Classification of Mars surface using CRISM enhanced by HiRISE and CTX

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Abstract

Mars, our planetary neighbor, is one of the most studied planets in the solar system. This is due to various factors that includes its habitability, geological resources and climate. In this endeavor we have sent multiple rovers and satellites to it to study the planet, within them is the Mars Reconnaissance Orbiter(MRO) which is outfitted with various imaging instruments that allow us to image the planet at resolutions we've never been able to before. These imaging instuments are known as: the Context Camera (CTX); the High Resolution Imaging Science Experiment (HiRISE); and the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM). This study aims to better understand the workflow of images from the MRO as well as sample one area of mars in which the images overlap.

Keywords: Mars, HiRISE, CTX, CRISM, Multispectral, Hyperspectral

1 Introduction

Mars is in many ways an important laboratory to study planets in our solar system. Many missions have been made in order to study it, most recently both the Mars Reconnaissance Orbiter (MRO) has been deployed to study it. Instruments on board the MRO and others have been transmitting a wealth of information relating to its geology, topography, climate and even mineralogical data. However due to the large volume of information, a great part of the data process is delegated to computers. It is the scientific community to go through the data and find potential discoveries, such as the recently presented location of liquid salty brine on the surface of mars.

The area selected for our study consist of a chasm called Greater Kasei Vallis which has been imaged from all 3 cameras onboard the MRO (Figure 1). More specifically it's The Chryse region crater wall or escarpment. It was imaged at HiRes from the CRISM instrument.

1.1 Instrumentation

Onboard the MRO there are 3 instruments: the Context Camera (CTX); the High Resolution Imaging Science Experiment (HiRISE); and the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM). Each of these instruments are used for different purposes, ranging from image classification to simple viewing.

1.1.1 MRO Context Camera (CTX)

The Mars Reconnaissance Orbiter (MRO) Context Camera (CTX) is currently orbiting Mars and acquring grayscale (black & white) images. The spacial resolution is 6 meters per pixel scale over a swath 30 kilometers wide. The CCD detects a broad band of visible light from 500 to 800 nanometers in wavelength. CTX provides context images for the MRO HiRISE and CRISM, is used to monitor changes occurring on the planet, acquires stereopairs of select critical science targets. As of February 2010 it has covered more than 50% of the planet. This camera will be used to find and place our study area in an overall picture of mars.

1.1.2 MRO High Resolution Imaging Science Experiment (HiRISE)

The Mars Reconnaissance Orbiter (MRO) High Resolution Imaging Science Experiment (HiRISE) has a telescopic lens that produces images at resolutions never before seen in planetary exploration missions. HiRISE acquires surface images containing individual, basketball-size (30 to 60 centimeters, or 1 to 2 feet wide) pixels. It has 14 CCDs (10 RED, 2 BG, 2 IR). It can image in three color bands, 400–600 nm (blue-green or B-G), 550–850 nm (red) and 800–1,000 nm (near infrared or NIR). This camera will be used to limit our study area and be able to study the surface for details. It may be used to pansharpen the image if possible.

1.1.3 MRO Compact Reconnaissance Imaging Spectrometer for Mars (CRISM)

CRISM is an imaging spectrometer, it measures composition of Mars' surface and atmosphere at hundreds of different wavelengths. CRISM is an imaging spectrometer with a scannable field of view that can cover wavelengths from 0.362 to 3.92 microns (362 to 3920 nanometers) at 6.55 nanometers/channel. CRISM can observe in both the visible range (0.38 – 0.70 microns) and shorter wavelengths within the infrared wavelength range (the full infrared wavelength range is 0.7- 1000 microns). It has a resolution of 18.4 meter/pixel at 300 kilometer altitude (60.4 feet/ pixel from 185 miles altitude) it can cover an width of 11.1 kilometers at 300 kilometer altitude (6.9 miles from 185 miles altitude)

2 Objectives

Our main objective is mainly educational and consists of seeing the workflow needed to prepare the data for use. This involves mainly of installing and using the Integrated Software for Imagers and Spectrometers (ISIS) Install and use CRISM Analysis Toolkit (CAT) add-on for ENVI (Beyer, 2015). Another objective is to learn to download, import and manipulate data from the Mars Reconnaissance Orbiter (CTX, HiRISE, CRISM). Secondary objectives are to georeference data on another planet and run a classification on data and overlay over higher definition images and study the relationship between topography and mineralogical data(CRISM Spectral library).

