An Analysis of the Bachelor of Science in Geology Degree as Offered in the United States

Carl N. Drummond — Department of Geosciences, Indiana University-Purdue University Fort Wayne, Fort Wayne, IN 46805-1499, drummond@ipfw.edu

Jane M. Markin — Office of Research and External Support, Indiana University-Purdue University Fort Wayne, Fort Wayne, IN 46805-1499

ABSTRACT

The Bachelor of Science in Geology degree is offered by nearly 300 universities and colleges in the United States. The curriculum of these degree programs is composed of three parts: core required and elective geology courses, cognate science requirements, and general education requirements. Analysis of the frequency of inclusion of courses in the required core has lead to the identification of four curricular patterns common to geology departments. Conversely, there is much more commonality in the cognate science requirements nationally in that two semesters of chemistry, physics, and calculus are required by two thirds of all Bachelor of Science programs. The structure and organization of general education requirements vary significantly as do the number of required credit hours embedded in the general education program. Analysis of the Bachelor of Science in Geology degree serves two important purposes: first, it provides a database upon which informed discussions of curricular content and accreditation standards can be made; second, it provides departments undergoing program review a basis for comparison with other institutions and national norms.

INTRODUCTION

Disciplinary accreditation for the geological sciences has been a long-running controversy in the United States (e.g., Hatcher and Corbett, 1996; Corbett and Corbett, 2001; GSA 2007a; 2007b). The Geological Society of America has, at various times, established *ad hoc* committees to review the concept, conduct surveys, and solicit feedback from its membership. Despite these efforts, no consensus for support or rejection of disciplinary accreditation has developed among members of the professoriate. At the heart of the dialog are two critical dimensions - resources and curriculum. It is generally recognized that disciplinary accreditation can be used by academic departments to leverage greater allocation of resources within the University. Anecdotal evidence is readily available at any institution in which a professional school is undergoing reaccreditation. For geology departments, however, there exists a significant risk that costs associated with achieving accreditation standards can exceed the benefits of maintaining the program being considered for accreditation. Depending upon which side of the resource equation a particular geology department falls, attempting accreditation could result in either program expansion or closure. Many faculty members consider presenting their administration with such a resource allocation decision a far too dangerous gambit and are therefore steadfastly opposed to the implementation of any form of disciplinary accreditation. The conversation becomes even more heated when topics of curricular standardization or reform are brought to the table. For some, the establishment of a common academic core and standards for assessing curricular content is a laudable goal. Others, however, consider such structures to be far too restrictive and prescriptive in nature and point to the importance of curricular innovation, regional focus, and variety within the geology curriculum.

It is not the purpose of this offering to debate the merits of disciplinary accreditation. As with any concept of reform or change, a significant number of positives and negatives can be identified. Rather, we set out to present an analysis of the Bachelor of Science in geology degree as offered in the United States. Only by reviewing our programs in detail can informed discussions of curricular modification more forward. Towards that end, 296 American universities and colleges were identified as offering the Bachelor of Science in geology degree option (Keane and Martinez, 2007). Online undergraduate catalogs were reviewed and degree requirements tabulated. The results of the analysis of those programs and their requirements follow.

THE BACHELOR OF SCIENCE IN GEOLOGY CURRICULUM

Geology is at its heart an interdisciplinary and integrative science. The ongoing natural experiment that is the evolution of the Earth presents enormous challenges to those who wish to understand our planet's past, present, and future. Developing a program of academic study that exposes students to both the complexity of geological materials and processes while at the same time provides knowledge of the basic scientific principles essential to developing a deep understanding of those geological materials and processes is a complex and unique challenge. While it is common for geology departments to offer programs of study in environmental geology, earth science education, and more recently earth system science, the Bachelor of Science degree is the foundation of geological education in the United States. As such, the Bachelor of Science degree in geology has traditionally served as the pathway to the profession from which the largest percentage of students go on to graduate study (AGI, 2001; AGI 2006).

