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Tectonics of the Northern Menderes Massif: The Simav Detachment and its relationship to three granite plutons

I. Introduction:

Purpose:

While reading through the literature regarding the Simav detachment in the Northern Menderes Massif, Turkey, I have noticed that some authors note the existence of a second NE-SW trending Simav detachment while others do not. The well-documented E-W trending Simav detachment shows significant elevation contrasts between the footwall and the hanging wall. Using ArcGIS software, I will determine whether there is any elevation data that may suggest the existence of this second detachment.

Also, I will be traveling to Turkey this summer and I need detailed field maps. There are no maps available that have both geologic units and the roads and towns on one map. In order to be better organized to go to the field, I will need a map that has not only the rock units that I need to visit but also the roads that I need to take to get to these rock units. This is important because, although we will have permits, the people who live in these areas do not like foreigners hiking around for extended periods of time. It is important that we know exactly where we need to go and how we need to get there before we begin.

The final product will be two maps: one showing the granite outcrops, contours, and detachments and the other showing the granites and their relationship to the roads. The first map will be used to determine if there is any topography that suggests a second detachment fault exists. The second map will be used as a field map this summer to more easily locate the granites for sampling. Both maps will focus on the granites that I am studying and the faults that deform these granites.

Problem:

Does the second NE-SW trending Simav detachment exist? I will answer this question with GIS software using detailed elevation data and geologic maps. I will analyze the area where the second Simav detachment might be located and look for any elevation differences that would denote the presence of this detachment. Because the main Simav detachment shows drastic elevation differences between the footwall and the hanging wall, the second Simav detachment should also be visible by topography. Some suggest that the second detachment trends NE to SW and forms western boundary of the Egrigoz pluton.

This summer I will be traveling to Turkey for two weeks to do field work in the Northern Menderes Massif. While I am there, I will need to quickly locate three plutons that are deformed by the main Simav detachment to collect rock samples. Geologic maps of Turkey are scarce. I will need a map showing the roads as well as the location of the plutons so we can drive to their probable locations. We will be there for a limited amount of time so our locations need to be well-mapped before we go.

II. Data Collection:

SRTM

Data collection for Turkey proved to be difficult. Due to national security, the United States has limited the amount of information public users can download for other nations. SRTM data was only available in 90m as opposed to the more detailed 30m available of the United States. I downloaded SRTM data from the USGS website: http://dds.cr.usgs.gov/srtm/version1/Eurasia/. Two files cover my field area, N39E28 and N39E29. These files were downloaded as a .hgt file.

Geologic Map

The geologic maps of Turkey available online for GIS software did not have enough detail for my project. Instead, I scanned a paper version of a geologic map from the area and saved it as a .jpeg to open in ArcMap.

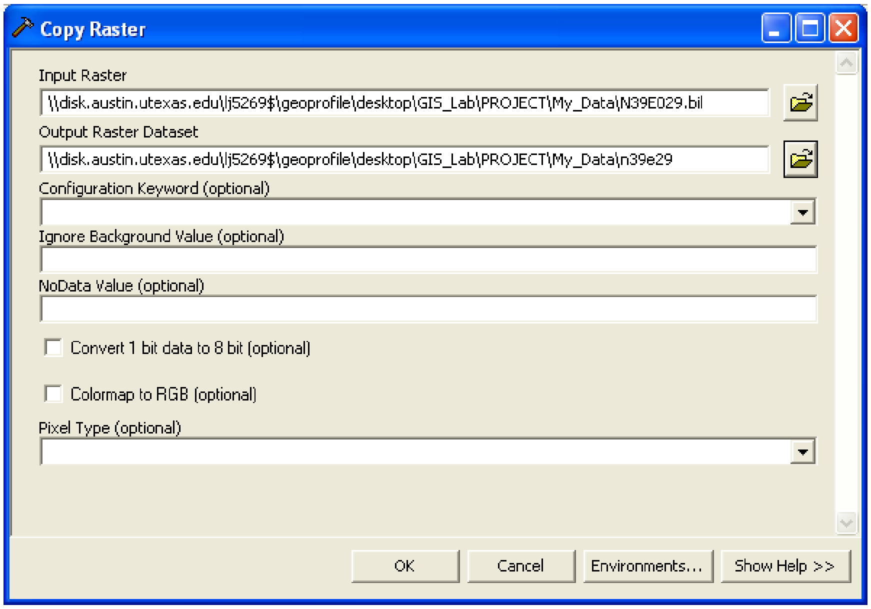
Roads

After searching for road data, I found that the most detailed road map available is the Google map of Turkey. To use this map, I simply took a screen shot of the Google map and cropped it using Adobe Photoshop. I saved this file as a .jpeg to open in ArcMap. Another feature of Google maps that makes it ideal for ArcGIS software is the ability to get latitude and longitude from any point on a map simply by right-clicking. Using the image collected and the latitude/longitude data available online, this road map was easily projected to be used for my project.

III. Data PreProcessing:

SRTM

When I downloaded the SRTM data from the USGS website, it was downloaded as two .hgt files. These files are not compatible with ArcGIS software so in order to fix this problem, I had to first create two header files using Notepad, one for each .hgt file. I saved these new header files with the same name as the data files but with .hdr extension (Software Tip 17). Then I replaced .hgt of the original files with .bil and opened these in ArcCatalog (Software Tip 9). After locating the .bil files in ArcCatalog, I exported each raster to a different format ***(Figure 1).*** The new rasters could now be opened in ArcMap and displayed for further processing.



Input Raster: \\disk.austin.utexas.edu\lj5269$\geoprofile\desktop\GIS_Lab\PROJECT\My_Data\N39E029.bil

Output Raster Dataset: \\disk.austin.utexas.edu\lj5269$\geoprofile\desktop\GIS_Lab\PROJECT\My_Data\n39e29

Figure 1: 'Copy Raster to a Different Format' tool available through ArcCatalog. The new raster could then be viewed in ArcMap. I did this procedure twice, once for each SRTM .bil raster.

Geologic Map:

There were no geologic maps available online that showed enough detail for my project. To get this information, I first scanned a paper geologic map of my area using the large scanner in the library. The file opened in Adobe Photoshop. I saved it as a .jpeg. This .jpeg was able to be opened in ArcMap for further processing.

Roads:

The most detailed road maps I could find for this area were on Google Maps. To use this map with ArcMap, I first zoomed in to the area of interest and took a screen shot. Next I loaded the image into Adobe Photoshop and cut the image ***(Figure 2).*** After saving the new image as a .jpeg, it was ready to be loaded into ArcMap for further processing.

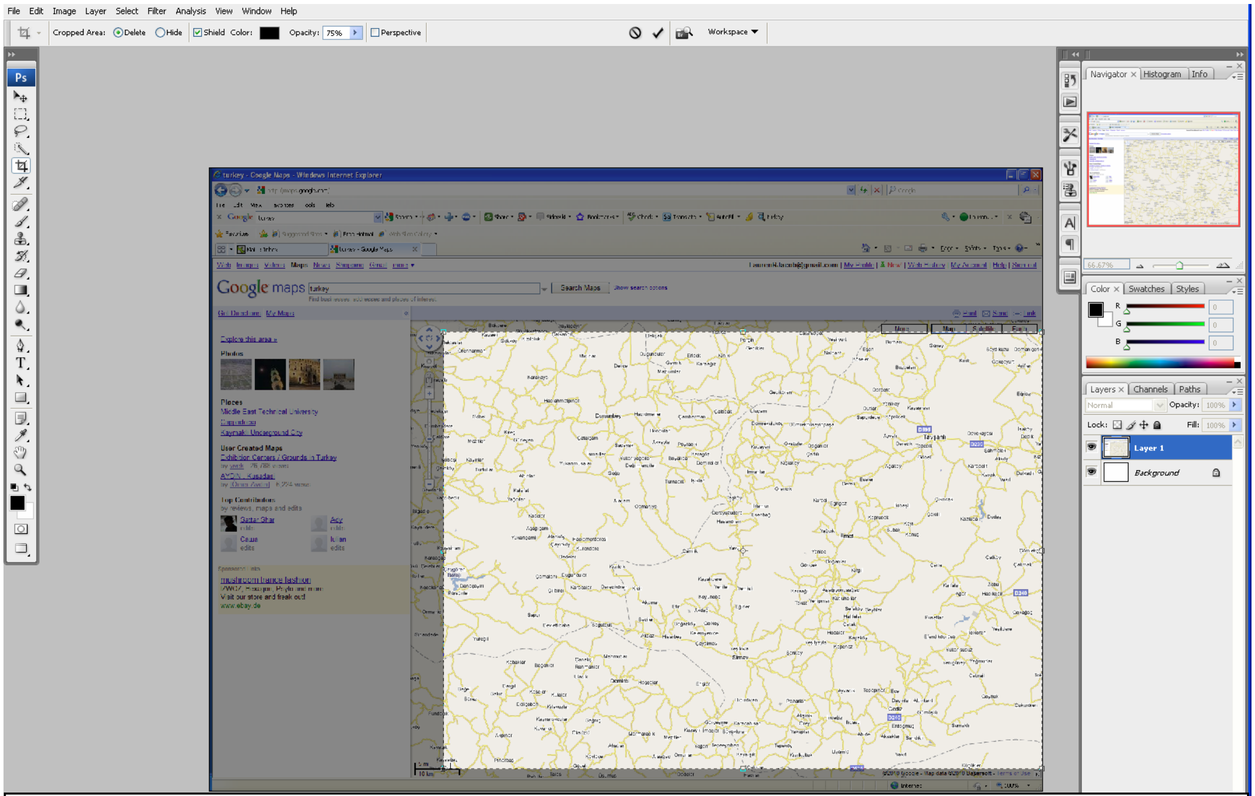
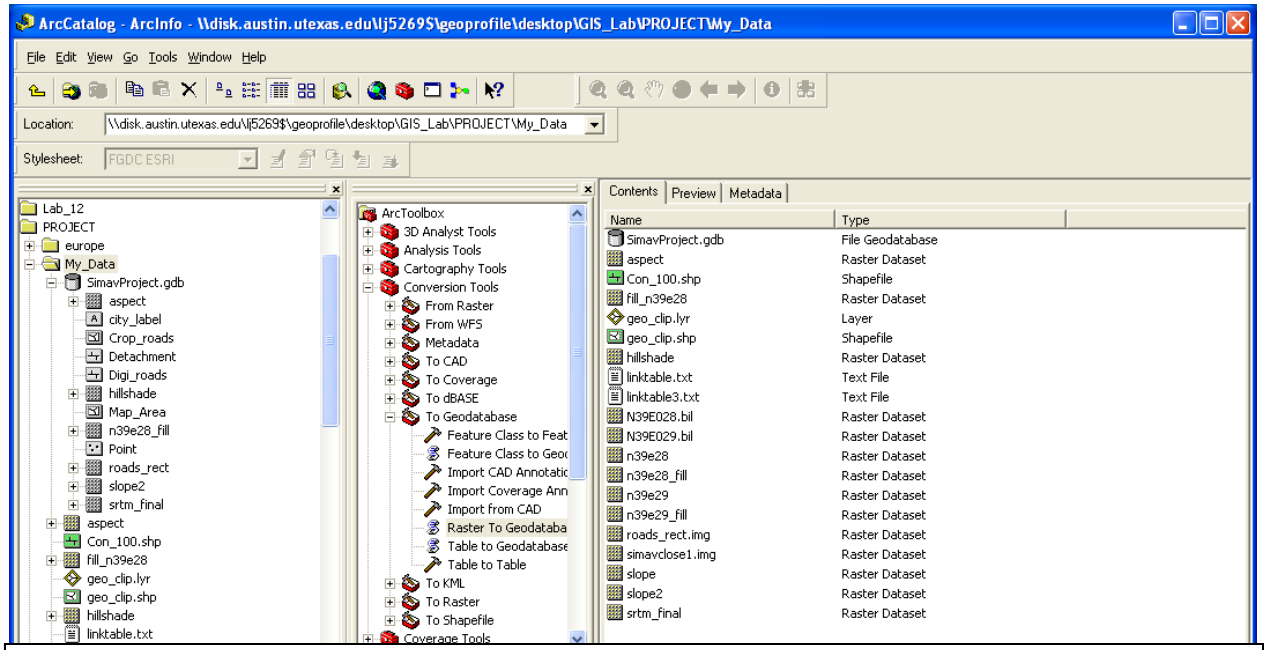


Figure 2: Screen shot of Adobe Photoshop. Here I cropped the screen shot of Google Map to the area I am interested in mapping.

IV. ArcGIS Processing:

Before processing any data with ArcGIS, I first created a Geodatabase called “SimavProject” to organize all of the rasters, shapefiles, and metada used for this project. A screen shot of ArcCatalog is show in ***Figure 3.***



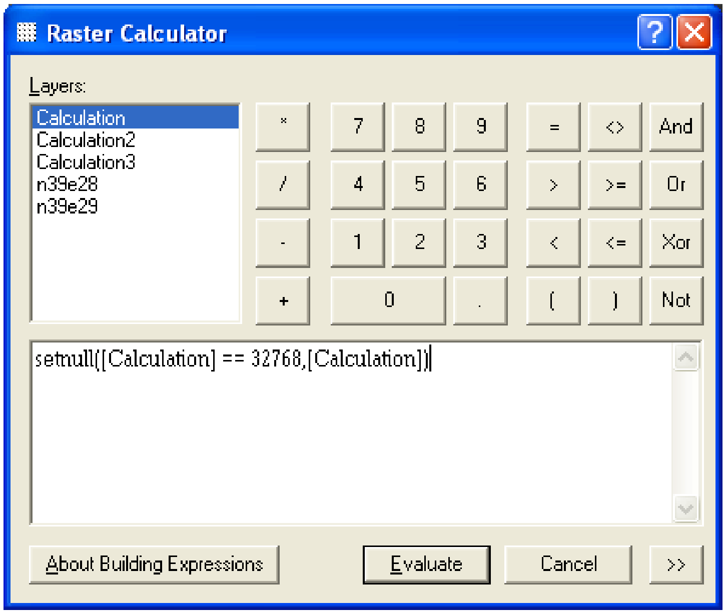
Location: \\disk.austin.utexas.edu\lj5269$\geoprofile\desktop\GIS_Lab\PROJECT\My_Data

Name	Type
SimavProject.gdb	File Geodatabase
aspect	Raster Dataset
Con_100.shp	Shapefile
fill_n39e28	Raster Dataset
geo_clip.lyr	Layer
geo_clip.shp	Shapefile
hillshade	Raster Dataset
linktable.txt	Text File
linktable3.txt	Text File
N39E028.bil	Raster Dataset
N39E029.bil	Raster Dataset
n39e28	Raster Dataset
n39e28_fill	Raster Dataset
n39e29	Raster Dataset
n39e29_fill	Raster Dataset
roads_rect.img	Raster Dataset
simavclose1.img	Raster Dataset
slope	Raster Dataset
slope2	Raster Dataset
srtm_final	Raster Dataset

Figure 3: Screen shot of ArcCatalog. The SimavProject geodatabase contains all of the files for this project.

