

# Extracting Hydrothermal Alteration Zones from ASTER Imagery: A Survey of Digital Image Analysis Techniques

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## Introduction

Remote sensing allows potential mineral resource deposits to be quickly identified on regional scales, and in a cost effective manner. Since it drastically reduces the time and financial investment required to locate and develop new mineral deposits, it is widely used by the resource exploration industry.

Hydrothermal alteration zones are associated with deposits of copper and gold. While it is not possible to directly identify these metals via remote sensing, alunite and the clay minerals associated with hydrothermal alteration are. This is because the spectral signatures of these minerals are characterized by high absorption in the SWIR region of the electromagnetic spectrum. Consequently, the ASTER SWIR subsystem was specifically designed for the identification of hydrothermal alteration minerals.

This project uses ENVI software to evaluate the strengths and weakness of imagery analysis methods that can be used to extract hydrothermally altered rocks from an ASTER image of Cuprite, Nevada. The study area was selected because it has been extensively researched by the USGS, and it has long served as a proving ground for remote sensing (Figure 1).

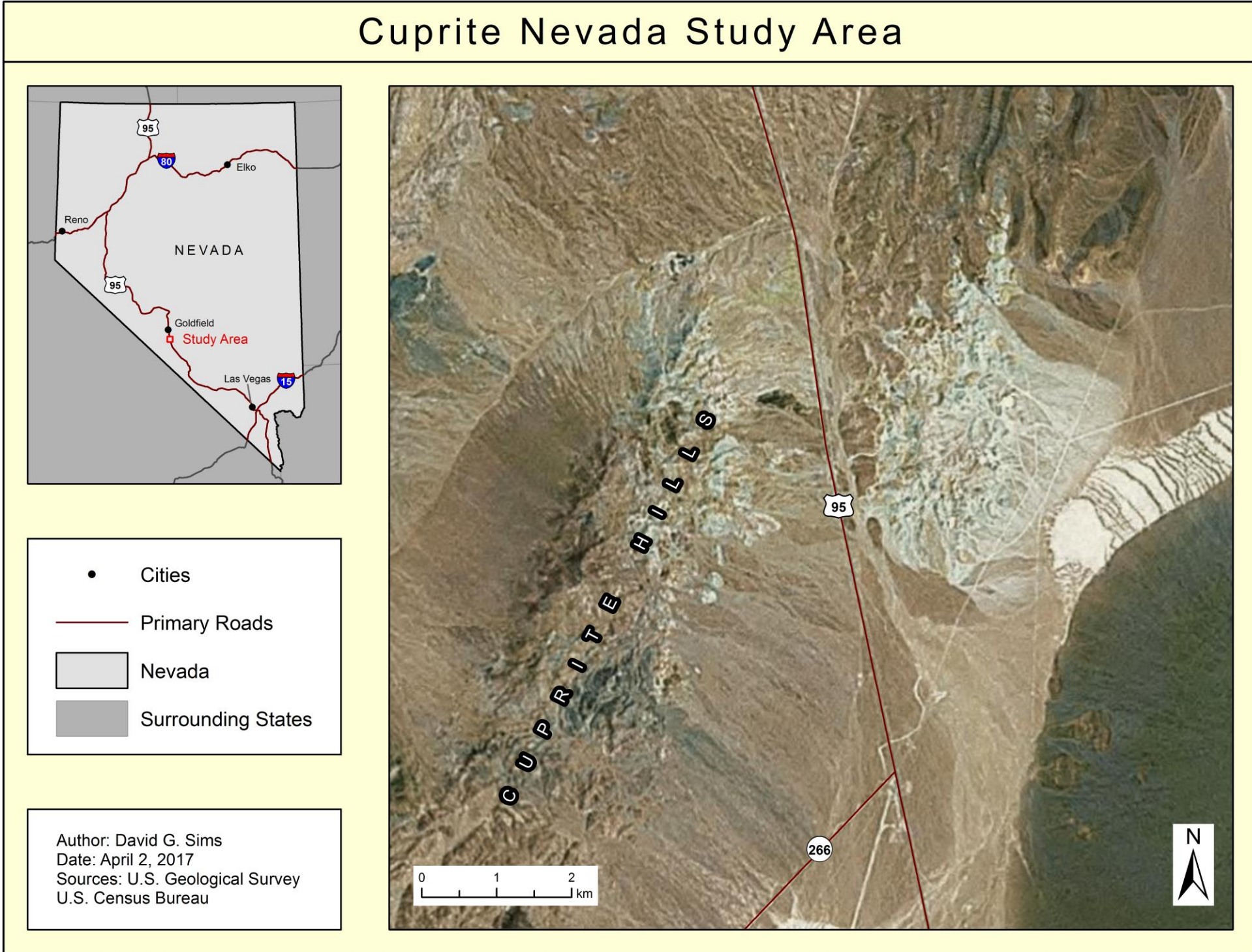


Figure 1. The Cuprite study area is located 15 km south of Goldfield, Nevada.

## Data and Data Sources

An ASTER level 1T image was used for this project. Level 1T images have been terrain corrected, and they have also had a UTM project applied to them. Additionally, a shapefile containing hydrothermal alteration zones produced from ASTER imagery using the Logical Operators algorithm was acquired. All other data acquired for this project were vector data used in the final products to provide spatial context for the map audience. These data were downloaded from the U.S. Census Bureau TIGER/Line website.