The Bachelor of Science in geology curriculum can be broken into three components: the core of required geology courses and electives, the cognate science requirements, and the general education requirements. Each component plays an essential role in enriching the educational experience of geology students.

The Required Core - Of the 296 academic departments offering the Bachelor of Science degree program in the United States 287 list required geology courses as part of their core curriculum on online undergraduate catalogs and departmental websites. This dataset represents the most accurate and readily available source of curricular data available. The number of courses required by those

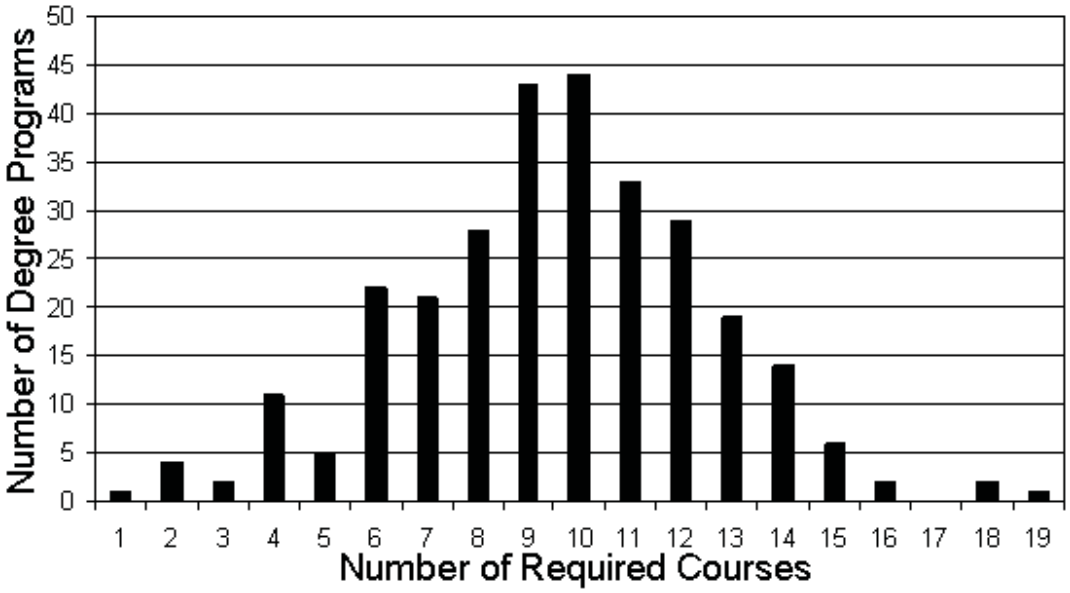

Figure 1. Distribution of the number of courses in the geology core as required by the 278 geology departments surveyed in the United States.

Group	Course Title	Frequency	Percentage
A	Field Camp	285	99.3
	Introductory/Physical Geology	275	95.8
	Structural Geology	266	82.7
	Petrology	259	90.2
	Sedimentology	238	82.9
	Mineralogy	228	79.4
	Historical Geology	217	75.6
B	Stratigraphy	184	64.1
	Paleontology	133	46.3
	Geomorphology/Surficial Processes	105	36.6
C	Geophysics	57	19.9
	Geochemistry	54	18.8
	Hydrology/Hydrogeology	52	18.1
	Geology Seminar	48	16.7
	Optical Mineralogy	45	15.7
	GIS/Cartography	45	15.7
	Environmental Geology	37	12.9
D	Computers/Quantitative Methods/Stats/Modeling	29	10.1
	Earth Science/Astronomy/Oceanography	36	9.1
	Tectonics	24	8.4
	Scientific Writing/Communications/Presentation	20	7.0
	Undergraduate Research	16	5.6
	Miscellaneous	16	5.6
	Earth Systems Science/Global Cycles	15	5.2
	Laboratory Methods/Techniques	14	4.9
	Careers/Introduction to the Profession	7	2.4
	Economic Geology/Petroleum Geology	6	2.1
	Regional Geology	5	1.7
	Geography	5	1.7
	Soils	4	1.4

Table 1. Summary of core geology core courses required for the Bachelor's of Science degree in the United States. Courses are lumped into groups related to their frequency of inclusion in the required curriculum (n = 278 programs).

