Findings Report:
North American Workshop on Critical Mineral Research, Development, and Education

August 13-14, 2025
Austin, Texas, USA

The University of Texas at Austin
Jackson School of Geosciences

Table of Contents

Acknowledgements and Disclaimer

The 2025 North American Workshop on Critical Mineral Research, Development, and Education was made possible by the National Science Foundation (NSF) through award #2507652: Conference EnvS: North American Workshop on Critical Mineral Research, Development and Education, August 13-14, 2025, Austin, Texas, USA awarded to the following University of Texas at Austin investigators: Marek Locmelis (PI), Brent Elliott (Co-PI), Wen Song (Co-PI), Estibalitz Ukar (Co-PI), Jani Das (Co-PI), Julia Gale (SP), Andras Fall (SP), Ning Lin (SP).

The findings presented in this report are based on discussions during the workshop, i.e., presentations and breakout sessions. The views and opinions presented here do not necessarily reflect those of the workshop organizers who prepared the report.

Preferred Citation

Locmelis, M., Clark, S., Gale, J., Elliott, B., Song, W., Ukar, E., Fall., A., Swain, R., Maldonado, T., Lin, N., (2025): Findings Report: 2025 North American Workshop on Critical Mineral Research, Development, and Education, 13-14 August 2025, The University of Texas at Austin, Austin, Texas, USA, 20 pages.

Executive Summary

On August 13-14, 2025, the Jackson School of Geoscience hosted the inaugural North American Workshop on Critical Mineral Research, Development and Education, in the Thompson Conference Center on the campus of the University of Texas at Austin, USA. The workshop was funded by the National Science Foundation (NSF) and was attended by 230 participants. 176 participants attended the workshop in-person while another 54 participants attended online via Zoom. Twenty-two participants (including 10 students and 7 early career researchers) received travel support through the NSF grant to attend the workshop in Austin. Out of the 230 workshop participants, 134 participants were from academia (34 students), 66 from the private sector and 30 from federal- and state-level government agencies.

The workshop was divided into four topical sessions that discussed current issues in critical minerals research, development, and education:

- Conventional and Unconventional Sources of Critical Minerals.
- How to grow the U.S. critical minerals workforce.
- Innovations in Critical Mineral Extraction and Recycling.
- Policy and Supply Chain Economics.

The topical sessions were composed of two keynote lectures and complemented by oral and poster presentations by the workshop participants. A panel discussion and breakout session explored recent developments in critical minerals research, development and education in the U.S., with particular focus on the implications of recent Presidential Executive Orders. The discussions highlighted, for example, that:

(i) The recent critical mineral-related Presidential Executive Orders by the Trump-Vance administration are encouraging steps towards fast-tracking US-based critical mineral production.

(ii) Lengthy permitting timelines and limited transparency in the decision-making process – with often unpredictable outcomes – remain major barriers for mining and mineral processing operations in the U.S. Workshop participants suggested the development of policies specifically aimed at streamlining permitting processes.

(iii) Funding initiatives are too often aimed at increasing short-to-mid-term critical mineral production while generation of 'pre-competitive data' to support and guide mineral exploration is largely neglected. Workshop participants recommended that future funding cycles place greater emphasis on generating fundamental geoscience data and insight that can be leveraged by the private sector for green and brownfield exploration.

(iv) The persistent negative image of the mining and mineral processing sector remains a major obstacle to attracting and developing a skilled critical minerals workforce. As possible starting points for long-term solutions, workshop participants suggested launching a media campaign, implementing industry-led K-12 outreach programs, and stronger and closer collaborations between academia and the private sector through student-centered research projects.

1. Introduction

Ensuring a stable and resilient supply of critical minerals is a central focus of U.S. policy and national security strategies. Although recent Presidential Executive Orders seek to strengthen domestic production of critical minerals, long-term success will have to rely on integrated, interdisciplinary approaches to critical minerals research and development (R&D), supported by the growth of a highly skilled, industry-ready workforce.

To provide an interdisciplinary platform for the budding critical mineral community in the U.S., the Jackson School of Geosciences, with support of the National Science Foundation (NSF), hosted the inaugural North American Workshop on Critical Mineral Research, Development, and Education on August 13-14, 2025, in the Thompson Conference Center on the campus of the University of Texas at Austin, USA. Online participation via Zoom was offered to participants who could not travel to Austin.

The workshop was divided into four different topical sessions that allowed for discussions on domestic critical mineral supply chain resilience from different perspectives:

- Conventional and Unconventional Sources of Critical Minerals
- Critical Minerals Workforce Development: How to grow the U.S. critical minerals workforce.
- Towards a Circular Economy: Innovations in Critical Mineral Extraction and Recycling
- Policy and Supply Chain Economics: Reshoring Critical Mineral Production

Additionally, a panel discussion and a breakout session discussed critical minerals R&D in the light of recent Presidential Executive Orders. The findings of the breakout sessions are discussed in section 4 of this report.

2. Workshop Content

The workshop was divided into four topical sessions that provided a platform for discussions around current issues in critical minerals research, development, and education.

