Sustaining the University of Arizona’s Leadership in Earth Resources: Building on Local to Global Needs and Opportunities

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Core Disciplinary Units
- Department of Mining and Geological Engineering, College of Engineering
- Department of Geosciences, Economic Geology Program, College of Science
- Division of Community, Environment, and Policy, College of Public Health

Overview and Recommendation
Regardless of the specific outcome, the UA transformation process should uphold and, ideally, enhance the programmatic strengths that enable the UA to lead in addressing the challenges of Earth Resources, including areas such as minerals and water. The cornerstone for transforming and building UA mineral resource efforts is the newly funded ($17M, public announcement pending), interdisciplinary "Institute for Mineral Resources." The multiple earth resource themes, along with the university's complementary strengths in the environment and the life sciences, comprise the forefront for understanding and sustaining humanity's interaction with the earth. These areas of expertise underpin an economically sound and environmentally sustainable future, and as such they are critical to the state and the nation.

Based in several departments, and engaging groups from across campus, the UA mineral resources community is widely recognized as a leading national, indeed a leading global center for research and education. This expertise complements campus-wide strengths in other Earth-focused fields including water resources and the environment. We presently have globally-engaged, nationally-leading programs that address many resource-related challenges that our state – and the world – face. This status is founded on having (1) key faculty in the central disciplines of mining engineering and geology, (2) clearly branded and self-sustaining core educational programs in these fields, and (3) cross-campus engagement beyond engineering and science with programs spanning public health to water resources to public policy.

To maintain and build on this reputation and growing opportunities, we must not lose curricular foci that make our graduates among the most desirable in the world. We must retain the identity and the energy that exists in our focused programs that are drawing increased federal, state, industry, and alumni support. And, we need to continue mobilizing the interests and breadth that transcend college and department boundaries.
This focus on excellence in resource-related studies is moving forward with the pending establishment of the "Institute for Mineral Resources" ("IMR") which, like other major interdisciplinary programs, will span many units on campus, bring together ongoing more specific efforts, and strengthen the already considerable collaborations with industry, government, and other organizations. The IMR is being founded on a new $17M research contract plus additional and growing endowments that now total near $10M. Beyond developing new interactions, the IMR will unify several disparate campus groups such as the U.S. Geological Survey - UA co-op (the "Center for Mineral Resources") and the "Mine Health and Safety" interdisciplinary program. These activities are already unique in the U.S. – and they reflect the exceptional economic importance of mining to Arizona and the Southwest (e.g. $8B/yr to the state economy). Although public and private groups (e.g., US News and World Report) do not rank mineral resources programs, those interested in addressing resource issues vote with their checkbooks and they have been consistently voting the University of Arizona as one of their top places in the world to invest.

Where are there opportunities and benefits, as well as savings that might come from a transformation? The IMR framework, with its substantial and growing support, already represents a fundamental transformation in the way that the UA will deal with mineral resource and related issues in contexts from interdisciplinary research and innovative education, to outreach and fundraising. Through this effort, we are using state funding to leverage outside research and philanthropic dollars to sustain and build required capacities within the core programs. As documented in the supplementary materials below, existing state resources support the key programs in a way that is allowing these disciplines to expand their scope of action by facilitating the acquisition of major new philanthropic gifts and funding through competitive sponsored research and educational grants. Through this approach, we are implementing a transformative model similar to the “core-in-cloud” model identified by James Duderstadt, former president of the University of Michigan in his book “A University for the 21st Century”. This model has core academic disciplines surrounded by a “constellation of quasi-university organizations – research institutes, think tanks, corporate R&D centers that draw intellectual strength from the core university and provide important financial, human, and physical resources in return.” (Duderstadt, p. 316). The “cloud” around the core mineral resources disciplines includes the US Geological Survey, the Institute for Mineral Resources, the San Xavier Mining Laboratory, expanding industry R&D facilities in or near Tucson (e.g. Freeport McMoRan Mine Technology Group, Process Technology Center, and Exploration Group, Caterpillar Proving Ground, Komatsu Proving Ground). The key point is that a number of structures might accommodate this, but each discipline must remain strong and retain a distinctive sustainable identity that is recognizable to those outside the institution. We gain organizational efficiency and cost containment by working with the university and our respective departments and colleges. We increase our global reputation by strong core disciplines and strong interdisciplinary collaboration through the Institute for Mineral Resources. We increase our access to resources through strategic alliances with a constellation of organizations such as those listed above. Duderstadt (p. 312) describes the University of Michigan as a “privately funded but publicly committed” university. This is the transformation model the UA is being driven to implement and it is one that implements the strategic approach that has underpinned planning in earth resources disciplines over the last decade.

