Status of Mineralogy and Petrology in U.S. Higher Education

Ann Benbow, Mineralogical Society of America; Carol Frost, University of Wyoming;

Sean Navat Balanon, Mineralogical Society of America

June 2022

A. Executive Summary

The expertise of mineralogists and petrologists is critical as society transitions to clean energy sources and advanced technologies, while sustaining a healthy natural environment. To assess the training of these geoscientists, in mid-2020, the Mineralogical Society of America's (MSA) Council voted to support a study examining the status of mineralogy and petrology teaching in U.S. institutions of higher learning. A comprehensive survey instrument was developed in 2021, piloted with 20 geoscience faculty members from across the U.S., revised, and distributed to an additional 73 institutions of higher education. Survey items included (among others): Demographic information, numbers of mineralogy and petrology courses taught, courses added or deleted over the past five years, resources used to teach the courses, whether courses had a field and/or laboratory component, average enrollment numbers, enrollment trends, levels at which courses were taught, degrees awarded, hiring prospects, key knowledge and skills for mineralogy and petrology, teaching suggestions, and interest in mentorship. Key findings were: The trend in enrollment in mineralogy and petrology courses over the past five years is decreasing; faculty emphasize content in teaching mineralogy and petrology, yet their teaching suggestions stressed teaching in context and including more about instrumentation; environmental companies are doing much of the hiring of mineralogy/petrology graduates at all levels, however, mining is perceived to have the greatest need for graduates in these fields; there is strong support for a mentorship program for mineralogy/petrology students that includes involvement by potential employers; there is a perceived decrease in demand for graduates trained in mineralogy/petrology concepts and skills; and, while 38 mineralogy/petrology courses were removed from institutions over the past five years, 30 new courses in those fields were added.

B. Methodology

In 2021, a survey (Appendix A) was created, reviewed, piloted with 20 faculty members, and revised for wider distribution (Appendix B). The survey was emailed to 174 MSA members in all 50 states. Seventy-four completed surveys were returned via email from 73 institutions in 37 states for a response rate of 43 percent. Respondents ranged in years of teaching from two to 40 years, with a mean of 19 years and a mode of 13 years. All responding institutions offered either B.S. or B.A. degrees in geology/geosciences. Forty-four offered all three levels of geoscience degrees: Bachelor's, Master's, and Ph.D. Twenty offered only Bachelor's degrees. Across all reporting institutions, the average number of Bachelor's students over the past two years was 14 (range 1-60); Master's was 6 (range 1-42) and Ph.D. was 5 (range 1-10).

The survey items covered these areas: Mineralogy and petrology courses offered; typical enrollment in those courses; labs, project work, and field trip components; textbooks and other materials used for instruction; syllabi; trends in enrollment and completed degrees in the past five years; key concepts and skills taught; entities hiring graduates at various levels; teaching and student recruitment/retention suggestions; and an indication of respondents' interest in serving as mentors.

The survey instrument was divided into four sections: Section A was demographic information, which is summarized in this section of this report. The items in Section B pertained to specific courses taught; Section C asked about student enrollment, degrees awarded, and hiring prospects for graduates; and Section D consisted of general questions about important knowledge and skills gained from study in the field; how to improve teaching; and respondents' opinions on the status of mineralogy and petrology in higher education.

C. Limitations

The study was limited to institutions of higher education in the U.S. and the data collected were dependent upon voluntary responses from academic members of MSA. Not everyone who returned a survey responded to all items.

D. Findings

Section A: Demographics

See the Methodology section above.

Section B: Courses

Item 1: *Number of mineralogy courses offered in institutions of higher education.*

Almost 60 percent of the institutions surveyed offered at least one course in mineralogy (Table 1).

Table 1: Numbers of mineralogy courses offered in institutions of higher education

Number of courses	Tally	Percentage
One	39	58.2
Two	23	34.3
More than two	5	7.5
Total	67	100.0

Item 2: *Number of petrology courses offered in institutions of higher education.*

Slightly over half of institutions surveyed offered at least one petrology course. However, there are a significantly greater number of institutions offering more than two petrology courses than those offering more than two mineralogy courses.

Table 2: Numbers of petrology courses offered in institutions of higher education

Number of courses	Tally	Percentage
One	33	50,8
Two	17	26.1
More than two	15	23.1
Total	65	100.0

Items 3 and 4: *Numbers of institutions offering laboratory and field components with their mineralogy and petrology courses.*

Mineralogy and petrology courses are fairly equivalent in their laboratory requirements, but quite opposite in their requirements for field components (Table 3).

Table 3: Numbers of mineralogy and petrology courses with lab and field components

	Min w/ Lab	Min w/o Lab	Total Min
	109	20	129
Percentages	84.5	15.5	100.0
	Pet w/ Lab	Pet w/o Lab	Total Pet
	81	16	97
Percentages	83.5	16.5	100.0
	Min w/ Field	Min w/o Field	Total Min
	42	87	129
Percentages	32.6	67.4	100.0
	Pet w/ Field	Pet w/o Field	Total Pet
	59	35	97
Percentages	60.8	39.2	100.0

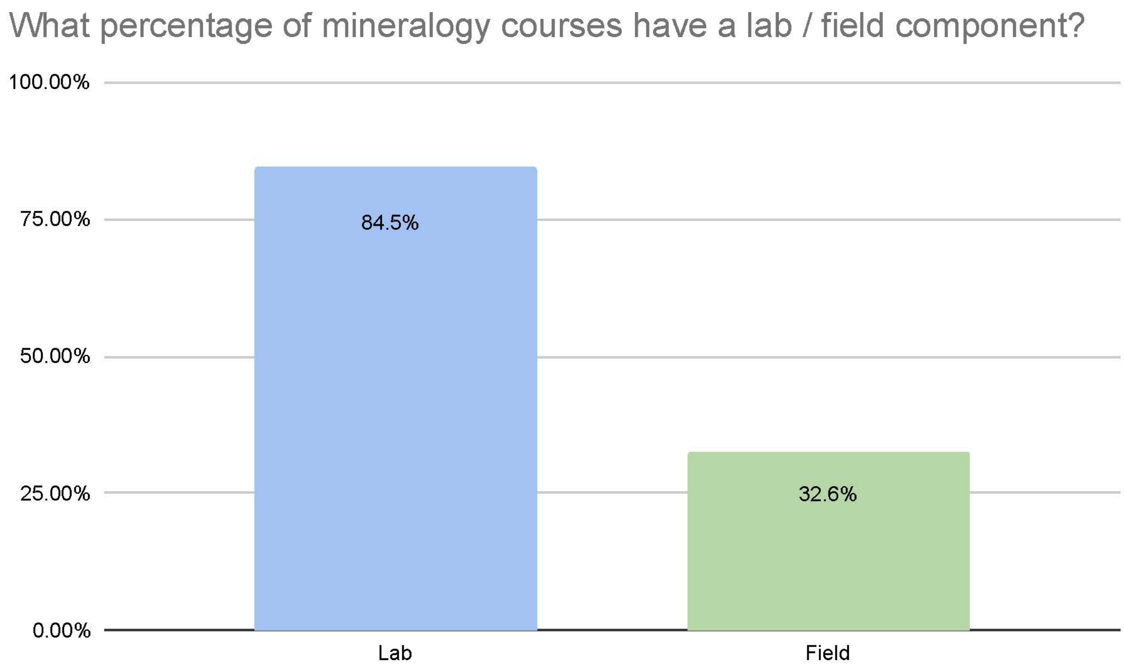

Figure 1: Percentage of mineralogy courses with laboratory and field components.

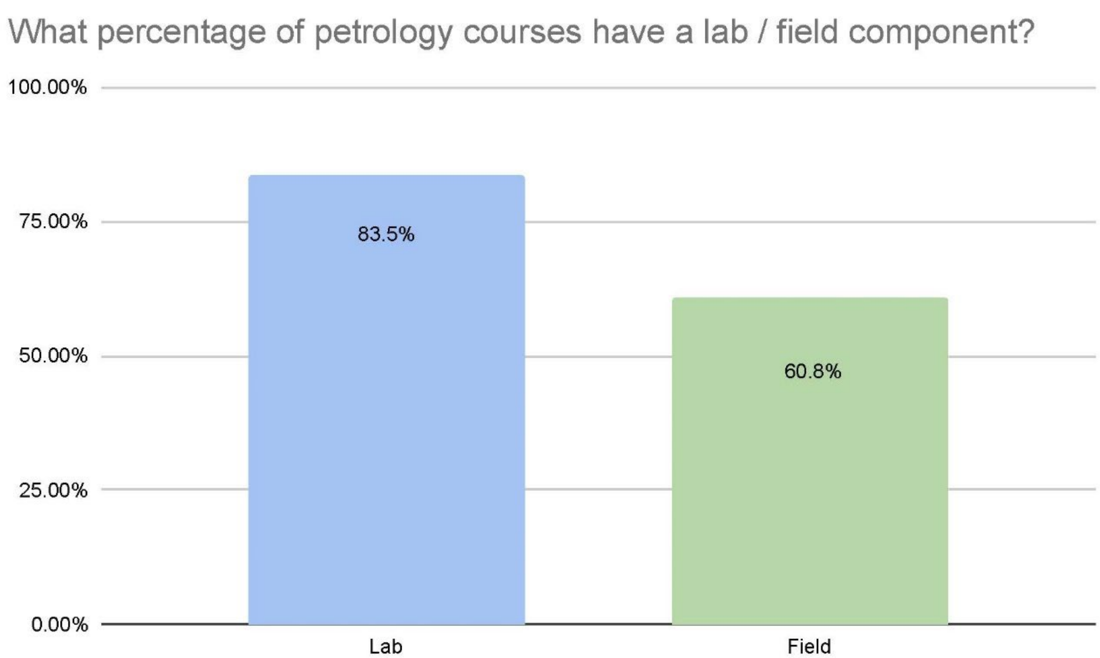

Figure 2: Percentage of petrology courses with laboratory and field components.

Items 5 and 6: *Levels at which mineralogy and petrology courses are taught*

Both mineralogy and petrology are most commonly taught at the 300 level, but both types of courses are offered at every level (Table 4).

