A BRIEF INTRODUCTION TO FIELD GEOLOGY

Geological mapping dates back to the Turin Papyrus of 1150 B.C.E. (Harrell and Brown, 1992), but field surveying and publication of printed geological maps did not begin in earnest until the nineteenth century with the contributions of pioneering workers such as William Smith (1815) in England and Wales, Richard Griffith (1838) in Ireland, Archibald Geikie (1876) in Scotland, George Cuvier and Alexandre Brogniart in France, Bernhard Studer and Arnold Escher von der Linth in Switzerland, and Florence Bascom in the United States (see, for example, Winchester, 2001). Following the hit-or-miss approaches of the California Gold Rush (1848–1855), and of wildcat oil drilling after its initial invention in Titusville, Pennsylvania, by Edwin Drake in 1855, the need for professional field geologists grew steadily and state
not carried out, so professors did not know how their course con-
tent matched the needs of employers or how it prepared students for any profession. The university was training students in skills that were useful only to the 1% who might become academics, not the skills required in the future extramural workplace, and even then, the academic content was dated. Some would justify this, citing the timeless benefits of academically oriented educa-
tion, but the pure pedagogical value of many classical exercises was debatable. Although we may think of geological mapping mainly as an academic exercise, it is worth noting that many of the pioneers of mapping were applied scientists and engineers. The goal for William Smith was to find coal—the fuel of the Industrial Revolution—and bring it to market via canals (Winc-
chester, 2001). Richard Griffith’s (1838) map was funded by the Irish Railway Commission. The Swiss were motivated by their country’s extreme engineering needs, and the U.S. Geological Survey (USGS) was initially tasked with classifying mineral-rich versus agricultural public lands (Thompson, 1988).

Students at the Maine camp did complain, however, about some faculty attitudes that were perceived as indifferent to females and about boot-camp conditions that even macho males found unpleasant (e.g., the spring and early summer black fly season). Furthermore, trends nationwide were shifting away from compulsory geology field courses as geology departments, including BU’s, morphed into “geological science,” “geology and geography,” “earth science,” “earth and planetary science,” “earth and space science,” “earth and environmental science,” etc. With the relaxation of many colleges’ residential field camp requirements, competition from deep-sea drilling cruises, labora-

tory-based independent study projects, and externally funded research experiences for undergraduates (REUs) was high. These examples reflected a growing nationwide sentiment that ques-
tioned the continued importance of field camps in undergraduate geoscience curricula around the turn of the millennium. Clearly, if field courses were to survive and remain a vital component of an undergraduate education, major changes were needed. Our experience, detailed herein, suggests that these reforms need to encompass changes in management styles and attitude, as well as modernization of the traditional field course curriculum.

**Field Camps in Crisis—The BU Perspective**

Less than a decade ago, Boston University’s (BU) Field Camp was in trouble and, like many others, it faced the real prospect of closure. The course had been held in northern Maine for over 50 years, during which generations of BU professors and graduate student instructors had dedicated six weeks of the summer session to training students in classical field methods. As with most field camps, students reported learning more effectively at the outcrop than they had done in the laboratory, and camaraderie around the campfire created a level of personal con-
tact among faculty and students that was the envy of nonfield sci-
dences. With the coming of the plate-tectonic revolution in the late 1960s, Appalachian tectonics was a vibrant academic research field, and the Maine field camp was appropriately located.

However, while tectonic interpretations of the Appalachians had changed radically since the heyday of the plate-tectonic revolution, the field skills being taught to the Maine field camp students had barely evolved. An alumnus from the class of 1949 would have been familiar with almost all of the equipment and methods in use in 1998: finding one’s location by pace and com-
pass; identifying minerals by hand lens, scratch plate, and acid bottle; classifying subtly different fine-grained gray rocks into laboriously named stratigraphic formations and members; meas-
uring dip and strike or plunge and trend using the compass-cli-
nometer; stereographic projection of structural data onto tracing paper overlays; and finally “inking-in” and compilation of a “fair copy” map using colored pencils.