3 Methods

Our methodology consisted of a series of steps that involved the following:

1. Download and install ISIS
2. Download RAW Images from NASA Website
3. Calibrate images to (I/F) (HiRISE and CTX)
4. Stitch images to create mosaics and false color images IRB (HiRISE only)
5. Georeference the images to Martian coordinates (HiRISE and CTX)

6. Download and install the CRISM Analysis Toolkit(CAT).
7. Use CAT to process and georeference CRISM Images.
8. Use the CRISM Spectral library to identify areas.
9. Identify areas in common in all images (CTX, HiRISE and CRISM).
10. Interpret the relationship between the regions of interest and the morphology.

I will expand on each of the steps in the following subsections.

3.1 Download and install ISIS

The now unfortunately named, ISIS program can be found on the USGS website (currently https://isis.astrogeology.usgs.gov/) and is easily installable in Linux and Mac. Windows requires a bit of work. The program will download a great deal of information on most planetary and interplanetary spacecraft and orbiters. This is used as supplementary data later on.

3.2 Download RAW Images from NASA Website

There are several ways to download RAW data from NASA as well as full products, most of them in RAW or ISIS Cub formats. For our purposes we mainly downloaded RAW data. It's important to note the image Levels established by nasa. Level 0 consist of RAW unaltered data direct from the satellite usually RAW and must be moved into ISIS Cub. Level 1 is a calibrated version of this data, any multiple channels at this point have been merged into an ISIS cub. Level 2 is a Geo-referenced image with all available information attached. For HiRISE six channels were downloaded two blue-green, two red and two infrared. For CTX one channel was downloaded. These two were found in the Planetary Image Locator Tool (PILOT) from the USGS (http://pilot.wr.usgs.gov/) and it's akin to Earth's EarthExplorer. CRISM data was found in the CRISM Website (http://crism-map.jhuapl.edu/).

3.3 Calibrate images to (I/F) (HiRISE and CTX)

At this point the data is ingested for both HiRISE and CTX (using the ISIS commands: hi2isis and mroctx2isis). Orbital information was then inserted using the ISIS spiceinit tool. Then calibrated to (I/F) (using ISIS hical and ctxcal). HiRISE CCD Sensor images were stitched together using the ISIS tool: hiccdstitch (Delamere et. al., 2010).

3.4 Stitch images to create mosaics and false color images IRB (HiRISE only)

HiRISE Images were stitched together using the ISIS tool histitch then normalized using the ISIS tool cubenorm. This step is required so that all the stiches are not seen and the imaged is normalized (Delamere et. al., 2010).

3.5 Georeference the images to Martian coordinates (HiRISE and CTX)

The two sensors are then georeferenced with orbit information onto the MARS 2000 Geoid. This created our final products which are geo-referenced images of CTX and HiRISE (Delamere et. al., 2010). (Figure 2 and 3 respectively)

3.6 Use CAT to process and georeference CRISM Images.

CAT (CRISM Analysis Toolkit) is a collection of ENVI and IDL procedures for reading, displaying, and analyzing CRISM data, produced by the CRISM Science Team. It was installed for two computers (Beyer, 2015). This software automates the ingestion, georeferencing and calibrating of CRISM data, including eliminating bad bands, creating products and includes a spectral library already suitable for CRISM (Beyer, 2015). The image was georeferenced and calibrated (Figure 4). Afterwad profiles for random areas were generated (Figure 5). A multi band product describing the amount of mineral abundances was created some results are shown (Figure 6). A spectral classification for CRISM information was also created by using the CRISM Spectral Library (Figure 7).