Academic Year	Fall Term	Spring Term
First Year	Introductory/Physical Geology	Historical Geology
Sophomore Year	Mineralogy	Petrology
Junior Year	Sedimentary Geology	Structural Geology
3rd or 4th Summer	Field Camp	

Table 2. Typical pattern for those courses most commonly included in the required geology core.

programs ranges from one to nineteen with nine and ten required courses being almost equally common (Figure 1). Interestingly, these programs use 319 unique course titles to describe the 2715 individual courses offered by their programs. In order to facilitate an analysis of the geology curriculum it was necessary to review the titles and combine similar courses into single titles (e.g. Structural Geology = Structural Geology and Tectonics = Structure and Tectonics of the Earth; Historical Geology = Earth History = History of Earth and Life). As a result, 30 required courses were identified including a "miscellaneous" category (Table 1). These courses were then subdivided into groups based on their frequency of inclusion in a departmental required core. Group **A** includes those classes required by at least three quarters of degree programs surveyed. Group **B** contains courses that are less common but which are required by at least one third of programs surveyed. Group **C** contains somewhat specialized courses that are only occasionally required. Finally group **D** contains courses that are required by less than fifteen percent of programs surveyed.

Seven courses are included in group **A**, the most commonly required courses in the geology core. These courses are often organized into a course sequencing pattern that comprises the first three years of study (Table 2). The introductory sequence of Physical and Historical Geology typically serves the duel purpose of satisfying general education science requirements for large numbers of students while also providing a pathway to the major. During the second year, students obtain knowledge of the mineral and rock classification and processes of formation in mineralogy and petrology to facilitate a higher order understanding of geological processes. The third year introduces students to processes of rock deformation as well as sedimentary systems in structural geology and sedimentology. Finally, students are required to participate in a field experience typically taught during the third or fourth summer. Interestingly, field camp is the most frequently required course in the geology curriculum (over 99% of programs surveyed). It should be noted, however, rapidly increasing capital, transportation, and liability costs coupled with declining enrollments have forced many departments to turn to consolidation or outsourcing of the field camp experience (Drummond, 2001). Taken at or near the end of the undergraduate curriculum, field geology can provide an ideal capstone experience for geology majors and, when not outsourced to another university, it is ideally suited for use as an instrument for the summative assessment of student learning (Aitchison and Ali, 2007). Together, the seven courses listed in Group **A** reflect a national consensus on the most essential components of the Bachelor of Science in Geology curriculum and serves as the foundation of the geology degree.

The three courses included in Group **B** represent a transition from the true "core" courses of the Bachelor of Science in Geology degree to the group of less frequently required and more specialized courses found in Group **C**. Stratigraphy, as a stand-alone course, is required by over 60% of all programs. In the remaining departments it is often taught in conjunction with sedimentology. Conversely, geomorphology/surficial processes courses are required by just more than one-third of the programs. Paleontology presents something of a special case. Required by less than half of the Bachelor of Science geology degree programs, paleontology is the most surprising omission from the Group **A** core courses. Two factors could be responsible for this omission. First, a brief introduction to invertebrate paleontology is commonly included in a course on historical geology. While this is not a substitute for a standard course in paleontology, it does at least provide students with a basic understanding of ancient life. Second, small departments may not have a paleontologist on the faculty and, as such, cannot adequately staff a required paleontology course.

Group **C** courses represent a higher level of subdisciplinary specificity than is found in courses from Group **A** and **B**. Courses such as geochemistry and geophysics provide students with a greater understanding of key geologic processes and are usually considered important electives for students considering graduate study. Commonly, large departments, or those with a strong focus on professional preparation require these courses. Conversely optical mineralogy, a somewhat anachronistic course, has been dropped from many departments' requirements with an optical module included in either the mineralogy or petrology course. Hydrology/hydrogeology, GIS/cartography, and environmental geology courses are required by those departments that have placed a greater emphasis on applied and technical training as part of the geology degree. A geology seminar is required by 16% of departments and commonly represents either a capstone course or a structure by which students are introduced to the modern geological literature.

