, shell, or teeth have been used by people of North America for thousands of years (Dubin 2009, 261). Pueblo people in the Southwest continue to manufacture and use beads made of turquoise, coral, and shell. The conveyance of social position and status, and communication with other tribes and the spiritual world, was and continues to be through a visual language. Further, hundreds of different languages spoken throughout North America combined with an extensive trade network necessitated a visual form of expression for communication.

The introduction of glass beads exponentially increased the opportunity for broader and more sophisticated visual articulation. In the Plains, glass beads quickly replaced traditional forms of adornment like quillwork, which were laborious and time consuming. A design explosion can be seen among tribes like the Apsaalooke (Crow) and Lakota with the availability of seed beads, needles, and trade cloth (Dubin 2009, 261). The Iroquois, Tuscarora, and Seneca sold Victorian-inspired items, heavily decorated with glass beads, to tourists visiting New York and Canada. Woodlands beadwork was inspired by French floral designs, created by women who were taught embroidery in the mission schools (Dubin 2009). Round, blue, Russian beads, not originally from Russia, but traded from Hong Kong or Bohemia, made an impact on Arctic and Pacific Northwest Coast cultures.

An affinity for glass beads, a medium that appealed to a well-established aesthetic need, inspired the beautification of objects and garments used in daily life or ceremony. The preservation of glass beads is inextricably linked to the preservation of Native American cultural material, and therefore, the importance of understanding the mechanisms of deterioration and treatment must be examined and well understood.

2. INTRODUCTION TO GLASS AND ITS DETERIORATION

Glass is made from approximately 70% silica (SiO_2), 20% alkali component (soda, Na_2O; potash, K_2CO_3; or lead oxide PbO), 10% calcium carbonate ($CaCO_3$) as a stabilizer, and other minor components (Koob 2006). Refined or processed sand, or another silicate material, provides the silica component and is called a *network former*. The soda or potash alkali flux releases carbon dioxide to leave sodium oxide or potassium oxide in the glass. The final ingredient, calcium carbonate, also releases carbon dioxide to leave calcium oxide (CaO) in the glass, which acts as a network stabilizer. It may have initially been unintentionally added as an impurity in the sand, but it can also be added intentionally (Francis 2002; Lovell 2006, 21, 23; Kunicki-Goldfinger 2008). Additional components can include other fluxes, oxidizing agents, fining agents, reducing agents, and colorizing or decolorizing agents. Previous studies on deteriorating glass focused on the percentages of calcium oxide and alkali components in the glass.

2.1 WHAT IS GLASS DETERIORATION?

Scholars and researchers use many different terms to describe unstable glass, including glass disease, glass illness, glass deterioration, sick glass, weeping glass, sweating glass, and crizzling glass. Visually, unstable glass will develop a fine network of cracks (crizzling), a white crystalline growth on the surface, aqueous or oily surface droplets (weeping), and pitting. Unstable beads may also break. Most of the glass beads with unstable compositions were made in Europe during the 17th to mid-18th century when glass makers tried to achieve particular visual characteristics such as color or transparency, or tried to produce beads with less expensive materials (Lougheed 1988; Kunicki-Goldfinger 2008).

Breakdown of the glass begins with the interaction of water—as liquid or vapor—with the glass surface. Hygroscopic components in the glass as well as surface dust and soiling attract moisture to the bead. If the surface pH is <9, then the moisture leaches the alkali and alkaline ions out of the network. This creates a leached layer at the surface of the glass that is depleted in alkali ions and enriched in silica. The ions interact with carbon dioxide or atmospheric pollutants in the air and form salts on the glass surface. Oily and fatty salts were found on the surface of some beads in contact with leather. When the pH becomes >9, the silica structure can break down (Kunicki-Goldfinger 2008, 50).

Most scientific research on composition and deterioration of glass beads focuses on blue beads, with significantly fewer articles about red glass beads (Sempowski et al. 2001; Burgess and Dussubieux 2007) or black beads (Lord 2001). These three colors will be discussed in detail throughout the article. In general, dark blue beads are most likely to be colored by cobalt. Light blue and turquoise beads tend to be colored by copper, in the form of cuprous oxide or as finely dispersed elemental copper (Weyl 1959; Hancock et al. 1994; Sempowski et al. 2001). There are three techniques for coloring glass red: copper to make opaque redwood beads (Sempowski et al. 2001, 503), a colloidal suspension of gold to make ruby red glass available after 1859 (Francis 2008, 64), and selenium and cadmium available after 1890 (Weyl 1959; Francis 2008, 73). Red glass also frequently includes lead oxide as an alkali flux (Weyl 1959, 385; Burgess and Dussubieux 2007, 62, 70). Research on black beads has identified their colorants as manganese—occasionally grayed with tin—and chromium with cobalt, copper, or ferric silicates (Karklin 2002; Ross 2005). These studies were done on glass from various regions and other trends may exist in glass from different locations.

The deterioration of glass beads occurs as a result of the chemical composition of the glass, the use-history of the object on which they are attached, and the environmental history of the object (Kunicki-Goldfinger 2008) (fig. 2).

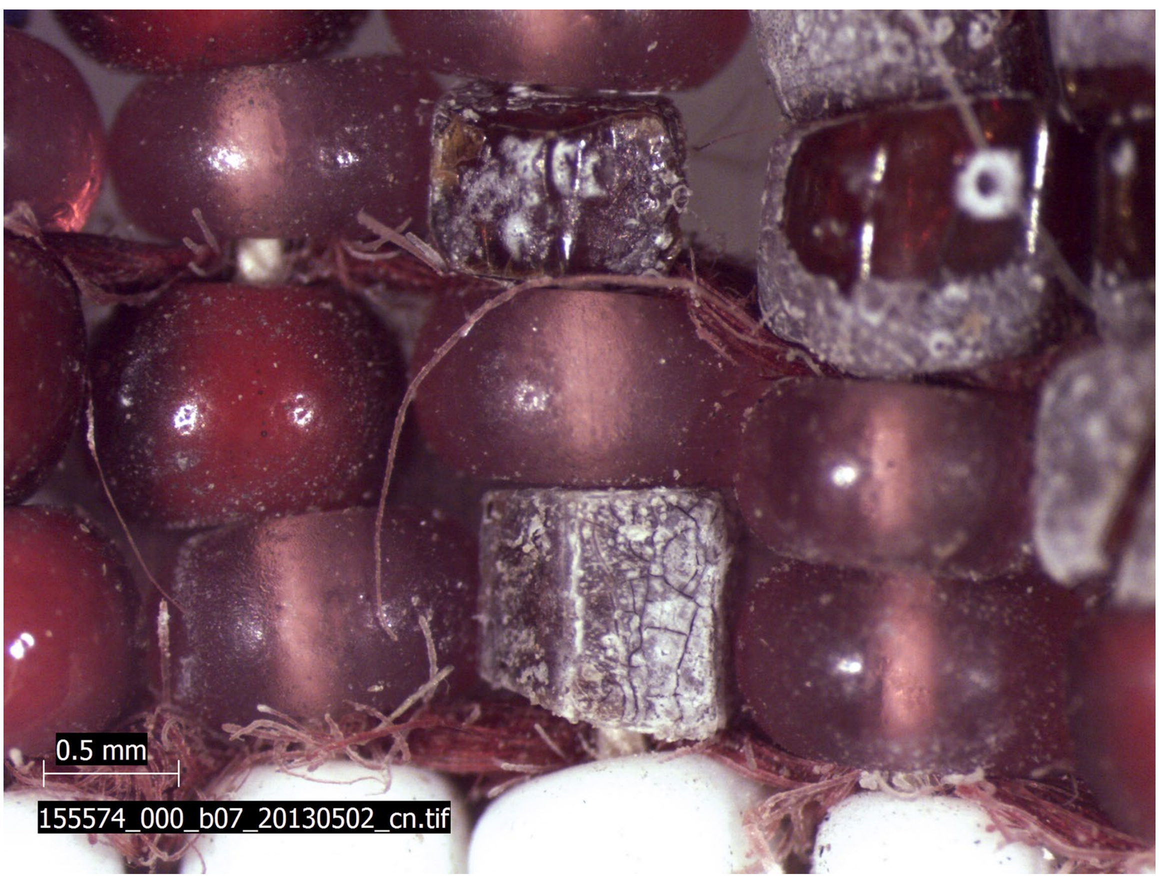

Fig. 2. Image of hexagonal red seed beads with glass disease. The other red beads are not deteriorating, which suggests that the glass composition of the hexagonal beads is unstable, Mushuaunnuat (Barren Ground Naskapi) bracelet (Courtesy of Robin O'Hern, National Museum of the American Indian, Smithsonian Institution, 15/5574)

