

## Geoscience Field Education: A Recent Resurgence

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Field education traditionally has been an integral component of undergraduate geoscience curricula. Students have learned the fundamentals of field techniques during core geology courses and have honed their field credentials during class-specific field trips, semester-long field courses, and capstone summer field camps. In many geoscience departments, field camp remains a graduation requirement, and more than 100 field camps currently are offered by U.S. universities and colleges (see <http://geology.com/field-camp.shtml>).

During the past several decades, however, many geoscience departments have moved away from traditional geologic fieldwork and toward a broader theoretical and laboratory-intensive focus that encompasses a range of subdisciplines. Trends that have influenced these shifts include (1) the decline in the late twentieth century of the petroleum and mining industries, which have consistently championed the values of fieldwork; (2) a decrease in the number of professional jobs that incorporate field mapping; (3) a decline in the number of geoscience majors nationwide [*American Geological Institute (AGI)*, 2009]; and (4) barriers to fieldwork, including time requirements, cost, liability, and decreasing access to field sites.

Faculty and administrative responses to these trends often have resulted in curriculum changes. Credit hours allocated to field-intensive geoscience courses have been reduced to accommodate broader curricula that emphasize analytical, experimental, or modeling approaches to geoscience research. Broader curricula also incorporate subdisciplines such as oceanography, climatology, and environmental geology. Coincident with these changes, many geoscience programs have reevaluated the importance of capstone summer field courses. In 1995, thirty-five percent of geoscience departments offered a summer field course; but by 2006, just 15% did so [*AGI*, 2006].

### *Recent Trends in Field Education and Research*

However, recent trends in geoscience education and research, as highlighted below, do not support curricular de-emphasis of field education. An examination of symposia and topical sessions at AGU and Geological Society of America (GSA) conferences from 1994 to 2009 showed that the number of sessions that include “field” (as it relates to field education or research) in the title followed a generally increasing trend (Figure 1). GSA sessions that highlighted summer field camps occurred in 1996, 1998, and 2007 (28 oral and/or poster abstracts that year), while sessions that focused on broader aspects of field education occurred in 2004 (73 abstracts), 2005 (14 abstracts), and 2007 (15 abstracts). For the 2009 national GSA meeting, held 18–21 October, the session entitled “T100: Field Geology Education: Historical Approaches and Modern Techniques”

received 61 submitted abstracts, the third-highest total for topical sessions.

Enrollment data for summer field courses show similar upward trends. A 2008 survey of active field courses showed a steady increase in the total number of enrolled students during the past 10 years [*AGI*, 2009]. The number of field camps offered during the same period apparently increased as well, which may indicate that the supply of summer field courses recently has risen to meet an increased demand from students (see the online supplement to this *Eos* issue ([http://www.agu.org/eos\\_elec/](http://www.agu.org/eos_elec/))), although this increasing supply may partly reflect an increase in the number of courses surveyed and not necessarily an increase in the number of courses available to students.

Industry professionals maintain that field competence is an essential skill that should remain a prominent component of undergraduate geoscience curricula. A common theme industry professionals note is the need for students who are entering the workforce to be comfortable with equating remote or indirect data sets with real-world examples; for example, the direct observation of potential oil reservoir rocks enables better interpretations of seismic reflection

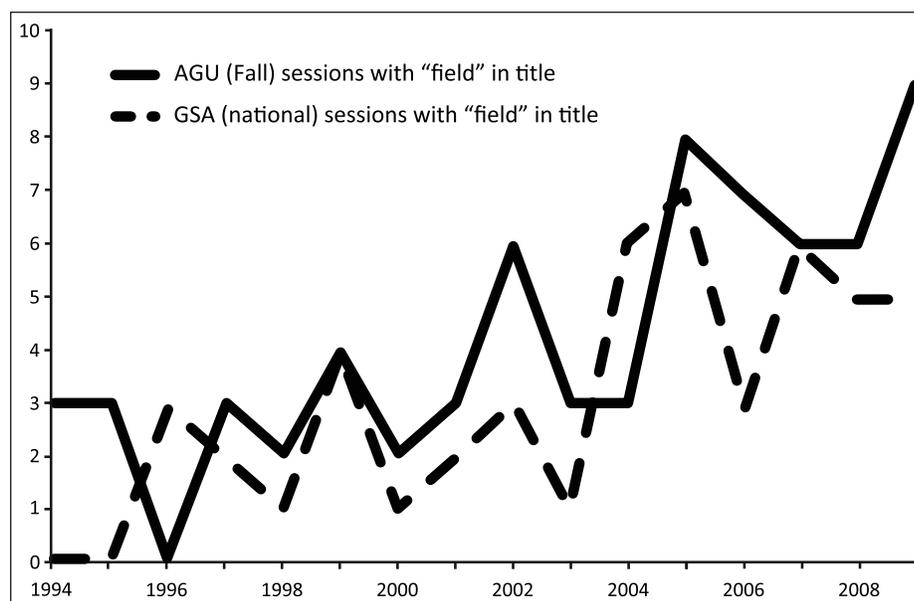


Fig. 1. Graph of the number of symposia and topical sessions at national Geological Society of America (GSA) and fall AGU meetings between 1996 and 2009 with titles that include the word “field” in relation to field research or field education. AGU data for 2009 are for proposed sessions.