3.7 Identify areas in common in all images (CTX, HiRISE and CRISM).

In order to put this all together Quantum GIS (QGIS) was used to display the data and create suitable maps to better understand how everything is related to one another.

4 Results

The primary objective was achieved by literature review, the workflow was analised and emulated and products were obtained such as: a georeferenced HiRISE false color image (fig 3); a georeferenced CTX image (fig 2) and a georeferenced color CRISM image (fig 4). Additional secondary objectives were also a success, after processing with the CRISM Analysis Toolkit(CAT) we arrived at 88 Bands for the Visible to IR and 430 NIR to MIR (Carter et. al., 2013). We can conclude that high elevation areas are free of dust/rock, while low elevation areas, dust/rock is made out of highly ferric materials with traces of olivine are present in the area (fig 6). This area is entirely basaltic, (maybe? even pillow lava) with different types of basaltic rock present, but could be a result of weathering and erosion (Fig 8).

5 Conclusion

In conclusion the ISIS and CAT are two incredible toolboxes readily available for anyone who wants to process planetary data. The MRO CTX, HiRISE, and CRISM instruments are very good for imaging and describing Mars' surface. In our particular area preliminary results indicate that is is mainly composed of basaltic rocks. There is an component of erosion due to the Martian climate.

References

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A Figures

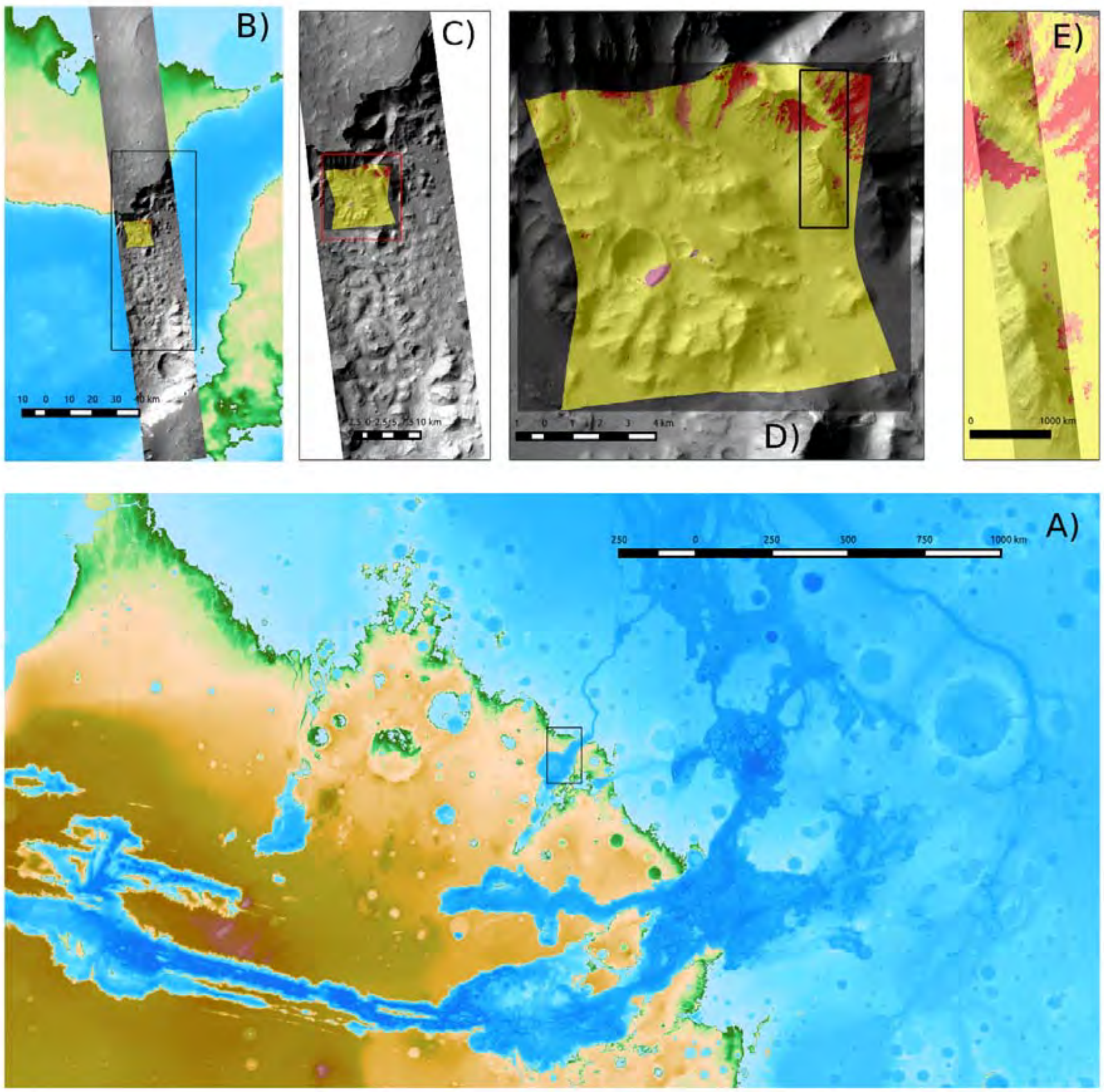

Figure 1. Area of Study: Greater Kasei Vallis specifically it's The Chryse region crater wall or escarpment. A) An overall look using MOLA using ETOPO1 Palette. B) A zoom in area showing CTX extent. C) and D) zoom in to the CRISM Extent. E) The HiRISE Extent of our area

