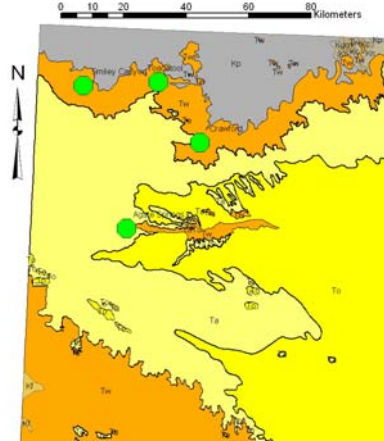


EARLY UNDERGRADUATE FIELD AND RESEARCH EXPERIENCE, THE TOADSTOOL GEOLOGIC PARK PROJECT IN NORTHWEST NEBRASKA

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Typically, students encounter both field and research experience later in their undergraduate careers. Field camp, field methods, senior theses and independent studies are often cast as capstone experiences. Yet, many believe that field and research experiences can provide a recruitment tool, capturing a student's interest in geoscience. Do students need prior coursework in order to successfully engage in a field research experience? An ongoing project, involving 7 undergraduates, explores this question and the utility of providing an early, field-based research experience. Pedagogic goals are to provide experience with: a) the process of novel scientific inquiry, b) the enabling role of technology and computers, and c) team work and the norms of professional behavior. Research goals are to develop a GIS database of fault, vein, and fracture traits in an area centered on Toadstool Geologic Park, and better understand intraplate deformation and associated fluid flow, scaling relationships, and fracture propagation histories. Excellent badland exposures in the study area allow details of fault and vein geometries to be examined. One challenge is to provide tractable and meaningful field exercises for students with little or no geoscience background. We provide a simple feature to start with. Associated data is easily related to concepts such as preferred directions, strain, stress fields and fluid flow. Students were subsequently introduced to gathering fracture density/orientation and fault data. Presently, students are involved in data compilation, analysis, and report writing. Each student chose a topic to work on, and a discussion of intellectual property developed. Prepared data templates, initial report outlines and other forms of guidance are provided. While self-discovery has advantages, it can also lead to student frustration. Two of the seven students involved are already committed geoscience majors, providing a range of undergraduate experience that was advantageous. Crucial to student involvement was the inducement of tuition reimbursement for students uncommitted to geoscience. Students who are not committed to a career choice likely need additional motivation to take the risk of engaging in such an unfamiliar experience

Below: Map showing location of Toadstool and other sites of known faulting in NW Nebraska. Geologic base map coverage from CALMIT and Conservation Survey Division, UNL



Description of the Toadstool GIS mapping project: We are building a GIS data base of features related to deformation in the Toadstool, Nebraska area. Layers include fault attributes, vein attributes, fracture density, sandstone channel positions, paleocurrent directions, USGS air photos (2m per pixel resolution), 10m USGS DEMs, and north central U.S. deformation localities (e.g. above map). Fault and vein attributes in the database include orientations, thicknesses, fault throws, types of mineralization, stratigraphic position and types of structures and/or textures (e.g. brecciation, zoning, vuggy cavities). More than 1200 GPS localities with attribute information have been entered for the Toadstool area so far, and there is potential for several times this amount of data (i.e. mapping is far from complete). Objectives of the project are to: a) investigate fault-vein propagation mechanics, b) explore fault and vein scaling relationships, c) possibly constrain fluid flow patterns, d) constrain the regional strain pattern and place in a context of intraplate strain history and deformation mechanisms, e) to explore the utility of GIS in investigating the above, and in the process give undergraduates research experiences (all but the first author are undergraduate students). We intend to study other localities (e.g. S. D. Big Badlands) in a similar way. **Acknowledgements:** Last summers field work was supported by an NSF STEP EUR grant to Hesham Ali, Jack Heidel, and Dana Richter-Egger, University of Nebraska.

- List of field experiences utilized at Univ. of Nebraska at Omaha:**
- 2-3 hour long lab exercise in Elmwood Park adjacent to campus, stream system modeling, in Earth System Science course.
 - Local day trips: to local quarry Physical and Historical Geology.
 - STEP EUR program described here.
 - Weekend regional field trips: Toadstool, Baraboo and Minnesota River valley, for Structure and Petrology
 - 10 day long annual Geology field trip (as far away as Ireland).
 - Virtual field trips (does this count, or more to the point is it useful?).
 - Field-based senior theses.
 - Field camp: our students utilize a range of approved field camps.

