Exercise 04
Topological Shapefile Editing
plus Importing and editing GPS data
Assigned Feb. 9, 2018
Due Feb. 16, 2018

This week we will use the same `laramie_quad_usgs_1963.tiff` as last week as well as the `laramie_quad_usgs_1963_crs.txt` file and two files containing GPS data: `exercise_03_track.gpx` and `exercise_03_waypoints.gpx`. Copy all four from your `exercise_03` (or the original zip file) to your local storage directory. But before doing that, read the hints below about **File Locations**.

Before class on Feb. 19 class you will create shapefiles which divide a region of the map up into adjoining but non-overlapping polygons, and will adjust display properties of those polygons to produce the equivalent of a geological map. You will also import GPS waypoint and track data and use it to generate additional shapefiles. Turn in the resulting shapefiles, project files, and the two map images, in class on Friday Feb. 19.

File locations

Before I go into the details of advanced shapefile editing, sometimes when reopening projects QGIS can't seem to find the layers you previously created. Here are a few recommendations to try to avoid that problem.

Both to keep your disk space organized (for turning in files later) and to keep QGIS happy, it's simplest if for each new project you create a new directory -- for example `exercise_04`, on drive where you know you have write permission. The H: drive is a good choice. So at the start of a project use Windows (not Internet) Explorer to create a new directory on `H:` (or another writable location. For example you may want to keep all the `exercise_nn` folders within a `geol_4200` folder on `H:`. Copy any of the provided data files into that new `exercise_04`. Then, when you use QGIS to create new files, tell it to put them within that directory. QGIS isn't very good about choosing a sensible directory when you first create a file, but usually it remembers your directory choice for later files of the same type. And when you do save the "project file" and image files, tell QGIS to put them in that same directory.

By default the QGIS project file uses "relative" file path locations. If your project file and all your data files are within one directory, or subdirectories of that, you can then later

copy that whole directory to a different location and QGIS will still be able to find all the files. If you open a project file and for some reason QGIS can't find a layer's file, then QGIS shows an error dialog box which lets you manually locate the missing shape file.

You can also tell QGIS to use "absolute" file path locations, and it then stores the full path to every file in your project. That can be useful when you have several projects which all use some very large common data file and you only want to keep one copy of that large file, in a fixed location. However this makes moving and reorganizing projects more complicated. You can find the option under **`Settings / Project Properties`** (or under **`Project / Project Properties`** for some machines) on the **`General Tab`**. But for this class it's probably simplest if you just use the default "relative" paths, and keep each exercise's data in its own directory. When you finally go to zip your files for submission -- just don't include the large distributed data files in the zip.

When you run QGIS, it needs a directory of real files, not just a zip "pseudo-directory". So if all you have is a zip file (which Windows shows as a folder with a superposed zipper), be sure to "unzip" it to create a directory of real files before trying to use those files in QGIS.

Exercise Part 1: Advanced Editing of Shapefiles

I give a brief overview of the advanced editing techniques below, but there is more detailed information in the QGIS manual under **`Working with vector data / Editing`** which you can reach via the QGIS Help menu, or the links on the home page. You can also go directory there with the following link:

`<http://docs.qgis.org/2.18/en/docs/user_manual/working_with_vector/editing_geometry_attributes.html>`

1) Create a new directory for this work (as described above) and copy the Laramie tiff file and the two gpx files to it. Start QGIS, open the Laramie map as a raster layer, then as in exercise 3, set the map layer CRS to the text in the provided in the **`laramie_quad_usgs_1963_crs.txt file.`** To make things simpler later, save the project as **`exercise_04`** in the directory you just created. Remember to "resave" to project later, after you've added more layers.

2) Create a new polygon shapefile using the **`Layer / Create Layer / New Shapefile Layer`** menu. After selecting polygon add a new field called **`year_added`**, with type **`Whole number`** . Rather than the default **`Width`** of 10 (digits), change that to 5. (Be sure to click

the **Add to fields list** to really add it.) Also keep the standard **id** field. When you click **OK** to create the layer, it will ask for a file name. Choose **land_additions**. With some luck, since you already saved a project file in your new directory, the default directory for this file will be that same directory. If it isn't, navigate to chose that directory. That way all your files will stay together.