Table 1. Acquired Data

Description	File Name
ASTER Level 1T Image	AST_L1T_00305242005183814_20150509150740_106293.hdf
Shapefile containing hydrothermal alteration zones in the Southern Basin and Range Province	ofr-2013-1139.shp

## Methodology

To complete this project, it was first necessary to familiarize myself with the geology associated with hydrothermal alteration zones. Next, I had to research the digital image analysis techniques that are useful to this application. Some of the basic techniques were familiar from previously completed coursework in remote sensing, but I was not aware of many cutting edge techniques such as Linear Spectral Unmixing. These advanced methods of digital imagery analysis are only supported by ENVI software, so using these methods required me to become familiar with ENVI.

To learn ENVI, I flew to Colorado to attend a three day workshop called Introduction to ENVI Analytics. With the initial research and software training completed, nine relevant methods of imagery analysis were attempted. This began with six basic techniques which included one false color image, two compound band ratio images, and three spectral indices. Next, an attempt was made to identify endmembers using the Spectral Analyst tool in conjunction with the ASTER spectral library, but my success with endmember selection was limited. I was only able to identify six endmembers, but the work of Rowan et al. (2003) suggests that there should have been eight

endmembers. After much effort, these six endmembers were used with the Spectral Angle Mapper, Mixture Tuned Matched Filtering, and Linear Spectral Unmixing tools. The outputs from these tools were then turned into classified images using the Raster Color Slices tool. Finally, all of the imagery products created were brought into ArcMap to turn them into complete map products.