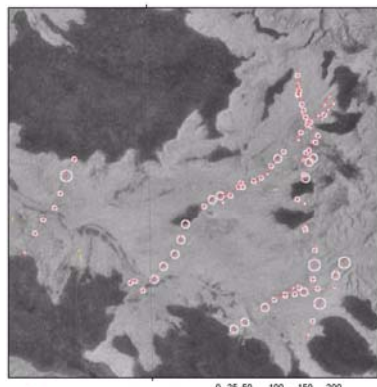


Right: View of badland exposures in Orella Mbr. Strata. Location was a challenge prior to GPS. Photo courtesy of Lucas Marshall.

History of utilization of Toadstool as a field experience for students:

While we have been visiting Toadstool with students for close to 20 years, it is only in the last 2-3 years that a focused, student-oriented research project has been developed. Early on one of the problems in using Toadstool as a mapping experience was the difficulty in accurate location in the intricate badlands (either by inspection or by triangulation, see adjacent photo). Too much precious field time was spent in locating sites, to the detriment of learning the geology. GPS alleviates this. Interestingly, students still learn to read and navigate the maps or air photos by inspection in getting around, finding that easier than navigating only by GPS. In addition, GIS allows for relatively easy map compilation of the GPS based data, and allows for easier exploration of phenomena such as segmentation of fault characteristics along the length of the fault. A demand for GIS knowledge is also an attraction. Thus, development of the present project was made possible by development of affordable GPS and GIS technology. To date a total of 23 students have been involved in the project, and one senior thesis has been completed and one is very near completion. The STEP EUR effort consisted of 7 students who conducted field work for a week last summer. The potential for further development of this GIS data base is such that this project could continue for another decade.

The merits of Toadstool Geologic Park as a site for an early undergraduate research field experience: The veins and faults exposed in the area are simple enough for undergraduates with little or no geology coursework to be able to learn about and work with, and the exposures are excellent. However, the structures that exist here also provide a wealth of depth of questions the students can pursue. I started students with the veins, measuring their position, orientation, maximum width, length (if both tips were exposed) and type of vein fill and internal textures). Some students also made traverses across vein fields measuring spacing and vein thickness. With this data the students are then introduced into questions about common orientations, scaling relationships, the source and evolution of the mineralizing fluids, the amount of strain, and spacing patterns. After the students have mastered working with the veins, then they are introduced into the additional complexities associated with the faults (e.g. measurement of slip direction and throw and additional fault zone textures). Mapping along the faults quickly introduces them to ideas about fault segmentation and possible propagation and linkage phenomena. Students became adept at measuring orientations, recognizing features, and recording data after one to two days. From the simple start students build a more complex understanding by thinking about relationships between the faulting and veining. Well developed channels, paleocurrent features, joint sets in the sandstone channels, sites of soft sediment deformation, and pipy concretions provide other features that can be mapped and added to the data base.



Above: Close up of striae on a fault surface. The mineralization along the fault surfaces causes the faults to be resistant to erosion and to outcrop as small ridges. Details of fault and vein structure are therefore well exposed in the area. Note the vuggy calcite fill.

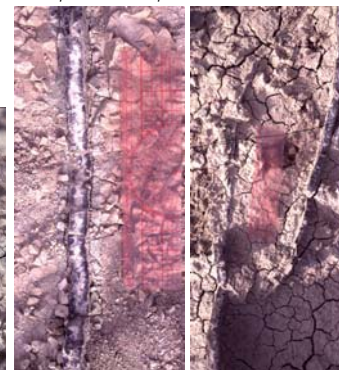
Left: Example of a product of the GIS data base. One can see fault segmentation in both the plotted fault plane strikes and dips, and in the fault zone thickness depicted by the size of the circles. The geometry depicted by the GPS data accurately depicts the patterns seen in the field

Why is field experience so vital pedagogically? Recognition and identification of geologic phenomena and patterns is a complex mental endeavor. Simple mineral identification can be taken as an example. In our experience, most students do not consciously and logically proceed through a series of tests and observations to a mineral identification. Instead, they 'recognize' a specimen as a certain mineral and then proceed to test and/or support the validity of that recognition with further tests, observations and logic. The 'recognition' is based on prior experience and training. The process of pattern recognition is often quick, and difficult to articulate or analyze. The neural mechanism is debated, but may involve the reinforcement of patterns of synaptic behavior by repeated experience. Such recognition is a starting point for conscious deliberation. The pattern recognition process is likely an adaptive time saving mechanism. Repeating the steps of a training module (an exemplar) or logical deliberation in a conscious mode is too inefficient. Development of artificial pattern recognition has given in depth thought to the mechanics of this pattern recognition process. Recognition of landforms, structures, geologic patterns thus depends on prior experience, and become reinforced through repetitive experiential patterns. A task of teaching in the field is to focus the student on the significant patterns (e.g. to ignore the fracture patterns to see other structures). Diagrams can be visually so different from the reality they depict that do not aid in development of pattern recognition for the phenomena they depict. Photographs may be better in developing pattern recognition. However, the 3D, animated, multi-perspective visual input of field work, rich in associations, is likely unequalled in developing geologic pattern recognition. Formal reasoning, the mainstay of the classroom environment, can inform development of pattern recognition, but the brain needs to be trained in additional ways. In this case, the more and the earlier field experience occurs the better for learning by providing food for thought.

