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Mineral displays as embodiments of geologic thought and colonial invisibility

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Abstract

Mineral displays embodied how we think about minerals: as symbols of social status, scholarly tools, theological objects, and instruments of education. Mineral displays are also representations of how we *don't* think about minerals: as human products embedded in wider human histories. This paper reviews the historical themes in mineral display, from the cabinets of curiosity of the Renaissance to modern museums, and articulates a major narrative that has been omitted from mineral display traditions: the human processes that bring mineral specimens from the ground to the display case, particularly Western colonialism and labour. Historically, mineral displays have been used to provoke thought about mineral formation and wider Earth processes; here, too, mineral displays can be used to provoke thought about the human processes that created modern Geology.

Keywords: Mineral collections, mineral displays, history of science, history of geology

Introduction

Mineral displays embody how we think about minerals. Starting with Renaissance cabinets of curiosity and continuing to modern natural history museums, minerals have been seen variously as symbols of social and political power (e.g., Wilson, 1994, Vogel, 2015), tools for understanding the Earth (e.g., Laudan, 1987), objects of theological significance (e.g., Guntau, 1996), expressions of nationalistic pride (e.g., Vogel, 2015), and instruments of both formal and public education. Those values have guided how minerals have been collected, organised, and displayed (Kohlstedt and Brinkman, 2004).

However, mineral displays have also revealed how we *don't* think about minerals: as human products entwined with human histories, particularly histories of Western colonialism. In both historical and modern displays, minerals are almost uniformly presented as 'wonders from the underground.' This display choice renders minerals as 'natural' objects that appear free of human contact. In reality, the vast majority of display-worthy mineral specimens have been collected by miners, by the chain of people who eventually brought those specimens into collections, and by the scientists who used those specimens in their work. Those processes did not happen in isolation: they were embedded in local, national, and international histories of land, labour, migration, racism, colonialism, and imperialism. Often, the minerals themselves were the central motivating forces in those histories: what is Western colonialism without gold, silver, diamonds, or copper?

This topic is particularly relevant right now, as museums' many-decades-long decolonising efforts extend into natural history collections (e.g., Das and Lowe, 2018; Gelsthorpe, 2021; Freedman, 2021). While the core of decolonisation must be material reparations (e.g., Tuck and Yang, 2012), dismantling Western colonialism in the sciences also requires understanding and articulating how the two are entwined. The omission of colonial narratives from mineral displays is not accidental; it reflects a corresponding absence within the geological community.

This paper will examine how mineral displays have embodied mineralogic thinking through time – and how shifting perspectives about the significance of human histories could exteriorize in mineral displays in the future. It will do so through the lens of the Bryn Mawr College Mineral Collection: a college collection of around 44,000 mineral specimens, most of which were collected in the mid-1800s to early 1900s.

Mineral displays from the Renaissance to today

Mineral collecting is probably as old as humanity itself (see Wilson, 1994, pp. 13-17, for a summary of pre-Renaissance mineral collecting in Europe); however, modern-style mineral *display* arose in response to the emerging principles of the Renaissance and Scientific Revolution, the rise of the middle class, and the growing body of specimens flowing from colonial sites back to European metropoles (e.g., Impey and MacGregor, 2000). These trends produced the iconic Renaissance 'cabinet of curiosity' or 'wünderkammer,' the start of the modern mineral display lineage. The sections below review themes in mineral displays from the Renaissance to today, in order to illustrate the ways that mineralogic displays have showcased mineralogic thought.

For the purposes of this paper, 'minerals' carry their modern definition: inorganic, naturally-occurring solids with ordered internal crystal lattices that can be represented by a single chemical formula. However, it should be noted that this definition has changed considerably since the 1500s. For many of the collections discussed below, 'mineral' meant anything that was neither animal nor vegetable, and could include rocks, fossils, and even liquids. Portions of the Bryn Mawr 'mineral' collection from the mid-1800s include vials of sand from the Sahara Desert, brines from various inland seas, and even a tube of gas. When the distinction is relevant, it is noted below.

As symbols of social status

In the West, minerals' most common cultural use has been as symbols of social standing: of the owner's wealth, power, taste, or education (e.g., Wilson, 1994, pp. 46-47). This role has yielded distinct display traditions.

Minerals as symbols of wealth and taste are exemplified by the collections of European aristocracy. From the 1500s onward, but especially during the Enlightenment, European aristocrats considered it highly fashionable to engage in – and to be *seen* engaging in – mineral collecting (e.g., Wilson, 1994, Vogel, 2015), and they designed their cabinets accordingly: displays housed large, rare, expensive, or visually stunning specimens in surroundings that were "correspondingly elegant" (Napolitani, 2018). In 1784, France's King Louis XVI (1754-1793) renovated a special *salon d'honneur* at the Hôtel de la Monnaie to house his mineral cabinet: 16 glass-faced mahogany cases "richly adorned with interwoven laurel leaves in lead" (Napolitani, 2018). In 1791, Austrian Empress Maria Theresa (1717-1780) commissioned an entire room in her *Naturalien-Cabinet* to display a "bouquet" of diamonds and other cut gemstones. By the 18th-century, mineral interest among European aristocracy had built into a "mineral craze" (Simon, 2002), making the time period "the zenith of mineral collecting" (Vogel, 2015). Paris and Vienna in particular became major hubs of the mineral trade, and, "by 1776, most of the Austrian nobility collected minerals and every nobleman … had a small cabinet of minerals in his apartment" (Franza *et al.*, 2019).

For the Enlightenment-era rising middle class, too, minerals served as social symbols, not of wealth, but of education. The aristocracy-driven interest in minerals gave rise to a professional mineral trade that allowed middle-class collectors to assemble personal cabinets of more affordable specimens (Fritscher, 2012). At the same time, publications like Michael Bernhard Valentini's popular 1714 *Museum Museorum* drove interest in mineral collecting among the educated middle class. Johann Gottfried Herder (1744–1803) commented on 1780s Weimer's educated, aristocracy-adjacent class: "At that time, the person was nothing, the stone everything… Everybody mineralogized; even the ladies found a higher meaning in the stones and started cabinets for their own" (Hamm, 2001, p. 280). The trend also spread to Europe's colonies, and, by the late 1700s, it was common for wealthy and educated middle-class Americans to establish their own natural history cabinets as well (Kohlstedt and Brinkman, 2004).

