Mapping Bedrock Outcrops with Stride & Compass and a GPS Unit *in a soil and forest mantled landscape*

Activity: Students take a two mile hike along a trail in a forest, and map bedrock exposures. The project takes place over a few days. Students will need 2-3 hours to collect the data in the field, and another 2-3 hours to create a digital map in the lab. Any form of spatial data could be targeted for this exercise. Bedrock outcrops were chosen in this case because of their rarity.

Objective: The main objective for the project is for students to learn how to collect spatial data in the field, convert the data into a digital form, and create a computer-generated map of the data combined with other spatial data.

Outcomes: After completing this exercise, students will be competent users of GPS and traverse mapping techniques. Students will be able synthesize data in a computer environment. The exercise combines lower level skills with higher level decision-making. This exercise asks students to make decisions about whether a house-sized glacial erratic on a forested hillslope is a bedrock exposure—thus they have to use observational skills *and* judgment to complete this task. An additional aspect of this project is the inherent nature of scale, and representing objects on a map. Students learn directly about the limitations of paper maps with a fixed scale. Spatial data collected at <10 m intervals will not show up on a map spanning several kilometers as more than a dot. However, *digital* maps permit easy change of scale (zoom). Students learn that detailed mapping can be done at very fine scales, and once georeferenced, such data can be placed into a larger framework while maintaining a high level of detail and information. Students of geology learn directly how sparse the real data are for many of the maps with which they work.

Necessary tools: Tape measure, compass, GPS unit capable of recording waypoints, computer, GPS data transfer cable and download software, spreadsheet software capable of performing calculations between cells, GIS software such as Global Mapper or ArcGIS, access to the internet via a fast server connection.

Learning objectives

1. Students will develop observational skills in recognizing bedrock outcrops.
2. Students will learn how to use a handheld GPS unit to map geologic features.
3. Students will gain expertise with recording waypoints with the GPS unit.
4. Students will gain expertise with translating tape-compass points into the UTM reference frame.
5. Students will gain facility with inputting data into GIS software.
6. Students will learn how retrieve free spatial data online.
7. Students will learn how to manage and combine spatial data in a computer-based mapping environment.
8. Students will develop skills in creating custom digital maps.

Exercise

In this exercise students map a trail and geologic outcrops along that trail using stride and compass and a GPS unit, and combine this data with other spatial data in GIS software. Students use the traverse method of surveying. The exercise focuses on just the locations of the bedrock outcrops, and leaves geologic description of these sites for a later exercise.

To begin, map the trail with the GPS unit, collecting waypoints at each significant bend in the trail. Map the edges of each bedrock outcrop that you find along the trail. The field area containing the bedrock outcrops lies between the practice fields and College Camp. Start at the practice fields, and locate the “Red” path leading north on the east side of the field toward College Camp. Map the Red trail up to the junction with the Orange trail, a little less than a mile. Note, you can find a map of College Camp trails at the start of the trail, or you can access it here:
http://www.oneonta.edu/oas/collegecamp/maps_directions.asp

For each bedrock outcrop you encounter, start at some point at the edge of the outcrop. Record the UTM coordinates of your starting point with the GPS unit. Then map the boundary of the outcrop with stride and compass: site to the next point with the compass, record the bearing, then count your strides to that point. (If you have not calibrated your stride, do so with a 50 m tape.) Return to the original starting point to close the boundary of the outcrop. Do this for each bedrock outcrop you encounter. Don’t map in the large blocks of thin-bedded sandstone that are scattered around out there as gigantic boulders. These are glacial erratics, and are not in place. It might be hard to tell at first if the rock is actual bedrock. If the layering looks like it is correctly oriented, and it’s not too obviously perched on soil (actually till), then map it as a bedrock outcrop. Only map the bedrock outcrops that you can see from the trail. I suspect you might find more and better outcrops if you went over the ridge to the east, but you will find sufficient outcrops along this section of the trail to keep you busy.

Why, you might ask, can you not just use the GPS receiver to record the waypoints around the outcrop? Well, you certainly could. In fact, it is probably a good thing to take the GPS measurements of all points around the outcrop. However, you will discover, even if you are just standing still, that your GPS coordinates are changing. The errors in GPS location can often exceed 15 or 20 m, especially in a forest, and this error is on the same scale as our outcrops. To reduce the errors in determining the boundary of the outcrop, we will use your stride and compass bearing, and reduce the data to local easting and northing coordinates, and then translate those into the UTM coordinate system.

How do you do that? If you have forgotten your notes from lecture and the methods from prior labs, see the appendix at the end of this lab.

Once you have converted all of your points into UTM coordinates, you will need to save these points in a text file (for Global Mapper; for ArcGIS, you will need to go through the steps to create a shape file and geodatabase file, not covered in this lab). You can copy-paste your coordinates directly into a text file opened from Notepad. First be sure that, for each closed loop that bounds a rock outcrop, the starting point is placed both on the first line and the last line for a given loop. Global Mapper will interpret the text file upon read in as a series of closed polygons, if you place a blank line between each data set. Alternatively, you can save each bedrock outcrop loop as a separate text file.