Moving forward: No single grouping of departments into a school, or simple merger of colleges can capture the diverse areas of expertise required for mineral resources (see list of Core Units and Relevant Units below). We have participated in many of the conversations with our colleagues in Engineering, Science, and CALS related to environmental science and engineering and we value all of our relationships with departments in these colleges. We believe that under the “big tent” of earth resources, other natural resources, and the environment, the University of Arizona probably has the strongest and deepest pool of faculty in the world. Beyond the faculty, our strength derives from having long-standing well-recognized programs that retain their identities with the outside world and with a strong base of loyal and highly successful alumni.
Recognizing that an optimum organization depends on many factors, we contend that form should follow function, and thus any organization must preserve disciplinary identities and their hard-earned reputations that represent decades of success and good will. Furthermore, disciplinary identity is essential to the success of educational programs and stable interdisciplinary collaboration. In this regard, many white papers have intriguing aspects, yet propose fundamental changes in disciplinary identities that would incur major costs without commensurate benefits. As this analysis progresses, the Institute for Mineral Resources can provide a cross-campus umbrella, however it can not substitute for the essential focus provided by core education and research programs in mining engineering and the solid earth sciences. Two examples suffice: In engineering, ABET accreditation requires discipline-specific, technically advanced education. In geology, mineral deposit (“economic”) geology depends on specialists plus a well-defined core in the solid earth sciences that underpin the applied science. These two disciplines are distinct in approach and requirements; neither group fits naturally or easily within other disciplines, although there are many overlapping needs. In a supportive institutional framework, some form of these current structures and the evolving IMR framework can address enduring intellectual and societal challenges, they can meet the sustained demand for this expertise and for well-prepared graduates at all levels, and therefore position the University of Arizona to continue its global leadership.

**Relevant Units**

We collaborate with many units at the University of Arizona on mineral resources education and research and the overlaps between these issues and others of environmental and social concern. A short list of those with critical expertise that we work with or need to strengthen or develop collaborations with include:

- Department of Hydrology and Water Resources
- Department of Civil Engineering and Engineering Mechanics
- Department of Chemical and Environmental Engineering
- Department of Material Science and Engineering
- Department of Systems and Industrial Engineering
- Department of Aerospace and Mechanical Engineering
- Department of Electrical and Computer Engineering
- Department of Soil, Water, and Environmental Science
- Department of Anthropology and the Bureau of Applied Research in Anthropology
- Department of Agriculture and Resource Economics
- Department of Planetary Science
- Department of Chemistry
- School of Natural Resources
- Department of Geography
- Udall Center for Public Policy

**Budget Savings/Increased Revenue:** As previously described, cost savings come from within University and College business process improvements and consolidation of some staff functions at the College level. We have already fully funded a tenure track faculty member on 100% endowed funds in MGE and one in GEOS on split state/endowed funds. We run the MGE Department on 100% non-state funds for operations. We are developing sources of external support for the programs described above.
SUPPLEMENTARY MATERIALS

Importance of Mineral Resources

As we consider humanity's relationship with the Earth, we have dual responsibilities, needs, and opportunities which can be cast as, first, our role in stewardship of the environment and, second, our need to make the best use of earth materials that are basic to our material-intensive civilization. Nearly every object we interact with in our daily lives consists of materials that were obtained from the earth as minerals. Some of the materials are highly visible, such as concrete and steel for civil infrastructure. Other materials are less visible but vital, such as tellurium for flash memory, tantalum for cell phones, and indium for flat panel displays. As many as 60 different minerals must be mined to make today's computer chips (Eggert et al., 2008). Some materials are generally common but rare in the purity needed for manufacturing such as silica for computer chips and solar panels. All mineral deposits are rare occurrences; elements that exist in the earth's crust at concentrations of a few parts per million must be concentrated by nature many fold to be extracted and processed into usable materials.

Development of "green technology" does not eliminate material consumption – it often can increase demand for the "materials capital" to create the required infrastructure. New technologies can cause critical mineral shortages when the new demand cannot be met with existing supply. For example, CIGS technology for solar energy requires copper, indium, gallium, and selenium. Nearly all of the indium supply is being used for flat panel display production and because indium is produced solely as a by-product of electrolytic refining of zinc (and not all zinc minerals contain indium as an impurity), the inability to bring new zinc production on line will restrict indium supply. The price of indium has risen from $100/kg to $980/kg in the last three years in response to the supply and demand. New mines can take 15 years or more to bring into production from the time of discovery and typically demand new approaches to minimize impact and maximize efficiency. Hence, it is critical that we advance our understanding of mineral resource distribution and our safety, environmental, and production technologies as fast as we advance our new material demands for those resources.

