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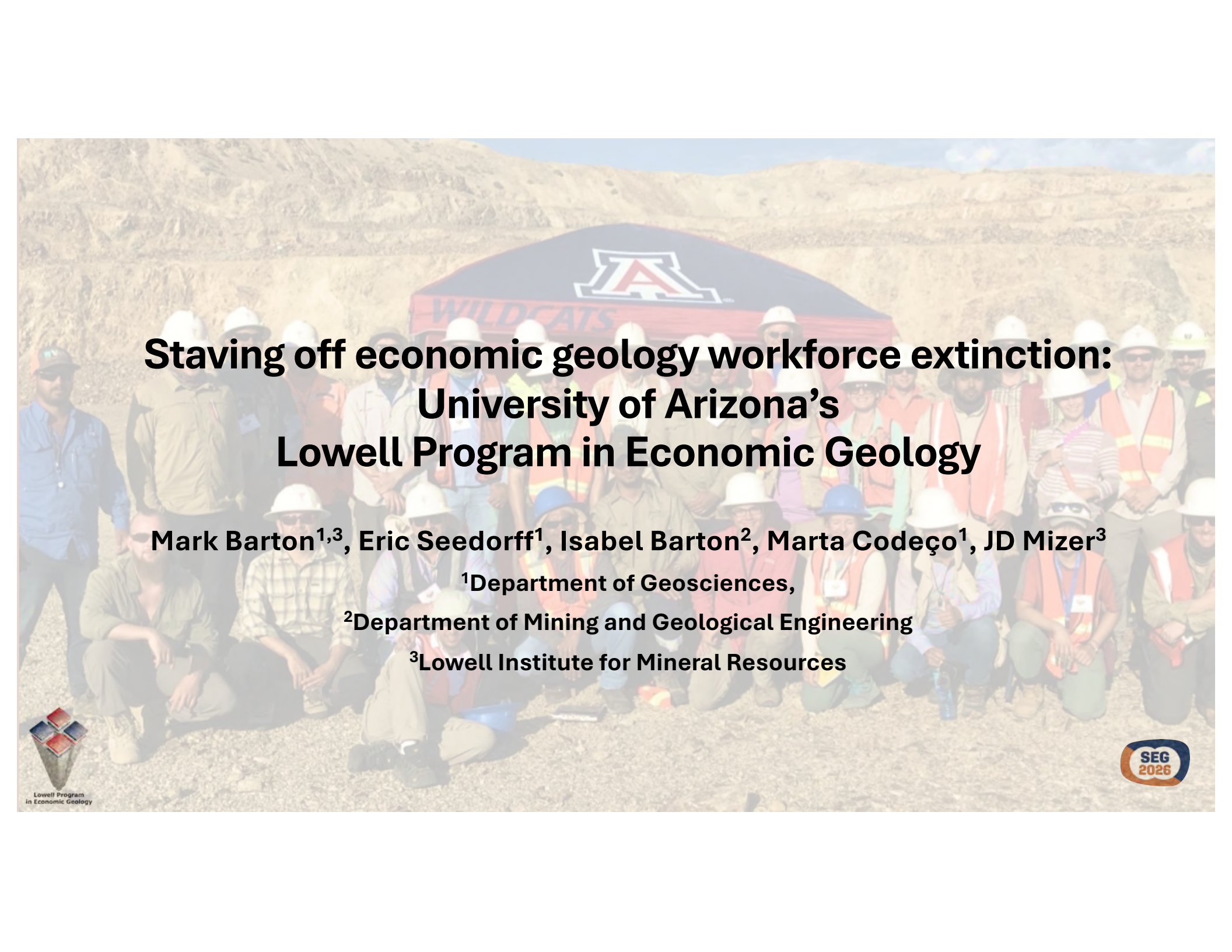
Staving off economic geology workforce extinction: University of Arizona's Lowell Program in Economic Geology

Mark Barton, Eric Seedorff, Isabel Barton, Marta Codeço, JD Mizer

Evolving, multi-faceted approaches can address the multi-decadal atrophy of economic geology education in the US and beyond. Recognized since the 1980s, causes for decline include research specialization, curricular changes, funding shifts toward other fields (and low commodity prices), corporate consolidation, and increasing segregation of geoscience departments from other mining-related programs. Contrasting challenges require different approaches at all levels – undergraduate to professional.