Group **D** courses span a wide range of topics, many of which directly address learning goals commonly articulated in departmental documents: quantitative skills, communication skills, knowledge of scientific techniques, and experiential learning through undergraduate research. Also reflected in this group of infrequently required courses is a transition from subjects commonly taught in the 1960's and 1970's such as economic geology and petroleum geology to courses that reflect modern views of Earth processes such as Earth system science and global biogeochemical cycles (Rankey and Ruzek, 2006).

CURRICULAR PATTERNS

Curricular reform in the geosciences is far from a new topic. Outcome based learning and content modification to reflect changing knowledge and technology have long

Core Curriculum Type	Required Courses	Credit Hours
Minimum	Introductory/Physical Geology Historical Geology Mineralogy Petrology Sedimentary Geology Structural Geology Field Geology	30
Traditional	Introductory/Physical Geology Historical Geology Mineralogy Petrology Sedimentary Geology Structural Geology Paleontology Stratigraphy *or* Geomorphology/Surficial Processes Field Geology	38
Advanced Academic	Introductory/Physical Geology Historical Geology Mineralogy Petrology Sedimentary Geology Structural Geology Paleontology Geophysics Geochemistry Field Geology	42
Applied Professional	Introductory/Physical Geology Historical Geology Mineralogy Petrology Sedimentary Geology Structural Geology Hydrology/Hydrogeology *or* Environmental Geology GIS/Cartography Field Geology	38

Table 3. Four different core curricular designs proposed for Bachelor's of Science in Geology degree programs in the United States. Program credit hours are calculated based upon an assumption of 4 credit hours per lab/lecture course with field camp carrying 6 hours. Some variation in this total would be expected among different programs.

been topics of discussion in the geoscience literature (Reams, 1981; Ulanski, 1995; Drummond, 2003; AGU, 2007). This offering presents the most comprehensive survey of curricular variability available and, as such, is a valuable resource for further discussion of curricular reform.

The preceding analysis has resulted in the identification of four different curricular patterns common to geology departments (Table 3). These versions of the required curriculum are presented as recommendations, with each serving as a template for course offerings depending upon departmental size and mission.

Minimum Core Curriculum - The proposed minimum required core geology curriculum is defined by the seven courses in Group A. These courses provide a basic foundation in geology, and could be delivered by most small departments. When the field camp course must be outsourced due to departmental size or resource base, it would be advantageous to identify an additional course taught within the department to serve as a capstone experience for assessing student learning. The 30 required hours would, of course, be augmented by additional advanced geology electives, cognate sciences, and general education courses.

Traditional Core Curriculum - The proposed traditional core geology curriculum is composed of the minimum curriculum supplemented with courses in paleontology and either stratigraphy or geomorphology/surficial processes. This curriculum provides students with a broad education in the geological sciences and includes requirements currently listed by at least one half of the geology programs nationally. As with the minimum core curriculum, the traditional core would be augmented by additional advanced geology electives, cognate sciences, and general education courses.

Advanced Academic Core Curriculum - The proposed advanced academic core geology curriculum is designed for programs that want to direct students specifically towards future graduate study. Augmenting the minimum curriculum with courses in paleontology, geochemistry, and geophysics, this program of study provides students with a depth of understanding of the underlying processes that shape the Earth. As the largest and arguably most rigorous of the four proposed curriculums, the professional sequence would likely only be adopted by larger departments with a significant resource base and strong enrollments. Additional electives, courses in the cognate sciences, and general education courses would significantly strengthen the students' preparation for graduate study.