SRTM:

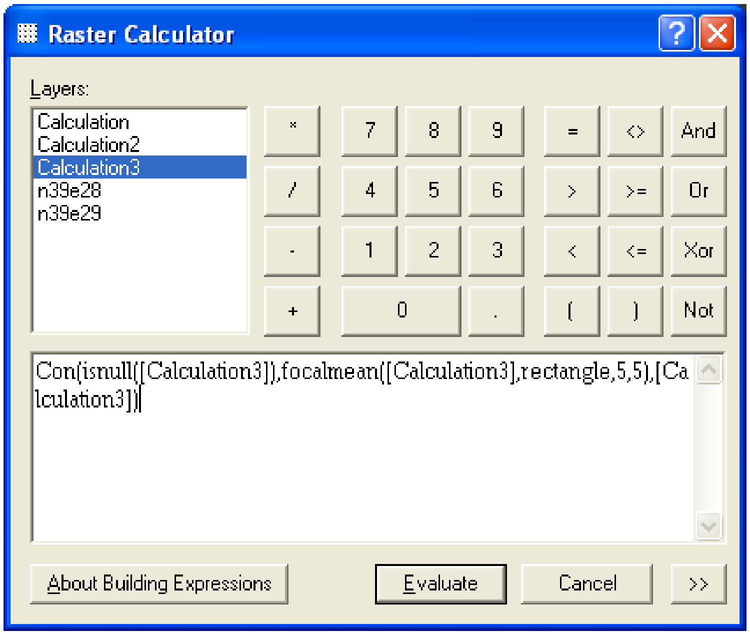
Because of the location of my area, the SRTM data is stored as two separate rasters. The SRTM data displayed had max elevation areas of 32768 that showed up as bright white rectangles. I know that the maximum elevation in this area is only 2101m so, using the raster calculator, I turned these cells into no data cells ***(Figure 4).***



```
setnull([Calculation] == 32768,[Calculation])
```

Figure 4: Raster calculation used to turn data cells of 32768 to no data cells. These 32768 cells were created in cells where no data was available. This calculation was done for both raster datasets.

Using the new rasters with the ‘no data’ cells, I then used the raster calculator to calculate an average height from the surround five rectangles for cells that had no data ***(Figure 5)***. This produced two clean raster with no holes in the data. I could not use simpler interpolation techniques because I only wanted to interpolate data for the cells with no data without changing the rest of the measured cells.



```
Con(isnull([Calculation3]),focalmean([Calculation3],rectangle,5,5),[Ca
lculation3])
```

Figure 5: Raster calculation used to calculate an average cell height for cells that previously had ‘no data’. This calculation used the average height from the surrounding five rectangles.

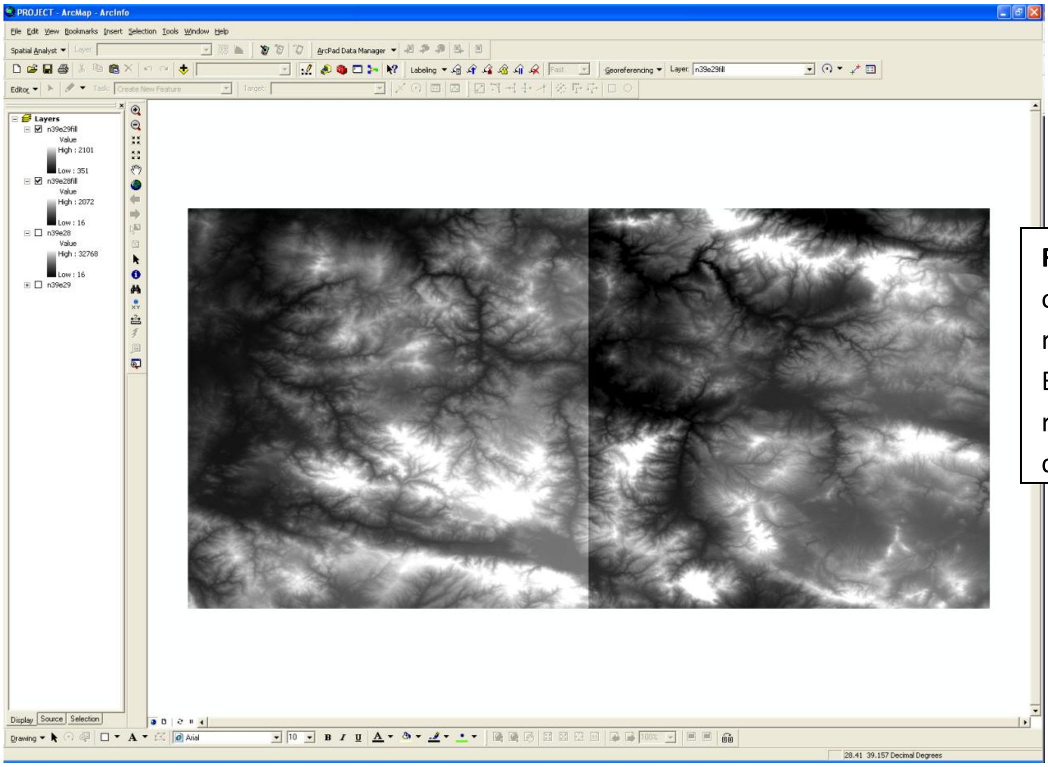
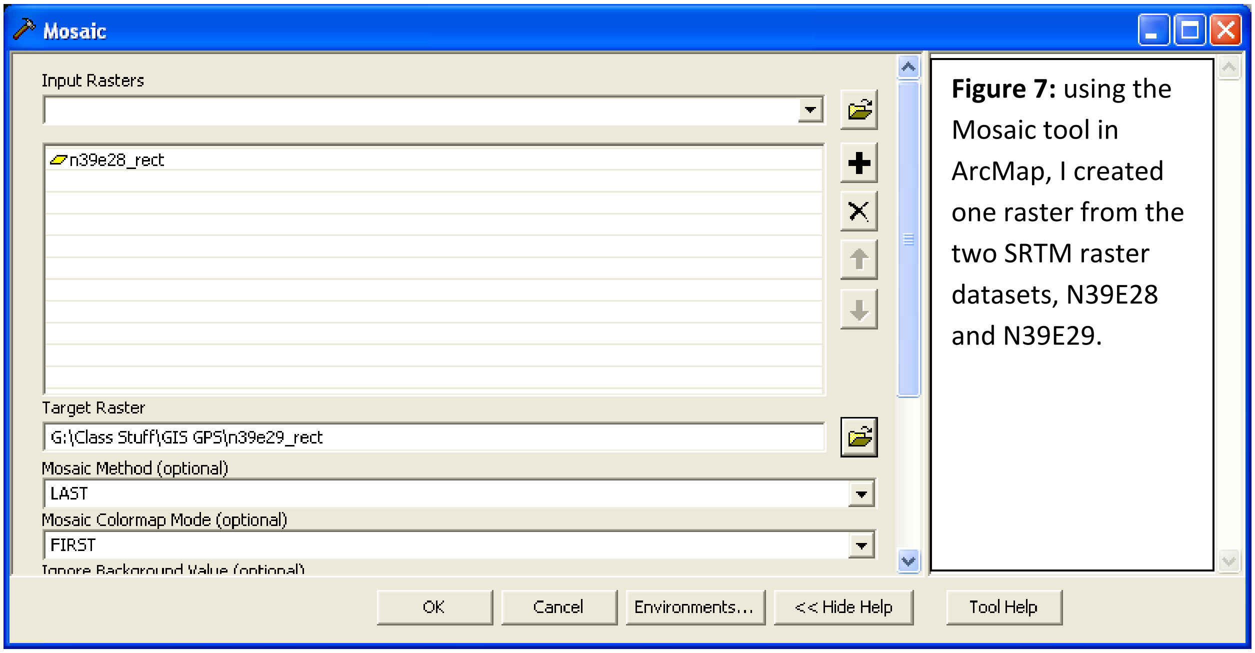


Figure 6: Screen shot of ArcMap with two rasters of SRTM data. Both are complete rasters with no empty cells.

Because my map area spans two datasets of SRTM data, there is a line between the two datasets ***(Figure 6)***. Now that both rasters have complete datasets, I can make a mosaic multiband image of the two rasters to combine them into one and get rid of this line ***(Figure 7)***.


Mosaic

Input Rasters

n39e28_rect

Target Raster

G:\Class Stuff\GIS GPS\n39e29_rect

Mosaic Method (optional)

LAST

Mosaic Colormap Mode (optional)

FIRST

Ignore Background Value (optional)

Figure 7: using the Mosaic tool in ArcMap, I created one raster from the two SRTM raster datasets, N39E28 and N39E29.

The result is one complete raster with the SRTM data from both of the original lat/long areas ***(Figure 8)***.

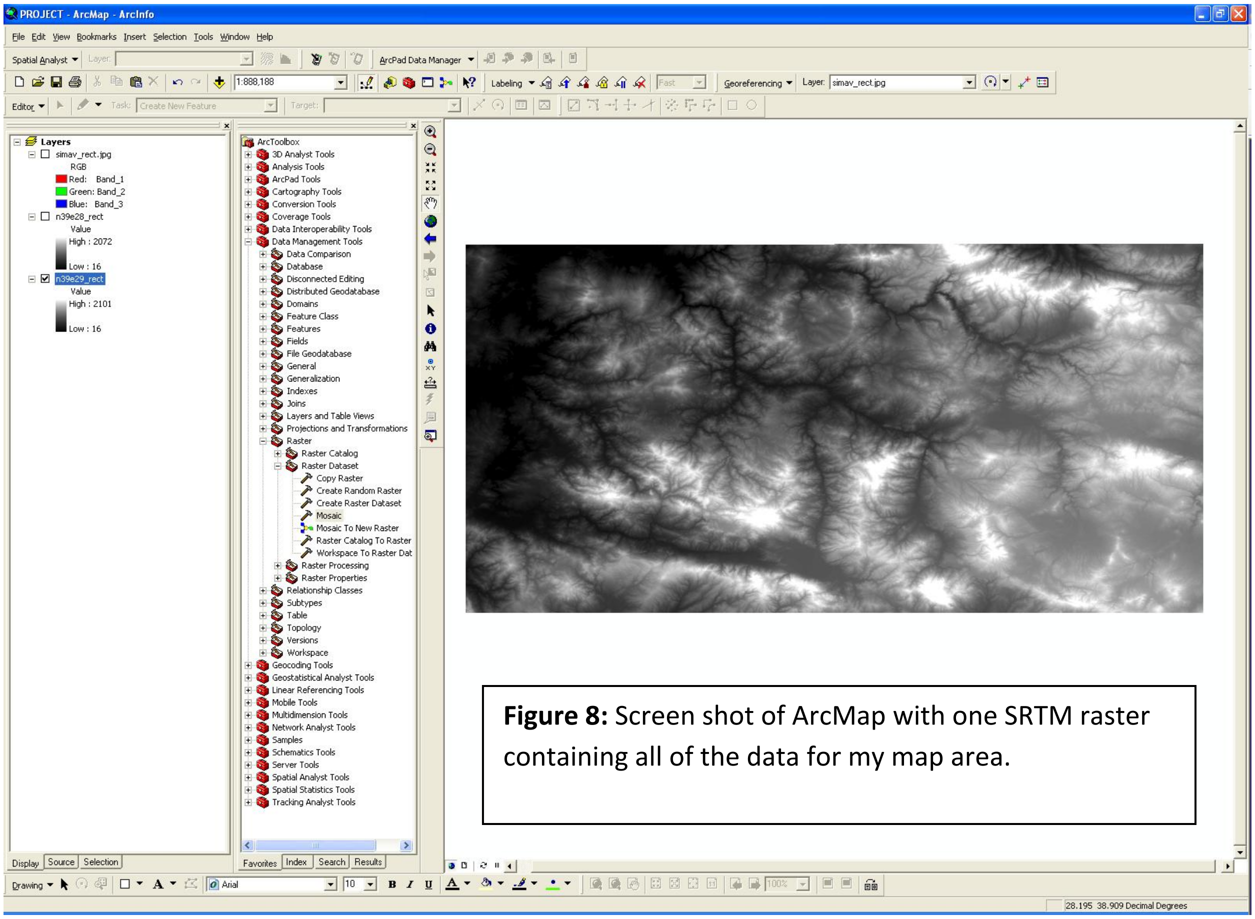
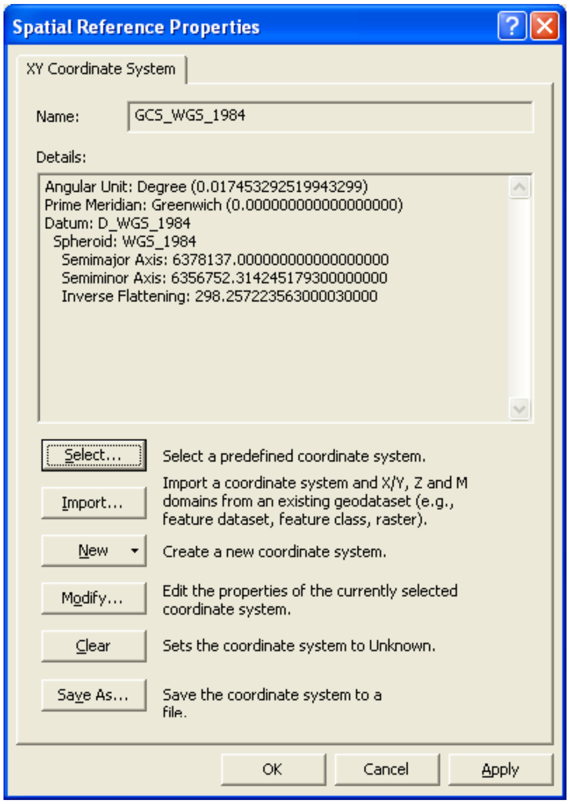


Figure 8: Screen shot of ArcMap with one SRTM raster containing all of the data for my map area.

My elevation data is now represented as one complete raster. The latitude/longitude data is also stored within this raster but the data has no georeference. To fix this, in ArcCatalog, I defined the geographic coordinate system for this raster. I used GCS WGS 1984 ***(Figure 9)***. My final product is a complete set of SRTM data that is correctly georeferenced in ArcMap.



Name: GCS_WGS_1984

Details:

```
Angular Unit: Degree (0.017453292519943299)
Prime Meridian: Greenwich (0.000000000000000000)
Datum: D_WGS_1984
  Spheroid: WGS_1984
    Semimajor Axis: 6378137.000000000000000000
    Semiminor Axis: 6356752.314245179300000000
    Inverse Flattening: 298.257223563000030000
```

Select a predefined coordinate system.

