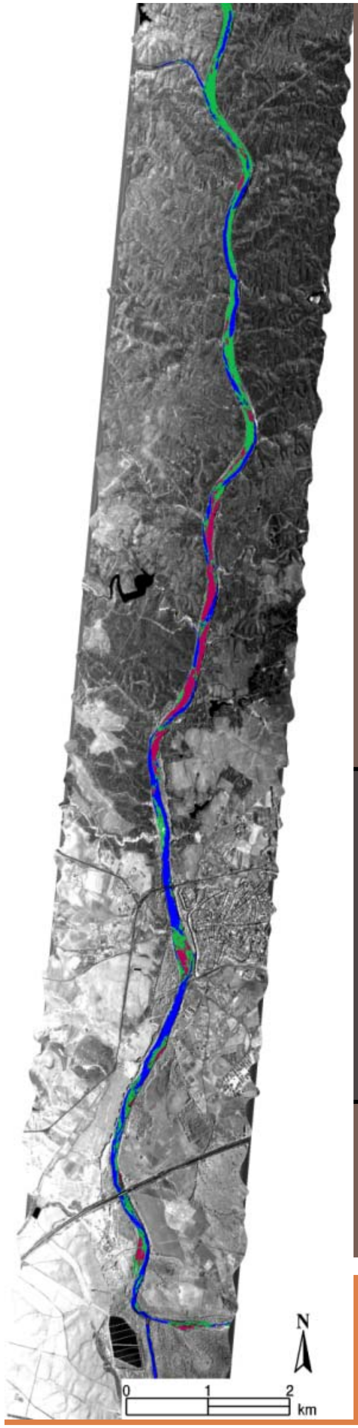

GEOdesy and GEOinformatics for sustainable Development in Jordan (GEO4D)

WP 4.1. Intensive training on remote sensing and image processing

Ponferrada (10th – 19th September 2018)

UNIT- 5

Hyperspectral remote sensing

T.2. MINERAL SPECTRAL BEHAVIOUR

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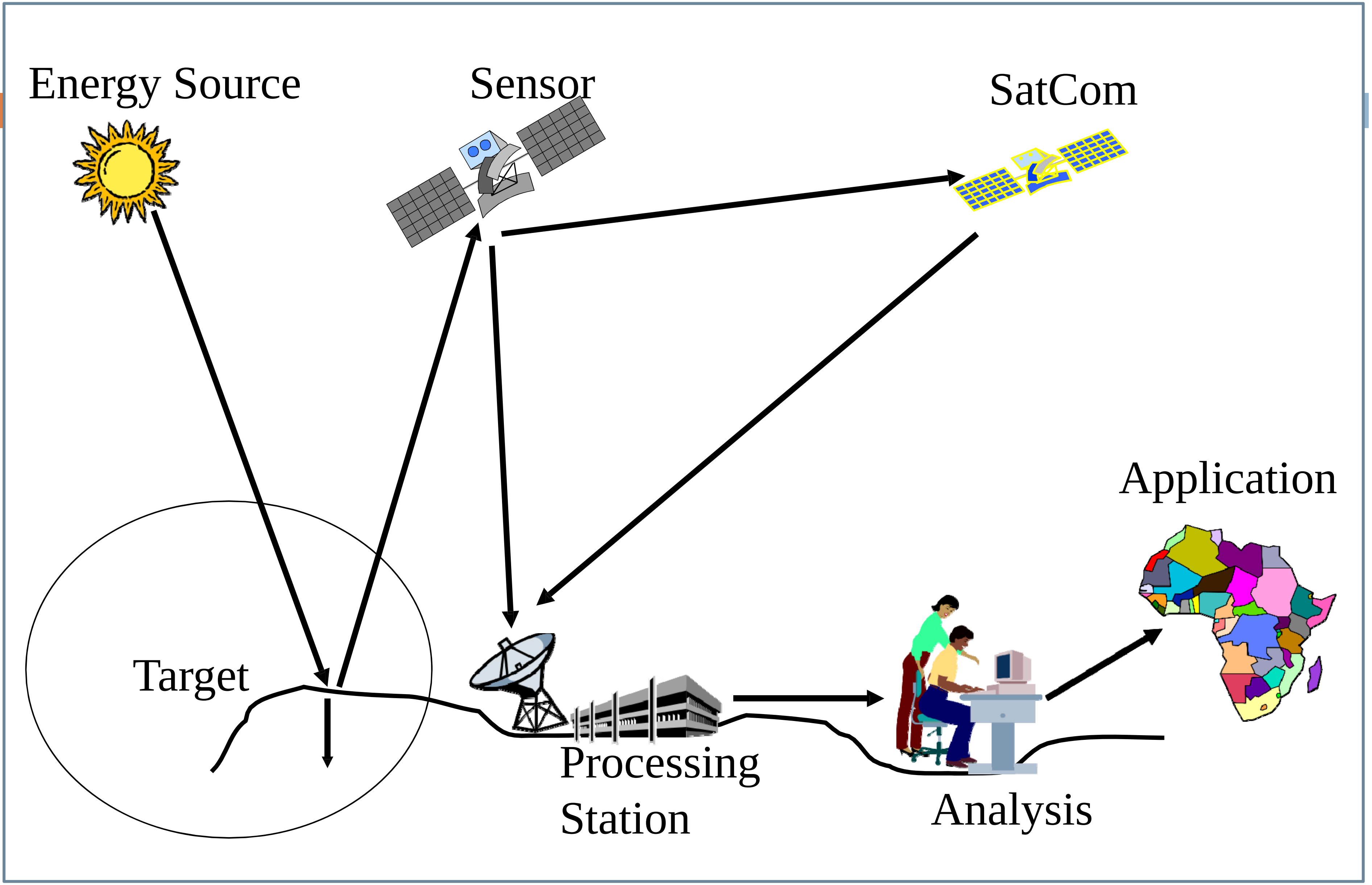
Faculty of Biological and Environmental Sciences

Outline

Mineral spectral behaviour

- Absorption processes
- Spectra of minerals, soils, rocks
- Interaction at the surface
- Continuum removal


Energy Source
Sensor
SatCom
Application
Target
Processing
Station
Analysis

Properties of Minerals and Rocks

Emissive

Chemical

Can be directly assessed with Remote sensing instruments

Reflective

Physical

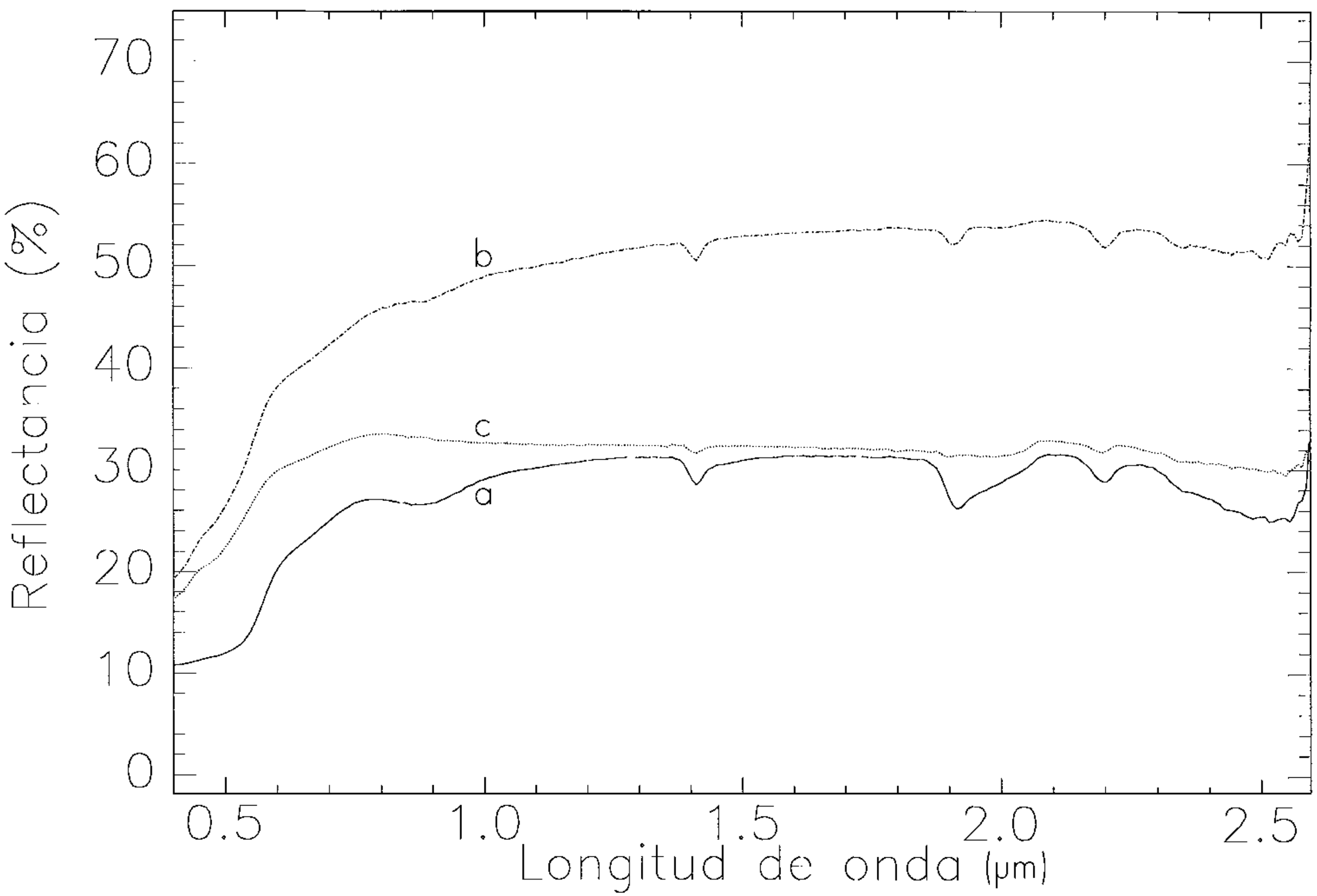
Mechanical

Absorption processes

- Interaction of electromagnetic radiation with atoms and molecules creates absorption "features" in spectra