Table 4: Levels at which mineralogy and petrology courses are taught

Mineralogy Level	Courses Offered	% of level offered
100 level	9	8.6
200 level	32	30.4
300 level	42	40.0
400 level	13	12.4
500+ level	9	8.6
Total	**105**	100

Petrology Level	Offered	% of level offered
100 level	14	11.5
200 level	17	13.9
300 level	41	33.6
400 level	30	24.6
500+ level	20	16.4
Total	**122**	100

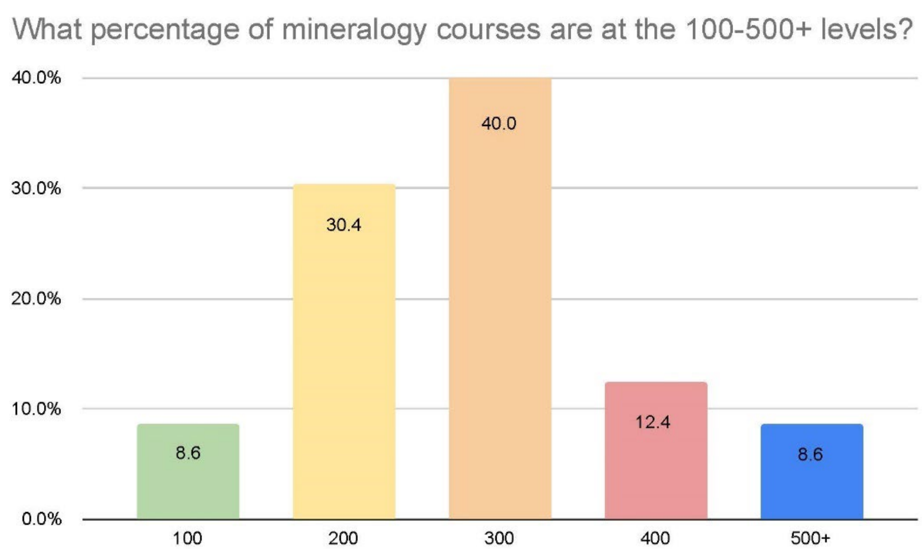

Figure 3: Percentage of mineralogy courses at the 100 – 500+ levels

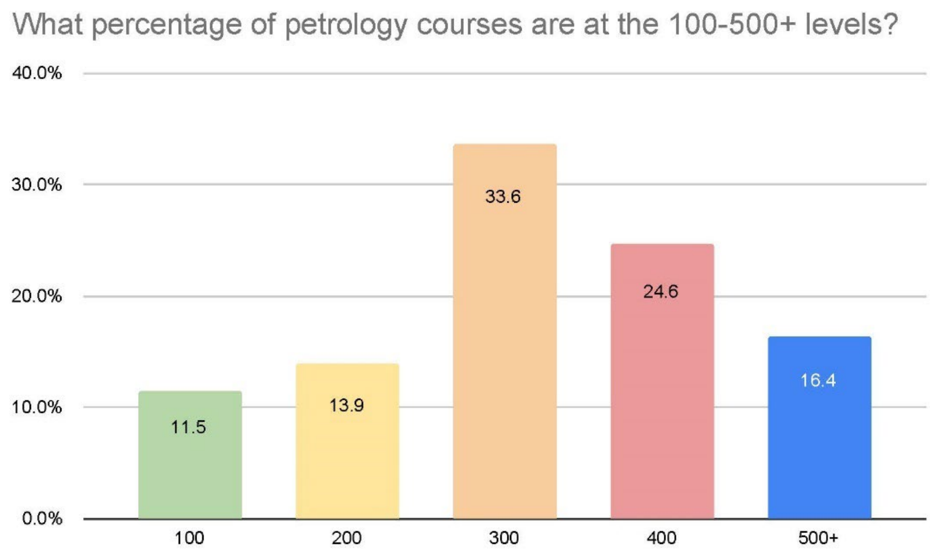

Figure 4: Percentage of petrology courses at the 100 – 500+ levels

Items 7 and 8: Departments in which mineralogy and petrology are taught

As might be expected, the majority of mineralogy and petrology courses are taught in geology/geoscience/Earth sciences departments, but there is some representation in departments of environmental science (Table 5).

Table 5: Departments in which mineralogy and petrology are taught

Departments	# Departments	# Min Courses	% Min Courses
Geology	23	40	38.1
Earth Sciences	20	27	25.7
Environmental	10	12	11.4
Geoscience	20	26	24.8
Totals	73	105	100.0

Departments	# Departments	# Pet Courses	% Pet Courses
Geology	23	35	28.7
Earth Sciences	20	37	30.3
Environmental	10	21	17.2
Geoscience	20	29	23.8
Totals	73	122	100.0

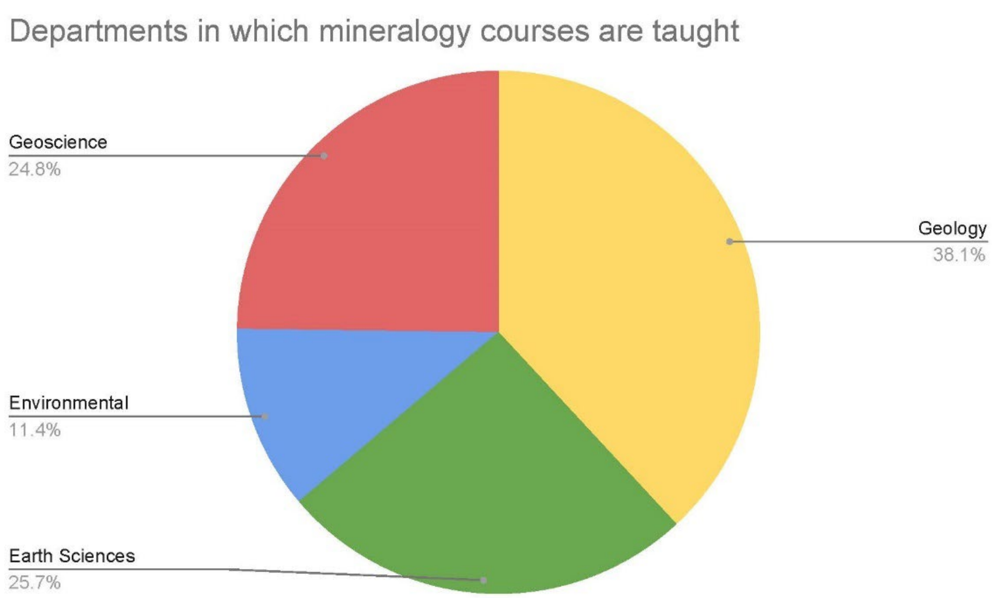

Figure 5: Departments in which mineralogy courses are taught

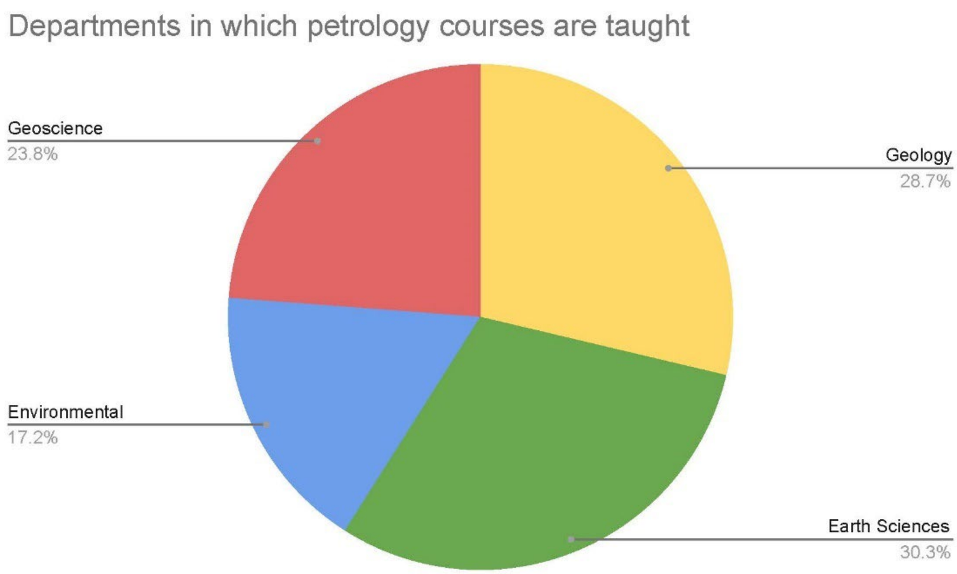

Figure 6: Departments in which petrology courses are taught

Items 9 and 10: *Are mineralogy and/or petrology required for a major in your institution?*

In 87.7 percent of the 73 institutions that responded to this item, mineralogy is required for a major. For petrology, this drops to 57.5 of the institutions (Figure 7).

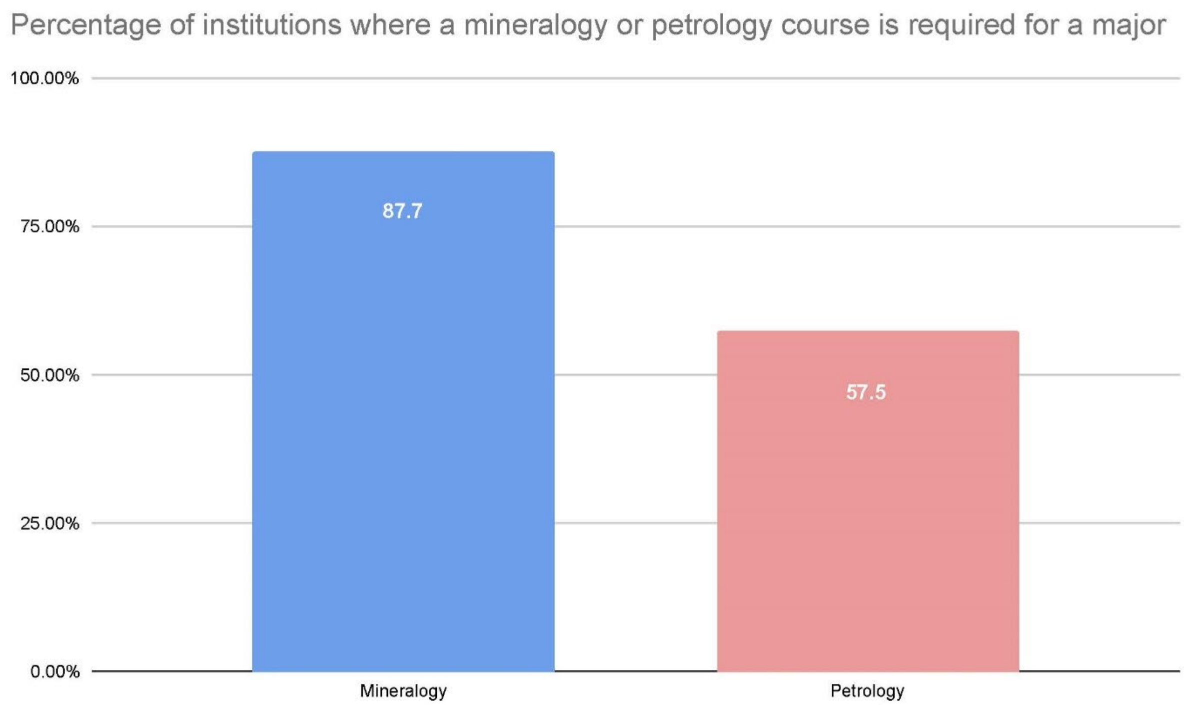

Figure 7: Percentages of institutions where a mineralogy or petrology course is required for a major.