Import a coordinate system and X/Y, Z and M domains from an existing geodataset (e.g., feature dataset, feature class, raster).

Create a new coordinate system.

Edit the properties of the currently selected coordinate system.

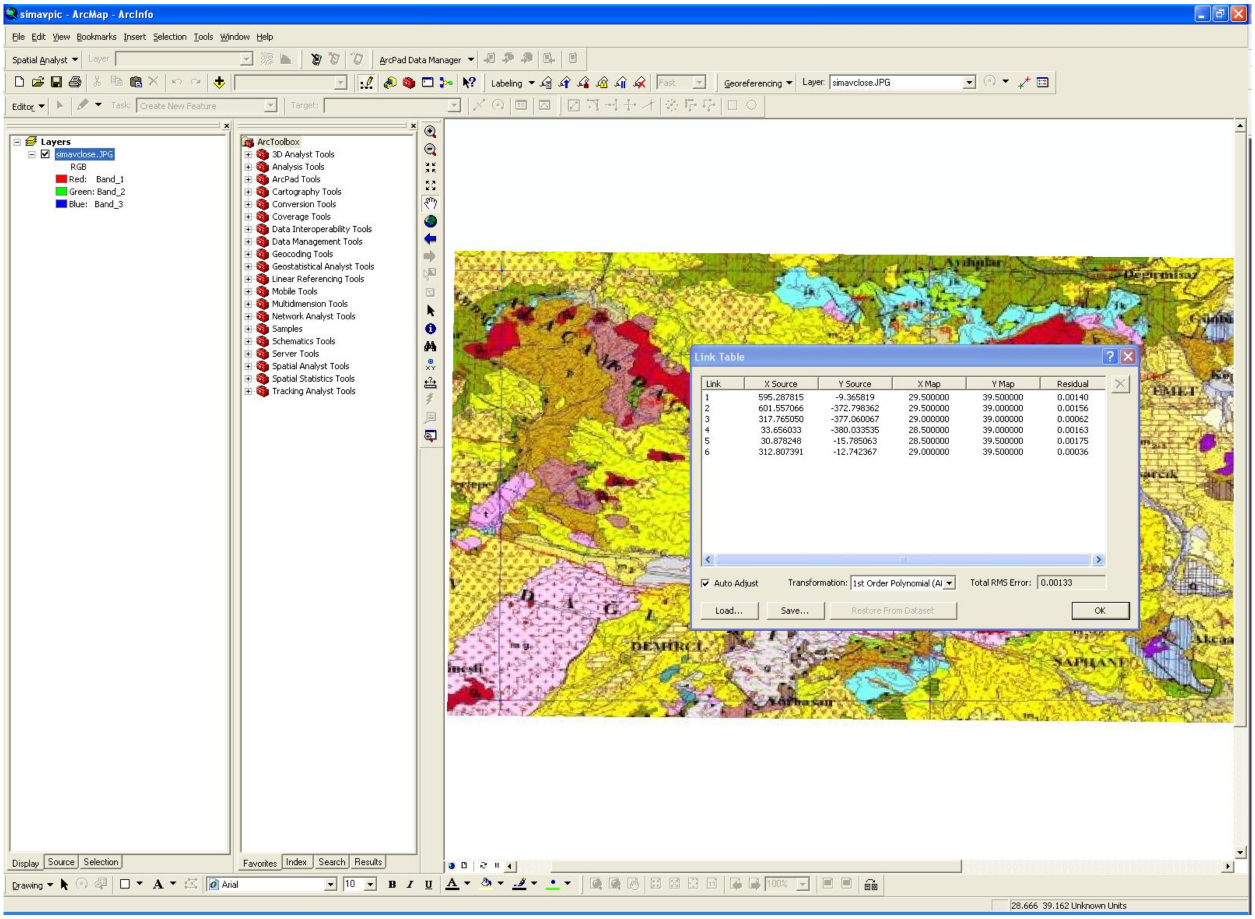
Sets the coordinate system to Unknown.

Save the coordinate system to a file.

Figure 9: Screen shot in ArcCatalog. Here I defined the spatial reference for the SRTM raster.

Geologic Map:

For the geologic map, I scanned a map of the area I am studying and cropped the map using Adobe Photoshop so only the portion of the map that I need to use is visible. This was saved as a .jpeg file. I then loaded the picture into a new ArcMap document. To georeference the image, I turned on the georeference toolbar and opened the link table. Then, using the 'add control points' tool, I clicked on the intersections of latitude and longitude lines on the map. I used six control points in all because, in this geologic map area, I have six points where the latitude and longitude lines intersect. In the link table, I then changed the X Map and Y Map locations to the precise latitude and longitude from the map ***(Figure 10)***. Now I have a geographically meaningful coordinates. I rectified the image and opened the new raster with meaningful geographic coordinates in ArcMap. Using ArcCatalog, I defined the coordinate system of the rectified image ***(Figure 11)***. For this project, all data will be projected as GCS WGS 1984.



Link Table

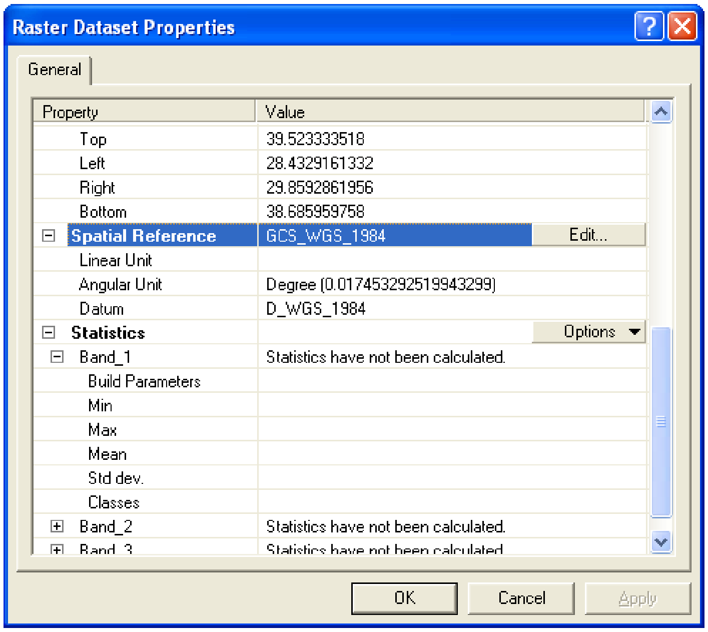
Link	X Source	Y Source	X Map	Y Map	Residual
1	595.287815	-9.365819	29.500000	39.500000	0.00140
2	601.557066	-372.798362	29.500000	39.000000	0.00156
3	317.765050	-377.060067	29.000000	39.000000	0.00062
4	33.656033	-380.033535	28.500000	39.000000	0.00163
5	30.878248	-15.785063	28.500000	39.500000	0.00175
6	312.807391	-12.742367	29.000000	39.500000	0.00036

☑ Auto Adjust

Transformation: 1st Order Polynomial (Al

Total RMS Error: 0.00133

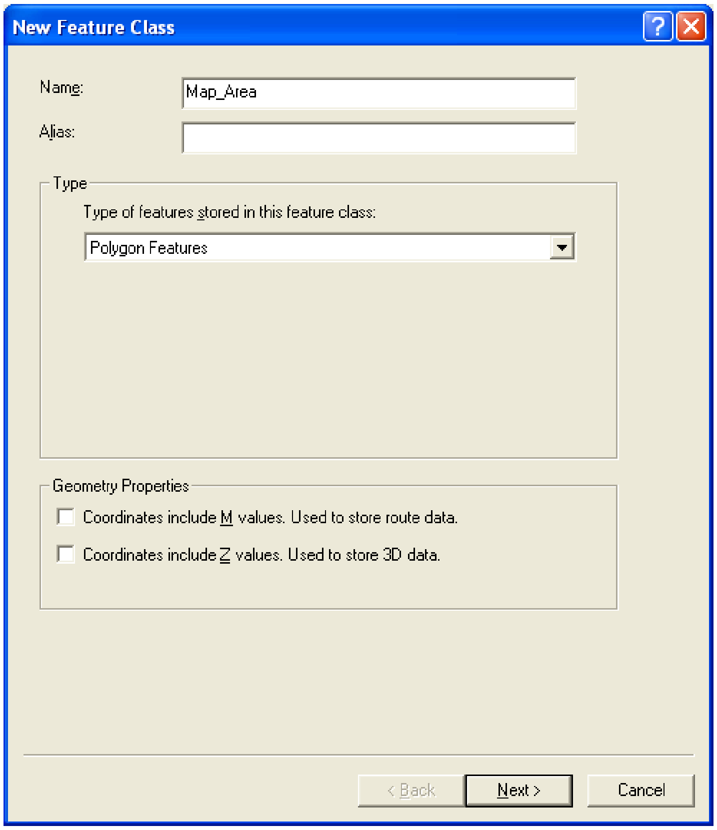
Figure 10: Screen shot of ArcMap. The Link Table shows six link locations from the Geologic Map with newly defined X Map and Y Map locations. The RMS Error is 0.00133.



Property	Value
Top	39.523333518
Left	28.4329161332
Right	29.8592861956
Bottom	38.685959758
⊟ Spatial Reference	GCS_WGS_1984
Linear Unit	
Angular Unit	Degree (0.0174532925199433)
Datum	D_WGS_1984
⊟ Statistics	
⊟ Band_1	Statistics have not been calculated.
Build Parameters	
Min	
Max	
Mean	
Std dev.	
Classes	
⊞ Band_2	Statistics have not been calculated.
⊞ Band_3	Statistics have not been calculated.

Figure 11: Using ArcCatalog, I set the spatial reference for the rectified geologic map to GCS_WGS_1984.

I now have a geologic map and SRTM data projected correctly on my map. However, both data sets cover more than the area that I am interested in. To fix this, in ArcCatalog I will create a new feature class named Map_Area within my personal Geodatabase for this project. The type will be polygon and it will be spatially referenced as GCS_WGS_1984 ***(Figure 12)***.



Name: Map_Area
Alias:
Type of features stored in this feature class: Polygon Features
☐ Coordinates include M values. Used to store route data.
☐ Coordinates include Z values. Used to store 3D data.

Figure 12: Here is a screen shot created in ArcCatalog. I created a new polygon feature class within my geodatabase to form a boundary of my Map Area.

After I created the polygon feature, I edited this polygon feature using the editor in ArcMap. With this tool, I created a new feature covering only the area I am interested in mapping. ***Figure 13*** shows the map area polygon that I created with the SRTM raster and geologic map projected underneath.

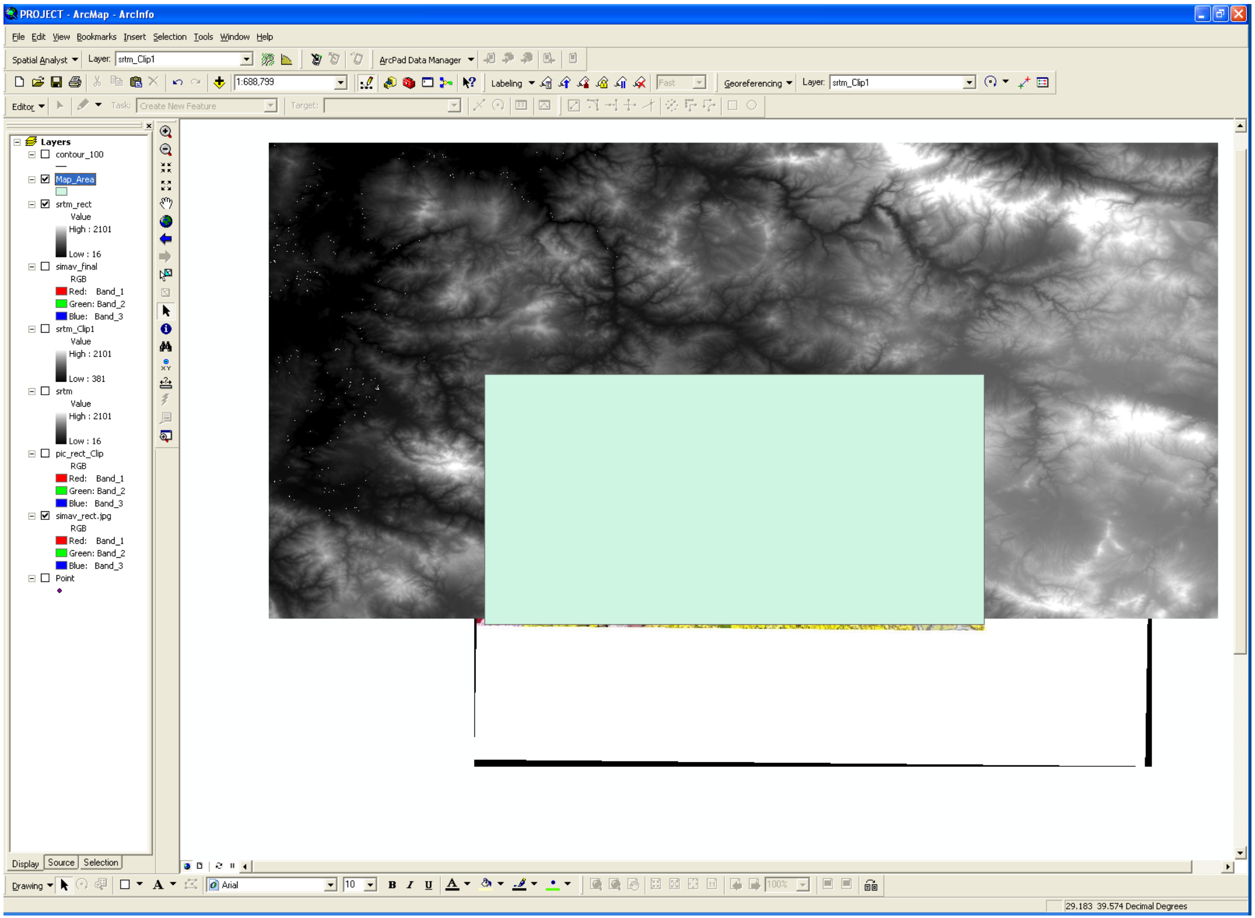
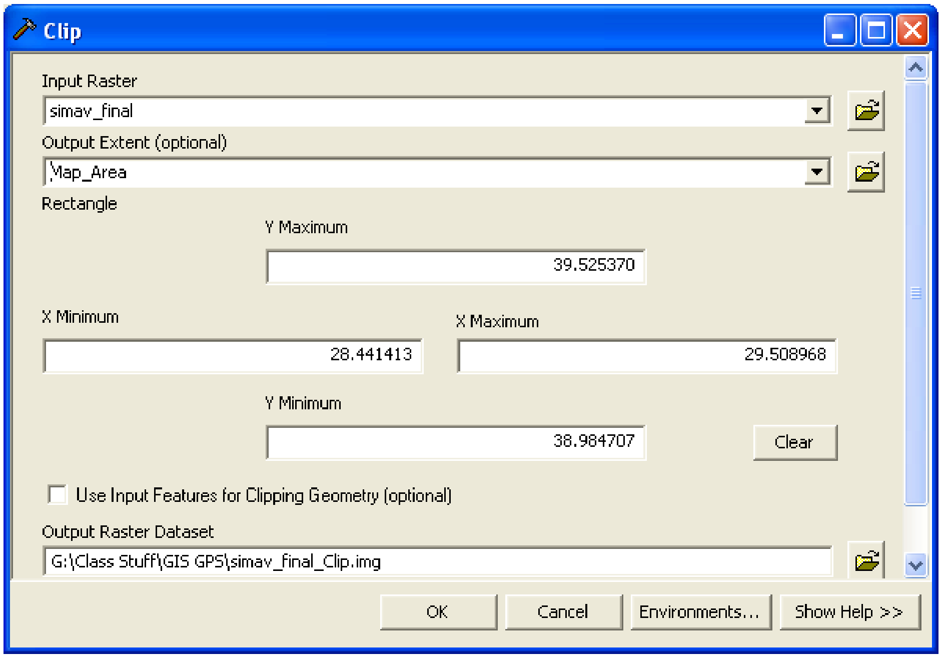


Figure 13: Screen shot of ArcMap. The green box is the map area that I created. The SRTM data extends to the west, east, and north. The small strip of yellow under the green box is the geologic map. The cropped map also extends to the south and west as a box.