As with the aristocracy, the social meanings of these minerals influenced their display: often, minerals (and other natural history specimens) were displayed in the most public part of a home (e.g., Olmi, 1993, p. 239). For example, Fritscher (2012) noted that it was common for mid-1800s German amateur collectors to display their minerals in their sitting rooms instead of locking them away in traditional cabinets. In England, the emerging middle class "displayed natural history collections as emblems of their cultural erudition alongside art galleries, libraries and gardens" (Alberti, 2002, p. 292). There, open displays "served the combined functions of display, entertainment, and improvement" (Guntau, 1996, p. 211).

The goal of impressing visitors gave early natural history cabinets their distinctive display aesthetic: ordered, neat, but simultaneously overflowing with the richness of the collection.

> "An orderly museum was a museum in which the various exhibits were arranged in an aesthetically pleasing manner. It contained no empty spaces, and was therefore capable of filling every visitor with wonder by immediately conveying the idea of great riches and variety. With this aim in view, time-tested and well-known expository models were followed: by hanging objects from the walls and especially the ceilings the naturalists were simply returning to the practice of medieval churches"
>
> (Olmi, 1993, p. 237)

For minerals, this display aesthetic often took the form of small divided shelves or boxes (cubbies), each with its own specimen or set of specimens (e.g., Figure 1). Specimens in these cabinets may or may not be labelled, and their organization was likely to be dictated by aesthetics or "arcane and symbolic arrangements of often mysterious significance" (Wilson, 1994, p. 19), rather than the taxonomies of more scholarly displays (see below).

The importance of the *audience* for social mineral displays can also be seen in a tendency for

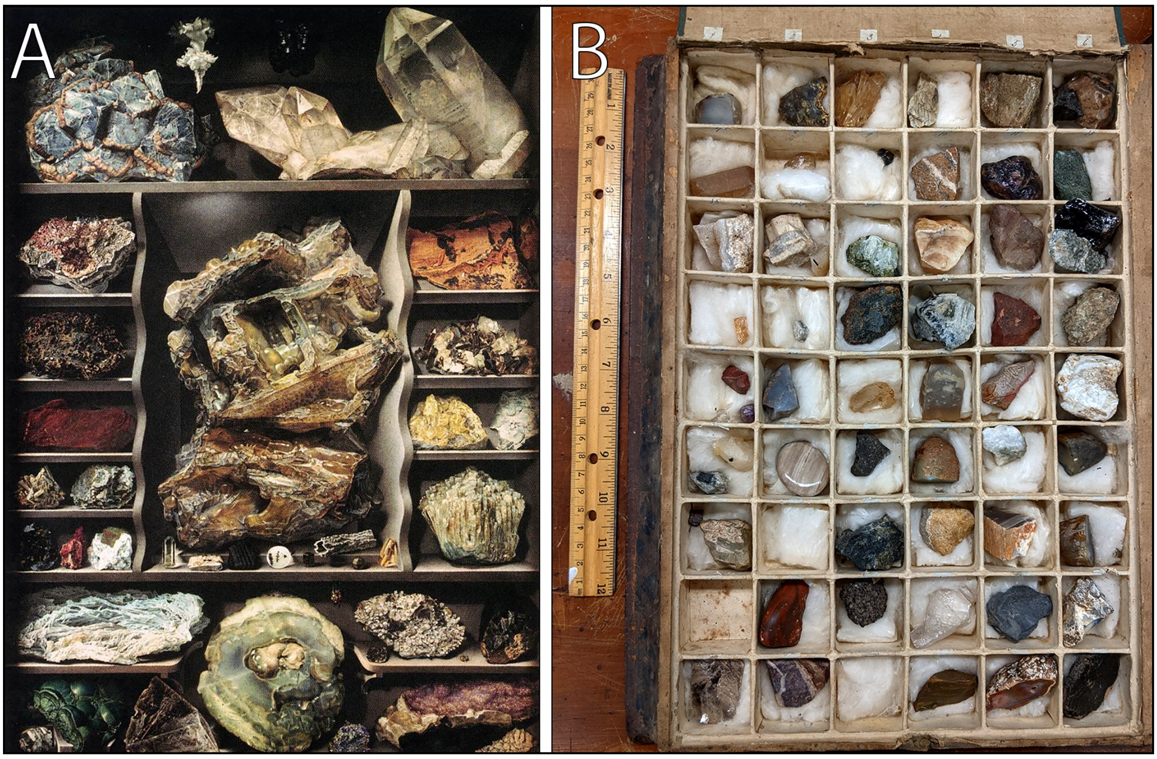

Figure 1. Hobbyist mineral displays. A) An 1813 painting of the mineral cabinet of Jacques-Louis de Bournon (1751-1825), by Alexandre Isidore Leroy de Barde (1777-1828), in the collection of the Louvre, Paris. B) Late 19th-century British mineral display box in the Bryn Mawr Lenker Collection (GC-148).

Renaissance and Enlightenment non-scholars to alter their minerals into art. Early mineral collector Ferdinand II, Archduke of Austria (1529 – 1595), commissioned artists to transform mineral specimens into artistic scenes ('handstones'), which could include minerals, sculpted human figures, metals, and wires assembled into landscape scenes (Wilson, 1994, p. 31). The naturally-occurring patterns in Florentine 'ruin marbles' so inspired some artists that they added hand-painted scenes to the 'landscapes' inside the rock or cut them into decorative display panels for mineral cases (e.g. Caillois, 1985, pp. 26-28). Especially for non-scholarly collectors, the line between the artificial and the natural was less interesting than the aesthetics of specimens.

As tools of study

From the 16th to 18th centuries, 'minerals as social indicators' dominated collecting: of the 60 largest 18th century European mineral collections (>4,000 specimens), only ten had been assembled by scholars (Wilson, 1994, pp. 46-47).

The pervasive use of minerals as status indicators pained many scholars, who often expressed "a high degree of intolerance … at the slightest trace of old-fashioned collectionism" (Olmi, 1993, p. 236). Early geologist Luigi Ferdinando Marsili (1658–1730) misogynistically lamented that natural history displays were "more intent upon stunning boys, women and ignorants than upon educating scholars about nature" (Spallanzani, 1984). A century later, Johann Wolfgang von Goethe (1749-1832) "could not contain his rage" when it was suggested that the Jena Museum's minerals be stored in glass cabinets, claiming: "the only advantage of glass was that it allowed for dangling something before the gaping masses" (Hamm, 2001, p. 295). Less dramatically but no less emphatically, mineral collector John Woodward (1665-1728) complained of collectors "perpetually heaping up of Natural Collections, without Design of Building a Structure of Philosophy out of them...." (quoted in Price, 1989, p. 80).