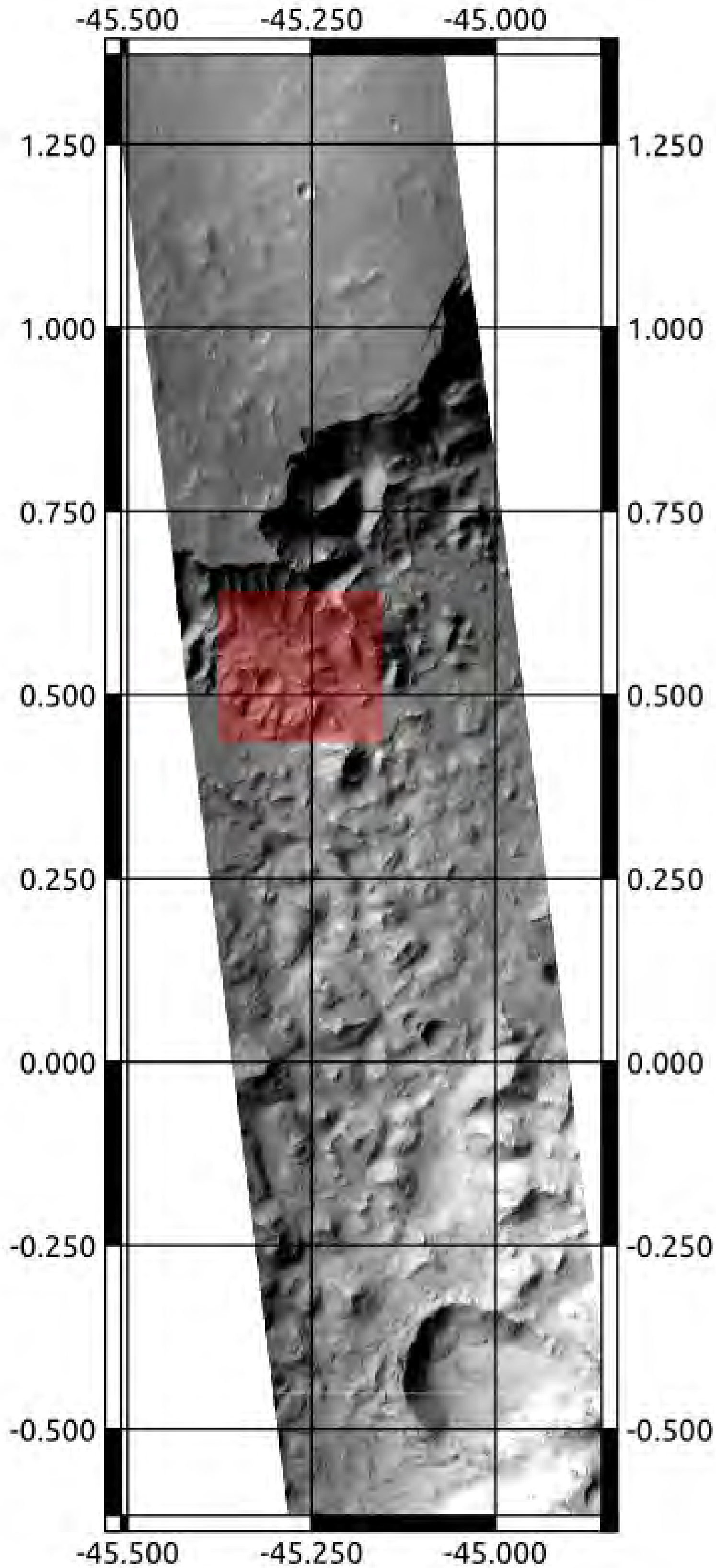

Figure 2. Context Camara for our area of study. In red: CRISM Extent.