Students of BU’s last Maine camp in 1998 did not seem to mind that most of the skills they were learning were verg-
ing on obsolescence in the professional workplace—how would they have known? Their professors did not work for, or interact with, the exploration companies, environmental management consultants, geotechnical contractors, or geological surveys that employed most students. Longitudinal assessment studies were not carried out, so professors did not know how their course con-

**RETHINKING FIELD COURSE MANAGEMENT AND LOGISTICS**

**Relocation**

An exciting location is a strong draw for prospective field camp students and probably is necessary for long-term field camp survival. For BU, the transformation began in 1999 with the relocation of their field camp to the Connemara region of western Ireland—a geological, if not climatological, paradise. Comfortable, full-board accommodations were leased from Petersburg Outdoor Education Centre, a well-managed residential facility that normally offered year-round outdoor courses for at-risk children from inner city schools. The summer income from our six week field camp enabled the center to modernize its...
facilities significantly, so the relationship was (and continues to be) symbiotic. In 2006, career moves involving field camp faculty led to a transfer of administration from Boston University to James Madison University (JMU), where a summer field geology course had not been offered since 2003. Thanks to faculty continuity, the new philosophy and curriculum of the Ireland field course continues to develop at JMU.

Despite the extra expenses involved with an overseas location, relocating the camp to western Ireland had several benefits. We were able to market potential financial savings to parents who could use one course to fulfill their children’s desire for a study-abroad experience in addition to learning modern geoscience field methods. The location was remote and decidedly foreign, but nevertheless very friendly toward the United States—a significant factor in the era of parental security concerns following the 9/11 terrorist attacks. It was located on the edge of the Connemara Gaeltacht, one of the Irish-speaking regions of Ireland where the local accent is so strong that it can be difficult to understand the people even when they speak English. In addition to U.S. faculty and teaching assistants, Irish faculty were hired from the Department of Earth and Ocean Sciences at the nearby campus of the National University of Ireland, Galway. Students appreciated the Irish faculty for their detailed knowledge of the local region (and liked their accents).

Faculty Quality and Undergraduate Research Opportunities

We believe that an important factor in the success of the new approach was faculty quality. All faculty—both U.S. and Irish—were active scholars with funded research programs and strong publication records, and many were keenly interested in pedagogical research (Johnston et al., 2005). The revitalized course attracted a diverse faculty (including several female instructors and one African American instructor) and an equally diverse student population from universities from across the United States. Students recognized the research opportunities available in conjunction with the course. Some field course alumni and alumnæ were recruited by faculty for other National Science Foundation–funded research opportunities in the United States, Ireland, and other locations (e.g., Antarctica), and many students went on to graduate programs in the geosciences in first-rank research universities.

One key to our long-term success was the support of our departmental chairs and higher-level administrators, who recognized the importance of field camp service when evaluating untenured faculty. Our experience suggests that such support and recognition are more easily obtained if the field camp produces sustained scholarship and publication-worthy research for the faculty. A modern field course cannot flourish if administrators see it as a job for adjuncts or nonresearch faculty. Both authors were fortunate to have department chairs that not only supported faculty participation in the Ireland field camp, but actively taught at the camp.

Student Agility and Fitness

The student applicant pool for our camp was highly varied in physical preparedness for fieldwork. Students qualified automatically if they were in good standing in the host department (BU Earth Science Department, or JMU Department of Geology and Environmental Science). Applicants from other colleges, who frequently made up half to two thirds of the class, were accepted on the basis of grades and their application’s statement of interest, without face-to-face interview. Hiking skills were often minimal, and some students’ field background consisted of only a few day trips as part of their coursework.

