

Remote Sensing Hydrothermal Alteration Zones in the Marysvale Volcanic Field, Tushar Mountains, UT; an Intercomparison of Landsat 8 and ASTER Imagery.



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Abstract

Understanding available resources is crucial for enhancing energy security, environmental sustainability, and economic growth. Traditional geologic mapping is characterized by time-intensive and high-cost fieldwork, but through multispectral and hyperspectral remotely sensed imagery it is possible to instantly map extensive areas using unique properties of minerals in the reflected spectral signature of the electromagnetic spectrum. This study explores an intercomparison of mineral mapping using Landsat 8, and ASTER in the Marysvale Volcanic Field, Utah. The satellites were chosen due to their varying number of spectral channels, spectral ranges, and spatial resolutions, allowing for a cross-analysis of their strengths, weaknesses, and overall capabilities. All analysis was conducted through open-source applications to promote accessibility in future research and reproducibility. Developing accurate and accessible mineral mapping tools may be the next step in strengthening our knowledge of resource availability, without the need for rigorous traditional mapping methods.

Background

The Marysvale volcanic field in Utah is one of the largest volcanic fields in the western United States, known for its uranium and alunite deposits. The igneous rocks found here were intruded ~32-20 million years ago, due to the subduction of the Farallon plate. The area continues to have episodic volcanism due to the extension of the Basin and Range.

Characteristic Minerals for Varying Types of Alteration

Propylitic alteration: chlorite, epidote, and sericite.
Phyllic alteration: muscovite, kaolinite, and sericite.
Argillic alteration: kaolinite, halloysite, and dickite.
Silicic alteration: quartz, silica, and chalcedony.
Advanced argillic alteration: pyrophyllite, diaspore, and kaolinite.
Potassic alteration: K-feldspar and biotite.
Sodic alteration: albite and nepheline.