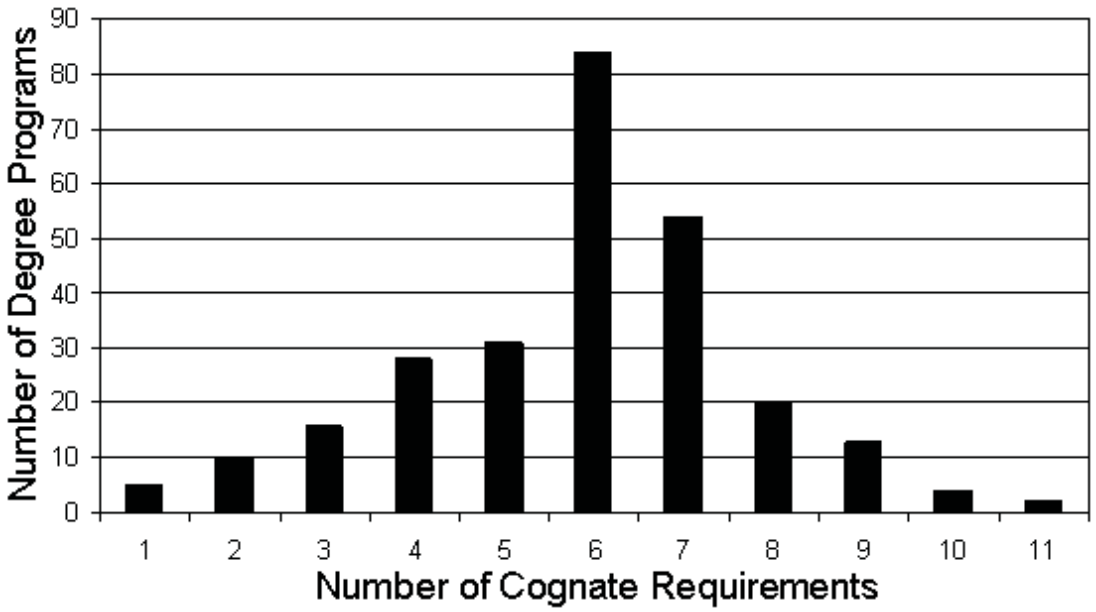

Figure 2. Distribution of the number of cognate science courses required by 267 geology departments surveyed in the United States.

Group	Required Course	Frequency	Percentage
A	Chemistry 1	246	92.1
	Chemistry 2	220	82.4
	Physics 1	236	88.4
	Physics 2	203	76.0
	Calculus 1	229	85.8
	Calculus 2	178	66.7
B	Statistics	48	18
	General Biology 1	37	13.9
	Computer Science/Programming/IT	20	7.5
C	Analytical Geometry	15	5.6
	Pre-calculus	15	5.6
	Calculus 3	14	5.2
	College Algebra	14	5.2
	Technical Writing	13	4.9
	Trigonometry	12	4.5
	Biology 2	11	4.1
	Miscellaneous	11	4.1
	Chemistry 3	9	3.4
	Physics 3	8	3.0
	Linear Algebra	5	1.9
	Zoology	5	1.9
	Differential Equations	4	1.5
	Ecology	4	1.5
	Calculus 4	2	0.7
	Public Speaking	2	0.7
	Organic Chemistry	1	0.4
	Physics 4	1	0.4

Table 4. Summary of the cognate science courses required as part of the Bachelor's of Science degree. Courses are lumped into groups related to their frequency of inclusion in the curriculum (n = 267 programs).

