Mobile GIS in Geologic Mapping Exercises

Klaus Neumann — Department of Geology, Ball State University, Muncie, IN 47305, kneumann@bsu.edu

Michael Kutis — Department of Geology, Ball State University, Muncie, IN 47305, mkutis@bsu.edu

ABSTRACT

We have been developing and teaching the components of mobile GIS in Field Methods courses and will be incorporating them into Structural Geology exercises. Since the bedrock in east central Indiana is topographically invariant, non-inclined, and often not exposed, we have developed a new introductory GIS project that simulates structural features. It utilizes inclined, one-foot square planes that are placed upon a series of pedestals stationed in an open area, each accompanied by a petrographic hand sample and an age label. An introductory one-hour session is held in the field to teach acquiring GIS data. Then the students independently acquire geologic data such as GPS-located "outcrop" locations, rock descriptions, and strike/dip, and enter the geologic data on a base map using Mobile GIS software (ArcPad). In a two-hour follow-up class students learn to add their field data to a map in the PC-based GIS program ArcMap. Strike/dip symbols are computer-generated and displayed at the GPS coordinates taken in the field. This exercise supports spatial organization with data availability of Mobile GIS in the field and prepares students for GIS-based mapping projects in our Field Camp in Wyoming.

INTRODUCTION

Mobile GIS, that is recording field data digitally and connecting them in-situ with geographical points on a map using GPS and GIS, is an emerging technology and can be used as a tool in geologic field mapping and data collection. Over the last years, the Ball State University Geology Department has integrated this technology in many of its geology courses, from field methods to structural geology to our five-week summer field camp. Being an outdoor method, clearly a lab is required to teach students the skills. Traditionally, we have introduced GPS and mobile GIS to students in our field methods class. However, due to a curriculum restructuring, these exercises are incorporated into other classes. The GPS-based exercises are run in structural geology where field mapping is now being emphasized. There are several advantages to this approach: students taking the upper-level structure class already have experience in map reading and skills in rock description. In the structure class, they learn to recognize structural features in the field and on maps. So, at least theoretically, exercises introducing GIS methods at this level can focus on applying the new technique while integrating advanced geological tasks. Structural geology is also a class that is required for field camp, where this technique is widely used, as described later.

The choice of location for this introductory lab proved to be not easy for us, given the topography and geology encountered in central Indiana - flat lying carbonates covered by till. We take students on field trips to Kentucky and, like most other Midwestern universities, to the Appalachians (Malone, 1999), but we like the students to know how to apply GIS methods beforehand in order to utilize time on these trips more efficiently. As a compromise, we developed this campus-based exercise. On-campus exercises are popular because they are easy to organize, do not require additional funding and travel time such as van-based field trips, and avoid increasing liability issues encountered with using vans (Keown, 1984). Other schools successfully use the geology encountered in and on campus buildings to conduct campus walking tours (Weiss and Walters, 2004), or have built rock gardens to make geology available (Dillon et al., 2000) For our exercise, we want to be able to control the settings, which makes using buildings on campus impractical, and to create a rock garden goes beyond the scope of our exercise. Accordingly, we developed temporary devices that mimic petrographic and structural features, that are easily movable, cheap, and that do not require as much preparation and administrative work as, say, creating a rock garden.

Our goal is to introduce the students to the new mobile GIS technique while incorporating geologic tasks they already know, such as strike/dip measurements and rock descriptions. The introduction of this new technology is expected to increase student enthusiasm. Although students have learned previously to take field notes, the use of the GPS and GIS gadgets seems to upgrade the attractiveness of the measurement tasks in the students' view: The exercise does initiate creative thought by connecting new technology with traditional mapping techniques. Student confidence in the field is enhanced by a satellite verification of location, while computer-generated strike/dip symbols, and spatially arranged lithologic data allow a quicker comprehension of geologic structures encountered.