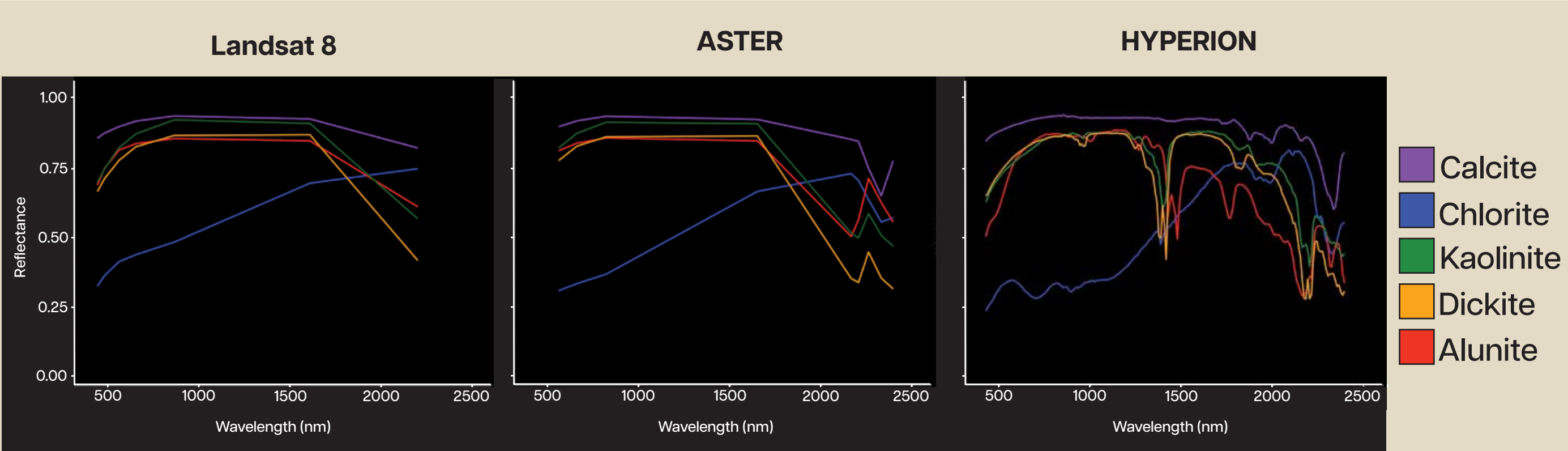
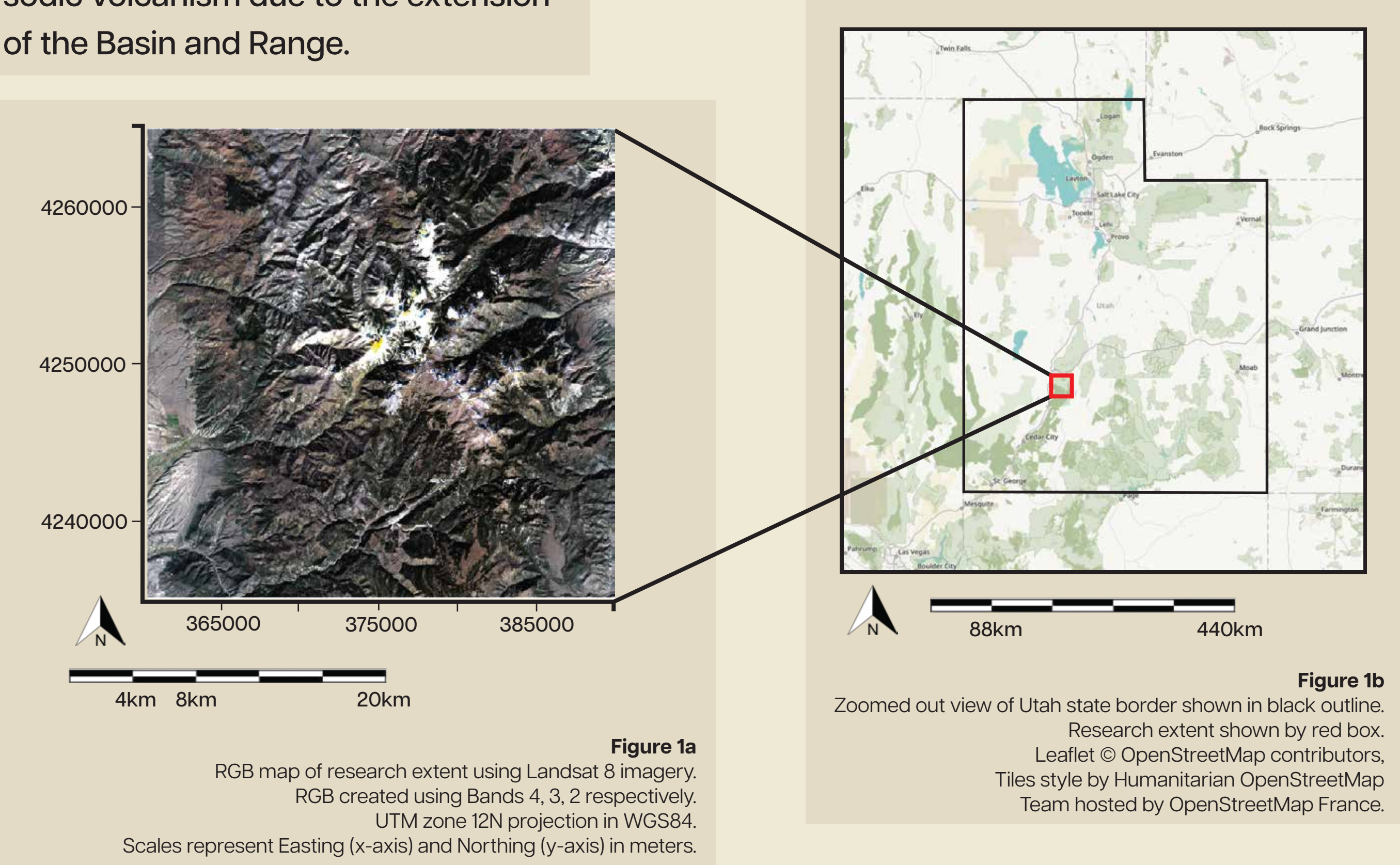


Figure 2
Spectral signatures for Calcite (purple), Chlorite (blue), Kaolinite (green), Dickite (orange), and Alunite (red) for Landsat 8 (left), ASTER (middle), and HYPERION (right). Plotted using the USGS Spectral Library. Wavelength represented in nanometers on the x-axis and reflectance on y-axis.