- Two types of Absorption Processes:
  - Electronic Processes
  - Vibrational Processes

Absorption processes



Absorption processes

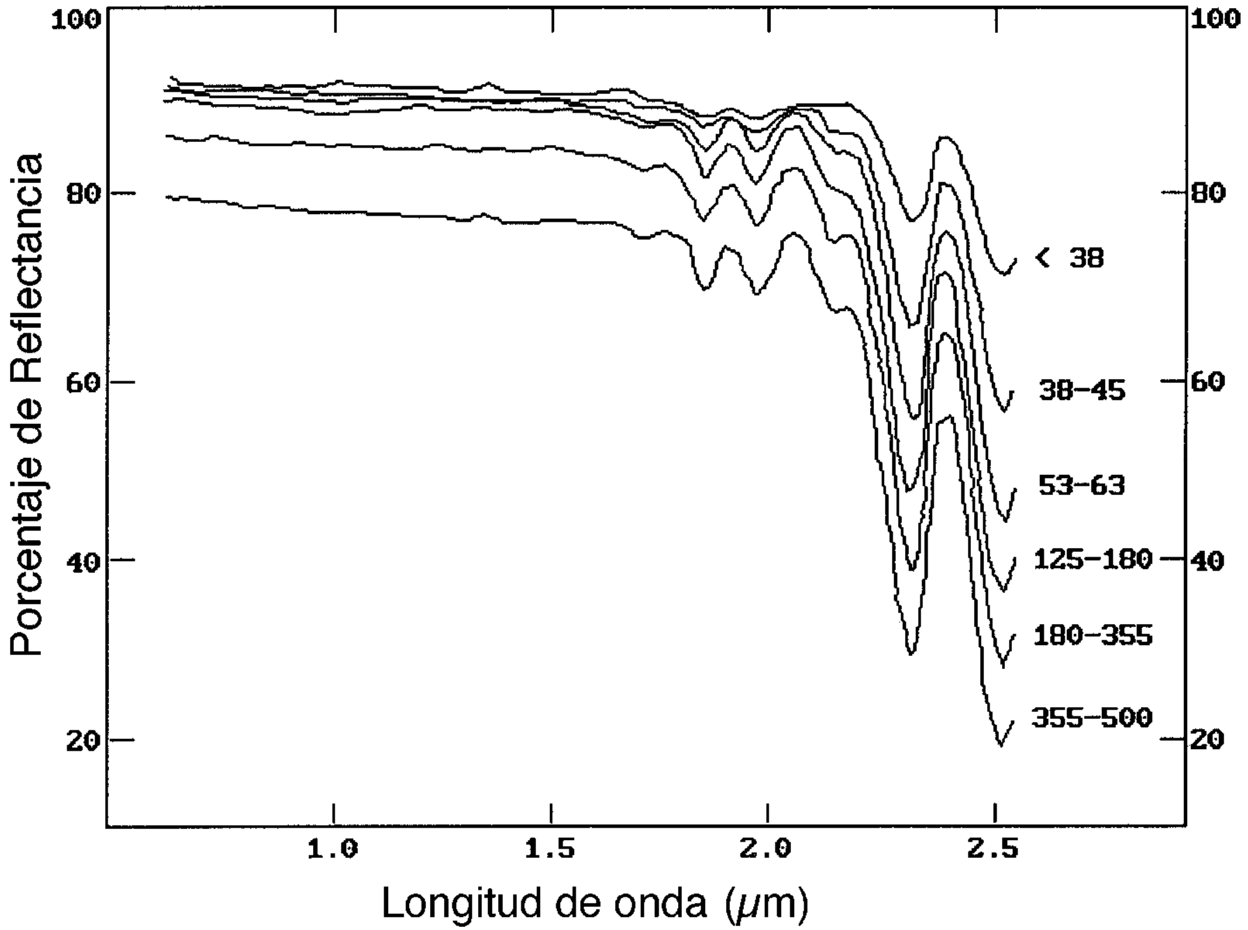
- The position, shape, depth, and width of the absorption features are controlled by the particular crystal structure in which the absorbing species is contained and by the chemical structure of the mineral.

↓

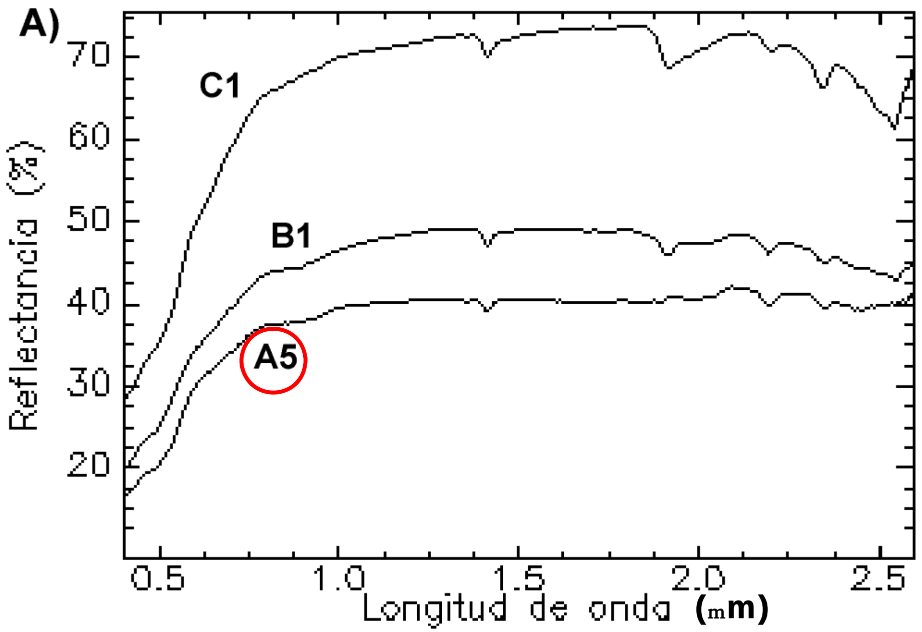
Variables characterizing absorption features can be directly related to the mineralogy of the sample

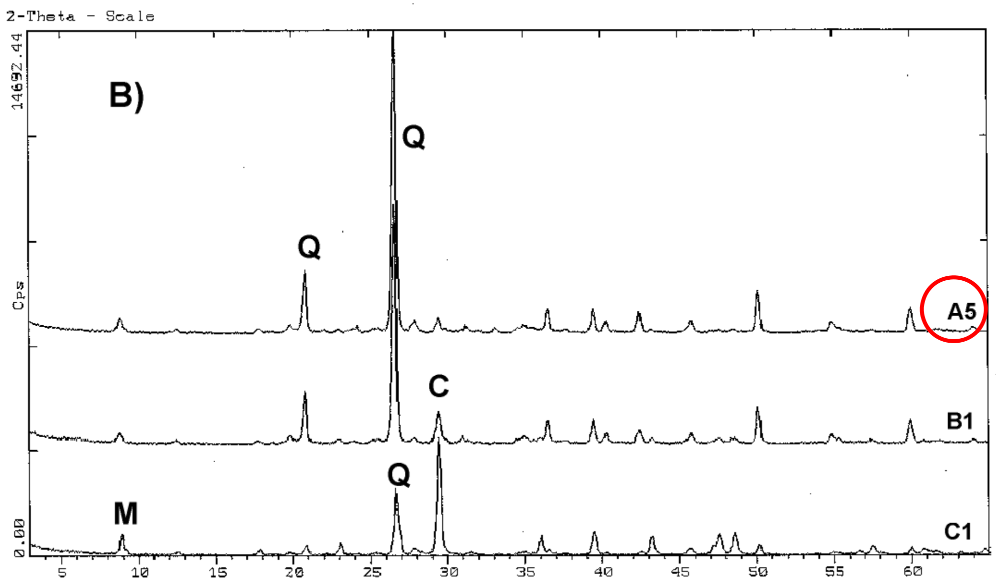
Absorption processes

Absorbed electromagnetic energy by Calcite



Spectra from calcite powder with different grain size (after Gaffey, 1986)