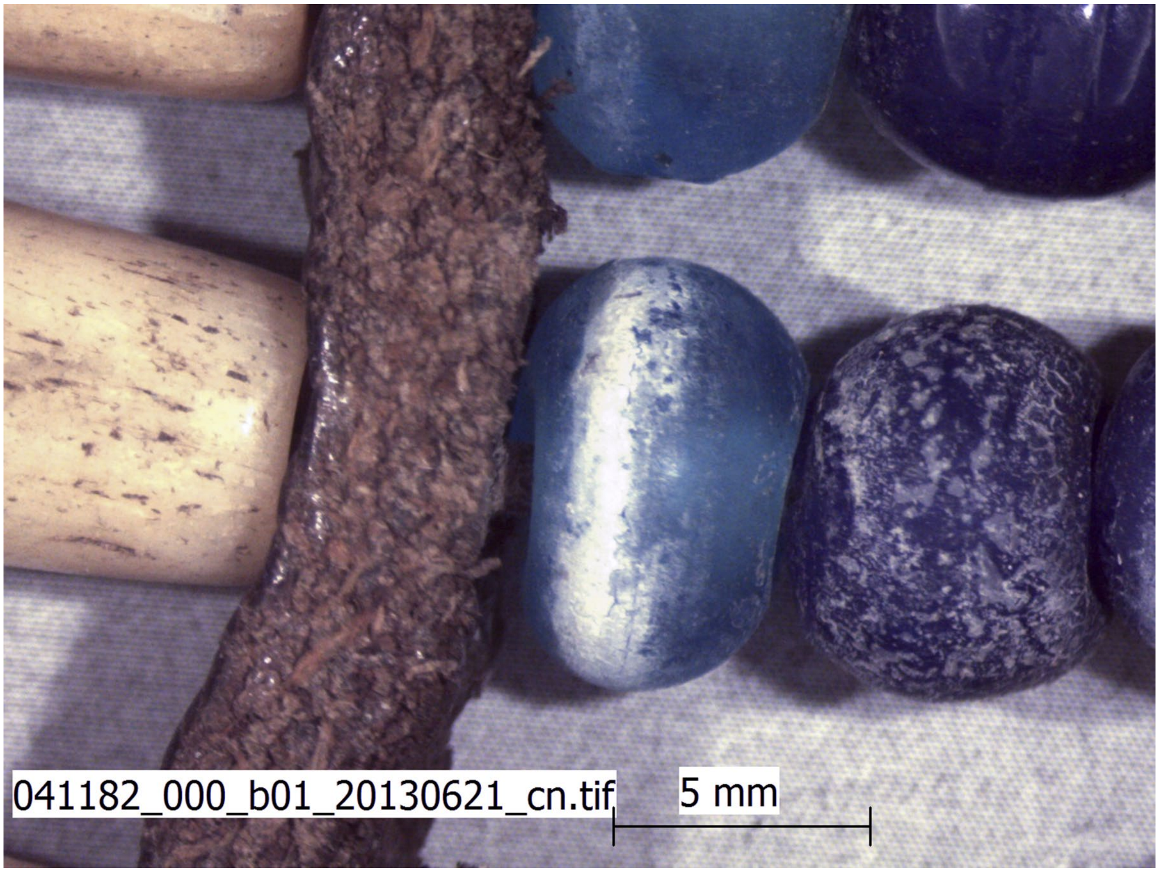

Fig. 3. Detail image of beads developing glass disease where they are in contact with leather on a Plains Breastplate (Courtesy of Robin O'Hern, National Museum of the American Indian, Smithsonian Institution, 04/1182)

It can also be influenced by the substrate and facilitated by the threading material (Fenn 1987; Carroll and McHugh 2001) (fig. 3). The interaction between glass beads and hide seems to facilitate their deterioration and the development of an oilier, waxy white crust or conversion into soap (Fenn 1987; Carroll and McHugh 2001). Glass objects with low concentrations of calcium oxide or high concentrations of flux (soda or potash) are susceptible to deterioration. An unstable glass composition will inherently cause the glass to deteriorate; however, any glass object can deteriorate given the wrong environmental conditions (Lovell 2006, 16). Unfortunately, the process cannot be stopped once it begins; it can only be slowed down by removal of the surface salts and by maintaining stable, low relative humidity conditions (Koob 2006; Kunicki-Goldfinger 2008).

2.2 UNSTABLE GLASS IN MUSEUM COLLECTIONS

Published literature was searched for other surveys of deteriorating glass beads (Carroll and McHugh 2001; Lord 2001; Lovell 2006; Fusco and Speakman 2010) and glass collections that assessed percentages of unstable glass (Cobo del Arco 1999; Oakley 1990, 1999).

The four published examples of collection-wide glass surveys include information about the percent of the collection susceptible to deterioration. These percentages range from 13.5 to 38% of collections:

- 20 and 13.5% of glass objects were unstable in two storage areas at the National Museums of Scotland (Cobo del Arco 1999)
- 17% of 344 beaded sculptures and costumes had unstable glass beads at the National Museum of African Art (Fusco and Speakman 2010)

- 16% (400 glass objects out of 6500) at the Victoria and Albert Museum were unstable (Oakley 1990)
- 38% (49 of 130) costumes required conservation, due to unstable glass and potentially other reasons, in the National Museums and Galleries' Merside Decorative Arts Department's collection (Lord 2001)

Three collections surveys discuss their results in terms of color and reach different conclusions. The survey of the National Museum of African Art glass beads found two different types of deterioration on specific colors of beads (Fusco and Speakman 2010). In contrast, the collection survey done in the United Kingdom in 2001 found "no obvious correlation between color and shape of bead and deterioration" (Lord 2001, 131). Finally, in Adam Lovell's discussions with bead researchers, he learned that "certain colors of beads—namely blues, reds, and black—tend to be more susceptible to glass disease" (Lovell 2006, 37).

2.3 CONSERVATION OF GLASS BEADS

Maintaining specific stable environmental parameters is the best method for the long-term preservation of unstable glass. The recommended parameters vary among the scholars who have published recommendations. Some of the ranges found in the conservation literature for unstable vessel glass include the following:

- 38% RH + 3% (Ryan et al. 1995; Oakley 1999, 2001)
- 40% RH + 1–2% (Koob 2006)
- < 35% RH (Sirois 1999)
- 35–40% RH (Lougheed 1988)

However, these relative humidity parameters may be too dry for the safe storage of adjacent leather or threading materials (Rose 1992).

At the NMAI, there is no separate storage area for objects with degrading glass beads—all the objects are stored in the same storage environment—because of a cultural mandate to store materials from the same culture, peoples, and nations together. The composite nature of the objects and collections at the NMAI requires environmental parameters that are best for the collection as a whole. The relative humidity of the storage environment ranges from 45% ± 8 RH, which is slightly higher and wider than the recommended percentages for unstable glass listed earlier but closer to the recommended parameters for stable glass. The actual RH range for the museum's storage environment is typical of conditions for other ethnographic collections.

Clearing surface salts from the glass bead can help to prevent additional deterioration by reducing the pH and removing hygroscopic components. When cleaning Native American beadwork, it is important to consider whether the surface grime is soiling or if it is a traditionally applied material like red ochre or kaolin (a type of white clay). According to conservation philosophy at the NMAI and other museums, these traditionally applied materials would not be removed from the object (Doyal 2001). The literature recommends several different options for cleaning glass beads: mechanical cleaning, swabbing with water, with ethanol, or with 1:1 water: ethanol. Conservators begin the cleaning process with mechanical techniques like vacuuming while brushing or using cosmetic sponges (non-latex polyurethane foam), which are least likely to cause damage (Doyal 2001; Frisina 2004).

Depending on the object, conservators can also use water or solvents to clean beads. These techniques are only used after testing the surrounding materials for adverse effects. Deionized or distilled water and ethanol have distinct advantages and disadvantages depending on the bead, substrate, and other factors (table 1). In all cases, a cotton swab is moistened with the solution and then rolled gently over the beads (Frisina 2004). Although the literature on glass beads strongly recommends using ethanol over water, a 2006 survey of conservators found that most choose water as their cleaning method (Lovell 2006, 62).