Figure 3. HiRISE image for our area of study

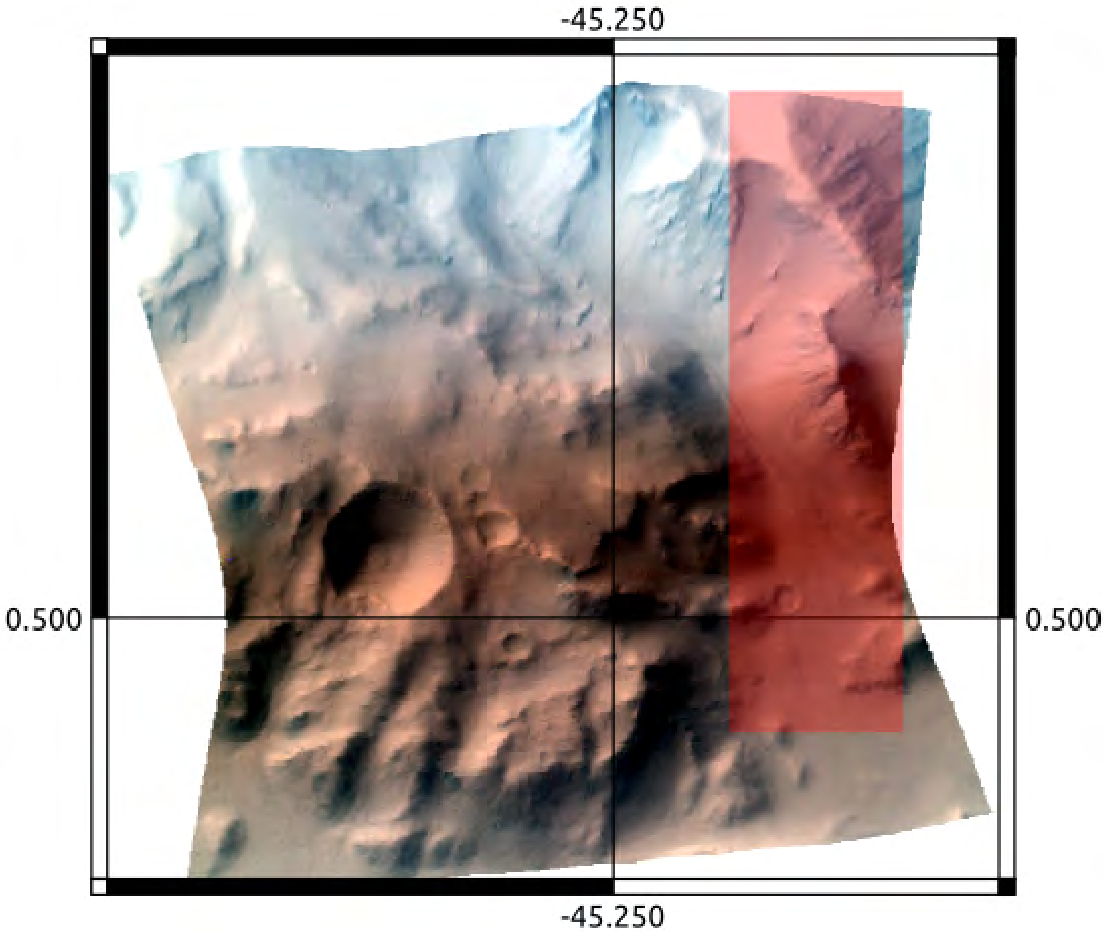

Figure 4. Georeferenced CRISM image. In red: HiRISE Extent.

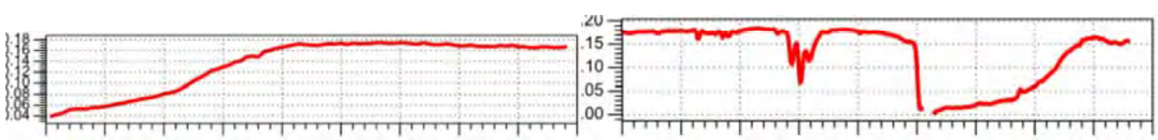

Figure 5. Spectral profiles for CRISM Data, VIS-NIR (left) to MIR-FIR (right)