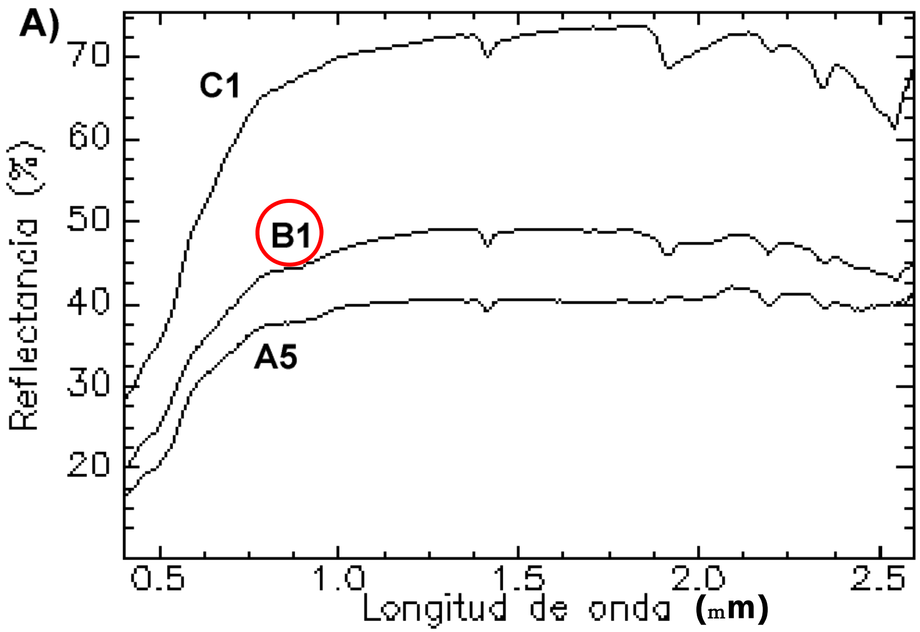


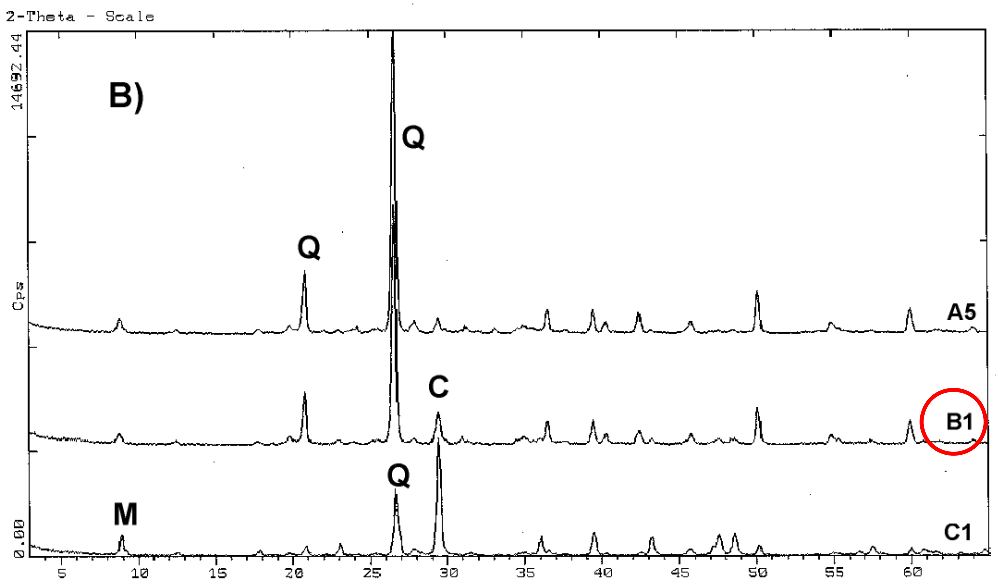
Relationships between Spectral response and composition

Sample A5: 4% carbonates

Sample B1: 17 % carbonates

Sample C1: 65% carbontes





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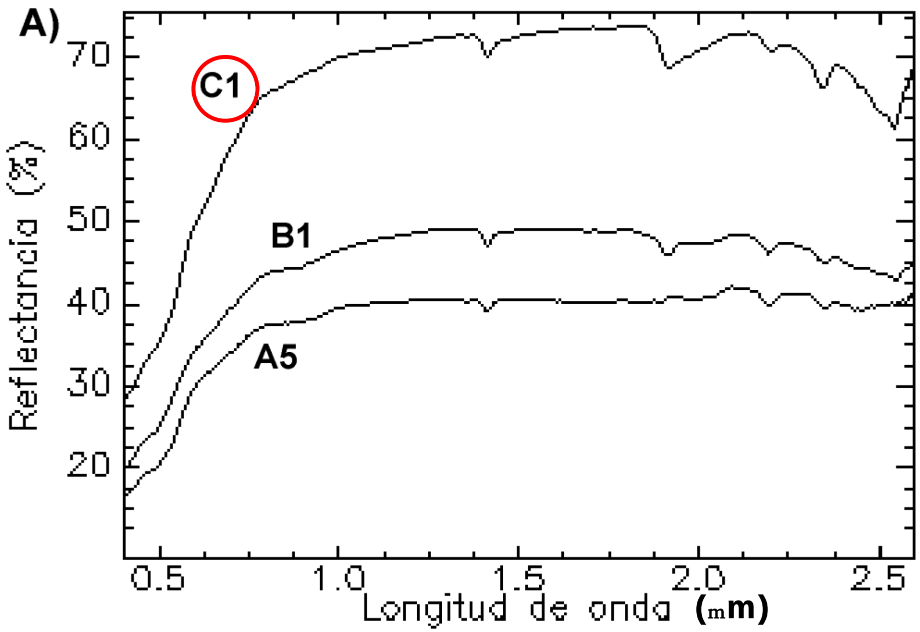

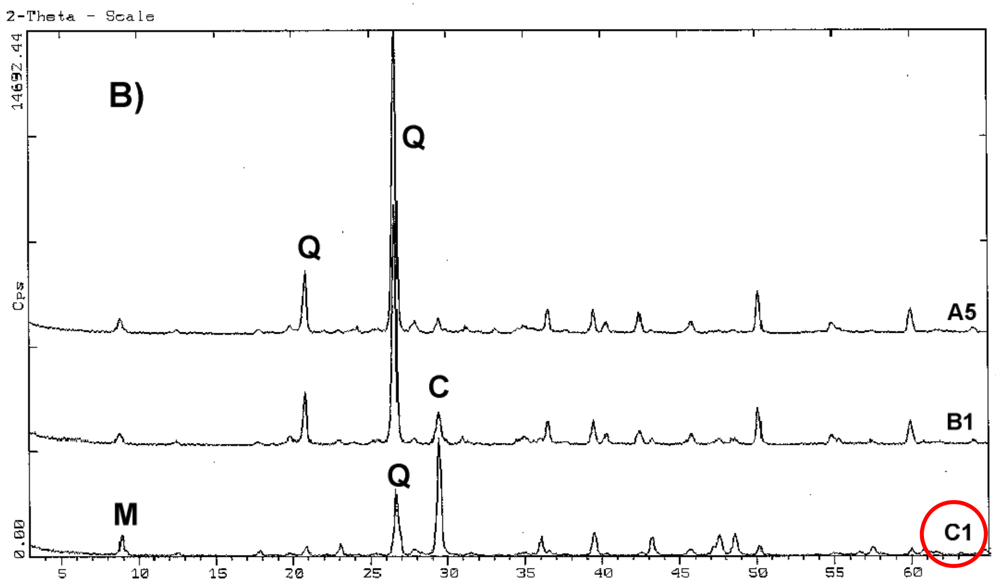

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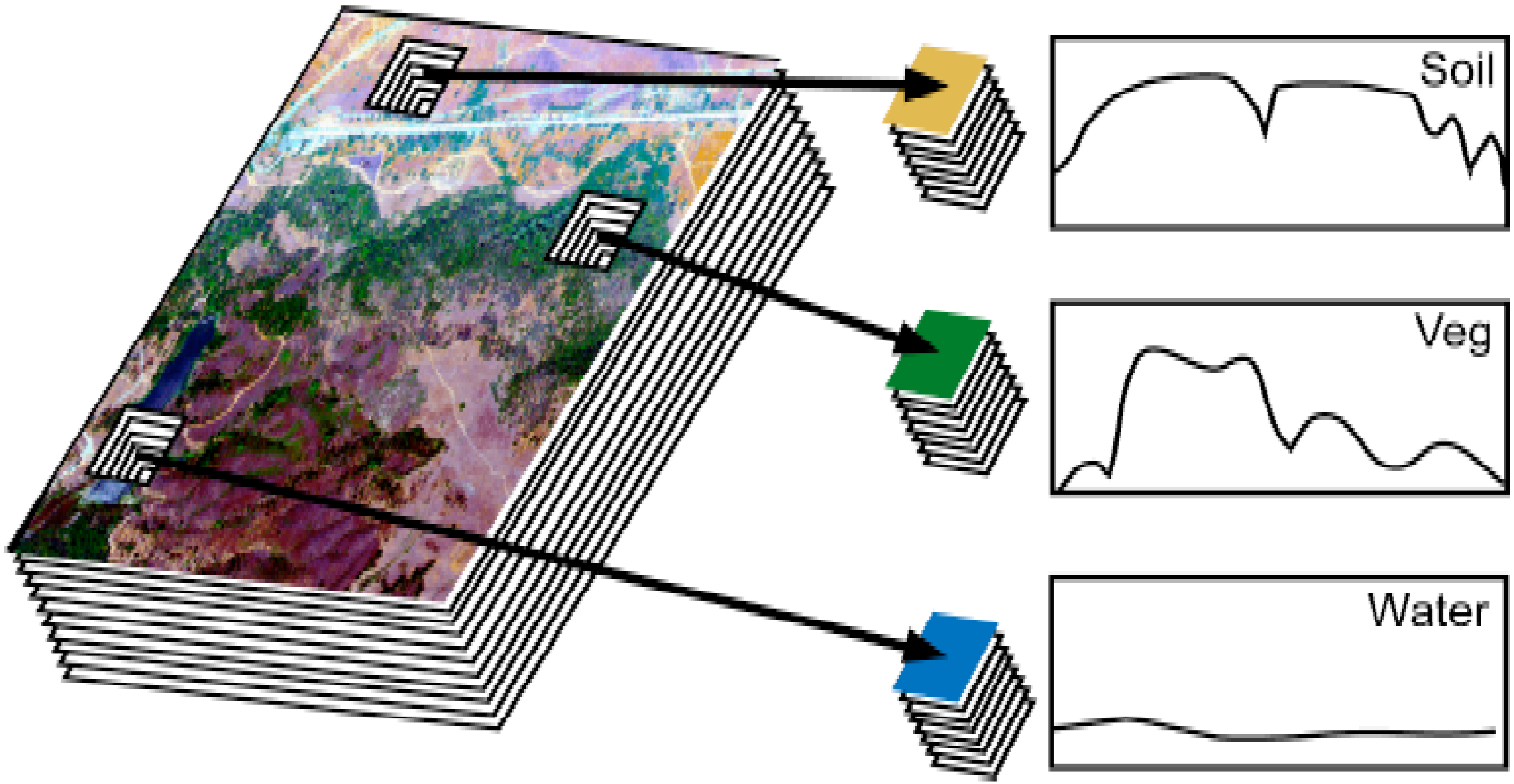


Figure 3. The concept of hyperspectral imagery. Image measurements are made at many narrow contiguous wavelength bands, resulting in a complete spectrum for each pixel.