At the University of Arizona, efforts to arrest this decline and rebuild began in the 1990s through conversations with industry partners and alumni, notably J. David Lowell. Endowments from the Lowell family enabled creation of the industry-focused Lowell Program in Economic Geology (2004) and later the campus-wide Lowell Institute for Mineral Resources (2009; collaboratively with Mining Engineering and others). Based on input from industry, LPEG began with a novel project-based professional masters program and a unique series of 10-day intensive professional development courses. These complemented traditional MS and PhD programs plus new (2020-25) graduate certificates, accelerated masters, and 2-day “inputs” overview courses (mostly online). Since 2005, two faculty (on average) advised >100 graduate students and >1,500 industry short course participants – all without significant university funding beyond faculty salaries. Success inspired creation (across campus) of affiliated programs in geometallurgy, geotechnics, and reclamation.

What was/is critical for success? (1) Partnerships/consortia with industry ± government focused on shared strategic needs including graduate/professional education plus relevant, fundamental geologic studies. (2) Engagement and support for capable faculty [when they can be found!] who will forsake some typical academic rewards to contribute to a longer-term vision. (3) Benign neglect by university management allowing programs to gestate, innovate and operate outside bureaucratic “strategic” constraints. Can we ensure that such programs (and future workforce) stay off the endangered list? – With long-term commitments and partnerships lasting through thick and thin, maybe. The jury's still out.



Staving off economic geology workforce extinction: University of Arizona's Lowell Program in Economic Geology

Mark Barton^{1,3}, Eric Seedorff¹, Isabel Barton², Marta Codeço¹, JD Mizer³

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This talk

- Challenge and needs
 - evolving state of affairs in EG education
 - how university programs can play a role in economic geology education
- Arizona context and approach
 - history and competitive advantage
 - conversations (listening!) & actions
 - build partnerships – internal & external
- What we're doing now
- Some take-aways – always changing



The Lowell Program in Economic Geology

The Lowell Program in Economic Geology (LPEG) encompasses education, training and research at all levels related to the geology of mineral resources and related applications. It includes undergraduate courses through graduate degrees, a graduate certificate in mineral resource geology, and continuing education for working professionals. Housed in the Department of Geosciences, it is also closely affiliated with the School of Mining Engineering and Mineral Resources and the Lowell Institute for Mineral Resources (LIMR).

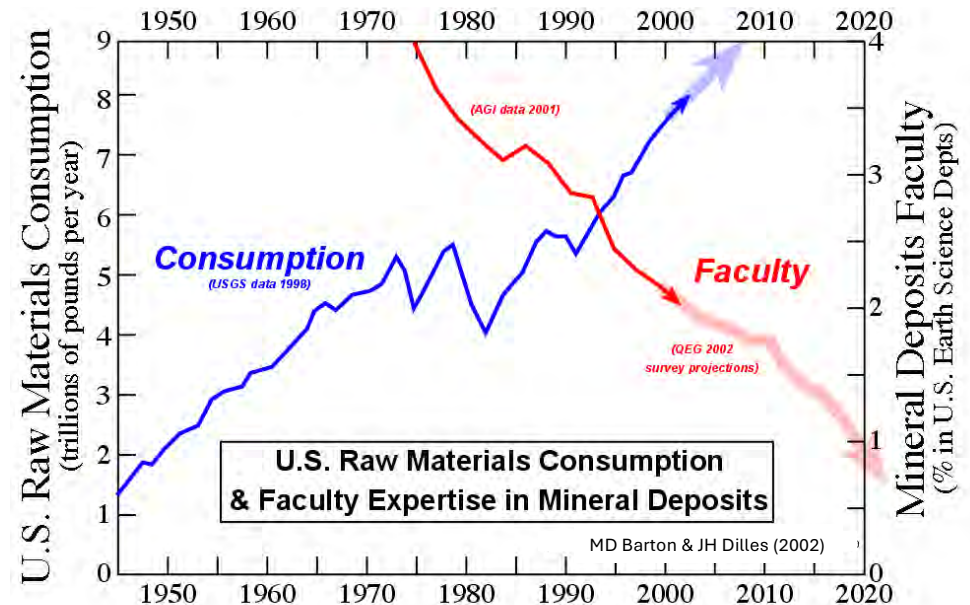
The Lowell Program in Economic Geology and the Lowell Institute were generously endowed by gifts from J. David Lowell and the Lowell family to the University of Arizona.