Table 1. Advantages and disadvantages of each treatment material

Material	Advantages	Disadvantages
Deionized or Distilled Water	Preferred for cleaning vessel glass. Effectively removes surface salts (Newton and Davison 1989; Ryan et al. 1996; Oakley 2001; Koob 2006; Smith 2006).	Can cause staining or tide lines on the substrate material. Can corrode nearby metal beads. May create a microenvironment around the thread facilitating glass deterioration. Can break weakened beads through the expansion of the moistened thread (Lougheed and Shaw 1982; Lougheed 1988; Stone 2010).
Ethanol	Does not cause corrosion of metal beads. Does not create a microenvironment around the threading material. Does not play a role in facilitating the beads' deterioration. May also help to solubilize fatty components of the surface accretion (Lougheed 1988; Doyal 2001; Lord 2001).	Can displace the moisture in the glass. Can reveal the full extent of crack development. May solubilize components of the backing material or substrate (Ryan et al. 1996; Koob 2006; Smith 2006).
1:1 Deionized or Distilled Water: Ethanol	Effectively removes surface salts. Dries more quickly than water on its own. May help to solubilize fatty components of the surface accretion (Stone 2010; Grabow 2011).	May cause staining. May corrode nearby metal beads. Can still create a humid microenvironment (Stone 2010).

3. EVALUATING CONDITION CHANGE FOR UNSTABLE BEADS

The previous survey of the NMAI's collection in 1999 provided the sample set used to examine the rate of deterioration for glass beads (Carroll and McHugh 2001). During the survey, conservators identified 187 objects with severe glass disease and undertook focused analysis on 20 objects. The objects studied in detail included bags, bracelets, breastplates, clothing, necklaces, fishing equipment, gloves, pipe stem fragments, and a rattle. Seventeen different cultures are represented by the objects, mostly from the Great Lakes Region, the Plains, and Alberta, Canada. These objects provide an ideal study group because they were rehoused shortly after surveying and have not received treatment since.

Resurveying the objects to evaluate whether the glass beads have deteriorated further is of particular interest because the objects moved from a variable storage climate in New York to a more stable—though not ideal for unstable glass—climate in Washington D.C. Because it is unlikely that glass beads on ethnographic objects will be stored in the ideal environmental conditions for unstable glass because of the presence of other materials, it is important to assess how the beads deteriorate in the standard museum environmental conditions.

3.1. SURVEY METHODOLOGY

The authors began with a survey of 20 objects on which McHugh and Carroll had focused additional analysis. None of these objects had been treated since their initial survey and they had each been rehoused shorlty after 1999. This means that if any condition change or loss has happened since 1999, the deterioration was not reduced through treatment. Each color or type of bead on an object—called a "bead type" for this article—has an individual survey entry. The survey of 20 objects resulted in 176 bead type entries.

O'Hern developed a Google survey form for internal use to survey the objects. The form includes questions designed to record bead color (using Munsell Color standards), manufacturing technique, size, shape, condition, pH, and standardized terminology for glass disease. The questions about manufacturing technique, size, and shape were designed to follow the Kidd and Kidd (1970) system as modified by Karklins (2012), but the information was not recorded in the codes developed by them.[1] Objects were always examined under UV-filtered fluorescent lighting conditions. We developed a visual glossary (fig. 4) to standardize the terms we used to describe glass deterioration products on the objects.

Measurement of the pH on the glass bead surface is essential for determining whether the bead has alkaline surface salts present, or culturally applied kaolin, or a matte surface (Lougheed 1988; Sirois

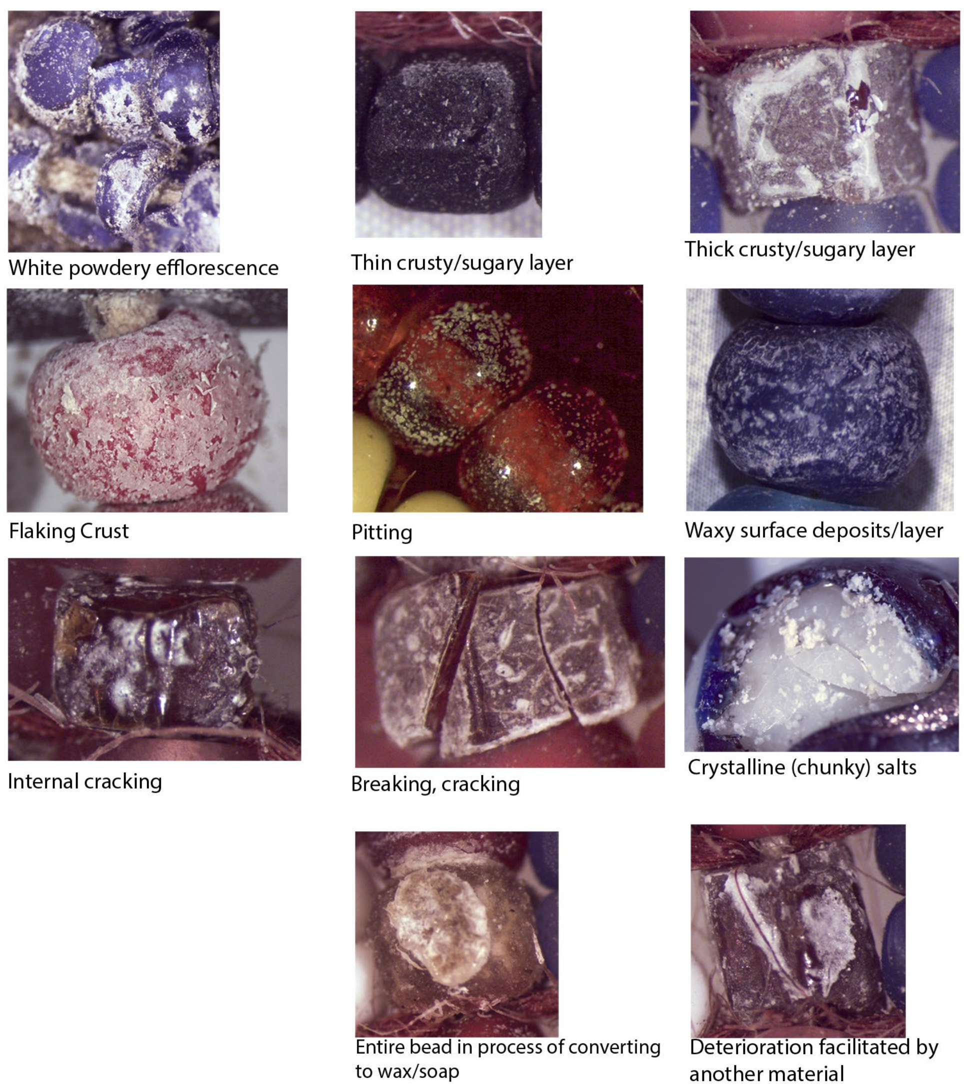

Fig. 4. A visual glossary of observed glass deterioration products (Courtesy of Robin O'Hern)

1999; Lord 2001, 129; Smith 2006; Lovell 2006, 37). Matte surfaces with neutral pH may be from manufacture, a sign of previous glass disease damage that disrupted the surface but has not reoccurred, or a result of wear (fig. 5a; 5b). Finally, in some instances, it is difficult to see the glass disease present on the beads, in which case an alkaline pH alerted us to its occurrence; therefore, measuring the pH of all the bead colors or types proved an essential practice.