Session 1: Conventional and Unconventional Sources of Critical Minerals

Keynote Lectures:

- **Jeffrey Mauk (United States Geological Survey, emeritus)**: Critical Minerals: Reasons for Hope.
- **Daniel Alessi (University of Texas at Austin)**: Development of lithium manganese oxide sorbents for the recovery of lithium from brines.

Session 2: Critical Minerals Workforce Development – How to grow the U.S. critical minerals workforce.

Keynote Lectures:

- **Robert Bodnar (Virginia Tech)**: Challenges and Opportunities for Students in Critical Minerals Space.
- **Leah Turner (Consortium of Universities for the Advancement of Hydrologic Science)**: Inspiring the Next Generation: Success Stories and Strategies from Youth Outreach.

Session 3: Towards a Circular Economy – Innovations in Critical Mineral Extraction and Recycling

Keynote Lectures:

- **Douglas Wicks (retired)**: Innovations to Address Challenges in Critical Mineral Processing.
- **Jesica Urbina (Infinite Elements)**: Revolutionizing Critical Mineral Recovery: Bridging Biotechnology & Mining for a Sustainable Future.

Session 4: Policy and Supply Chain Economics – Reshoring Critical Mineral Production

Keynote Lectures:

- **Simon Jowitt (Nevada Bureau of Mines and Geology, University of Nevada-Reno)**: The 21st Century Minerals Industry: Energy Transition Challenges and Opportunities and Policy Influences on Metal Supply and Demand.
- **Jani Das (Bureau of Economic Geology)**: Environmental impacts of critical mineral supply chains and policy implications.

Keynote lectures were followed by oral presentations of attendees. The oral presentations were complemented by a poster session (*cf.* Appendix 1: Workshop Schedule). The first day included a panel discussion on recent developments in critical minerals R&D in the U.S., with a particular focus on the implications of recent Presidential Executive Orders. Panelists were selected to represent a wide range of professional sectors and career stages and included:

- Douglas Wicks – retired.
- Lorena Moscardelli – Director, Bureau of Economic Geology.
- Ellis Sullivan – CEO, Element USA.
- Holiday O'Bryan – PhD student, University of Texas at Austin.

The panel discussion was structured around the following questions:

- Critical minerals R&D has undergone significant policy changes, with more changes on the horizon. What has worked and what has not?
- What would you like to see as the next steps?
- How can and/or should higher education, government agencies, and the private sector work together to build a strong critical minerals workforce?

To collect comments from all workshop participants, the same questions were asked during a breakout session on Day 2. The findings of the breakout sessions are summarized in section 4 of this report. To provide networking opportunities for the workshop participants, both workshop days had a Happy Hour, including during the poster session at the end of Day 1. Further, a workshop dinner was held in the Texas Science and Natural History Museum on the University of Texas at Austin campus near the workshop venue.

3. Workshop Demographics

The workshop was attended by 230 participants (Fig. 1-A). 176 participants attended in-person in the Thompson Conference Center on the University of Texas campus in Austin, Texas. Another 54 participants attended online through a Zoom Webinar. 134 participants were from academia (34 students), 66 from the private sector, and 30 from federal- and state-level government agencies (Fig. 1-B). The majority of the registrants who stated their affiliation were from the U.S. (212, 92%; Fig. 2). The remaining participants were from South Korea (6), Canada (5) and one each from the following countries: Austria, Brazil, India, Italy, Mexico, Netherlands and Switzerland. Within the United States, participants were from 31 states (Fig. 3). Twenty-two participants (including 10 students and 7 early career researchers) received travel support through the NSF grant to attend the workshop in Austin.

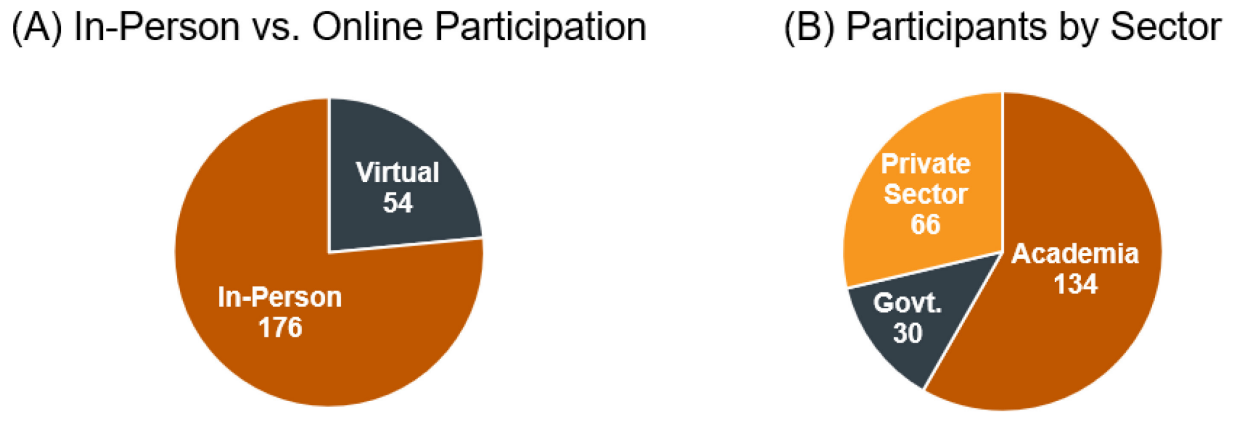

Figure 1: Breakdown of workshop participants based on (A) In-person vs. online participation, and (B) Sector of employment.