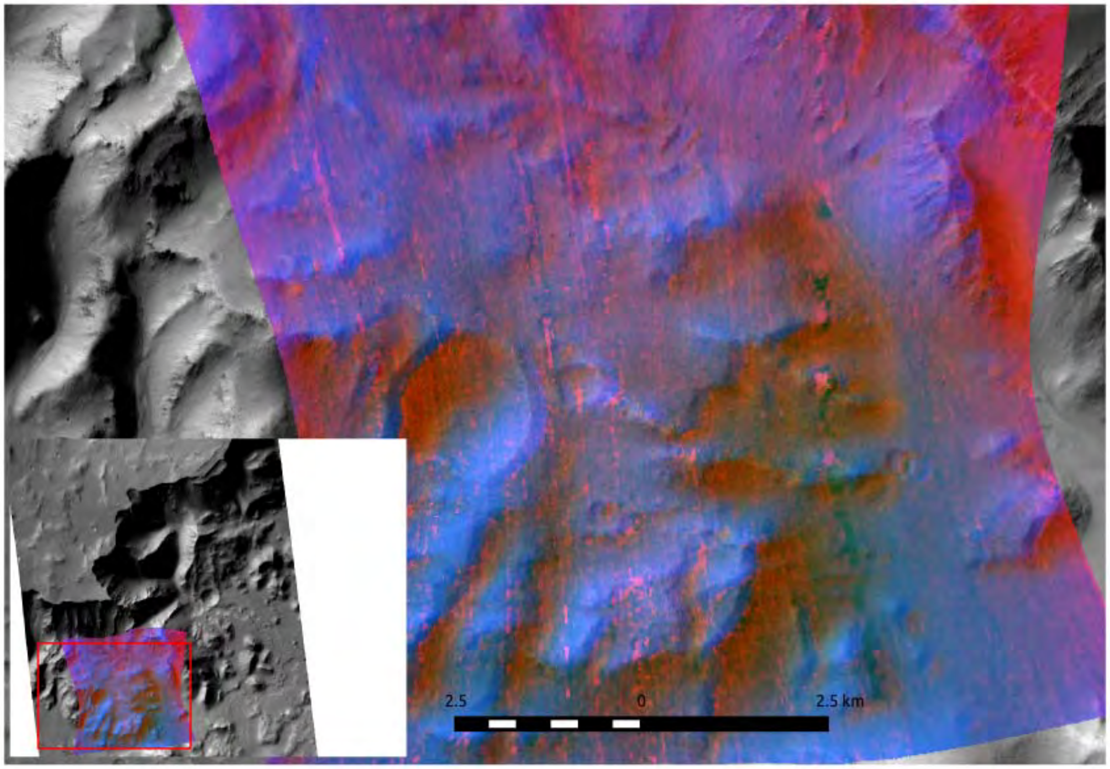

Figure 6. CRISM Product, multi band data with different information. Red: Dust/Rock abundance; Blue: Ferrite mineral rock, Green: Olivinic minerals.