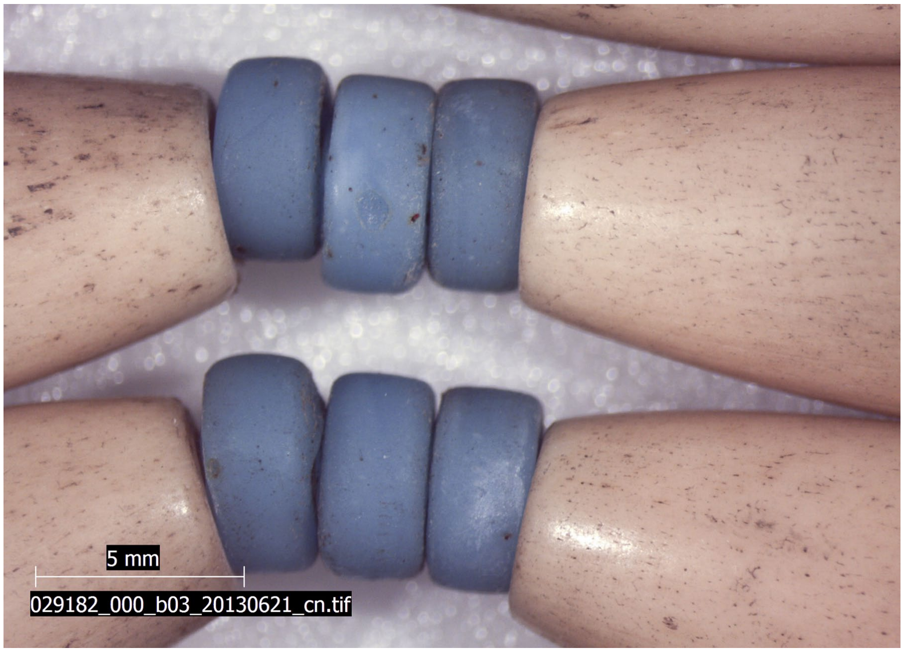

Fig. 5a. Northern Athapaskan Necklace with unstable glass beads that initially appear stable but have an alkaline pH. 5b. The matte surface on these beads in a detail from an Anishinaabe (Chippewa/Ojibwa) Man's leggings looks like glass deterioration; however, pH testing results were neutral. This indicates that the matte surface may be a sign of previous glass disease damage that disrupted the surface but has not reoccurred, or a result of wear. (Courtesy of Robin O'Hern, National Museum of the American Indian, Smithsonian Institution; NMAI 02/9182, NMAI 18/8382)

Fig. 6. Hollow blown black faceted beads on a Mi'kmaq (Micmac) Necklace that have continued to break apart since rehousing (Courtesy of Robin O'Hern, National Museum of the American Indian, Smithsonian Institution, 17/6455)

We used the following technique for measuring pH (fig. 6):

1. Cut tiny rectangle of ColorpHast paper (pH 6.5–10.0).
2. Moisten paper with deionized water.
3. Tap on towel to draw off excess moisture.
4. Place and hold on bead for 3 seconds.
5. Evaluate color change of pH paper.

The color change—or lack thereof—of the pH paper indicated if the surface pH was close to neutral and the glass was stable. Alternatively, a pH of 8 usually corresponds with barely visible surface salts, and a pH of ≥9 usually occurs when the salts are clearly visible on the bead surface.

3.2 RESULTS AND DISCUSSION

The results of the survey were studied to assess trends in the beads most susceptible to deterioration and whether their condition has changed in the past 15 years.

3.2.1 Percentage of Beads with Further Deterioration

Sixteen percent (28 out of 176) of all the bead types have more glass deterioration present now than they did during the 1999 survey. This number comprises the 23 types of beads that did not have a record of glass deterioration in 1999 but do have alkaline salts on their surfaces now and the five bead types that did have a record of glass deterioration in 1999 and have visibly deteriorated further (fig. 6). The visibly identifiable further deterioration typically takes the form of split beads, or beads with fragments that have or are about to separate.

The evaluation of change in the quantity of white deposits on a bead's surface is somewhat subjective in the case of glass disease. It depends on the relative humidity at the time of surveying because of the deliquescence point of the salts involved and involves comparing an image or description of the beads with the object to determine if there is an increase in the appearance of white salts.

3.2.2 Assessing Trends in Unstable Glass by Color

We evaluated the results of the survey to assess whether particular colors were more susceptible to deterioration than others. To determine this, we calculated the percentage of each bead color that had unstable glass and then compared the colors in figure 7.

Three colors have approximately 60% of their bead types display glass deterioration: black, red, and blue. Three colors have approximately 50% of their bead types—yellow, brown, and purple—exhibiting deterioration; however, there were many fewer beads of these colors. Green, clear, and orange beads were approximately 40% likely to have glass deterioration. White and pink beads had no examples of unstable glass.

For comparison, we conducted a similar investigation (figure 8) on the objects with conservation records in the museum's database that included the words "glass disease" or "bead disease." The beads on these objects were summed by color and then the percentage of each color identified as having unstable glass was calculated.

This technique for assessing trends in glass deterioration yields slightly different results: The blue beads are much more likely to have a record of glass disease (68%), followed by the red (48%) and then black (30%) beads. The other beads are less than 20% likely to exhibit glass degradation. The information in this graph does depend on the conservators accurately reporting which beads have glass deterioration as well as on them naming each of the colors of beads on the object in their treatment report.

These results correspond with Lovell's findings from discussions with bead researchers that blues, reds, and black tend to be most susceptible to glass disease (Lovell 2006, 37). There are several

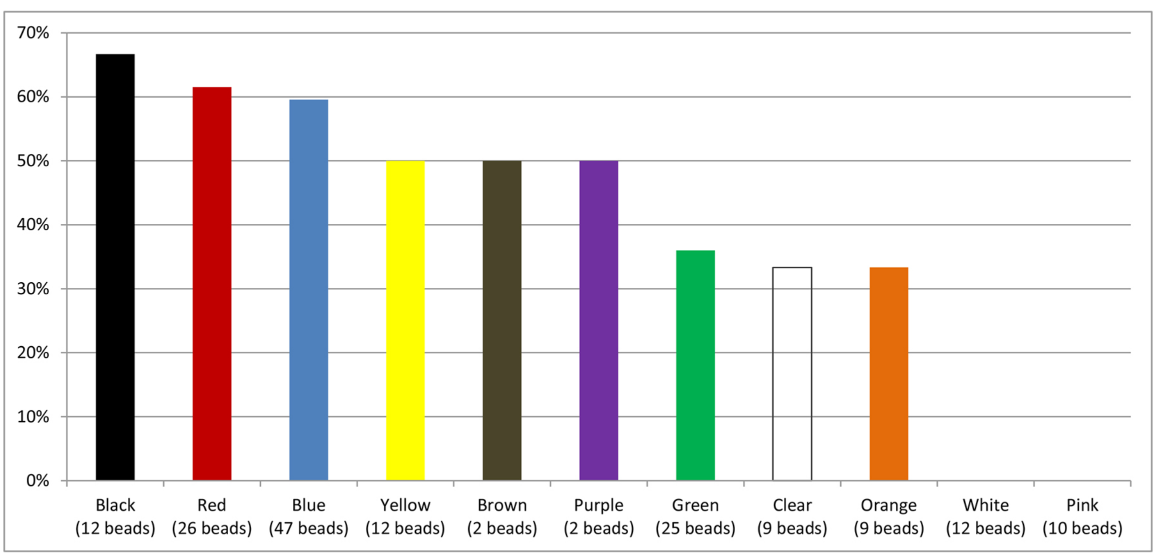

Fig. 7. Percentage of beads that have glass disease by color. The number below each column is the total number of beads of that color included in the survey. (Courtesy of Robin O'Hern)

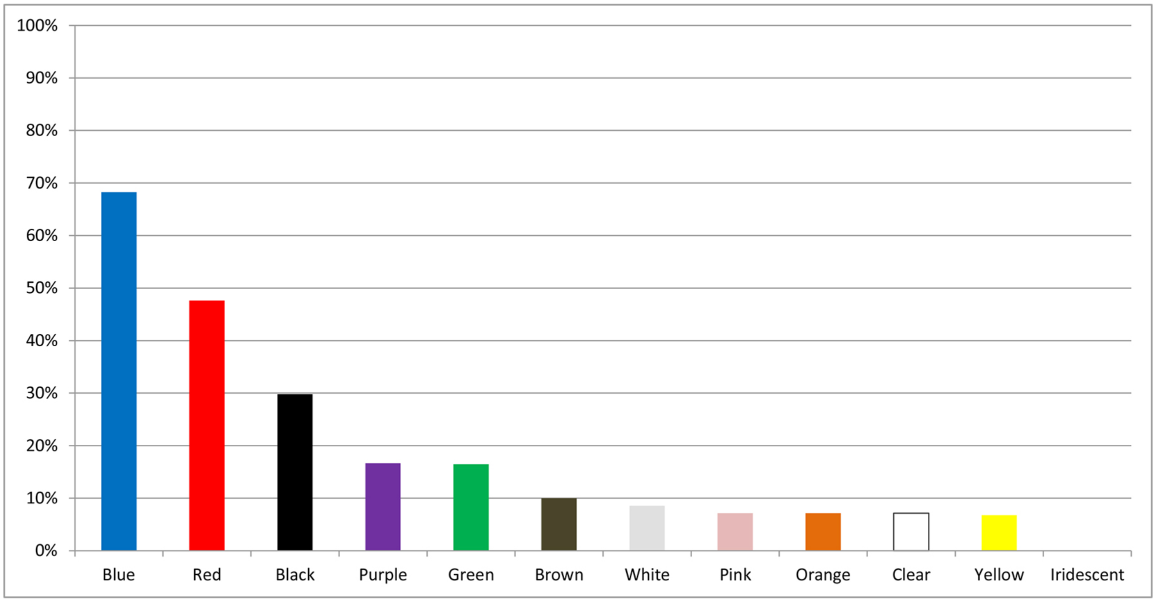

Fig. 8. Percentage of deteriorating beads by color on objects with records of unstable glass (Courtesy of Robin O'Hern)