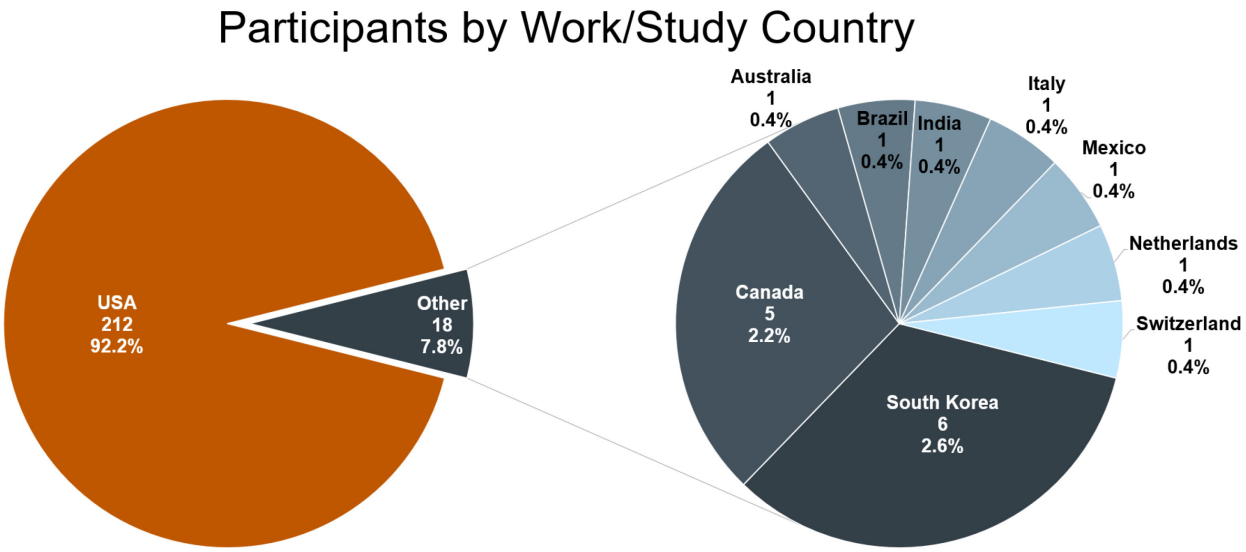

Figure 2: Workshop participants by country of residence (in-person + online participants).

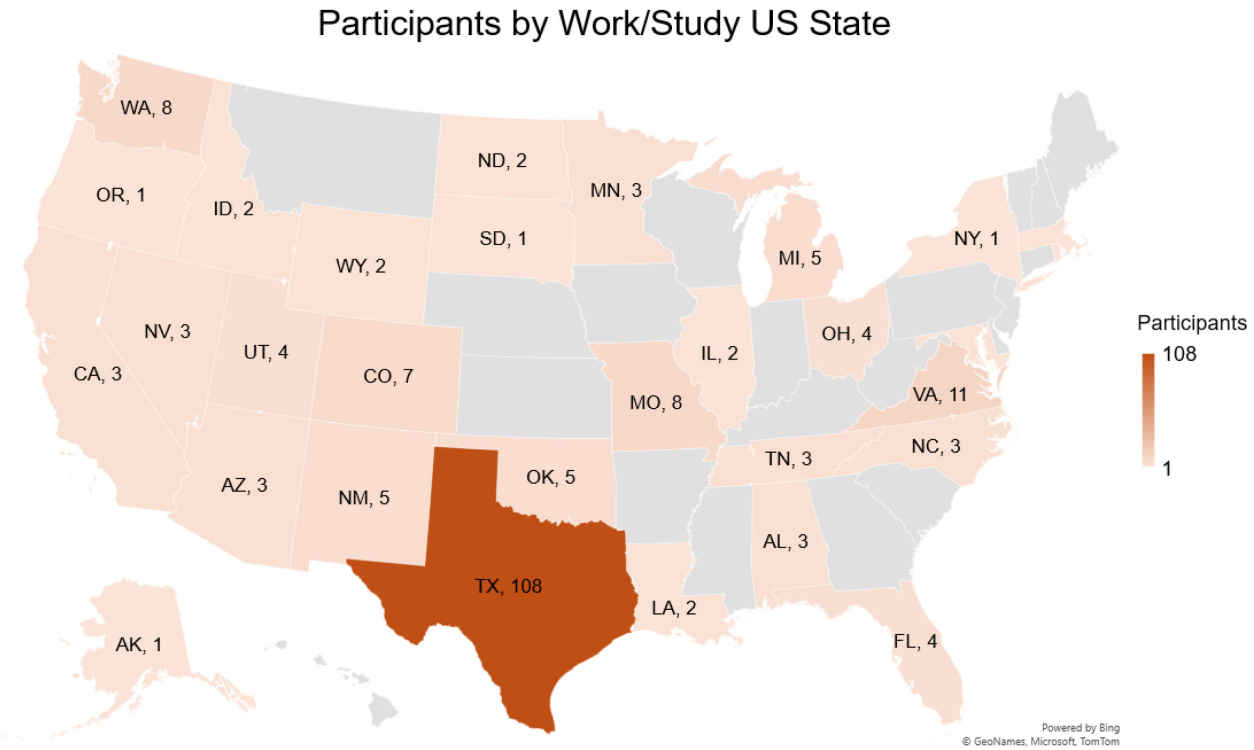

Figure 3: Distribution of workshop participants within the U.S. (in-person + online participants).