Using the clip tool, I clipped both the SRTM raster and the geologic map to fit within the map area ***(Figure 14)***. This produces a map containing both of the datasets within the boundaries I am interested in.

SRTM (ArcGIS Processing continued):

The next step is to make contours using the spatial analyst tool to analyze the elevation data ***(Figure 15)***. Having contours will make it easier to analyze the location of the detachments with respect to the surrounding elevation.



Input Raster: simav_final

Output Extent (optional): Map_Area

Rectangle

Y Maximum: 39.525370

X Minimum: 28.441413

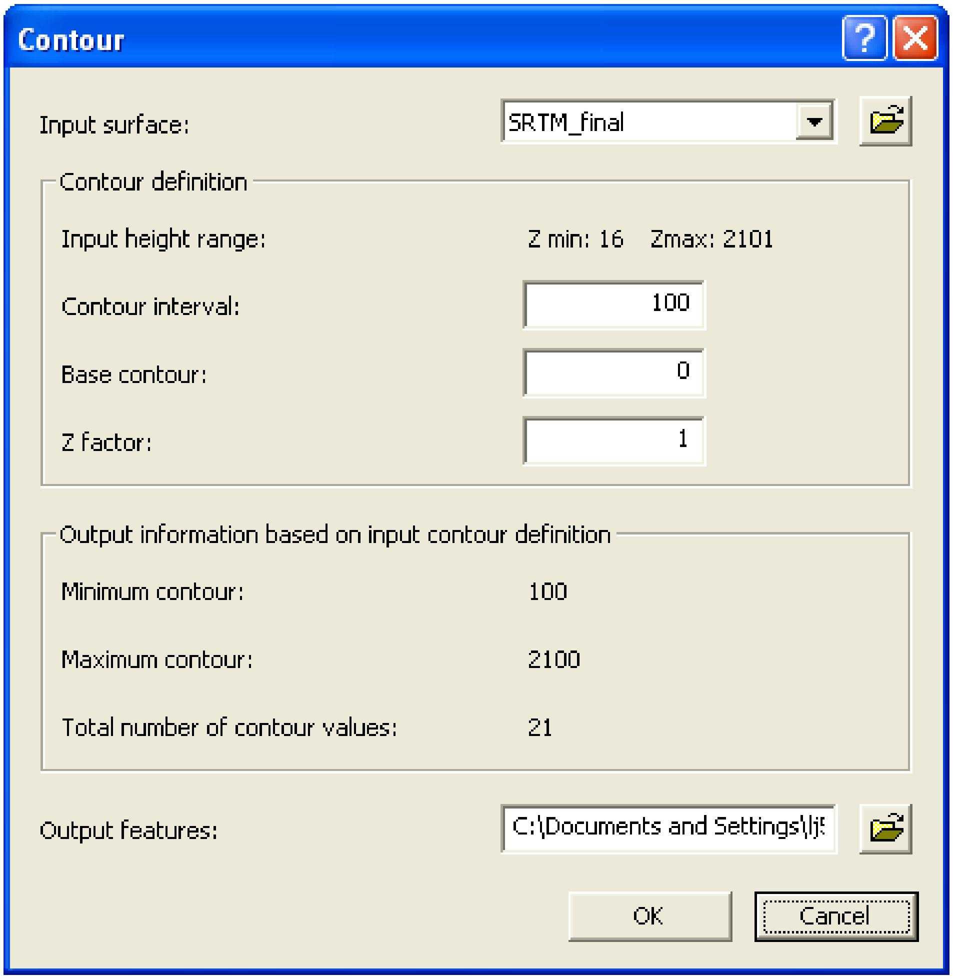
X Maximum: 29.508968

Y Minimum: 38.984707

☐ Use Input Features for Clipping Geometry (optional)

Output Raster Dataset: G:\Class Stuff\GIS GPS\simav_final_Clip.img

Figure 14: Screen shot of the Clip tool in ArcMap. Here I clipped the geologic map (Simav_final) to extend only within the map area. The new raster was saved as Simav_final_clip.img on my flash drive. This step was repeated to clip the SRTM data.



Input surface: SRTM_final

Contour definition

Input height range: Z min: 16 Zmax: 2101

Contour interval: 100

Base contour: 0

Z factor: 1

Output information based on input contour definition

Minimum contour: 100

Maximum contour: 2100

Total number of contour values: 21

Output features: C:\Documents and Settings\lj!

Figure 15: Using the contour tool under Spatial Analyst→ Surface Analysis→ Contour, I created 100m contours from the SRTM raster.

Geologic Map (ArcGIS Processing continued):

To get a better idea of where the detachments are in relationship to the granites that they have deformed, I created a new polygon feature class called “granites” in the geodatabase within ArcCatalog. After uploading this new feature class into ArcMap, using the editor I outlined all of the granite plutons so they are in a separate shape file. I also created a new line feature class called “detachment” within ArcCatalog and used the editor in ArcMap to draw the location of the Simav detachment and the second inferred Simav detachment. The map now shows the location of granites and detachments as well as SRTM data ***(Figure 16)***.

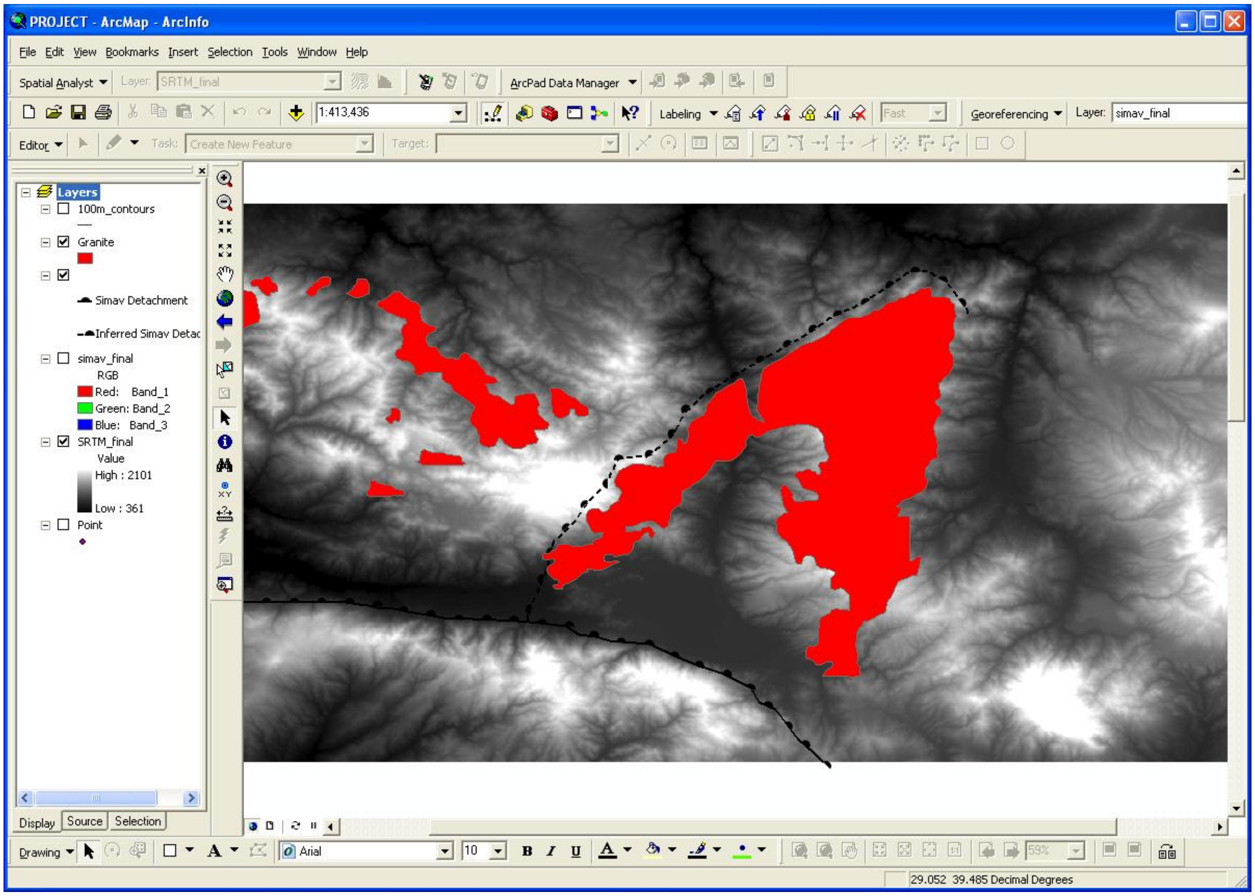
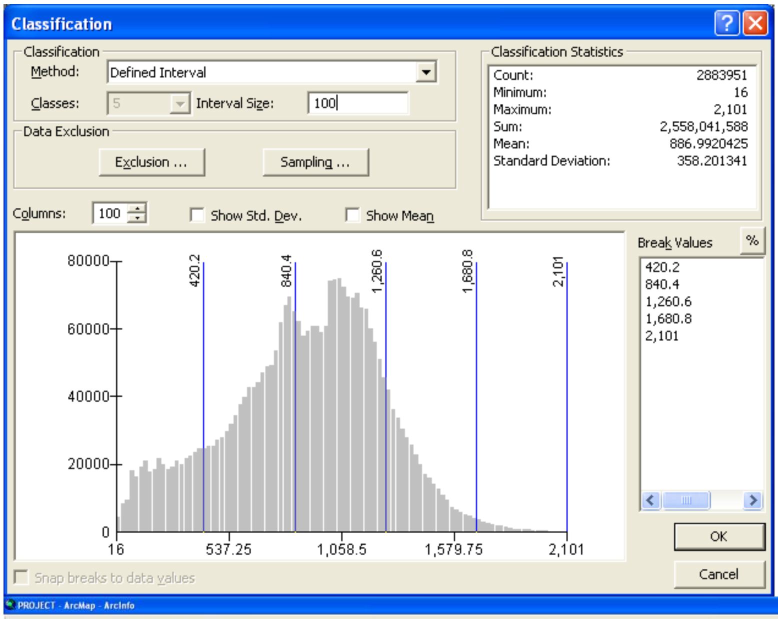


Figure 16: Screen shot of ArcMap. The granites I am studying are shown as red polygons, both detachments are drawn, and the data is projected on top of SRTM data to see elevation differences with respect to the detachments.

SRTM (ArcGIS Processing continued):

As previously stated, the goal of this project is to use GIS data to make assumptions about the existence of the NE-SW trending Simav detachment. To better analyze this problem, I classified the SRTM raster with equal intervals of 100m ***(Figure 17).*** The result is shown in ***Figure 18.***



Classification

Classification

Method: Defined Interval

Classes: 5

Interval Size: 100

Classification Statistics

Count:	2883951
Minimum:	16
Maximum:	2,101
Sum:	2,558,041,588
Mean:	886.9920425
Standard Deviation:	358.201341

Columns: 100

☐ Show Std. Dev.

☐ Show Mean

Break Values

420.2
840.4
1,260.6
1,680.8
2,101

☐ Snap breaks to data values

Figure 17: Here I have opened the properties of the SRTM data and changed the symbology to classified with 100m intervals.

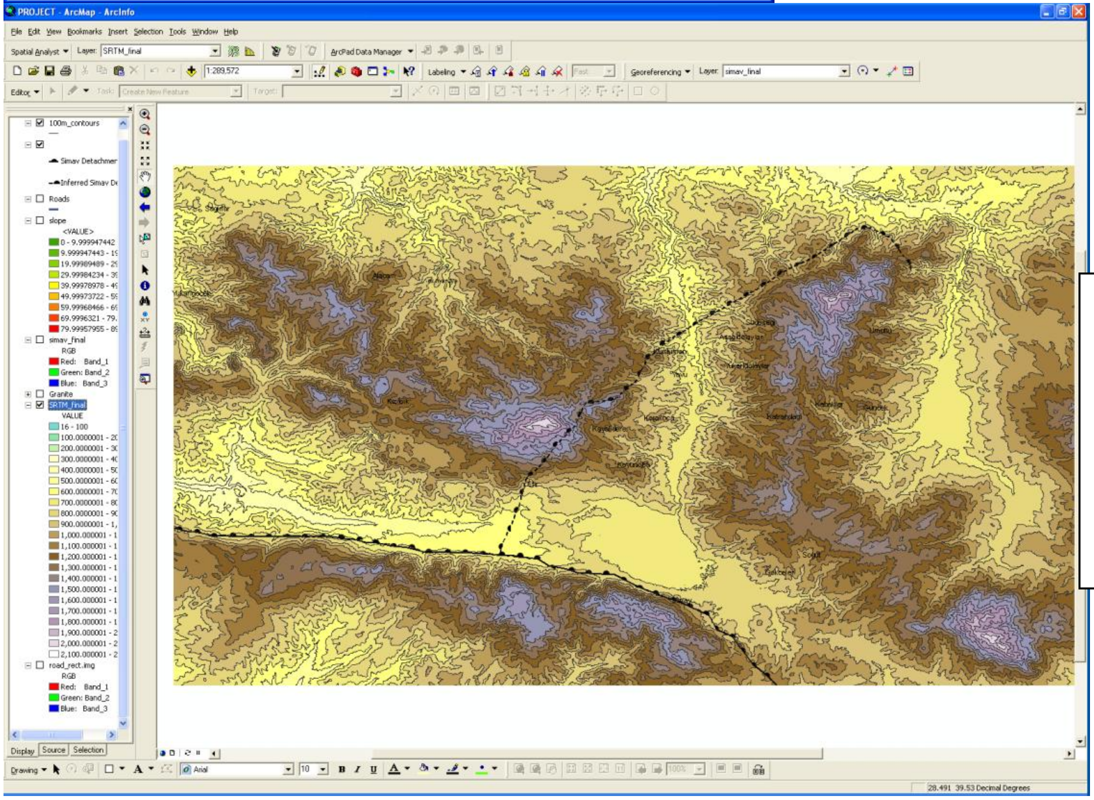
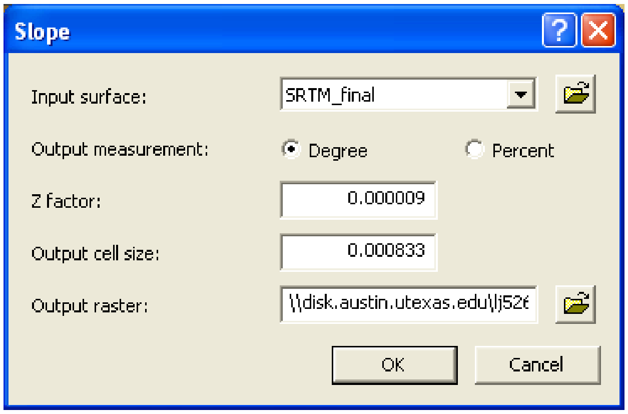


Figure 18: Screenshot of ArcMap showing the result of classifying the SRTM data.