3) From the main menu select **Settings / Snapping Options.** You can change snapping options for the current layer, for all layers, or, if you select **Advanced** in the upper drop-down box, for individual layers. Do select **Advanced** then check the box just before the **land_additions** name if it isn't already checked. Set the **Mode** to snap **to vertex and segment** which may not be the default. Set the tolerance to **0.0001 map units,** check the **Avoid Intersections** box on that same line, and check the **Enable topological editing** box at the bottom. (Hint: if the **Avoid Intersections** box isn't visible, it's probably because you mistakenly created a point or line shapefile, not a polygon one.)

More details on these options are given on the manual pages mentioned above.

- **Snapping** means moving the cursor exactly to a nearby vertex or line, if you are within the specified distance "tolerance" of that location. It lets you match the vertices of one object to another -- for example to make one line end exactly where another one starts, or to make multiple lines intersect at exactly the same location.

  As an experiment later, after you have saved your shapefiles, temporarily open one for editing and with one of the polygon tools active, like the **new feature**, or **node tool**, move the cursor around the polygons you have created, and notice how the cursor snaps to different locations. Try increasing (temporarily) the above tolerance and see how it changes the snapping. Try also changing the **Mode** from **to vertex and segment** to just **to vertex** or **to segment**.

- **Avoid Intersections** means if we try to create a polygon which overlaps (intersects) another one, then the boundaries of the new one are adjusted to exclude the existing one. It does this by creating vertices for the new polygon which lie exactly on the vertices of the existing one.

- **Enable topological editing** means if we try to move the vertex of one polygon (for example using the node tool) and that boundary is adjacent to another polygon, then the system will also move the corresponding vertex of the adjacent polygon to keep them adjoining. Otherwise you would end up with "gaps" between them

which did not belong to either.

4) Toggle the **land_additions** layer open for editing (the pencil icon), select the **add feature** tool, then add two polygons showing the original built-up area of Laramie, one for the area west of the railroad tracks, and another for the original main part of town. When you right click to end the polygon, the attributes box will pop up. For now, for each new feature, increment the ID count by one. So use 1 for the first, and 2 for the second. For both regions, since this based on a 1963 map, just enter 1963 as the year. Note that we could also create a single "feature" composed of the two different polygons, a so called a "multipolygon". But for now we'll just use single polygons. The common **year_added** field will let us keep them associated. As you are adding vertices you may see an error message at the top warning you that the segment from your most recent point back to the beginning vertex intersects (cuts across) other segments. As you"walk around" the boundary adding vertices that message will come and go. Just be sure that by the time you add the final vertex you don't have any intersecting lines and that message has disappeared.

To keep the town visible, right click on the **land_additions** line in the layers panel, select **Properties**, and under the **Style** tab adjust the transparency to roughly 60%. (The transparency option appears in different locations for different types of layers.)

5) Add several more features representing later additions to the town, and give them plausible addition dates. To make them adjacent to the original, as you create the polygon, draw the outer boundary as desired, but for the part adjoining town, deliberately try to make the polygon extend into the established ones. The **avoid_intersections** option will make it jump back when you right click to finish it.

If you are having trouble remembering the next id value to use for each feature, right click on **land_additions** in the layers pane and **open attribute table** so you can see the values entered thus far.

If you create a boundary which, rather than being a simple polygon, intersects itself in complex loops, QGIS will show the error message mentioned above and flag the intersections with X's. We'll see later how to correct that. For now just try to avoid this -- and if necessary delete a polygon which has problems.

When you are finished be sure to toggle off editing, so it saves your shapefile. If you are making a very long series of edits it is a good idea to occasionally toggle off then back on editing, to be sure your work is saved in case a program crash occurs.

6) Change the display to show different year additions with different colors. Right click on **land_additions** in the layers panel, select **Properties**, then select the **Style** panel on the left. The default **Single Symbol** style will be used initially. Keep that for the moment and click on **Simple Fill** in the window below -- and explore the various options in the panel which opens at the right. For example try changing widths and colors for the border and for the interior fill. Note that changes are not actually displayed till you click **Apply**. There is also a **Data defined properties ...** button. Using it we could tell QGIS to base colors or widths on values in the attribute table. For example if we had a "roads" layer we could have a field for "traffic" and show the heavily used roads as thicker, or as a different color.