Landsat

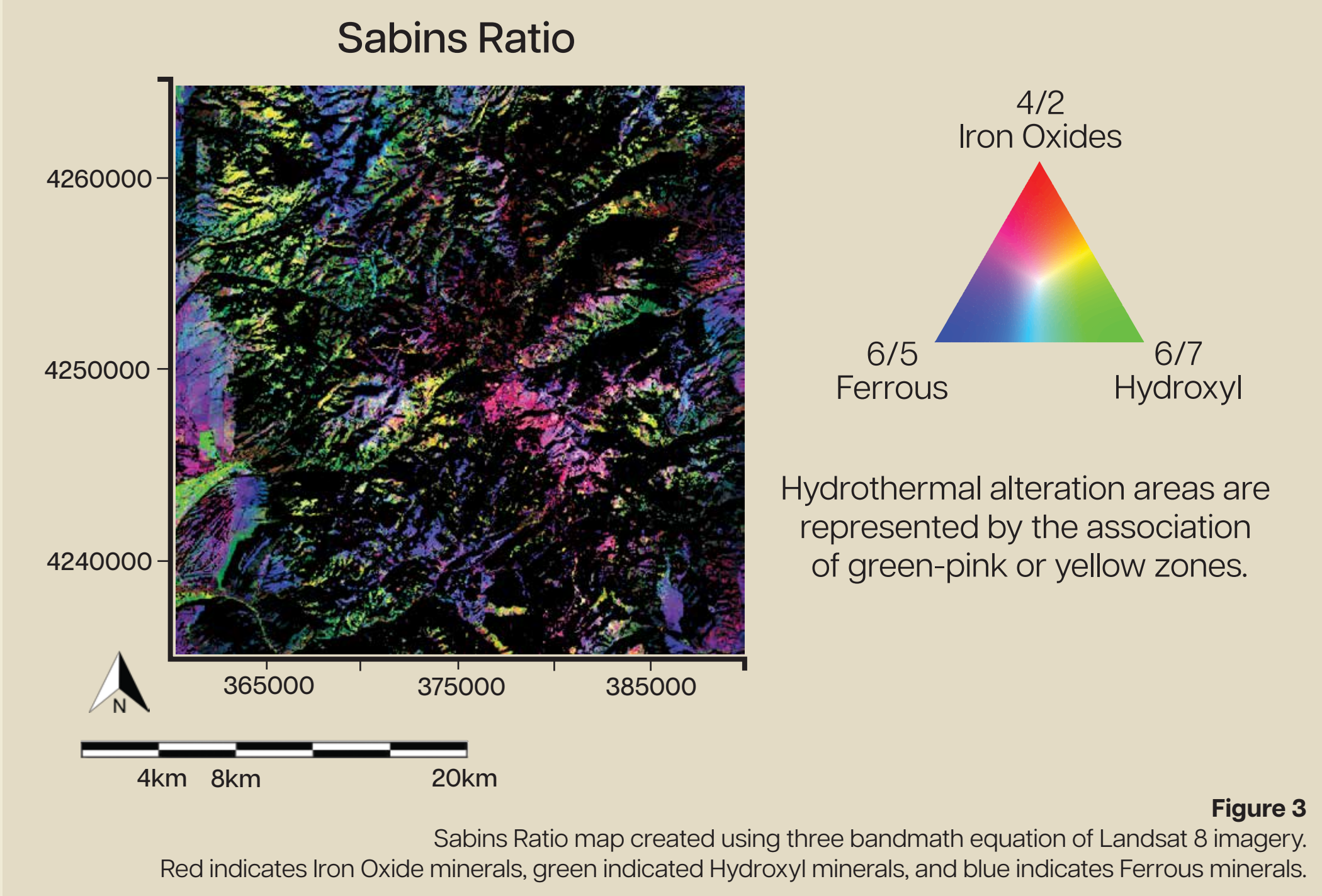


Figure 3
Sabins Ratio map created using three bandmath equation of Landsat 8 imagery. Red indicates Iron Oxide minerals, green indicated Hydroxyl minerals, and blue indicates Ferrous minerals.