4. Breakout Session Summary

Groups of 10-15 workshop participants (separated into in-person and online groups) were asked to answer the following questions:

- Critical minerals R&D has undergone significant policy changes, with more changes on the horizon. What has worked and what has not?
- What would you like to see as the next steps?
- How can and/or should higher education, government agencies, and the private sector work together to build a strong critical minerals workforce?

The findings of the group discussions are summarized below (sections 4.1 to 4.3). All answers and/or comments (anonymized) are provided in Appendix 2, including word clouds that visualize the most frequently used words for each question.

4.1 Critical minerals research and development (R&D) has undergone significant policy changes, with more changes on the horizon. What has worked and what has not?

The workshop participants applauded the U.S. government's continued efforts to increase domestic critical mineral supply chain resilience. The attendees generally agreed that the recent critical mineral-related Executive Orders by the Trump-Vance administration (e.g., "*Immediate Measures To Increase American Mineral Production,*" "*Ensuring National Security and Economic Resilience Through Section 232 Actions on Processed Critical Minerals and Derivative Products,*" "*Unleashing America's Offshore Critical Minerals and Resources*") are encouraging steps towards fast-tracking U.S.-based critical mineral production. In particular, attendees frequently stated that the Executive Orders have the potential to mitigate issues caused by restrictive permitting processes that remain major obstacles for establishing domestic operations. Commonly cited examples of permitting issues were long-permitting times and a lack of transparency in the decision-making process that can result in unpredictable outcomes. Further, it was generally agreed that continued tax credits and incentives for U.S. producers of critical minerals are an effective way to increase domestic production capabilities. Workshop participants also emphasized the positive impact of recent critical mineral-focused federal funding initiatives and how these, in some instances, encouraged interdisciplinary collaborations between academia, government agencies, national laboratories, and the private sector. However, many participants cautioned that it is too early to determine if funded research projects will translate into real-life solutions with regards to increasing critical mineral supply chain resilience.

Although workshop participants were generally optimistic about the future of critical minerals R&D in the U.S., it was generally agreed upon that the continued negative perception of mining and mineral processing operations remains a significant challenge, not only in terms of local opposition to production facilities, but also in attracting and developing a skilled workforce. Further, it was frequently stated that scientists and engineers must be more frequently included in the decision-making progress (on both the federal and state levels) to ensure that strategic decisions align with actual research needs.

4.2 Critical minerals R&D: What would you like to see as the next steps?

Attendees applauded the U.S. government's efforts to enhance supply chain resilience for critical minerals. Participants particularly appreciated that recent funding opportunities allowed for interdisciplinary collaborations between academia, government agencies, national labs, and the private sector that otherwise likely would not have happened. It was generally agreed upon that continued funding is required to keep the current momentum in critical minerals R&D. Several attendees recommended extending project funding timeframes from the typical 3–5-year durations to 7-10 years to support long-term R&D efforts.

Notably, many participants emphasized that funding initiatives are too often aimed at increasing short-to-mid-term critical mineral production, while generation of 'pre-competitive data' that can guide mineral exploration is largely neglected. Consequently, it was recommended that future initiatives should allocate funding for fundamental geologic studies aimed at understanding the subsurface geology of the U.S. The funding should have the goal of generating publicly available data that can be used to guide greenfield and brownfield mineral exploration. The USGS Earth Resources Initiative, which is aimed at characterizing known reserves and resources, could be used as a blueprint for 'pre-competitive' prospectivity studies.

4.3 How can and/or should higher education, government agencies, and the private sector work together to build a strong critical minerals workforce?

The attendees generally agreed that the negative public perception of mining and mineral processing operations remains a major challenge in building a critical minerals workforce. Declining enrollment in many programs with focus areas related to critical minerals (e.g., geology, mining, and mineral processing), along with the closure and/or merger of relevant departments, has been identified as a major concern. Several possible solutions were proposed. (i) Interdisciplinary collaborations between the private sector and universities that engage high school and undergraduate students to demonstrate the real-world impact of mining and mineral processing operations. (ii) Providing incentives to students in the form of fellowships, internships, and other opportunities. (iii) Industry outreach at the high school level. (iv) A national PR campaign that highlights the importance of critical minerals in daily life, shows that careers in the mining sector can be rewarding, and that young people can make a difference. From an educational perspective, it was recommended that curricula are revisited and better aligned with the needs of the industries that are the future employers of students. Some participants further suggested creating new majors focused on critical minerals; however, the declining enrollment in related disciplines, department closures and mergers, and the anticipated enrollment cliff, were identified as major obstacles to establishing new degree programs.