The challenge – long developing

in spite of increasing consumption...

- EG programs have been disappearing for decades
 - student numbers follow faculty
 - university priorities changed
- Partly reflects disinvestment by state and federal governments – and by industry
 - the impact of commodity cycles and politics



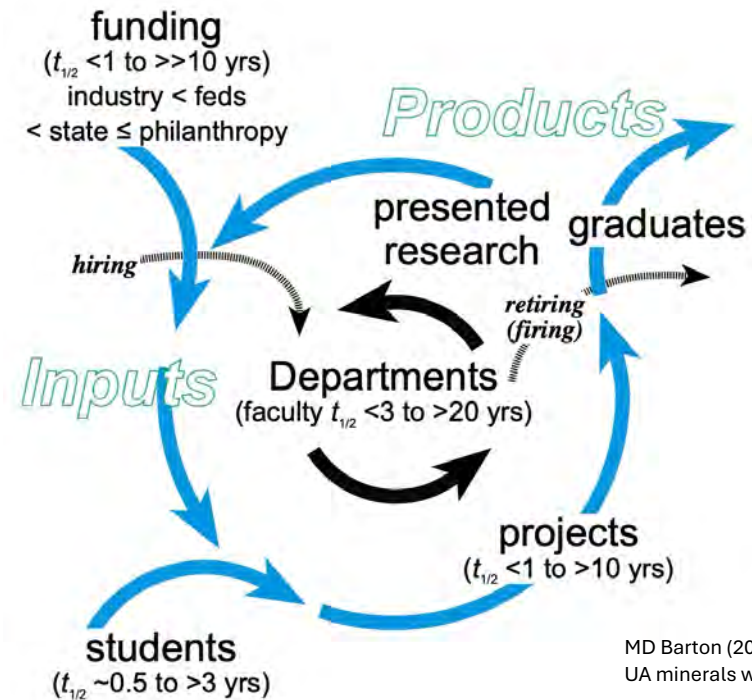
“it is unclear that there will be a sufficient number of economic geologists in academia in 20 years time to make any difference”

MT Einaudi (1994) Meyer Symposium



What's needed: strategic approach

- Focus on the big picture
 1. civilization uses earth materials
 2. to provide minerals responsibly requires appropriate expertise
 3. universities can provide expertise via training and knowledge creation
– *yet have their complex challenges >>*
- Short-term fixes aren't sufficient
 - project funding goes away, leadership changes, broader context evolves
- Sustainable programs need:
 - long-term financial base
 - stable broad-based 'political' support (too small otherwise so always at risk)
 - *a clear value proposition*



MD Barton (2003) UA-USGS
UA minerals workshop

the university 'flywheel' challenge

matching inputs and products with different time scales



University of Arizona context

- >100 year minerals history but wilting in the 1980-90s
 - EG-related faculty from 6 to 2
 - mining engineering threatened
 - *reflected changing priorities but also lack of a shared vision*
- Yet there remained many competitive advantages
 - exceptional location – geology, deposits, industry
 - broad-based research university (e.g., law, medical, social science)



What to do? Options...

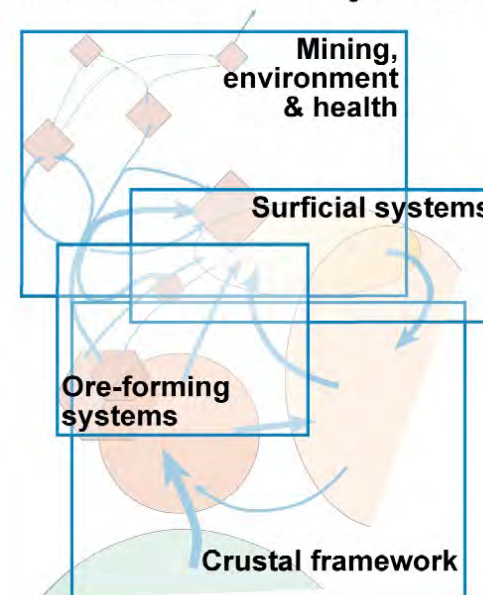
- muddle along with more of the same
- think different; work with & listen to others (alumni, industry, government)

starting in late 90s our approach has been strategic:

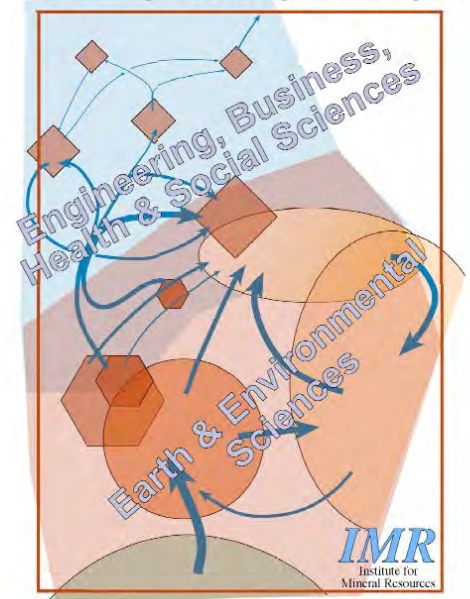
Strategy – exploit institutional advantages *across the mining / minerals lifecycle*

- SW North America location
 - geology/exposure
 - deposits and industry locus
- People – faculty, alumni *et al.*
 - *partnerships of many types*
- Specific expertise
 - porphyry, structure, etc.
- University breadth beyond core
 - law to health to social science
- **Administrative indifference**
(until ~2021)

**Mineral Resources:
Natural & human systems**



**U of A: Emphasis Areas
& Strengthening Linkages**



Start (and continue) with conversations

– *alumni, industry, government, university colleagues*

- Discussions with David Lowell among many others
 - focus on training in fundamentals
 - led to first endowment to support industry-focused masters
- Listening to what others suggest
 - reviewed landscape and needs
 - designed & created new programs
 - distinctive prof ed courses
 - consortia that can address both education and research



J David Lowell



UA approaches to economic geology workforce

Level	Education objectives	LPEG/GEOS <i>Lowell Program in EG</i>	LIMR/CoS <i>Lowell Institute for MR</i>	MGE(SMEMR) <i>Mining Engineering etc</i>
K-12	into to mineral resources	—	— [^]	outreach / recruiting [^]
undergrad	intro to mineral resources / careers	a few courses	#	MR minor *
undergrad EG	to industry or step to further ed	accelerated masters (AMS-EG) *		
masters	to industry or step toward PhD	PSM [^] MS	(course support) lab support *	courses / Geomet / GCE #
doctoral	for faculty / research-oriented positions	PhD	(course support) lab support *	courses / Geomet / GCE #
continuing ed	prof training geologists	short courses [^] certificate *	(course support)	short course [*] GCE courses [^]

What did post-2000 additions address?

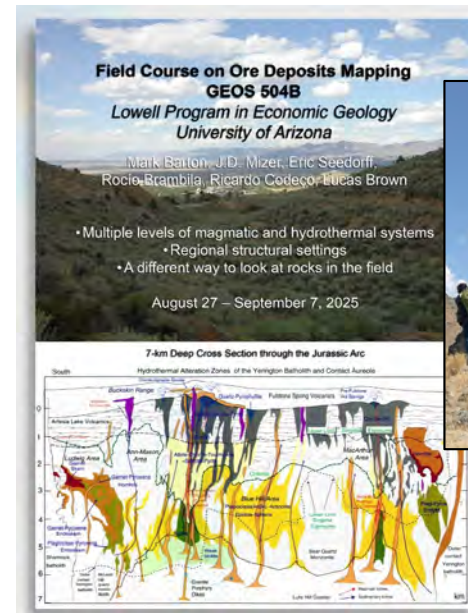
[^] since 2003; # since 2009; * since 2022



Lowell field & short courses

build on competitive advantages for industry-suggested professional education courses