ASTER

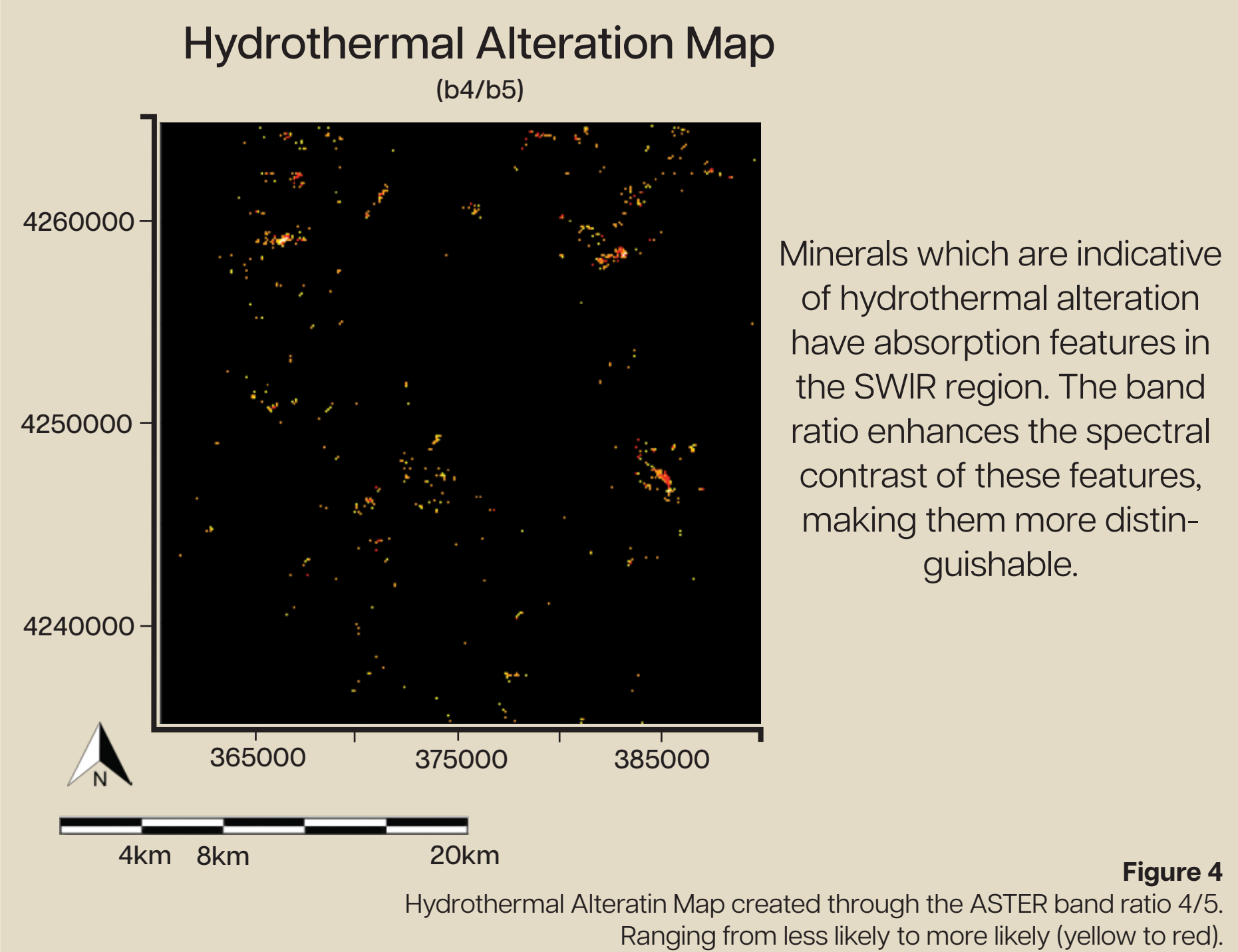


Figure 4
Hydrothermal Alteration Map created through the ASTER band ratio 4/5. Ranging from less likely to more likely (yellow to red).