In order to get the most accurate elevation analysis, I created other rasters using the SRTM data. With the spatial analyst tool, I created a slope raster ***(Figure 19)***. I classified the symbology and manually moved the break values to emphasize the differences in slope ***(Figure 20)***. The results are shown in ***Figure 21.***



Input surface: SRTM_final

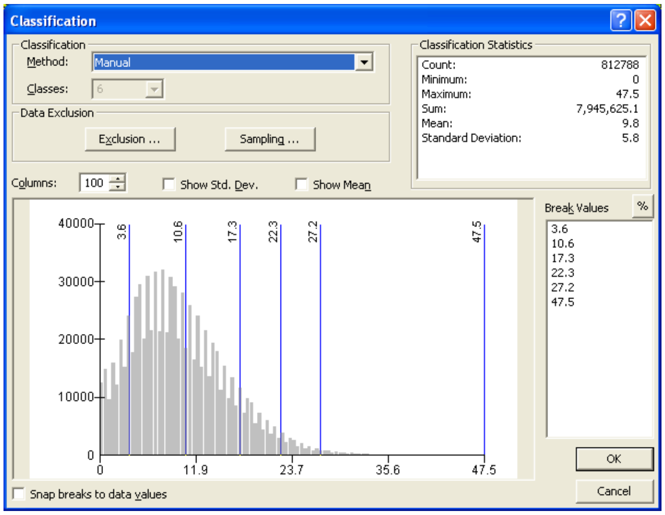
Output measurement: ● Degree ○ Percent

Z factor: 0.000009

Output cell size: 0.000833

Output raster: \\disk.austin.utexas.edu\lj52€

Figure 19: The Slope tool is found under Spatial Analyst→ Surface Analysis→ Slope. Here I created a slope raster using the SRTM data.



Method: Manual

Classes: 6

Columns: 100

☐ Show Std. Dev.

☐ Show Mean

Count:	812788
Minimum:	0
Maximum:	47.5
Sum:	7,945,625.1
Mean:	9.8
Standard Deviation:	5.8

Break Values
3.6
10.6
17.3
22.3
27.2
47.5

☐ Snap breaks to data values

Figure 20: Screen shot taken from ArcMap. Within the Slope raster properties, I classified the symbology into six separate classes determined by the location of the blue vertical lines. Each class is represented with a different color.

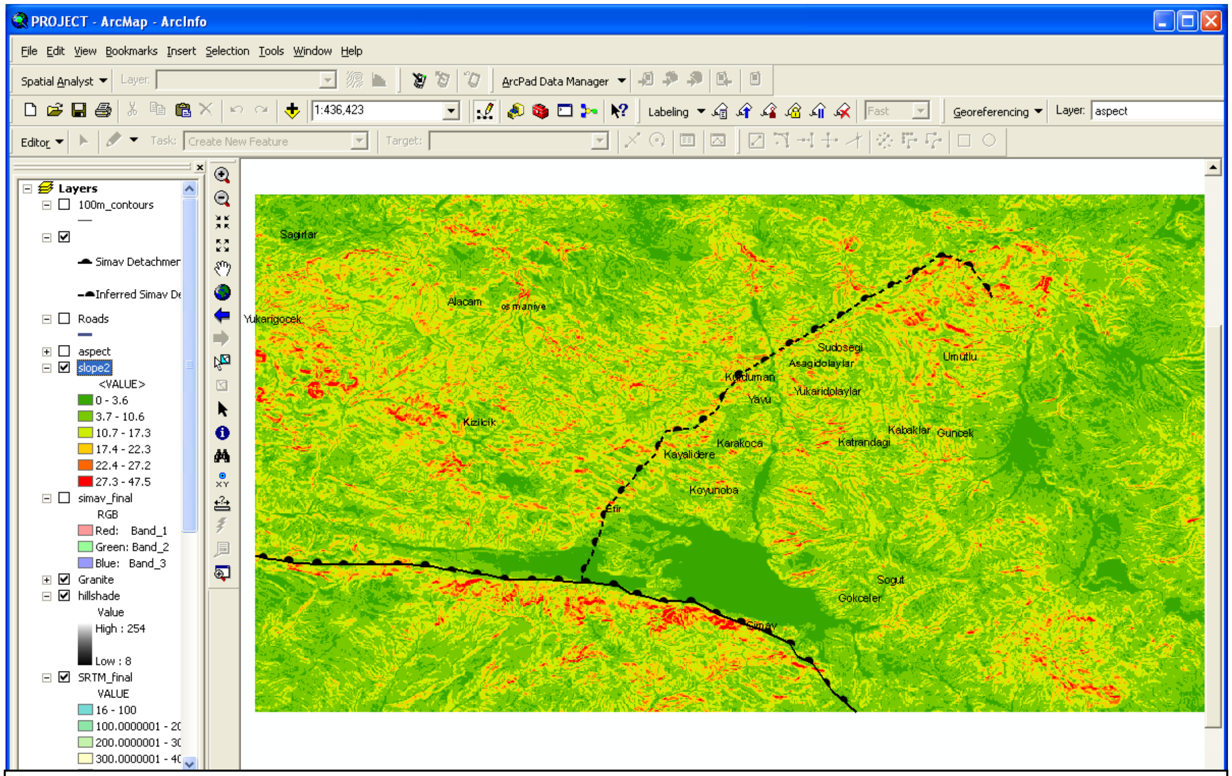
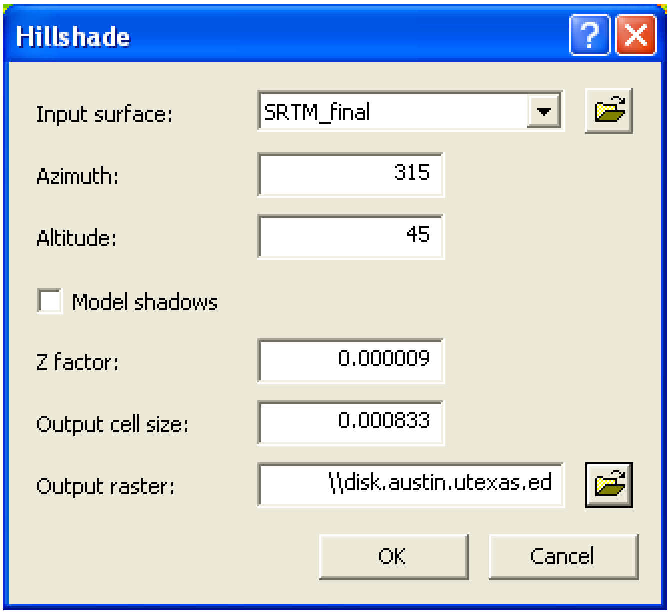


Figure 21: Screen shot of ArcMap showing the classified slope raster and how it compares to the location of the two detachments.

After analyzing the SRTM elevation data and slope data, I created a Hillshade using the Spatial Analyst tool ***(Figure 22)***. Results are captured in ***Figure 23.***


Hillshade

Input surface: SRTM_final

Azimuth: 315

Altitude: 45

☐ Model shadows

Z factor: 0.000009

Output cell size: 0.000833

Output raster: \\disk.austin.utexas.ed

Figure 22: The Hilshade tool is found under Spatial Analyst→ Surface Analysis→ Hilshade. Here I created a Hillshade raster using the SRTM data.

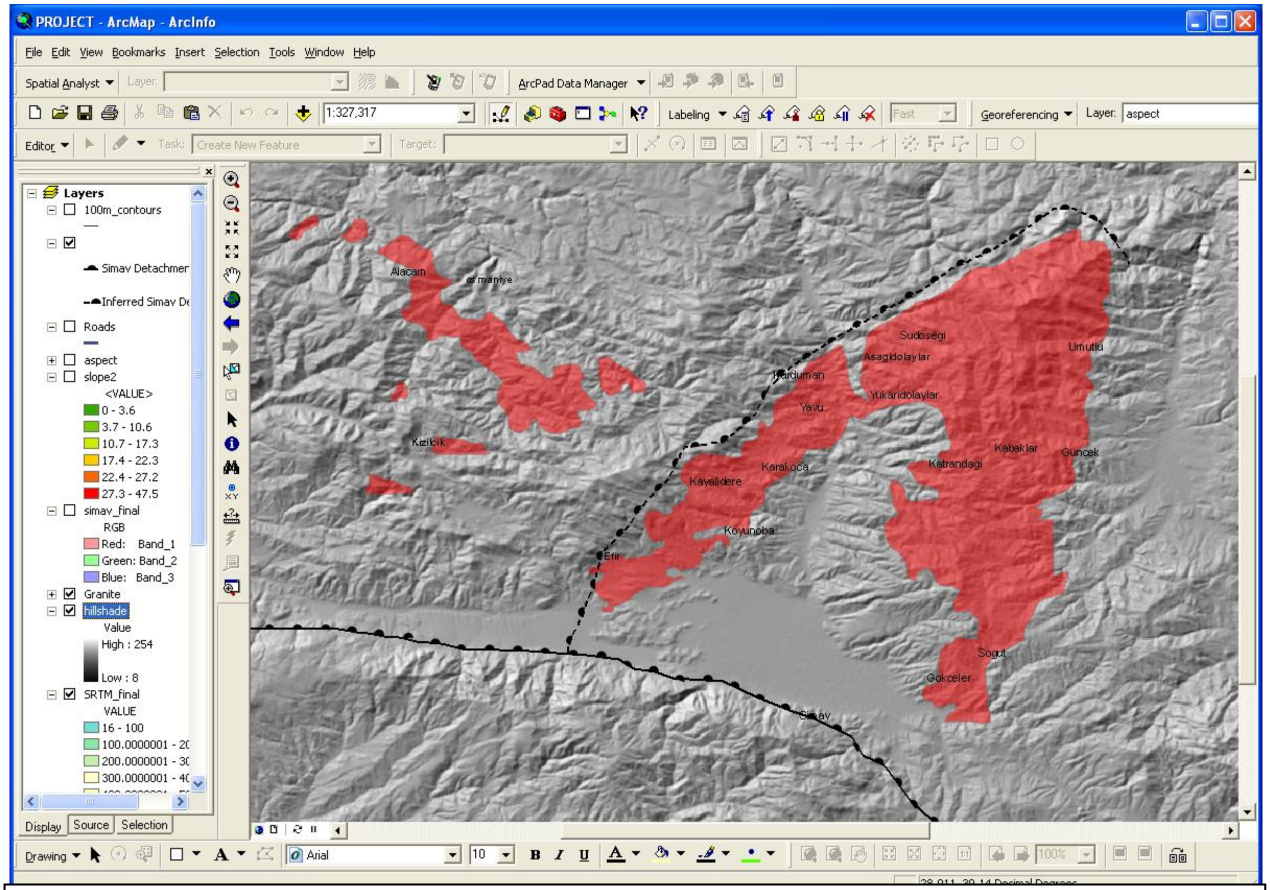
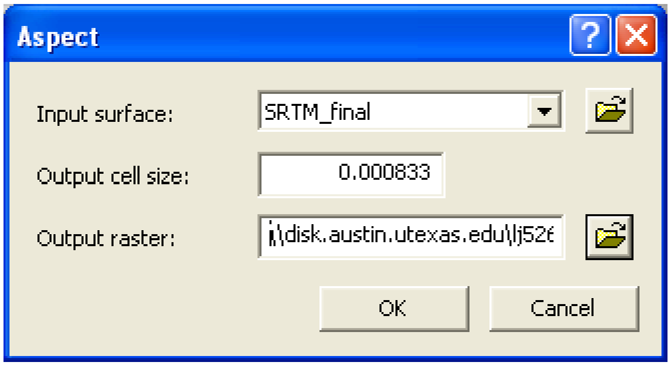


Figure 23: Screen shot of ArcMap showing the Hillshade raster and how it compares to the location of the two detachments and granite plutons.

The final analysis tool used to determine if any elevation data shows the existence of a second NE-SW trending Simav detachment is an Aspect raster ***(Figure 24)***. The Aspect raster with the location of the detachments is shown in ***Figure 25.***



Input surface: SRTM_final

Output cell size: 0.000833

Output raster: i:\disk.austin.utexas.edu\lj52

Figure 24: The Aspect tool is found under Spatial Analyst→ Surface Analysis→ Aspect. Here I created an Aspect raster using the SRTM data.