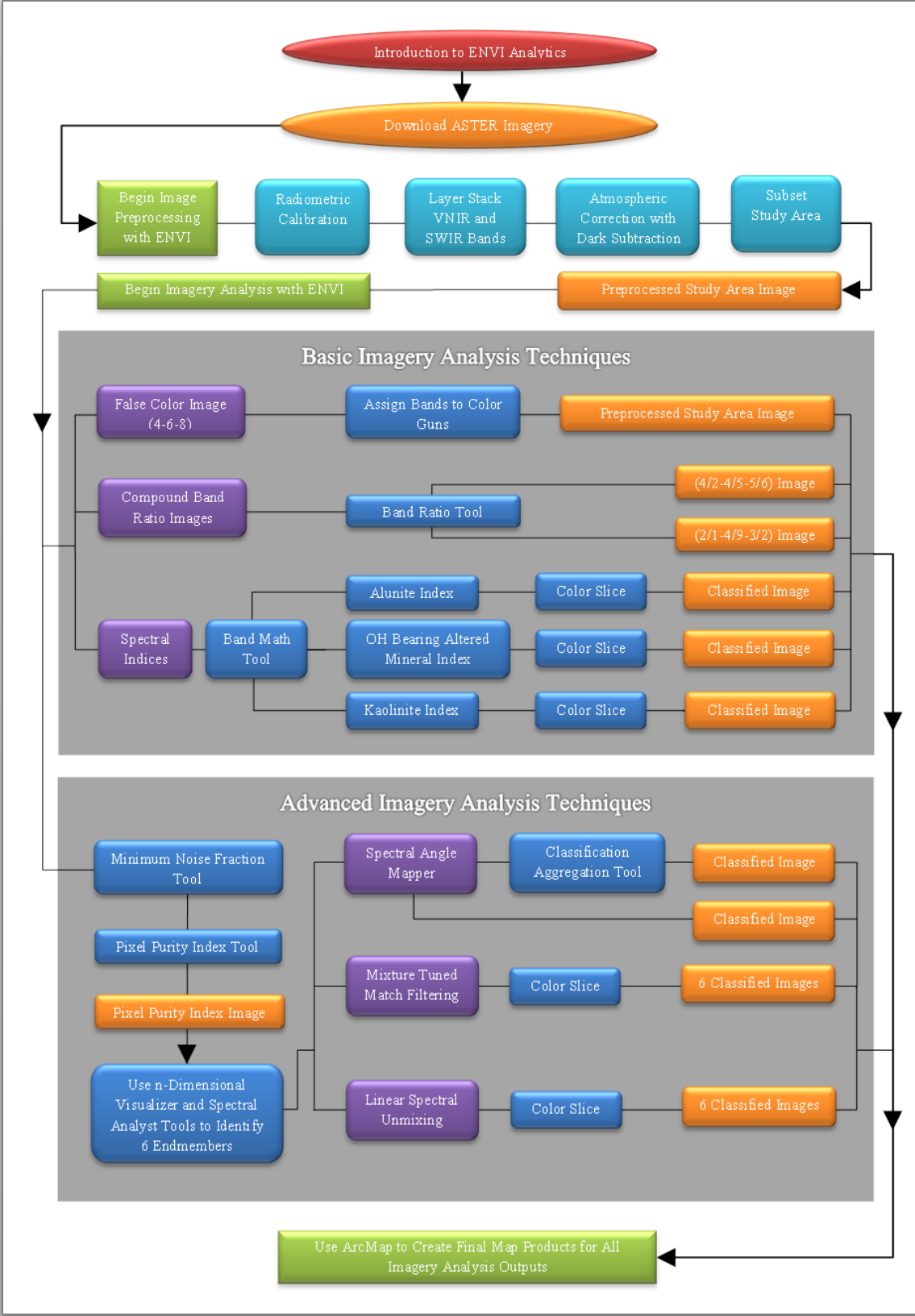


Figure 2. Methods overview flowchart

## Timeline

The project got off to a great start, because the basic imagery analysis methods went much faster than expected. Unfortunately, I did not account for the difficulty of endmember selection, so I finished the technical work four days later than anticipated.

Table 1. Project Timeline

Project Task	Estimated Completion	Actual Completion
Compound band ratio image	May 18, 2017	May 18, 2017
Three Spectral Indices	May 23, 2017	May 20, 2017
Endmember selection	Not accounted for	May 28, 2017
Spectral Angle Mapper	May 26, 2017	May 30, 2017
Mixture Tuned Matched Filtering	June 1, 2017	June 3, 2017
Linear Spectral Unmixing	June 3, 2017	June 5, 2017
Produce Final Maps	June 10, 2017	June 14, 2017

## Results

While a total of nine final map products were generated, the OH Bearing Altered Mineral Index and (4/2-4/5-5/6) compound band ratio image stands out (Figure 3).