- Inputs Series – online with global reach
 - 16-hour surveys of technical fields in mining
 - taught by industry experts & faculty
- Intensive 10-day field courses – Tucson & Great Basin
 - ore deposit mapping ('mineral systems')
 - mineral deposit types (Cu-Au focus)
 - structural geology for exploration & mining
 - hyperspectral applications to mining
- Broadly self-supporting
 - **income supports students and staff**
 - field courses have had nearly 2,000 participants since 2004 involving >80 organizations and >20 countries



Consortia to address collective challenges

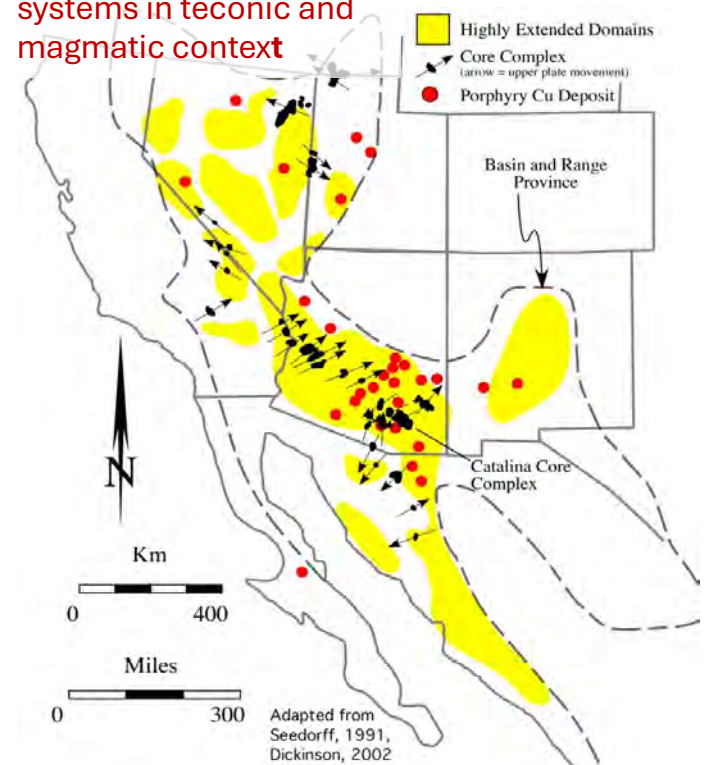
– *education coupled with applied research in areas of expertise*

- **Mexico Consortium** (1993-1999) 6 companies, USGS
 - Focus on Mexico-wide metallogensis, data synthesis and deposit studies – *first digital compilation for Mexico*
- **Porphyry Copper Lifecycles** (2002-2008) 3 companies, USGS
 - Focus on SE Arizona Laramide
 - Crustal framework, structure, magmatism and deposit studies
- **Cordilleran Consortium** (2010-2018) – 8 companies
 - Basin and Range tectonics, magmatism & Cu / Au ore-systems
 - Emphasis on using crustal sections and transects
- **Keck Consortium** (2017-2022) – 5 universities, USGS, 3 companies
 - Focus on Colorado Plateau U-V-Cu-Ag-Co ore systems
- **Regents Grants on Arizona challenges:** (1) abandoned mine lands (2022-26); (2) critical minerals in Cu tailings (2024-27)
 - Co-op with state agencies (Department of Environmental Quality; State Mine Inspector), 2 universities and 7 companies



Lowell Program
in Economic Geology

Cordilleran Consortium Cu and Au mineral systems in tectonic and magmatic context



Adapted from
Seedorff, 1991,
Dickinson, 2002

Building cross-campus links: Lowell Institute for Mineral Resources

- Started (2004) as a hub for minerals-related activities campus-wide
 - endowed (2009) to support mining-related professional education
 - past emphasis on catalyzing campus-wide minerals activities and collaborations
 - has involved >10 colleges across campus
 - created new programs – geometallurgy, GCE, CESM
 - new ‘School’ – SMMR (2021, now SMEMR)
- Two current functions
 - supports professional education – primarily for continuing (industry) and graduate students
 - supports shared laboratory and other facilities related to mineral resource teaching and research

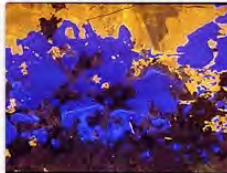


Key: enrolling and supporting motivated people

Lowell Mineral Characterization Facility (Lowell MCF)

Overview

The Lowell Mineral Characterization Facility (MCF) contains a wide variety of analytical and imaging equipment for the study of mineral deposits and related materials. Users include faculty, staff, students and collaborating investigators. The MCF is a joint effort of the Lowell Program in Economic Geology (LPEG), Department of Geosciences, the School of Mining Engineering and Mineral Resources (SMEMR), and the Lowell IMR. Support for the facilities and staff comes from SMEMR and LPEG funds and from contracts, grants and fees.

