

# Buckskin Detachment Surface Interpolation, Southern Lincoln Ranch Basin, Buckskin Mountains, Western Arizona

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## Introduction

The Lincoln Ranch basin in Buckskin Mountains in west-central Arizona contains a large detachment fault known as the Buckskin Detachment fault. This area has been thoroughly mapped by John Singleton, a professor at Colorado State, and he has developed cross sections and a geologic map detailing the geology of the area as well as the locations of the detachment fault. In his cross sections, Dr. Singleton has shown the detachment fault surface in some areas as well as how it would possibly project as a surface.

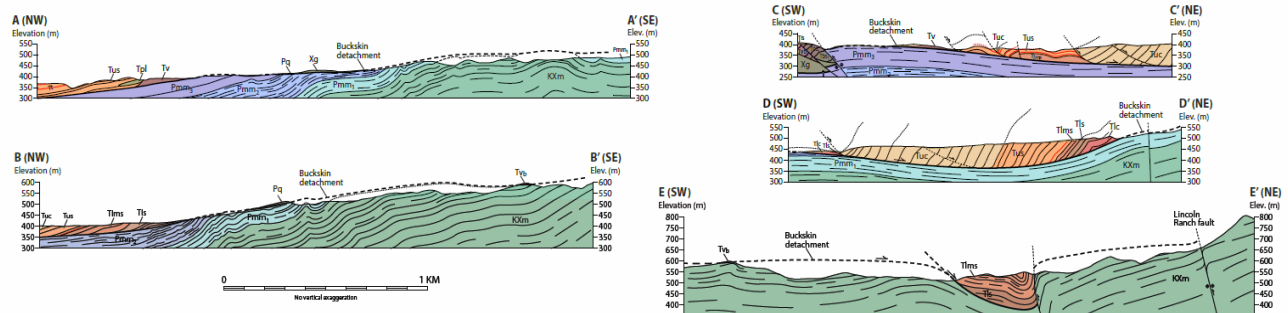


Figure 1. Cross sections displaying the Buckskin Detachment fault as it was mapped in the Lincoln Ranch basin in Western Arizona (Singleton et al. 2014)

These cross sections are an example of the problem that this project is going to try and address. The detachment fault surface is shown projected at the surface in the cross sections where the cross section crosses the detachment fault in the geologic map. The Buckskin detachment fault crops out in many places throughout the geologic map of the Lincoln Ranch basin and therefore an attempt can be made to map this detachment fault surface utilizing GIS method. Using Dr. Singleton's geologic map as a base and elevation data, downloaded from the National Map Viewer, a detachment fault surface will attempt to be created in order to understand the trend of the detachment surface over the basin area.

## Data Files

Geologic Map of the Southern Lincoln Ranch basin, Buckskin Mountains, west-central Arizona

- Obtained in email traffic with Dr. John Singleton, Colorado State University
- Can also be obtained from the Arizona Geological Survey Document Repository
  - [http://repository.azgs.az.gov/uri\\_gin/azgs/dlio/1592](http://repository.azgs.az.gov/uri_gin/azgs/dlio/1592)
- File Name: Singleton\_et.al\_2014\_Geologic\_map\_Lincoln Ranch\_basin\_AZGS.pdf
  - File Renamed in ArcCatalog: Singleton\_Map
- Projection from Geologic Map File – NAD 1983
- Map Scale: 1:10,000

Digital Elevation model – USGS NED n35w114 1/3 arc-second 2013 1 x 1 degree ArcGrid

- Obtained from the USGS National Map Viewer
  - <http://viewer.nationalmap.gov/basic/#productSearch>
- File name: n35w114.zip
  - Unzipped DEM raster file name: grdn35w114\_13
    - DEM File Renamed in ArcCatalog: 10m\_DEM
  - Published Date 2013-01-01
- Spatial Reference
  - Coordinate System – GCS\_North\_American\_1983
  - Datum – D\_North\_American\_1983

Elevation Points

- No point shapefile detailing detachment fault on geologic map readily available for download
- Created point shapefile separately in ArcGIS and handpicked points along Dr. Singleton's mapped detachment fault in his geologic map
- Geographic Coordinate System – GCS\_North\_American\_1983
- Datum – D\_North\_American\_1983

## **Methodology**

The first thing that needed to be done was the geologic map file needed to be georeferenced in order to allow for it to be displayed in ArcGIS located in its proper geographic location within the DEM file. This was carried out by taking the Singleton\_Map.pdf file and opening it in Adobe Illustrator. Once in Illustrator the file was cropped to show only the geologic map portion of the file:

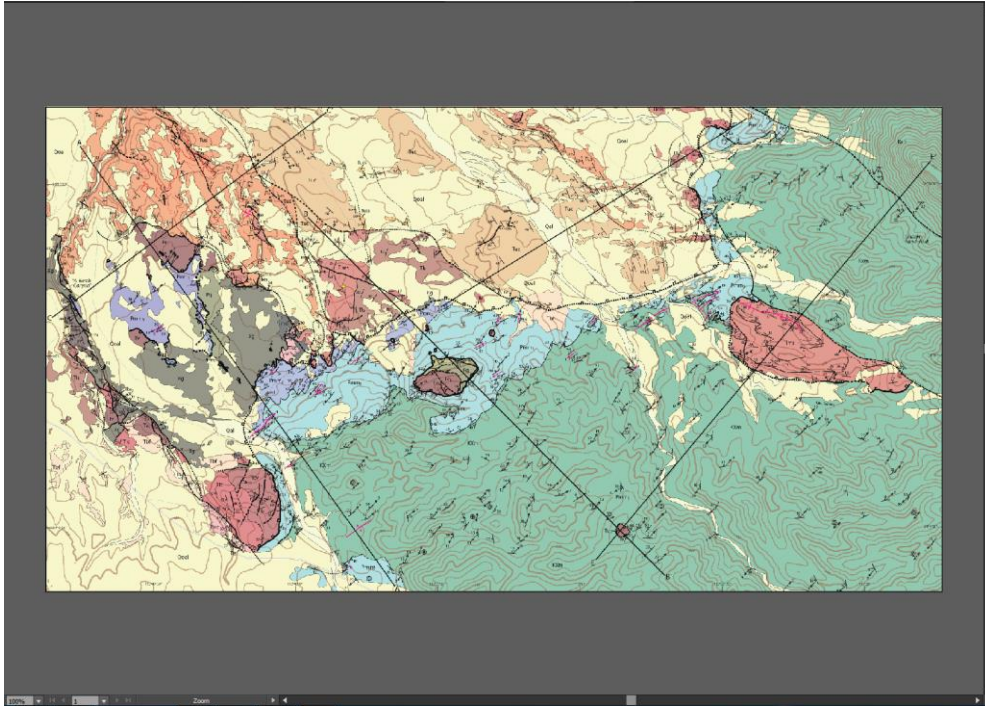


Figure 2: Cropped Adobe Illustrator screenshot showing the geologic map file cropped.