Source: http://satjournal.tcom.ohiou.edu/pdf/shippert.pdf

Absorption processes

Electronic processes:

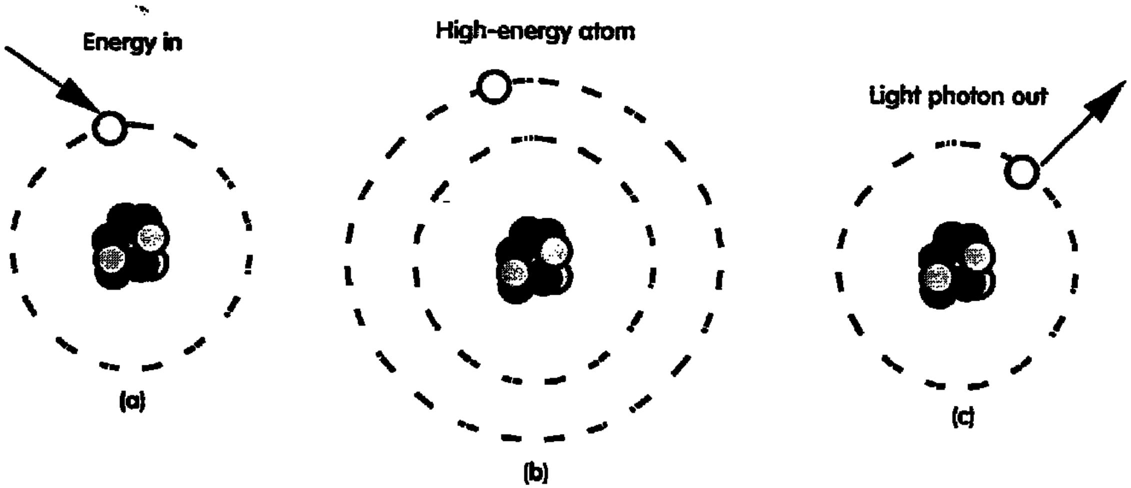
Isolated atoms and ions have discrete energy states. Absorption of photons of a specific wavelength causes a change from one energy state to a higher one.

Vibrational processes:

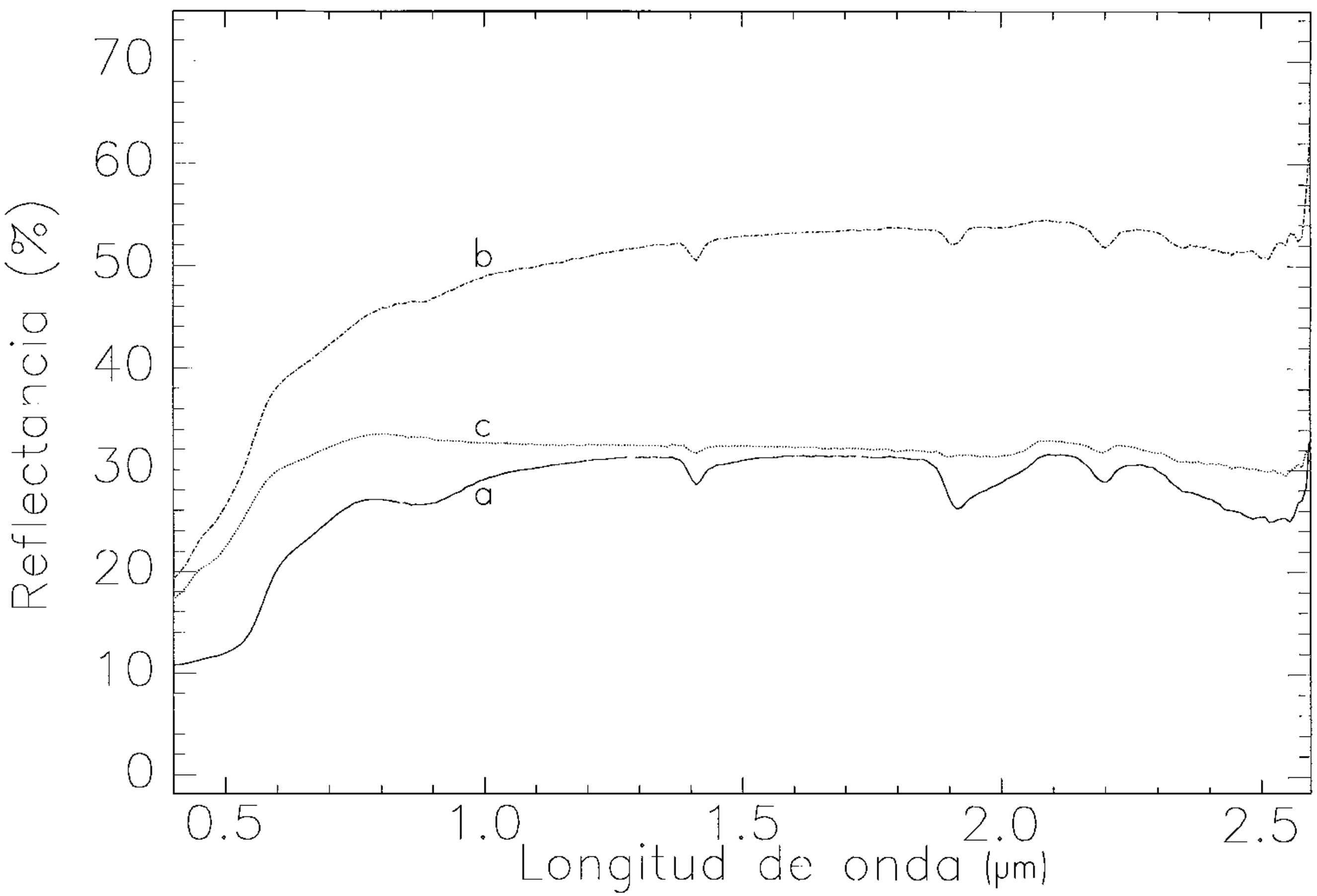
The bonds in a molecule or crystal lattice are like springs with attached weights: the whole system can vibrate

Electronic processes

- Isolated atoms and ions have discrete energy states. Absorption of photons of a specific wavelength causes a change from one energy state to a higher one.
- High energy - low wavelength
- Broad features
- Between 0.2 - 1.1 microns



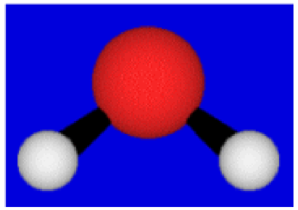
Absorption features



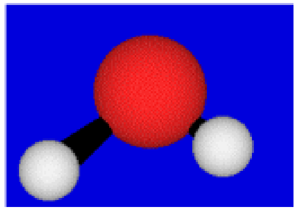
Vibrational processes

- The bonds in a molecule or crystal lattice are like springs with attached weights: the whole system can vibrate
- low energy - high wavelength (usually >2.5 µm)
- narrow features (10-20 nm)
- stretching of molecular bonds of
  - water, 1400 + 1900 nm
  - OH, 1400 nm
  - Al OH, 2200 nm
  - MG OH, 2300 nm
  - Ca CO3, 2320-2350 nm