Given the diverse enrollment, we attempted to make field conditions friendlier to less rugged or outdoors-inclined students. Ironically, the female faculty members were relatively disinclined to slow the pace or accommodate student requests. These professional women were self-selected successful products of traditional educational systems that had alienated the vast majority of their gender; they expected students to cope with their ablations in hedges and ditches, and to keep up with the most alpine of trip leaders. The authors’ somewhat more accommodating managerial approach was influenced by previous anecdotal experiences such as (1) an embarrassing rebellion by irate students on a 13 hour day-trip in a windswept, barren, restroom-free landscape lead by a clueless male professor; and (2) the experience of discovering that a student with prosthetic legs was enrolled in a structural geology course after said student commented on soreness at the end of a field trip and took his legs off. The student in question performed as well as his classmates and subsequently went on to serve as a field assistant to another professor on an international expedition. These experiences engendered respect for both the needs and abilities of nontraditional students.

On the other hand, some students had great difficulty completing assignments due to mobility and agility limitations (especially obesity), even though none of the exercises required technical climbing or particularly dangerous maneuvers. Accepting physically limited students into field programs is more or less mandated by nondiscrimination policies at most universities, so formulating successful approaches for dealing with these issues cannot be avoided (e.g., Butler, 2007). Allowing such students to complete alternative, less physically demanding, assignments was only a partial solution, as this created peer resentment. As obesity becomes more prevalent in the student population, this issue is likely to crop up more frequently in the future. Our current policy is to allow students with mobility issues extra time to complete assignments but to require that they get there in the end. Alternate exercises are restricted to those with predeclared disabilities or current injuries. This policy, though not foolproof, has been endorsed by many students. As an example of this approach, on a moderately difficult hike, one of the instructors would get to the top of the hill first, establishing his credentials among the most fit, while the other brought up the rear. Several students (mostly overweight) expressed deep appreciation for the fact that faculty were still waiting for them when they eventually got to the mountaintop.
Their previous common field experience had been that of meeting their professor and the majority of their classmates on their way back from the outcrop to the bus, and thus missing out on any lecturing or instruction imparted at the outcrop.

R and R

A common issue with residential field courses is the provision of appropriate social activities, to ensure that R-and-R does not translate into rowdy and rambunctious rather than rest and relaxation. Our policies follow university guidelines banning binge drinking, and we have had only a few isolated incidents. The 6 km roundtrip walk to the local village presumably damps (literally) the enthusiasm of potential revelers, but perhaps the more important factor is the availability of alternative leisure-time activities. Approved student drivers are permitted to take classmates to events such as horse-racing meets and nearby concerts in Galway City by visiting celebrities such as Bob Dylan and U2. Many students seem happier when they have opportunities to rejoin (nongeology) civilization on occasional evenings and at weekends. Those that prefer outdoor activities, such as leisure hiking/hill-walking, kayaking, or campfires under star-filled skies also have those options.

One unanticipated problem was the desire on the part of some “helicopter” parents to take the opportunity to visit their offspring in the field. We allow visits only grudgingly and outside of class hours. We also receive visits from field camp alumnae and alumni who return to the region for vacation with their fiancées, spouses, and children. Undoubtedly, field camp in the west of Ireland is a positive memory and character-forming experience for many.

When the international cell phone and iPod generation came to camp, our first reaction was to shun the intrusive gadgetry, following the lead of others that advocate a formal approach to the use of travel time (Elkins and Elkins, 2006). However, we soon recognized the benefits of accommodation and, in our own case, we would prefer if students spent bus time between outcrops pondering regional tectonics, but, in truth, students in previous years mainly slept. If they opted to listen to music or call their parents at enormous expense on their cell phones in order to say “Hi, I’m on the bus,” then they might work more attentively at field stops. On the way home from the last outcrop, students would appoint a “DJ” to hook their music players up to the bus speakers and face their peers’ evaluation of their music taste.

Of course, iPods and “smart” cell phones like the iPhone can also be used as mobile reference sources. Early on, we experimented with use of photo and video iPods as teaching devices by uploading sample images of rocks, minerals, and structures for use by students as a digital reference library on location. However, before this effort reached maturity, technological advances overtook it. The latest devices such as the iPod Touch and iPhone include a fully zoomable web browser, giving students access to vast resources of reference information without need for custom software. Traditional, pocket-sized paper field manuals such as Freeman (1999) can compete only if the subject matter of the field exercise is restricted to classical hard-rock mapping.