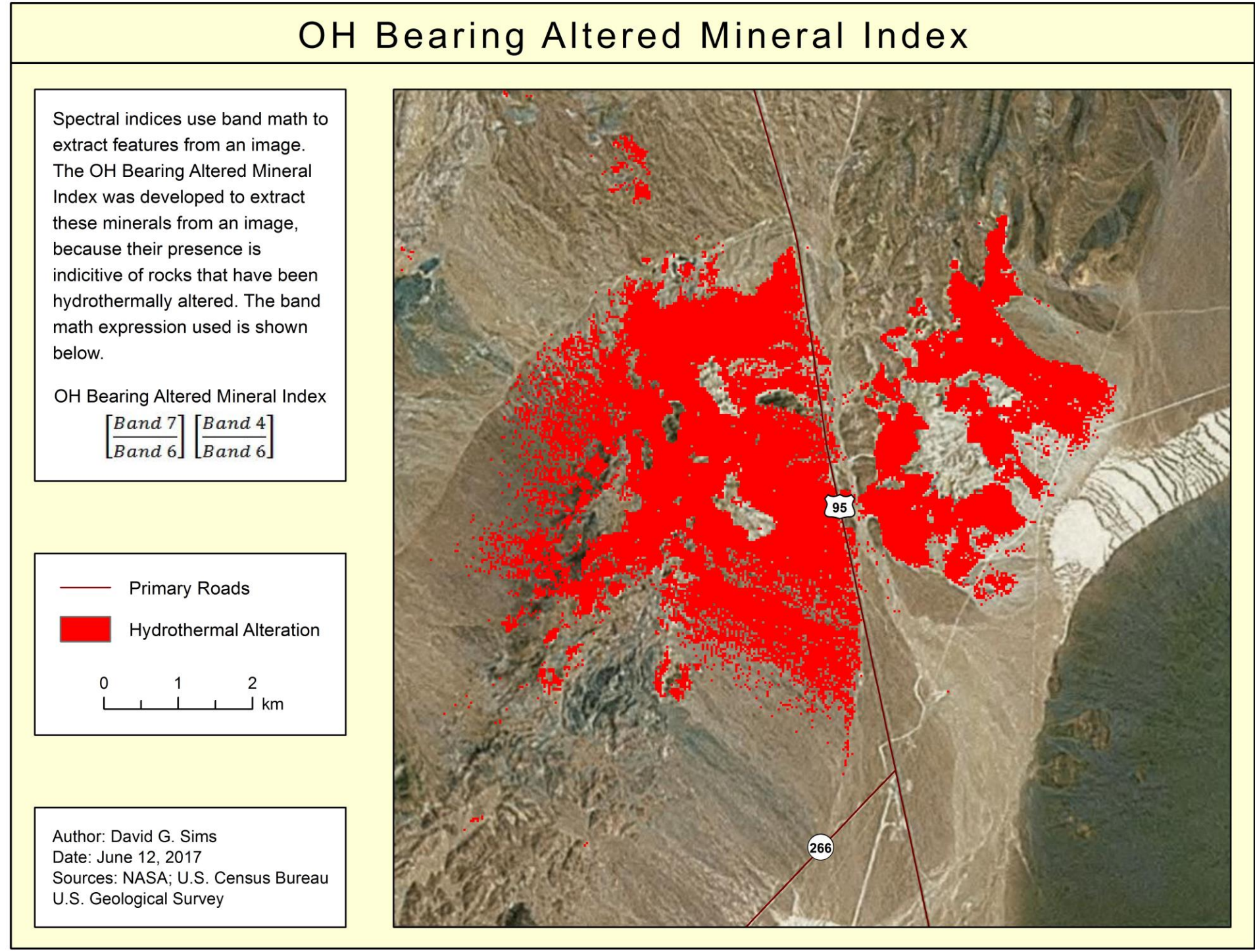


Figure 3. OH Bearing Altered Mineral Index

The classified image resulting from the OH Bearing Altered Mineral Index successfully highlights hydrothermally altered rock. Compared to Figure 4 shown below, this method highlights a significantly larger area to the west of highway 95. Most of this additional area seems to be alluvial material that has eroded from the exposed bedrock on the ridge above.

