PROFESSIONAL SCIENCE MASTER’S IN ECONOMIC GEOLOGY
Department of Geosciences, College of Science, University of Arizona

I. PROGRAM NAME AND DESCRIPTION AND COP CODE

A. DEGREE(S), DEPARTMENT, AND COLLEGE AND CIP CODE
Professional Science Master's in Economic Geology.
Department of Geosciences.
College of Science.
CIP Code: 40.0699: “Geological and Earth Sciences/Geosciences, Other.” Any instructional program in geological and related sciences not listed above.”

B. PURPOSE AND NATURE OF THE PROGRAM
The purpose of this program is to provide training for geologists in the global mineral industry who want to return to school to further their careers. The Professional Science Master's (PSM) in Economic Geology aims to meet the needs primarily of economic geologists, although students interested in land management and public policy would also be well served. The main target group consists of young professionals who have obtained Bachelor's degrees in geosciences and have a job in the minerals industry but wish to obtain further training that will allow them to compete globally with other professionals for career-track positions leading to management opportunities. The program will also address the request by industry that a Professional Master’s degree be offered in economic geology that emphasizes cross-disciplinary training in business, engineering, and other fields. The program would be affiliated with the Professional Master’s Degree Program of the College of Science at the University of Arizona. Successful implementation of the Lowell Program would contribute to fulfilling the goals of the Sloan Foundation to implement new science master's programs nationally and across the State of Arizona.

C. PROGRAM REQUIREMENTS
The degree requires a minimum of 30 units. The proposed new course in the Geosciences Department, Project Stages and Best Practices, is required, and it includes a colloquium series with invited speakers from industry. Students are required to take at least one of the two business courses (BAD 510: Business Fundamentals for Scientists, and MIS 578: Project Management) especially designed for the Professional Master's Degrees by the Eller College of Management at the University of Arizona. An internship requirement, which normally would take four months to complete, will be waived for those coming into the program from industry (a waiver does not impact the number of units required to complete the degree). Two to five units of research credits are required that leads to a written research report and a public presentation (talk or poster), but a formal thesis is optional.

At least 18 units must come from lists of qualifying courses in four subject areas: (1) exploration and development, (2) mining and processing, (3) economics, business, and people, and (4) health, safety, and environment. Every student must take at least one course from three of the four subject areas, which is designed to establish breadth across fields that contribute to the mineral industry.

The student is required to select an emphasis area, depending on the career goals of the student: (a) exploration geology, (b) development geology, (c) mining geology, and (d) environmental geology. The remaining course requirements are intended to develop depth pertinent to the emphasis area:

- Students with an emphasis in (a) exploration geology are required to take at least three courses in
the (1) exploration and development subject area and one course in the (2) mining and processing subject area.

- Students with an emphasis in (b) development geology are required to take at least two courses in the (1) exploration and development subject area, one course in the (2) mining and processing subject area, and one course in the (4) health, safety, and environment subject area.

- Students with an emphasis in (c) mining geology are required to take at least two courses in the (1) exploration and development subject area and two courses in the (2) mining and processing subject area.

- Students with an emphasis in (d) environmental geology are required to take at least one course in the (1) exploration and development subject area, one course in the (2) mining and processing subject area, and two courses in the (4) health, safety, and environment subject area.

Course offerings change over time, but current courses that qualify in each of the four subject areas are as follows:

- **Exploration and Development subject area**
  - Orogenic Systems (GEOS 527)
  - Regional Structural Geology (GEOS 523)
  - Advanced Ore Deposits (GEOS 646A/646B)
  - Volcanology (GEOS 570R/570L)
  - Applied Mineralogy and Petrology (GEOS 509)
  - Geophysical Exploration and Engineering (GEN/GEOS 517/548)

- **Mining and Processing subject area**
  - Ore Reserve Estimation (MN E 545/MATH 574)
  - Geomechanics (MN E 427)
  - Mineral Processing Methods (MN E 411)
  - Mine Design (MN E 535)
  - Mine Geology Methods (GEOS 533M/ MN E 533M)

- **Economics, Business, and People subject area**
  - Mine Investment Valuation (GEOS 533/MN E 530)
  - Foundations of Business for Scientists (B AD 510)
  - Project Management (MIS 578)
  - Information Systems Management (MIS 331)
  - Mining and Public Land Law (LAW 640)