A CURRICULUM FOR THE TWENTY-FIRST CENTURY

Working collaboratively over several years, American and Irish faculty overhauled the Ireland field course curriculum. The move from Maine meant that mapping exercises had to be redesigned from scratch, and we took the opportunity to rethink our teaching philosophy and pedagogical approach. We deemphasized professorial lecturing at the outcrop in favor of a student research approach (asking students to frame the key questions; see May et al., this volume), and we introduced small group (three to four students) mapping exercises in advance of the main independent mapping exercise. Students reported increased confidence following group exercises, and they wasted less time in the first days of their independent mapping.

Recognizing the importance of the balance between an understanding of fundamental principals and knowledge of practical, transferable skills, we identified four areas of emphasis (see following) that could be developed in the Connemara region of western Ireland. Although Caledonian tectonics or Quaternary glacial geomorphology may not be accessible at other field camps, we believe that all camps can benefit by a reassessment of the ways in which their local geologic features can address the universal strengths of field-based pedagogy: cross-disciplinary knowledge integration, open-ended problem solving, etc.

Regional Tectonics as a “Big Picture” Unifying Theme

Connemara is a classic area of Caledonian tectonics. It lies along strike from the Appalachian orogen of Maritime Canada and New England in a pre-Atlantic reconstruction (Fig. 1A). Given the Appalachian historical base of both BU’s and JMU’s original field courses, and the blossoming career opportunities for hard-rock geologists in industry and academia (U.S. Department of Labor, Bureau of Labor Statistics: www.bls.gov/oco/ocos288.htm), it made sense to maintain a strong component of regional stratigraphy, tectonics, and paleogeography. However, we eliminated the “stand and deliver” approach to teaching regional geology at the outcrop, whereby the learned professor tells the story as it is, complete with much tectonic arm-waving. Information is no longer passed on only to those students lucky enough to be within hearing range of the field-trip leader. Instead, we employ scaffolded discovery-learning techniques by posing challenging questions to students, encouraging hypothesizing and constructive discourse, and surreptitiously guiding students to make observations that will provide critical hypothesis-discriminating evidence (McConnell et al., 2005).

As an example, students are asked to explain the easterly dip of the Connemara penepale, as seen in the local landscape (Fig. 1B). Initial efforts usually invoke local tilting, regional folding, or isostasy. With continued discussion and prompting, students learn to position local outcrop evidence within the
regional tectonic context and arrive at a more complete explanation of the uplift and exposure of Caledonian rocks in western Ireland resulting from regional extension associated with the opening of the Atlantic Ocean (Coxon, 2005a). Students also must relate their local mapping areas and outcrop-scale details, such as kinematic indicators, to regional tectonic problems, such as the position of Connemara in relation to other Dalradian terranes of Ireland and Scotland, mechanisms of terrane transport, and possible docking events. The key is that students must learn to view their individual projects in a larger framework that has relevance to the outside world. Like most field camps, our projects incorporate igneous, sedimentary, and metamorphic rock identifications, but these are now undertaken with tectonic synthesis in mind. We do not teach students to distinguish granodiorite from adamellite or paragneiss from orthogneiss for its own sake.

**Glacial Geomorphology**

The second area of emphasis focuses on the glacial geomorphology of western Ireland (e.g., Coxon, 2001, 2005b). Again, students are taught to map locally while thinking globally. Students usually notice without prompting that the western seaboard’s vegetation, including palm trees and Versailles-style formal gardens, differs from that of Maritime Canada or Moscow at the same 55°N latitude. Historic records of local climate document the rarity of freezing weather (data from the Irish National Meteorological Service: www.met.ie), with snow flurries no more than once or twice a year at sea level, yet the landscape is dramatically glaciated (Fig. 2). Students arrive at the field camp with a range of experience in glaciated terrains, from little to no previous exposure (Virginia) to fairly extensive knowledge of gradual terminal moraine retreat in New England, or direct experience with present-day glaciers in Alaska. In each
case, fieldwork that documents kame fields and other indicators of rapid down-wasting in Connemara is unfamiliar, despite coverage of the subject in common texts (e.g., Tarbuck and Lutgens, 2002). Our lesson plans highlight the differences in the history of climate change from Virginia to New England to western Ireland as a consequence of the off-and-on switching of the Gulf Stream and the process of North Atlantic Deep Water formation (Bond and Lotti, 1995; Coxon, 2001; Bowen et al., 2002).