profiles in oil and gas exploration. Professionals emphasize the importance of an extensive background of field experience, especially in situations where large-scale geology must be extrapolated from limited data. Programs such as the U.S. Geological Survey (USGS)/National Association of Geoscience Teachers (NAGT) Cooperative Field Training Program ([http://serc.carleton.edu/nagt/programs/usgs\\_field.html](http://serc.carleton.edu/nagt/programs/usgs_field.html)) were established to further enhance the field experience of geoscience students through internships with industry professionals. Though student participation in the USGS/NAGT program generally declined in the 1990s, participation apparently is increasing during the 21st century (Figure 2).

The link between industry and academic field education often has included financial support. Among many established field camps that have received industry support are the Yellowstone-Bighorn Research Association (YBRA; <http://www.ybra.org/aboutybra/history1.htm>) camp and the Justin Mead Geologic Field Station (<http://www.indiana.edu/~iugfs/>). In some cases, federal support has been significant as well (e.g., the Branson Field Laboratory; <http://fieldcamp.missouri.edu/Camp%20History.htm>). External support for field education may be making a comeback, e.g., the new Precambrian Field Camp at the University of Minnesota, Duluth, which was established in 2007, with partial sponsorship from the mining industry (<http://www.d.umn.edu/prc/industry-members/>).

### Curriculum Changes in Field Camps

Changing perceptions and realigned curricula within geoscience departments have induced extensive changes in modern field camps. Many established field courses have moved away from being predominantly bedrock-mapping projects to include exercises in geohydrology and environmental topics. Several field courses—such as the Summer of Applied Geophysical Experience (SAGE; <http://www.sage.lanl.gov/>) and the Urbino Summer School in Paleoclimatology (<http://www.uniurb.it/ussp/index.html>)—exclusively focus on geoscience subdisciplines. In some departments, field-based research programs (e.g., the U.S. National Science Foundation's Research Experiences for Undergraduates) or oceanographic research cruises (e.g., Integrated Ocean Drilling Program [*St. John et al., 2009*]) can fulfill the same degree requirements as traditional field camps.

New equipment and technologies that facilitate data collection, analyses, and processing while in the field also have induced changes within field courses. Mobile personal computers with an integrated global positioning system (GPS) and a geographic information system (GIS) have revolutionized methods of fieldwork and mapping, and many field

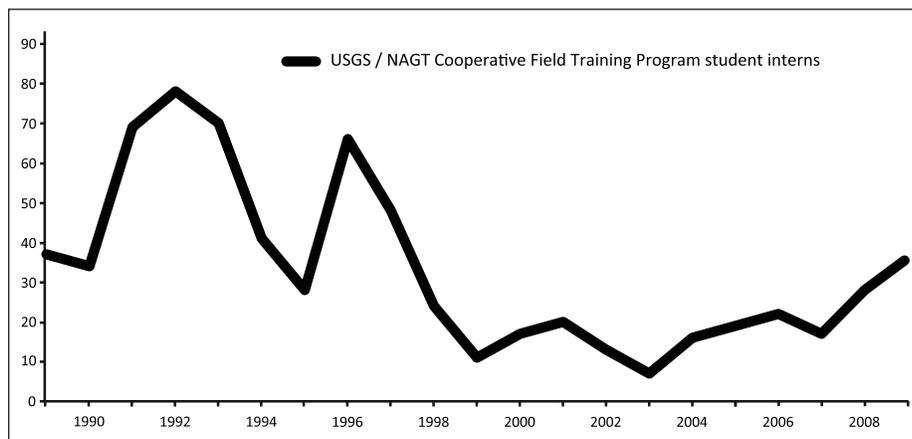


Fig. 2. Graph of data from the past 20 years showing the total number of student interns involved with the U.S. Geological Survey/National Association of Geoscience Teachers (NAGT) Cooperative Field Training Program. The 1990s generally are characterized by a downward trend and the 2000s generally are characterized by an upward trend, although these trends may have been partly dependent on the availability of internships. Data were compiled from the NAGT Web site ([http://serc.carleton.edu/nagt/programs/usgs\\_field.html](http://serc.carleton.edu/nagt/programs/usgs_field.html)).

programs now include digital mapping within their course curricula [*Walker and Black, 2000; Knoop and van der Pluijm, 2006*]. Other modern equipment, such as ground-penetrating radar and lidar (light detection and ranging), are standard tools for field-oriented professionals, and some courses have incorporated these tools within their field exercises [e.g., *Vance et al., 2009*].