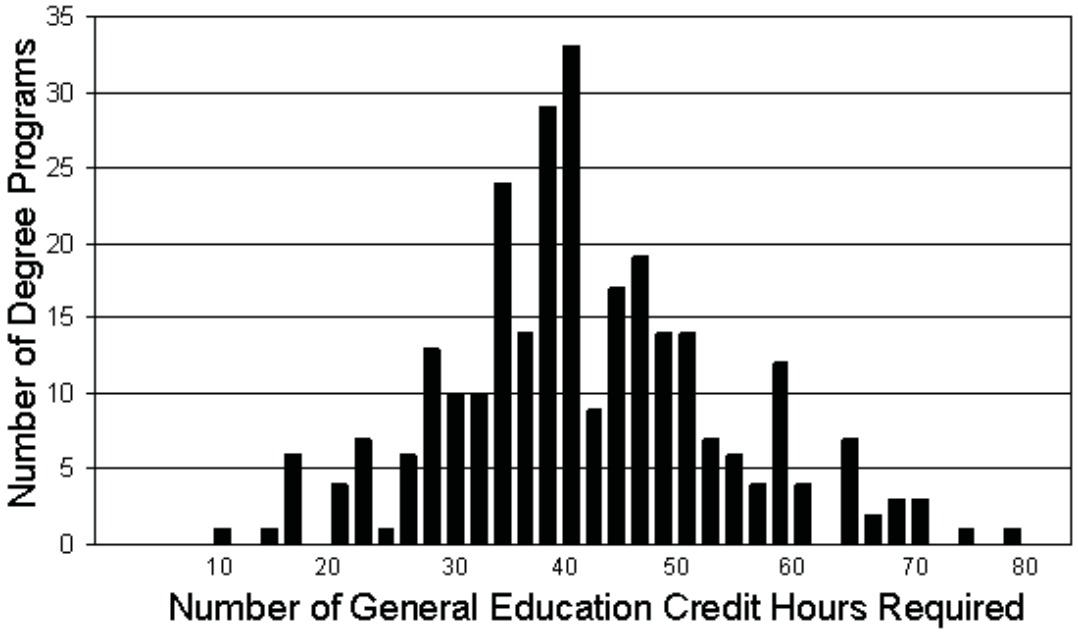

Figure 3. Distribution of the number of general education credit hours required by 283 geology departments surveyed in the United States (binning interval 2 credit hours).

Applied Professional Curriculum - The proposed core curriculum in applied professional geology could be considered something of a hybrid between the traditional Bachelor's of Science in geology degree program and an environmental science degree. Starting with the minimum core curriculum, courses in GIS/cartography and hydrology/hydrogeology or environmental geology are added to provide students with a general background in modern techniques and approaches to applied geoscience. This required core would be supplemented with additional elective courses in applied and technical subdisciplines. A field course with emphasis on applied geophysical techniques would be more valuable than a traditional mapping course to this curriculum.

The four proposed core curriculums described above could serve as starting points for discussions regarding accreditation standards for the Bachelor's of Science in geology degree. Given the range in size, the differing availability of resources, and uniqueness of mission of the various geology departments in the United States, enforcing an accreditation standard based on a single curriculum is an untenable position. The preceding analysis does, however, present a review of the current curriculums used by geology departments and serves as an essential database for any future conversations regarding accreditation standards and curriculum reform. Additionally, departments undergoing institutional program review should find these data useful in making comparisons between their program and national norms.

COGNATE SCIENCE REQUIREMENTS

An essential component of a sound undergraduate education in geology is training in the cognate sciences. Of the 296 Bachelor of Science degree programs reviewed, 267 list cognate science requirements on their online catalogs and departmental websites. The number of courses required by those departments range from one to eleven, with six the most frequent (Figure 2). Cognate requirements display a markedly different distribution than do the core geology requirements. The vast majority of departments offering the Bachelor of Science in Geology degree require one semester of chemistry, physics, and calculus, and two-thirds require two semesters of each subject (Table 4). After these six cognate courses (Group **A**), there is a large drop in the frequency with which other courses are required by departments.

Group **B** cognates include statistics, general biology 1, and courses covering topics in computer science, computer programming, or information technology. Despite the infrequency with which group **B** and **C** courses are required as part of the degree program, many are very useful and perhaps even essential to an adequate preparation for graduate study.

There is a clear national consensus regarding the importance of cognate sciences to the Bachelor of Science in geology degree. Courses in chemistry, physics, and calculus provide a foundational understanding of nature as well as serve to introduce future geologists to laboratory and analytical techniques that will be expanded upon by their training in subsequent geology courses.