Students were brought to Iceland one year on an experimental basis for a four day expedition prior to commencing their western Ireland mapping. Witnessing first-hand the products of active, present-day glaciation and viewing the ubiquitous evidence for rapid climate change proved to be of great pedagogical value. Students completed a 1 day mapping exercise at the face of Vatnajökull Glacier, where recessional and lateral moraines, eskers, kame fields, kame deltas, and ground till were visible in 100% exposures. Irish landforms of Quaternary age have a subdued topographic expression and are generally covered in vegetation, yet students recognized equivalent features with ease. Students’ recognition of volcanic structures also benefited from the Icelandic experience. However, financial and logistical burdens prevented us from making this a permanent part of the course, and the unique combination of fire and ice that characterizes the Icelandic landscape is not a perfect analogy for the Tertiary volcanic rocks and later Quaternary glacial carving of western Ireland. Although it is not quite as immersive an experience, today’s students can “fly” over the Icelandic terrain using Google Earth or NASA World Wind, and thus gain some appreciation of neotectonics and neoglacialism.

Environmental Geology and Hydrogeology

Western Ireland has a history of mineral exploration and mining dating back to prehistoric times (Cole, 1998). The practice of agriculture stretches over 5000 years (Cooney, 2000; Anonymous, 2007c), and the pressure of population, both native and visitor, has impacted water quality and created waste disposal issues on a number of occasions, including the crowded times before the Great Famine and the present era of tourism. Given the high number of employment opportunities in environmental sciences, we emphasize field-based exercises with themes spanning resource exploitation and conservation. Subtopics included in this part of the course are: bulk country-rock geochemistry, exploitation of mineral resources, impact of mining and rock composition on mine-water geochemistry, surface-water capacity and sediment-transport rates, and impact of geotourism in the Burren, a region of karstic topography in County Clare.

Students go underground in caves and Victorian mines that have been reopened as tourist attractions (Glengowla mine; Ailwee and Doolin caves), and they make observations and measurements on surface and subsurface water flow. The Burren area, in particular, is a fascinating karstic region that was previously glaciated. Students compare and contrast sediment-transport processes via surface glaciers with underground rivers and other karstic features to determine the relative importance of each of these agents in landscape modification. In Connemara, intense rain events drench bogs and alter river morphologies in a matter of hours; therefore, we have expanded exercises in geohydrology and riverine processes (see May et al., this volume).

Despite the competing dangers from hill-walking, bog-hopping, and quarry visits, our water-chemistry exercise brought us the closest to a serious injury in the five years in which it has been run. A student slipped in thigh-high water, became immersed for no more than a few seconds, and developed hypothermia within minutes. The first-response treatment—sharing a sleeping bag with fellow students—was great for team morale but the experience reminded instructors and management of the fine line between exciting learning experiences and potentially harmful consequences.