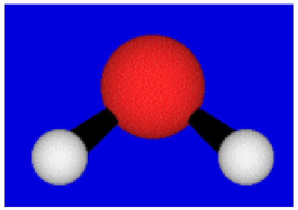
Stretching



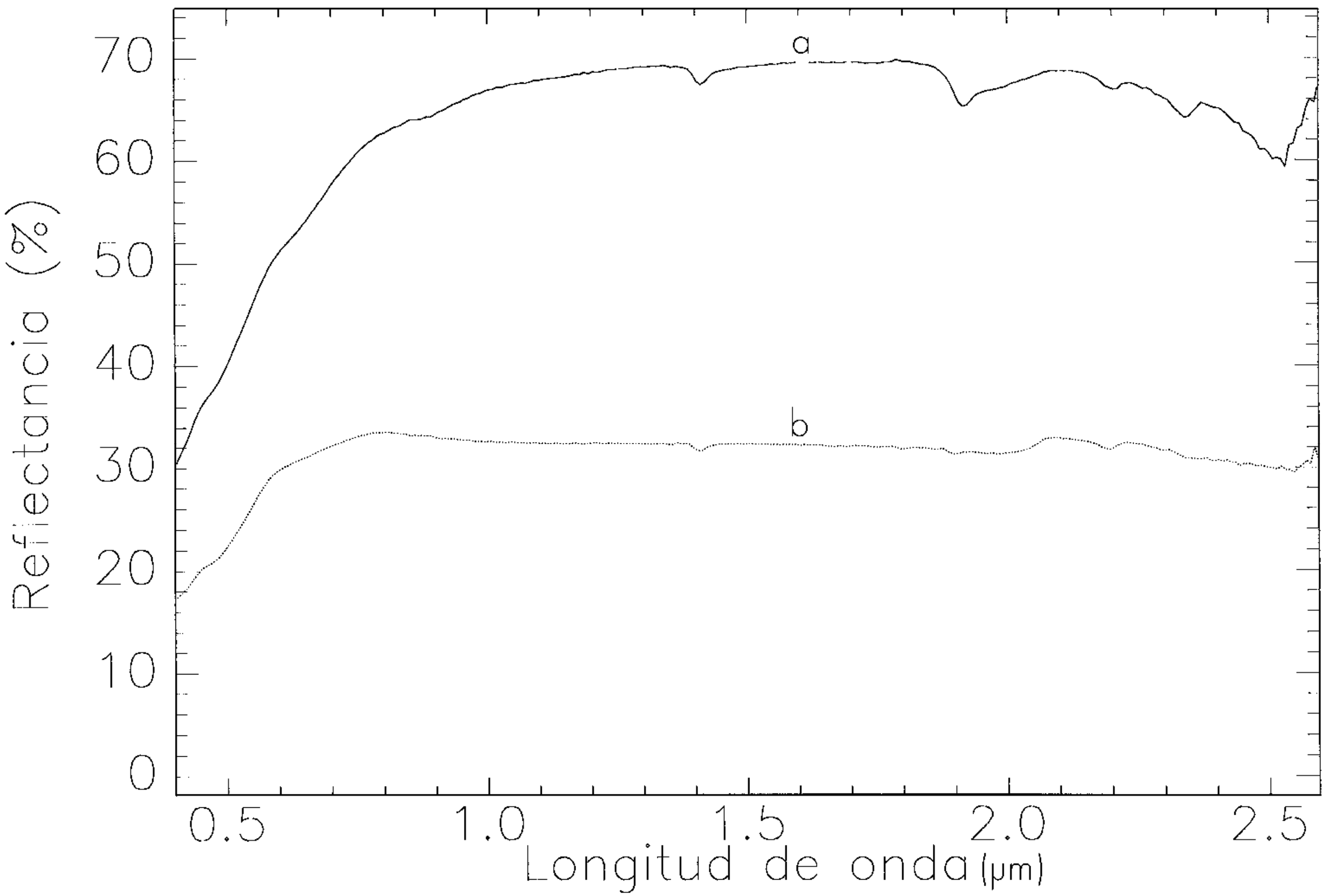
Asymetric Stretching



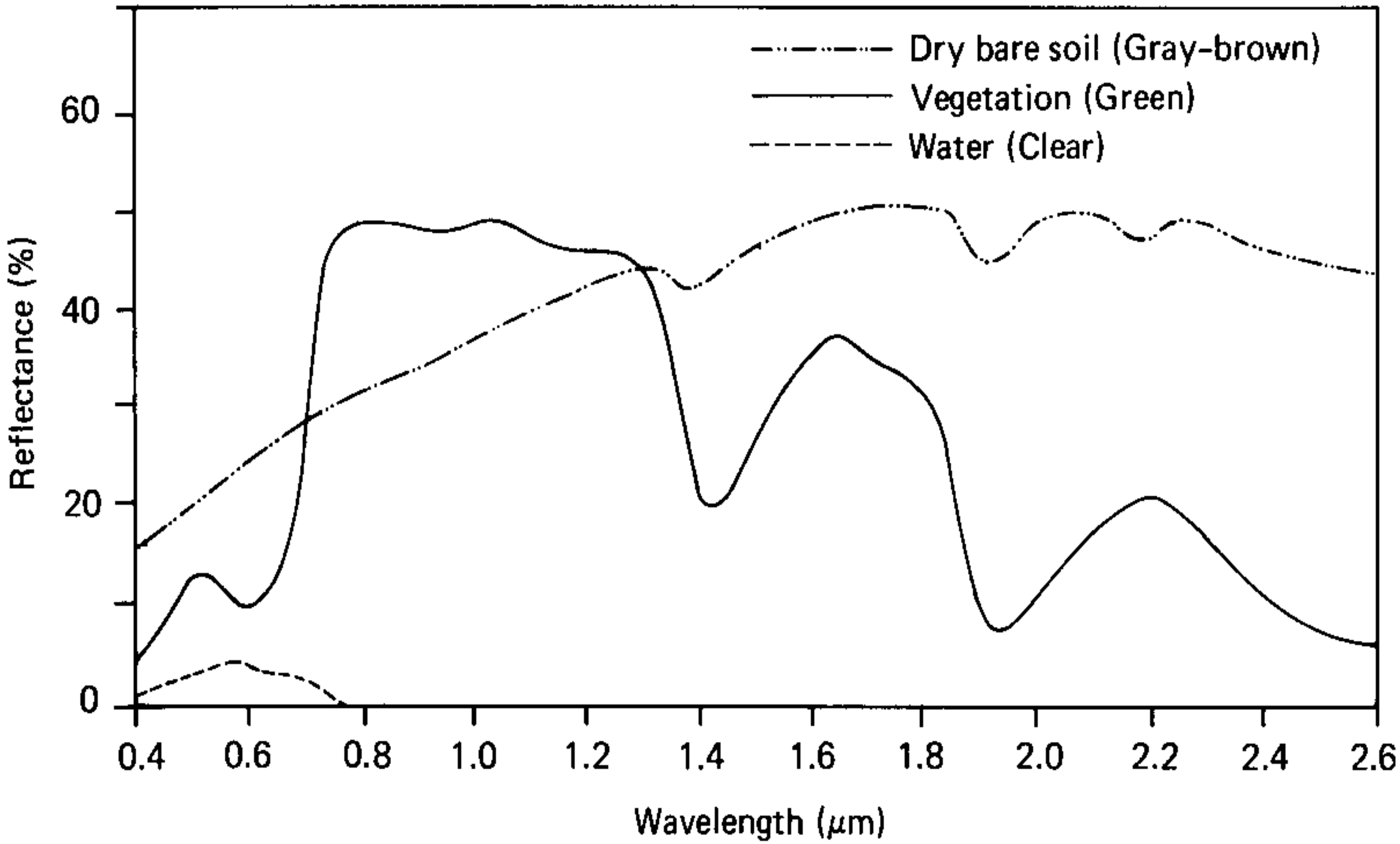
Bending



Absorption features

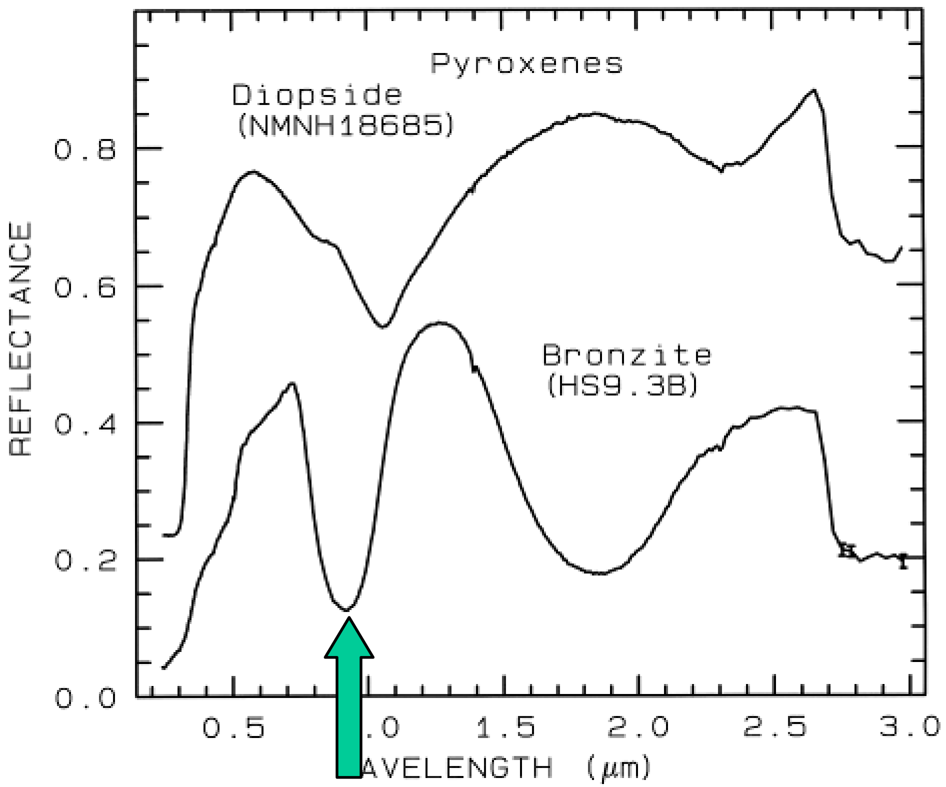


Absorption features



Spectral curves of the main land cover types (Swain & Davis, 1978)

Electronic processes: crystal field effects

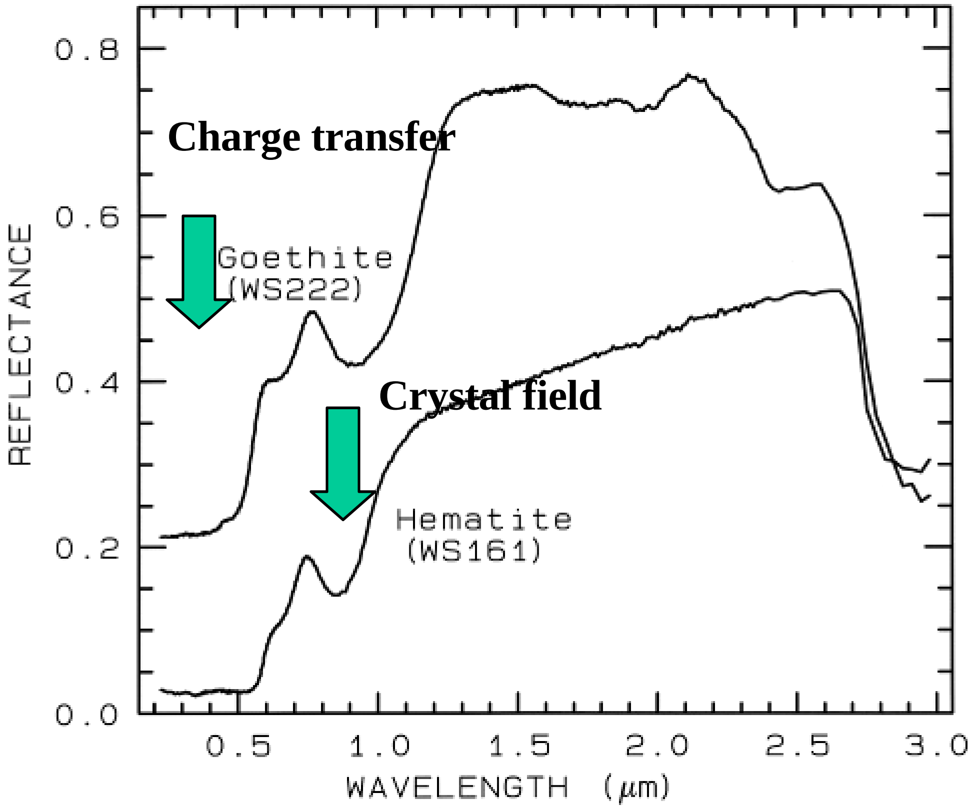


Reflectance spectra of two pyroxenes showing the change in Fe^{2+} -absorption band position and shape with composition

Crystal field: absorption due to unfilled electron shells, transition metals are promoted to higher shells, depends on crystal structure

- Absorption due to unfilled electron shells of transition elements (Ni, Cr, Co, Fe, etc.) that are excited/promoted to higher/lower shells. The allowed transitions are based on electrostatic field around atoms which in turns in dependent on the crystal structure.