5. Workshop feedback

The workshop received overwhelmingly positive feedback from the workshop participants. When asked to rank the workshop experience on a scale from 1 to 10 during a post-workshop

online survey, the 28 participants who completed the survey gave the workshop an average overall score of 9.4/10 (with a range of 8 to 10 points). The quality of oral presentations received a score of 8.7/10 (range of 5-10). The poster session also received an average score of 8.7/10 (range of 5-10). Based on the survey comments, the low scores given by some participants for the oral and poster sessions reflect the interdisciplinary nature of the workshop and that one or more sessions may have been outside of the area of interested for some participants. 89.3% stated that they are very likely or somewhat likely to continue attending the workshop in the future (the categories were: very likely (67.9%), somewhat likely (21.4%), not sure (7.1%), somewhat unlikely = 0%, very unlikely = 3.6%).

In their survey comments, participants particularly appreciated the unique networking opportunity the workshop provided, owing to the wide range of science and engineering disciplines that were represented as well as the different sectors (i.e., academia, government, non-profit organization, private sector, venture capitalists, entrepreneurs, politicians/staffers). The participants also appreciated the hybrid in-person/online mode of the workshop that gave the workshop a wider reach. The participants further appreciated the welcoming atmosphere that promoted discussions between participants in different stages of their careers, including students.

Negative aspects were the limited amount of available workshop dinner spots (120 seats) that filled up quickly and isolated problems with logins to the virtual component. Some participants commented that the two days were overloaded with talks and recommended extending the workshop to a third day in the future.

6. Conclusions

The 2025 North American Workshop on Critical Minerals Research, Development and Education was attended by 230 participants. 176 participants attended the workshop in-person in the Thompson Conference Center on the University of Texas campus in Austin, Texas, USA, while 54 participants attended online via a Zoom webinar. Twenty-two participants (including 10 students and 7 early career researchers) received travel support through the NSF grant to attend the workshop in Austin. The feedback the workshop received was generally positive and highlighted the importance of providing a platform that allows participants from a wide range of backgrounds to interact. The vast majority of participants stated that they would attend a 2026 workshop in Austin.

Appendix 1 – Workshop Schedule

WEDNESDAY, AUGUST 13, 2024

SESSION 1
CONVENTIONAL AND UNCONVENTIONAL SOURCES OF CRITICAL MINERALS

8:30-9:00 **Welcome and Opening Remarks**
Marek Locmelis, Workshop Chair
Claudia Mora, Dean of the Jackson School of Geosciences
TCC 1.110

9:00-9:30 **Keynote Speaker**
Jeffrey Mauk, United States Geological Survey

9:30-10:00 **Keynote Speaker**
Daniel Alessi, The University of Texas at Austin

10:00-10:45 **Oral Presentations**
10:00-10:15 *Kristina Butler – The University of Texas at Dallas*
10:15-10:30 *Rona Donahoe – University of Alabama*

10:30-10:45 Break

10:45-12:00 **Oral Presentations**
10:45-11:15 *Jorge Crespo – Nevada Bureau of Mines and Geology*
11:00-11:15 *Toti Larson – The University of Texas at Austin*
11:15-11:30 *Stefanie Brueckner – Laurentian University*
11:30-11:45 *Jeffrey Catalano – Washington University in St. Louis*
11:45-12:00 *Margaret Goldman – United States Geological Survey*

12:00-13:30 **Lunch and Posters (Sessions 1&2)**
Lunch: Under the Oaks
Posters: TCC 3.102

SESSION 2
CRITICAL MINERALS WORKFORCE DEVELOPMENT
How to grow the U.S. critical minerals workforce

13:30-14:00 **Keynote Speaker**
Robert Bodnar, Virginia Tech

14:00-14:30 **Keynote Speaker**
Leah Turner, CUAHSI

14:30-15:30 **Oral Presentations**

14:30-14:45 *Joe Biasi – University of Wyoming*

14:45-15:00 *Tetteh & Motlagh – Freeport McMoRan Inc./ New Mexico Tech*

15:00-15:15 *James Kubicki – UTEP*

15:15-15:30 *Clémentine Hamelin – William & Mary*

15:30-15:45 **Break**

15:45-16:30 **Panel discussion**

Critical Minerals R&D in the light of recent Executive Orders
TCC 1.110

16:30-18:30 **Happy Hour and Posters (Sessions 1&2)**

TCC 3.102

19:00-21:00 **Workshop Dinner (reservation only)**

Texas Science and Natural History Museum at The University of Texas at Austin

THURSDAY, AUGUST 14, 2024

SESSION 3
TOWARDS A CIRCULAR ECONOMY

Innovations in critical mineral extraction and recycling

8:30-9:00 **Welcome and Opening Remarks**

Marek Locmelis, Workshop Chair

John Ekerdt, Interim Associate Dean of Research, Cockrell School of Engineering

TCC 1.110

9:00-9:30 **Keynote Speaker**

Douglas Wicks, retired.