After initial trials, however, we also learned to repeatedly emphasize careful measurements and descriptions in the field. We observed that students (incorrectly) imply that the high-tech digital recording is the most important part of field work as opposed to low-tech initial observations, i.e. rock descriptions and strike/dip measurements. Also, the digital user surface can (again, incorrectly) suggest to the students that data collected in the field could be "corrected" later such as photos can be reworked in Photoshop and similar programs, and some students saw that as an excuse for some sloppiness in the field. The students also encountered some limits of modern technology, ranging from accidentally deleting data sets to dead batteries to poor or complete lack of GPS reception in campus areas with high tree coverage or close to buildings. Once those problems were overcome, using the organization and representation of field data on a mobile GIS increased the student comprehension of relationships between their data and geologic structure, leading to an overall better product and understanding of the geologic exercise.

HARDWARE/SOFTWARE

Mobile geographic information systems consist of three main components: PDA (personal data assistant), GPS

Figure 1. A pedestal with board for inclination measurement set up on the soccer field of Ball State University. We encourage students to work in small groups but require that everybody reports their own measurements.

(global positioning system) receiver, and mobile GIS software.

The PDA is the main processing unit of the GIS. It must be capable of running the GIS software and accept input from the GPS receiver. We use HP / Compaq and Dell PDAs that both use the Microsoft Pocket PC operating system. The two brands of PDA accept input from the GPS receiver differently: Dell PDAs accept input via the Compact Flash (CF) or Secure Digital (SD) slot from a GPS receiver that is directly attached to the PDA (we use both Transplant CF Primum and Pharos IGPS-SD CF and SD-slot GPS receivers). The HP / Compaq PDAs can receive the GPS signal via SD or CF slot, or through a serial port via a cable. A serial cable data connection provides the advantage of being able to use a stand-alone GPS receiver (we use Garmin brand GPS units) within the mobile GIS and allows the operator to record data both on the PDA and the GPS receiver. All of the GPS receivers we use send data in NMEA 0183 format to a PDA. The software used on the PDAs is ArcPad 6 by the ESRI company. We also use PCs and laptops in this exercise, and the software for them is ArcMap 9, also and ESRI product. Currently (Spring 2005) a set-up with an HP / Compaq PDA and a Garmin GPS unit costs about $550 per unit, while a Dell PDA with a SD or CF slot GPS costs about $400 per unit. Ball State University has a multiple-user contract for ArcPad and ArcMap, so there were no extra expenses involved with the software.

The advantage of separate GPS units is that they can easily be disconnected and used for other, GPS-only exercises, an option the slide-on units do not offer. The disadvantage is the cost (currently stand-alone GPS receivers cost more then a CF or SD slot GPS units) and that two units, PDA and GPS connected by the serial cable, have to be handled. The advantages of the slip-on version are lower cost and easier handling in the field since PDA and GPS form one unit; however, we discovered that after a while our units developed some connection problems between GPS and PDA, probably caused by either the weight of the GPS unit sitting on top pf the PDA, or by continuously dislocating the GPS unit when handling the unit. In summary, our technical suggestion leans towards the stand-alone GPS combination because of the greater flexibility as the GPS can be used separately. If that feature is not necessary,

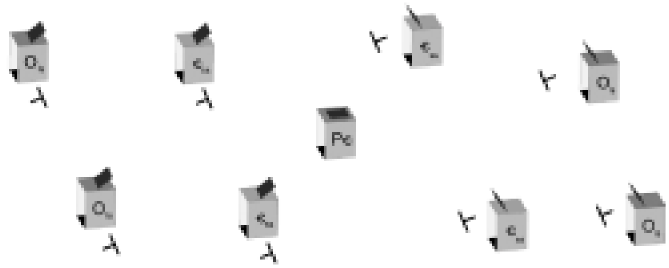

Figure 2. Set up of pedestals with plywood boards on top. This arrangement simulates an anticline. The rock samples are granite at PЄ (Precambrian), sandstone at Є (Cambrian) and limestone at locations marked O (Ordovician).

and / or when budgets are very tight, the slip-on option is a valid alternative.