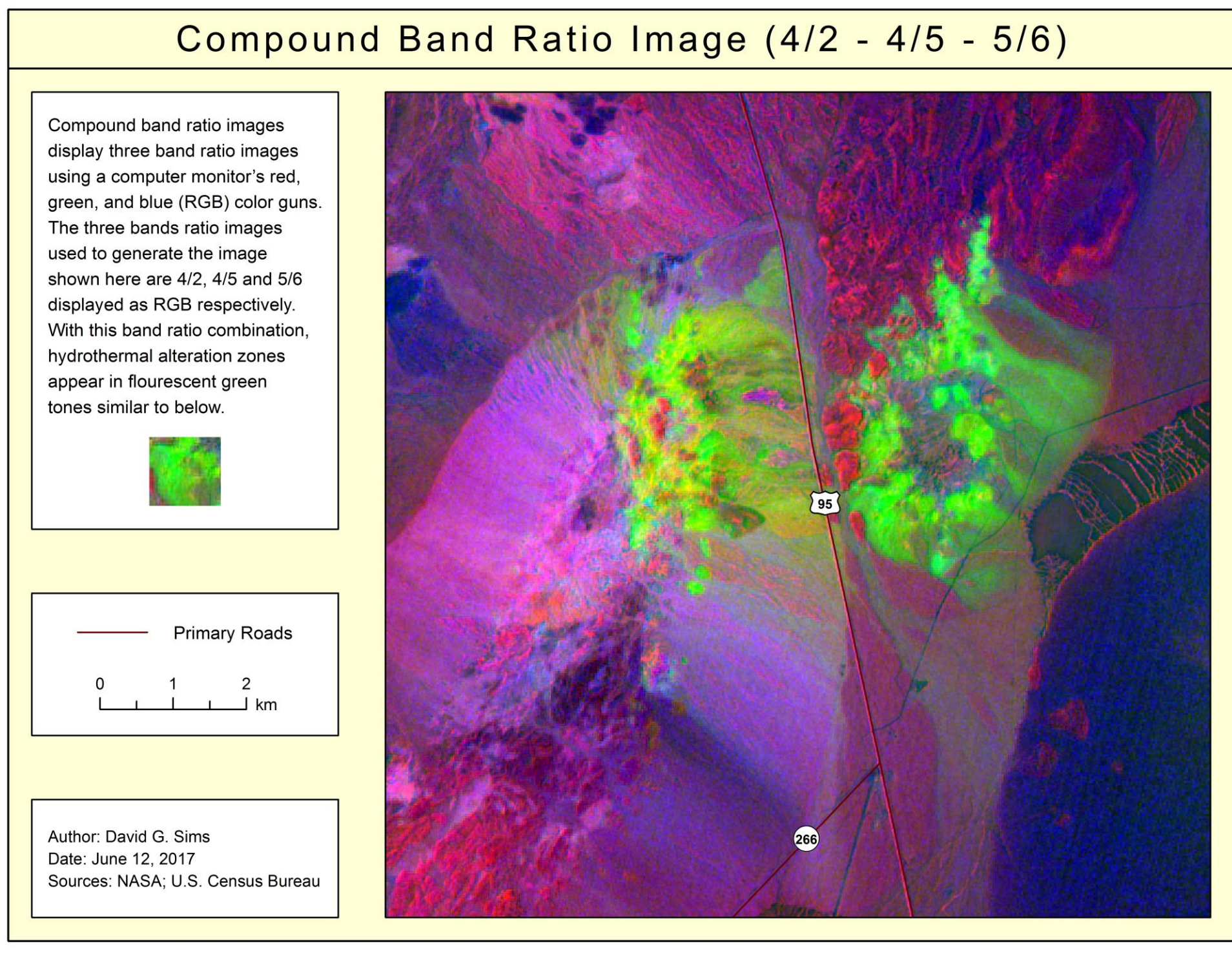


Figure 4. (4/2-4/5-5/6) compound band ratio image

Figure 4 is a compound band ratio image. The three band ratio images used are bands 4/2, 4/5, and 5/6, and they are displayed using a computer monitor's red, green, and blue color guns respectively. The resulting image highlights hydrothermally altered rocks in fluorescent green. In contrast to Figure 3, highlighted alluvial material is mostly confined to the east of the highway, where it almost looks as though it is flowing toward the playa.

## Discussion

In my opinion, the best results were obtained with the (4/2-4/5-5/6) compound band ratio image. This is for three reasons. First, it primarily highlights bedrock, and this can identify where the zone of alteration outcrops. Next, this technique is not subject to the biases of the imagery analyst, because it does not require the analyst to select a class break. Finally, it is easier to implement than most other techniques. The OH Bearing Mineral Index does have one advantage, and this is the ease of interpreting the results. Unlike the compound band ratio image, the area of alteration is distinctly defined, because there is no gradation of color around the periphery. Both of these methods produced products that agree favorably with the USGS shapefile shown in Figure 5, and this is testament to their efficacy and validity.

