CRITICAL MATERIALS MUSEUM DISPLAY
STATUS AND "HOW-TO" REPORT NO. 1
04-01-2015

Introduction

The Critical Materials display was initiated by the Outreach and Education Coordinator for the Critical Materials Institute (CMI) and the Director of the Colorado School of Mines (CSM) Geology Museum as an opportunity to leverage the relationship between CSM's very successful museum outreach and CMI's desire to reach audiences of all ages across the nation. The display will be designed to provide a visual outreach opportunity with visitors and guests to the Colorado School of Mines Geology Museum, while highlighting critical materials, rare earth elements (REE), and the national purpose of the CMI.

The CSM Geology Museum is the second most visited geology museum at an American university. Tripadvisor.com ranked the CSM Geology Museum as the second most visited tourist attraction in Golden, Colorado in terms of visitor satisfaction. The museum attracts over 20,000 national and international visitors annually. It offers numerous guided tours to local school groups and clubs, which are often repeated on an annual basis. Last year, the museum had over 37,000 guests from all 50 states and 45 foreign countries. Dignitaries from across the globe regularly visit the museum. Most recently, the museum was selected to place an exhibit in the Colorado State Capitol with an expected quarter-million visitors annually.

How the Project and Team Developed

Dr. Cynthia Howell, Energy Education Specialist and Research Faculty with the Critical Materials Institute (CMI), and Colorado Energy Research Institute (CERI) at Colorado School of Mines approached Dr. Bruce Geller, Director of CSM's Geology Museum, regarding a partnership that would be advantageous for both institutions. Both CMI and CSM are interested in advancing the story of critical materials as they relate to technologies and energy in our everyday life.

Upon agreement to common goals and needs, a team was assembled to develop and complete the project. The team includes Dr. Cynthia Howell, Mr. Ed Raines, and Mandi Hutchinson. Mr. Raines is the Collections Manager for the CSM Geology Museum. Mandi Hutchinson is a Masters Candidate with a focus in REE-deposits in the CSM Department of Geology and Geological Engineering and an experienced museum student employee and volunteer.

To begin the work, several meetings were held during January and February of 2015 to plan strategy and set goals for the Critical Materials display. During those meetings, the team

decided to highlight three important concepts within the exhibit which were selected to reveal the full story of critical materials. The concepts are as follows: Source, Process, and Product. Source refers to the geologic and recyclable resources from which the critical materials are derived; Process refers to the extraction and processing of the critical materials into a useable form; and, Product highlights the advanced technological products used strategically and sparingly from cell phones and computers to wind turbines and catalytic converters. In short, critical materials keep us connected and on the go and in the know. Keeping these three points in mind, the team hopes to conceptualize the role of critical materials and near critical materials as currently identified by the Department of Energy. These materials include four rare earth elements (neodymium, europium, terbium, and dysprosium) plus yttrium as critical materials. The DOE has identified two additional elements, lithium and tellurium, as "near-critical" materials.

Understanding the three points of source, process, and product are key to establishing a continual supply of critical materials in any period of time.

Designing, Planning and Building Ideas

The team found it important to keep in mind the following ideas when planning, designing, and building the display in priority order:

- Ensure the display represents the Critical Materials Institute goals and outreach ideals.
- Ensure the display fits into the design and goals of the CSM Geology Museum.
- Manage costs by utilizing what is already available in the museum, including display cases, display space, materials (minerals, processed materials, etc.)
- Consider multiple parts to the exhibit so that it can be separated, rearranged and/or built upon to ensure a lasting sustainable exhibit and increase the replicability of the exhibit by others. Remember to make the display versatile and malleable so that it can remain current – including how to fund new additions, how to change it around annually if needed, and how to move items from display into the collection at large. Keep in mind the museum's goal to change out 25% of the displays each year.
- Engage young minds by representing science and engineering in such a way to inspire them to question, dream and envision themselves solving problems and inventing new technologies. Focus on the aesthetics of each component and demonstrate how the critical materials affect daily lives.

Display Components

The planning team decided that display items could take the form of either physical objects or images of the source, process and/or product items. Images are advantageous tools for showing difficult to obtain items, materials which could be more interesting in a photograph (such as luminescing phosphors), and small items which would be challenging to make visible in

a display case. One way of displaying images or videos is in the form of a digital frame. Currently the team plans to engage the audience by using between one to three digital frames for the display.

It may be important to include banners. One such banner would define the critical materials for the average viewer. The Critical Materials Institute a currently has a banner which highlights the current critical and near critical elements (Li, Y, Te, Nd, Eu, Tb, Dy) on a periodic table. This banner can be repurposed for the museum display.

Critical Material Sources

Minerals

The display will be housed in the CSM Geology Museum, so it is important to include museum quality minerals. This will ensure the display lives up to the expectations of esteemed and/or specialized guests and inspires all guests. Current plans include exhibiting authentic physical minerals, with little to no use of pictures.