Following the cropping of the file it was then important to create anchor points within the file that would be used for georeferencing the map. The map contains tick marks along the bottom and sides representing longitude and latitude coordinates. Guidelines were used in Illustrator in order to properly place red boxes representing georeferencing points that would be used as anchor points in ArcGIS:

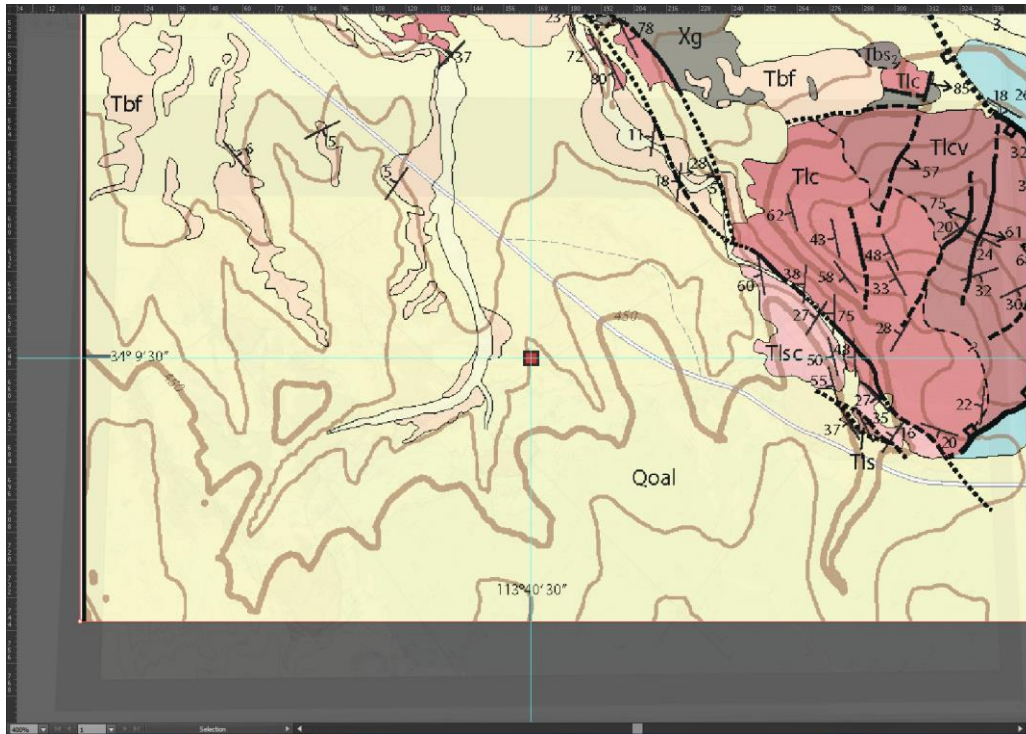


Figure 3: Zoomed in screenshot displaying how guidelines in Adobe Illustrator were used in order to place georeferencing anchor points in the form of red boxes on the geologic map.

This process was carried out throughout the map in order to create 12 anchor points of latitude and longitude for georeferencing the map for placement on the DEM. Utilizing 12 anchor points allows for higher precision georeferencing than if only 6 or a lesser number were used for this process.

With the anchor points placed on the geologic map it is time to bring the map into ArcGIS and georeferenced it. Once the geologic map and the DEM are brought into ArcGIS it is obvious that the two files will not display together, due to the map not being georeferenced. Zooming to the map layer, the georeferencing points are manually put in to orient the map properly:

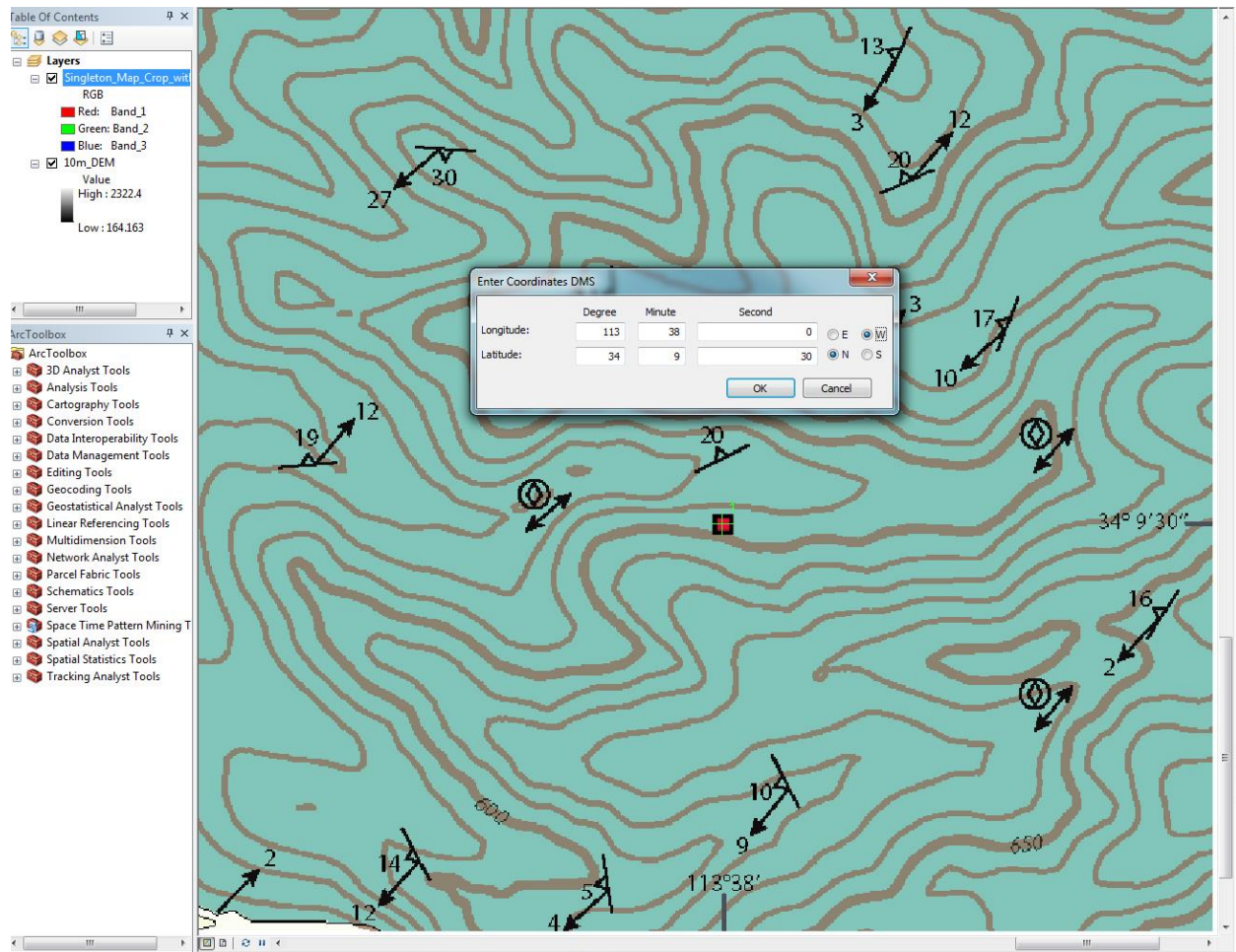


Figure 4: Zoomed in ArcGIS screenshot displaying a georeferencing anchor point, the red box that was placed in Adobe Illustrator, and the process of manually entering the coordinates of the georeferencing link.