Electronic processes: charge transfer bands



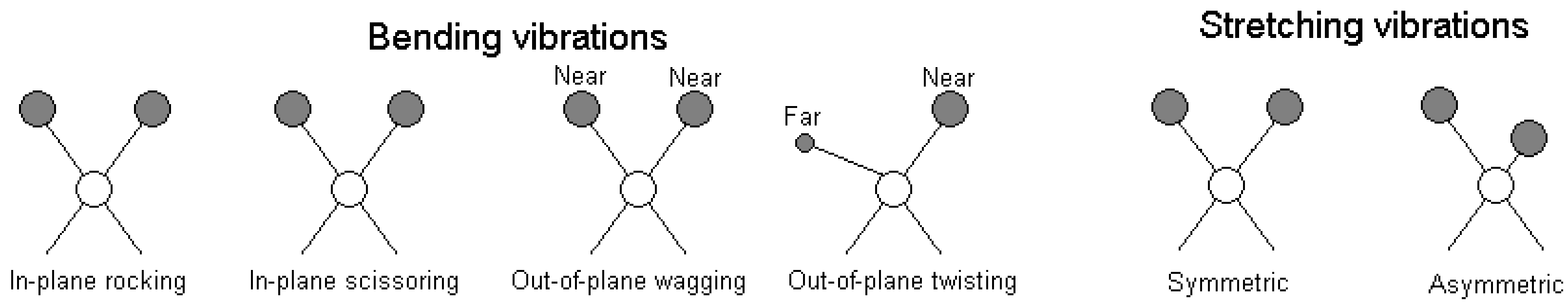
Intense charge-transfer band in the UV (< 0.4 µm) is "saturated" in reflectance, so only first surface reflection is seen in these spectra.

Absorption bands can also be caused by charge transfers, or inter-element transitions where the absorption of a photon causes an electron to move between ions. The transition can also occur between the same metal in different valence states, such as between

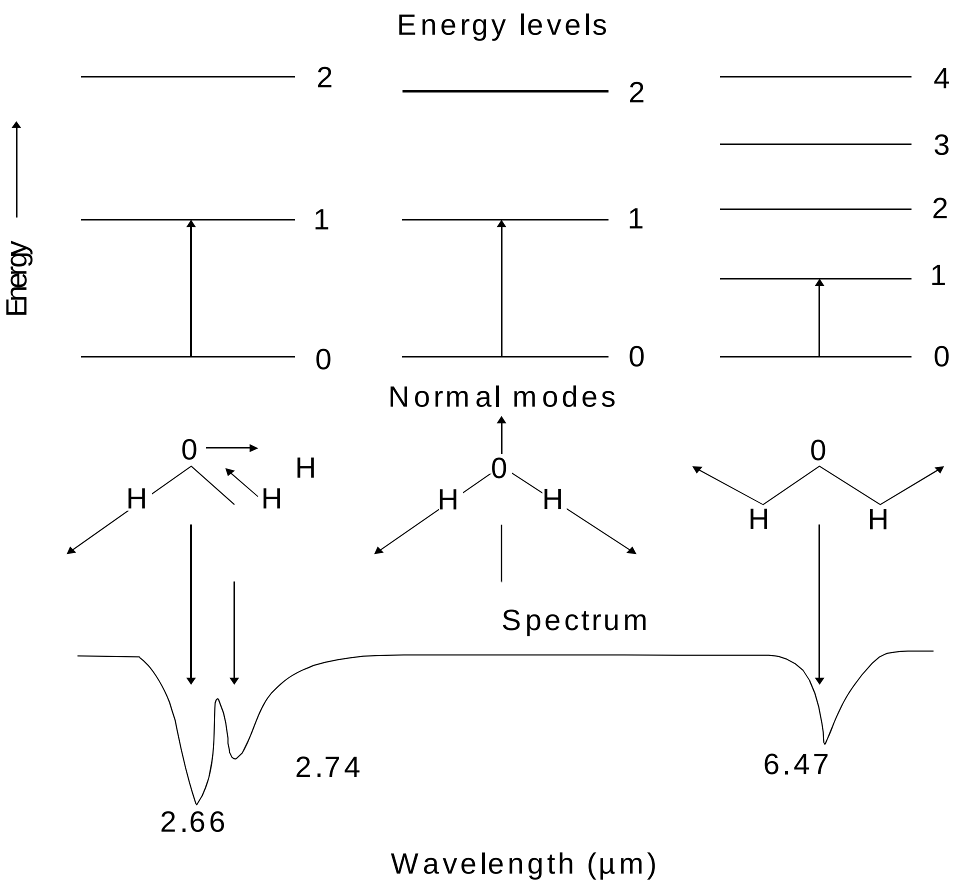
Fe^{2+} and Fe^{3+}.

Vibrational processes

- Different types of vibration possible
- Each have different energy levels
- Produce different absorption features
- Combination of absorption features can be diagnostic



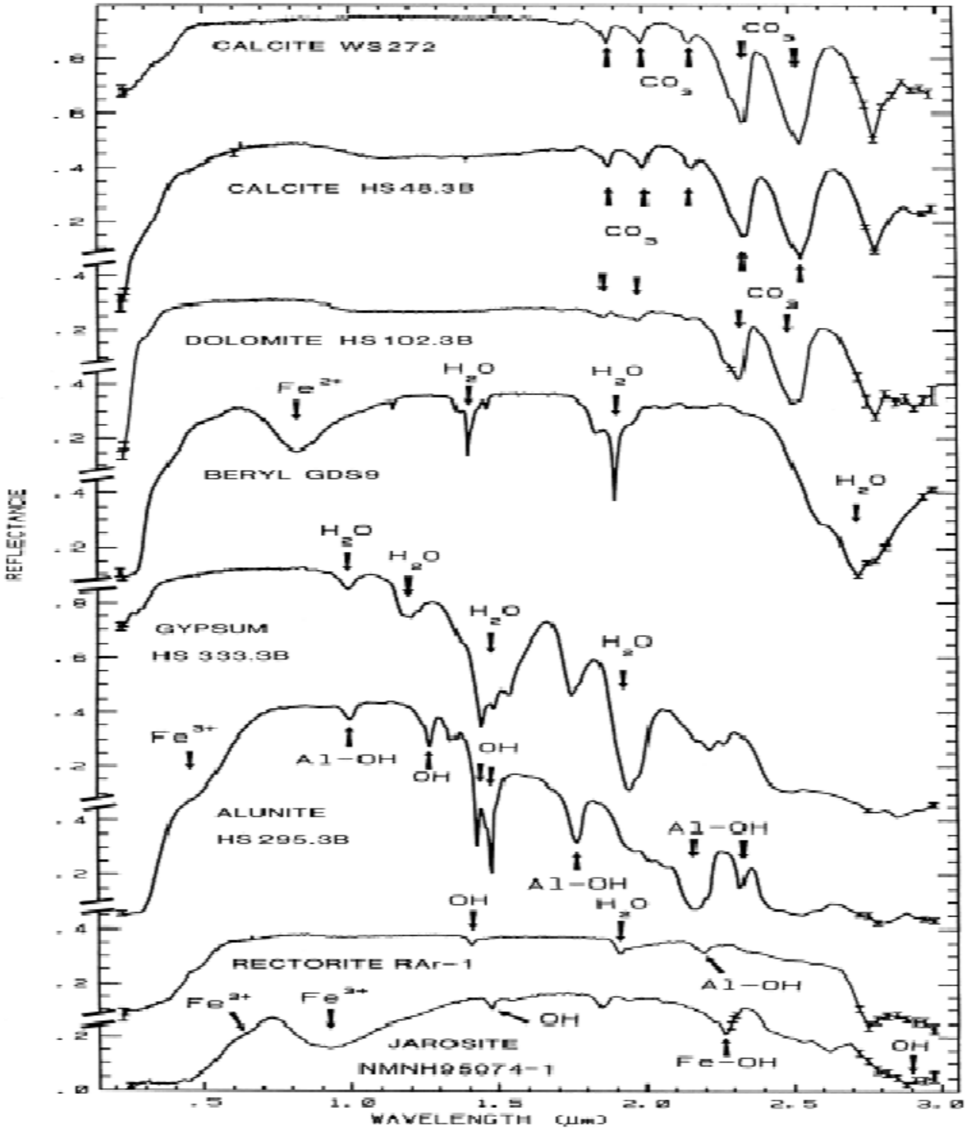
Vibrational processes



- The frequency of vibration depends on the strength of each spring (the bond in a molecule) and their masses (the mass of each element in a molecule).

The bonds in a molecule or crystal lattice are like springs with attached weights: the whole system can vibrate.

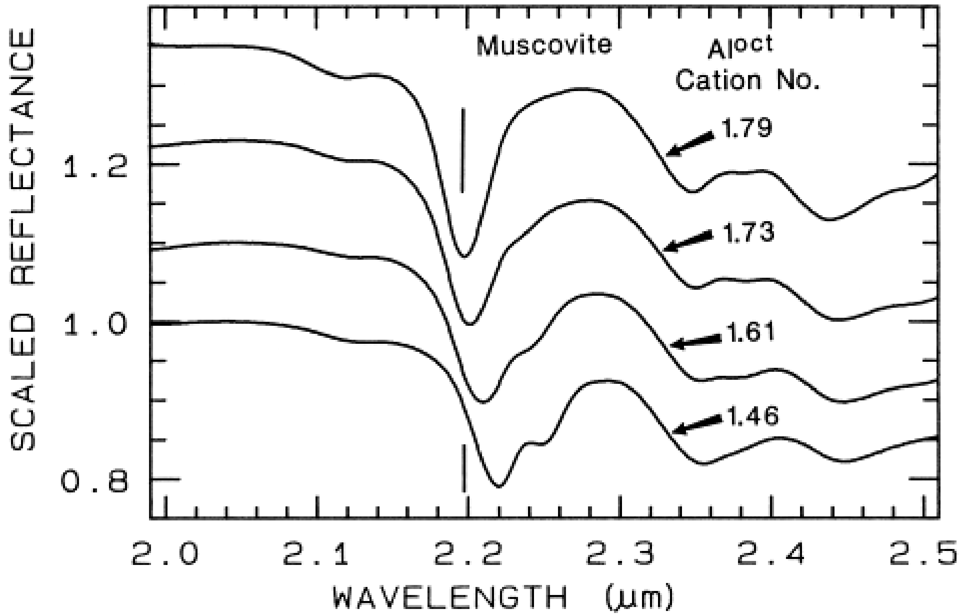
Vibrational processes



- Reflectance spectra of calcite, dolomite, beryl, gypsum, alunite, rectorite, and jarosite showing vibrational bands due to OH, CO_3 and H_2O.
- Water = 1.4 + 1.9
- CaCo3 = 2.32 - 2.35