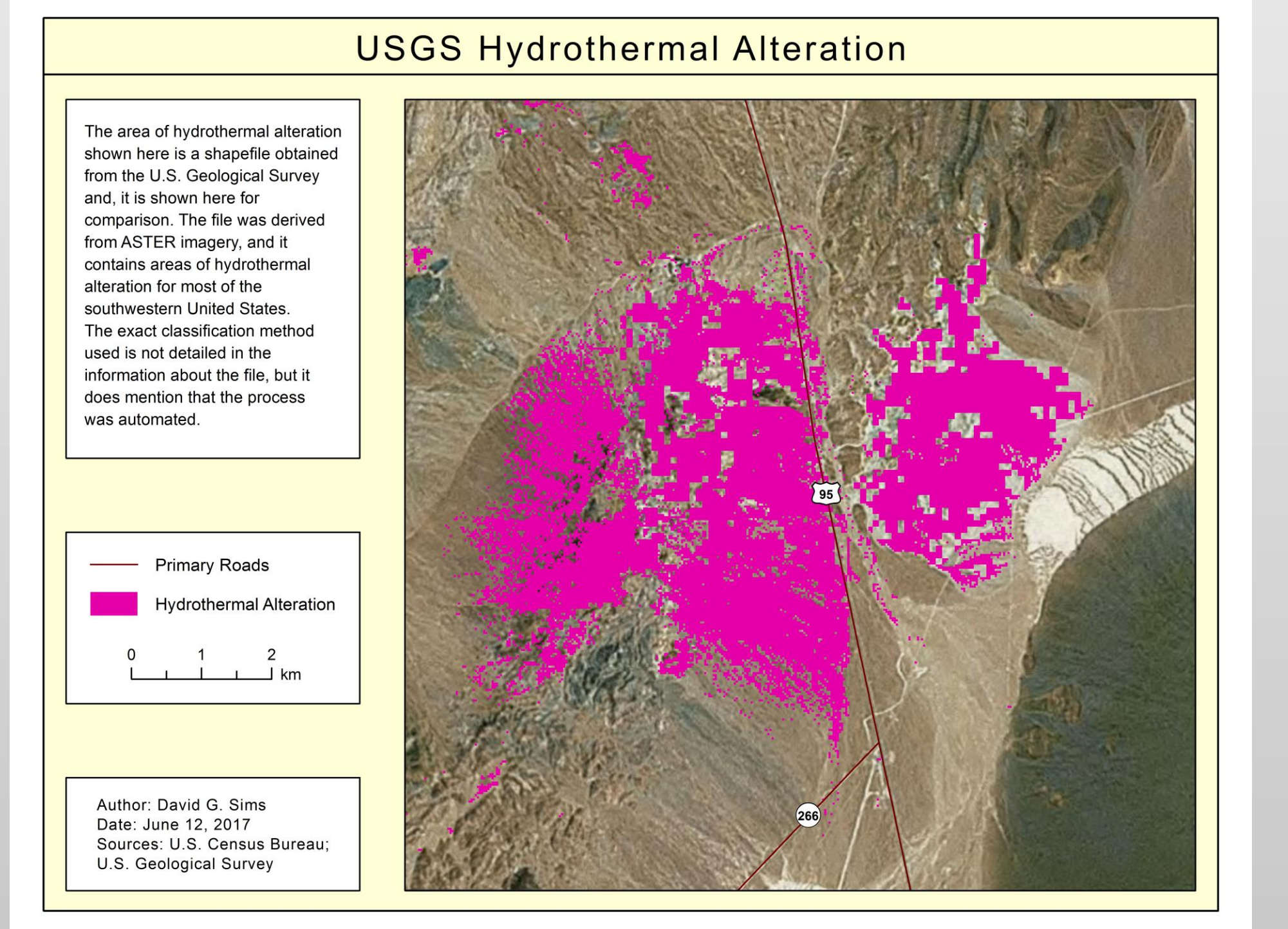


Figure 5. Hydrothermal alteration extracted from ASTER imagery using Logical Operators

## Conclusion

Despite my failure to overcome the obstacle of endmember selection, I feel this project was a major success. Before it began, I had never even heard of hydrothermal alteration or ASTER. Similarly, I was not aware of any sub-pixel imagery analysis methods, and I had no experience with ENVI. This project has given me a basic understanding of the geology behind hydrothermal alteration, and I have become familiar with ASTER imagery. Maybe most important of all, I can confidently add ENVI to my resume. With the fundamental knowledge and skills acquired, I am now prepared to attend the Advanced ENVI Analytics workshop. Hopefully, this professional instruction will help me learn how to select endmembers for use with advanced imagery analysis techniques. Also, I hope complete additional coursework in geology, so I can gain a more detailed understanding of hydrothermal alteration. This additional training will make it possible to revisit the advanced analysis methods, and apply what I have learned to analysis of hyperspectral sensor data. In closing, remote sensing for mineral resource exploration is a vast, complex, and interesting topic, and I look forward to the challenges that future research will provide.

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