This time, rather than using a specially created formula, we'll use a standard method. Click on the **Single Symbol** drop-down list at the top and instead select **Graduated**. Right below that it shows the column (field) used for determining how it will be graduated. Choose the **year_added** field instead of the default **id** for determining how it will be graduated. You can also modify the color ramp. For this type of data its better to have different colors rather than just different shades of a single color. For example **Spectral** is a good choice for the type of color ramp. Finally, make the number of **Classes** equal to the number of different years_added you have, and explore how the other **Mode** choices beyond the default **Equal Interval** affect the display. We could also explicitly choose a different color for each layer, which is more-or-less what we would do with a geological map.

When you save your QGIS project, the **Style** properties are saved with the QGIS project file -- not the individual shapefiles.

7) After you have a display you like and have saved the project, use the **Project / Save as Image** menu to create a **exercise_04.jpg** image to include with your other files. Finally, when you are done with this Part 1, to avoid confusion, uncheck (in the layers panel) the shapefile you created, so it is no longer visible.

Part 2: Importing GPS Data

Often instead of inputting the shapes by hand, you will have GPS data. As you saw in exercise 3, I walked around campus and recorded a "Track" on my handheld GPS unit, as well as a few "Waypoints". The former will be imported as a line and the latter will be imported as a set of points. The **exercise_03_track.gpx** and **exercise_03_waypoints.gpx**

files are standard "GPX" GPS Interchange files. They can be be read from a GPS unit using QGIS or other software. (I've actually modified these slightly to avoid some complications we'll learn to deal with later.)

8) Use either the menu (**Layer / Add Layer /Add Vector Layer**) or the toolbar icon to the left of the layers panel to add each of these files. In the dialog window which appears **Source Type = File** should be the default. Select that if it isn't. We'll explore **Databases** later. Click **Browse** to open a file selection dialog. Sometimes the system is only showing the ESRI shape files. At the bottom of the window select either **GPS eXchange Format** or **All** to show those types of files then double click on one of the gpx files. Back in the QGIS dialog click **Open**. Another window showing what type of data can be imported will appear. I could have placed both track *and* waypoint data into a single gpx file, but decided to keep them separate. Select either **tracks** or **waypoints**, as appropriate for the file you are opening. A new entry should now appear in the layer panel. Repeat the process for the second GPS file.

9) While QGIS can display gpx file data (and export to gpx files) it cannot edit the data in that format. We'll want to convert it to standard shapefiles first. For each of these two gps layers right-click in the layers panel, and select **Save As**. The default export type (give at the top of the dialog which opens) should be a standard ESRI Shapefile. Leave the other options at their default values and just click on the **Browse** button next to **Save as** to be sure it IS trying to save this in your working directory. Provide a name, either **gps_track** or **gps_waypoints** and click **Save**. Back in the QGIS dialog, be sure the box in the middle which says **Add saved file to map** is checked then finally click **OK**. A new layer should appear. Repeat this for the second GPS data set. Now with the GPS data in standard shapefile format, we can remove the **gpx** layers from the map. Right click on each original gpx layer in the layers panel, and select **Remove**.

10) First lets explore the waypoint data. Pretend these are locations of samples for which you want to record additional information. Right click on **gps_waypoints** in the layer panel and select **Open Attribute Table**. Most of the rows just contain NULL's -- information which some GPS units may provide, but mine does not. Toggle on editing (the "pencil" icon on the right above the table), click on the **Delete Column** icon (the yellow column with the small red x) and tell it what columns to delete. You can select more than one by holding down the **Ctrl** key while clicking. The useful columns to preserve are **ele** (elevation in meters), and **name**,. The **name** and the duplicate numbers in **cmnt** and **desc** are just the waypoint names or numbers from my GPS unit. Delete the redundant **cmnt** and **descr** columns. Add a new field column named **sample_id**, of type **Text**, and **Width** 10. Enter a short text string to identify each sample -- for example **ex03_nnn** where **nnn** is the

name or gps_waypoint number. If you want, you can explore using the string functions in the field calculator to automate this. The reason we don't just change the entry in the name field is that its width was set at creation, and might not be long enough to hold the full sample_id's we want to use. You could of course add additional fields which would contain a detailed description of the sample.