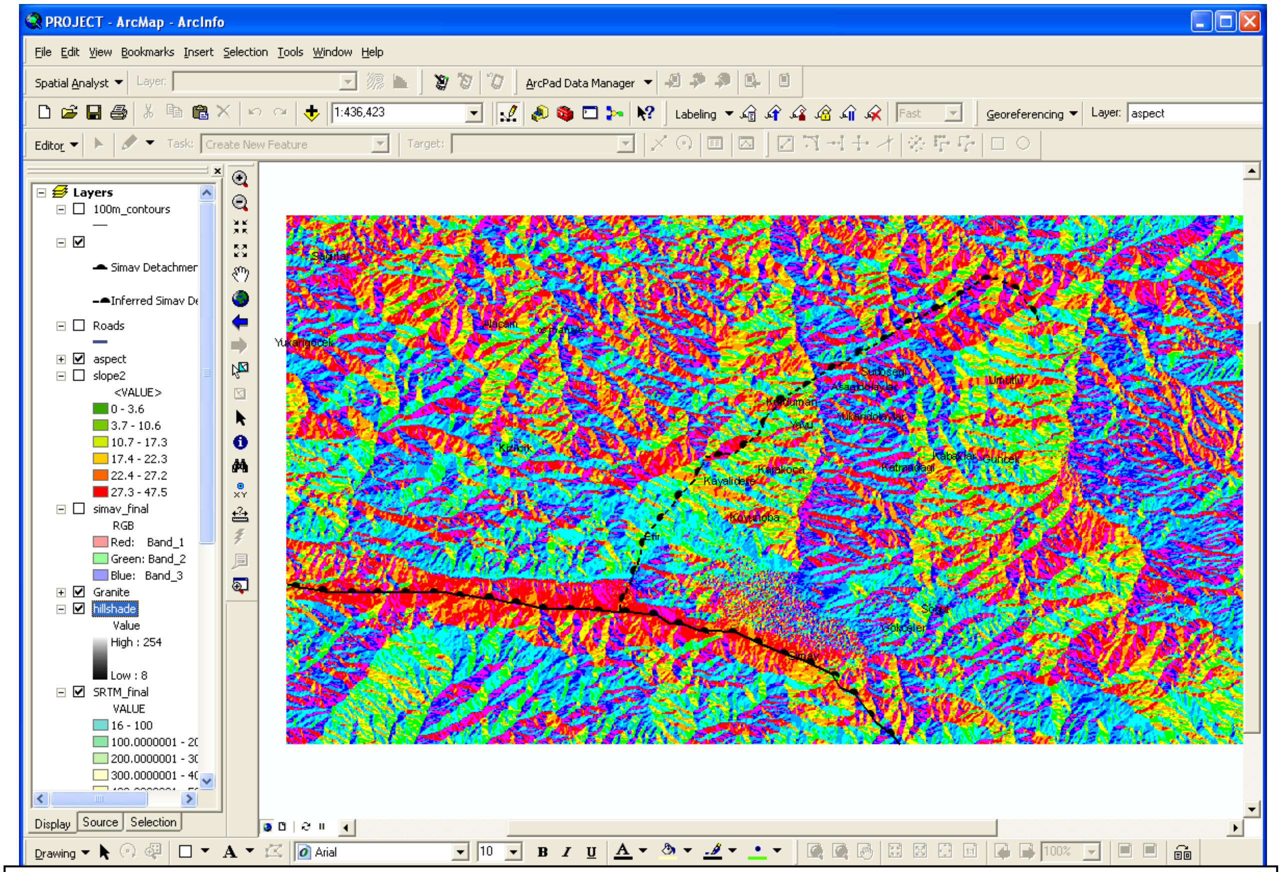


Figure 25: Screen shot of ArcMap showing the Aspect raster and how it compares to the location of the two detachments.

Roads:

The shape files of roads available online for this area in Turkey only show the main highways. I need a map that has all roads, including dirt roads, of the area. Using Google Maps, I zoomed into my study area in Turkey. All of the roads were outlined so I took a screen shot and then cropped the image using Adobe Photoshop to the area that I am mapping ***(Figure 2)***. I then loaded the image into ArcMap and, with the Google Map pulled up on one screen so I could capture precise lat/long measurements ***(Figure 26)*** and the ArcMap on the other screen for georeferencing ***(Figure 27)***, I entered 4 spots into the map ***(Figure 28)***.

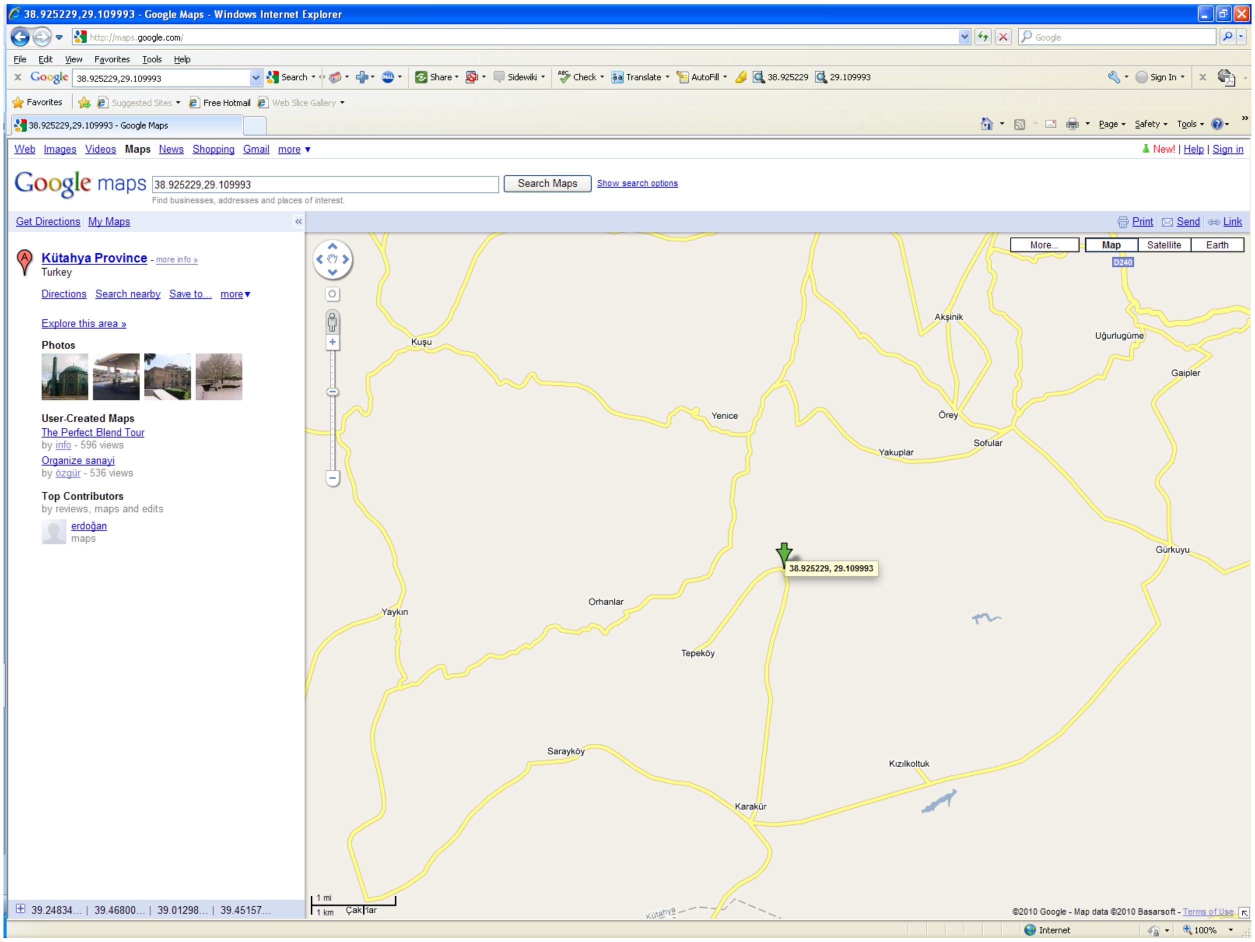


Figure 26: Here is a screen shot of Google Maps used to reference the image in ArcMap. I can add a green arrow to any place on the map by right-clicking. This green arrow is located at 29.109993^{o}E and 38.925229^{o}N.

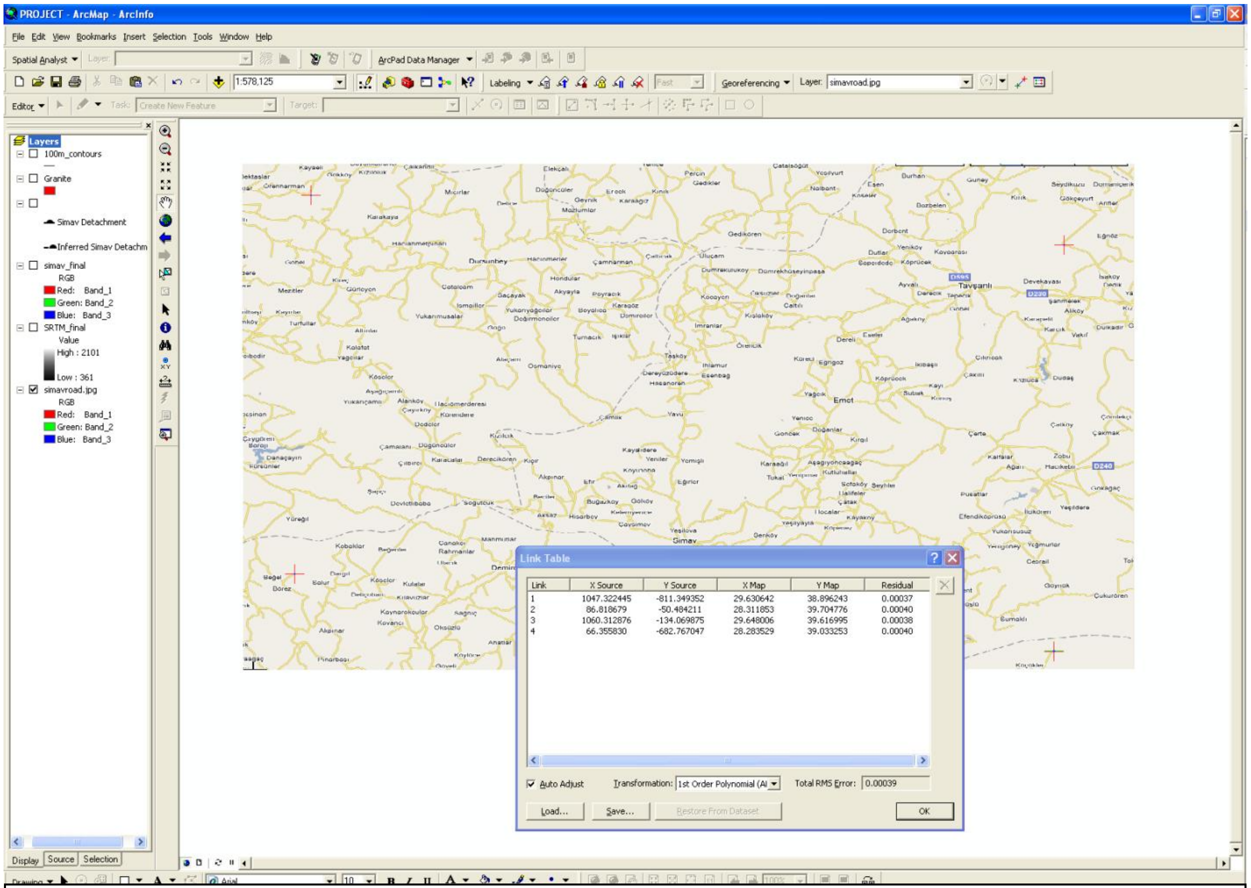
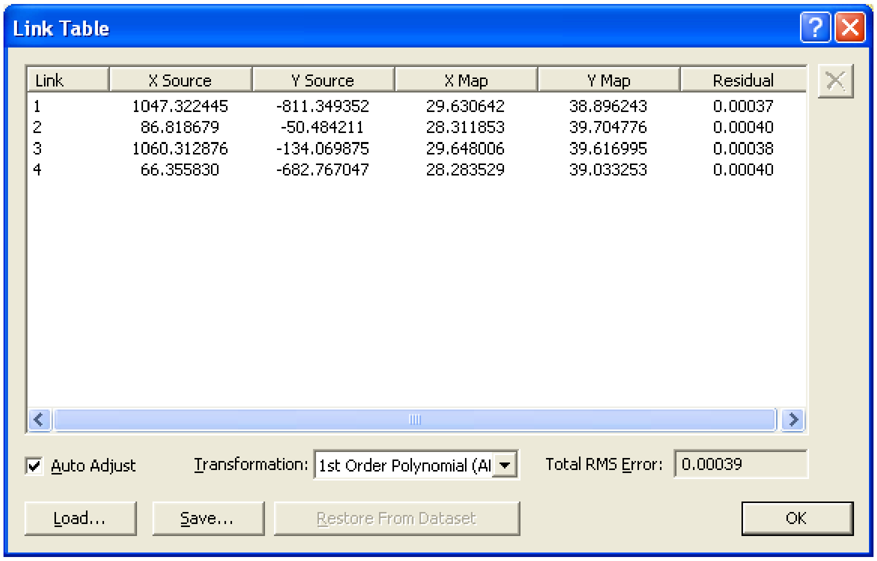


Figure 27: Screen shot of ArcMap. Here I have georeferenced four precise points near each corner of the map. The RMS Error is .00039.



Link	X Source	Y Source	X Map	Y Map	Residual
1	1047.322445	-811.349352	29.630642	38.896243	0.00037
2	86.818679	-50.484211	28.311853	39.704776	0.00040
3	1060.312876	-134.069875	29.648006	39.616995	0.00038
4	66.355830	-682.767047	28.283529	39.033253	0.00040

☑ Auto Adjust

Transformation: 1st Order Polynomial (Al

Total RMS Error: 0.00039

Figure 28: Here is the link table used to georeference the Google Map image. After clicking on a precise point within ArcMap, I then defined the X Map and Y Map points by locating that exact position within Google Maps and right-clicking to get the lat/long measurements of that point.

Although I could have entered an endless number of georeferencing positions, one spot from each corner of the map gave me a very low RMS error (0.00039) so more points were not necessary.