Items 11 and 12: *Which courses have been deleted* (Table 6) *and added* (Table 7) *at your institution over the past five years?*

Table 6: Courses Deleted

Course Title	# faculty cited	Reasons for Deletion
Mineralogy/Optical Min	22	Replaced min with Earth Materials – combined min and pet (9 mentioned this)
		Not enough room in students' schedules for min./credit hour limits (7 cited this)
		Retirement of faculty (5 cited)
		Not enough enrollment (2 cited)
		Expansion of environmental studies course
		Opt. Min was eliminated in 2008 – Environmental Geology degree was created
		Obsolete
Optical Petrology	1	No requirement for course
Petrology	3	Combined with min
		Faculty left (2 cited)
Clay Mineralogy	1	Faculty retired
Min/Pet course	1	Split into two courses
Physical Petrology	1	Faculty retired/departed
Petrology Lab	1	Merged into igneous and metamorphic petrology. Needed to reduce hours to accommodate Electron Microscopy
Adv. Ig. Petrology	2	Faculty retired (2 cited)
Earth Materials	3	Combined with petrology (2 cited)
		Faculty retired (2 cited)
Economic Geology	2	Lack of student interest (2 cited)
		Faculty retired
Chemical Thermodynamics for Geoscientists	1	Faculty retired

Table 7: Courses Added

Course Title	# faculty cited	Reasons for Addition
Non-renewable Natural Resources	1	Increased awareness of those resources
Inner Earth	1	Geochemistry and petrology with a modern view of Earth
Igneous and Metamorphic Petrology	1	Elective for students interested in the topic
Ore Deposits	2	Increased student interest in mining jobs
Field Petrology	1	New class focusing on petrology processes in the field

Analytical and Technical Lab	1	Course replaces optical petrology and intro to more contemporary methods
Petrology	3	New faculty to teach
		Replaced Earth Materials (min/pet combination)
Mineralogy & Crystallography	1	New syllabus emphasizing instrumentation
Earth Materials	4	Designed for teacher training
		Designed for engineers (non-major course)
Isotope Geochemistry	1	Grad course that undergrads can ask to take
Mineralogy, Rocks, Resources, and the Environment	1	New course to replace Earth Materials
X-Ray Powder Diffraction	1	New course to replace Earth Materials
Clay Analysis	1	New course to replace Earth Materials
Crystallization	1	New course to replace Earth Materials
Characteristics of Geological Materials	1	Students were interested in the topic
Advanced Petrology II	1	Students were interested in the topic
Optical Mineralogy and Petrology	2	Students were interested in the topic
		Decided to re-introduce mineralogy
Geology of the Solar System	1	New hire to teach the course
Earth's Deep Interior	1	New hire to teach the course
Volcanology	1	Student demand and instructor interest
Diffractometry	1	Faculty willing to teach it
Crystal Chemistry	1	Faculty willing to teach it
Microstructures	1	Faculty willing to teach it

Section C: Students

Item 1: *How many students graduate with degrees in geology (B.S., M.S., Ph.D.)?*

Sixty-eight (68) faculty surveyed completed this item. For B.S. graduates, the range was between one and 60 each year. Forty-three percent of the institutions reported between five and 10 B.S. graduates annually (Table 8).

Table 8: B.S. Graduates in geology per year

Range	BS	Percentages
1 to 4	4	6.0
5 to 10	29	43.0
11 to 15	11	16.0
16 to 20	9	13.0
20 to 25	7	11.0
>25	7	11.0
Total	67	100.0

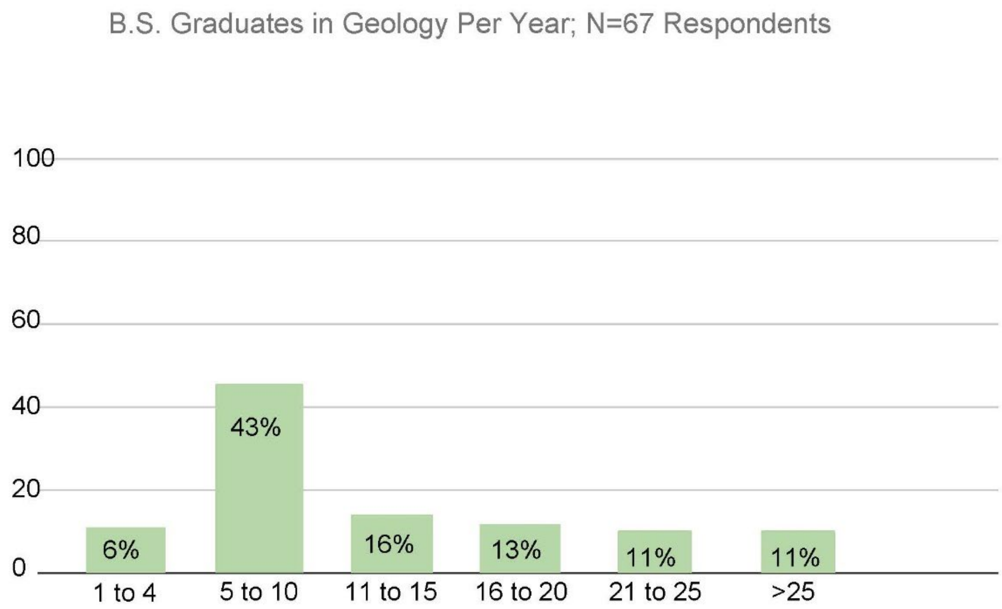

Figure 8: Percentages of institutions with B.S. graduates per year

At the M.S. level, the range was between one and 42 per year. The highest percentage of graduates (56 percent) also fell within the five to 10 range (Table 9).

Table 9: M.S. graduates in geology per year

Range	Count of students	Percentages
1 to 4	15	34.0
5 to 10	25	57.0
>10	4	9.0
Total	44	100.0

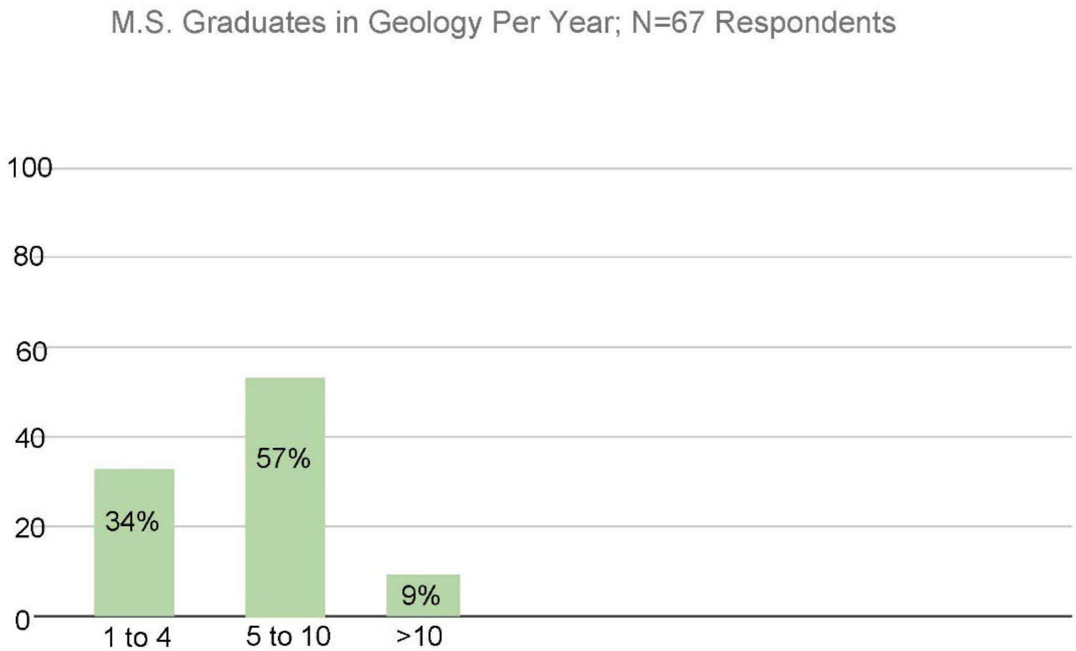

Figure 9: Percentages of institutions with M.S. graduates per year

At the Ph.D. level, the range was between one and ten each year. Once more, the highest percentage was at the five to 10 range annually (Table 10).