Click on the row number at the far left of each waypoint, and note how that selects (and changes the color) of each waypoint in the map. Two pairs of waypoints are very close together -- in fact mistakes where I double pressed the button on my GPS as I was acquiring the waypoints. In fact, if you can't see a waypoint change color when you select a row, it may be that the other one is almost exactly on top of it. Try zooming in on the suspected area. With the duplicate rows selected, click on the **Delete Selected Feature** icon (the red trash can). When finished, remember to toggle off editing, which will then prompt you to save the modified shapefile. If the table shows **Error** on the bottom couple rows QGIS is confused. Just close then reopen the attribute table.

11) Now examine the track layer. Zoom in on the region of the track by right clicking on this layer in the layers panel then select **Zoom to Layer Extent**. Note the "hook" near the beginning of the track. The GPS unit simply did not have an accurate position when it was first turned on -- so the jump in position is an artifact as its position value improved. Lets eliminate these bad points. Toggle on editing for this layer (the pencil icon) and note how a small x appears at each vertex. Zoom in further on the region of the hook. Select the **node tool** from the editing toolbar and first select the line by clicking somewhere close to it. The vertex x's should change to red squares. Next select the bad vertices by dragging the cursor (holding down the left mouse button) across a rectangular region containing them. The selected vertices should change to blue. If the selection looks OK press the **Delete** key. Zoom out and notice that a number of vertices have green crosses. I'll discuss those shortly. Finally, toggle off editing to save the result.

12) The green crosses are "double vertices" where the GPS unit apparently created two or more points with essentially identical coordinates, and QGIS recognizes that something is wrong. QGIS contains a tool that can fix this, and can in fact eliminate other unnecessary vertices. Before you access this tool, if you happen to have the layer's attribute table open (you probably don't), close it. Then from the menu select **Vector / Geometry Tools / Simplify Geometries.** For this first trial we will use all the default settings, including the default tolerance of 0.0001. We we will see shortly that this tolerance is too large. Click **OK** and after a short period QGIS should report **Simplify Results** saying that it has reduced the number of vertices from roughly 150 to roughly 15. Click **OK** , then when the (annoying) **Processing Finished** box appears click **OK**

again. Finally, **Close** the **Simplify Geometries** dialog which is still open. You can see that we have lost not just the duplicate vertices but most of the detail in our line. To get back to our original line, from the menu select **Edit / Undo** or press the the **CTRL-Z** key. Toggle editing off, as it was left on by this procedure.

Repeat the above, but this time set tolerance to 0. (You *ought* to be able to set it to some intermediate level between 0 and 0.0001, but unfortunately the current version of QGIS just doesn't give you a way to enter this many decimal places. The tolerance we entered is in degrees of latitude and longitude (because that is how the GPS coordinates are stored), and even 0.0001 degrees is 11 meters. Simplifying the line on this scale gets rid of too much detail. But a tolerance of zero will at least get rid of duplicate vertices. Later we'll see how to work around this decimal place limitation. When you run the simplification with a tolerance of zero, QGIS should decrease the number of vertices from roughly 150 to about 120. If the result looks OK then toggle off editing to save the file.

13) We'll do one final operation on this track. It is a line, not a polygon, as right now the ends do not quite close. Suppose we have just walked the contact around some given rock unit and we do want to turn this into a polygon, to include in our set of geologic features. From the menu select **Vector / Geometry Tools / Line to Polygon** and this time in the dialog which opens, click **Browse** to select a new shapefile to contain this polygon. (For some reason QGIS does not seem to remember which directory we are working in when we use plugin tools like this one so you may need to navigate back to your working directory.) Name the new shapefile **gps_track_polygon** and click **OK.** QGIS should report that it has converted the line to a polygon. If you had the default box checked saying to add this new shapefile to the map it will be added. Adjust its display properties to make the polygon partly transparent, letting you still see the map.

14) Zoom the image to include just the central UW campus, and once again save an image of your map, this time called **exercise_04_gps.jpg**. Also save your QGIS Project.

15) Zip up all the files except the large Laramie map tiff. If you can, select the standard zip format , not the default zip7. Name the resulting file **exercise_04_lastname_firstname.zip**. Turn it in during class on Friday Feb. 16.

Next time we'll see how to combine this GPS shapefile with the ones created manually.