The above step was carried out for all 12 anchor points in order for the geologic map to be properly georeferenced with the DEM which then allowed for the geologic map to be displayed with the DEM as seen below:

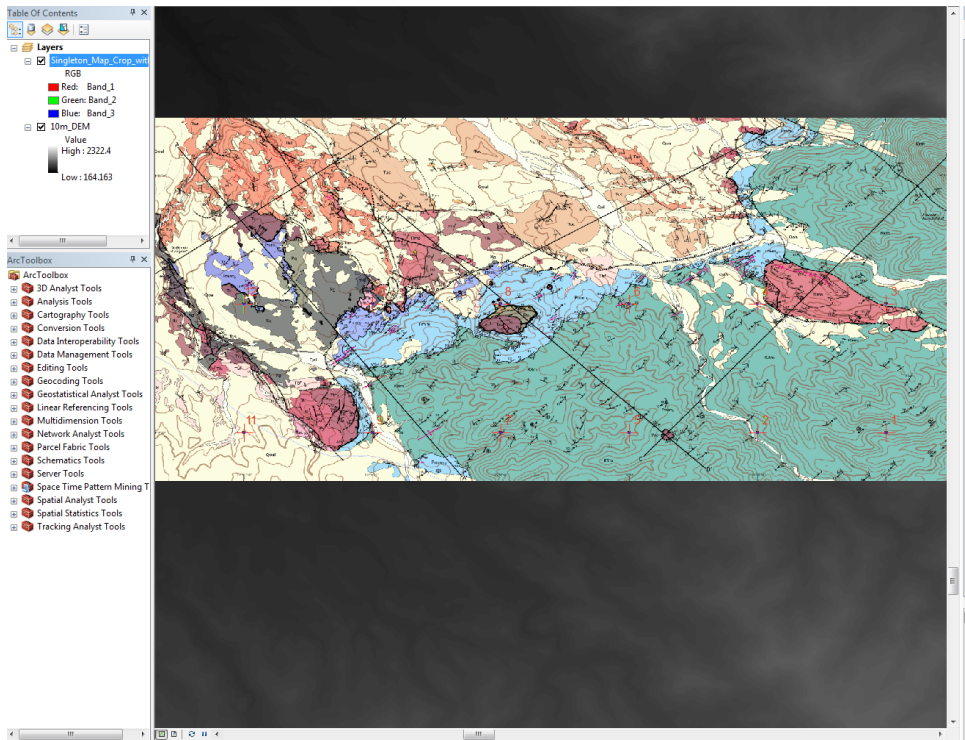


Figure 5: Georeferenced geologic map file on top of the DEM showing the 12 anchor points.

Link								
Total RMS Error: Forward: 1.03699e-005								
	Link	X Source	Y Source	X Map	Y Map	Residual_x	Residual_y	Residual
<input checked="" type="checkbox"/>	1	5225.705001	-2674.330355	-113.633333	34.158333	8.17245e-006	-1.50299e-006	8.30951e-006
<input checked="" type="checkbox"/>	2	4318.094299	-2674.153260	-113.641667	34.158333	6.821e-006	-2.79511e-006	7.37148e-006
<input checked="" type="checkbox"/>	3	5227.934815	-1581.118389	-113.633333	34.166667	-9.88285e-006	1.05315e-005	1.44424e-005
<input checked="" type="checkbox"/>	4	4318.350659	-1579.636007	-113.641667	34.166667	6.88515e-006	-6.96051e-007	6.92024e-006
<input checked="" type="checkbox"/>	5	3411.742046	-2674.756028	-113.650000	34.158333	-6.08489e-006	1.84886e-006	6.35957e-006
<input checked="" type="checkbox"/>	6	3412.345638	-1578.879799	-113.650000	34.166667	-9.20538e-006	-6.39634e-006	1.12095e-005
<input checked="" type="checkbox"/>	7	2502.688718	-2675.264175	-113.658333	34.158333	5.80564e-006	5.77275e-006	8.18719e-006
<input checked="" type="checkbox"/>	8	2503.271547	-1578.416204	-113.658333	34.166667	2.8779e-006	-9.86915e-006	1.02802e-005
<input checked="" type="checkbox"/>	9	1596.935844	-2673.202340	-113.666667	34.158333	-1.25967e-005	-9.86573e-006	1.60003e-005
<input checked="" type="checkbox"/>	10	1596.379460	-1579.775816	-113.666667	34.166667	-5.07391e-006	5.35785e-007	5.10212e-006
<input checked="" type="checkbox"/>	11	688.037238	-2675.343148	-113.675000	34.158333	-2.13019e-006	6.48563e-006	6.8265e-006
<input checked="" type="checkbox"/>	12	686.498733	-1580.479858	-113.675000	34.166667	1.44118e-005	5.95084e-006	1.55921e-005

Figure 6: Link table showing the 12 georeferencing points used to accurately place the geologic map on the DEM and their residual distances which can be seen as all being very minimal.

A hillshade of the DEM was created in order to visually check the georeferencing with known locations on the geologic map (A-Bomb Canyon, the field site for my thesis research) as a measure of double checking the previous georeferencing work. This was done by setting the map layer on top of the created 10m\_hillsh raster file and setting the transparency of the map file to 50% in order to see the underlying hillshade raster through the map layer.

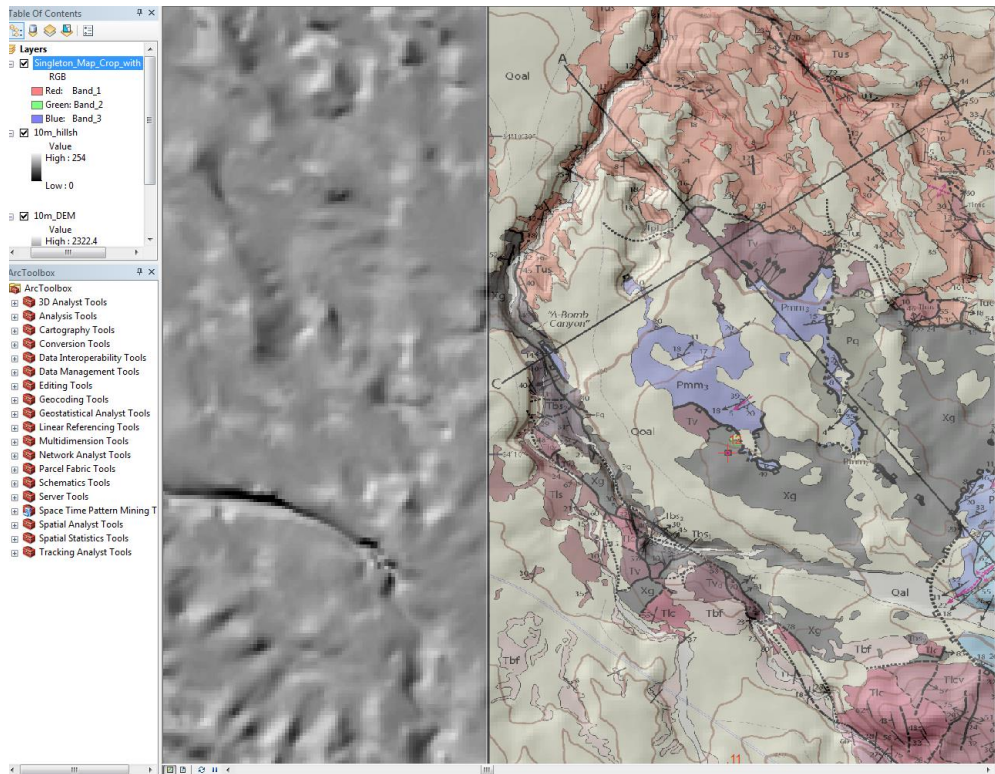


Figure 7: ArcGIS screenshot showing how A-Bomb Canyon was used along with a hillshade of the 10m\_DEM file to double check the georeferencing of the geologic map.

