Examples of Higher level Products Possible from Existing Assets: Landsat, MODIS, ASTER, MASTER, AVIRIS, Hyperion, ALI

CQ5. Surface Composition and Change
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CQ5: Overarching Question
What is the composition of exposed terrestrial surface of the Earth and how does it respond to anthropogenic and non anthropogenic drivers?

MINERAL MAPS - HIGHER LEVEL PRODUCTS FOR HYSPIRI
RADIANCE - REFLECTANCE - EMISSIVITY

EXISTING PRODUCTS

LANDSAT TM - LAND COVER LAND USE – TRAINING SITES - DECISION TREE
MODIS MOD12 - LAND COVER LAND CHANGE – TRAINING SITES - DECISION TREE
ASTER - DECORRELATION STRETCH TIR DATA (DISCONTINUED)
AVIRIS - NONE
MASTER - NONE
ALI – NONE
HYPERION - NONE

SO WHAT DATA AND MAPPING METHODS HAVE BEEN DONE FOR EXPOSED TERRESTRIAL SURFACES THAT CAN BE USED FOR HYSPIRI SCIENCE INVESTIGATIONS INVOLVING CQ5?
CQ5: Overarching Question
What is the composition of exposed terrestrial surface of the Earth and how does it respond to anthropogenic and non anthropogenic drivers?

Science Issue:
Mapping the mineralogical composition of the earth’s surface is critical in understanding the distribution and formation economic ore deposits and hydrocarbons, and determining and monitoring processes that impact ecosystems such as acid runoff, desertification, and sediment flux into coastal and marine systems.

Tools:
VNIR-SWIR-TIR imagery, spectroscopy, mineral maps, false color composite band ratio images,

Approach:
The exposed terrestrial surface of the earth is composed of minerals that exhibit diagnostic spectroscopic absorption features in the 3.25 to 12.0 micrometer region. Mineral maps compiled from VNIR, SWIR and TIR spectroscopic data will be used to monitor desertification processes, determine soil quality, and map acid drainage and increased salinity. Rocks and sediments typically contain mixtures of different minerals and thus exhibit multiple absorption features in the VNIR-SWIR-TIR region. Band ratio false color composite images of VNIR-SWIR and TIR data will be used for rock and sediment type mapping.

Results:
Crowley and others used AVIRIS VNIR and SWIR data to map chemical weathering products of mine waste at the Elizabeth Mine, Vermont. Mineral maps show the distribution of jarosite, hematite and goethite which indicate low pH conditions around mine dumps that produce acid runoff.

AVIRIS Minerals Map of Elizabeth Mine, Vermont

EXPLANATION:
- JAROSITE
- MUSCOVITE
- HEMATITE
- GOETHITE
- WATER

Crowley and others, 2001
• What is the composition of the exposed terrestrial surface of the Earth? (DS 220)

False color composite HyspIRI simulated image of Grand Canyon, Arizona derived from TIR (red band - quartz-rich rocks), SWIR (green band - clay and muscovite-rich rocks; blue band - carbonate-rich rocks), and VNIR (dark green - green vegetation) data.

**Red** - Band Ratio 11.30 μm/9.10 μm (TIR Data)

**Green** - Matched filter of 2.17 μm - 2.20 μm absorption feature (SWIR Data)

**Blue** - Matched filter of 2.33 μm absorption feature (SWIR Data)

**Dark Green** - Vegetation - Matched Filter of 0.66 μm absorption feature

**Science Issue:**
How to compile more descriptive-detailed lithologic maps?

**Tools:**
With VINIR-SWIR-TIR capability, HyspIRI will be able to map the most common surficial minerals including quartz (TIR), carbonates (TIR, SWIR), clays (SWIR), oxides (VNIR) and evaporites (VNIR and SWIR).

**Approach:**
Use false color composite band ratio maps of common mineral groups

**Results:**
The Grand Canyon is an example where the quartz-rich sandstones were mapped using TIR data, and the clay-rich shale and carbonate rocks were mapped using SWIR data.
Sedimentary Rocks
Rocas sedimentarias
Roches sédimentaires
• How does the surface mineralogy and soil composition relate to the plant physiology and function on the terrestrial surface of the Earth? (DS 114)

Rowan and others, 1998
Monitoring dune migration in the Mojave Desert, California using TIMS (TIR) data

Science Issue:
Monitoring of desertification

Tools:
- Field spectral data
- HyspIRI VNIR, SWIR and TIR data, multiple temporal datasets

Approach:
- HyspIRI VNIR-SWIR data can be used to map vegetation, and clay, carbonate, and evaporite compositions of soils.
- HyspIRI TIR data can be used to map soil quartz content and quartz sand movement.
- Multiple HyspIRI data sets can be used to monitor landscape changes

Results:
- Chikhaoui and others used ASTER VNIR-SWIR field spectra and VNIR SWIR ASTER data to compile a land degradation index map.
- Ramsey and Lancaster used TIMS TIR data to monitor dune migration of quartz-rich sands.