explanations for the susceptibility of these colors to deterioration. Copper oxide creates different colors in glass, ranging from blue to green. Low lime and high alkali components help to achieve a blue—rather than green—color with copper. Unfortunately, this also destabilizes the glass and renders it susceptible to deterioration (Weyl 1959, 164; Hancock et al. 1994). The red beads we surveyed tend to be more translucent than opaque; therefore, their susceptibility to deterioration can be explained by the reduction in calcium oxide that causes the glass to be translucent or transparent. An explanation for the high deterioration rates for black beads is harder to establish but is likely also related to reduced calcium content (Karklin 2002). Further analysis on the unstable and stable glass beads is recommended to better understand the factors leading to their deterioration.

3.2.3 Assessing Trends in Unstable Glass by Manufacturing Technique

As part of our survey, we recorded information about the beads' manufacturing technique. Upon interpreting the results, we found a potential correlation between manufacturing technique and the stability of the glass composition. While most of the beads we encountered are drawn beads (108 bead types), only 20% of those bead types were deteriorating. In contrast, of the 50 wound beads types on the objects, 95% of them were deteriorating. We encountered two other techniques, hollow-blown beads and mold-made beads. Of the three hollow-blown bead types, all exhibit deterioration. Sixty percent of the five mold-made bead types are made of unstable glass. We focused our interpretation on the wound and drawn beads because we encountered the most of them; however, further work could be done to explore whether hollow-blown beads are also particularly susceptible to deterioration.

There are two possible explanations for the difference in wound and drawn bead deterioration: one based on composition and one based on bead usage. Drawn beads tend to be soda-lime-silica glass, whereas wound beads are made of potash glasses with slightly lower calcium oxide percentages. The lower calcium oxide concentration could contribute to the tendency for wound glass to be unstable. Additionally, the larger size of potassium ions in comparison with sodium ions could result in larger voids in the silica network, which could in turn cause more cracks or splits in the beads (Karklins 1983; Hancock 2013, 460–461). Alternatively, our data may be influenced by the small number of objects chosen for this subgroup. Additionally, drawn beads such as seed and pony beads tend to be used in significantly higher numbers on objects than wound beads, thereby increasing the probability that some of the beads will be unstable.

There are numerous challenges with conducting research on the deterioration of glass beads. The challenges can be roughly broken up into those related to glass disease and those related to the collection itself. Unstable glass is difficult to study because of the number of factors that can contribute to its deterioration—most of which are unknowable for a museum object. One important factor includes the composition of the glass, which will vary from batch to batch even within the same factory and which is difficult to determine on a large scale using noninvasive techniques. Additionally, the current and previous environmental conditions and the use of the object can contribute to the deterioration of glass beads. Once again, most of the information about their preaccession life remains inaccessible for museum objects. Compiling the complete environmental history of an object after it enters the NMAI's collection—or the earlier collection of the Museum of the American Indian—can be difficult. Beads are used in innumerable ways and associated with a variety of media to adorn items across the Americas—this also presents a significant research challenge.

4. EVALUATING TREATMENT TECHNIQUES FOR UNSTABLE BEADS

Does it matter if glass beads with salts on the surface are cleaned with water, ethanol, or 1:1 water: ethanol? Do beads treated with the different techniques redevelop glass disease differently? No published research was found that evaluated the long-term effects of different cleaning options for glass beads. The authors developed this second survey to assess whether there is a correlation between the treatment material and the redevelopment of visible deterioration products on the beads' surfaces. If there is no correlation between treatment material and redevelopment of salts on the surface, then conservators can choose the cleaning material on the basis of other factors, such as the sensitivity of surrounding materials.

This survey has several challenges associated with it. First of all is the difficulty of selecting a representative sample. Ideally, the objects would all be from the same culture, of the same type (i.e., moccasins), and treated using the different techniques in the same year. Unfortunately, this ideal sample group does not exist. The selected objects are based on those with treatment records, which naturally biases selection towards those areas of the collection that were chosen for exhibitions. Objects included in exhibitions tend to be in better condition than those that are not selected. Finally, individual conservators may clean beads with slightly different techniques, for example, using different amounts of moisture and cleaning the entire bead or just the exposed areas.

To research the long-term effect of treatment, objects that have a history of glass disease on blue and red beads and documented conservation treatments from each technique were surveyed to assess their current condition. The authors chose to use color to identify a subset of the collection, as opposed to object type (e.g., moccasins), culture, or treatment date because of the importance of glass composition. Although the colorant is a relatively small percentage of the glass composition, we expect it to roughly correlate with other components in the glass, as discussed earlier. Additionally, for a conservator without access to analytical equipment, color is the main feature by which we identify beads. Twenty-one objects with red beads and 38 objects with blue beads were chosen that have records of the presence of glass disease in the conservation database and are currently located in collections storage. Many objects had more than one type of blue bead or both red and blue beads; therefore, a total of 84 bead types were surveyed.

Forty-two cultures are represented by the 52 objects, with the most objects attributed to the Kiowa, Apsáalooke (Crow/Absaroke), Niitsitapii (Blackfoot/Blackfeet), and Tlingit. The objects included bags, baby carriers, clothing, breastplates, bridles, cradleboards, earrings, dolls, necklaces, and pipe bags, among other items. All of the objects were previously cleaned with water (deionized or distilled), ethanol, or 1:1 water: ethanol. Although we initially planned on including objects with red and blue beads that had records of unstable glass but that had not been previously cleaned, we ended up excluding those objects from our survey. We did not survey them because in most cases only overall images of the objects existed, which did not provide sufficient detail to assess changes in the presence of white surface material on the beads. None of the beads on the objects have been consolidated as part of their treatment. The treatments occurred from 1994 through 2011 for exhibitions and loans by the NMAI.

4.1 SURVEY METHODOLGY

This second survey recorded information about the bead (shape, manufacturing technique, opacity, Munsell color number), materials in contact with the beads, the bead's pH, and a comparison with the previous condition. The results were then entered into a Microsoft Excel spreadsheet. The pH of the beads was measured using the same technique as described in the previous survey. Only bead types that had records of unstable glass were examined. Additionally, objects that had only three or fewer beads of the color in question were not included in the survey because the number of beads was considered too small to be a representative sample.

4.2 RESULTS AND DISCUSSION

The red and blue bead types were analyzed to look for trends in the susceptible beads as well as the effectiveness of cleaning with different techniques. Of the surveyed red bead types, 54% were red-on-white beads also known as white hearts or *cornaline d'Aleppo* (Sprague 1985; Ross 2000; Billeck 2008). The rest of the red and blue beads were made with what appears to be a single layer of glass; however, it is likely that some of the beads have a clear glass layer on the top that would only be visible with cross sectional analysis (Shugar and O'Connor 2011). Eighty-five percent of the red and blue bead types were seed or pony beads made with the drawn technique. Most of the glass beads (76%) were in contact with hide; however, 19% were in contact with fabric (two of these were in contact with both hide and fabric). Other materials were also present as substrates, including tin, basketry, fur, wood, and plant fibers. We did not notice the glass deterioration affecting the substrate, for example, by causing darkening or discoloring, or the threading material. Although the surveyed beads are not necessarily representative of the overall collection, the relative unity of the red and blue beads (mostly drawn seed beads of similar color on hide) enables comparison of treatment techniques.