Combined, we have 22 units operating. The units were bought over time, depending on funding possibilities, which explains the inhomogeneous composition of our devices. This causes some extra work and requires extra time since each device works slightly different and has to be explained separately. However, this has not been a major problem since, once the basic functions of the units are explained, the advanced work is very similar.

THE EXERCISE

The exercise consists of an afternoon-long field exercise, and a two-hour long classroom section on a different day. In the field exercise, the students learn to use the technology, take measurements, record them, and should be able to identify the simulated structure. In the class part, the students transform their field data and maps into a final map product that can be printed out and handed in for grading. The exercise is set up in a way that students, correct measurements implied, will discover a (fictional) anticline that stretches across campus.

Preparation - An ArcPad map is created for the study area and loaded on each PDA before given to the students. This is the default file type that is opened and modified in ArcPad. It contains the base map of the study area and one shapefile for each feature type of data collected. In our case, we use a digital 1:24,000 USGS topographic map that covers the Ball State Campus.
Angled boards using a small wooden base plate onto which four dowels are mounted and hand specimens are placed on pedestals out in an open field, in our case the campus quad or the soccer field (Figure 1). The pedestals can be labeled, for example with a formation name or an absolute age. Each pedestal station is GPS-located by staff and this location is later compared with the students' measurements. The stations are set up on campus according to a plan; for example, they can represent an anticline (Figure 2). Rock samples and age labeling of the pedestal are coordinated so that the results gained by the students throughout the exercise should allow them to describe not only an anticline, but also a process such as a transgression.

Class - In the first hour of the field session the students, supported by staff, assemble the various mobile GIS, experience basic use of the ArcPad software, and become accustomed to the procedure of collecting and recording data. The students learn the procedure required to correctly connect the GPS receiver with the PDA, turn the PDA on, invoke the software, and open the appropriate

Figure 3. Representation of a PDA with ArcPad software displaying a project map created by a student. Strike/dip symbols can be seen on the location of the campus quad.

ArcPad map on the PDA; then, turn on (stand-alone units) and activate the GPS receiver, display the appropriate tool bars on it, and acquire and record an accurate point location. Next, the students get introduced to recording strike, dip, rock description, and rock formation on their PDA, and referencing the quality of the GPS signal. Finally, they learn to deactivate the GPS, save the current ArcPad map, and turn the PDA off. In this exercise we do not discuss GPS itself. We run an on-campus exercise earlier on in the semester to let students get familiar with GPS units. The exercise is similar to the "around the quad" exercise described by Herrstrom (2000).

After this instruction the students collect field data in the study area (Figure 1). The students have about three hours to cover nine stations. The most help from faculty and staff is needed at the first stops, and is mainly concerning problems with data entry as some of the required commands are not very intuitive. Once the students become more familiar with the techniques, the speed of data collection increases markedly. As mentioned above, we think it is necessary to remind students repeatedly that the quality of their original observations and measurements is as important as learning the new technique. We encourage students to work in small groups throughout the project, but require separate measurements and rock descriptions. This group work clearly helps by fostering discussions among students. Often students can work out problems with measurements or data entry among themselves, helping them to feel more secure about their skills. At the end of the exercise each student has stored the pedestal locations in the PDA and placed it on the ArcPad map. The strike and dip measurements and rock descriptions are saved in the PDA as well, and can be displayed on the ArcPad map, next to the site location. Before releasing the students for the day, we make sure their data collections are complete and do not contain severe errors.