For natural philosophers, this "Design of Building a Structure of Philosophy" was the core purpose of natural history cabinets: to gather all the important pieces of the Universe in one place so that natural order would reveal itself (e.g., Kohlstedt, 2020). Because of this, cabinet mineral displays were both *representations* of how scholars thought about minerals – and active *tools* for thinking about minerals.

As representations, cabinet mineral displays were physical evidence of the thoughts of the scholar who organized them (e.g., Laudan, 1987, p. 21). This can be seen playing out on several levels. On the broadest scale, 16th century cabinets often contained both human-made (*artificialia*) and natural objects (*naturalia*), as scholars still believed the realms of the human and natural were intertwined. Sulfur, for example, was seen in the alchemical-lapidary tradition of the Middle Ages as the material form of Lucifer and imbued with correspondingly destructive energies (Hughes, 2012, p. 44). However, as the Scientific Revolution began to center observations and experimentation, scholars separated *artificialia* and *naturalia* in their cabinets, a physical representation of the intellectual separation that was happening at the same time (e.g., Franza et al., 2019, p. 183). Similarly, on the level of institutional collections, the pattern of displays as representations of thinking can be seen in the treatment of meteorites in the mineral collection of Austria's Imperial and Royal Natural History Cabinet in the late 18th century. As the thinking among natural historians shifted to a consensus that these materials fell from space, so shifted the Cabinet's meteorite displays: in 1806, the curators built an entirely separate room in the public cabinet to display the meteorites, physically separating their presentation from other geologic materials (Koeberl *et al.*, 2018). On the level of the individual scholar, mineral displays as representations of thinking can be seen in French mineralogist Balthazar-Georges Sage's (1740-1824) collection. Sage developed his mineral taxonomy hand-in-hand with his chemical experiments on minerals; as his experiments changed his thinking about minerals, so changed his personal cabinet layout (Napolitani, 2018, p. 246).

Displays were also *tools* for thinking about minerals (e.g., Bennett, 2004, pp. 67-68). An individual mineral must be intentionally *placed* in a display, and, for natural historians, that placement signified the mineral's relationships with surrounding specimens (e.g., Simon, 2002, p. 134). A display could not be assembled until the scholar chose – or *developed* – a system for classifying the minerals. However, unlike other natural history disciplines, mineralogy did not have a single widely-accepted classification system until the late 1800s (Hazen, 1984). Instead, individual scholars were left to make their own mineral classification systems for their cabinets. The minerals in front of a scholar, then, became the tools they used to develop their own hypotheses about mineral structures, relationships, and formation processes.

A single scholar might arrange and rearrange their mineral layouts repeatedly as their thoughts on mineral classifications changed (e.g., Vogel, 2015, p. 311). John Woodward (advocate of "Building a Structure" cited above) published, over the course of his career, a long series of mineral classifications, revisions, and additions that reflected his continual reorganization of his personal mineral collection (Price, 1989, pp. 93-95). This display of minerals was not done to impress viewers: it was an act of knowledge production. This was the central research question of mineralogy from the mid-1500s to the late 1800s: how are minerals to be *classified*?

This focus on mineral taxonomies did not arise in the Renaissance – Aristotle had tackled mineral classifications in the 4th century BCE, Avicenna in the 10th century CE, and Albertus Magnus in the 13th (Laudan, 1987, pp. 23-25) – but for Renaissance mineralogists, mineral taxonomies had a new *methodology*. This new standard had been set in 1556 when Georgius Agricola (1494-1555), the 'Father of Mineralogy,' posthumously published his 12-volume treatise on mineral classifications. In the preface, he famously wrote: "I have omitted all those things which I have not myself seen, or have not read or heard of from persons upon whom I can rely. That which I have neither seen, nor carefully considered after reading or hearing of, I have not written of" (Agricola *et al.*, 1912, pp. xxx-xxxi). Departing from Middle Ages mineralogic wisdom, Agricola held that minerals must be classified by their *observable* physical properties.

This mandate was in line with the emerging principles of the Scientific Revolution – which valued observation and experiment over philosophical musings – but it put mineralogists in a bind. The terrible truth for early mineralogists was that they did not have the tools they needed to classify minerals in an exact fashion; those tools would not emerge until the chemical revolution of the 1800s yielded an understanding of elements (e.g., Dana, 1880; Porter, 1981). Instead, Renaissance and Enlightenment natural philosophers had to classify minerals based on the limited physical properties they could observe: colour, luster, hardness, tenacity, cleavage, fracture, parting, taste, grittiness (upon being chewed), electrical properties, optics, growth habits, geographic occurrence, tendency to grow with or near other minerals. They could also make chemical observations: flammability, dissolvability, reactions to various acids. Within many of these categories, a single mineral species might vary widely: quartz, for example, can be *any* color, nearly any habit, a range of lusters, etc.

The result was a glut of classification schemes: Woodward in 1704, Linnaeus in 1735, Henckel in 1730 and again in 1744, Pott in 1746, Wallerius in 1747, Cronstedt in 1758, Bergman in 1783, Werner in 1789, Phillips in 1816, Werner again in 1817 – to name only the most influential (Laudan, 1987, pp. 23-25; Hazen, 1984, pp. 296-297).

This obsession with taxonomy was reflected in mineral displays in both private and public collections. In 1776, mineralogist Ignaz von Born (1742-1791) organized the Imperial Natural History Cabinet's mineral displays "according to the most recent scientific knowledge [of Linnaeus]" (Klemun, 2004). In the mid-1800s, the newly founded Australian Museum organized its mineral displays by taxonomy (Bennett, 1998). French mineralogist Jean-Baptiste Louis Romé de l'Isle (1736-1790) wrote and re-wrote his mineral taxonomies while assembling cabinet displays for French aristocrats (Guntau, 1996, p. 212). The examples of this are endless: 'minerals by chemical class' is still the dominant mode of display to this day, and can still be seen in internationally-recognized natural history museums like the National Museum in Prague, the Smithsonian's National Museum of Natural History, London's Natural History Museum, and the Museum für Naturkunde in Berlin. It can also be seen in the two large (>10,000 specimen) collections that make up the bulk of Bryn Mawr's mineral collection: the George Vaux Jr. and Theodore D. Rand Collections are both organized by different chemical class systems (the Vaux, for example, classifies the quartz family as Tectosilicates, while the Rand classifies it as an Oxide of Silica).