Once the geologic map is properly georeferenced and placed on the DEM it is time to start creating the elevation point file that will be used in order to create the Buckskin detachment fault surface later. To do this, a point shapefile, named Elevation\_Points, was created and then through use of the editing toolbar, points were placed along the geologic map in accordance with the mapped Buckskin detachment fault. Points were placed closely together, ultimately outlining all the areas of the detachment fault mapped by Dr. Singleton within the geologic map.

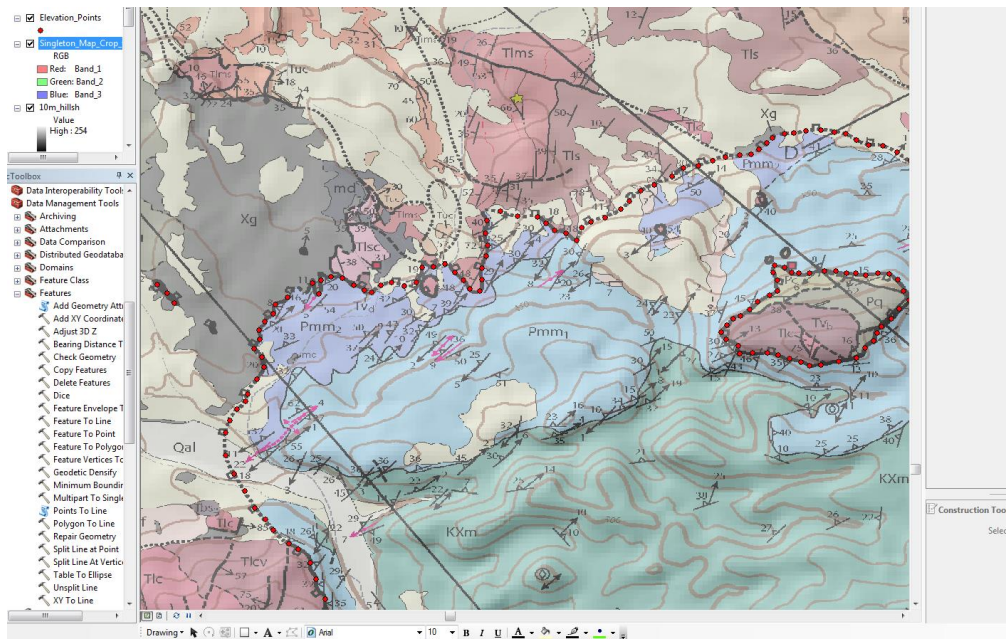


Figure 8: Screenshot displaying how the 405 elevation points were digitized along the mapped detachment fault in accordance to where the fault was mapped on the geologic map.

The digitized Elevation\_Points file only contains 3 columns with the following headers: FID, Shape\*, Id. None of these columns contains any of the elevation data necessary to create a surface from so the elevation data must be extracted from the DEM raster file at each points location and brought into a new column in the Elevation\_Points file in order for the digitized points to contain the necessary elevation data. This is done using the “Extract Values to Points” tool found in the Spatial Analyst toolbox under the subset of tools titled “Extraction.”

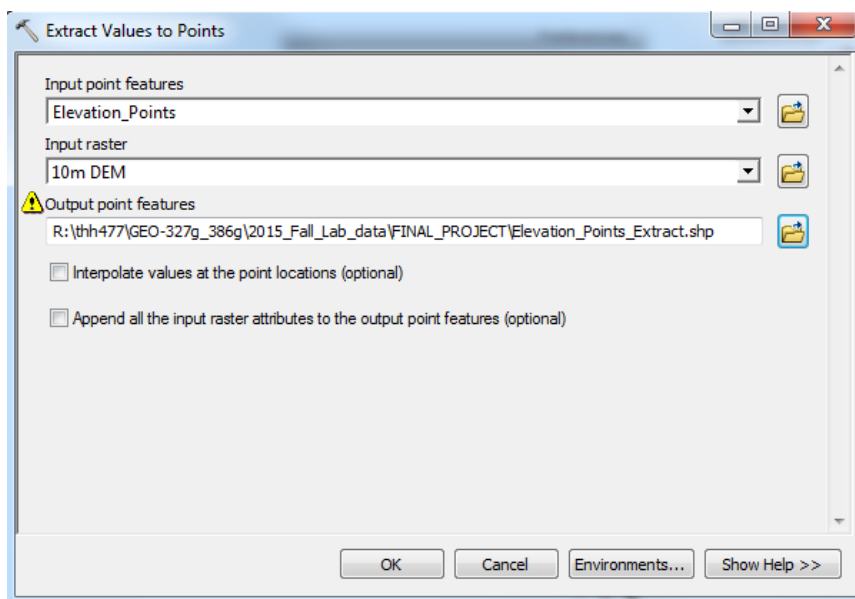


Figure 9: Extract Values to Points tool screenshot showing the DEM elevation values being extracted to the Elevation\_Points file



FID	Shape *	Id
0	Point	0
1	Point	0
2	Point	0
3	Point	0
4	Point	0
5	Point	0
6	Point	0
7	Point	0
8	Point	0
9	Point	0

Extract Values to Points Tool →

FID	Shape *	Id	RASTERVALU
0	Point	0	457.251587
1	Point	0	462.051453
2	Point	0	465.52536
3	Point	0	474.176544
4	Point	0	477.11322
5	Point	0	477.275269
6	Point	0	477.42804
7	Point	0	478.298218
8	Point	0	477.083557
9	Point	0	469.605377

Figure 10: Figure showing the extraction of elevation data from the DEM to the Elevation\_Points file. Left shows attribute table of Elevation\_Points file before extraction. Right shows attribute table of newly created Elevation\_Points\_Extract file which includes column with header, RASTERVALU, that contains elevation data from DEM at each digitized point.

Before beginning to create raster surfaces from the extracted elevation data, a polyline shapefile was created in order to digitize the Buckskin detachment fault for later display with the raster surfaces to be created. Using the Elevation\_Points shapefile as a base, a polyline shapefile, named Buckskin Detachment Fault, is created in ArcCatalog and then brought into ArcGIS. Utilizing the editing toolbar, the detachment fault was then digitized by snapping a polyline from point to point of the Elevation\_Points file in order to create a polyline representing the mapped detachment fault.