GENERAL EDUCATION REQUIREMENTS

General education is an essential part of the university experience. The development of foundational skills in reading, writing, communication, and quantitative reasoning is essential to success in every academic subject and professional occupation. Likewise, an understanding of history, culture, the arts, and society have never been more important than in the modern era of growing globalization. The notion that we have entered a new geological epoch dominated by human alteration of the Earth, the Anthropocene (Zalasiewicz et al., 2008), makes clear that future geoscientists must have as rich an understanding of culture and society as possible.

Of the 296 American universities and colleges identified as offering the Bachelor of Science in geology degree option, 283 identify the number of general education credit hours required for completion of the degree. These requirements range from 12 to 79 credit hours (Figure 3) with a mode of 42. Because every university has its own unique way of exposing students to a general education, either through a prescriptive set of curricular requirements or a less structured cafeteria system where students select from a broad listing of courses, a detailed analysis of general education requirements is beyond the scope of this offering. However, geology departments can use the data presented in figure 3 to evaluate the magnitude of general education requirements at their university in relation to those of other programs around the country.

CONCLUSIONS

The Bachelor of Science in Geology degree, as offered in the United States, is defined by a high degree of commonality in the core course content and cognate science requirements. From an analysis of curricular requirements, four suggested core curricular patterns are presented. These proposed patterns could be used as the basis of accreditation standards or by individual departments undergoing program review. Despite significant variation in the size and mission of individual geology departments nationwide, national curricular norms can and should be developed from data presented here.

ACKNOWLEDGEMENTS

The authors are indebted to Associate Editor Libarkin who kindly ushered this manuscript through a double-blind review process. The reviewers provided thoughtful and helpful criticism that strengthened this offering. Data collected for this survey is available upon request.

REFERENCES

Aitchison, J.C., and Ali, J.R., 2007, Tibet field camp as a "Roof of the World" capstone experience for earth science majors, Journal of Geoscience Education, v. 55, p. 349-356.

American Geological Institute (AGI), 2001, Report on the Status of Academic Geoscience Departments, 9 p.

American Geological Institute (AGI), 2006, Introductory geoscience enrollment in the United States Academic Year 2004-2005, Report GW-06-001, 10 p.

American Geophysical Union (AGU), 2007, Shaping the future of undergraduate earth science education: Innovation and change using an earth system approach, http://www.agu.org/sci_soc/spheres/panel-2.htm (May 7, 2007).

Corbett, R.G., and Corbett, E.A., 2001, Geology programs and disciplinary accreditation, Journal of Geoscience Education, v. 49, p. 130-134.

Drummond, C.N., 2001, Can field camps survive?, Journal of Geoscience Education, v. 49, p. 336.

Drummond, C.N., 2003, Do we have a 20th or 21st century curriculum?, Journal of Geoscience Education, v. 51, p. 162.

Geological Society of America (GSA), 2007a, "Would some form of accreditation of academic program be beneficial to the geosciences?" http://www.geosociety.org/aboutus/accreditation.htm (May 7, 2007).

Geological Society of America (GSA), 2007b, "Professional Licensure & National Accreditation: Opportunities and Constraints for Geology Practice in the Millenium", http://www.geosociety.org/sectdiv/05licensure.htm (May 7, 2007).

Hatcher, R.D., and Corbett, R.G., 1996, An accreditation program for the geosciences?:, GeoSpectrum, January/February 1996, p. 2.

Keane, C.M., and Martinez, C.M., 2007, Directory of Geoscience Departments 2007, 45th Edition, American Geological Institute, 648 p.

Rankey, E.C., and Ruzek, M., 2006, Symphony of the spheres: Perspectives on earth system science education, v. 54, p. 197-201.

Reams, M.W., 1981, An entire undergraduate geology curriculum based on educational objectives, Journal of Geological Education, v. 29, p. 69-71.

Ulanski, S. L., 1995, Curriculum reform in undergraduate geology programs, Journal of Geological Education, v. 43, p. 43-46.

Zalasiewicz, J., et al., 2008, Are we now living in the Anthropocene?, GSA Today, v. 18, p. 4-8.