Because of the variety of classification schemes being published, Enlightenment mineral displays were also tools for scientific debate. When von Born reorganized the Austrian Imperial Cabinet, he did so according to Carl Linnaeus' (1707-1778) mineral classification scheme, which focused entirely on mineral *external form*. At the same time, Berlin mineralogist Dietrich Karsten (1768-1810) organized the Leskean Cabinet according to the competing taxonomy of influential early geologist Abraham Gottlob Werner (1749-1817), a classification scheme based on mineral *chemistry*. Austrian Count Moritz von Fries (1777-1826) organized his cabinet in line with the taxonomy of rising French crystallographer René Just Haüy (1743-1822; Vogel, 2015, pp. 310-312), and Antoine-Laurent de Lavoisier (1743-1794) organized his own according to a chemical tradition started by Axel Fredrik Cronstedt (1722-1765; Beretta, 2005, p. 127). In choosing a taxonomic scheme for a display, an organizer was taking sides in broader scientific debates about the nature of minerals and structure of mineralogy.

Simultaneous to the proliferation of mineral classification schemes was the rise of mathematics as a lens to view the world – and the subsequent rise of crystallography. The observations that mineralogists could make of crystals included their crystallographic forms: the exact angles at which their planes met, their symmetries and axes, and their breaking patterns. The rise of this discipline led, in mineral cabinets, to a particular interest in large, crystallographically perfect specimens – and in broken ones. René Just Haüy (the 'father of modern mineralogy') famously smashed crystals in his personal cabinet as he tried to assemble his understanding of how minerals' internal structures controlled their external forms (Whitlock, 1918). Broken pieces of these crystals were displayed as part of his personal collection, because of their importance in illustrating the fundamentals of crystallography (Bureau and Feininger, 2011, p. 664).

From the mid-1500s onward, the iconic scholarly mineral cabinet was a set of drawers that could be removed to examine and study the specimens inside. Many scholars specially designed these drawers to accommodate their taxonomic visions; Johannes Kentmann (1518-1574)'s inventory of his collection included no illustrations of mineral specimens but a detailed illustration of his display cabinet (Wilson, 1994, p. 25). Goethe's mineral cabinets were capped with glass cases, "a concession to the uninformed curiosity of those who longed for a display of a few lovely samples; the real treasures were inside the cabinets" (Hamm, 2001, p. 283). Portions of Bryn Mawr College's mineral collection still reside in the large wooden drawers that George Vaux Jr. (1863-1927) designed to house his taxonomically-sorted specimens in the late 1800s; each drawer houses specimens by type, and can be removed to study or show the specimens inside.

As objects "charged with theological meaning"

The history of science from the 1500s has been a long process of untangling science and religion. This has been especially true for geology, where, even through the 19th century, geologic formations were often ascribed Biblical causes. These 'physico-theologists' argued, for example, that Noah's Flood was responsible for all manner of geologic phenomena ('diluvialism'), including fossils and all sedimentary rocks (e.g., Huggett, 1989).

As a result, for some mineral collectors (both amateur and scholarly), earth materials were often "charged with theological meaning" (Guntau, 1996, p. 211) and their description and interpretation were less about aesthetics, social status, or taxonomies – and instead about affirming religious convictions (e.g., Håkansson, 2020, pp. 456-459). (Fossils in particular inspired theological speculation, but those are outside the scope of this paper).

This religious framing exhibited in mineral collections as interest in specific types of rocks and minerals seen as having biblical significance. 'Graphic granite,' for example (Figure 2A), are light

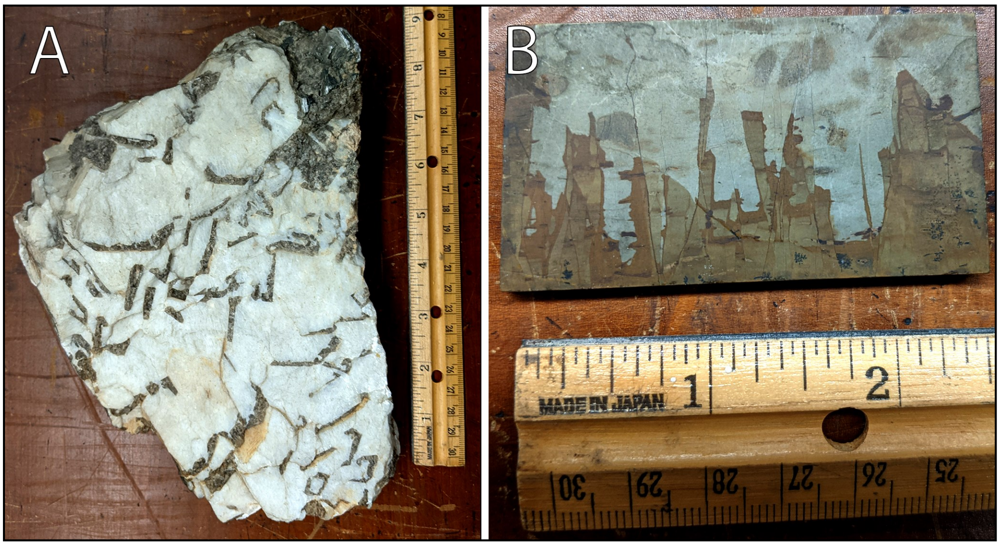

Figure 2. A) Graphic granite: the light-colored material is alkali feldspar, the gray twisting shapes stringers of quartz that chemically separated from the feldspar as it cooled in an underground magma chamber. These twisting stringers were once interpreted as writing, and collected and displayed as religious artifacts. Bryn Mawr Teaching Collection, unnumbered. B) Ruin Marble: a siltstone heterogeneously stained by iron-rich groundwater filtering through fractures. Bryn Mawr Rand Collection, sample 22-6. Like the graphic granite, ruin marbles were sometimes collected and displayed as religious artifacts.

-colored plutonic rocks that underwent mineral exsolution, separating quartz and alkali feldspar into distinctive stringers that look like cuneiform or Hebrew writing, giving them their French name, *Pierre hebraïque*. Some collectors interpreted the graphic texture as the Christian God's attempt to write Hebrew inscriptions into the granite (e.g., Guntau, 1996, p. 218; Davies, 1856, pp. 136-139). Similarly, rare siltstones from near Florence, Italy, when cut, show on their surfaces networks of cracks and stains that look like ruined landscapes and burning cities. These *Ruinenmarmor* (also called *Pietra Paesina*, *Pierres-aux-masures*, Ruin Marbles, or Landscape Marbles) are caused by water-transported color-causing elements (e.g., iron or manganese) staining the rock around the fractures. The apparent ruined cities trapped in these specimens inspired centuries of theological speculation (Caillois, 1985, pp. 15-36). 'Figured' stones, or stones shaped by weathering into shapes suggestive of human form, were also popular collecting items (Coglitore, 2004, p. 49).