Note that Global Mapper will ask for things like projection (reference frame), order of points in the file, etc upon read in. Read the options, and select the appropriate ones.

You can now combine your data with other layers that you download from the USGS Seamless Server (http://seamless.usgs.gov/). Find the field site on the clickable map by zooming in, then select the download tool, drag a box over the area of interest, and select the 1/3 arc second NED (elevation data), the NAIP 1 m color (aerial photographs), and the BTS roads layers for download. You should map the trail as a line feature. You should map the outcrops as area features. Make sure the elevation layer plots first. Also, make sure that the projection in Global Mapper is UTM.

Summary of Activities:

- Map the trail.
- Map the bedrock outcrops you encounter next to the trail.
- Convert your field data to digital georeferenced data.
- Combine your data with air photo, roads and topography.
- Generate contours for your map, so that any relationship between topography and bedrock outcrop can be examined.
- Refine your map with title, legend, etc.

***What to hand in*:** A map of the outcrops of bedrock along the Red trail. The map must have all of the necessary elements, listed below. Your effort in accomplishing each element will be awarded a quality score where 4 = excellent; 3 = good; 2 = fair; 1 = poor; 0 = no credit. The weight for each element will be multiplied by the quality score divided by 4, and then summed across all elements. A letter grade will be assigned according to the ranges given below.

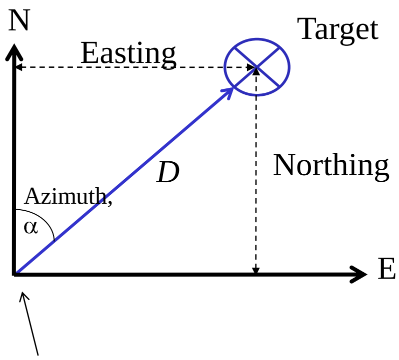
- **Title, Author, Date** (6%) [Title must be descriptive and clear]
- **North arrow** (1%)Scale (UTM grid lines at an appropriate spacing suffice!) (1%)
- **Source(s) of information** on the map (such as the USGS Seamless Server) (2%)
- **Mapped bedrock outcrops** (60%) [This is the most important part. Color the polygons to provide a clear picture of the bedrock distribution. Your grade for this consists of properly locating the outcrops, and how well you render them.]
- **Map of the path** (20%) [Clearly portray the trail.]
- **Legend** (10%) [Provide a legend for all important mapped features.]

A letter grade will be assigned according to the following ranges

Grade	Mininum %	Grade	Mininum %	Grade	Mininum %
A	93.8	C+	54.2	D-	12.5
A-	85.4	C	45.8	F	0
B+	79.2	C-	37.5		
B	70.8	D+	29.2		
B-	62.5	D	20.8		

Work with your map until you are pleased with the appearance, style, and clarity. If the air photo is too obtrusive and hides too much of your outcrops, either change its transparency or feel free to leave it out of the map. It may help you locate yourself when you're working on your map, and checking the accuracy of your GPS data.

Appendix: Converting Stride & Compass Measurements to UTM Coordinates



$\sin\alpha = \frac{Easting}{D}$; $\cos\alpha = \frac{Northing}{D}$

So, rearranging the above equations,
the Easting and Northing coordinates are:

$Easting = D\sin\alpha$

$Northing = D\cos\alpha$

You are here, and you measure a distance D and azimuth α to the target. We want to convert these to components (yes, this is a vector!) , which are the easting and northing coordinates.

The easiest way to perform these calculations when you have a significant number of points is in a spreadsheet. First, create 2 columns for your stride and bearing data. Enter each measurement in a separate row. Then, in an adjacent column, convert your strides to distance *D* in meters, using your stride calibration. You only have to enter the formula once and then copy-paste it down. Type "=RC[-1]*0.92" into the cell (don't include the quotation marks in the formula, and use the appropriate scale value for your stride in the formula). Then move the cursor over the lower right corner of the cell until the cursor appears as a small plus symbol. Double-click the little black square to copy-fill the formula down. Very quick, no?