The planning team wants to showcase minerals that are actually mined in current or past REE-deposits. These minerals are often very small, down to microns in size, in the deposits where they occur. Therefore, in order to obtain museum quality minerals for the display, the team will have to obtain pieces from other locations than the actual deposit locale. For example, while bastnäsite is the predominant mineral mined at the Mountain Pass, CA deposit, we hope to find and acquire a specimen from the Zagi Mountain, Pakistan region, where bastnäsite can occur as large (commonly quarter-size to the rarer golf ball-size in diameter), well-formed, and often partially gemmy or translucent crystals.

Current possible sources of minerals include the following:

- CSM Geology Museum's and/or the CMI's contacts, including companies or people who have previously donated or loaned items to the museum, local companies or persons known to have REE-bearing minerals in their collections and CMI members and affiliates who can guide us to premium donations or acquisitions
- Any Li- and Te-bearing minerals which are already a part of the museum's collection. Currently most of the REE-minerals already in the museum's collection are not suitable for display.
- Minerals from online mineral dealer sources. Three small specimens (shown below) have been purchased from John Betts Fine Minerals.
- Available sources at the Tucson Gem and Mineral Show. This proved useful. One mineral specimen, the eudialyte shown below, was acquired. Other potential sources found during this show are in consideration. Some of those contacts will likely prove useful in the future.

Minerals Acquired:

1. Eudialyte, from Kukisvumchorr Mt., Khibiny, Kola Peninsula, Russia. This mineral was purchased from Russian Minerals Co., at the Inn Suites Mineral Show in Tucson, Arizona on February 14, 2015. Eudialyte is a common source of REE and Y.

Figure 1. Eudialyte specimen acquired form Russian Minerals Co. Location Kukisvumchorr Mt., Khibiny, Kola Peninsula, Russia. Specimen is approximately 1.25in.

2. Three other minerals were acquired on January 25, 2015 from John Betts Fine Minerals for the exhibit. These include two parisite crystals from the Muzo Mine, Vasquez-Yacopí District, Boyacá Department, Colombia and one donnayite from Olary Block, Paratto copper deposit, Yunta, South Australia, Australia. All three are thumbnail type specimen, meaning that they are smaller in size and typically less than 1 inch in height. Parisite is a LREE-bearing mineral and commonly contains Nd. Donnayite is Y-bearing.

Minerals to Acquire:

The team plans to acquire 5 to 10 minerals for the exhibit. The following is a list of minerals under consideration. The most desirable minerals which are most likely to be museum-quality are shown in bold. Note that eudialyte, parasite, and donnayite are already acquired.

Bastnäsite, parasite, synchysite, **monazite, eudialyte, xenotime,** apatite, gorceixite, goyazite, florencite, rhabdophane, loparite, churchite, mosandrite, britholite, synchysite-Y, chernovite, gadolinite, aeschynite, allanite, donnayite, mosandrite, samarskite

Ore samples

If ore samples are available, the team plans to include them in the exhibit. These samples could prove difficult to acquire for proprietary, economic, or political reasons. While still narrowing down contacts for acquiring the ore samples, the following ore types are being considered:

- SE China Clay (REE)

- Carbonatite from Mt. Pass, CA REE-mine
- Residual deposit ore from current or prospective source (REE)
- REE-bearing Nepheline Syenite
- Lithium Brine
- Tellurium ore
- Recyclable product sources, such as fly ash or recycled electronics. While completing initial research for this exhibit, the team found that much research is in-progress to create new secondary sources for the critical materials, such as extracting the desired ions from coal fly ash. Including these secondary sources highlights the DOE's initiative to promote a "green" industry.

Critical Material Processing

This is an important educational piece to promote CMI's significant work, since the majority of research completed through and involving CMI revolves around the critical material processing technologies. With this in mind, the team aims to inspire and engage the viewer with this portion of the display. Processes are often difficult to show. The examples of extracted and processed REE, Li, and Te in the display will therefore need to be displayed as both physical object and images.

REE-oxides and Phosphors

Currently, the team plans to include the REE-oxide powder/phosphors and REE-metals as physical objects in the display. Should one of the two types or REE-materials prove to be difficult in obtaining, or difficult to display in an aesthetic way, it may be included as an image instead. Non-proprietary processing techniques and methods could also be displayed as an image or as a video clip (digital frame).

The oxides/phosphors are typically displayed in sealed glass tubes which are injected with argon gas and vacuum-sealed in order to preserve the powder. The powders range in color from white to pink. The team is currently exploring a way to display tubes of the powders in an interesting way, perhaps modelled after a display at AMES Laboratory. Images of the phosphors exhibiting incandescence or luminescence may be included.

The metals are often displayed as cuttings or in crystalline form, and the latter is more desirable for the exhibit in the museum. Several of the metals oxidize and corrode easily with exposure to atmospheric conditions, so they are typically displayed in glass vials or surround in epoxy. Displaying the metals may prove challenging due to the small sample size, the ease of corrosion, and the lack of available sources for crystalline REE-metals.

The museum currently owns four REE-metal samples, which were obtained from a yard sale. The samples, which are shown below, have been analyzed and show 99.9% purity.