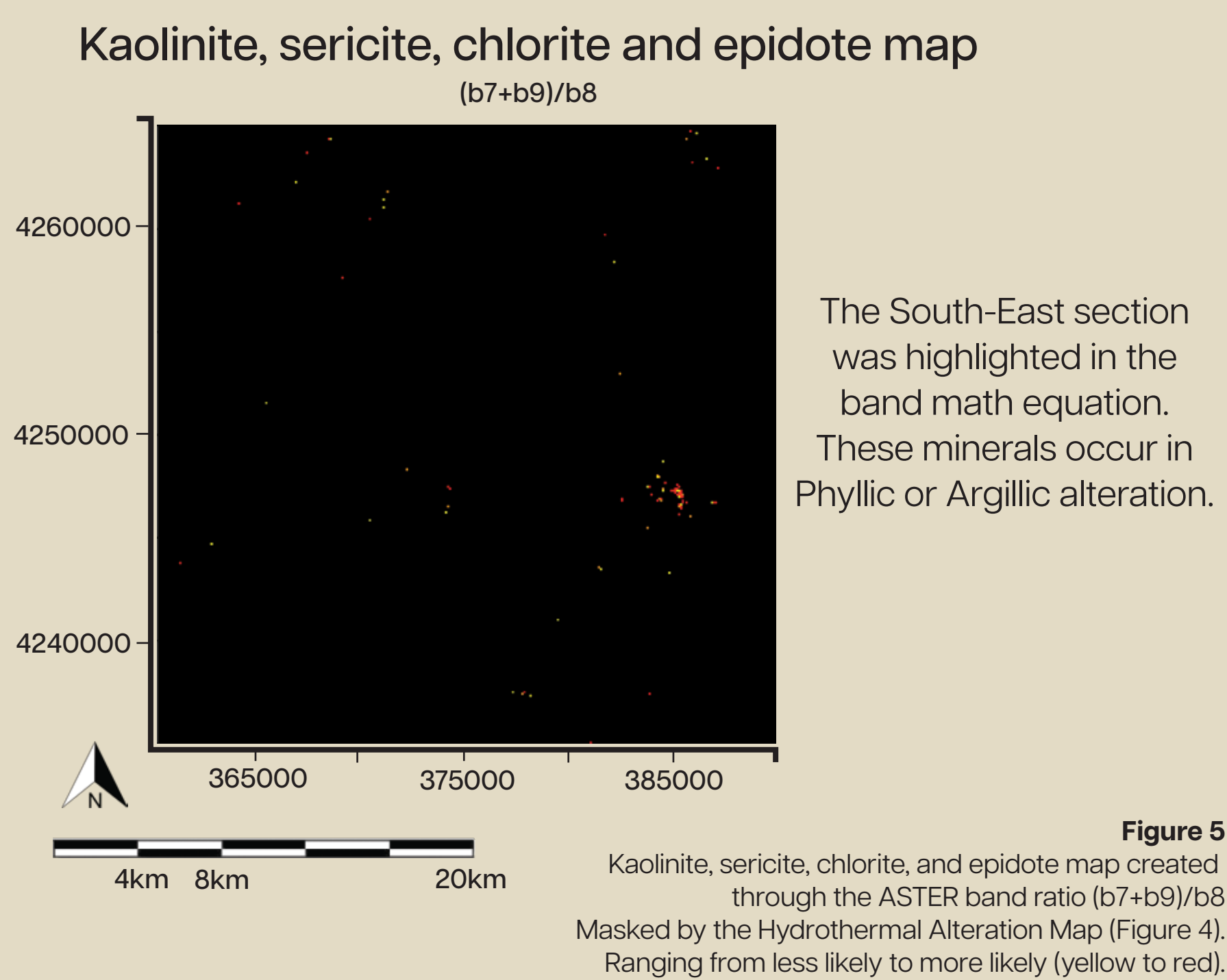
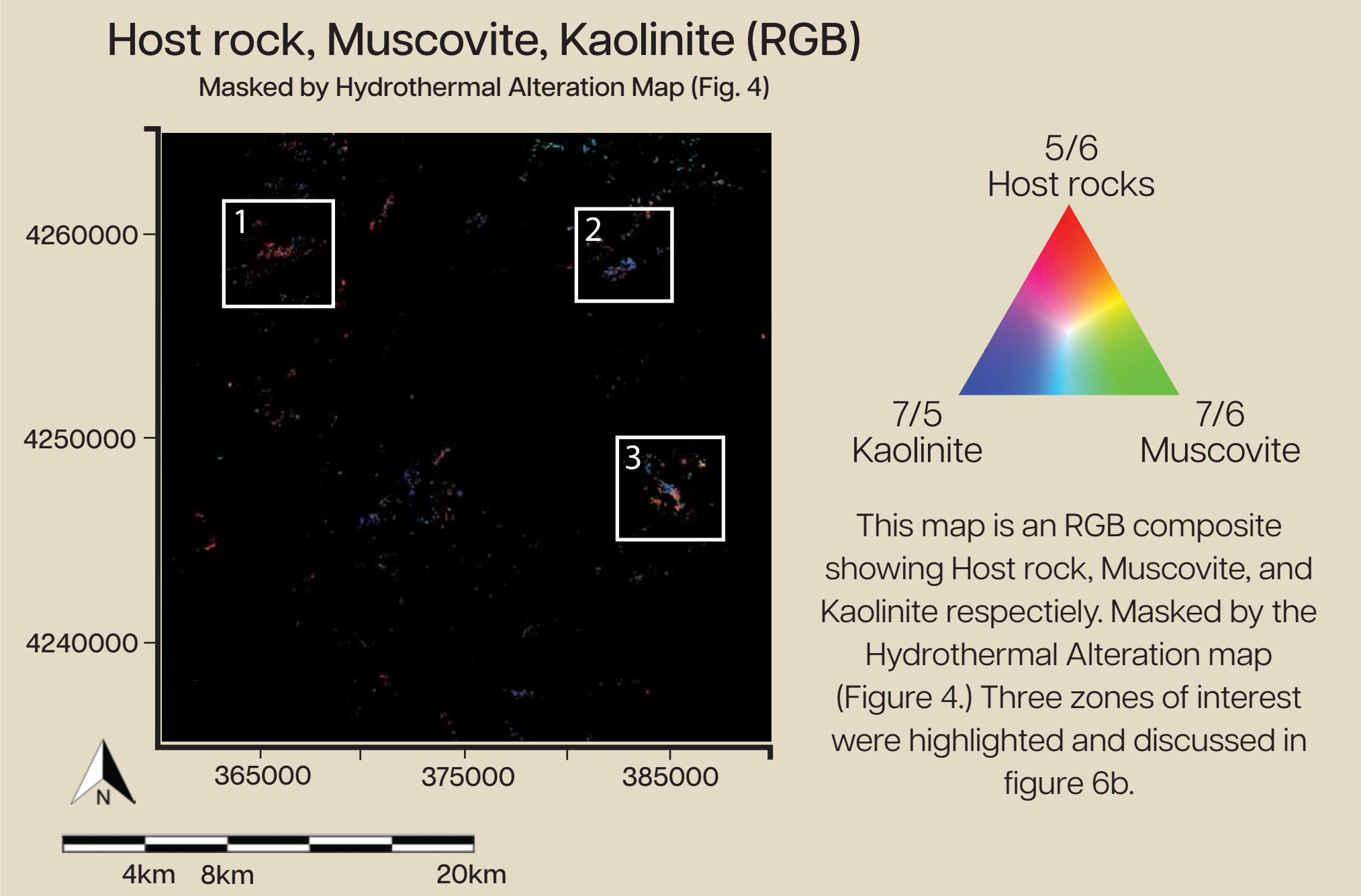