After georeferencing my map, I rectified the image and saved it as road_rect.img. Using ArcCatalog, I made sure this file had the correct spatial reference (WGS_1984) before loading it into ArcMap. Now I have the roads, the geologic map, and the SRTM data together on one map ***(Figure 29).***

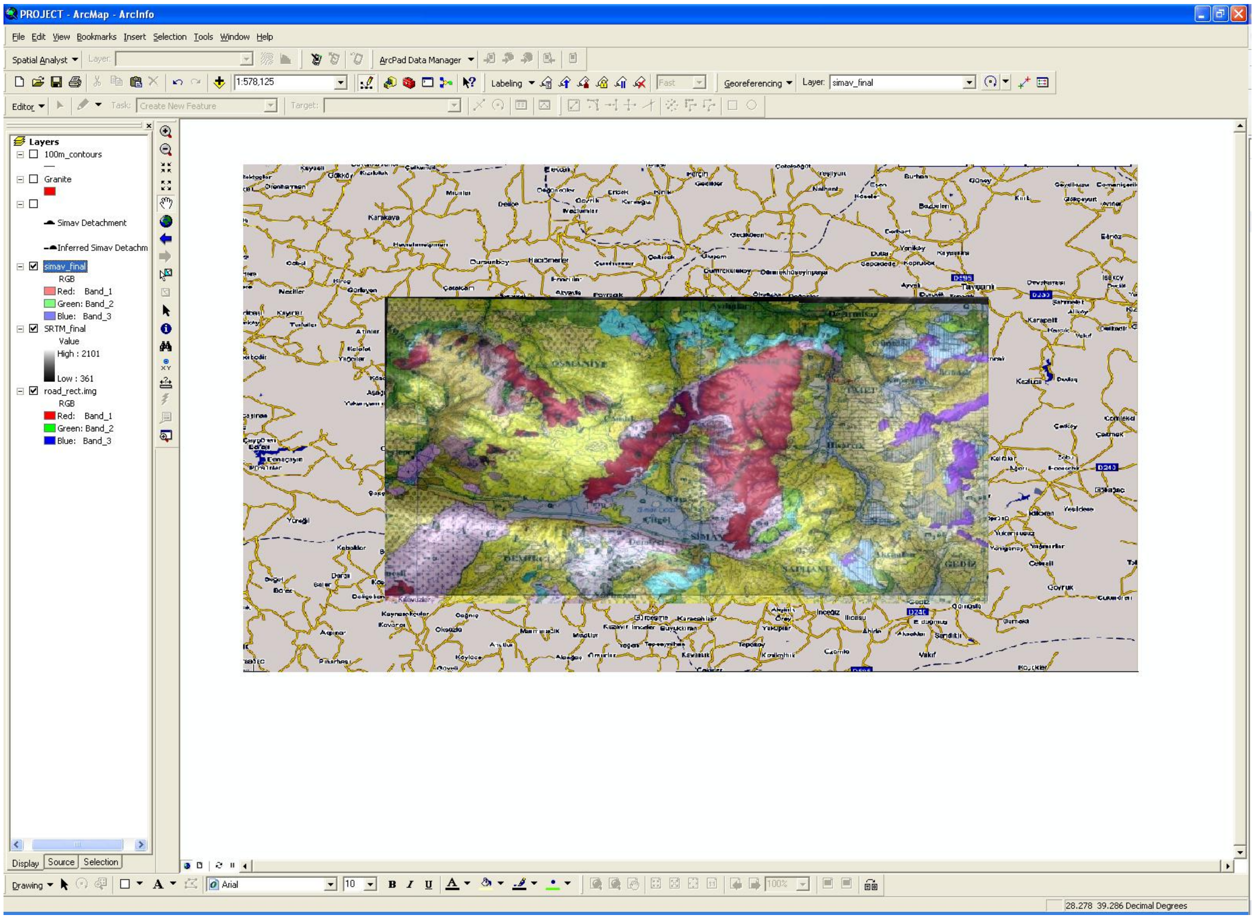


Figure 29: Screen shot of ArcMap. Here I have the Geologic Map (50% transparent) with the SRTM data underneath. Notice this data is within the Map Area boundaries. The road map is now correctly georeferenced underneath. It covers a much larger area than the other datasets.

To get rid of the large road map from Google, I added a line feature class in ArcMap using the same method as I did for the map area polygon, granite polygon, and detachment line. I loaded this new line feature class (called “Roads) into ArcMap to edit. Hiding the geology and SRTM data, I turned the editor on for the Roads feature class and digitized the roads on the map. The only roads I need are the roads that are near the granites and the roads that connect between the granites and major towns ***(Figure 30)***.

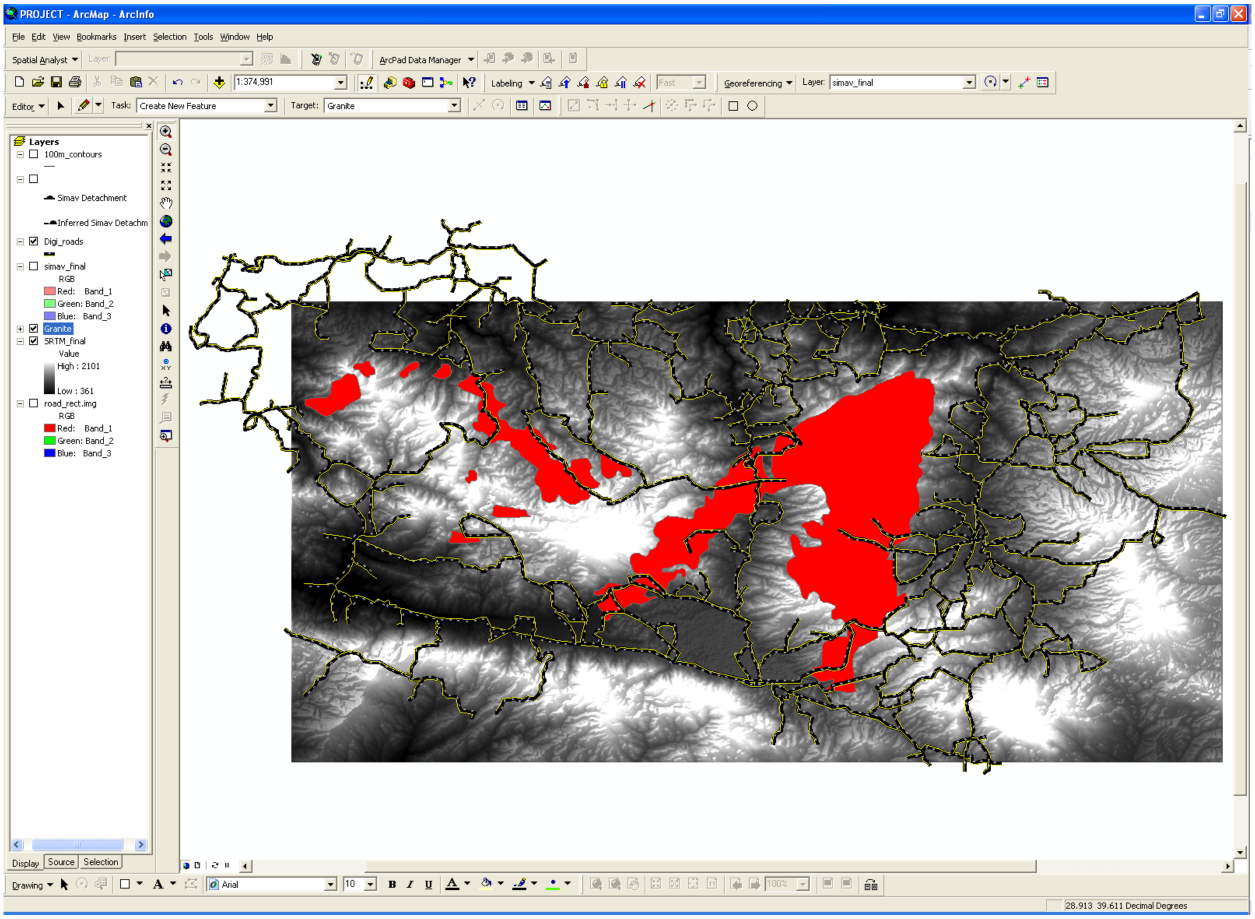


Figure 30: Here is a screen shot of ArcMap. The SRTM raster is overlain by the digitized granites. On top of both of those layers is the newly digitized roads layer. Here I have digitized the roads that will help me drive to the granites.

Although the roads that I have digitized go out of the boundaries of the map area, I do not want to crop them because these roads connect to areas inside the map boundary that I will be trying to get to. Because most of these roads are dirt roads, they typically are not named. Instead, intersections are marked with names of towns and arrows towards their direction. For this road map to be useful, I added labels (using the label tool in ArcMap) to all of the towns near the granite outcrops because these will be the towns we will look for on road signs ***(Figure 31)***.

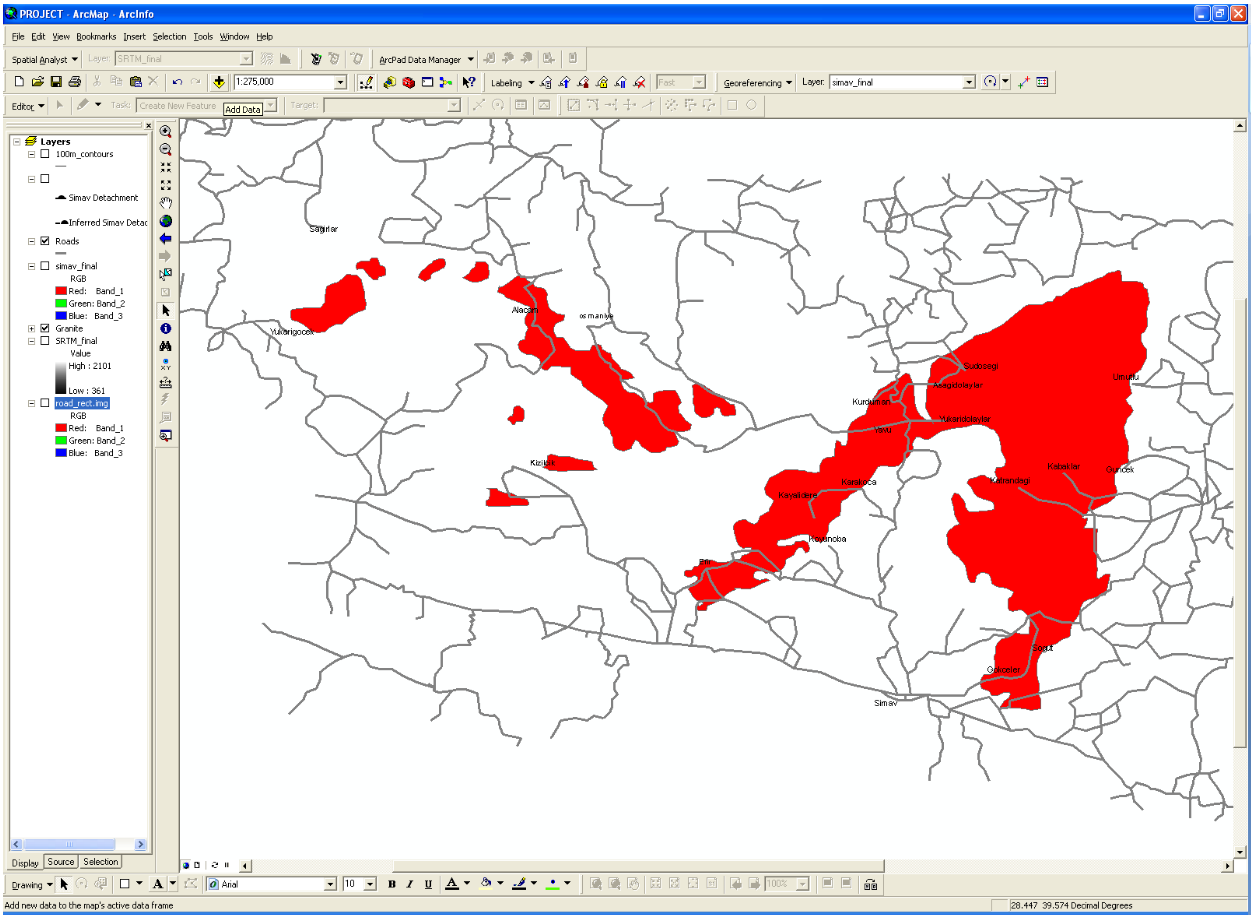


Figure 31: Screenshot of ArcMap showing the granites and the digitized roads. Also shown are the labels of towns near the location of granites. Not many towns are shown because population is sparse in this area.

V. Data Presentation:

Part One: Does the second detachment exist?

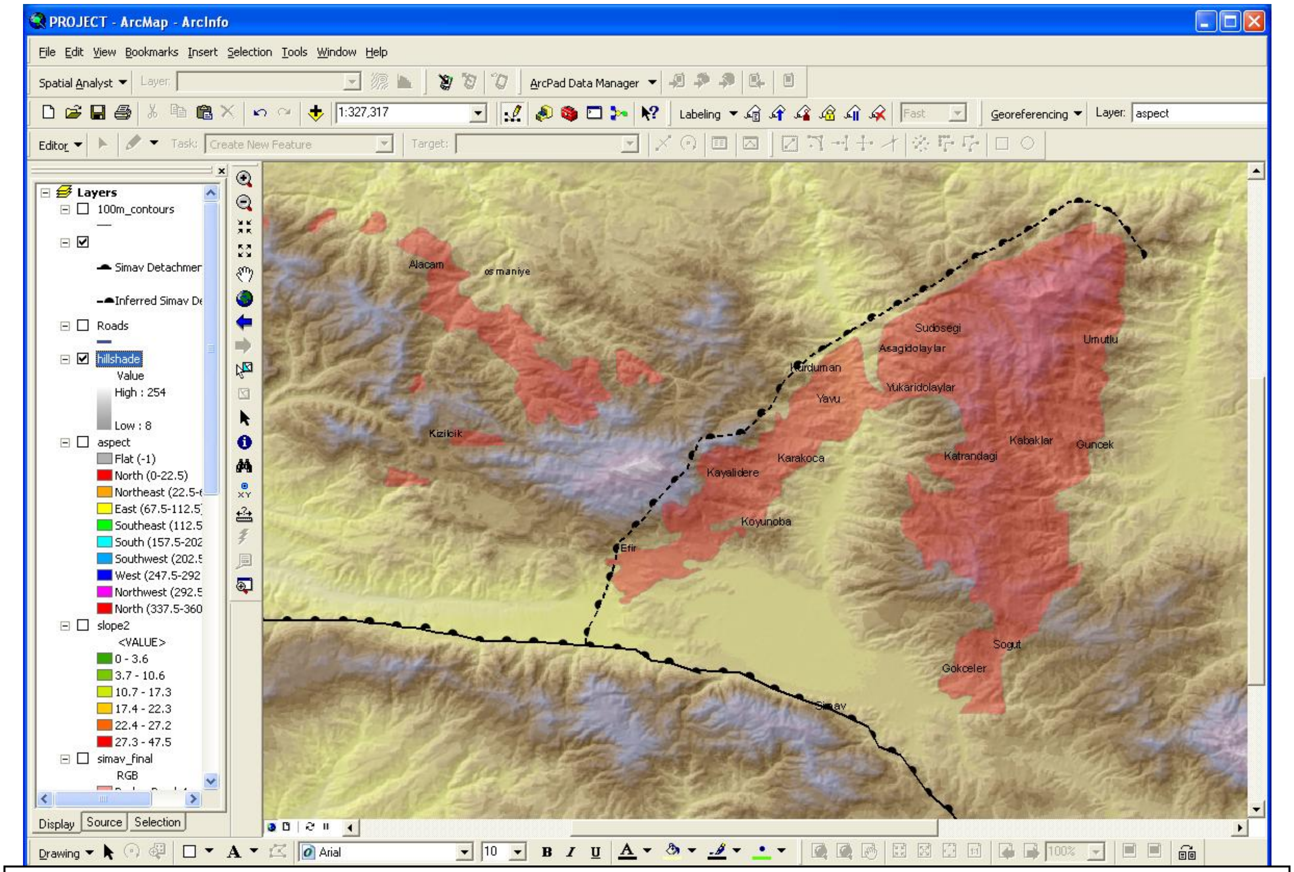


Figure 32: Screen shot of ArcMap showing the deformed granites and both detachment faults with respect to SRTM data and underlying Hillshade. The E-W trending Simav detachment follows the steep valley highlighted by the SRTM data. The second SW-NE trending detachment does not follow any elevation trends.