Field experiences have expanded in other new directions, such as international programs (e.g., the James Madison University Ireland Field Course; <http://www.jmu.edu/geology/fieldcourse/>) and international research collaborations that involve undergraduates (the Polar Project [*Holmes et al., 2009*]). The scope of field education has expanded beyond capstone experiences to include introductory-level undergraduate courses targeted at nonmajors (e.g., <http://www.lsa.umich.edu/geo/undergrad/campdavis>; "GEOSCI 116: Introductory Geology in the Rockies"), and programs designed for in-service geoscience teachers seeking professional development. In many cases, a primary driver for these initiatives is the recruitment of future geoscience majors.

### Reevaluating the Importance of Field Education

Several recent initiatives have brought field education back to the forefront of discussions about geoscience curricula. Recent AGU and GSA sessions have highlighted modern methods and techniques of field-based education. Many of these ideas are assembled in GSA Special Paper 461, *Field Geology Education: Historical Approaches and Modern Techniques* [*Whitmeyer et al., 2009*], expected to be published this winter. Example field exercises and educational field trips covering many geoscience subdisciplines are available from NAGT's Teaching in the Field

Web site (<http://nagt.org/nagt/field/index.html>). Teaching in the field will be highlighted in August 2010 during the Teaching Geoscience in the Field in the 21st Century workshop (<http://serc.carleton.edu/NAGTWorkshops/workshops.html>).

An emerging body of scholarship is beginning to demonstrate the cognitive gains made by students through field instruction [e.g., *Boyle et al., 2007; Butler, 2008*]. Immersion in the natural environment helps to develop a deeper understanding of spatial and temporal relations [*Kastens et al., 2009*], enhances the ability to draw conclusions or inferences from incomplete data, and helps students integrate observations with stored knowledge gained from across the geoscience curriculum. Field experiences also help initiate students into the methods, techniques, and intellectual mindset of the geosciences; help develop higher-order thinking skills; and commonly provide transformative experiences, all of which contribute to the recruitment of new students and to the overall development of geoscience majors.

The data presented in this article suggest that geoscience professionals and students increasingly are recognizing the importance of field-focused education. Field courses and camps have broadened their scopes to encompass new technologies, subdisciplines, and alternative audiences, and these broader scopes apparently have encouraged increased student enrollment. And industry professionals continue to support the incorporation of field experiences within undergraduate curricula. This calls into question whether the perception that field education is no longer necessary as an important component of undergraduate geoscience coursework is incorrect. Rather, the resurgent interest in field education represents a renewed appreciation for basic skills needed by almost all geoscience professionals, and balances other equally important theoretical and laboratory-oriented educational experiences necessary for geoscience students.

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## Expeditions to the Russian Arctic to Survey Black Carbon in Snow

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Snow is the most reflective natural surface on Earth, with an albedo (the ratio of reflected to incident light) typically between 70% and 85%. Because the albedo of snow is so high, it can be reduced by small amounts of dark impurities. Black carbon (BC) in amounts of a few tens of parts per billion (ppb) can reduce the albedo by a few percent depending on the snow grain size [Warren and Wiscombe, 1985; Clarke and Noone, 1985].

An albedo reduction of a few percent is not detectable by eye and is below the accuracy of satellite observations. Nonetheless, such a reduction is significant for climate. For a typical incident solar flux of 240 watts per square meter at the snow surface in the Arctic during spring and summer, an

albedo change of 1% modifies the absorbed energy flux by an amount comparable to current anthropogenic greenhouse gas forcing. As a result, higher levels of BC could cause the snow to melt sooner in the spring, uncovering darker underlying surfaces (tundra and sea ice) and resulting in a positive feedback on climate [Hansen and Nazarenko, 2004].

BC particles are produced by incomplete combustion from diesel engines, coal burning, forest fires, agricultural fires, and residential wood burning [Bond and Bergstrom, 2006]. When injected into the atmosphere, these particles may travel thousands of kilometers before they are removed by rain or snow precipitation. In 1983–1984, a wide-area survey of BC concentrations in Arctic snow was carried out by Clarke and Noone [1985] across the western Arctic; however,

access was not available to the eastern Arctic at that time.

During the 2007–2009 International Polar Year (IPY) an opportunity arose for collaboration between U.S. and Russian scientists to organize a survey of BC in the snow across the Russian Arctic during springtime expeditions in 2007 and 2008. The expeditions were carried out as a central part of a comprehensive IPY survey over the entire Arctic.

### Survey Results

The surveys were conducted in April and early May so that the entire winter snow accumulation could be studied and snowpack conditions could be documented just prior to the onset of the spring melt (see Figure 1). The observation areas were reached by commercial airlines to locations near the Arctic coast spanning longitudes 50°E–170°E. Local transportation provided access to individual sites 30–100 kilometers away from these centers.



Fig. 1. (Left) Sampling snow on the sea ice north of Tiksi, Russia, and (right) surface transportation west of Tiksi. Photographs by Stanislav Kogan and Stephen Warren.