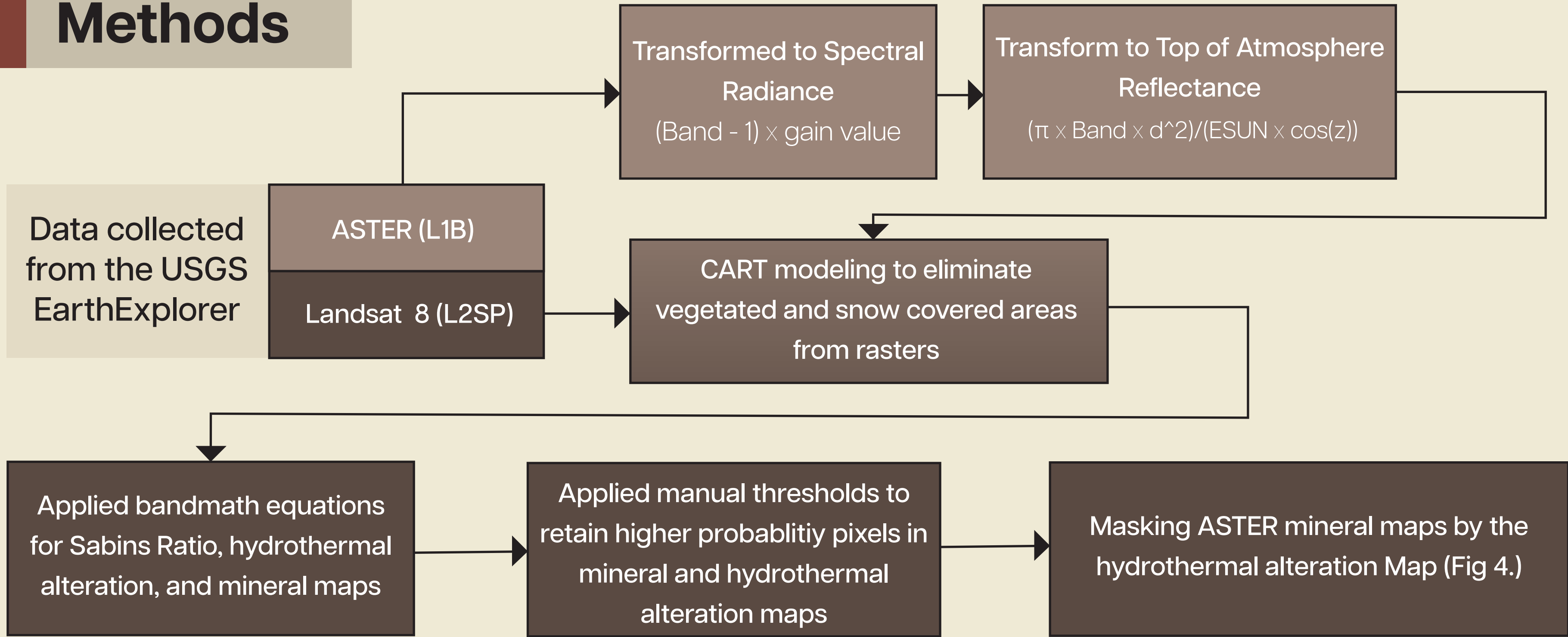
Figure 5
Kaolinite, sericite, chlorite, and epidote map created through the ASTER band ratio (b7+b9)/b8. Masked by the Hydrothermal Alteration Map (Figure 4). Ranging from less likely to more likely (yellow to red).