Table 10: Ph.D. graduates in geology per year

Range	Ph.D.	Percentages
1 to 4	20	49.0
5 to 10	21	51.0
>10	0	0
Total	41	100.0

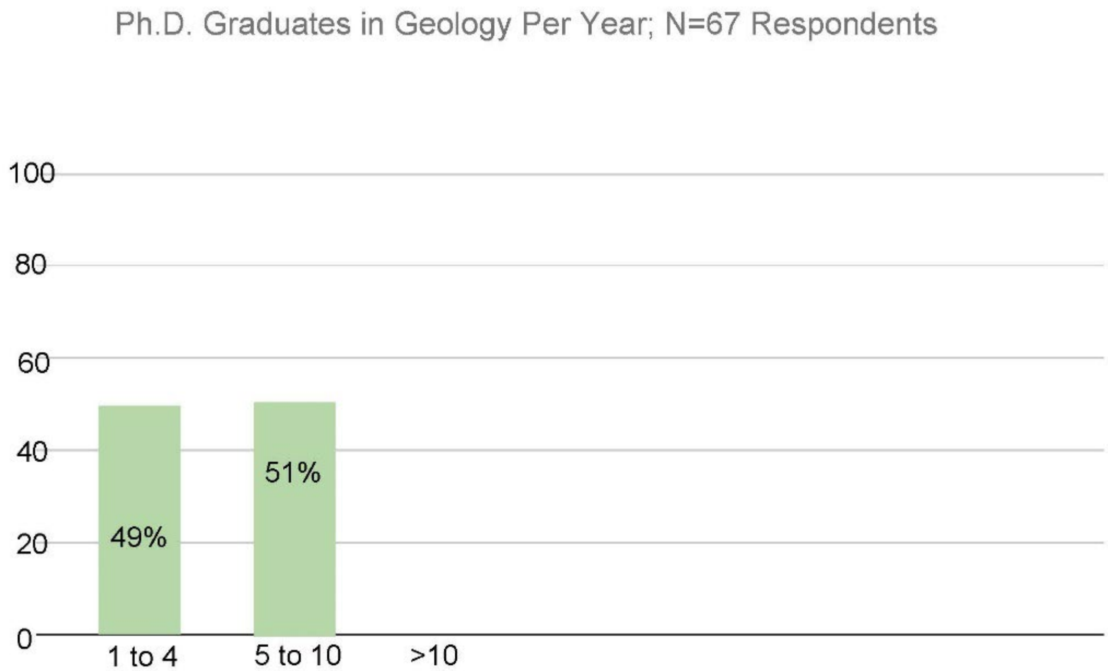

Figure 10: Percentages of institutions with Ph.D. graduates per year

Item 2: *Who is hiring your B.S. level graduates?*

The highest percentage of B.S. graduates were hired by environmental companies (20.9 percent), followed by state and local governments (14.6 percent), K-12 education (12.1 percent), and the energy industry (10.6 percent) (Table 11). The Other category for this item included: Geotech firms, media/communications, ceramics and manufacturing, and military and graduate school.

Table 11: Entities hiring B.S. graduates in geoscience

Entity Hiring	Tally	Percentage
Environmental Companies	63	20.9
State/local gov't	44	14.6
K-12 Education	36	12.1
Energy Industry	32	10.6
Mining	29	9.6
Federal agencies	26	8.6
Other	24	8.1
Higher Education	17	5.6
Recreational companies	17	5.6
IT companies	13	4.3
Total	301	100.0

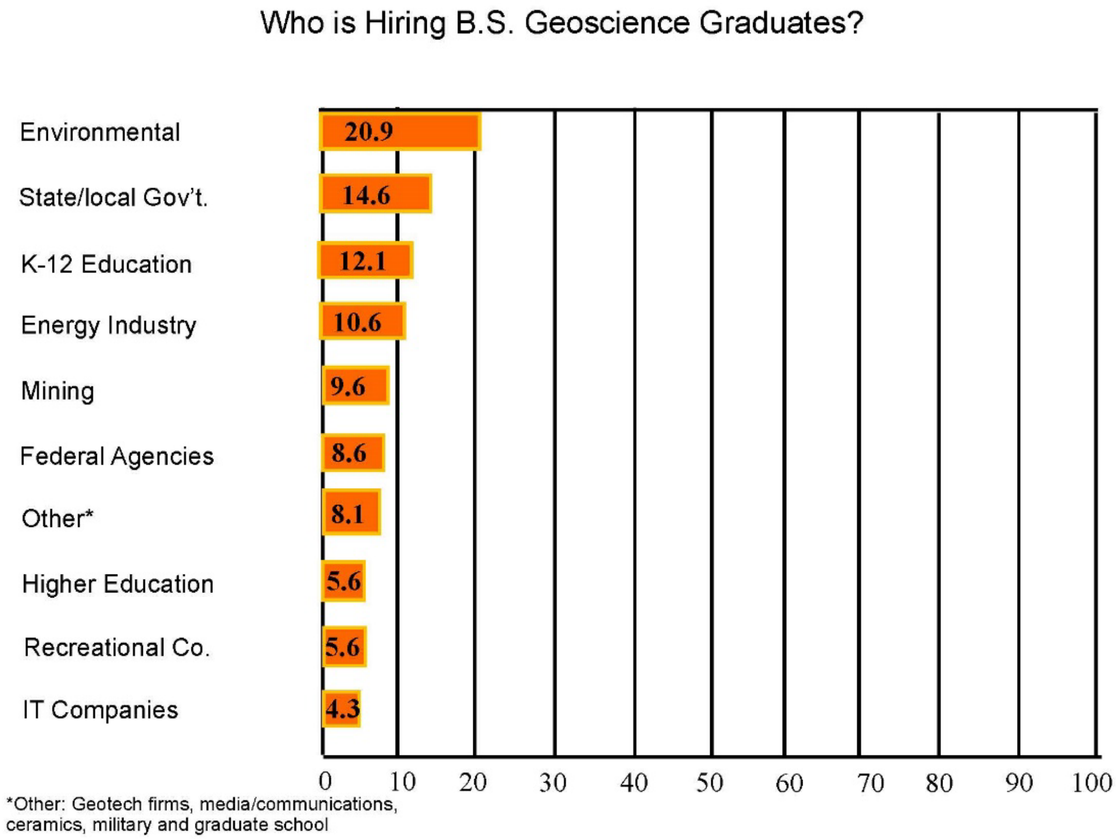

Figure 11: Entities hiring B.S. graduates in geoscience

Item 3: *Who is hiring your M.S. level graduates?*

As with B.S. graduates, most of those with M.S. degrees were hired by environmental companies (18.8 percent). This was followed by state and local governments (16.1 percent), the energy industry (15.6 percent), and the federal government (13.8 percent) (Table 12). The Other category for this item included: Geotech firms and graduate school (Table 12).

Table 12: Entities hiring M.S. graduates in geology

Entity Hiring	Tally	Percentage
Environmental Companies	42	18.8
State/local gov't	36	16.1
Energy Industry	35	15.6
Federal agencies	31	13.8
Mining	27	12.1
Higher Education	16	7.1
K-12 Education	16	7.1
Other	11	4.9
IT companies	6	2.7
Recreational companies	4	1.8
Total	224	100

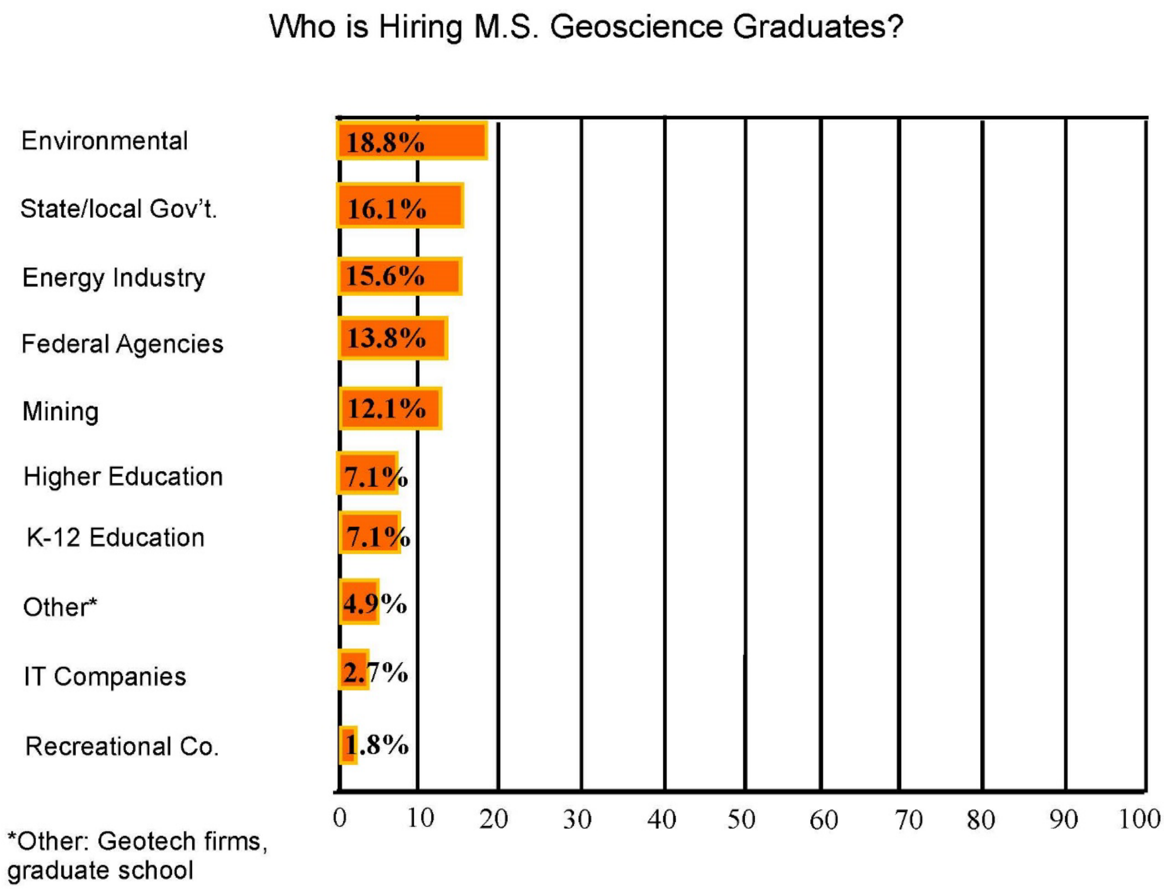

Figure 12: Entities hiring M.S. graduates in geoscience

Item 4: *Who is hiring your Ph.D. level graduates?*

Higher education is where most of the Ph.D. level graduates find jobs (20.7 percent), followed by federal agencies (18.1 percent), the energy industry (16.5 percent), and environmental companies (14.4 percent) (Table 13). The Other category for this item included: High tech materials and instrumentation companies, museums connected to universities, and geotech companies.