- **Health, Safety, and Environment subject area**
  - Field Hydrology Methods (HWR 412 and HWR 414)
  - Spatial Analysis of Hydrology and Watershed Management (HWR 569/WSM 569)
  - Environmental Hydrology (HWR 450/550)
  - Environmental Risk and Economic Analysis (HWR 443)
  - Health and Safety in Mining (G EN 526/MN E 526)

**D. CURRENT COURSES AND EXISTING PROGRAMS**

As shown above, the core offerings for these degrees are existing courses in the Geosciences Department, complemented by courses offered in the Departments of Mining and Geological Engineering and Hydrology and Water Resources in the College of Engineering and business courses offered by The UA College of Science, Geosciences Department Professional Science Master’s Program in Economic Geology Implementation Authorization Request
E. NEW COURSES NEEDED

One new course is needed in the Geosciences Department, Project Stages and Best Practices, which will incorporate a mineral industry colloquium.

GEOS 529 – Project Stages and Best Practices (3 units)
Description: Description of the stages through which mining projects evolve from exploration through development, mining, and closure, with an emphasis on the geologic contributions to each stage and an inquiry into how best practices might be achieved in each stage. Course incorporates a mineral industry colloquium component.

Grading: Regular grades are awarded for this course: A B C D E.

Usually offered: Fall.

F. REQUIREMENTS FOR ACCREDITATION

N/A

II. STUDENT LEARNING OUTCOMES AND ASSESSMENTS

A. What are the intended student outcomes, describing what students should know, understand, and/or be able to do at the conclusion of this program of study?

1. Understand the various types of economic mineral deposits, their occurrence in geologic time and distribution on the Earth, and the principle genetic processes that lead to their formation.
2. Be able to identify indications of mineralization, be able to map those features in the field, and be able to interpret their potential economic significance.
3. Understand the business context of the minerals industry.
4. Understand the geologic contribution to the stages by which mineral occurrences become economic, through exploration, development, mining, and closure.
5. Be able to communicate geologic facts, observations, and interpretations orally and in writing.

B. Provide a plan for assessing intended student outcomes.

Student assessments in each case will be done through problem sets, oral presentations, term papers, examinations, and laboratory exercises that are provided in classes offered through the courses in this program. Field trips and associated field exercises are an important components of the teaching and assessment effort. The program culminates in a research project that includes a written report reviewed by a faculty advisor and a public presentation of the results as a poster presentation or oral presentation. We will also be able to evaluate student outcomes through our contacts with employers and members of the economic geology community after students have returned to the workforce.

II. STATE’S NEED FOR THE PROGRAM
A. HOW DOES THIS PROGRAM FULFILL THE NEEDS OF THE STATE OF ARIZONA AND THE REGION?

The PSM Program in Economic Geology is designed to meet the needs of the global minerals industry and the State of Arizona. The size of the global industry continues to grow with increase in population and demand for a higher standard of living, which requires mineral products. The industry has historically had an important role in the state, and it remains a significant part of the economy and a source of high-paying jobs. Even during the industry’s long slump in the last decade, the direct value (excluding economic multipliers) of Arizona’s annual mineral production was well over two billion dollars. The industry turned around several years ago and is now in a boom period: a new copper mine is being constructed near Safford; a major new copper deposit is in the early stages of development near Superior; and exploration activity in Arizona has returned to vigorous levels. Even as mineral production gradually shifts more to developing and underdeveloped countries, Arizona and the West remain a geology and mining center. The developing world depends on the United States for educational leadership, and the bulk of the minerals education resides in the West. This program strengthens the University of Arizona in its position as the only major research university with a large program in mineral resources.

B. IS THERE SUFFICIENT STUDENT DEMAND FOR THE PROGRAM?

There is strong interest in this type of program based on our conversations with managers in the mineral industry and potential students. The interest is particularly strong in Latin America, but we have also received inquiries from young professionals elsewhere, including from the Tucson area. We project three students enrolled in the first year, rising to eight students after five years, with many students completing the degree in about one year. A key to the success of the program over the long term will be to seek endowed scholarships, to damp the effects of enrollment downturns related to periods of industry recession (when financial support from industry might diminish) and extraordinary boom (when industry is so short handed that they could be reluctant to encourage employees to leave their jobs). For comparison, the largest such program in the world (CODES at the University of Tasmania, Australia) has about 15 students enrolled per year, and the most similar program in North America (MinEx Program of Queen’s University, Ontario) limits enrollment to 8 – 10 students per year. When initiated, we would have the only such program in the United States.