4.2.1 Assessing Color Trends within Red and Blue Beads

We recorded the Munsell color number for each of the types of beads on the objects. The red beads ranged from dark red to medium red, to a dusky rose (fig. 9). Forty five percent of the red beads, however, fall in the mid-range of the Munsell chips (2.5R 3/10, 5R 3/8, 5R 3/10, 7.5R 3/8, 7.5R 3/10, 7.5R 3/12).

We expected to find mostly light blue beads affected by glass deterioration because of the inherent instability of blue beads colored by copper. The wide spread of blue beads that had unstable glass (fig. 10) surprises us. Thirty-seven percent of the bead types are in the dark blue color range. As expected, the lightest red and blue colors are not unstable, probably due to the calcium oxide used to create the paler colors.

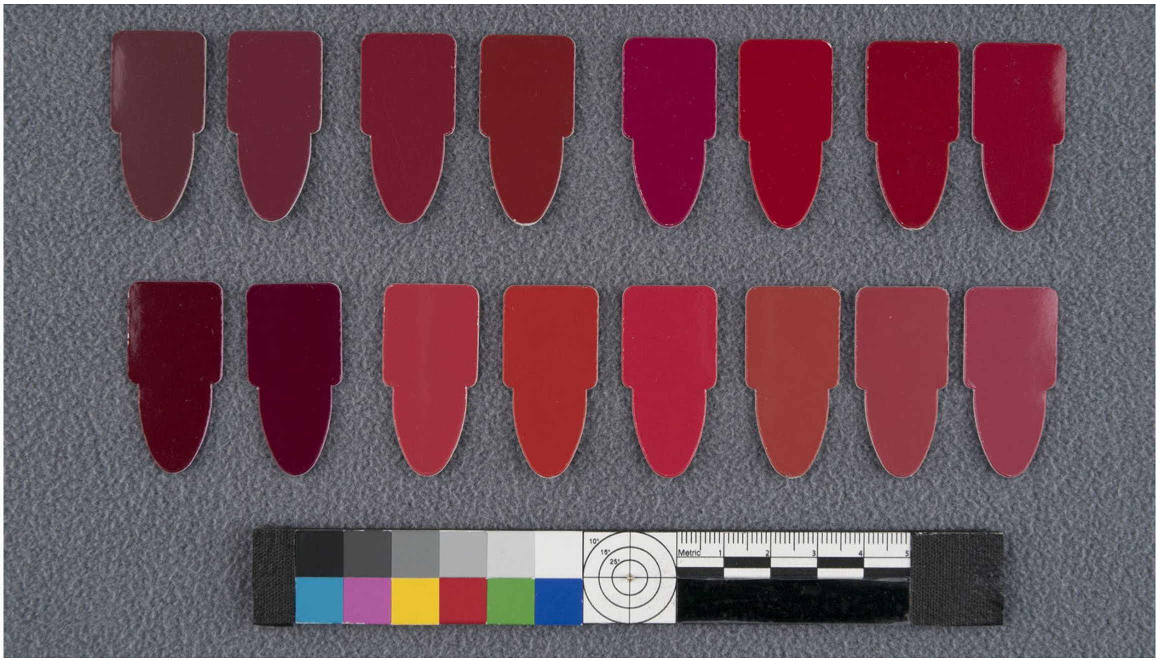

Fig. 9. Image of the red Munsell color chips that correlated with the beads that had records of unstable glass. Munsell numbers from left to right of the upper row: 5R 3/4, 2.5R 3/6, 5R 3/8, 7.5R 3/8, 2.5R 3/10, 7.5R 3/12, 7.5R 3/10, 5R 3/10. Munsell numbers from left to right of the lower row: 7.5R 2/8, 5R 2/8, 5R 4/10, 7.5R 4/10, 5R 4/12, 7.5R 4/8, 5R 4/8, 2.5R 4/8. (Courtesy of Robin O'Hern)

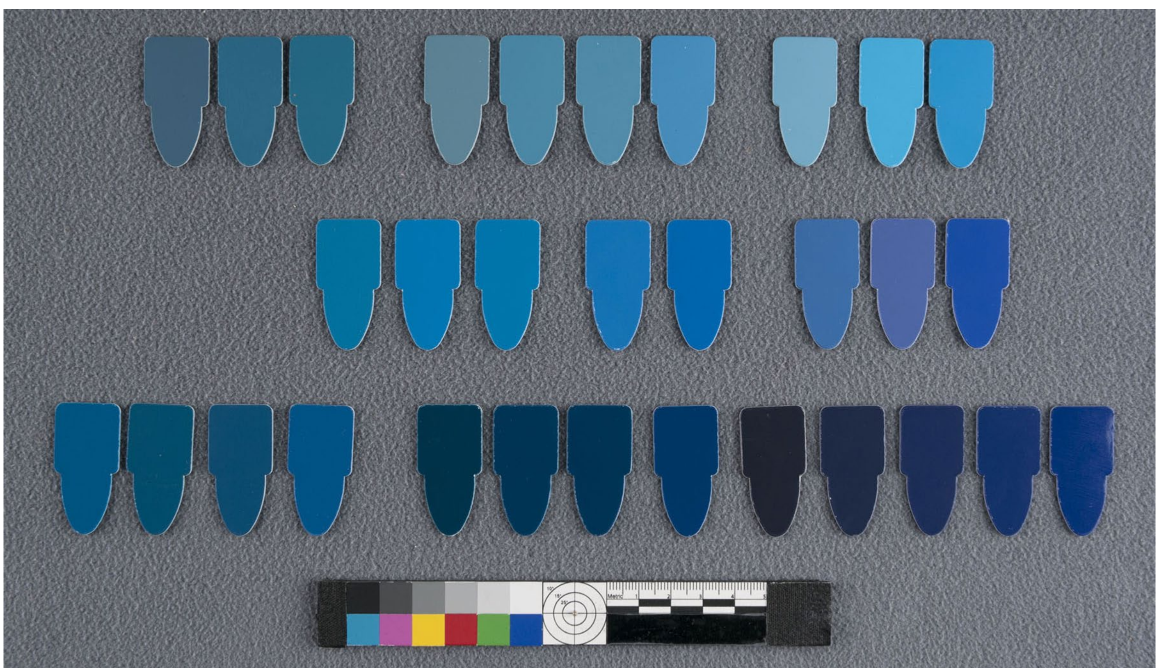

Fig. 10. Image of the blue Munsell color chips that correlated with the beads that had records of unstable glass. Munsell numbers from left to right of the upper row: 10B 4/4, 7.5B 4/6, 5B 4/6, 7.5B 5/4, 7.5B 5/6, 5B 5/6, 10B 5/8, 7.5B 6/6, 5B 6/10, 7.5B 5/10. Munsell numbers from left to right of the middle row: 7.5B 4/8, 7.5B 4/10, 5B 4/10, 2.5PB 4/10, 10B 3/10, 5PB 4/8, 7.5PB 4/8, 7.5PB 3/12. Munsell numbers from left to right of the lower row: 5B 3/8, 7.5B 3/6, 10B 3/6, 2.5PB 3/8, 2.5B 2/6, 10B 2/6, 2.5PB 2/6, 5PB 2/8, 7.5PB 2/2, 7.5PB 2/4, 7.5PB 2/6, 7.5PB 2/8, 7.5PB 2/10. (Courtesy of Robin O'Hern)