As formal teaching tools

Hand-in-hand with the rise of natural philosophy came the teaching of natural philosophy – for this purpose, too, mineral displays were central. Up to the mid-20th century, science pedagogy was based heavily on developing students' practical skills, often relying on the study of physical specimens. Examples of these teaching displays are abundant. Rutgers University's natural history cabinet grew to occupy an entire building by the mid-1800s, and its mineral displays were used as teaching tools in its geology and natural history courses (Neitzke-Adamo *et al.*, 2018). Bryn Mawr College's Geology Department had in its mineralogy lab, up until 2017, a series of glass cases displaying representative minerals by type, classification, and physical properties (Figure 3A). To this day, the Smithsonian's National Museum of Natural History includes a "Study Gallery" of minerals by chemical class, as does the mineral gallery at the Natural History Museum, London.

Physical specimens are still central to geologic pedagogy today (e.g., Chatterjee and Hannan, 2015), but not the physically exceptional specimens of the mineral cabinet. Today's Bryn Mawr mineralogy students learn to identify minerals as they are usually seen in the field: altered, small, and imperfect. As practicing geologists, students will almost certainly never encounter inches-long azurite crystals in the field; they'll more likely encounter smashed-up bits of alkali feldspar. So, in class, they practice with smashed-up bits of alkali feldspar. The inches-long azurite crystals are stunning – but no longer *pedagogically* central to training geologists. Indeed, our mineralogy course goals have expanded to include emphasizing student understanding of the social roles of minerals, the wider geologic context under which minerals form, and the ways that minerals can be used to learn about geologic processes. These later goals do not even require physical specimens. The old teaching display cases have been disassembled and the minerals inside repurposed for public education display.

Instructing students in mineral taxonomies reinforced the dominant mode of mineral display as 'by class;' however, it also introduced a new

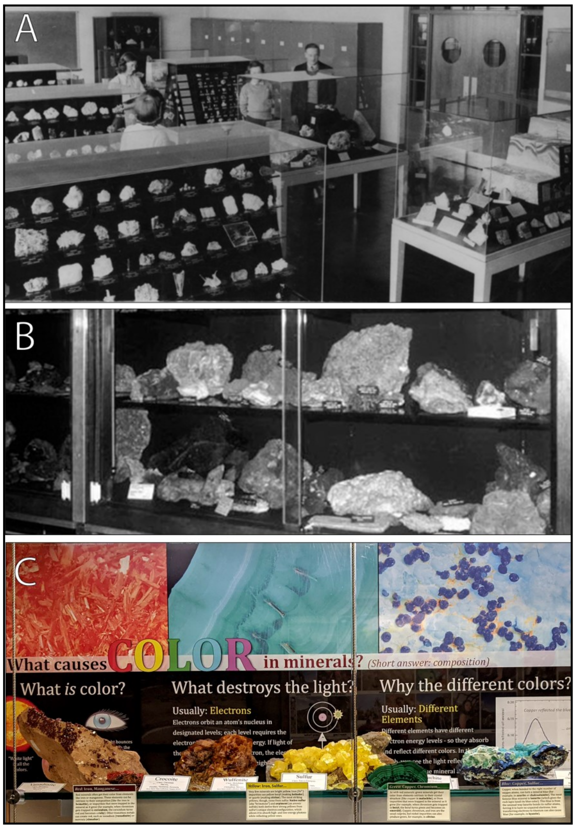

Figure 3. Bryn Mawr mineral displays as formal pedagogical tools. A) Minerals displayed by chemical class in glass cases in the Mineralogy teaching lab at Bryn Mawr. Undated, but likely taken around 1940, when the glass cases were first assembled. These cases were used to teach mineralogy from about 1940 to approximately 2000. They were disassembled in 2017 as part of the Park Science Center remodeling. Image from Bryn Mawr College Special Collections, image ID PA_00511. B) Minerals displayed in Bryn Mawr's Park Science Center educational exhibits for the general public, prior to the 2019 remodel. The labeling is minimal, and there is hardly any explanatory material accompanying the specimens; nevertheless, the specimens succeeded in inspiring a sense of wonder in generations of visitors. C) A 2019 display on the causes of color in minerals in the Bryn Mawr Park Science Center.

form of mineral display: by locality. This mode of display ('suite collections') was popular in mining districts, arising from the need to teach miners about co-occurrences of minerals. It was important that miners knew that, for example, galena (the chief ore of lead) most often occurs in proximity to sphalerite and calcite, not mica and garnet.

As mining operations expanded in the wake of the Industrial Revolution, so did the need to educate miners about minerals. For example, an 1885 report to the Australian Museum advocated for remodeling their current mineral display (which had been based on mineral classifications), and turning them instead into displays of mineral co-occurrences so that miners arriving for the new Australian mineral rushes might "at a glance, understand something of the science of mining" (Bennett, 1998). (The idea that mineral displays could convey important information "at a glance" was controversial. Goethe, for example, thought it "sheer madness" that an uninformed person could glean useful information about minerals just by looking at them; Hamm, 2001, p. 295). Similarly, in 1888 in South Africa, geologist William Guybon Atherstone (1814–1898) advocated for the founding of a national museum specifically to educate students in the "mineral and metallic discoveries [that] are rapidly assuming gigantic propositions" in the colony (quoted in Mackenzie, 2009, p. 114). Prussia used its Royal Mineral Cabinet to train mining engineers, and intentionally organized the collection and its displays geographically around major mineralogic deposits both in and outside of Prussia (Vogel, 2015, p. 313).

The expansion of economic mineralogy in the wake of the Industrial Revolution influenced two other shifts in mineral collection and display: displays as nationalistic marketing tools, and displays as tools of informal public education.

As "patriotic visions"

For governments – Imperial, Royal, and, eventually, democratic – minerals were not just symbols of wealth, but of power: power over nature, but also over *territory* and *populace* (e.g., Vogel, 2015; Rosenberg and Clary, 2018). For example, Napoleon summoned mineralogic specimens from lands occupied by French forces to be housed in the *Musée d'histoire naturelle* (Vogel, 2015, p. 306). The move symbolized his authority over the newly occupied territories – but also over the French populace: the *Musée d'histoire naturelle* had begun as the royal cabinet, had been transformed into the national museum during the French Revolution, and was now under his control. Similarly, in the newly-formed United States, Thomas Jefferson donated the minerals that had been brought back by the Lewis and Clark Expedition to Peale's Museum of Natural History in Philadelphia: the minerals displayed as part of U.S. natural history reinforced that those lands were now part of the U.S. (Conn, 1998, p. 34).