In the lab period, a two-hour class session is held in the computer lab to create a final product. ArcPad, the program used on the PDAs, is a scaled-down version of ArcMap and not powerful enough to handle the next step, turning location points into strike/dip symbols. To do this, the students connect a PDA with a laptop or a PC and transfer the data. On the PC the students export the data gained in the field as an ASCII file, use an in-house strike/dip-generating program (for a similar program, see Mies, 1996) to create strike and dip symbols, and then export them back into ArcMap. Once added to the base map within ArcMap, the new map now bears the strike/slip symbols at the measurement locations. This map can be printed out and handed in, and also transferred back to the PDA (Figure 3) where it can be used in future mapping exercises in the same region. This multiple transfer of data is time-consuming, and certainly the weakest spot of this exercise as it introduces a time-lag between data acquisition and representation. However, currently we have to follow this procedure because no software exists that allows this conversion in the field, and we consider laptops as too fragile to take them into the field. We further discuss this issue in the evaluation chapter of this article.

Maintaining the computer facilities for exercises like this is a time and money-intense undertaking (Wallace, 1999), but the effort provides students access to up to date technology in this exercise, and it also provides the hardware that can be used in other classes. In spite of the complexity, the results of the exercise, and of using mobile GIS in general, are very promising in that students produce up to date digital geologic maps.

APPLICATIONS AT FIELD CAMP

This exercise also serves a preparation for field camp. One of the shortcomings of our one-day field exercise is that students cannot go back in the field, with their original data set displayed on the PDA as strike/dip symbols, and collect more data because the pedestals have to be removed at the end of class time. The full advantage of the technique can be experienced during long-term assignments such as the four-day exercises we run in our field camp in Wyoming. Here this technique provides our students with a quick graphic representation of the data they collect over a day (Figure 4). We provide laptops that cannot be taken directly into the field, but are used in the evenings to process data in the way described above. This use of laptops is an approach that becomes more and more common in field camps (Brown, 1998; Schlische and Ackermann, 1998). One of the great advantages we have seen so far is that students have to spend less time plotting their field data on maps when using mobile GIS; instead, that time can be spend discussing their results. We also provide digitized air photos onto which the strike/dip measurements can be projected. This feature is particularly helpful for correlating geologic features with landscape forms and proves to be a teaching tool which is very popular with students. The students go back into the field and they see their previous day's measurements graphically displayed on their PDAs. This helps them to address remaining questions, fill gaps in their maps, and