Table 13: Entities hiring Ph.D. graduates in geology

Entity	Tally	Percentage
Higher Education	39	20.7
Federal agencies	34	18.1
Energy Industry	31	16.5
Environmental Companies	27	14.4
State/local gov't	18	9.6
Mining	11	5.8
Other	10	5.3
K-12 Education	9	4.8
IT companies	9	4.8
Recreational companies	0	0
Total		100

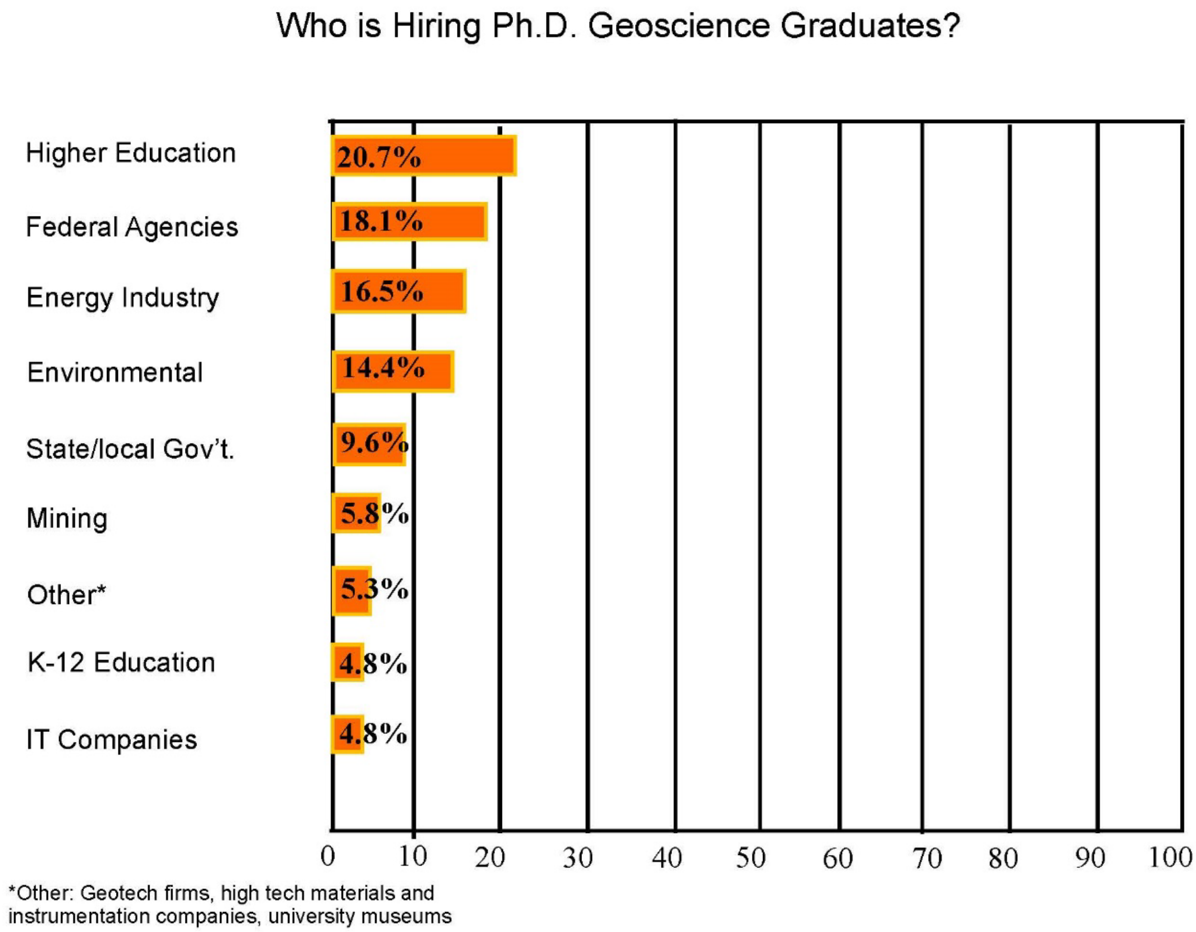

Figure 13: Entities hiring Ph.D. graduates in geoscience

Item 5: *How many declared geology majors do you currently have among freshmen, sophomores, juniors, and seniors?*

There were 56 respondents for this item. The percentage of declared geology majors in the sophomore and senior years was the same: 33.2 percent. This dropped to 24.8 percent in the junior year and 8.8 percent in the freshman year (Table 14).

Table 14: Declared geology majors across the four years of college.

	FR	SOPH	JR	SR	Total
Tally	272	1034	772	1034	3113
Percentage	8.8	33.2	24.8	33.2	100.0

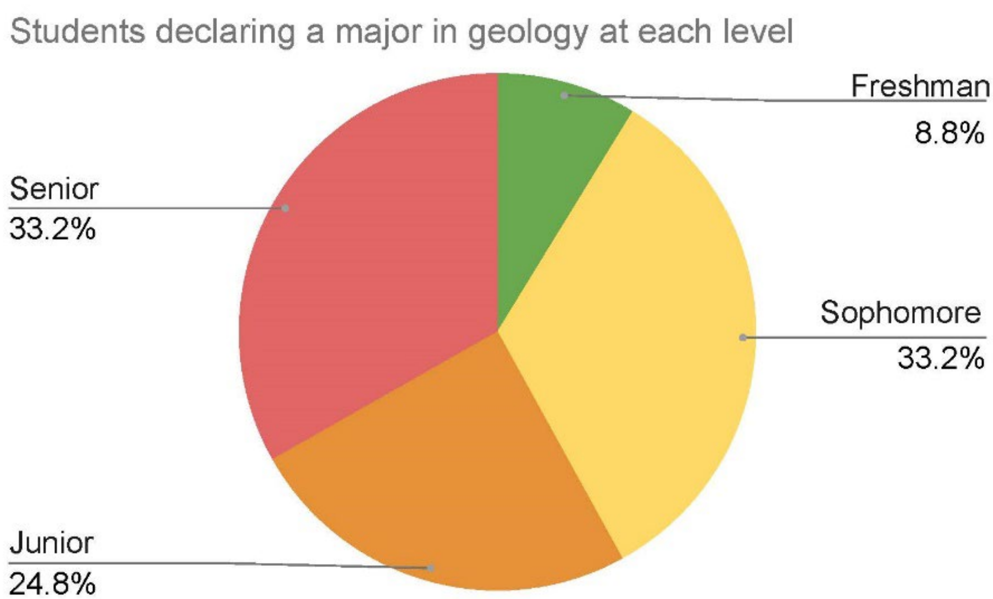

Figure 14: Students declaring a major in geology at each level

Item 6: *Over the past five years, have the overall numbers of declared geology majors increased, decreased, or stayed fairly constant?*

Of the 67 faculty who completed this item, 13.4 percent stated that their numbers increased, 56.7 percent reported a decrease, and 29.9 percent said that their numbers stayed fairly constant (Figure 15).

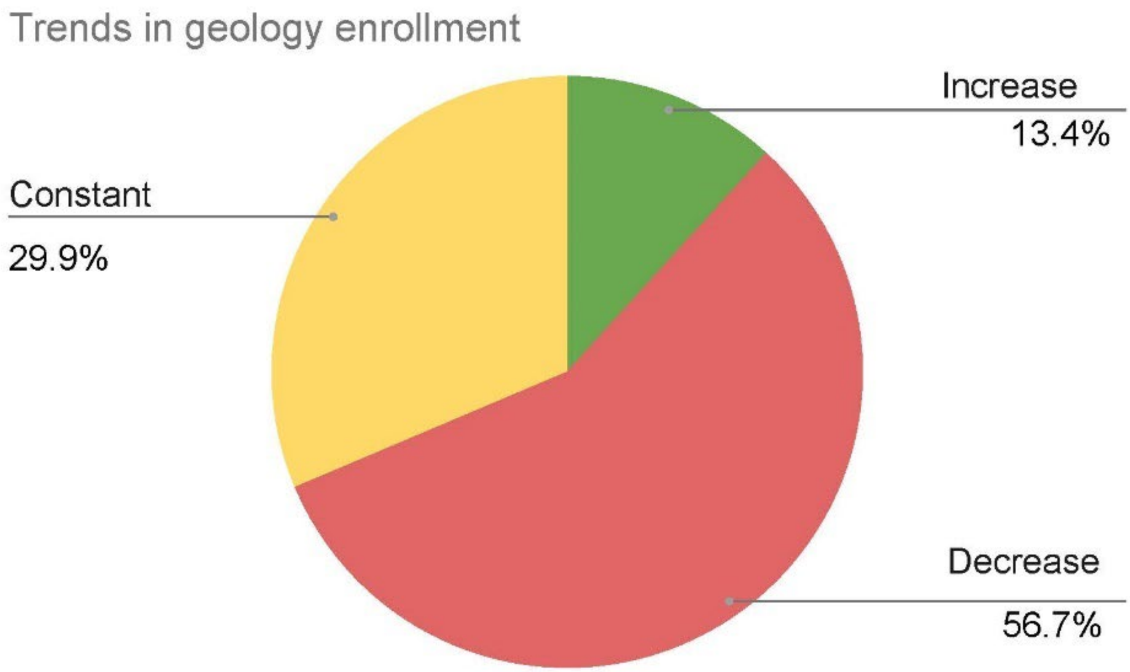

Figure 15: Trends in geoscience enrollment

Section D: General Questions

Item 1: *What are the most important concepts and skills gained from the study of mineralogy?*

Table 15 shows that mineral identification and knowledge of the relationship between crystal structure and mineral properties were thought to be equally important by the respondents and were at the top of the list. Other important concepts/skills were (in descending order): chemical composition of minerals; conditions for forming minerals; being able to think in 3D; and the importance of minerals to human society. Sixty-seven (67) people responded to this question.

Table 15: Important concepts and skills in mineralogy

Concept	Tally	Percentage
Mineral identification	28	42.0
Crystal structure relating to mineral properties	28	42.0
Chemical composition of minerals	21	31.0
Conditions for forming minerals	20	30.0
Thinking in 3D	13	19.0
Minerals and society	12	18.0
Physical and chemical properties of minerals	11	16.0
Problem solving/thinking logically	10	15.0
Rocks and their relation to minerals	9	13.0
Optical mineralogy	6	9.0
Observations to interpretation	6	9.0
Using instrumentation	5	7.0
Recording and reporting data	4	6.0
Mineral classification	3	5.0
Using mineralogy to interpret Earth's past	3	5.0
Mineralogy related to other sciences	2	3.0
Ability to analyze the literature	2	3.0
Phase diagram	2	3.0
Thermodynamics	2	3.0
Mineral evolution	2	3.0
Physical processes and equations	2	3.0
Participating in mineralogical organizations	1	2.0
Measurement and statistics	1	2.0
Systems thinking	1	2.0
Planetary differentiation	1	2.0