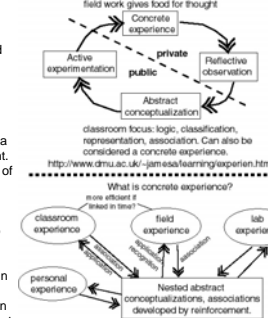


Below left: View of simple vein. In addition to noting its orientation students also noted the type of fill, types of internal textures, and any evidence of alteration. From this they can explore implications for the source of the fluids and mechanisms of vein growth (antitaxial versus syntaxial).

Below right: View of two vein tips that curl towards each other. This provides an excellent opportunity for intro students to think about vein growth and tip migration, and the possible interaction between two growing fractures. Vein length-width relationships can also be explored.



One version of Kolb cycle of experiential learning:



Above: Models for experiential learning as a context for field work. **Right:** Students looking at some small en echelon chalcodony veins during initial training. Photo courtesy of Lucas Marshall.

Below: A key challenge in the EUR project is how to engage students who do not have experience with the research process in addition to limited or no geologic coursework. Below is a conceptual matrix mapping out instructor versus student responsibility for steps in the research process and different student levels. For the Toadstool project students the focus was on implementation of an already developed research design, but the rationale for that design was shared with the students.

matrix for research process and level of expertise	problem formulation	background research	methodology development	data collection	compilation and analysis	writing and drafting	comments
non-major	instructor given	instructor given	instructor given or aided	student implemented	instructor aided, student implemented	student implemented, instructor aided	◦ student who do not yet implement one or two steps
intro major	instructor given	instructor given	instructor given or aided	student implemented	instructor aided, student implemented	student implemented, instructor aided	◦ students get through some steps but still do not give a practice exercise
advanced major	instructor given	student implemented, instructor aided	instructor aided, student implemented	student implemented	instructor aided, student implemented	student implemented, instructor aided	◦ students get through all steps, but do not record and label some questions
senior thesis	student developed	student implemented	student implemented & instructor aided	student implemented	student implemented, instructor aided	student implemented, instructor aided	◦ students get through all steps but do not complete all steps
graduate thesis	instructor aided	student implemented	student implemented	student implemented	student implemented, instructor aided	student implemented, instructor aided	◦ students get through all steps but do not complete all steps

Discussion: The felt importance given by many geoscience instructors to field work can be supported by models for learning. It is especially important for students who will work in the field (e.g. in the environmental industry). We are using an early undergraduate field research experience for both learning and recruitment processes. Since this is an initial exploration by a student of geoscience, and their level of commitment is lower, the potential for frustration is significant, and care must be taken that the research questions and associated concepts are accessible. Some research projects may be better suited to an EUR experience than others. Toadstool, because of the character of its geology, offers the possibility of pursuing questions that range from simple to complex, and provides a good natural laboratory for undergraduate research and experiential learning, one we intend to continue to use with students at several different levels. Especially advantageous to the enterprise was having more advanced students that can serve as role models for less experienced students. One aspect we may change is how specific research projects are assigned to students. Instead of collecting data collaboratively as a group and then having students pick from a range of possible projects at the end of field work, we will have students choose a research topic prior to field work and concentrate on it for the duration. Ownership is a very important issue in a collaborative project like this one, and the earlier a student is assigned their project the greater the feeling of ownership. The downside of this change, is that the breadth of the student experience will be reduced. Quantitative assessment of the value of introducing non-majors or intro majors into a complete field research experience is difficult because of the varied nature of the students and numbers to small for meaningful statistics. Our department has long stressed undergraduate research, with an emphasis on the senior thesis, one of our capstone courses. Several years ago a teaching circle at UNO explored what constitutes undergraduate research, and how it can be differently utilized with different student audiences. This project is in part an outcome of that exploration. Continuing this approach of Early Undergraduate Research experiential learning with a field component, we are developing labs for an introductory Earth System Science course and a summer science camp that combines field mapping and sampling with compilation and analysis in a computer environment, using a stream within walking distance of campus as a field site.