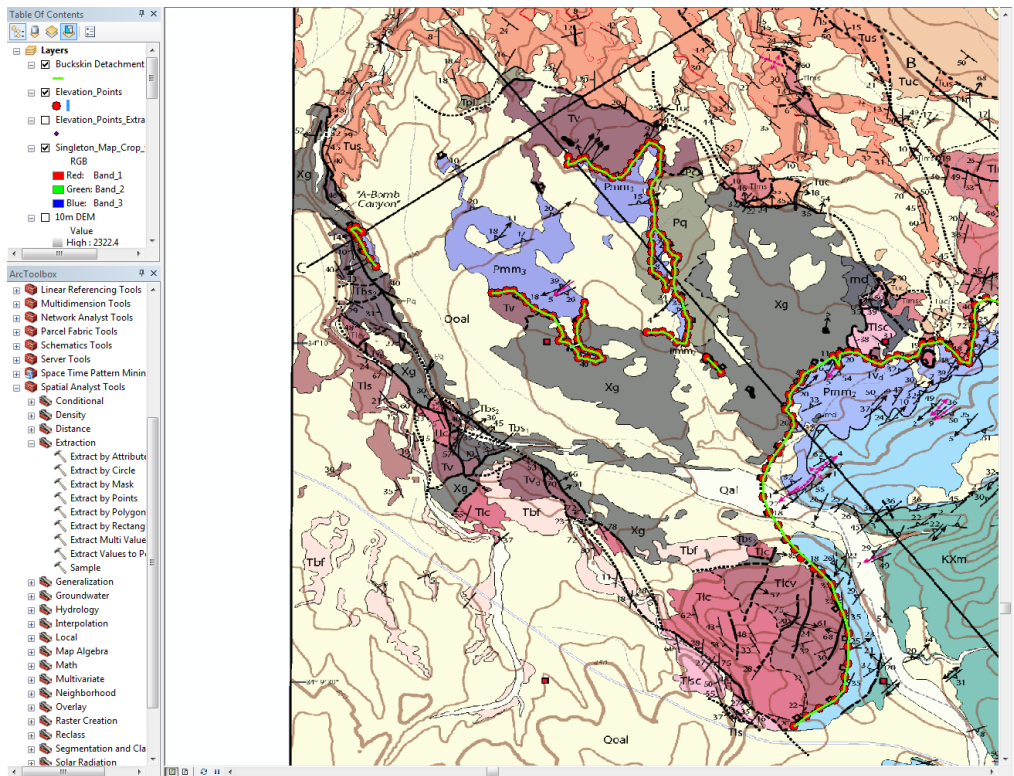


Figure 11: ArcGIS screenshot showing how the Buckskin Detachment Fault polyline shapefile was digitized from the Elevation\_Points file in order to create a polyline of the detachment fault throughout the entire map area.

Now that the digitized elevation points contain elevation data creating a surface of the detachment fault is possible by using spatial interpolation techniques available in ArcGIS. Two spatial interpolation techniques will be examined in this project in order to determine which technique provides the best fit, smoothest surface of the detachment fault.

The first method that will be examined will be the Inverse Distance Weighting (IDW) technique. IDW assumes that the influence of adjacent points decreases with distance, and this technique will be applied to the Elevation\_Points\_Extract shapefile in order to create a raster surface layer of the Buckskin detachment fault. The tool "IDW" found in the Spatial Analyst toolbox under the "Interpolation" toolset will be applied to the Elevation\_Points\_Extract in order to create a raster surface of the detachment fault in the map area.

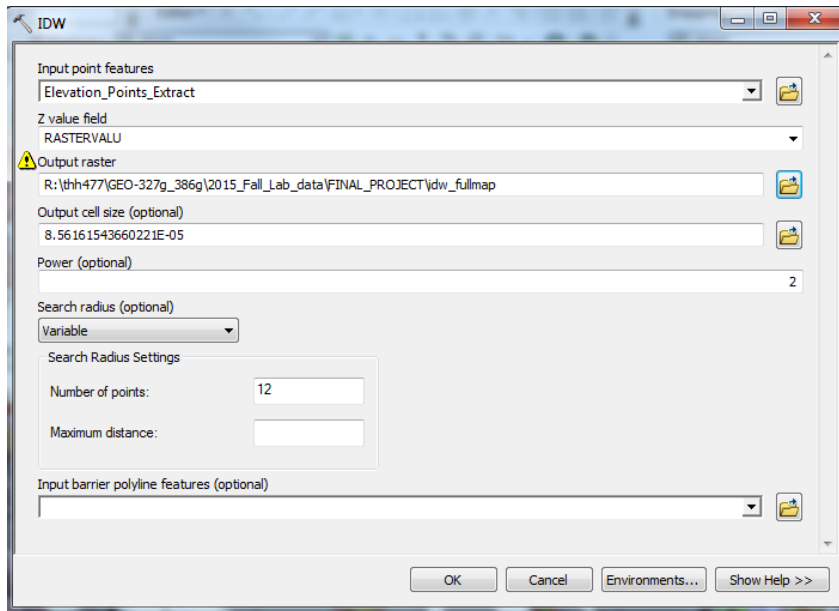


Figure 12: A ArcGIS screenshot of the IDW tool being used on the Elevation\_Points\_Extract file in order to create a raster surface of the Buckskin detachment fault.

When examining the IDW tool one thing to note is that the output cell size is an extremely odd value. This is due to the fact that the Elevation\_Points\_Extracted shapefile is in the coordinate system GCS\_North\_American\_1983 which has values in degrees. This presents a problem as it is hard to understand the cell size value in this format and will present the same problem when attempting the spline interpolation technique. To circumvent this problem, the Elevation\_Points\_Extract will be projected into a new coordinate system, NAD 1983 UTM Zone 12N. After the projection a new elevation point file is created with values in meters and named Elevation\_Points\_Extract\_UTM. Carrying out this projection will allow for the cell size in the IDW tool to be much more understandable as seen below.

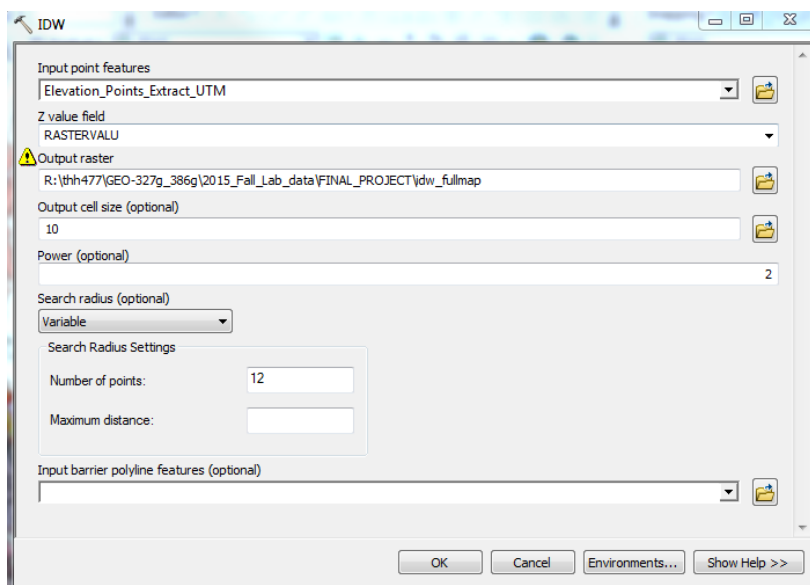


Figure 13: A ArcGIS screenshot of the IDW tool being used on the Elevation\_Points\_Extract\_UTM file in order to create a raster surface of the Buckskin detachment fault.