The well-documented Simav detachment can be clearly seen by the contours. The detachment has a typical elevation difference of >200m. However, the second detachment that is said to run along the western boundary of the Egrigoz pluton is not evident by elevation data alone. Here is another look at the map with only the contours and detachments shown ***(Figure 33)***. Notice that the Simav detachment can be easily mapped by following the contours while the second detachment appears to be randomly drawn through the contours.

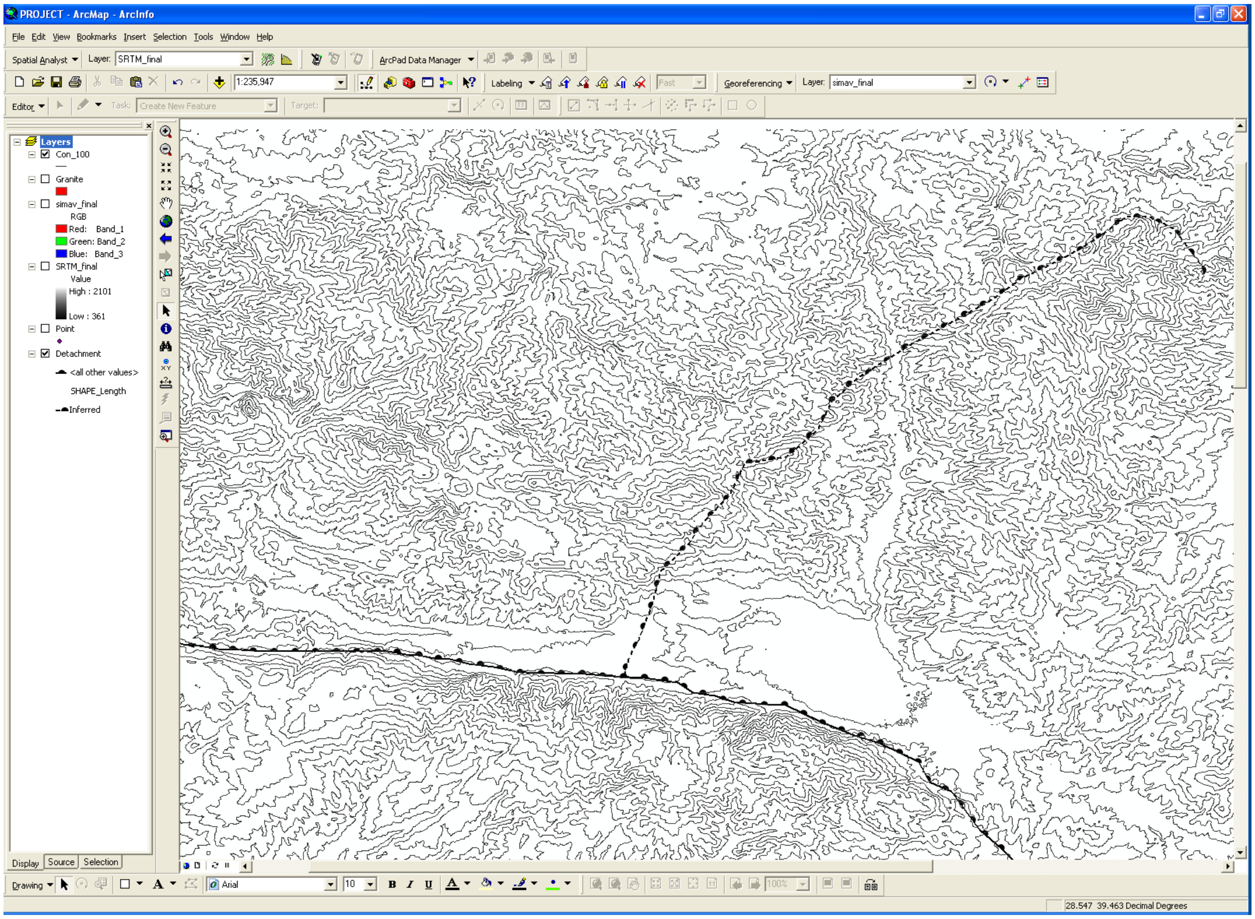


Figure 33: Screen shot of ArcMap showing 100m contours from the SRTM data and the location of the detachments. Notice the E-W trending detachment is marked by an elevation difference of >200m while the NE-SW trending inferred detachment does not follow any contour trends.

The SRTM data shows a defined elevation difference between the footwall and hanging wall of the E-W trending Simav detachment. However, the inferred NE-SW detachment does not follow any obvious elevation trends ***(Figure 18)***. Analyzing the slope raster, I find that the main E-W trending Simav detachment is marked by a steep slope. However, the NE-SW trending detachment is not clearly defined by a steep slope but instead cuts across changes in slope. The curve of the inferred detachment in the north follows a steeper slope but the rest of the detachment does not ***(Figure 21)***. The Hillshade data was the most interesting dataset I created. This raster showed E-W lineations that parallel the extension in the area. I noticed that these lineations are more defined in the hanging wall of the main Simav detachment. I also noticed that these lineations cross the inferred Simav detachment with no offset. If this detachment exists, a difference in lineations should be seen between the eastern footwall and the western hanging wall. The Hillshade data shows no difference between the inferred hanging wall and footwall, implying that this second detachment does not exist ***(Figure 23)***. The Aspect raster is the final raster that I created to analyze the elevation. The Aspect raster shows the main Simav detachment dipping steeply towards the North. This well-documented detachment fault follows dip direction. However, the NE-SW trending inferred detachment fault cuts across changing dip directions throughout the extent of the fault ***(Figure 25)***.

Based on this elevation data, the second detachment does not exist. However, if offset on this detachment was significantly less than the well-defined Simav detachment, it could be possible that erosion has erased any topographic evidence. The Simav detachment is dated to ~21Ma. This period of time would be long enough for erosion to erase any topographic evidence of a smaller detachment. More field work will have to be done to verify these results.

Part Two: Field Map

I need a map that shows the location of the granites to be sampled and the roads that lead to these locations. To create this map, I first georeferenced a geologic map of the area and digitized the granites with polygons. I then georeferenced a road map of the area and digitized the roads with lines. To complicate matters in the field, most of these roads are not named but merely have arrows pointing towards the next town. For this map to be applicable I labeled the names of the towns closest to the granites that need to be sampled ***(Figure 34)***. The final map shows the granites, roads, and towns and is attached as a separate PDF to this report. Because of space issues on the 8.5x11 map, I have only labeled the towns closest to the granites. For the field map, which will be printed on larger map-size paper, all of the towns within the map area will be labeled. To my knowledge, this is the first map combining roads and geologic features of this area. The final map is shown in ***Figure 35.***

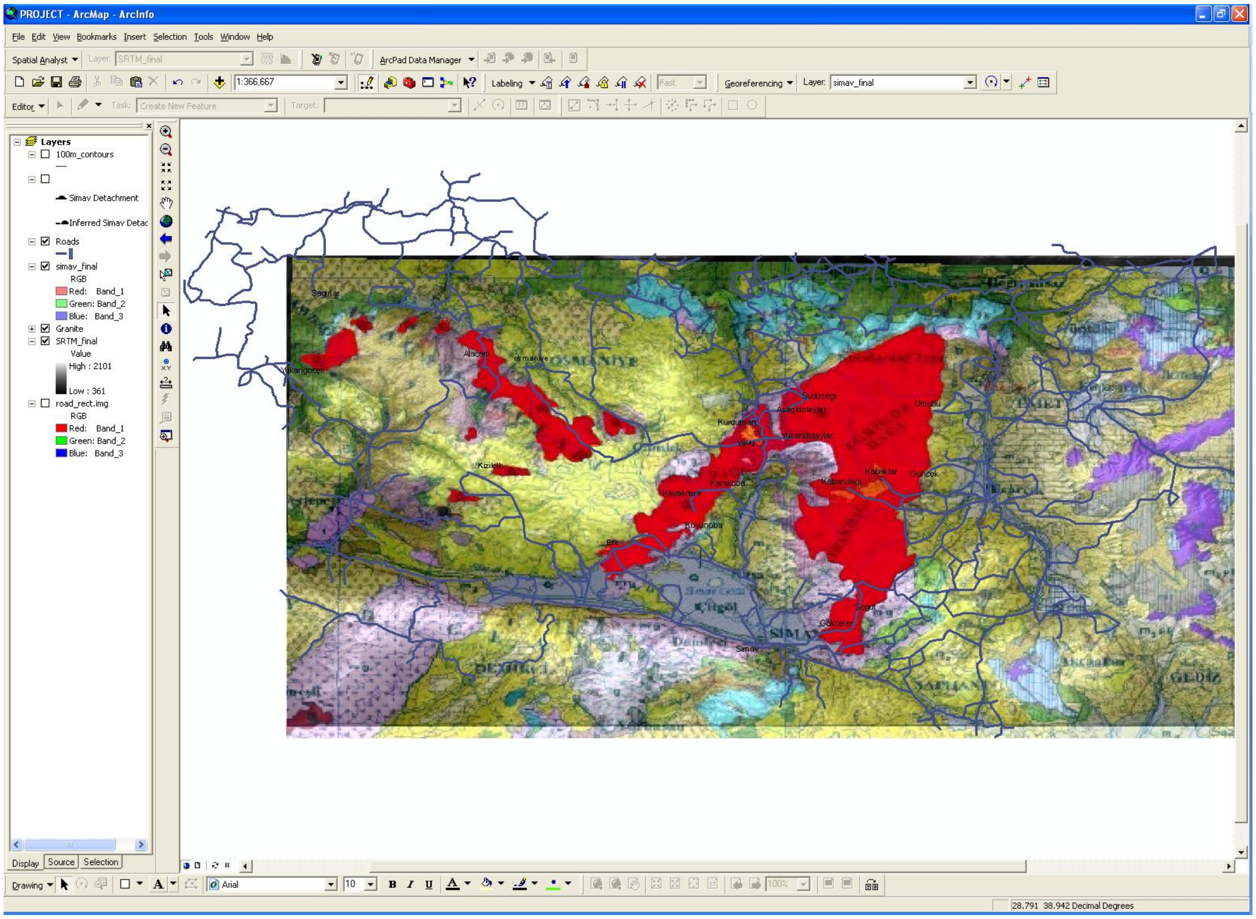


Figure 34: Screen shot of ArcMap showing SRTM data, geologic map, location of granites, digitized roads, and labeled towns.

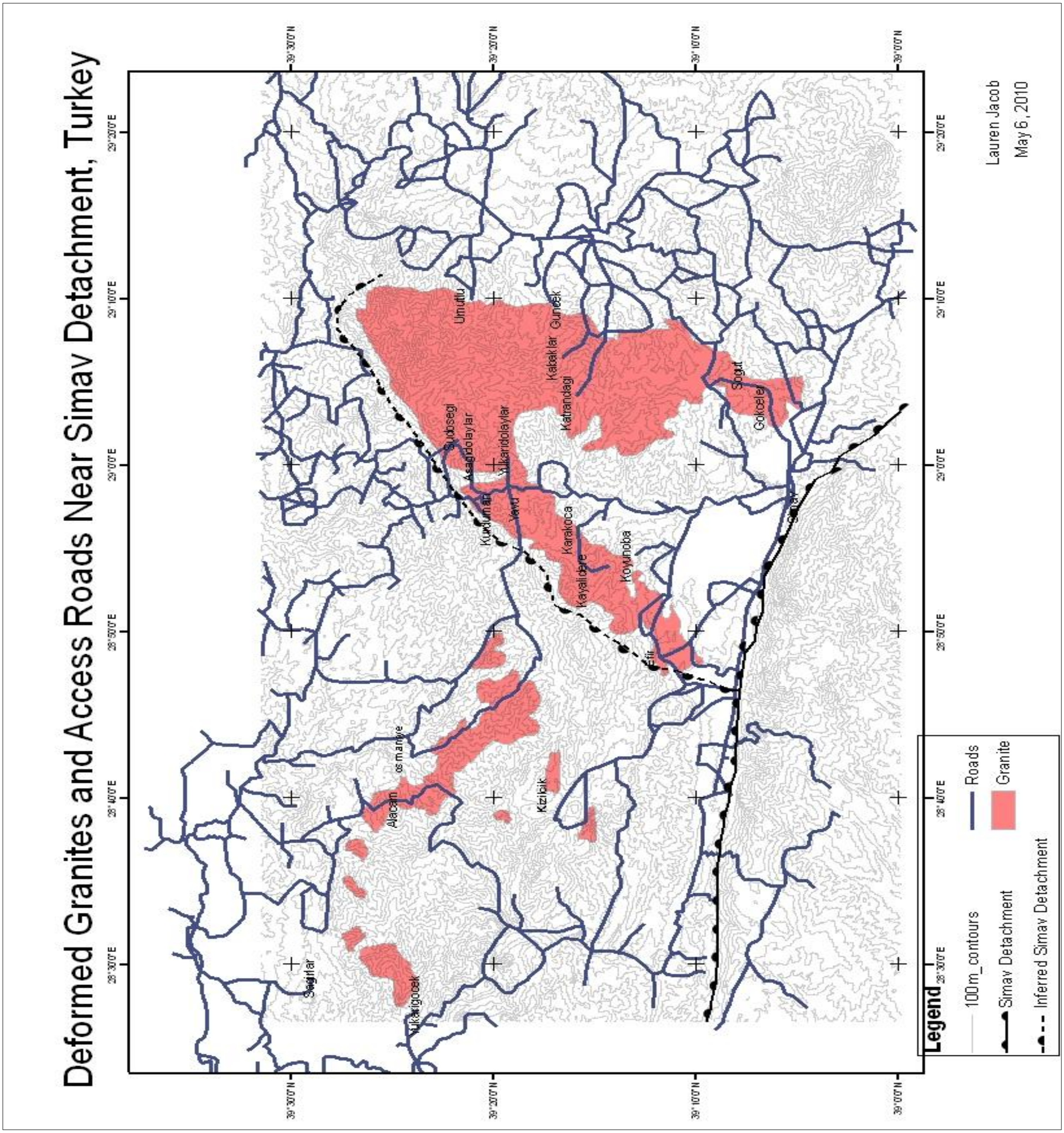


Figure 35: Final Field Map