 Laser ablation ICP-MS laboratory The mass spectrometry laboratory houses two laser ablation systems and three mass spectrometers. This array allows analysis of a wide variety of liquid and solid samples (bulk and in situ) for chemical and isotopic compositions. Dr. Jason Kirk manages and leads development activities in the LA-ICP-MS lab. Find out more	 Microscopy lab The microscopy lab supports imaging and analysis of geological materials at the microscopic scale. Included are petrographic and stereo microscopes, cold-cathode cathodoluminescence, and a Horiba LabRAM HR Evolution Raman microscope. The lab supports both teaching and research and is overseen by Dr. Frank Mazdab and Ms. Jennifer Weiss. Find out more	 Scanning electron microscopy lab The scanning electron microscopy (SEM) lab contains both a JEOL 6010LA benchtop SEM with EDS and BSE coupled to a Gatan MonoCL4 panoramic cathodoluminescence (CL) detector and a QEMSCAN Minisite SEM (donated by Freeport McMoRan). The SEM lab is overseen by Dr. Isabel Barton and Ms. Jennifer Weiss. Find out more
 Sample preparation and collections The LMCF maintains sample preparation labs with rock saws, laps for polishing, micro drilling equipment, a photography station, and a wet chemistry lab. Extensive collections are curated for LPEG and MGE teaching while ~100 yrs of worldwide suites are used for research. All are managed by Jennifer Weiss. Find out more	 Fluid inclusion laboratory The LMCF fluid inclusion lab contains both Linkham and USGS type stages with controllers and other related peripherals. Samples for fluid inclusion studies (including melts) can be prepared and examined using microthermometry, conventional petrography, Raman spectroscopy, and LA-ICP-MS techniques. Find out more	 Spectral imaging lab The spectral imaging lab is a state-of-the-art laboratory and includes VNIR, SWIR, and LWIR reflectance spectroscopy equipment and is linked to computers and software for image processing of lab, field, and remote spectral data. The spectral imaging lab is led by Dr. Dean Riley. Find out more

Summing up

– *reflections on what has worked well (and has not)*

- LPEG has helped stave off workforce extinction by
 - exploiting breadth, distinctive strengths, location
 - providing flexible options for different groups
 - e.g., alternative masters options, interdisciplinary
 - has led to >100 graduate degrees in 20 years (w/ 2 faculty)
 - potential step change with new people and opportunities
 - offering distinctive prof ed (~2,000 since 2004)
 - *yet finding adequate and consistent student support for a large program is a huge challenge*
- Collaborative applied (and basic) research
 - consortia can be more effective than one-off projects
 - best when closely tied to education goals
 - *developing pre-/non-competitive projects has been difficult and is becoming more so*



Persistence – keep at the big challenges and opportunities



Sisyphus (1548–49) by Titian,
Prado Museum, Madrid, Spain

Wikipedia

Summing up

– *reflections on what has worked well (and has not)*

- Strategic view, breadth & communication
 - focusing on long-term needs & competitive advantages
 - building campus-wide opportunities/programs
 - discussion with all stakeholders
 - *finding time and institutional support to do this*
- Enrolling and supporting good people
 - let them lead in areas they care about
 - *sustaining support and communication*
- **Managing up – perhaps the biggest challenge**
 - leaders and context evolve for better or worse
- *Keeping at it* matters most
 - there have been many ups and downs in the last 40 years, failure (lack of trying) could have ended things several times



Persistence – keep at the big challenges and opportunities



Sisyphus (1548–49) by Titian,
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Thank you

***especially to all who have been involved
over the last several decades***