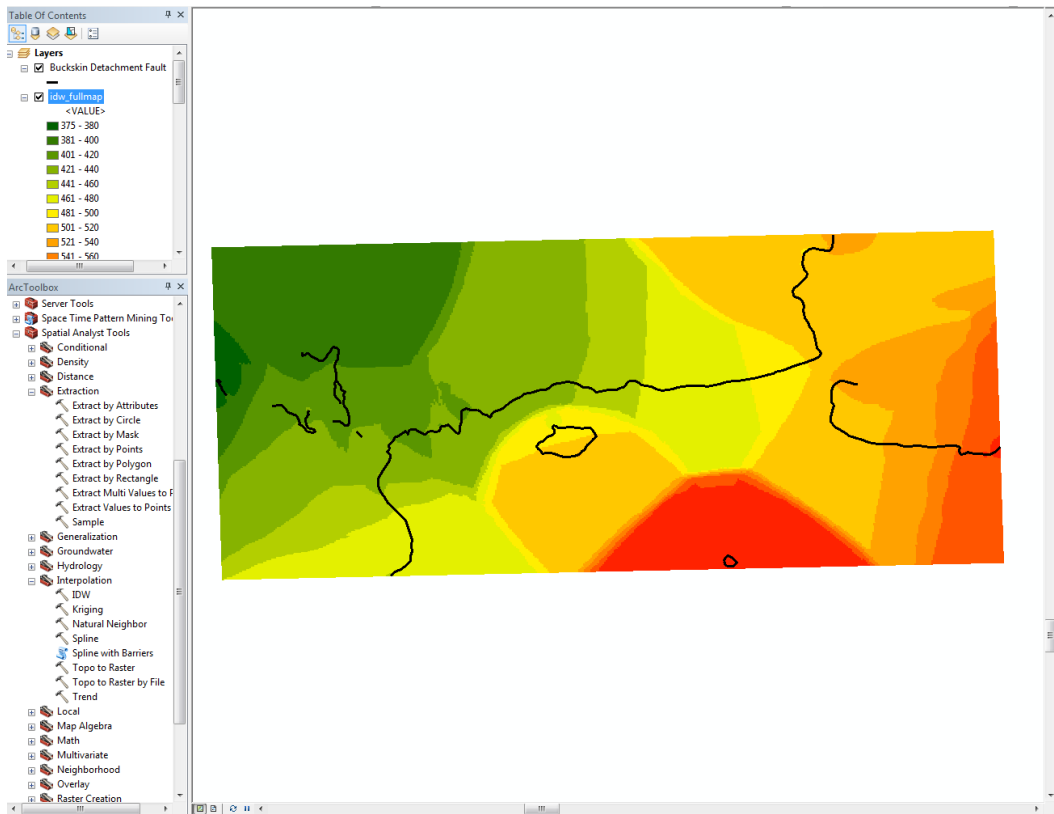


Figure 14: IDW interpolated surface of the Buckskin detachment fault from the Elevation\_Points\_Extract\_UTM file. The black line shows the detachment fault digitized earlier from the geologic map of the area.

After the IDW interpolation technique runs it produces the above raster surface of the detachment fault as interpolated from the extracted elevation data at the digitized points. The surface created appears to be fairly rough throughout the map area.

Due to the roughness of the IDW interpolated surface, the spline technique will be applied to the Elevation\_Points\_Extract\_UTM file in order to see if a smoother surface is created from this other interpolation technique. The "Spline" tool is found in the Spatial Analyst toolbox under the Interpolation subset.

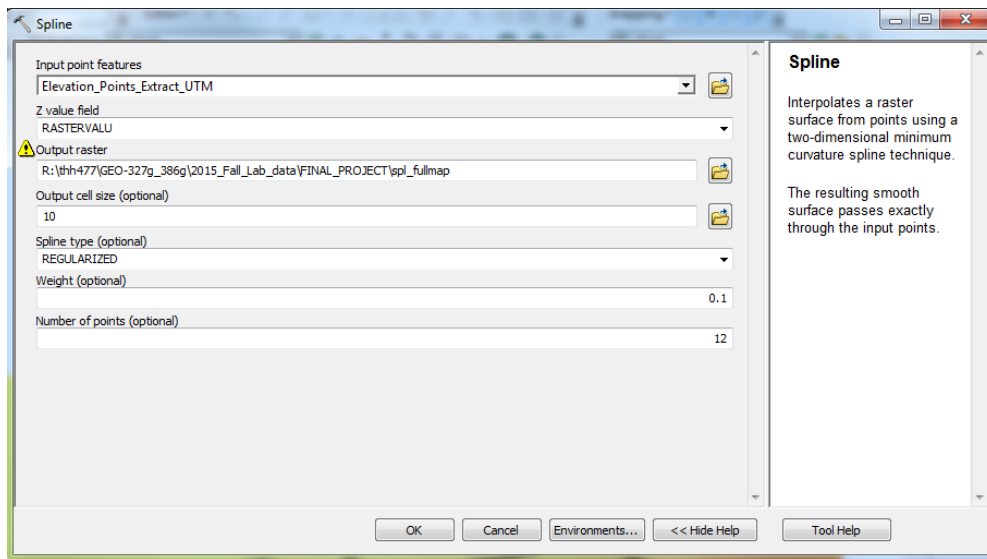


Figure 15: A ArcGIS screenshot of the Spline tool being used on the Elevation\_Points\_Extract\_UTM file in order to create a raster surface of the Buckskin detachment fault.

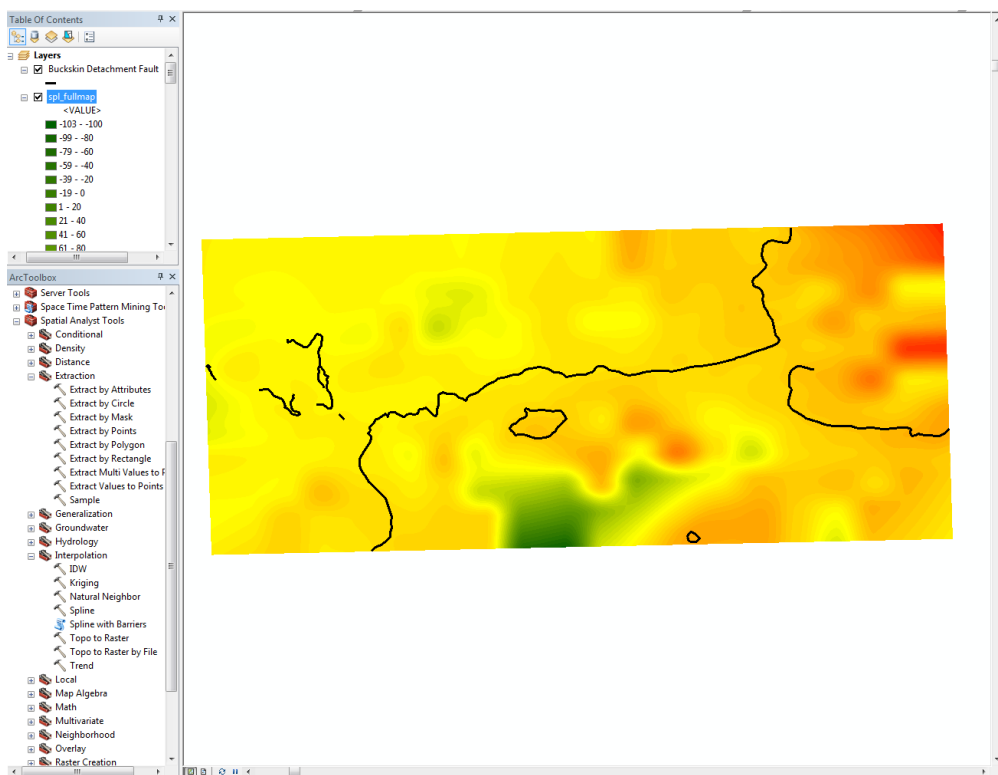


Figure 16: Spline interpolated surface of the Buckskin detachment fault from the Elevation\_Points\_Extract\_UTM file. The black line shows the detachment fault digitized earlier from the geologic map of the area.