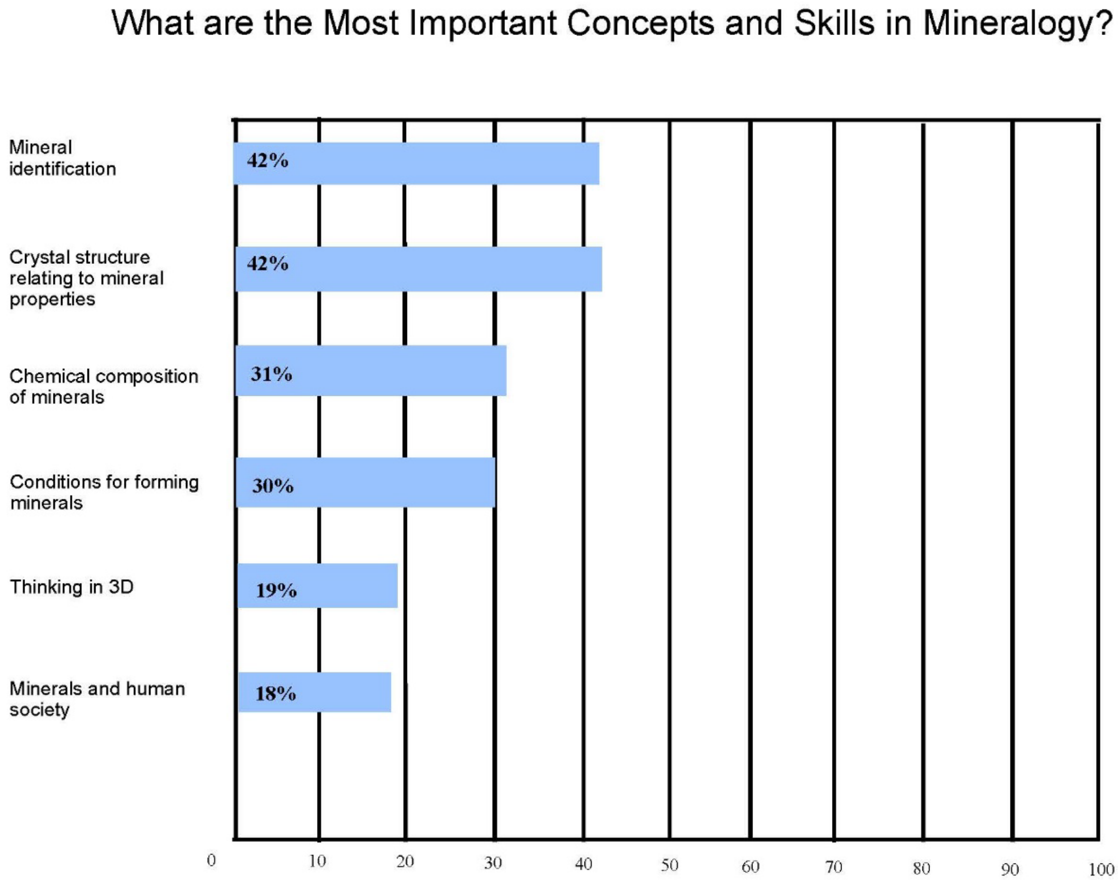

Figure 16: The most important concepts and skills in mineralogy

Item 2: *What are the most important concepts and skills gained from a study of petrology?*

Those concepts/skills cited by the 36 percent or more respondents were, in descending order: knowledge of conditions and contexts for petrogenesis; rock identification and description; knowledge of Earth processes through rocks; use of observational skills and tools (including lab equipment); and the relationship between chemistry, minerals, and rocks. Table 16 contains the entire list. Sixty-nine (69) people responded to this question.

Table 16: Important concepts and skills in petrology

Concept	Tally	Percentage
Knowledge of conditions and contexts for petrogenesis	33	48.0
Rock identification and description	27	39.0

Knowledge of Earth processes through rocks	27	39.0
Relationship between chemistry, minerals, and rocks	25	36.0
Use of observational skills and tools (including lab equipment)	23	33.0
Using data and databases to solve scientific problems	18	26.0
Use of thermodynamics to predict or interpret rock formation	14	20.0
Use of phase diagrams in petrology	14	20.0
Conducting a research project and presenting results	12	17.0
Difference between mineral assemblages and associations	11	16.0
Rock classification schemes	10	14.0
Data documentation and synthesis	4	6.0
Working in the field	3	4.0
Knowledge of Earth's interior	3	4.0
Optical properties	3	4.0
Integrating physics and chemistry in petrology	2	3.0
Connections between petrology and other sciences	2	3.0
Petrology's importance to society	2	3.0
Knowledge of rock and mineral distribution in Earth	1	3.0
Chemical and mechanical differentiation of planets through time	2	2.0
Learning how to work in a group	1	1.0
Role of water in the carbonate/silicate cycle	1	1.0
Mountain building processes	1	1.0
Natural hazards	1	1.0
Thinking in 3D	1	1.0
Petrology is on the professional geologist licensure exam	1	1.0

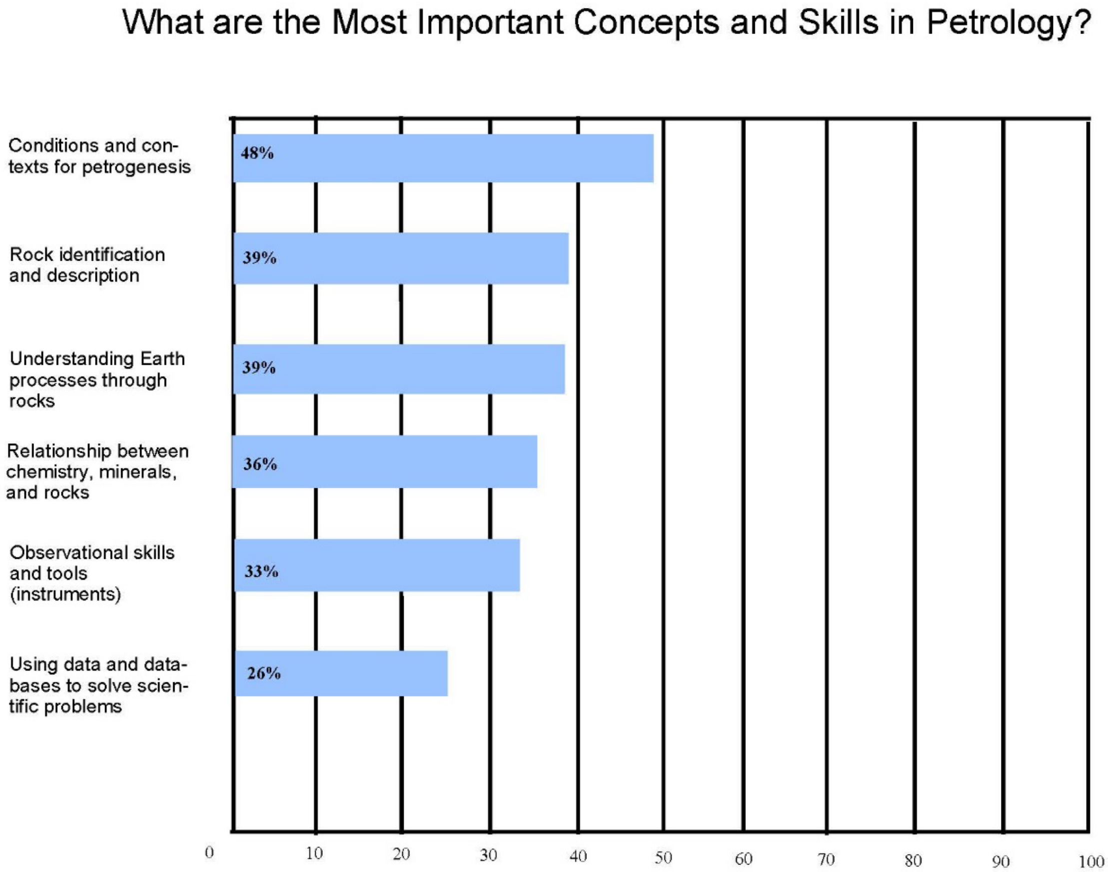

Figure 17: The most important concepts and skills in petrology

Item 3: What employers, in your opinion, depend most on hiring students trained in mineralogy and petrology?

Over half of the sixty-nine (69) respondents named mining as their number one category. This was followed by environmental companies (43 percent); oil and gas industries (28 percent) and federal agencies and education (both with 26 percent). Table 17 shows the complete list.

Table 17: Employers depending on knowledge of mineralogy/petrology in their hires

Employers	Tally	Percentage of respondents who mentioned this category
Mining	36	52.0
Environmental	30	43.0
Oil and gas (energy industries)	19	28.0
Federal agencies	18	26.0
Education	18	26.0
Materials science	11	16.0
State agencies	11	16.0
Chemical manufacturers	5	7.0
Outreach (museums, parks, etc.)	5	7.0
Microscopy	5	7.0
Geotechnology companies	5	7.0
Engineering	4	6.0
Gemology	4	6.0
Construction/concrete	3	4.0
Soil science	3	4.0
Analytical labs	3	4.0
Policy	1	1.0
Anthropology jobs	1	1.0
Economic geology	1	1.0
Nonprofits	1	1.0
Medicine	1	1.0
Total	185	

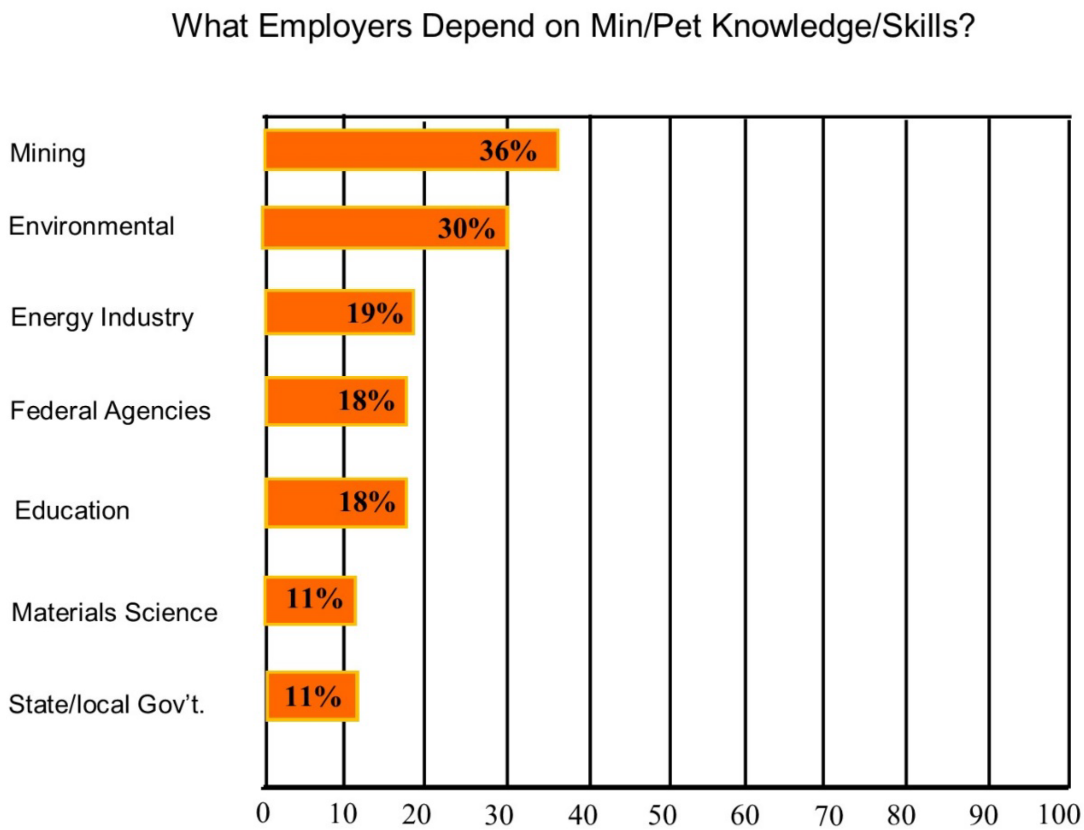

Figure 18: Employers that depend on min/pet knowledge and skills

Item 4: *Do you think that the demand for skilled mineralogists and petrologists is increasing or decreasing? Why?*

Forty percent of respondents thought that the demand was decreasing; 21 percent thought that it was increasing; nineteen percent thought that demand was holding steady; and nineteen percent didn't know. The reasons for the opinions are listed below.