1. What is the anticipated student enrollment for this program?

5-year Projected Annual Enrollment (1st year denotes year of inception)

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<tr>
<th>5-YEAR PROJECTED ANNUAL ENROLLMENT</th>
<th>1st yr.</th>
<th>2nd yr.</th>
<th>3rd yr.</th>
<th>4th yr.</th>
<th>5th yr.</th>
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<tbody>
<tr>
<td>No. Student Majors</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>7</td>
<td>8</td>
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Hence, we are aiming to grow to a steady-state level of eight per year, and the program has the resources to handle up to ten new enrollees per year.

2. What is the local, regional, and national need for this program?

The size of the global industry continues to grow with increase in population and the ceaseless demand for a higher standard of living, which requires mineral products. The industry has historically had an important role in the state, and it remains a significant part of the economy and a source of high-paying jobs. Arizona is the country’s leading producer of copper and mined gemstones and is the state with the fourth-largest production of construction materials (sand and gravel). Even during the industry’s long slump in the last decade, the direct value (excluding economic multipliers) of Arizona’s annual mineral production was well over two billion dollars, and it now exceeds three billion dollars. The industry turned
around several years ago and is now in a boom period: a new copper mine is being constructed near Safford; a major new copper deposit is in the early stages of development near Superior; and exploration activity in Arizona has returned to vigorous levels.

Even as mineral production gradually shifts more to developing and underdeveloped countries, Arizona and the West remain geology and mining centers. The developing world depends on the United States for leadership in education and research, and the bulk of the educational infrastructure for mineral resources resides in the West. The University of Arizona is the only major research university with a major program in mineral resources.

Although little known to most of the residents, Tucson and the surrounding region constitute a major hub of knowledge and technology in the mining industry. In addition to companies that extract and process earth materials, the area is home to a high-tech mining communications company, a mining software company, a mining equipment testing ground, and consulting companies in such fields as rock mechanics, ore reserve estimation, mining hydrology, and underground mining techniques. The Geosciences Department in the College of Science and the Department of Mining and Geological Engineering in the College of Engineering at the University of Arizona have global reputations in the minerals industry.

3. Beginning with the first year in which degrees will be awarded, what is the anticipated number of degrees which will be awarded each year for the first five years?

| PROJECTED DEGREES AWARDED ANNUALLY |
|------------------|------------------|------------------|------------------|------------------|------------------|
|                  | 1st year | 2nd year | 3rd year | 4th year | 5th year |
| No. Degrees      | 2        | 3        | 5        | 6        | 7        |

We expect to be flexible in how students can complete the degree, but these estimates assume that many students will adopt an aggressive schedule and complete the program in about one year.

IV. APPROPRIATENESS FOR THE UNIVERSITY

This Master’s Degree program promotes virtually all the missions of the University of Arizona. The University of Arizona is the most appropriate location for this endeavor because of the strong Geosciences Department and internationally renowned program in Economic Geology, the growing importance of the Professional Master’s Program in the College of Science, and the presence of supporting components in the College of Engineering, the Eller College of Management, and the Rogers College of Law.

IV. EXISTING PROGRAMS AT OTHER CAMPUSES

A. EXISTING PROGRAMS IN ARIZONA

1. There are no existing programs at other campuses of Arizona public universities that duplicate the proposed program.

2. Other Institutions--Also, there are no existing programs offered by private institutions in the state of Arizona that duplicate the proposed program.

B. PROGRAMS OFFERED IN OTHER WICHE STATES

1. To our knowledge, there are no other such programs anywhere else in the country,
much less in the western states region.

V. EXPECTED FACULTY AND RESOURCE REQUIREMENTS

A. FACULTY

1. Current faculty. A new endowed chair, the Lowell Chair in Economic Geology, provided the opportunity to add a faculty member in the Department of Geosciences, in part to initiate and direct this program: Eric Seedorff, Associate Professor, Ph. D. (see attached vita)

2. Additional Faculty. No other additional faculty are needed to implement this program.

3. Current FTE Students and Faculty. There are approximately 150 FTE students and 28 FTE faculty in Geosciences.

4. Projected FTE Students and Faculty. As a result of the addition of the proposed program, there would be no change in the number of FTE faculty, but the number of FTE graduate students would increase by 3, 4, and 5 students, respectively over the next three years.

B. LIBRARY

1. Current Relevant Holdings. Current library holdings in the geology and mining sections of the Science and Engineering Library are adequate for this program.