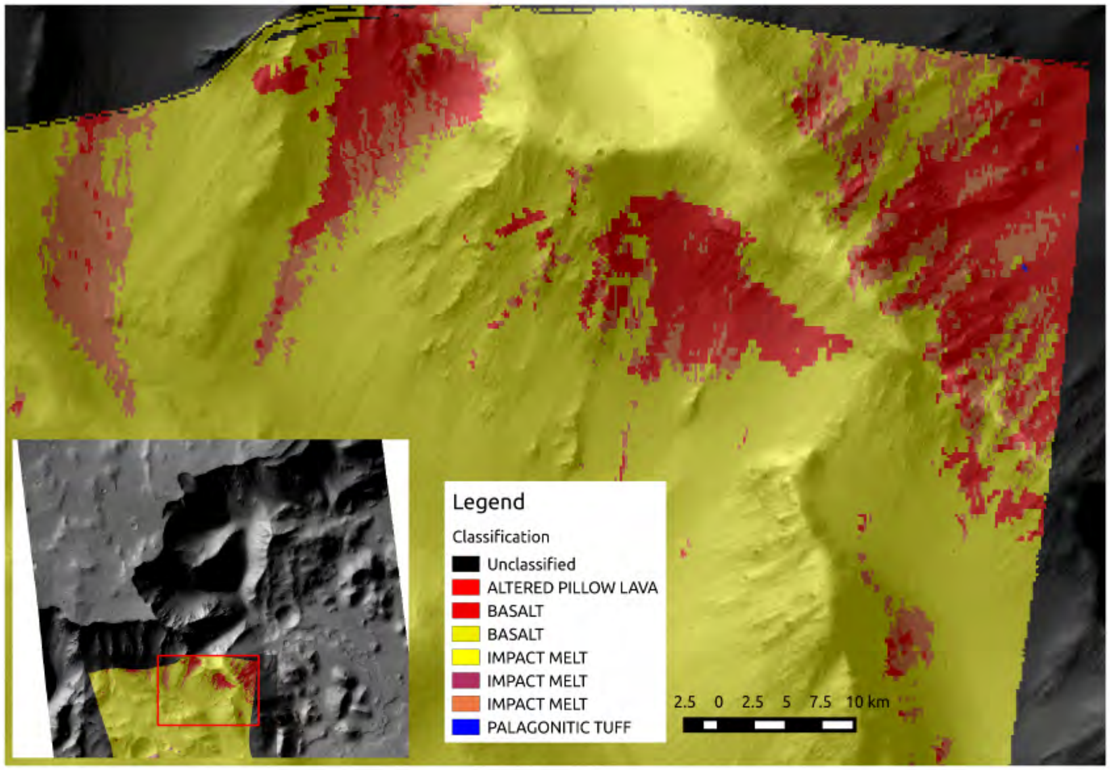

Figure 7. CRISM Classification Close-up