9:30-10:00 **Keynote Speaker**

Jesica Urbina, Infinite Elements

10:00-10:45 **Oral Presentations**

10:00-10:15 *Emma Zhang – George Mason University*

10:15-10:30 *Benton Wilcoxon – Critical Elements Extraction Technology*

10:30-10:45 **Break**

10:45-12:00 **Oral Presentations**

10:45-11:00 *Ben Ruchte – IXRF, Inc.*

11:00-11:15 *Bridget Scanlon – Bureau of Economic Geology*

11:15-11:30 *Yihan Li – The University of Texas at Austin*

11:30-11:45 *Wencai Zhang – Virginia Tech*
11:45-12:00 *Andrew Gordon – Iofina Natural Resources*

12:00-13:30 **Lunch and Posters (Sessions 3&4)**
Lunch: Under the Oaks
Posters: TCC 3.102

SESSION 4
POLICY AND SUPPLY CHAIN ECONOMICS
Reshoring critical mineral production

13:30-14:00 **Keynote Speaker**
Simon Jowitt, University of Nevada-Reno and Nevada Bureau of Mines and Geology

14:00-14:30 **Keynote Speaker**
Jani Das, Bureau of Economic Geology, The University of Texas at Austin

14:30-15:45 **Oral Presentations**
14:30-14:45 *Karin Olson Hoal – Cornell University and CSIRO*
14:45-15:00 *Holiday O'Bryan – The University of Texas at Austin*
15:00-15:15 *Monika Ehrman – SMU Dedman School of Law*
15:15-15:30 *Homay Fath – Nevada Bureau of Mines and Geology*
15:30-15:45 *Jim Kennedy – Caldera Holding LLC*

15:45-16:00 **Break**

16:00-17:30 **Breakout sessions**
Critical Minerals R&D in the light of recent Executive Orders
TCC 3.108, 3.110, 3.120

Appendix 2 – Anonymized Compilation of Questions and Answers during the Workshop Breakout Session

Question 1: Critical minerals R&D has undergone significant policy changes with more changes on the horizon. What has worked and what has not?

- A major challenge is that research and development cannot begin while the future is in flux.
- Several issues in critical minerals mining have disappeared.
- Silos have been bridged more efficiently than before. However, there is still a long way to go between different players from all parts of the mine value chain, from exploration to down-stream production.
- Precompetitive data generation has not been as fast as other related activities. More projects in mining-friendly states need to be funded in partnership with the mining industry.
- Copper companies are willing to share their geochemical data, a practice that could be adopted by other industries.
- Tax credits and incentives that increased manufacturing and on shore refinement 45 times have worked.
    - These could be applied to mine exploration.
- Negative connotations around mining and frequent changes in the political landscape and the resulting changes in priorities have not worked.
- Right now, the focus is on extraction. However, it needs to be on fully understanding mineralogy before focusing on extraction. Characterization must be (at least) contemporaneous with extraction research, and we need to know the economic potential of a site before pushing projects that are non-starters.
- Having non-scientists as decision makers isn't working.
- Confidentiality of data causes duplicative work in areas that may not be promising. Other countries have the state share the data and have non-proprietary data, aiding progress. Scientific data is valuable and monetized.
- The lack of collaboration between state and federal governments has not worked. There is no sustainable policy and no academic justification for the "witty" changes with each administration.
- The presence of an aggressive and large research population willing to do the work has worked. The academic community has an open mind to do the research.
- Government is dysfunctional and constipated, making it hard to know what the policy is and policy changes are being made.
- The DOE has re-released previously allocated money.
- Nothing has worked and scientific input is lacking. However, this is a long game, so results may be forthcoming.

- There is uncertainty about the future of EarthMRI and other science initiatives over production push.
- We need more precompetitive data. Federal money is focused within the 2–4-year election cycle and spending money downstream. Instead, the goals of this money need to be filled with data, prospects, or wells.
- Inconsistency in successive administrations makes long term planning challenging.
- From an academic perspective big funding under Biden admin provided funding for projects and project proposal development.
    - Stalled or cancelled funding caused momentum to be lost.
- Strong executive order statements from the current presidential administration signal intent to focus on mining. However, without proper policy development these remain impotent.

Figure A-1: Visualization of answers to Question 1 as a word cloud. Shown are the 200 most frequently used words.

Question 2: What would you like to see as the next steps?

- We need to make mining more public and let people know that mining is occurring in the US.
- We need to raise awareness of neglecting and/or exploiting critical minerals and the consequences of each of these options.
- We need to let people know that mining is not a problem. We also need to mine different minerals and foster public focus on mining common minerals like silver, gold, and iron.
- No big mining companies!
- Demand for critical minerals is unknown.