2. Additional Acquisitions Needed. No additional acquisitions are needed.

C. PHYSICAL FACILITIES AND EQUIPMENT

1. Existing Physical Facilities—The physical facilities and equipment in the Gould-Simpson Building, such as laboratories and student office space, are adequate for the proposed program.

2. Additional Facilities Required or Anticipated. No additional physical facilities or equipment are required or anticipated for the proposed program.

D. OTHER SUPPORT

1. Other Support Now Available. Current Geosciences support staff are adequate for the proposed program.

Other Support Needed, Next Three Years. No additional support staff are needed for the proposed program.

VII. FINANCING

A. SUPPORTING FUNDS FROM OUTSIDE SOURCES
Individuals and companies in the mineral industry have expressed an interest in supporting scholarships for the program once it is formally approved.

**B. NEW ACADEMIC DEGREE PROGRAM BUDGET PROJECTIONS FORM**

The operating funds of the Chair and revenues from courses taught as continuing education will support operations, recruitment, the web site, and other administrative costs. There are no impacts on the Geosciences departmental budget.

**VII. OTHER RELEVANT INFORMATION**

As part of a national initiative, the Alfred P. Sloan Foundation has funded the implementation of new science master's programs at a number of American universities. The proposed Professional Science Master’s in Economic Geology is consistent with Foundation’s attempt to promote ways to bridge the gap between science and business, so that universities provide the types of students that are trained to become the future leaders of industry. The Lowell Program in Economic Geology would be affiliated with the Professional Master’s Degree Program of the College of Science at the University of Arizona, joining the existing programs in Applied and Industrial Physics, Applied Biosciences, and Mathematical Sciences. The Sloan Foundation supported launching of those programs, as well as the one track in bioinformatics at Arizona State University.

Approval of a PSM in Economic Geology at the University of Arizona guarantees listing in the PSM national data base and on the PSM web site. Approval also would provide opportunities to interact with many other PSM programs in geology, geographical information systems (GIS), and environmental science. The Lowell Program would be part of a national community of similar programs that is gaining greater attention.
ERIC SEEDORFF

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Professional preparation
University of California at Davis, B. S. in Geology, 1977
Stanford University, M. S. in Ore Deposits and Exploration Program, Department of Applied Earth Sciences, 1981
Stanford University, Ph. D. in Ore Deposits and Exploration Program, Department of Applied Earth Sciences, 1987

Honors and awards
Brian J. Skinner Award for outstanding paper of 2004 in Economic Geology, Society of Economic Geologists

Appointments
1/02-Present: University of Arizona. Associate Professor, Lowell Chair in Economic Geology, Department of Geosciences, College of Science; Courtesy appointment, Department of Mining and Geological Engineering, College of Engineering and Mines
3/00-1/02: University of Arizona. Adjunct Professor, Department of Geosciences
9/99-1/02: Specialty Product Systems, LLC. Co-founder and Vice President Business Development, Tucson, Arizona
4/96-2/99: BHP Copper, Vice President Mineral Resources, Tucson, Arizona
2/95-3/96: Magma Copper Company, Chief Geologist, Tucson, Arizona
1/92-1/95: Magma Copper Company, Chief Mine Geologist, Robinson Project, Ruth, Nevada
4/91-1/92: Magma Copper Company, Staff Geologist, Robinson Project, Ruth, Nevada
1/90-2/91: WestGold, Senior Geologist, Reno, Nevada
9/87-12/89: Chevron Resources Company, Geologist, Reno, Nevada

Five publications most relevant to proposed research

**Five other publications**


**Synergistic Activities**

Director, Lowell Program in Economic Geology, Department of Geosciences, Univ. Arizona

Industry Leadership Board, Department of Mining and Geological Engineering, Univ. Arizona, member 2004-present


**Advisor**

Marco T. Einaudi, Stanford Univ. (M.S., Ph.D.)

**Collaborators during last five years**

Barton, M.D., Univ. Arizona; Dilles, J.H., Oregon State Univ.; Einaudi, MT., Stanford Univ.,


ETH Zürich; Landtwing, M.R., ETH Zürich; Maher, D.J., Univ. Arizona; Proffett, J.M., Jr.,

Geologic Consultant, Shaver, S.A., Univ. of the South; Stein, H.J., Colorado State Univ.;

Zurcher, L., Univ. Arizona

**Graduate students**

Keeler, D. A. (M. S.), Maher, D. J., (co-advising Ph. D.), Stavast, W. J. A. (Ph. D.), Takaichi, M. L. (M.S.); Total number of graduate students advised: 4; Total number of postdoctoral scholars sponsored: 0.