At first glance, the spline interpolation technique certainly offers a smoother surface than the IDW interpolation technique creates. But there is a noticeable issue with the created surface: there are negative values associated with the elevations which we know cannot be as there are no negative values in the Elevation\_Points\_Extract\_UTM file:

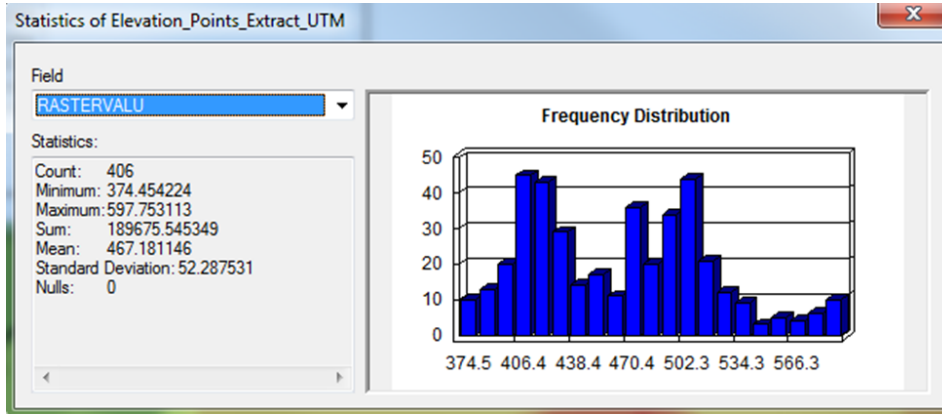


Figure 17: Attribute table statistics calculated for the column with the header RASTERVALU representing the elevation data in the point file. Note: No negative values are seen.

To adjust for the negative value issue in the spline surface, adjustment to how the tool is run must be made.

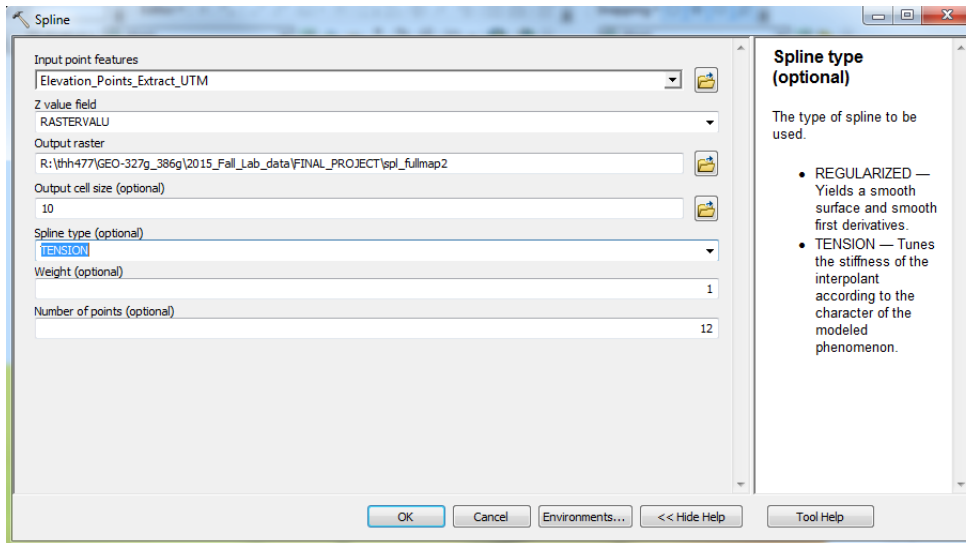


Figure 18: ArcGIS screenshot of the spline tool with changes to how the tool will be run

The changes made to the tool are as follows: the spline type is changed from “REGULARIZED” to “TENSION” and the weighting is adjusted to 1. The differences between the spline types can be seen in the screenshot of the spline tool above. The weighting factor when using the TENSION spline type defines the weight of the tension itself.

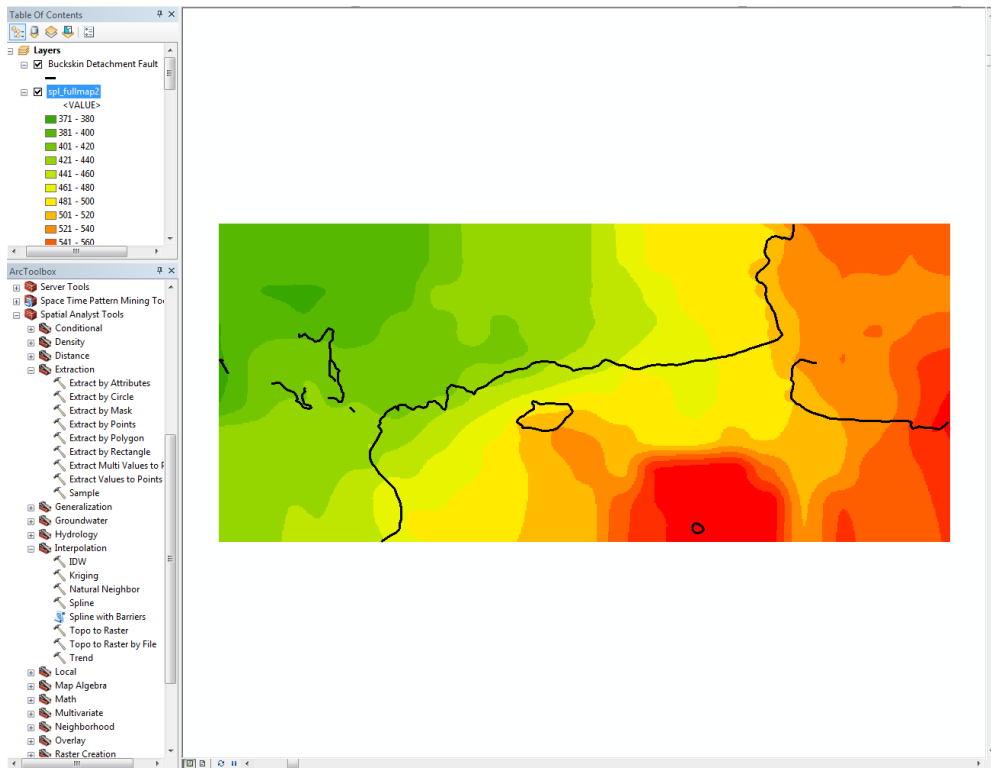


Figure 19: Spline interpolated surface with new tool changes of the Buckskin detachment fault from the Elevation\_Points\_Extract\_UTM file. The black line shows the detachment fault digitized earlier from the geologic map of the area.