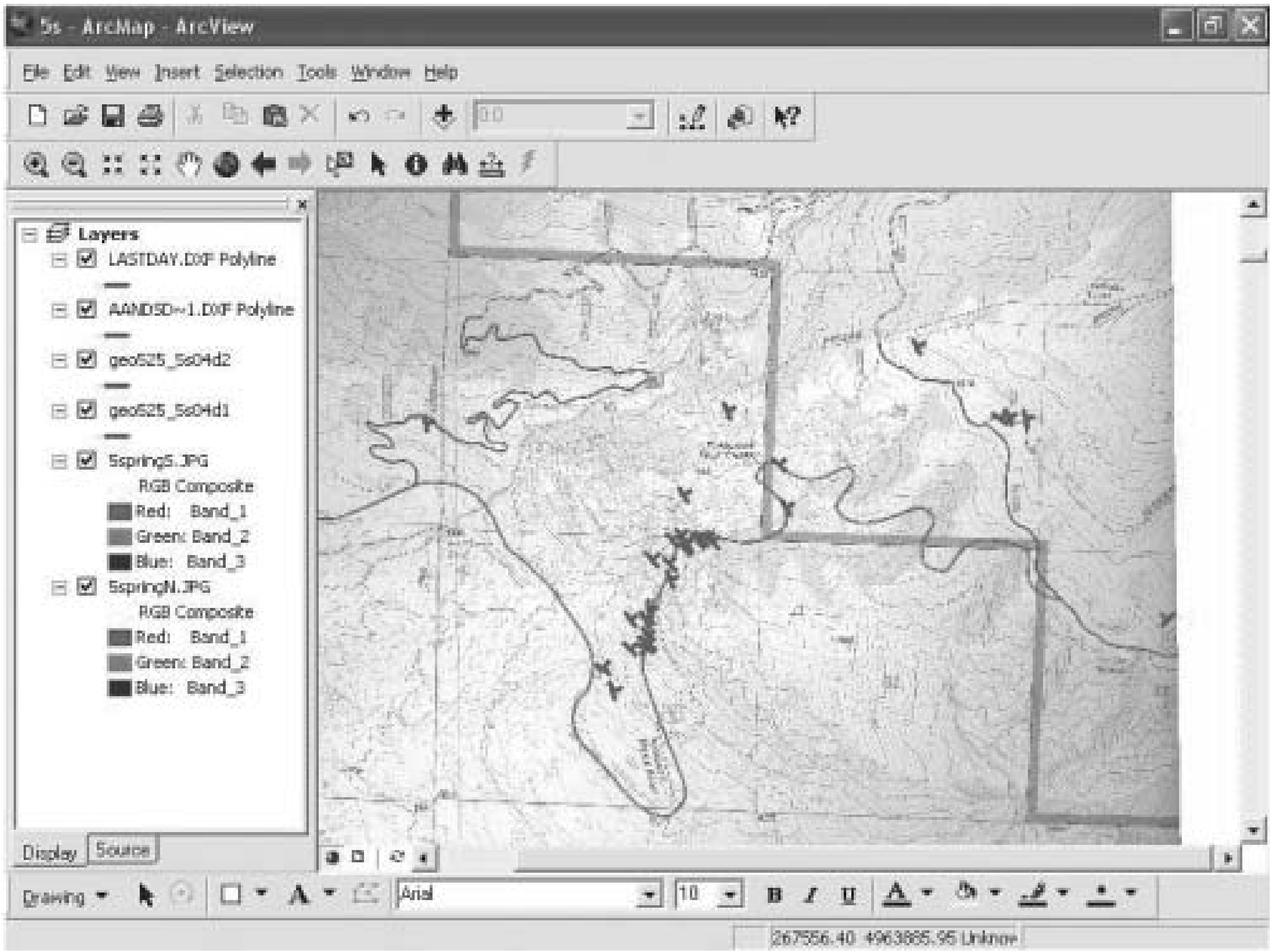

Figure 4. ArcMap presentation of the Five Springs project done during field camp in Wyoming. This exercise uses the skills gained by the students in the project described in this paper and expands it by applying it to geologic mapping in the field. This map represents a day's work of collecting data in the field reworked on a laptop.

generally by helping with locating themselves in the field.

EVALUATION OF THE EXERCISE

This is a new exercise in a newly configured class applying new technology, and a direct comparison with previous exercises is not possible. In order to assess the introduction to mobile GIS, we sent a questionnaire to the students and asked them evaluate the exercise. We summarize the results of this evaluation below, and then briefly discuss it from our instructors' point of view.

Student Assessment - All students mention that this exercise increased their interest in mapping and GIS by being hands-on and introducing new interactive equipment. Students generally like the fact that our mobile GIS exercise builds on previous geologic experiences and is integrated into a structure class; only one student would rather take a separate field class. According to the students, using the equipment in a real geologic project enhances their knowledge of both the mobile GIS and the structural feature they are studying. On the other hand, several students found that combining a strike/dip with a GPS/GIS exercise taxed them heavily and would rather see a more extensive strike/dip measurement training prior to this exercise.

All students agree that using mobile GIS saves time in the field, which is attributed mainly to the availability of accurate GPS location information and the ability to directly store this information without having to enter the UTM coordinates manually. This direct notation also eliminates typing errors. However, entering strike/dip and other geologic data into the PDA is not necessarily seen as a major advantage, mostly for technical reasons. Approximately half the students admit that they are not confident enough in their PDA skills to solely trust them and will also take field notes. Students suggest enabling them to hand-write directly on the PDA instead of using the "tiny" keyboard on the PDA screen would be more practical. Other students express interest in sketching preliminary strike/dip symbols on the map displayed on the screen. They stated that they are aware that this initial sketching would not replace accurately drawing the symbols afterward, but they state it would help them to get a better overview earlier on in the exercise and help detect errors in their strike dip measurements. The students predict that the entering of strike/dip data into the PDA in the field would become more beneficial during larger projects, when entering data into a laptop after field work would take more time.