The band ratios aim at highlighting varying absorbing minerals. Phenigite may be present in red, muscovite and illite in green, and pyrophyllite, alunite, dickite, and kaolinite in blue. Red to tones are theoretically related to Aluminum poor area, and green to Aluminum rich.

Figure 6a
Host rock, Muscovite, and Kaolinite RGB. Mapped using ASTER bandmath. Masked by to delineate zones of interest by Figure 4.

Methods



d = Earth Sun Distance in Astronomical Units
ESUN = Mean Solar Exoatmospheric Irradiance of Each Band
z = Solar Zenith Angle
Gain value found in metadata
Collection ID for Landsat image: LC09_L2SP_038033_20231019_20231020_02_T1
Collection ID for ASTER image: AST_L1B_00310012005182513_20231130134446_13225

Conclusion

The results of this study indicate that both Landsat 8 and ASTER imagery can provide valuable insights into hydrothermal alteration zones and their potential mineral assemblages. Landsat 8 is more limited in its application for mineral analysis due to the amount of spectral bands in the shortwave infrared and nearwave infrared; where minerals show their most diagnostic features. Landsat 8 did provide a similar delineation of large-scale alteration features and provided an overview of the distribution of alteration zones across the study area. However, ASTER, with its additional spectral bands, allowed for deeper delineation between minerals associated with hydrothermal alteration, contributing to a more in depth identification of alteration types. This finer level of detail is particularly valuable for understanding the geological processes and mineralogical composition of the Marysvale volcanics.

Continued research implementing AVIRIS imagery and field validations will allow for mineral basis delineations, leading to a more accurate alteration zone type classification. AVIRIS being a hyperspectral sensor, allows for much more detail in mineral mapping, as well as finer area analysis due to the higher spatial resolution. Performing principle component analysis with AVIRIS can highlight specific spectral characteristics associated with minerals in a quick and efficient way.

Citations

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Barnaby Whitson Rockwell. (2009). Comparison of ASTER- and AVIRIS-derived Mineral and Vegetation Maps of the White Horse Replacement Alunite Deposit and Surrounding Area, Marysvale Volcanic Field, Utah. Barnaby W. Rockwell.

Spectral Library | U.S. Geological Survey. (n.d.). www.usgs.gov/labs/spectroscopy-lab/science/spectral-library

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