- From an economic geology perspective, we need more data on by-products and their hidden potential across greenfield projects.
- We need more people from across different fields to make mining projects more friendly prior to the projects going online.
- Permitting for the right projects should be fast tracked with ongoing support and return of investment. Processing is another existing and challenging bottleneck.
- We need more engagement from major mining companies.
- We should be making geologist and exploration geologist roles more accessible to a broader group of people.
- There needs to be greater accountability between the public and private sectors with economic measurements in place.
- Remove roadblocks to funding getting into hands of researchers. Current actions are hurting progress and future scientists/students, which will cause problems for the future of the workforce. Put resources toward pre-competitive data collection and distribution to incentivize and mitigate private risk.
- Continue collaboration between federal and state governments, academia, and industry.
- Confidence needs to be created through research and economic certainty that this is worth the investment and time.
- There needs to be a level of risk management in place.
- There needs to be an assurance that funding will be distributed as promised. A change in presidential administration should not change the distribution of funding.
- Streamline the regulatory procedures.
- The NSF should expand on the 2021 Critical Minerals letter to release more basic science funding, workforce development, and exploration.
- More basic science needs to be conducted and a BES program manager needs to be put in place. No Energy Frontier Research Centers (EFRCs) have been released recently either, which needs to change.
- We need a critical mineral EFRC.
- There need to be long-term incentives for trade, more data, and consistent funding with long-term proposals.
- There should be a Mine of the Future effort through the DOE in 2026, funded through a congressional allocation.
- There needs to be more precompetitive data funding
- There should be geology, mapping, drilling, mineralogy, chemistry, modeling, and mineral systems re-evaluations.
- We need to engage with financial community at the highest levels to get supportive resources to change how mining is done.
- We need money for academia, industry, federal programs, state survey support, and national lab support.
- There should be industry collaboration for Ni, Cu, and Co.
- We need more policy suggestions and advice for Li batteries, HREEs, and magnets.

- There should be more jobs.
- We need stakeholder buy-in.
- There should be a balance between U.S. and global interests.

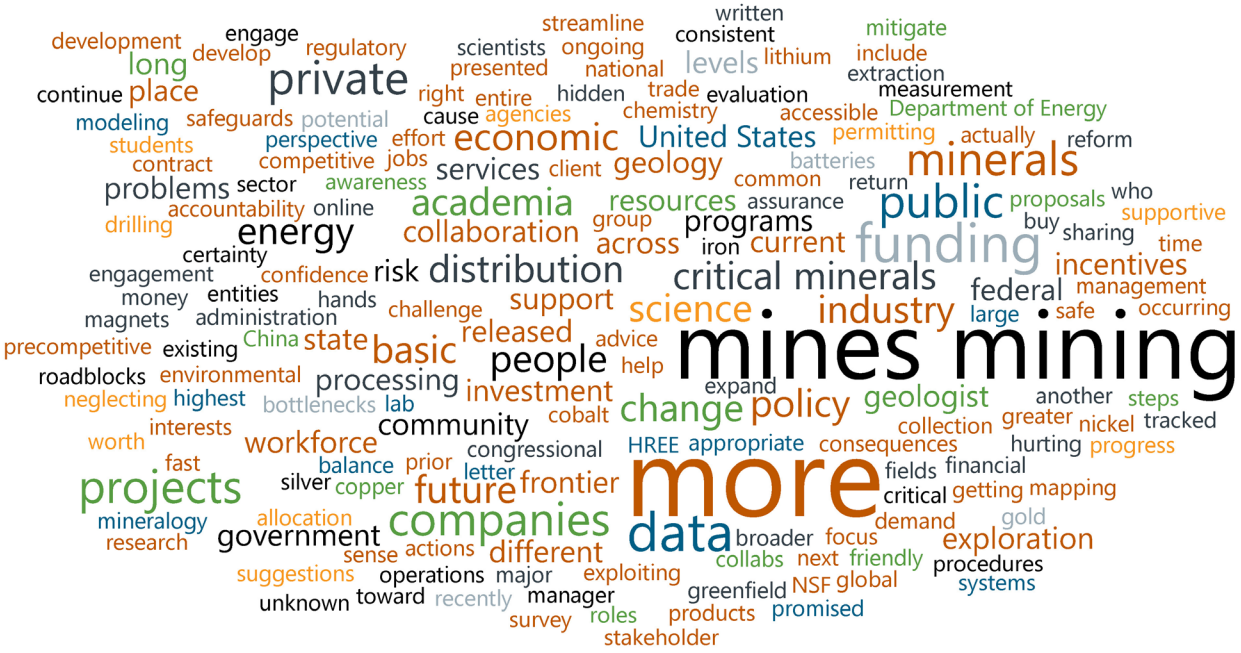

Figure A-2: Visualization of answers to Question 2 as a word cloud. Shown are the 200 most frequently used words.

Question 3: How can / should higher education, government agencies, and the private sector work together to build a strong critical minerals workforce

- Uncommitted freshman should get an introduction to critical minerals as a geology course.
- Create an interdisciplinary program to make students aware of the subject and reach out to chemists.
- There are not enough geology majors. Educational efforts need to be made more relevant to other subjects, include educators, and advertise geology to other fields.
- There should be less focus on mining and engineering and more on metal refining and metal work.
- The high cost, energy intensive, and water intensive nature of mining is a problem. Can the American west sustain this much mining and extraction?
- We should be tapping into new sources and connecting with people.
- Students need the incentives of jobs and scholarships.
- Make mining exciting to students as “the kids do not yearn for the mines.”
- Most higher education programs do not have hands-on and mining related activities. This is true from high school to graduate programs.