Reasons the demand is increasing

1. Demand for environmental mitigation/monitoring
2. Need for rare Earth minerals
3. Climate change and need for "green" materials
4. Need for materials scientists
5. Mining still needs min/pet knowledge and skills
6. Increased attention on infrastructure revitalization

Reasons the demand is decreasing

1. Decline on mining industry
2. Not enough emphasis on teaching SEM, XRD, laser raman
3. Pandemic
4. Colleges are introducing more diverse courses, leaving little room for min/pet courses
5. Funding agencies are not supporting min/pet research – not transformative enough
6. Min/pet students now needs a wider variety of skill sets
7. Fewer jobs out there that require the physical evaluation of samples; rise of computational assessment techniques
8. Move to mining outside the U.S.
9. Min/pet may be considered "old fashioned" or "low-tech"
10. Increased emphasis on environmental concerns, rather than straight geology
11. Business hiring doesn't connect mineralogy to key geological problem solving

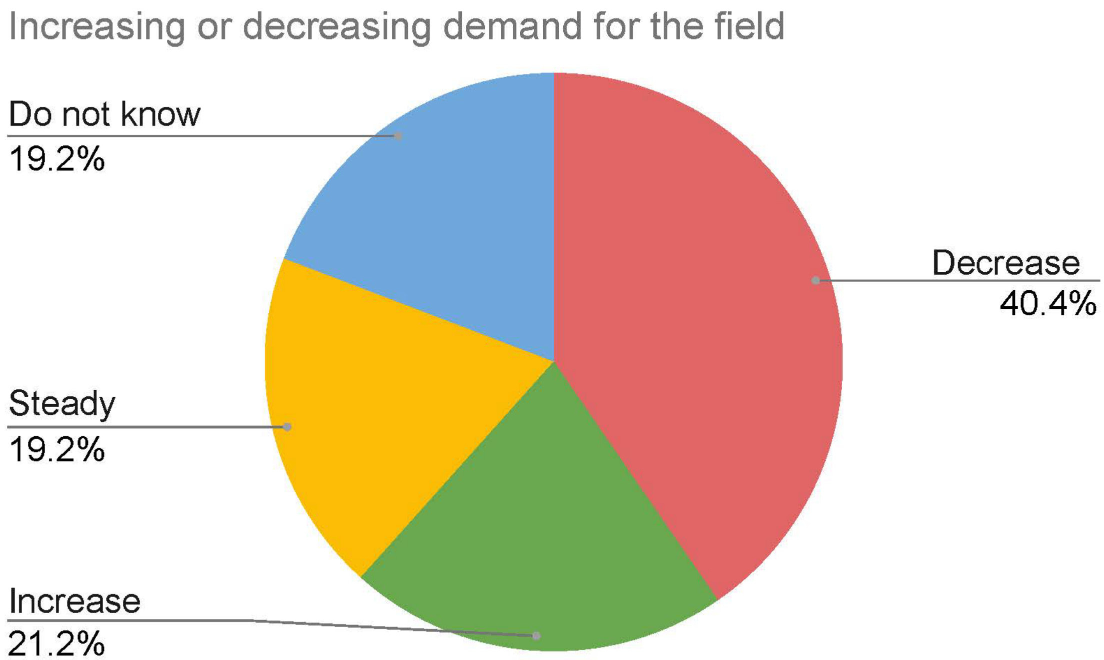

Figure 19: Increasing or decreasing demand for geoscientists

Item 5: *What do you think should be changed, if anything, in the way mineralogy and petrology are taught to make the field relevant and useful for today's undergraduates?*

The suggestion offered by the most respondents was to make connections between the course content and the needs of human society (22.4 percent). Specifically, climate change, health, forensics, geohazards, rare Earth elements, and other resources. The next most popular suggestion overlaps somewhat with the first, as it was to focus on the research and applied aspects of the science. The focus on technology and making connections to other sciences tied as the third most mentioned suggestions. The remaining suggestions are in Table 18.

Table 18: Suggested changes to the ways in which mineralogy and petrology are taught

Change	Tally	Percentage
Make connections to society (climate change, health, forensics, geohazards, REES and other resources)	20	22.4
Focus on applied/research aspects of min/pet	13	14.6
Focus on technology, SEMs, XRD, etc.	10	11.3
Make connections to other sciences	10	11.3
Connect with materials science and engineering	6	6.7
Focus on careers	6	6.7
Emphasize chemistry/geochemistry	5	5.7
Focus on transferrable skills (problem solving, measurement, recording and reporting)	5	5.7
Teach in a broader geological context (tectonics, Earth's structure, minerals and magmas)	4	4.5
Don't water down or combine mineralogy and petrology	3	3.4
Make the course fun	2	2.2
Include fieldwork	2	2.2
Include real world projects	2	2.2
Start from where students are	1	1.1
Total responses	89	100

Item 6: Would you be willing to serve as a mentor to a student if MSA were to establish such a program?

Sixty-nine (69) percent of the respondents were willing to be mentors. Twenty-one (21) percent were not willing, mainly due to imminent retirement, overcommitments, and current involvement in a mentorship program. Ten percent of those who returned their surveys did not respond to this item.

E. Discussion

Course availability: Sixty (60) percent of institutions offered at least one mineralogy course. Therefore, forty (40) percent of institutions offered no mineralogy course. Over one-third of institutions offered two mineralogy courses, while only 7.5 percent offered more than two mineralogy courses. Half of the institutions surveyed offered one petrology course. However, twenty-three (23) percent offered more than two petrology courses.

These results suggest that more petrology courses are offered than mineralogy courses. It is likely that this reflects how petrology is broken into more parts, such as igneous and metamorphic and sedimentary, leading to a greater number of courses.

Laboratory and field components: Mineralogy and petrology are fairly equivalent in requiring a laboratory component, but opposite in field components. Fieldwork appears to be more vital to the teaching of petrology than mineralogy. This makes sense as it is important and relatively easy to see rocks in the field on student field trips. However, a laboratory component is equally important to both.

Levels at which courses are taught: Mineralogy and petrology are most commonly taught at the 300 level, but available at every level. A further study could collect information on prerequisites for the courses, particularly if only an introductory Earth science course is required which could tend to push most other geology courses to upper division.

Departments in which courses are offered: Mineralogy and petrology are overwhelmingly offered in Earth science/geoscience/geology departments, but there is some representation in environmental science departments. None of the institutions reported that mineralogy or petrology courses were taught in engineering or materials science departments. It appears that, in the institutions returning the surveys, that the courses are taught in the departments where they have traditionally been taught.

Requirements for a major: Almost ninety (90) percent of the institutions require mineralogy for a major, but only sixty (60) percent require petrology. This raises the question of whether petrology concepts are covered in other geology courses, thus lessening the need for requiring petrology, per se, for a major.

Percentage of geoscience graduates at various degree levels: The highest percentage of graduates at the B.S., M.S., and Ph.D. levels was between five and ten per year. The Ph.D. level seems to be fairly healthy, since the range of graduates was between one and ten per year. The picture is not as vibrant at the B.S and M.S. levels, as their ranges were between one and 60 and one and 42 per year.

Entities hiring geoscience graduates from different degree levels: The entities hiring B.S. graduates are (in descending order): environmental companies, state/local governments, K-12 education, and the energy sector. At the M.S. level, those hiring graduates are environmental companies, state/local governments, the energy sector, and the federal government. At the Ph.D. level, entities hiring are higher education, federal government, the energy sector, and environmental companies. The energy and environmental sectors are options at all levels. The federal government wants more than a B.S. degree to hire, however, state and local governments are options at both the B.S. and M.S. levels.

Declared majors: For declared geology majors: 33.2 % in both sophomore and senior years, but a lower percentage in the junior year (24.8%), where most majors are typically declared. Of the 57 institutions responding to this item, 38 (67.0%) reported that the number of seniors declaring a geology major was equal to, or greater than, the number of juniors making that declaration. Of that group of colleges, 28 institutions reported more seniors making the declaration than juniors. This seems to indicate a trend toward waiting to make that final decision.

Trends in the number of majors: Over the past five years, geology majors decreased (56.7 percent reported); increased (13.4 percent reported) and 29.9 percent reported that they stayed fairly constant. The trend seems to be that majors are decreasing.

Important concepts and skills in mineralogy (most popular, in decreasing order): Mineral identification; crystal structure and properties; chemical composition of minerals; conditions for forming minerals. Content is valued more highly than a focus on skills or placing concepts in context.

Important concepts and skills in petrology (most popular, in decreasing order): Petrogenesis, rock identification, using rocks to understand Earth processes, observation skills, chemistry and physics of rocks, thermodynamics, phase diagrams. Content is also valued most highly in petrology, with the exception of observation skills. Intrinsically, however, as petrogenesis is about the origins of rocks, this involves placing concepts in context.

Employers depending most on students with skills in mineralogy and petrology: Most cited by respondents, in descending order: Mining, environmental companies, oil and gas, federal government, education. This list differs from the results of the earlier survey item about who is hiring graduates. Mining is not at the top of the earlier list. It is possible that mining companies see mineralogy as essential, but they are not hiring lots of graduates.