Digital Mapping and Visualization

On 1 May 2000, President Clinton turned off Selective Availability (i.e., civilian scrambling) of the Global Positioning System, and the accuracy of cheap, handheld global positioning system (GPS) devices such as those made by Magellan™ and Garmin™ increased enormously overnight, just in time for our digital mapping curriculum. At about the same time, National University of Ireland—Galway opened a state-of-the-art geographical information system (GIS) computer laboratory. GIS had already been in widespread use by the USGS and in industries such as environmental engineering (Longley et al., 2001), but rather trivial limitations—for example in plotting dips and strikes (Mies, 1996)—slowed its adoption by field geologists. Initially, we did not have the resources to invest in the newest technology. The sum of $4000 per person required to equip students with backpack-mounted GPS devices, such as those manufactured by Trimble™, and ruggedized tablet personal computers (PCs) was beyond our budget in 2001. This was not entirely a bad thing, as adopters of first-generation technology now find themselves encumbered with bulky equipment and heavy car-battery banks just as light, cheap, second- and third-generation technologies have become readily available. In 2001–2002, we concentrated on palmtop devices—initially personal digital assistant (PDA) devices such as Palm Pilots™ and handheld computers such as Hewlett-Packard iPAQs™—with somewhat cumbersome GPS attachments and waterproof cases. In successive years, we advanced to handheld Trimbles™ (GeoXM model) running the Windows Mobile operating system and ArcPad™ digital mapping software (see Whitmeyer et al., this volume). In the laboratory, we used ArcGIS™ and National Geographic Topo™ software and developed custom programs using Flash Actionscript™ to allow students to create visualizations of their own field data (Fig. 3).

Although many others have adopted mobile GIS solutions (e.g., Knoop and van der Pluijm, 2004; Neumann and Kutis, 2006), our approach was, to our knowledge, unique in one respect: whereas most digital mapping courses aim to
produce publication-quality cartography, we encouraged students to scan their rough field slips and penciled cross-sectional sketches into digital files for use with three-dimensional (3-D) modeling programs such as Bryce™, Carrara™, and our own block-diagram generator in order see their geological interpretations draped over local digital terrain models or projected onto the sides of a solid block diagrams. Students responded enthusiastically to the experience of flying by a digital terrain that highlights the locations that they had visited on foot the previous week and seeing their own sketch maps draped onto the digital elevation model (DEM). Our digital mapping efforts have progressed to the stage where we now use these exercises as part of an ongoing research project (Whitmeyer et al., 2008a, 2008b, this volume), and one of our image-draping exercises sowed the seeds for a subsequent publication by camp instructors and colleagues (McCaffrey et al., 2008).

Traditionally, after several days of field trips led by professors, students embark on their own map-making. While we retain five day individual mapping projects as the capstone exercise of our course, digital mapping technology has allowed us to incorporate collective mapping projects. Students gather digital field data and upload it to a base workstation each evening. They then create a collective map from that database using ArcGIS (Whitmeyer et al., this volume). The key innovation is that data are accumulated over several years and map interpretations are driven by group consensus, not individual interpretation. The feeling that their work is incorporated in ongoing geologic research and will survive beyond the grading exercise helps promote student engagement.

Today, we are in the midst of a new phase in the digital mapping revolution as GES (Google Earth Science) is added to GPS and GIS. This is dramatically illustrated by the geo-mashup of Figure 4 (see wikipedia.org/wiki/Mashup), in which the original

Figure 3. High-end graphic workstations at Galway University help students see their own recent fieldwork in a regional context.

Figure 4. William Smith’s (1815) map of England and Wales, Richard Griffith’s (1838) map of Ireland, and Archibald Geikie’s (1876) map of Scotland draped onto the Google Earth terrain (from Simpson and De Paor, 2009). Geologic maps are courtesy British Geological Survey, Geological Survey of Ireland, and the Natural Environmental Research Council, UK.
maps of Smith, Griffith, and Geikie are seen draped over the 3-D Google Earth digital terrain model (De Paor and Sharma, 2007; Simpson and De Paor, 2009; Whitmeyer et al., 2007). Hard-copy maps may be scanned and the resultant digital images draped over the virtual globe’s digital terrain (Fig. 5A). Digital maps superposed on the terrain may be rendered semitransparent for comparative purposes (Fig. 5B; see also Simpson and De Paor, 2009). The potential for removing the time-consuming step of hand-drawing a field map, while retaining the full fidelity of digital data with true outcrop evidence, suggests that digital field mapping is the method of the future for geologic map preparation. In addition, computer-based visualization of 3-D surfaces containing geologic map information introduces new prospects for constraining interpretations based on incomplete field data. In our field course, we advocate an iterative approach to geologic field mapping, whereby field interpretations on sketch maps are draped over the virtual 3-D terrain and continually evaluated throughout the mapping process.