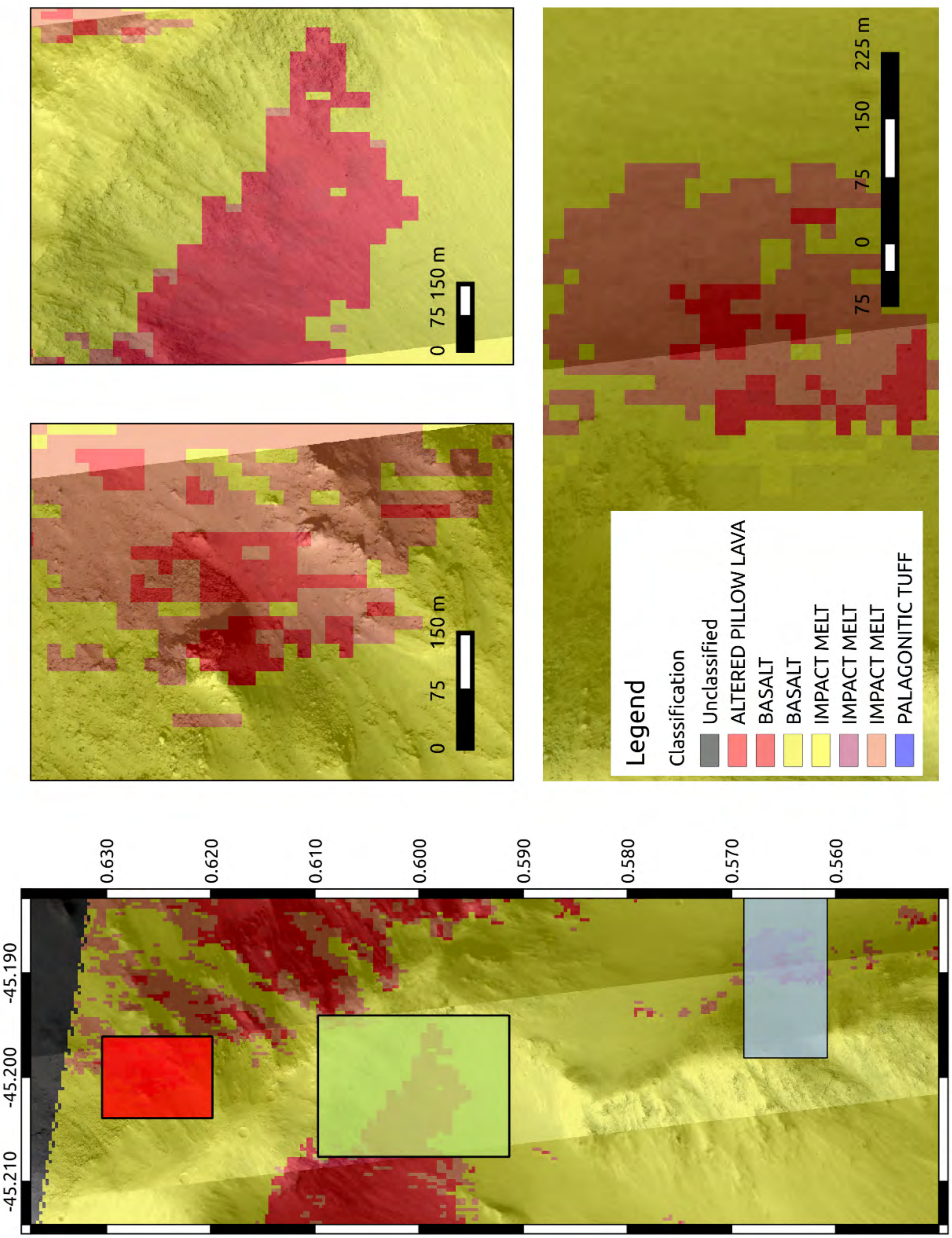

Figure 8. A closeup of the HiRISE Images overlain by the classification.