Importance to Arizona: Status and Opportunity

Competitive advantage: Arizona has one of the richest mineral endowments of any place on Earth and the University of Arizona has a long, distinguished history as a world leader in the science and engineering of mineral resources dating to the creation of the university. We have the challenges of resource development in an arid environment, with expanding urban population centers, diverse ecosystems, and spectacular scenery. Analogous challenges are faced in mineralized regions throughout the world. By virtue of its location in an area with these exceptional natural endowments and because of the long-term success of its relevant academic programs, the University of Arizona has a reputation for excellence that cannot be replicated elsewhere in the United States.

Value to Arizona: The value of mineral production in Arizona was $7.6B in 2007. Although this number fluctuates with the commodity prices and the economic cycle, mineral production remains a major contributor to the state economy through high-paying jobs, technical innovations and spin-offs, and tax revenues. Major mining districts have life-spans measured in many decades to centuries – far longer than those of many other businesses. Geologic information suggests that known districts alone can be expected to produce through much of this century. Apart from the direct impact of mining (which is a technology intensive industry), Arizona companies, both large and small, are leaders in the global mining industry, in related technical developments such as equipment automation, and fields such as environmental science. Many of these companies are either headquartered in Arizona (e.g. Freeport-McMoRan, the world's largest publicly traded copper company) or have major operations here (e.g., Caterpillar). The UA, through its research and through its graduates has been the incubator for many fundamental insights and innovations in this field.

Breadth of opportunity: Also of great importance is the opportunity to engage the full University campus and the broader community in the dialog and efforts required to develop a
sustainable approach to the stewardship and use of earth resources in the broader context of our developing region, and similar issues globally. Mineral resources expertise complements and strengthens the focus on environmental science, but also has additional needs to understand deep-time, solid earth geosciences, maintain the health and safety of workforces and communities, engineer structures for extreme conditions, develop efficient ways to create finished materials and how to recycle them at their end of life, understand long-term consumption needs of developing and developed nations, develop insights on geo-political risk and world population dynamics, and what resource development policies facilitate development and protect the environment.

**Enhancing education, service and outreach:** We have a world-wide reputation for the quality of our scholarship, teaching, and outreach to related professions. For instance, our economic geology group is one of only three in North America and ten globally to regularly participate in the leading industry-led mineral exploration research organization (AMIRA International). An effort that combines teaching and outreach is the innovative, dual Lowell Programs in Mining Engineering and Economic Geology. These have been developed with recent endowments and have global reach. We have just developed a strong distance delivery system for our entire mining engineering curriculum from sophomore through PhD classes and short courses. This program reaches a wide population beginning with students and professionals in Arizona but extending throughout the US. Ultimately these efforts reach into other parts of the world, such as Latin America where there have been long-term links to the U of A and there remain enormous opportunities and challenges. Already, our field courses in economic geology are oversubscribed months in advance and, in four years, have had about 300 participants from over 50 companies (plus two government agencies) in 22 countries representing all continents except Antarctica. Demand is such that if we had the capacity we could double the number of annual participants. Over 70 graduate students have participated in these courses along side junior to mid-career industry professionals.

**Improving our near and long-term fiscal stability:** We have received approval of a $17M research contract to develop the interdisciplinary Institute for Mineral Resources and have over 12 research projects starting in addition to at least that many already under way. We expect to fund 17 additional graduate students per year under the new research contract beyond those already in our programs. The Institute for Mineral Resources will elevate the collaborations with other researches at the UA as well as partners at universities around the world such as the University of Queensland. Within the last decade, mostly in the last few years, we have raised $9.5M in UA endowments and another ~$5M held at the Denver Foundation. This philanthropic support was given in recognition of the quality of our programs and the need to support and strengthen the best.

There is precedent at other universities for world-class philanthropic support related to earth resources (cf. the Jackson School of Geosciences at the University of Texas, Austin which was created with a gift now worth over $300M and a total endowment exceeding $400M). We believe that with strengthening our "brand" through the IMR that there are excellent opportunities for generating very large endowments. In addition to industry and philanthropic dollars, and existing Federal funding streams, there are several developing opportunities for major increases in federal funding. One, already implemented in part through our efforts, is a (presently small) competitive grants program through the U.S. Geological Survey Mineral Resources Program. A second, larger initiative – the "Energy and Mineral Schools Reinvestment Act" (EMSRA) – is pending in 7 bills before Congress and will, if approved, provide major funding streams for mineral resource studies and education.

**References Cited**