Obsolescence in the Traditional Curriculum

As outlined herein, our students have to learn many new ways to collect, analyze, and present field information. They need to learn how to use GPS for location; ArcPad, and ArcGIS for data collection, analysis, and visualization; KML for interactive Google Earth maps; etc. Where traditionally they collected four-dimensional data regarding the geological evolution of a region and reduced that to the two dimensions of a paper or Mylar map, today they must create a link between the four dimensions of field evidence (latitude, longitude, altitude, time) and the four dimensions of the virtual globe (pan, tilt, zoom, play). However, the price to be paid for early adoption of technology is the certainty that much of it will be redundant in a matter of years, if not months. Palm Pilots are passé, and with the advent of virtual globe technologies such as Google Earth and NASA World Wind, the use of modeling programs such as Bryce and Carrara for DEM draping is now obsolete. Most recently, we have replaced our custom Flash Actionscript block diagrams with emergent block models created in Google SketchUp™ (De Paor et al., 2008). We need to avoid the pitfalls of teaching short-lived technological skills by emphasizing the importance of appreciating what current technology can do and being willing to experiment with it, rather than teaching rote-learning steps involved in a particular method (Fuller et al., 2002; Niemi et al., 2002; Brodaric, 2004).

For financial and logistical reasons, it is not possible to lengthen the duration of most field courses, and new efficiencies in teaching and learning techniques can only save a limited amount of time. In order to make room for the new curriculum components, we need to remove obsolete material from the traditional syllabus. At the same time, we want to retain classical methods that have professional or pedagogical value. Inevitably, some readers will disagree with the cuts we propose, but like those faced with the task of balancing a budget, we encourage age critics to present alternative solutions provided they “stay within budget.”

We would argue that students do not need to know how to locate themselves on a map by taking bearings. It is a nice skill to have in case one’s GPS batteries fail, but if such logic were our way of selecting course content, there would be no end of useful fall-back skills in the curriculum, from the abacus to smoke signals.

More controversially, given software such as Allmendinger’s StereoNet (2007), we question whether students need to know how to manually plot a great circle on a stereographic net. Rules about turning tracing paper in the opposite direction to the required strike are not of deep significance. It grieves us to say this because we love teaching this subject, and we witness instances of sudden insight in a significant minority of students. However, it is much more important for students to be able to interpret stereographic data in terms of tectonic models such as progressive pure or simple shear deformation than to be able to follow the geological equivalent of knitting instructions. Like many other traditional methods, the tedious of plotting data on stereonets these days is most efficiently accomplished by using a computer.

Finally, construction of strike lines is a quintessential example of an exercise that professors love to give to their students but that is never used in professional practice. Even when those same professors are drawing maps, they almost never employ strike lines, as can be verified by examining published structural maps. The best way for students to learn about contour maps is to manipulate them on a virtual globe such as Google Earth or NASA World Wind. Students can use solid models (as created with programs like Google Sketchup™) to “slice” through the topography and see the cut effects of structures.

LEARNING OUTCOMES AND EVALUATION

During the early years of the Ireland field camp, we did not have research funding to support objective evaluation of learning outcomes by an external assessor, nor would it have been easy to compare in detail the outcomes from such different courses as BU’s and JMU’s North American–based camps versus the western Ireland camp. However, student evaluations and students’ subsequent, postcamp communication with the instructors suggest that our innovations were highly successful on the whole (see Pyle, this volume). Students felt empowered by their geomorphological group mapping project, attesting to the value of peer learning. They also reported great pride and joy in seeing their maps printed using GIS workstations (Fig. 6) and approved of the incorporation of new digital technologies and research-based teaching methods in their evaluations (see Whitmeyer et al., this volume).