In this context, Western governments starting in the late 18th century began to commission mineralogic surveys of their home countries and occupied territories – and to house the resulting specimens in state cabinets and, increasingly, museums. In 1836, for example, the New York State legislature launched a program to document the mineral resources of New York State. The geologists they hired began by sending specimens back to the State Library, which was quickly overwhelmed. Next, they established the State Cabinet as a repository, but it too outgrew its space and budget within a few years. Finally, in 1870, the State Cabinet was reorganized into the New York State Museum of Natural History (Fakundiny, 1987).

As the scale of geologic research increased, so did geologists' reliance on museums as keepers of specimens. Britain established the world's first national Geological Survey in 1835, under Henry De la Beche (1796-1855) – who immediately also established the Museum of Economic Geology as a repository for the survey's specimens (Clary, 2020). Like the New York cabinet, this survey outgrew its space, and was morphed into the Museum of Practical Geology, then the Geological Museum (Knell, 2000, 2007). For a science so dependent on specimen analysis, these large-scale repositories were central; William Smith – the 'Father of English Geology' – saw geology as permanently "wedded to the concept of the museum" (Knell, 2000, p. 79).

One side effect of this permanent wedding of specimen repositories to government institutions was the expansion of mineral displays as tools for educating the public.

As a means of public education

Natural history cabinets as a means of public education extend as far back as the cabinets themselves. Francesco I de Medici (1541–1587) transformed his private room of rarities into the Uffizi Gallery, open to the public (Conticelli, 2007), and Ulisse Aldrovandi (1522 – 1605) opened his famous private museum to the public in the late 1500s. In 1638, Oxford University opened to the public its Ashmolean Museum of natural history specimens (Lipps, 2018). Maria Theresa threw open the doors of the Imperial Natural History Cabinet as soon as her husband died in 1765:

> In contrast to [her husband] Francis I, who considered collecting a private activity, Maria Teresa was a fervent supporter of the educational value of scientific exhibitions. She firmly believed that opening the imperial mineralogical collection to the public would allow citizens not only to deepen their scientific knowledge, but also to learn the economic value of minerals, thus stimulating new studies and discoveries
>
> (Franza *et al.*, 2019)

Similarly, in the newly-founded United States, Charles Willson Peale (1741-1827) transformed his private natural history cabinet into a public museum in a series of spaces in Philadelphia. Peale considered educating the public about natural history a part of his civic duty: “Natural History is not only interesting to the individual, it ought to become a National Concern since it is a National Good” (Kohlstedt and Brinkman, 2004).

The insistence on museums as institutions of public good via public education was emphasised and re-emphasised from the 1700s onward, but had a major expansion in the last two decades of the 1800s (Bennett, 1998, p. 29). In Britain, Queen Victoria encouraged her citizens to visit museums and even to start their own collections in their homes: “Museum culture was for the people’s own good: possession promised self-possession” (Black, 2000, p. 32). If all social problems stemmed from the lack of education and culture of the working class, then perhaps exposing them to culture was the solution.

In terms of display, this resulted in a call for better labeling and more accessible design. For example, the British Association for the Advancement of Science (BAAS) produced a report in the late 1880s, calling on provincial museums to label all objects so the visitors might benefit: “A museum without labels is like an index torn out of a book; it may be amusing, but it teaches very little” (BAAS, 1887, p. 127). Similarly, in the 1890s, geologist and curator of the American Museum of Natural History Louis Pope Gratacap (1851-1917) wrote: “the careful luminous exhibition and exposition of its collections, so that the public may fully understand them, and learn their lessons, is the chief purpose of the Museum” (quoted in Bennett, 1998, p. 29).

This framing of museums as instruments of public education expanded over the course of the 20th century (e.g., Rader and Cain, 2014), and, although many mineral displays remain in the traditional ‘by class’ or ‘by locality’ formats, the emphasis on public education has produced several new themes in mineral exhibits. These remain the dominant themes to this day, and include:

“Marvel!”

> “Marvel at nearly 400 dazzling and dramatic specimens from the Academy's geology collection—from iconic gems to newly-displayed natural wonders”
>
> (California Academy of Science, CAS, n.d.)

Today, one of the most common goals of mineral displays is to incite wonder and curiosity in the viewer by displaying the biggest, brightest, strangest minerals. The Smithsonian’s National Museum of Natural History (NMNH) has an entire wall dedicated to a single mass of quartz crystals from Arkansas. The Carnegie Museum of Natural History (CaMNH) mineral display “invites you to appreciate the wild variety and beauty of minerals … that come in a large range of striking colors, fascinating forms, and dramatic shapes” (CMNH n.d.). The Denver Museum of Natural History (DMNH) invites visitors to “be dazzled by the largest known pocket of aquamarine ever discovered” (DMNH n.d.). Examples of this type of display are endless. From a scientific perspective, they are more boring than literal dirt, but they are not there to teach about cutting-edge science; they are there to incite wonder.

Inciting wonder is not necessarily an ‘unscientific’ goal. Modern science requires curious questioners. Rosenberg and Clary (2018, p. 2) note that curiosity is a necessary prerequisite for science as we know it, but it has not been universally appreciated as a virtue:

> Long before the Scientific Revolution, curiosity was viewed in Western civilization with suspicion. During antiquity, in Greece, curiosity was regarded as a trait of busybodies and, later in Rome, as an expression of dangerous or useless knowledge. In the Middle Ages, curiosity was deemed a vice: It was a sin to be curious! Even during the Scientific Revolution, Francis Bacon and Galileo had their doubts about its value … Thus, the expression of curiosity has a history and cultural context that requires nurturing because it is vital to science literacy.

Museum displays that seek to inspire curiosity do so with giant, colorful crystals – but also with sheer numbers. The CaMNH, for example, has a display of dozens of cut colored sapphires that, alone, would have been beautiful, but massed together are visually arresting. Lipps (2007) articulates the value of these kinds of wonder displays in natural history collections more generally:

> I love the parade of stuffed animals appearing to march in some orderly manner through the center of the place and the whale skeletons hanging above visitors, again with limited labeling. Elsewhere the exhibits remain outstanding but the explanations get more detailed and more complex. The kids, who stand in amazement along the parade or silently gaze upwards to see the whale, run right by these exhibits in the quest for items that excite them more ... [Museums] have become "educational" centers with elaborate explanations of evolution, geologic time, paleoenvironments, plate tectonics, etc, etc. Everything is well explained, leaving nothing to the imagination. They are very educational, and I hate it.