- Government, universities, and involved industries in both mining and workforce development must work together, so people could work together to build a sustainable supply chain for critical minerals.
- There need to be more internships and prioritization of hiring students.
    - For example, the case study of Talon Metals, MN, which included outreach within the state starting with middle school and high school and hiring high school students out of northern MN.
- There needs to be cooperation between the entities. Bring in academic researchers and the students that work with them, not just internships.
- We need to help remove stigma of mining and promote the societal needs that mining fulfills and mining as a place where young people can make an impact that aligns with their values.
- Private industry should utilize academia for analytical work, involving students when possible.
- Oil and gas companies, car makers, and NASA should fund:
    - A mining PR campaign.
    - Public outreach through k-12 supported initiatives, including STEM nights and teacher workshops.
    - A national campaign for mining.
    - Lobbying to integrate more geoscience education in K-12 schools.
    - Social media highlighting the positives of the industry and the importance of CM in daily lives.
- There should be a collaboration between higher education and industry to show that the work of students is having an impact. High school students should also be included to get buy-in.
- There need to be new majors and improved recruiting for universities.
- There also needs to be more community college and BS degrees in mining engineering.
- Mining schools should be funded by mining companies, along with early education and training.
- There should be more DOE internships for a wider range of student career stages.
- There needs to be consistent research and funding for attracting superstar talent in academic positions.
- There has been no tenure track mining law professor in more than 30 years! We need law and permitting experts.
- The National Association of Geoscience teachers should hold workshops on how to teach critical minerals and, broadly, resource geoscience and work to develop robust educational materials.
- An early career network modeled on the Deep Carbon Observatory's program could be useful.
- There need to be more economic geology courses in the same template as the month long Geobia field course held at Templeton.

- Field courses and early modules for high school student preparation, along with activities for teachers, should be developed.
- Google maps version with geo data available for teacher/student exploration.
- The NSF needs to announce a 10-year emphasis on critical minerals: money talks!
- We need to let universities charge higher overheads for critical mineral projects.
- There needs to be more outside capital, including big western hemisphere mining companies.
- Government incentives, like tax credits, for investments in critical minerals are needed.
- We should lead companies into investing via government awarded grants.
- We must use lessons learned from tax incentives and workforce development from semiconductor industry in the mining industry.
- There needs to be at least a decade of investment in the mining industry.
- Internships in companies and state regulatory agencies should be funded.
- The TIP program at NSF was an excellent shift toward bringing together multidisciplinary teams in a community and user-based scenario. Do more of that.
- There needs to be a consortium of mining companies.
    - This needs to include timely, rapid-response focused research.
    - There also needs to be workforce training, student exposure to practical application with industry partners, and industry access to student talent including internships and hiring.

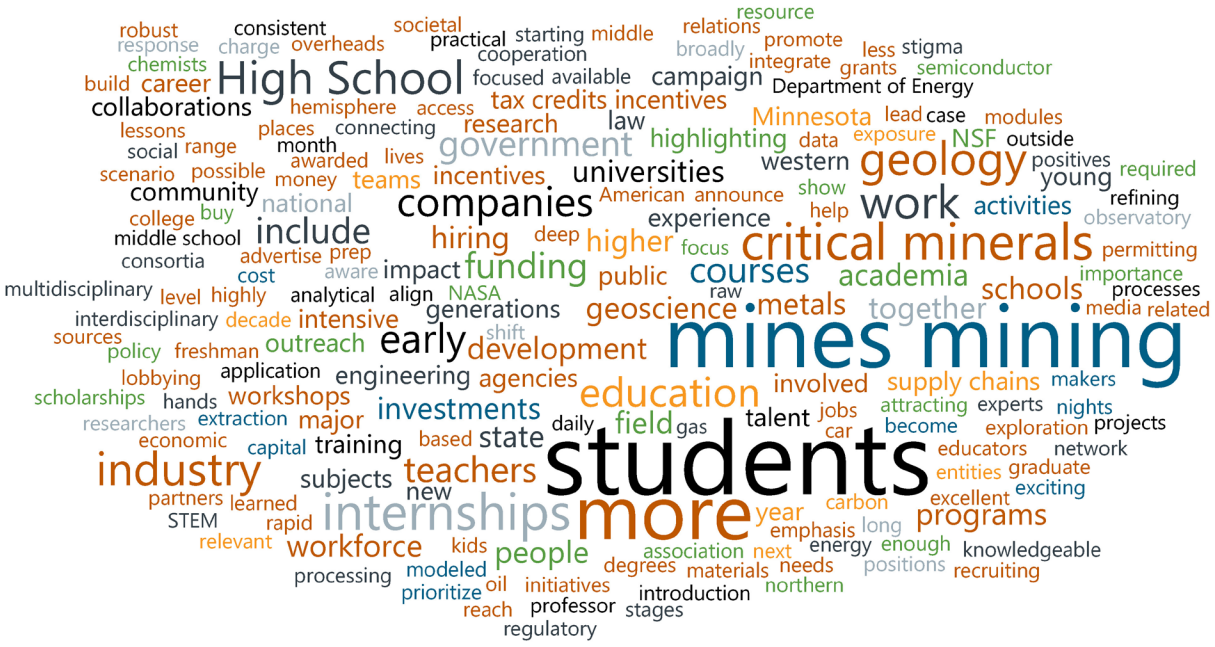

Figure A-3: Visualization of answers to Question 3 as a word cloud. Shown are the 200 most frequently used words.