Student evaluations are valuable course assessment tools, but field camp faculty need to be prepared for critical evaluations that at times can be quite off topic. After six weeks in the field, some students suffer serious homesickness, others develop
Figure 5. (A) Classical mapping of the Connemara region (Leake et al., 1981) viewed as a three-dimensional (3-D) Collada model in Google Earth (De Paor and Sharma, 2007). (B) Student mapping of the Knock Kilbride area, draped over the Google Earth virtual globe (see Whitmeyer et al., this volume). Note semi-transparency and time slider. Downloads for Google Earth images and models are available from the Web site: http://www.lions.odu.edu/~ddepaor/Site/Google_Earth_Science.html.
personality clashes and petty jealousies, both with their professors and among their peers, and many let the stresses of independent mapping dominate their evaluation. In the end, a few cheery students spreading positive vibes through the group can be as important as project design in affecting learning outcomes. Similarly, a few malcontents can have a disproportionate negative effect on learning. In the case of western Ireland, the vagaries of the climate (ranging from only six wet days in one year to only six dry days in another) can be critical to a successful course. In this respect, when student evaluations are considered, an understanding department chair is essential.

Not all new course elements that we introduced when we first moved to western Ireland stood the test of time. Irish faculty initially set unreasonably high standards based on their expectation of capstone course content in the British and Irish system, where undergraduates study geology in greater depth (especially in the field) and have few, if any, distribution courses. After consultation, they then erred in the other direction by devising projects that lacked sufficient challenge. It took a few iterations to reach a working curriculum, and indeed the process of reassessment and revision continues. Finally, the postcamp success of our Ireland field camp students suggests that dropping exercises that we identified as obsolete or redundant did not have a significant negative effect on the students’ final ability to map and “do” geology in the field.

CONCLUSIONS

In a sense, today’s students “know” everything. Equipped with their field computers and iPhones, they are walking digital encyclopedias. They do not need to memorize all the knowledge that previous generations had to store in their heads. As a corollary, professors should stop acting as incomplete, error-prone walking encyclopedias to their students. In contrast, professors need to train students not to ask for information that their cell phone already contains. Instead, professors need to help students to evaluate, analyze, and pose the right questions. In short, we as educators should be teaching our students to think on their feet, as opposed to teaching the rote memorization of a field mapping methodology or detailed information about the Jack and Jill Formation or the Humpty Dumpty fault (names from C. Simpson, 1985, personal commun.).

We all want future generations to benefit from the field experience, but if field courses are to survive (Drummond, 2001), let alone prosper, we have to convince deans and provosts that these courses are of value beyond the training in geologic mapping that a handful of students will benefit from in graduate studies or industry careers. Despite the increasing popularity of “hands-on projects,” university science courses are still dominated by lectures that students listen to passively and by laboratory courses that have little relationship to how science is practiced by professionals in academia or industry. Working scientists are not presented with apparatus and a set of instructions to follow in order to discover something that is already known to their supervisor. The greatest transferable skill that students learn in the field is how to handle open-ended problems where they must pose the right questions before trying to answer them. Perhaps because they developed this vital skill, students consistently report, both verbally and in course evaluations, that they learned more in a few hours at the outcrop than in weeks of lectures or laboratory assignments.

At the Ireland field camp, students grasp and integrate several different fields, e.g., geology, geomorphology, and environmental geology. We are certainly not the first in any individual aspect of this endeavor (e.g., Brown, 1998; Manone et al., 2003), but we have assembled a unique blend of tradition and innovation, hard- and soft-rock, analog and digital, that others may find interesting for comparison. As pointed out by Day-Lewis in 2003, some more traditional geology programs required their stu-
dents to attend pure, hard-rock mapping field courses. Six years later, we have virtually no students complaining that our multidimensional curriculum will not fulfill their departmental requirements. It may be that field camps that adapt to changing student needs have survived better than geology departments that stood by time-honored standards. We should all recognize that within our small discipline of geology, we have already achieved a level of interdisciplinary study that deans and provosts wish other sciences would adopt.

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