Minerals are powerful instruments for provoking awe. Anecdotal accounts from generations of Bryn Mawr alumni repeat again and again that the mineral displays of Park Science Center were their favorite parts of campus, even in days when the minerals were barely labeled and their presentations were perhaps more *piled together* than *displayed* (Figure 3B).

Immediately answering questions

Another common display tactic for minerals is to immediately answer the questions that are likely popping up in viewers' minds; like: "what causes all those colors?" or "how do they grow in those shapes?" This tactic is almost the opposite of the "Marvel!" display: it offers an object to provoke questions – then immediately answers them. For this, too, examples are abundant: the Smithsonian's NMNH includes mineral displays dedicated to how different shapes of minerals form, and Bryn Mawr's 2019 mineral displays include cases on the cause of color in minerals and the shapes they take as they form (Figure 3C).

"Minerals and you"

Another mineral display tactic in service of public education is to connect minerals with our everyday lives. The list of these connections goes on and on: salt in our food, apatite in our bones, gypsum in our walls, copper in our wires, dozens of rare minerals in our technologies, minerals in the pigments of our favorite paintings. The Museum für Naturkunde, Berlin, focuses several displays on minerals in technology. CaMNH mineral displays invites viewers to "learn about minerals that make up everything from table salt to diamond rings" (CaMNH n.d.). CAS similarly offers: "Learn about minerals in your everyday life, present in products from smartphones to toothpaste" (CAS, n.d.). Bryn Mawr's 2019 displays include the paint pigments of van Gogh's *Starry Night* and the minerals used to make cell phones.

Fundamentals of Earth processes

Another modern mineral display tactic is to link minerals to the fundamentals of Earth processes: how do geologists use minerals to understand how geology works? Displays at the Smithsonian's NMNH link minerals to growth mechanisms like evaporation. CAS features a "Gems and Minerals Unearthed" exhibit focusing on minerals' roles in geologic processes. The San Diego Natural History Museum (SDNHM) invites viewers to "discover how the same Earth processes that build landscapes produce dazzling gemstones" (SDNHM n.d.), and Bryn Mawr's 2019 displays illustrate the geologic history of the Philadelphia region using local minerals and rocks.

Illustrating the process of science

Mineral displays are more likely to attempt to illustrate fundamental principles of geology than to dive into modern mineralogic research, and for a good reason: modern research is usually incredibly removed from the lived experiences of the average person. Questions like, "How does the bond angle of this mineral change?" are fairly alienating for non-experts. As science has become more specialized, discussion of science with the general public has become less about current research and more about fundamentals.

Still, there are some examples of mineral displays as exhibits of current research: the Natural History Museum of Vienna renovated their mineral displays in 2017 to illustrate the concept of 'mineral evolution:' how the types of minerals formed on Earth have changed over its history in relation to changes in the biosphere (Koeberl *et al.*, 2018). The Cleveland Museums of Natural History (CIMNH) features a fishbowl-style display of the process of research: "volunteers sorting and cataloging specimens; and student researchers cutting, grinding, and analyzing the mineralogy of rock specimens with an Ultraphot polarizing microscope" (CIMNH, n.d.). Bryn Mawr's 2019 displays include minerals as tools to understand past water on Mars, a rare field where minerals are both still scientifically exciting and accessible to the general public.

Old themes, modern exhibits

Modern mineral exhibits also incorporate older themes explored above. 'Minerals by chemical class' and 'minerals by locality' are still the dominant modes of display for both small- and large-scale museums. Additionally, museums still use minerals as social symbols, not of *personal* wealth and power, but of their *institutional* distinctiveness. The Smithsonian NMHN toutes the Hope Diamond. The Museum National d'Histoire Naturelle (MNHN), Paris, features "minerals and crystals that belonged to the great scientists of the 18th and 19th centuries, like Romé de l'Isle, Haüy, Des Cloizeaux or Lacroix" (MNHN, n.d.). The Natural History Museum of Los Angeles County (NHMLAC) describes theirs as "one of the world's most valuable collections of gems and minerals," and invites visitors to "marvel at over 300 pounds of gold—including the 'Mojave Nugget,' the largest known nugget of California gold" (NHMLAC, n.d.). The old show pieces of European aristocracy are still central specimens in modern museums: Paris's Musée de Minéralogie, for example, still exhibits gems from the French Crown Jewels.

Mineral displays and colonial invisibility

> *"...certain kinds of narratives, images and objects become canonised and accepted as the most truthful or appropriate ways of organising the world."*
>
> (Mason and Sayner, 2019)

In almost 500 years of mineral display, minerals have been indicators of social status, objects of study, theological specimens, pedagogical tools, nationalistic marketing, and instruments of public education. Often absent from these display traditions are the broader human processes that delivered these specimens from the ground to the display cabinet.

This invisibility is not limited to minerals: Western museums and collections are in the midst of a many-decades-long reckoning with the human histories of their objects, particularly their relationships with Western colonialism, imperialism, and the racism that has infused and enabled those processes (e.g., Simpson, 1996; Barringer and Flynn, 1998; Scott, 2007; Mackenzie, 2009; Edwards and Mead, 2013; Das and Lowe, 2018). Most of this discussion has centered on cultural objects, though Mackenzie (2009) and Das and Lowe (2018) illustrate how natural history collections in particular retain colonial narratives and whitewash object acquisition histories.

Mineral collecting is deeply entwined with histories of social violence. For colonialism in particular, mineral deposits have been some of its greatest motivators and funders: colonising forces could sell mineral wealth to pay for additional colonising efforts. Silver from Potosí (in modern Bolivia) upended the global economy starting in the mid-1500s (e.g., Brown, 2016); Kimberley diamonds and gold fueled South Africa's colonization (e.g., Worger, 1987); lead and zinc from Broken Hill, Australia, poured directly into the smelters of Europe's expanding factories (e.g., Forsyth, 2018); rubies propelled the British in Myanmar (Turrell, 1988), gold the U.S. in the Black Hills, silver the Spanish at Zacatecas, and copper the Spanish throughout Chile. It is not an exaggeration to say that the entire modern Western world is built on minerals mined from colonised land.

The same mines that motivated, funded, and fueled Western colonialism, imperialism, and industrialisation also yielded the museum-quality mineral specimens now displayed throughout the West. Potosí, Kimberley, Broken HIll, Myanmar rubies, Black Hills gold, Zacatecas silver, and Chilean copper specimens can be found throughout the Smithsonian NMNH, London's Natural History Museum, the American Museum of Natural History – and the Bryn Mawr College mineral collection. These specimens are both products of and symbols of the colonial processes that delivered them from the ground to the museum, but those histories are rarely (if ever) addressed in mineral display until recently (Gelsthorpe 2021).