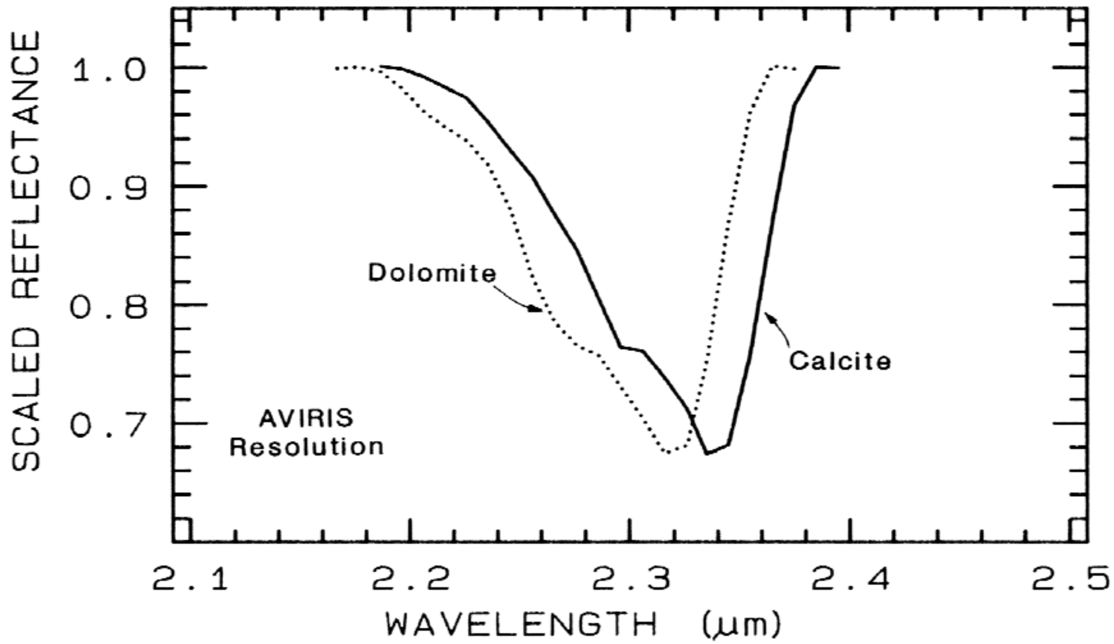
Vibrational processes

AL OH bond stretching!



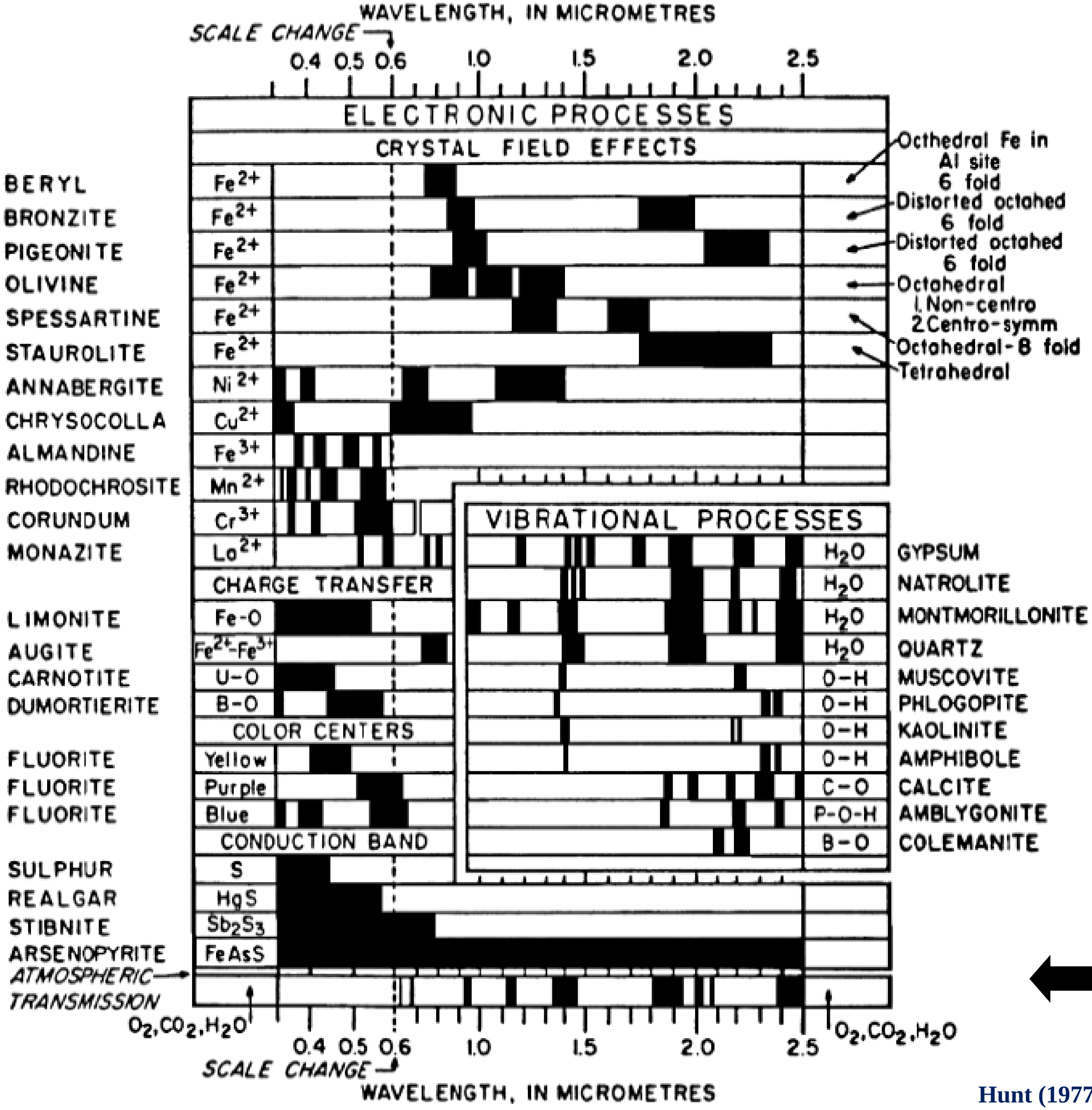
- Reflectance spectra of muscovite showing band shifts due to changing aluminum composition (as elements substitute for aluminum in the crystal structure).
- This graph illustrates that compositional information can be quantified from spectral data

Vibrational processes: Calcite vs. dolomite



- Comparison of calcite and dolomite continuum-removed features.

  Ca is heavier than Mg => calcite absorption occurs at a longer wavelength than the dolomite absorption.

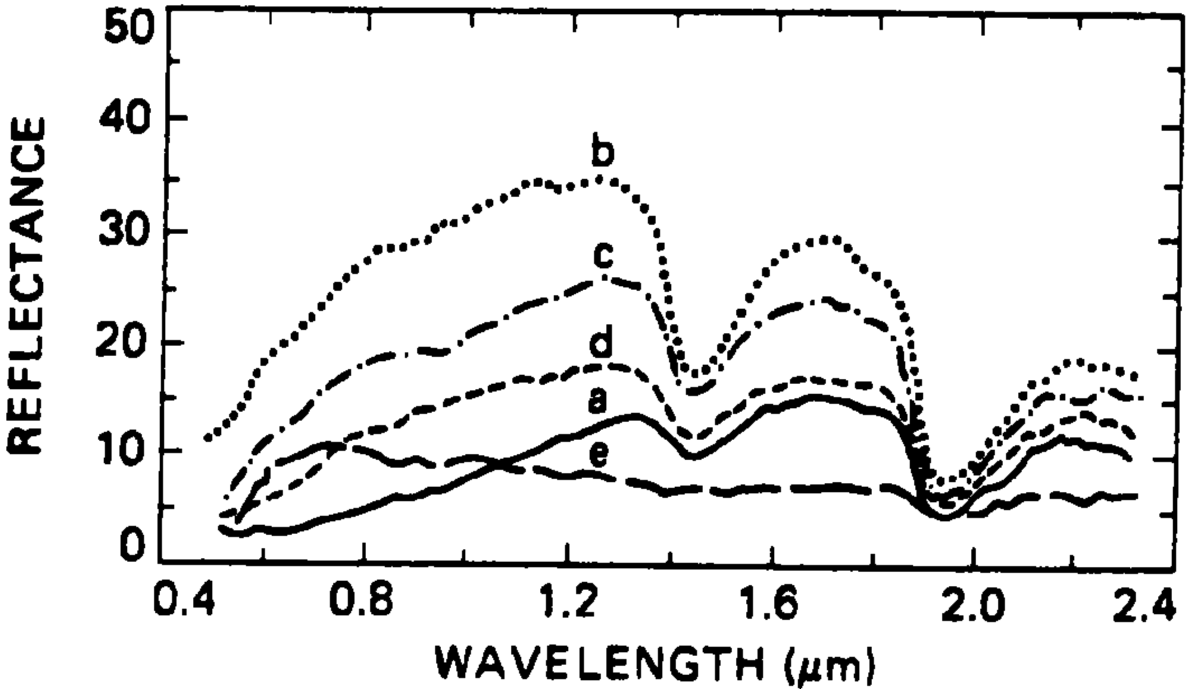


Rosetta stone
Egypt

Rosetta stone
spectra

Hunt (1977), Geophysics, 42, p. 501-513.