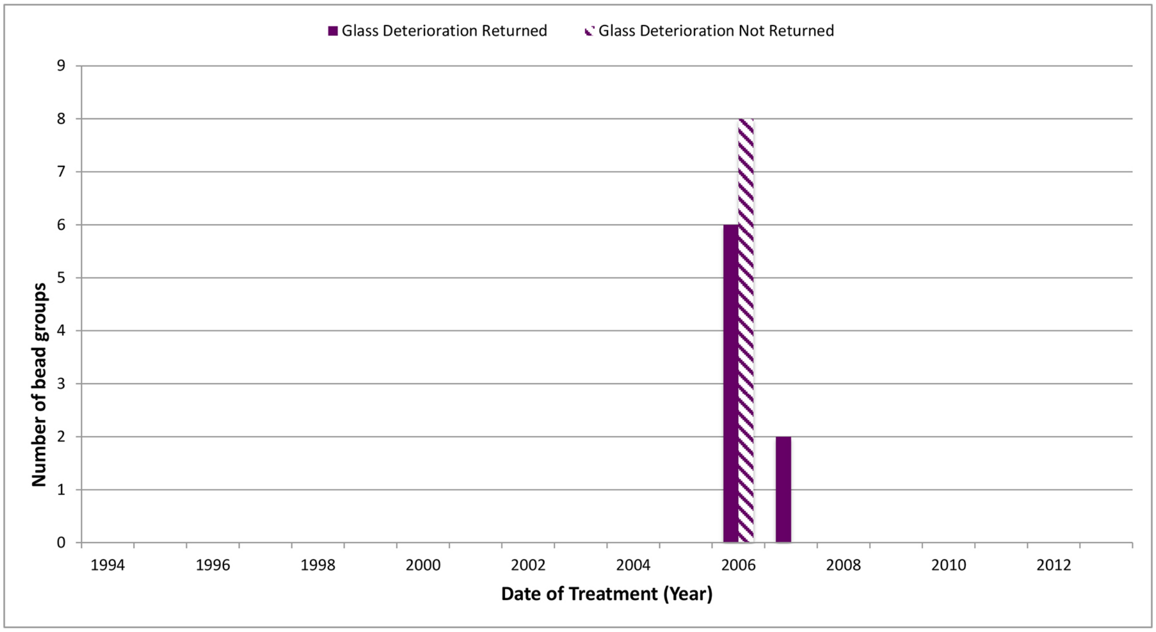

Fig. 11. Reoccurrence of deterioration on glass beads with records of unstable glass that were cleaned with deionized or distilled water (Courtesy of Robin O'Hern)

4.2.2. Does Cleaning Technique Matter?

We evaluated objects that had been cleaned 3–20 years previously. Not all the cleaning techniques were used across the same time span, which makes comparison difficult. The 16 red and blue bead types (fig. 11) that were cleaned with deionized or distilled water were all treated in 2006 and 2007 in preparation for an exhibition called Identity by Design. Half of the bead types cleaned with water have redeveloped alkaline surface salts and half of them have not over the past 7–8 years (table 2). We did not see any beads that had developed glass disease on the interior due to water wicking into the thread and creating a humid microenvironment, an issue found by Lougheed (1988). Similarly, other conservators also have not seen any facilitation of deterioration by using water to clean glass beads (Roundhill 2011).

The 21 bead types cleaned with 1:1 water: ethanol were treated over a wider period of time—from 2000 to 2009—which covers many different loans and exhibitions (fig. 12). The water component was either deionized or distilled water. Of the 21 beads cleaned with 1:1 water: ethanol, 52% of the beads redeveloped alkaline surface salts and 48% of the beads are still stable (table 2). There is not a strong correlation between duration since cleaning and redevelopment of alkaline surface salts: beads that were cleaned 5 years ago have both had glass disease redevelop and also remained stable, as have beads that were cleaned 13–14 years ago.

The 47 bead types cleaned with ethanol were treated over the widest period of time, from 1994–2011 (fig. 13). Forty-seven percent have redeveloped surface salts since cleaning (table 1). Once again, there isn't a strong correlation between duration since treatment and the redevelopment of glass deterioration; however, most of the beads cleaned in the 1990s have glass disease now. If the beads cleaned with ethanol are compared over the same period of time to the beads cleaned with 1:1 water:ethanol (e.g., from 2000 to 2009), then only 42% of the beads cleaned with ethanol have redeveloped glass deterioration. This suggests that using ethanol on its own may result in slightly fewer beads redeveloping glass deterioration; however, the surface salts will still eventually return. Further research could be done on why ethanol seems to delay the return of deterioration slightly more effectively

Table 2. Percentages of bead types per year that have had glass disease return by treatment material

Year	Number of Bead Types Cleaned with Water by Year	Percentage of Bead Types Cleaned with Water by Year that Have Redeveloped Glass Deterioration	Number of Bead Types Cleaned with 1:1 Water: Ethanol by Year	Percentage of Bead Types Cleaned with 1:1 Water: Ethanol by Year that Have Redeveloped Glass Deterioration	Number of Bead Types Cleaned with Ethanol by Year	Percentage of Bead Types Cleaned with Ethanol by Year that Have Redeveloped Glass Deterioration
1994	0	N/A	0	N/A	2	100%
1995	0	N/A	0	N/A	0	N/A
1996	0	N/A	0	N/A	2	100%
1997	0	N/A	0	N/A	1	100%
1998	0	N/A	0	N/A	2	0%
1999	0	N/A	0	N/A	1	100%
2000	0	N/A	1	100%	12	33%
2001	0	N/A	4	50%	2	100%
2002	0	N/A	0	N/A	10	40%
2003	0	N/A	2	50%	0	N/A
2004	0	N/A	2	50%	6	50%
2005	0	N/A	0	N/A	4	25%
2006	14	43%	3	100%	0	N/A
2007	2	100%	4	25%	1	100%
2008	0	N/A	2	50%	1	0%
2009	0	N/A	3	33%	0	N/A
2010	0	N/A	0	N/A	0	N/A
2011	0	N/A	0	N/A	3	33%
2012	0	N/A	0	N/A	0	N/A
2013	0	N/A	0	N/A	0	N/A
Total	16	50%	21	52%	47	47%

than the other techniques. It is possible that the ethanol has a dehydrating effect on the bead that removes some of the moisture present, which is causing the glass to deteriorate.

This second survey reinforced conclusions made during the first condition change survey. Measuring pH of beaded surfaces is critical in identifying which beads have alkaline surface salts and which are either dirty or contain culturally applied kaolin. Evaluating condition change based on an overall documentation image is very difficult. Detail photos are necessary to visually measure a change in the condition of a bead. It was the aim of the second survey to evaluate treatment methods used to remove surface salts on deteriorating beads at NMAI over a period of 20 years. The use of water, 1:1 water: ethanol, and ethanol were examined, and it was found that while there was no clear frontrunner, beads cleaned with ethanol had the lowest rate of return. It should be noted, however, that the rate of return could be influenced by more than just solvent choice/use alone. It was continually observed in the survey from 1999 that the interaction of beads with the substrate or sewing material affected the type or amount of salts present (Carroll and McHugh 2001). Additionally, the method of manufacture can affect

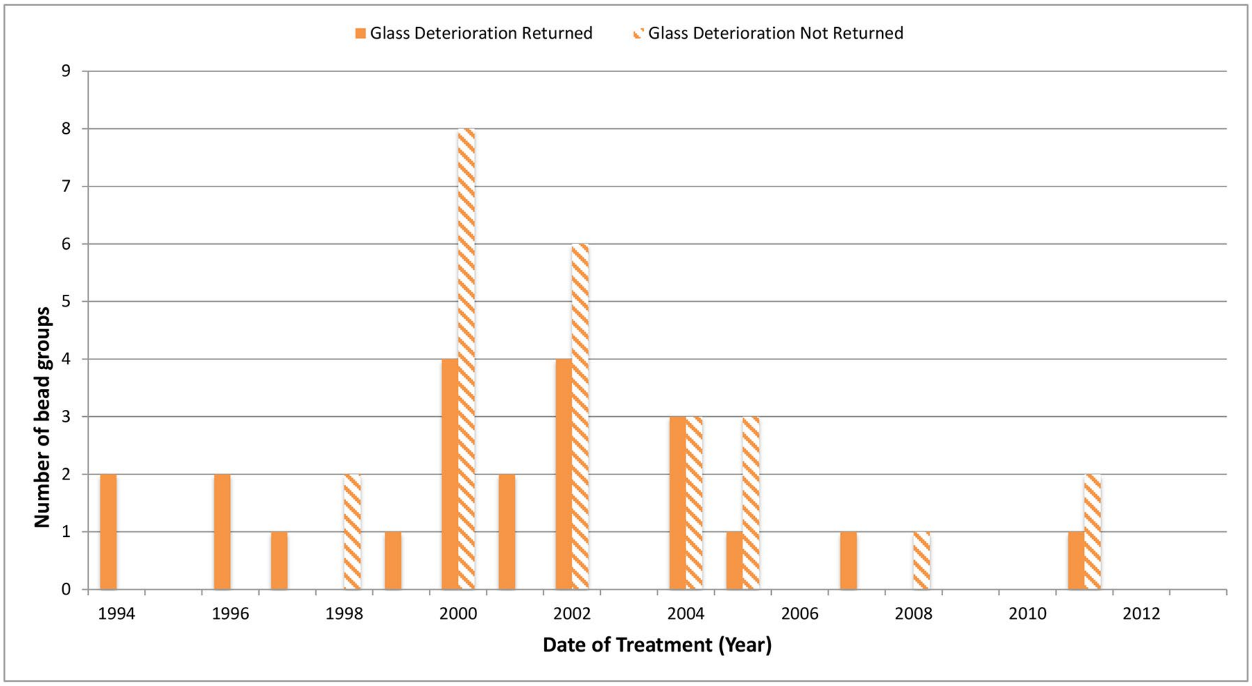

Fig. 12. Reoccurrence of deterioration on glass beads with records of unstable glass that were cleaned with 1:1 (deionized or distilled) water:ethanol (Courtesy of Robin O'Hern)