## Results and Conclusions

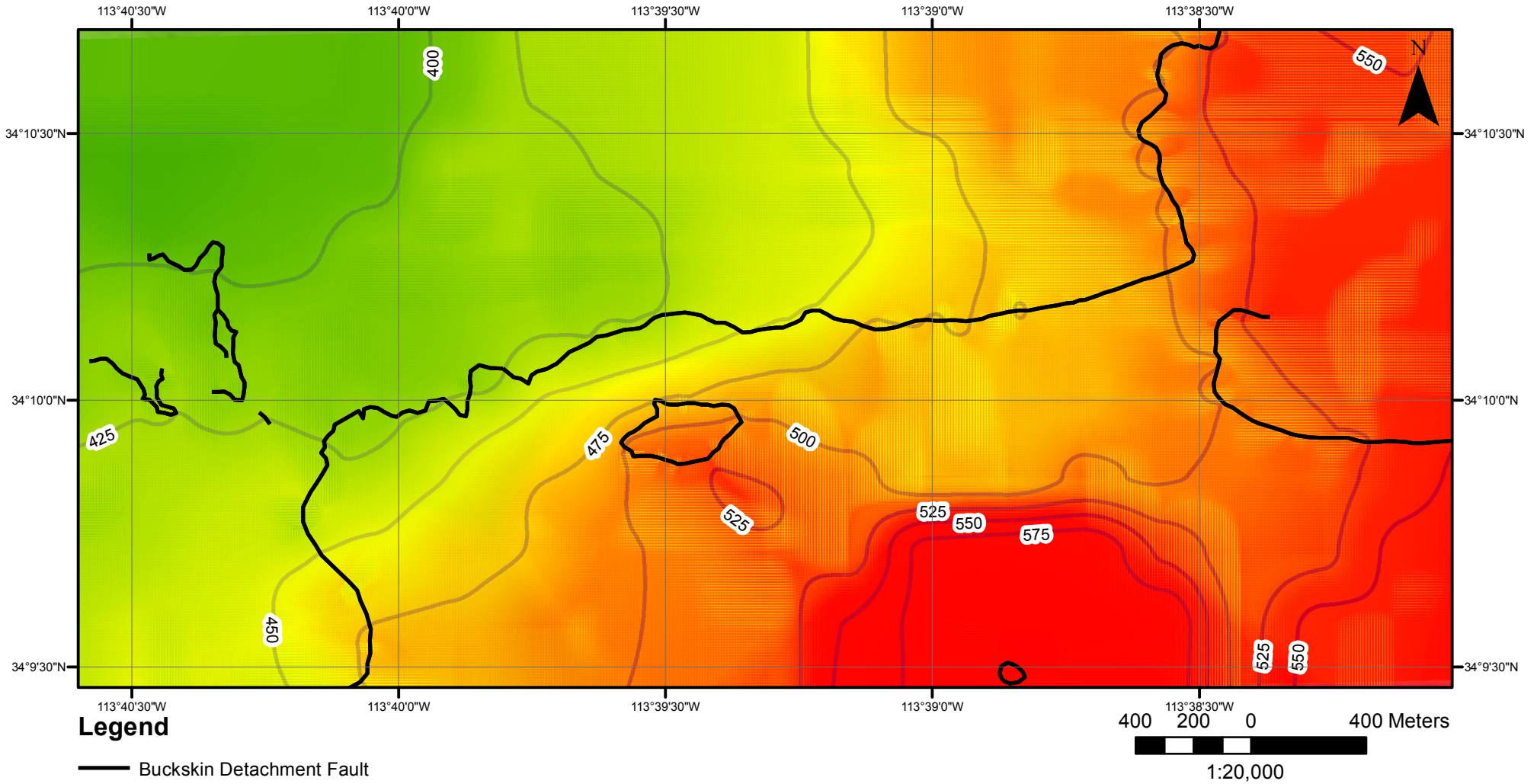
Both an IDW interpolation surface (Figure 14) and a Spline interpolation surface (Figure 19) were created from elevation data along the detachment fault extracted from a 10 meter resolution digital elevation model (DEM) in order to gain an understanding of the Buckskin detachment fault surface. When both surfaces were examined under the same symbology conditions, 12 classes with those classes each representing 20 meter elevation increments, the spline created surface was determined to be the smoother and containing a larger range of the elevation data, 370 meters to 600 meters, whereas the IDW created surface was seen as being much rougher and having a slightly smaller range in elevation data, 375 meters to 600 meters. This project concludes that the spline interpolated surface is a better representation of the Buckskin detachment fault surface found in the Southern Lincoln Ranch Basin in the Buckskin Mountains of Western Arizona. When examining the spline interpolation surface it can be determined that there is a trend of increasing elevation in the detachment fault surface as the detachment fault moves to the western portion of the study area. It is important to note that this was an interpolation technique, meaning that the elevation values that make up the created surface where there is no elevation data were determined on the basis of nearby values. With this thought in mind, determining the trend of the detachment fault surface was done by moving east to west across the areas interpolated but containing the majority of the known elevation points.

## **References**

- Singleton, J.S., Bird. E., and Hatfield, M.E., 2014, Geologic map of the southern Lincoln Ranch basin, Buckskin Mountains, west-central Arizona: Arizona Geological Survey Contributed Map, scale: 1:10,000.



# Buckskin Detachment Fault Surface Interpolation Southern Lincoln Ranch Basin Buckskin Mountains, Western Arizona



## Legend

— Buckskin Detachment Fault

— 25m Contour

## Detachment Fault Surface

### Value

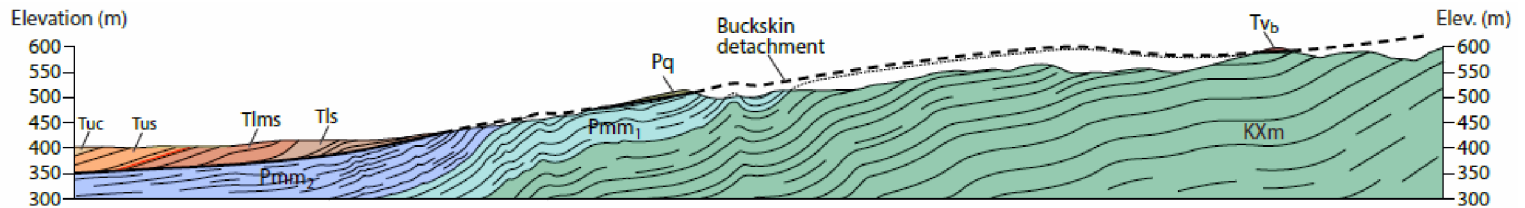
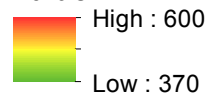


Figure A: Example cross section from Singleton et al. geologic map of the study area illustrating the geometry of the Buckskin Detachment