"Museal silence"

The "museal silence" around the social violences of mineral acquisition probably has several causes; the most obvious of these is "museums thinking they have nothing to say" (Mason and Saynor, 2019). The mineral display traditions outlined above mask the human narratives that underlie mineral acquisition. In particular, mineral displays' 500-year obsession with taxonomies is so ingrained that both large internationally-renowned and the smaller local natural history museums often default to it, despite the fact that mineral taxonomy has not been an interesting scientific question for almost 200 years.

More recent mineral display tactics that try to link minerals to the human realm do so by linking minerals to the *viewer*, not the mineral's own human past; CAS invites visitors to "Learn about minerals in your … toothpaste "(CAS, n.d.), but not "*How* do these get into your toothpaste?" For example, a large percentage of toothpaste's magnesite abrasives are mined by a Chinese corporation in Kamaduo, Tibet. The mine poisons local waterways and grazing lands used by fishermen and herders (Denyer, 2006), and the extreme altitude makes it a profoundly hazardous place for workers, even by mining standards (e.g., Wong, 2013). The human processes that bring minerals from Tibet to toothpaste are compelling, important - and hidden. This omission is partly because these stories are difficult to find -- but also, difficult for the public to hear (e.g., Gelsthorpe, 2021).

Mineralogical silences also likely stem from gaps in the historical record -- and whose voices are considered important (e.g., Mason and Saynor, 2019). The voices most likely to be recorded in the process of mineral collection are those of the (almost always) white Western male mineral collectors sent to the mine to acquire specimens, often on collecting trips sponsored by museums (e.g., Wilson, 1994, pp. 136-150). The voices of the miners themselves or the communities affected by the mines – particularly in colonised countries – are substantially less likely to have been recorded, and might only be able to be pieced together in aggregate from disparate historical sources or oral histories of modern descendents.

For some museums with more modern collections, external pressure could also inhibit telling human histories (e.g., Mason and Saynor, 2019). The University of Arizona's Mineral Museum, for example, highlights spectacular copper minerals from the Bisbee mines of southern Arizona. In addition to Bisbee's long colonial histories, these mines are the site of one of the most infamous labor rights violations in U.S. history: in 1917, the Phelps Dodge Corporation kidnapped about 1,300 striking miners and abandoned them in the desert 200 miles away (e.g., Foner, 1987). As Phelps Dodge is now a donor to the UofA mineral museum, it is unlikely that the UofA mineral displays will engage with the labor histories under which many of their specimens were produced.

'Re-reading minerals as human products

Failing to address histories of violence surrounding mineral acquisition continues rendering those parts of our histories invisible (e.g., Edwards and Mead, 2013; Fletcher, 2012, p. 423). This is particularly damaging right now, as our modern world is more reliant than ever on minerals. The historical conditions that yielded individual minerals in our collections also yielded the modern mining world, which delivers mineral products to Western consumers as everything from phones to earrings – all while masking the human realities of their production. Using displays to examine and illuminate the human histories of mineral specimens in our collections makes visible the fact that minerals are human products – in the past, and in the present.

One way of engaging with mineral colonial histories is through the kind of "object biographies" described by Alberti (2005). Such biographies examine museum objects through the lenses of the people they have encountered on their way to the collection, illuminating both the immediate human realities of mineral production and the larger social mechanisms that produce those realities.

For example, the Bryn Mawr College mineral collection houses several world-class specimens of the copper carbonate mineral azurite from the Tsumeb Mine of what is now northeastern Namibia. Over the course of their histories within the collection, these azurites have embodied many of the themes that have shaped mineral displays: they have been social symbols of the collector (George Vaux Jr.), tools of study (their crystallographies are exceptional), and instruments of both formal and public education. In Bryn Mawr displays, they have been quintessential 'Marvel!' objects, with shockingly blue colors and eye-catching crystal forms. They have also been tools for immediately answering questions: the blue colour is a textbook example of electron transfer as a cause of mineral color. They have been displayed according to a range of themes, including 'Minerals and You' (azurites were ground for paint pigments throughout history), 'minerals by locality' (azurites are the most famous of the Tsumeb specimens), and 'minerals as clues to fundamental Earth processes' (crystal growth). In the course of their 'lives' within the collection, the Tsumeb azurites have embodied many of the historical themes of mineral displays.

The Tsumeb azurite crystals, though, had 'lives' before they entered our collection; and those were defined by first German and then South African occupation of what is now Namibia. The human biographies of Tsumeb azurites begin with the precolonial Namibian communities who spent centuries mining, smelting, and trading Tsumeb copper, and the early colonial struggle between Germany, Britain, the independent Boer republic of Upingtonia, the Kingdom of Ondonga, and the local Hai||om and Herero communities over control of the copper mines (Hearth, 2021). German control of the copper deposits was one of the issues that provoked the Herero War that attempted to end German occupation, and Germany's subsequent 1904 Herero Genocide. The azurites now housed at Bryn Mawr were produced by Ndongan and Herero miners in 1929, amid a backdrop of extensive colonial changes in Namibian migration, labour, and recruitment practices, many of which were directly caused by the Tsumeb mine (e.g., Cooper, 1999).

Conclusions

This work has shown that mineralogic displays have always embodied mineralogic thinking -- and that they can also be drivers. As Geology reckons with its colonial histories, thoughtful display of specimens with deep colonial histories can both embody and provoke that process (e.g., Das and Lowe, 2018; Gelsthorpe, 2021). For a small-scale institution like Bryn Mawr College, this starts with examining the origins of the collection and doing the time-intensive work of identifying the human processes that brought specimens into this institution. This process can be reflected in displays as it is carried out: with updated labeling, displays centered on areas of ongoing research, and student involvement in the form of classes and volunteer student assistants. Currently, the focus of our collection's colonial research are the Tsumeb azurites: articulating the colonial histories that brought them from the ground (Hearth, 2021), and translating those into public displays in our science center.

New pedagogical goals for mineralogy meant the old teaching display cases could be disassembled, the minerals inside repurposed for public education display. But our goals for public education and museum displays should be similarly revised to include the human processes that produced them. Both historically and today, minerals have not been mute objects, but rather "things that talk" (e.g., Daston, 2004), or, as Claude Levi-Strauss put it: objects that are "good to think with." Shifting the conversation with these specimens to include the human processes that produced them must be a part of the 're-reading' of both natural history collection and the history of Geology more generally.

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