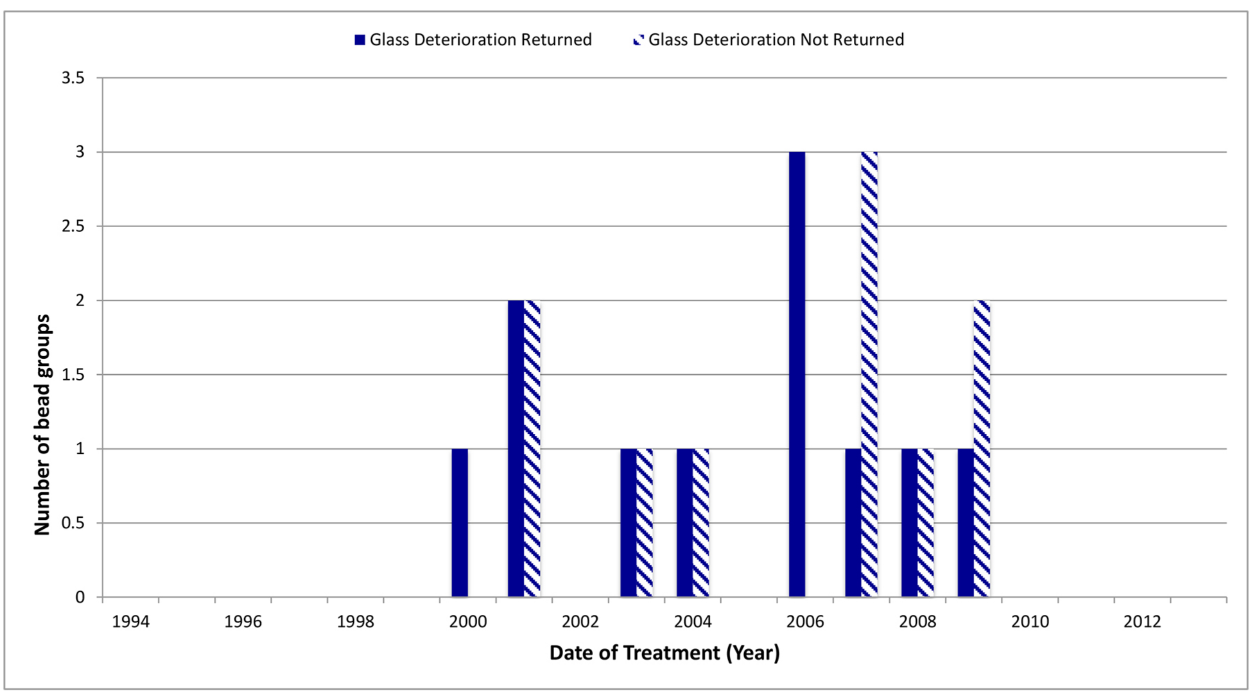

Fig. 13. Reoccurrence of deterioration on glass beads with records of unstable glass that were cleaned with ethanol (Courtesy of Robin O'Hern)

the way that glass beads deteriorate in terms of the glass composition, the direction of cracks, or the surface treatment (Sirois 1999, 85).

5. FURTHER RESEARCH

There are many different aspects of this project that merit further research. It would be beneficial to have a larger sample size of objects cleaned with the different techniques, particularly if they had more comparable date ranges. This would be best done through collaboration with another institution. We have considered surveying uncleaned objects known to have unstable glass to assess whether deterioration has progressed. The lack of detailed images makes comparison difficult, but we could resurvey only those objects that have sufficiently detailed images. Further research could also be done on why beads cleaned with ethanol seem slightly less likely to redevelop glass deterioration—does slightly dehydrating the bead during solvent cleaning help stabilize the bead? Additionally, what is the deterioration mechanism for beads whose surface accretions include oily or fatty components from the hide substrate?

It would be particularly beneficial to analyze the composition of the surveyed beads to look for additional correlations; for example, how much stabilizing calcium oxide is present in the beads and does that correlate with which have redeveloped alkaline surface salts? Or, does the alkali component (sodium oxide, potassium oxide, or lead oxide) seem to influence the deterioration of the bead? We are also interested in pursuing more information about the composition of the deteriorating black beads identified by our survey of the conservation records database because this color has received relatively little investigation.

6. CONCLUSIONS

Glass deterioration affects numerous beaded objects in the collection of the NMAI. These composite objects have conservation requirements different from unstable vessel glass or non-composite objects. The surveys found that there may be a correlation between the glass composition associated with manufacturing technique and the long-term stability of the glass. Seed and pony beads tend to make up the largest numbers of beads affected—perhaps due to the large numbers of those beads used on objects. Finally, blue, red, and black beads are the most unstable colors used on objects in the NMAI's collection.

The second survey evaluated cleaning methods and found that the results were very similar for water (50% of bead types had glass deterioration return), 1:1 water: ethanol (52% of bead types had glass deterioration return), and ethanol (47% of bead types had glass deterioration return). When the bead types cleaned with ethanol are compared over the same time with the bead types cleaned with 1:1 water: ethanol, then the rate of return of glass deterioration for beads cleaned with ethanol decreases to 42%. Revisiting these treatments was only made possible through the use of the NMAI's Collections Information System, allowing for objects containing glass disease and treatments for glass disease to be searched. Expanding the size of the survey group may offer different results; however, this project provides a foundation and a methodology in which to proceed with this evaluation. These studies confirm the importance of several conservation practices, such as recording treatment materials in reports and documenting post treatment condition with words and images, especially if the object is tagged as requiring long-term monitoring.

Glass deteriorates due to unstable composition, environmental factors, contact with substrates such as hide, and the way an object was used. Unstable glass composition is an inherent vice; therefore, distinguishing which beads might be more susceptible to glass disease is important. By assessing the distribution of unstable glass beads throughout the collection and understanding the mechanisms of deterioration, the authors aim to inform and identify beaded objects at risk of deterioration. This information can be used to assist in the long-term preservation of these important collections.

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NOTES

[1]The authors decided to record the information in separate questions so that the data could be analyzed more thoroughly. Seed and pony beads—the majority of those encountered in the surveys—are coded as Ia (undecorated tubular monochrome beads) or IIa (undecorated rounded monochrome beads) based on the Kidd and Kidd system as modified by Karklins (2012).

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ROBIN O'HERN is an Andrew W. Mellon Fellow in objects conservation at the National Museum of the American Indian (2012–2014). Robin has completed internships at the Walters Art Museum, the Straus Center for Conservation and Technical Studies at the Harvard Art Museums, Peabody Museum of Archaeology and Ethnology, the Agora Excavations of the American School for Classical Studies at Athens, the American Museum of Natural History, the Pitt Rivers Museum at Oxford University, and the Corning Museum of Glass. She received a Master of Theological Studies degree from Harvard Divinity School, where she studied religion and material culture, and holds a master of arts from the UCLA/Getty Program in archaeological and ethnographic conservation. Address: Smithsonian Institution National Museum of the American Indian, NMAI Cultural Resource Center, 4220 Silver Hill Road, Suitland, MD 20746. E-mail: OhernR@si.edu

KELLY McHUGH is an objects conservator at the National Museum of the American Indian (NMAI), where she has worked since 1996. She holds a MA in art history with a certificate in conservation from New York University's Institute of Fine Arts, and BA in art history and peace and global policy studies, again from New York University. She specializes in evolving NMAI's initiatives in collaborative conservation and in caring for the museum's contemporary art collection. Address as for O'Hern. E-mail: McHughK@si.edu