Demand for people with mineralogy/petrology backgrounds: Forty percent said that demand was decreasing; 21 percent said that demand was increasing; 19 percent thought that demand was holding steady, and 19 percent didn't know. The number of respondents for decreasing and increasing/steady, was almost evenly split. A further data analysis would be useful to link these responses to the geographic areas of the respondents and their proximity to mines.

Reasons for an increase in demand for mineralogy and petrology included (in descending order): Environmental mitigation, need for minerals, climate change and green materials, materials science, mining needs, and infrastructure improvements.

Reasons for a decrease in demand for mineralogy and petrology included (in descending order): Decline of the mining industry, faculty not teaching instrumentation, pandemic, no room for min/pet in curriculum, lack of funding for research in these areas, students needing a greater set of skills than they were getting. One factor to consider is: Do faculty need to change how they teach mineralogy and petrology courses? Do they need to increase instruction in instrumentation and problem solving, and make a greater connection to the world of work from the start?

Possible changes to the ways in which mineralogy and petrology are taught (in descending order): Connect to society's needs, focus on technology, and make strong links to other sciences. It would be enlightening to survey departments with high enrollment, graduation rates and post-graduate employment to collect data on their teaching strategies.

Interest in a mentorship program: Almost seventy (70) percent of faculty surveyed would be willing to serve as mentors, if MSA were to establish such a program.

F. Next Steps

Information from the surveys (syllabi; teaching and recruitment suggestions) will be added, with the permission of the survey respondents, to the Online Teaching Resources on both MSA's website and the Minerals Day website. Results of the survey will also be used to craft a series of online webinars on teaching methods, expanding job opportunities for graduates, recruitment/retention strategies to bring more diversity into the geosciences, and effective mentoring techniques. As a first step, MSA scheduled a series of virtual presentations for Minerals Day and Earth Science Week 2021 featuring careers for those with knowledge and expertise in the fields of mineralogy, petrology, geochemistry, and crystallography. The presentations featured speakers from the FBI Laboratory, Gemological Institute of America, US Geological Survey (science communications), Young Mineral Collectors, National Stone, Sand, and Gravel Association, National Science Foundation, American Museum of Natural History, an environmental company, Corning, Inc., and NASA. These videos are on the MSA YouTube channel.

MSA is also exploring launching a mentorship program for students, faculty, and those with a strong interest in mineralogy and petrology, but do not necessarily have an academic background in those fields. MSA contacted each of its student members, inviting them to complete an online survey to determine what the students would seek in a mentorship program. In addition, MSA is investigating an online secure platform to link mentors and mentees.

In addition, MSA is also investigating the possibility of starting an Early Career Network for its members.

G. List of Tables and Figures

TABLES

Table 1: Numbers of mineralogy courses offered in institutions of higher education

Table 2: Numbers of petrology courses offered in institutions of higher education

Table 3: Numbers of mineralogy and petrology courses with lab and field components

Table 4: Levels at which mineralogy and petrology courses are taught

Table 5: Departments in which mineralogy and petrology are taught

Table 6: Courses Deleted

Table 7: Courses Added

Table 8: B.S. Graduates in geology per year

Table 9: M.S. graduates in geology per year

Table 10: Ph.D. graduates in geology per year

Table 11: Entities hiring B.S. graduates in geoscience

Table 12: Entities hiring M.S. graduates in geology

Table 13: Entities hiring Ph.D. graduates in geology

Table 14: Declared geology majors across the four years of college.

Table 15: Important concepts and skills in mineralogy

Table 16: Important concepts and skills in petrology

Table 17: Employers depending on knowledge of mineralogy/petrology in their hires

FIGURES

Figure 1: Percentage of mineralogy courses with laboratory and field components.

Figure 2: Percentage of petrology courses with laboratory and field components.

Figure 3: Percentage of mineralogy courses at the 100 – 500+ levels

Figure 4: Percentage of petrology courses at the 100 – 500+ levels

Figure 5: Departments in which mineralogy courses are taught

Figure 6: Departments in which petrology courses are taught

Figure 7: Percentages of institutions where a mineralogy or petrology course is required for a major.

Figure 8: Percentages of institutions with B.S. graduates per year

Figure 9: Percentages of institutions with M.S. graduates per year

Figure 10: Percentages of institutions with Ph.D. graduates per year

Figure 11: Entities hiring B.S. graduates in geoscience

Figure 12: Entities hiring M.S. graduates in geoscience

Figure 13: Entities hiring Ph.D. graduates in geoscience

Figure 14: Students declaring a major in geology at each level

Figure 15: Trends in geoscience enrollment

Figure 16: The most important concepts and skills in mineralogy

Figure 17: The most important concepts and skills in petrology

Figure 18: Employers that depend on min/pet knowledge and skills

H. Appendices

Appendix A: Pilot Survey Instrument

Appendix B: Revised Survey Instrument

Appendix A: Pilot Survey

Status of Mineralogy and Petrology in Higher Education

2021 Survey

Instructions:

Please save and complete this form in MS Word. When complete, save the document with the title: "[your first initial.surname]MSA Survey;" e.g., "E. Johnson MSA Survey", and return to Ann Benbow at abenbow@minsocam.org by February 15, 2021. When you return the survey, please indicate in your email which *Reviews* volume you would like from the attached list and your preferred mailing address. Also include any suggestions for improving the survey. With many thanks for your help!

A. Demographic Information

1. Name:
2. Position/Title:
3. Department:
4. Institution Name:
5. Institution Address:
6. Your email:
7. Your telephone number:
8. Years taught:

B. **Course Information**: Please complete the table below for the mineralogy and petrology courses taught at your institution

Course Name	Semester(s) taught (fall, spring, etc.)	Typical enrollment	Text(s) used	Lab component? Y/N	If Yes for Lab, # hrs/wk	Field component? Y/N	If Yes for Field, # hrs/wk	Course Level (100, 200, etc.)	Dept. in which course is offered	In person, online, or both?	Pre-req., if any	Required for Major? Y/N	If Yes for Major, what Major?

1. Which mineralogy or petrology courses have disappeared from your institution? What was the reason?
2. Which mineralogy or petrology courses have been added at your institution? What was the reason?
3. For mineralogy and petrology courses that you teach, would you be willing to share your syllabi with MSA?

C. Student Information

1. How many students per year graduate with B.S. degrees in Geology? ______ M.S.?__________ Ph.D.s?______________
2. Who is hiring your B.S. level graduates?
3. Who is hiring your M.S. level graduates?

4. Who is hiring your Ph.D. graduates?
5. How many geology majors does your department have each year?
6. Over the past five years, has this number increased, decreased, or stayed fairly constant?

D. General Questions

1. What are the most important skills gained from the study of mineralogy?
2. What are the most important skills gained from the study of petrology?
3. What employers, in your opinion, depend most on hiring students trained in mineralogy and petrology?
4. Do you think that demand for skilled mineralogists and petrologists is increasing or decreasing? Why?
5. Would you be willing to serve as a mentor to a student if MSA were to establish such a program?

Appendix B: Final Survey

Status of Mineralogy and Petrology in Higher Education

2021 Survey

Instructions:

Please save and complete this form in MS Word. When complete, save the document with the title: "[your first initial.surname]MSA Survey;" e.g., "E. Johnson MSA Survey", and return to Ann Benbow at abenbow@minsocam.org by March 31, 2021. When you return the survey, please indicate in your email which *Reviews* volume you would like from the attached list and your preferred mailing address. The survey will take about 20 minutes to complete. With many thanks for your help!

E. Demographic Information

9. Name:
10. Position/Title:
11. Department:
12. Institution Name:
13. Institution Address:
14. Your email:
15. Your telephone number:
16. Years taught:

F. **Course Information**: Please complete the table below for the **undergraduate and graduate** mineralogy and petrology courses taught at your institution:

Information Requested	**Course Name**	**Course Name**	**Course Name**	**Course Name**
Semester(s) taught (fall, spring, etc.)				
Typical enrollment				
Text(s) used				
# hrs in lecture/week				
Lab component? Y/N				
If Yes for Lab, # hrs/week				
What instructional materials are used for the lab component?				
Is there an embedded research component in the course? Y/N				
Field component? Y/N				
If Yes for Field, # hrs/wk				
Course Level (100, 200, etc.)				
Dept. in which course is offered				
In person, online, or both?				
Prerequisites, if any				
Required for Major? Y/N				
If Yes for Major, what Major?				

4. Which mineralogy or petrology courses have disappeared from your institution over the past five years? What was the reason?
5. Which mineralogy or petrology courses have been added at your institution over the past five years? What was the reason?
6. For mineralogy and petrology courses that you teach, would you be willing to share your syllabi with MSA?

G. Student Information

7. How many students per year graduate with B.S. degrees in Geology? ______ M.S.?__________ Ph.D.s?______________
8. Who is hiring your B.S. level graduates? (Please check all that apply):

___ energy industries
___ mining industries (including aggregate)
___ environmental companies
___ education-higher education
___ education-K-12
___ federal agencies, including national laboratories
___ local and state government
___ IT (including software development)
___ outdoor recreation companies
___Other (please specify)

9. Who is hiring your M.S. level graduates?

___ energy industries
___ mining industries (including aggregate)
___ environmental companies
___ education-higher education
___ education-K-12
___ federal agencies, including national laboratories
___ local and state government
___ IT (including software development)
___ outdoor recreation companies
___Other (please specify)

10. Who is hiring your Ph.D. graduates?

___ energy industries
___ mining industries (including aggregate)
___ environmental companies
___ education-higher education
___ education-K-12
___ federal agencies, including national laboratories

___ local and state government
___ IT (including software development)
___ outdoor recreation companies
___Other (please specify)

11. How many declared geology majors do you currently have among:
_______First-year students
_______Sophomores
_______Juniors
_______Seniors

12. Over the past five years, have the overall numbers in 5 above increased, decreased, or stayed fairly constant?

H. General Questions

6. What are the most important concepts and skills gained from the study of mineralogy?
7. What are the most important concepts and skills gained from the study of petrology?
8. What employers, in your opinion, depend most on hiring students trained in mineralogy and petrology?
9. Do you think that demand for skilled mineralogists and petrologists is increasing or decreasing? Why?
10. What do you think should be changed, if anything, in the way mineralogy and petrology are taught to make the field relevant and useful for today's undergraduates?
11. Would you be willing to serve as a mentor to a student if MSA were to establish such a program?