The students find that the time lag between field work and manipulating data in GIS, caused by the inability of PDAs to generate strike/dip symbols in the field, is generally not satisfactory. However, everybody, except one student who already had GIS experience, considers the separate 2-hour lab session spent to introduce students to ArcMap essential and helpful. Even the student with GIS experience likes the concept of separate lab / field instruction, stating that an instruction into GIS software during field time would distract from learning the field-based part of the exercise.

Asked for an evaluation of their perceived progress throughout the exercise, the students unanimously write that this introduction field project helped them to become independent mobile GIS users. Most students express further interest in doing more field exercises to get more practice. They feel confident to construct simple maps such as the one created in this exercise, but said a dedicated GIS class is necessary to master ArcMap.

Asked for some overall impressions, the students unanimously say they like the exercise, especially the outside, hands-on experience and the use of new technology. They would keep the exercise and actually dislike that this is currently our only mobile GIS exercise, except those in field camp. If they could make changes, they would address the technical issues with the PDAs mentioned above, and run the exercise in one day, shortening the lag time between measurements and map preparation. The multi-step data conversion itself is not criticized.

Instructor Assessment - We expected the students to reach the following goals: acquire a GPS location on a map, record the location and geologic data in a PDA, transfer data to a laptop, generate a map strike / dip symbols in ArcMap, determine what kind of structure was mapped, print the map and transfer the map back to the PDA for future field work. All of the students reached those goals; that is, they handed in a finished product demonstrating their success. The amount of assistance for each student varied. In the field, the assistance level depended primarily on the students' performance in strike / dip measurements and on their comfort level with using a PDA, while in the lab it is based on students' previous experience with GIS and computers in general. The time allotted to the exercise was sufficient for everybody to finish it.

We concur with the students' judgment that this introductory exercise is successful in instilling basic map-making skills. We also agree that, after learning the basics, more practice for the students is desirable. In addition to GIS classes offered by the Geography Department, we provide extensive practice during our field camp. In that course we noticed that students take significantly more (three to five times) strike / dip measurements during multi-day mapping projects since the introduction of mobile GIS. More data points led to better representation of geologic structures and more accurate geologic maps. We have not analyzed this development yet, but assume it is based on the same impressions we gained in this exercise; namely, easier establishment of locations in the field using GPS, easier recording of location coordinates, and working with new equipment. In multi-day projects students also experience the full benefit of creating a map for the PDA that can be taken back into the field.

Based on the students' and our observations, we plan to keep this introductory exercise while improving several details: assuring students are truly familiar with strike / dip measurements before the exercise so we can solely focus on the mobile GIS part; having the data transfer from PDA to laptop scheduled directly after the exercise so the time lag is shortened; and demonstrating students how to make preliminary strike / dip sketches on the PDA in the field. Our ultimate goal is to have them construct the final map while they are in the field; however, currently existing software does not allow for this yet.

CONCLUSIONS

Having an intro-GIS class on campus is a very practical way to introduce students to a new technique. An exercise that uses cheap, easily moveable pedestals with setups to measure strike / dip and rock samples can be implemented at practically any place, regardless of the geology, but still challenge students to use mobile GIS to solve geologic problems. It takes some time to set up the exercise and to train the students, but this is rewarded by enthusiastic students and good mapping products. Setting up the technology involved is not cheap; however, the devices can be bought over time (students initially can work in pairs), they can be used in many classes at all levels (especially if stand-alone GPS units are used), and they provide students with an up to date training with equipment they are likely to encounter in their professional life. Students generally like the hands-on aspect of the exercise and the option to work with new equipment; dislikes were based on technical aspects, most of which can easily be improved. Mobile GIS offers many new options to help students during mapping exercises; amongst them the motivation to take more measurements in the field, the possibility of overlaying measurements onto aerial photos and maps, freeing time traditionally spent drawing maps by hand, and producing digital maps as a result of their work.

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