Figure 2. Crystalline terbium, holmium, yttrium, and ytterbium metals in glass vials. These samples are currently in the museum collection.

The team is currently looking for additional sources for the crystalline REE-metals and is in-process of contacting one online source which specializes in samples for metal collectors. We are also looking for samples of the REE-oxide powders. Ideally, an internal source will emerge within the Critical Materials Institute and/or a contact through the Institute's industry team members and affiliates.

Critical Material Products

The products which utilize the critical materials are numerous and often very large and therefore it will be difficult to display all of them. These products may also prove challenging to isolate for display purposes. Images will be utilized to show these types of products, including wind turbines and electric vehicles. Several products will be easy and interesting to display and the display could include any of the following:

- Smartphone parts (display screen, speaker and microphone, etc.)
- Computer parts (hard drive with Nd-magnets)
- Li-ion batteries (rechargeable batteries)
- High-strength magnets
- Small thin film
- CFL bulbs

How to Display

Here we want to recapitulate several of the goals stated earlier in this report. These goals are our cornerstone for any brainstorming and decision-making regarding our design, organization, and structure for the museum display.

- Ensure the display represents the Critical Materials Institute goals and outreach ideals
- Ensure the display fits into the design and goals of the CSM Geology Museum
- Utilize what is already available in the museum, including display cases, display space, materials (minerals, processed materials, etc.)
- Consider multiple parts to the exhibit that each part can be separated, stand alone, rearranged and/or built upon to ensure a lasting sustainable exhibit
- Remember to make the display versatile and malleable so that it can remain current – including how to fund new additions, how to change it around annually if needed, and how to move items removed from display into the collection at large
- Keep in mind Museum's goal to change out 25% of the displays each year. Display will be a large part of the budget, so minimize cost of items in display.
- Engage young minds by representing inspiring science and engineering and causing them to question
- Focus on aesthetics of each component
- Show how the critical materials affect daily lives

Keeping these goals in mind, we are considering the two following layouts for the Critical Materials Display:

- Single Standard Museum Cabinet
- Multiple Free-standing Pedestal Cases

Single Standard Museum Cabinet

This display is a standard type display case currently used in the CSM Geology Museum, and its use would be advantageous in that it is easy to merge with the overall atmosphere of the museum. The standard display would allow the museum to move the exhibit to another location within the museum if needed in the future.

The design would need to be adjusted to move the shelves to different levels as needed, instead of the current 3-shelf standard model. The modifications would be minimal and easy. The contractor who makes the cases for the museum is easily accessible. The timeline for production could be 3-4 months.

Multiple Pedestal Cases

The CSM Geology museum has several free-standing pedestal type cases which are currently in use throughout the museum. These cases are both aesthetic and functional. The display concept using three of the pedestal cases would give a very unique feel to the exhibit. It can be crafted to feel modern and avant-garde. It can easily display the three points of the

display, which are source, process, and product. It can be adapted for future design changes; however, it could be more challenging to adapt to a new location within the museum should it need to be relocated.

Challenges and Advantages

It is helpful to take into account any difficult situations or challenges faced during every step of this project. Additionally, each unique situation also has advantages. Here we outline our biggest challenges and how we have and/or will work around them, as well as how we will use our unique situation and available resources to our advantage.

Challenges

- Sourcing museum quality minerals of larger size (larger than thumbnail) – not widely available. This will likely take some time to complete and may require loaned minerals in the interim.
- Sourcing REE-oxides/phosphors and finding an aesthetic way to display them
- Sourcing crystallized REE-metals (crystal form apparent) – not widely available.
- Displaying REE-metals so they are aesthetic and easily visible. Samples of this nature are often small and require protection from atmosphere.

Advantages

- Association with CMI could make display materials more widely available or easily accessible through CMI lab, university resources, and industry partners.
- Academic atmosphere provides a unique opportunity to engage previous, current, and future students and perhaps the future workforce.
- Location of the display in the CSM Geology Museum offers security, visibility, and museum-quality resources and expertise at our finger tips. Also noted in the introduction, the museum brings in over 20,000 visitors annually.

Websites for Critical Materials Information

CM/REE Exhibit How-To Links

Metallium, Inc. is a source for REE-metals
http://www.elementsales.com/

This photographer provides images of REE-metals on Wikipedia:
http://commons.wikimedia.org/wiki/User:Alchemist-hp

The Earth Science Museum built a display for the Tucson Gem and Mineral Show, showcasing minerals and elements used in smartphones. Here's a video:
https://www.facebook.com/video.php?v=10153115606538035

Rare Earths on display in the Inner Mongolia Autonomous Region Museum, Hohhot, China
http://clas.berkeley.edu/research/research-tilling-rare-earth

CM/REE Exhibit Case Vendors

http://www.casewerks.com/museums/

http://zonedisplaycases.com/

http://guenschel.com/hgi/

http://www.ww-pedestals.com/

http://www.williamsminerals.com/cabinetintro.html

CM/REE Educational Resources Links

The Denver Art Museum uses rare earth magnets to display art
http://denverartmuseum.org/article/staff-blogs/how-dam-uses-magnets-art-installations