Note that you should select the row-column format for cell references (under the Office Button, Excel Options, Formulas tab, select R1C1 Reference Style. The R stands for row. The C stands for column. The absolute reference to a cell for this system is R#C#, *where # is the row number and column number. Relative references take the form of* R[-#]C[#], *where a minus sign refers to number of rows above or number of columns to the left of the cell with the formula in it. Note the plus sign is not used if the numbers are positive (positive refers to a row below or cell to the right). A very good reason to use row-column format is the ease with which once can work with large numbers of columns. Alphanumeric format starts doubling letters for column assignments when it reaches the end of the alphabet, and this leads to some difficulty, especially if one starts writing macros for operations spanning more than 26 columns.*

Now we need to compute the local change in easting (that is, x) and northing (that is, y) from each point to the next. Use

$$Easting = D\sin\alpha$$
$$Northing = D\cos\alpha.$$

Label one column Change in Easting, and the next column Change in Northing. To enter the formula for Easting into a cell, type “=RC[-1]*sin(radians([RC[-3]))”. Note, this formula thinks that distance D is in the cell one column to the left, and that the bearing is in 3 columns to the left, both in the same row. Note that Excel trig functions require angles in radians, so that is why “radians” shows up in the formula. When typing formulas and you are using relative referencing, you can just click the cell you want in the formula instead of typing its cell reference. For northing, type “=RC[-2]*sin(radians ([RC[-4]))”. Copy-fill both formulas down.

We now have the local change in x and y to move from one point to the next. To compute the actual local coordinate, with the origin at your starting point at the outcrop, you need to add sequentially the change in easting and change in northing as you move along the path. Set up two new columns titled Easting and Northing. Set the first value as 0 for both easting and northing. In the next row down, type “=R[-1]C+R[-1]C[-2]”. Copy-fill this formula down. Then use the same formula for the northing. Copy-fill this formula down. This performs a running sum of the changes in easting and northing between points, and thus provides the local coordinates for each point. Magic. Note that you should extend the copy-fill to the row below your last data point. This will “close the loop”, and the last coordinate should be the same as the first coordinate in the column. It very rarely is. Closing the loop provides us with a rough estimate of errors in our measurements.

The next step is to take our local reference frame and move it into the global reference frame. It’s a huge leap! But one that can be taken by just adding on the correct shift in easting and northing coordinates to our local coordinates. The easiest global reference frame to use is the Universal Transverse Mercator system, since its coordinates are given in meters. The shift in coordinate location consists of a translation. To find the translation between two coordinate systems, we need to know the coordinates of a point in both systems. For our situation, the coordinates {E,N} of the local origin is {0,0}. From our GPS unit, we know the local origin’s easting and northing in UTM coordinates. The translation in easting, T_e, is given by $T_e = E_{UTM} - E_{local}$, and the translation in northing T_n, is given by $T_n = N_{UTM} - N_{local}$. Adding the translations to each of the local easting and northing coordinates brings our bedrock outcrop location into the global UTM coordinate system. Set up the UTM Easting and UTM Northing columns, then type “=RC[-2]+ #]” where # is the easting translation. Do the same for the northing column. Copy-fill the formulas down. You are now global!

You will find on the following page an example data set with the computed values for all the steps above. The example shown is for an area some tens of meters across.

Example Worksheet, Values for Calculations

UTM Coordinate, starting location:				***meters/stride***				
Easting:	494834	*Northing*	4702499	0.89				
bearing, degrees	strides	distance, m	Change in Easting, m	Change in Northing, m	Local Easting, m	Local Northing, m	UTM Easting, m	UTM Northing, m
357	17	15.13	-0.79	15.11	0	0	494834	4702499
271	18	16.11	-16.11	0.28	-0.79	15.11	494833.21	4702514.11
17	26	22.78	6.66	21.79	-16.90	15.39	494817.1	4702514.39
7	34	29.82	3.63	29.59	-10.24	37.18	494823.76	4702536.18
292	21	18.60	-17.25	6.97	-6.60	66.77	494827.4	4702565.77
188	21	18.69	-2.60	-18.51	-23.85	73.74	494810.15	4702572.74
243	26	23.14	-20.62	-10.51	-26.45	55.23	494807.55	4702554.23
203	28	24.92	-9.74	-22.94	-47.07	44.73	494786.93	4702543.73
140	36	32.04	20.59	-24.54	-56.81	21.79	494777.19	4702520.79
79	40	35.42	34.77	6.76	-36.21	-2.76	494797.79	4702496.24
					-1.44	4.00	494832.56	4702503

Example Worksheet, Formulas for Calculations

distance, m	***Change in Easting, m***	***Change in Northing, m***
=RC[-1]*R2C5	=RC[-1]*SIN(RADIANS(RC[-3]))	=RC[-2]*COS(RADIANS(RC[-4]))
=RC[-1]*R2C5	=RC[-1]*SIN(RADIANS(RC[-3]))	=RC[-2]*COS(RADIANS(RC[-4]))

Note that R2C5 is an absolute reference to row 2 column 5, for stride conversion to meters.

Local Easting, m	***Local Northing, m***	***UTM Easting, m***	***UTM Northing, m***
0	0	=RC[-2]+R2C2	=R2C3+RC[-2]
=R[-1]C+R[-1]C[-2]	=R[-1]C+R[-1]C[-2]	=RC[-2]+R2C2	=R2C3+RC[-2]

Note that R2C2 is an absolute reference to row 2 column 2, the UTM easting coordinate of the starting location, and R2C3 is an absolute reference to row 2 column 3, the UTM northing coordinate of the starting location.