Land Degradation Index Northern Morocco-Index compiled from ASTER VNIR-SWIR data
Ramsey and Lancaster, 1998

Dune migration in the Mojave Desert, California using TIMS data

Chikhaoui and others, 2005
Land Degradation Index Study, Northern Morocco

Text:

TIR map quartz sand, VNIR SWIR map clay carb and veg.
How do types and distributions of altered rocks define regional trends in hydrothermal fluid flow for magmatic arcs and tectonic basins, better define hydrothermal deposit models, and assist in the discovery of new economic deposits? (DS 227)

**Science Issue:**
How can alteration be used to identify new economic deposits and better define hydrothermal fluid flow in hydrothermal systems?

**Tools:**
HyspIRI SWIR and TIR data

**Approach:**
- Deposit models such as Lowell and Guilbert (1970) suggest that most hydrothermal systems produce zones of different altered rocks based on geochemical conditions and alteration intensity.
- Propylitic, argillic, and phyllic-altered rocks have SWIR absorption features and potassic altered rocks have TIR absorption features. Thus, HyspIRI SWIR data could be used to map the propylitic, argillic and phyllic-altered rocks, and HyspIRI TIR data could be used to map potassic-altered and silicified rocks with the TIR detector.

**Results:**
Mars and Rowan (2006), have used ASTER data to regionally map argillic, phyllic, and potassic-altered and silicified rocks along magmatic arcs.

**Results (cont.):**
Porphyry copper deposits typically consist of circular to elliptical patterns of potassic, silicified, phyllic and argillic-altered rocks. Linear patterns of alteration have been associated with epithermal systems. Thus, the regional alteration data have been used to identify potential deposits and assess hydrothermal fluid flow.

False color composite HyspIRI simulated image of the porphyry copper Konyrat Mine near Balquash, Kazakhstan. Elliptical patterns of altered rocks define the porphyry copper deposit at the surface (Mars and Rowan, 2006).

- Potassic-altered - Silicified rocks (TIR data)
- Argillic-altered rocks (SWIR data)
- Phyllic-altered rocks (SWIR data)
LOGICAL OPERATORS USED TO MAP MINERALS - HYDROTHERMAL SILICA-RICH
((float(b3)/b2)le1.55) and (b4gt2400) and ((float(b4)/b7)ge1.41) and ((float(b13)/b12)ge1.021)
ge - greater than or equal to; gt - greater than; le - less than or equal to; float - floating point
How do regional trends of minerals and shale thermal maturity within basins better define depositional models and assist in the discovery of new hydrocarbon reserves? (DS 235)

Khan and Jacobson, 2008

Khan and Jacobson used Hyperion data to map altered – bleached rocks due to hydrocarbon seepage:

**Science Issue:**
How can mineral trends help identify new hydrocarbon reserves?

**Tools:**
HyspIRI VNIR, SWIR, and TIR data.

**Approach:**
- As hydrocarbons migrate, they alter rocks in the form of oxidation. Hyperspectral VNIR data could be used to identify bleached zones which may represent hydrocarbon seeps.
- Determine thermal maturity of source rocks using VNIR, SWIR and TIR data by compiling vitrinite reflectance maps.

**Results:**
- Khan and Jacobson (2008) have mapped bleached hydrocarbon seeps using VNIR-SWIR Hyperion (hyperspectral data).
MODIS image (04/09/00) of Chesapeake water shed during heavy rainfall. Yellow arrow illustrates location of increased sediment loading at the Little Conestoga water shed into the Susquehanna River and resulting sediment plume in the upper part of the Chesapeake Bay.
VNIR-SWIR LABORATORY SPECTRA AND RESAMPLED ASTER SPECTRA

Reflectance (Offset for clarity)

Wavelength, micrometers

0.5 1.0 1.5 2.0 2.5

Reflectance (Offset for clarity)

Wavelength, micrometers

0.5 1.0 1.5 2.0 2.5

CALCITE
ALUNITE
SMECTITE
OPAL

UNALTERED TUFF


DICKITE
KAOLINITE
MUSCOVITE
BUDDINGTONITE
ASTER FALSE COLOR COMPOSITE IMAGE OF THE KHANNESHIN VOLCANO AREA

(Red = Band 6, Green = Band 3, Blue = Band 1)

(FROM, MARS AND ROWAN, 2011)
CARBONATITE VOLCANO - KHANNESHIN, AFGHANISTAN

DECORRELATION STRETCH OF ASTER TIR BANDS 13-12-10

(FROM, MARS AND ROWAN, 2011)
REGIONAL MINERAL MAPPING
LOGICAL OPERATORS USED TO MAP MINERALS - HYDROTHERMAL SILICA-RICH
((float(b3)/b2)le1.55) and (b4gt2400) and ((float(b4)/b7)ge1.41) and ((float(b13)/b12)ge1.021)
ge - greater than or equal to; gt - greater than; le - less than or equal to; float - floating point
Landsat TM false color composite image (7=R, 4=G, 2=B) showing area mapped for hydrothermally altered rocks using ASTER data. Completed area outlined in black, area to be completed outlined in yellow, states are outlined in white.
Satellite WA ASTER Geoscience map of iron oxide composition (blue: goethitic; red - hematitic).
GLOBAL SENSOR

NEED A UNIFORM MAPPING SYSTEM

NO INPUT – EXPERT SYSTEM – TETRATCORDER – LOGICAL OPERATORS – DÉCOR – BAND RATIOS (COLOR COMPOSITE)

INPUT – SPECTRA?  CONTROL FILE?