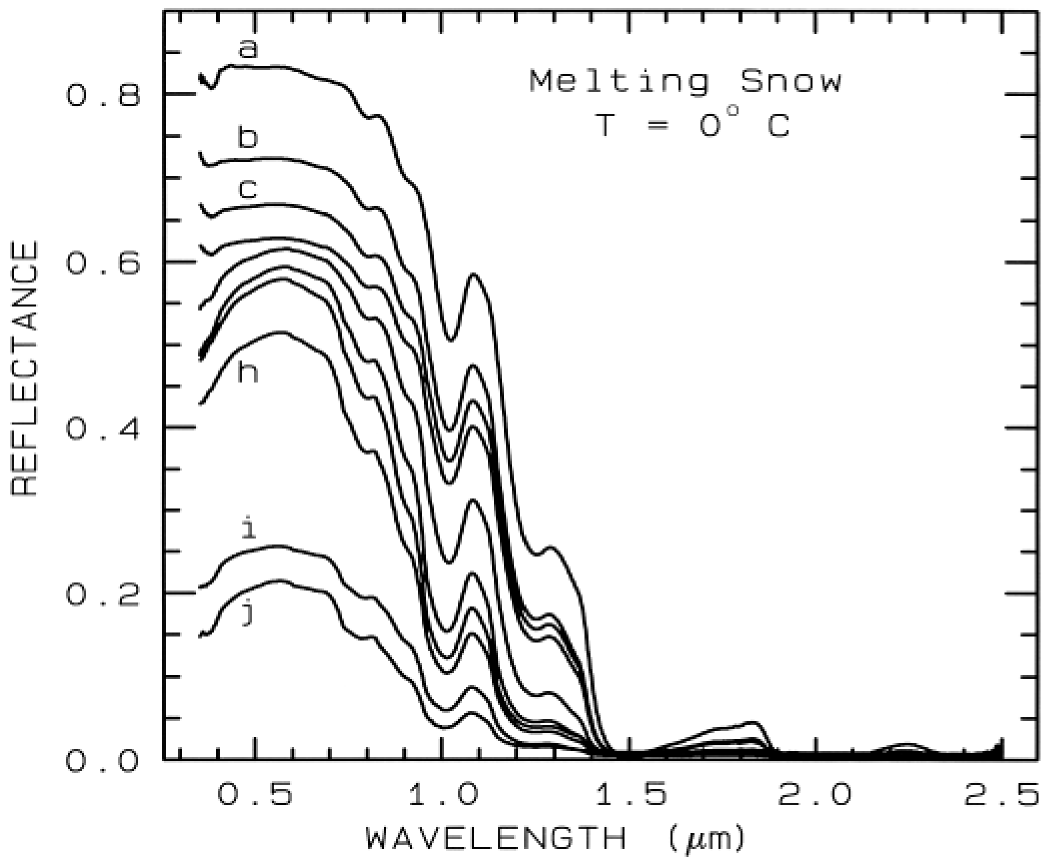
Soil spectral response



a = organic, b = altered, c = iron affected, d = organic affected, e = iron dominated

- Five soil spectral classes from over 190 spectra studied by Stoner (1979)

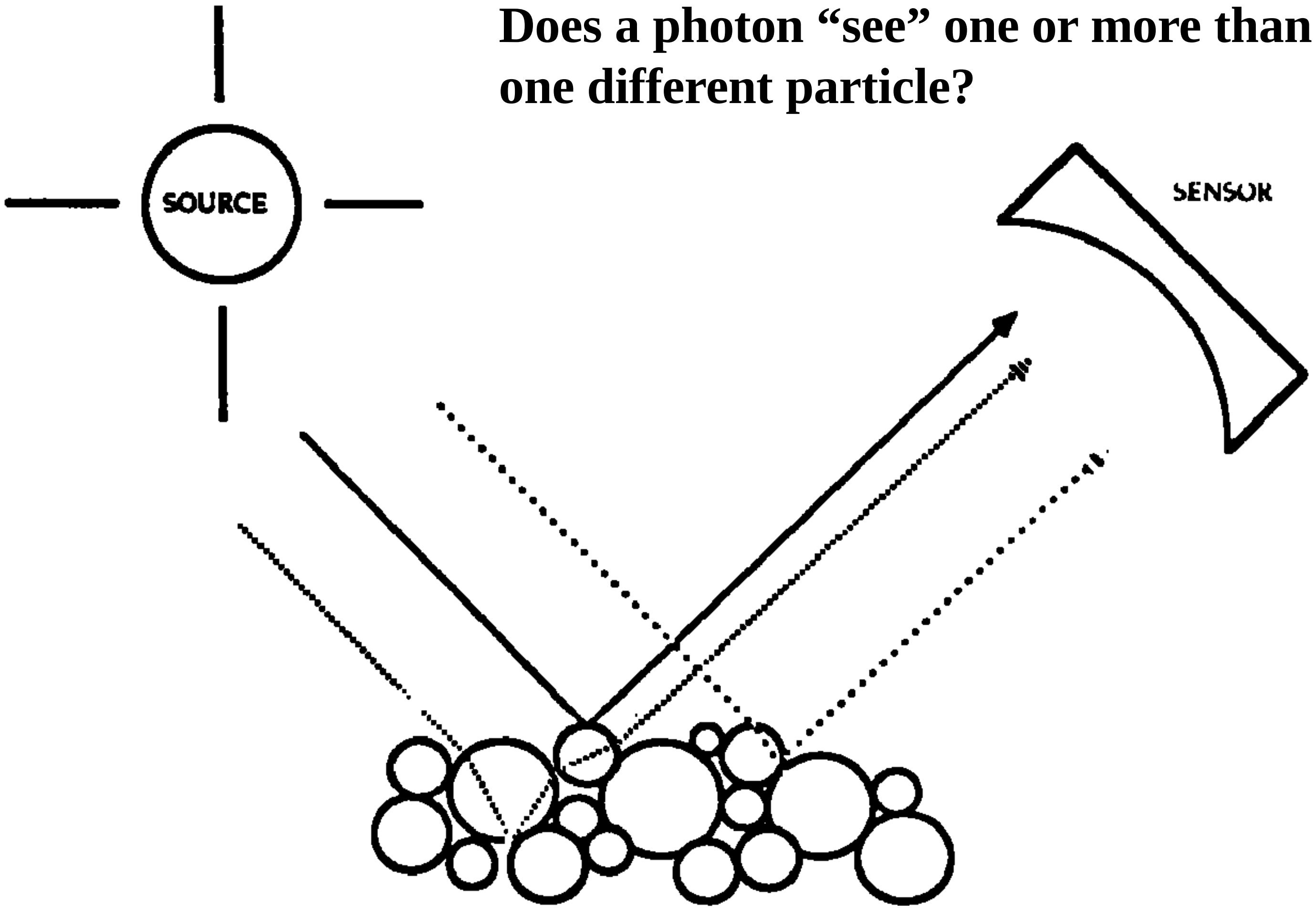
Spectral response of water and snow



- A series of reflectance spectra of melting snow. The top curve (a) is at 0º C and has only a small amount of liquid water, whereas the lowest spectrum (j) is of a puddle of about 3 cm of water on top of the snow.

Interaction at the surface

Does a photon "see" one or more than one different particle?



Mixtures of spectral signals

1)Linear Mixture**.** The materials in the field of view are optically separated so there is no multiple scattering between components. Signal = linear summation of endmembers + fractions

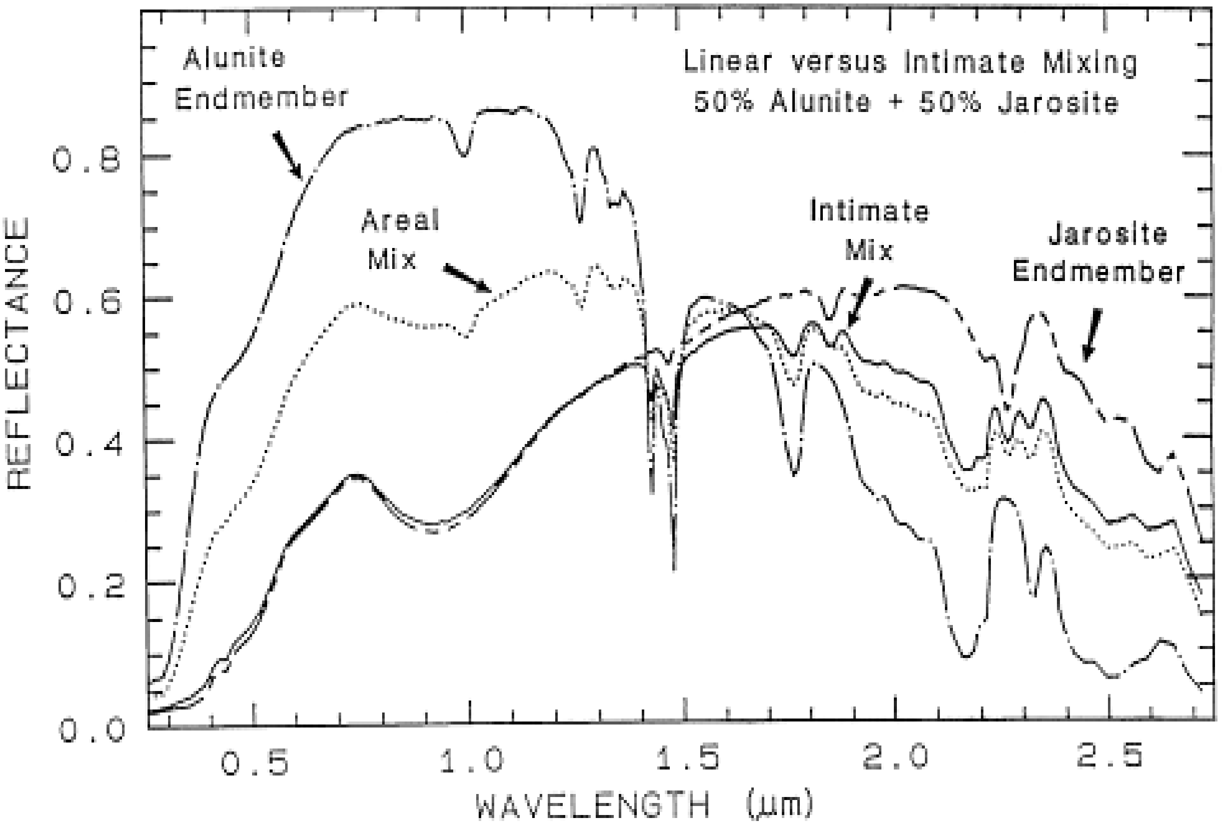
1)Intimate Mixture**.** An intimate mixture occurs when different materials are in intimate contact in a scattering surface, such as the mineral grains in a soil or rock. Highly non-linear

Mixtures of spectral signals (cont.)

***3)Coatings*.** Coatings occur when one material coats another. Each coating is a scattering/transmitting layer whose optical thickness varies with material properties and wavelength.

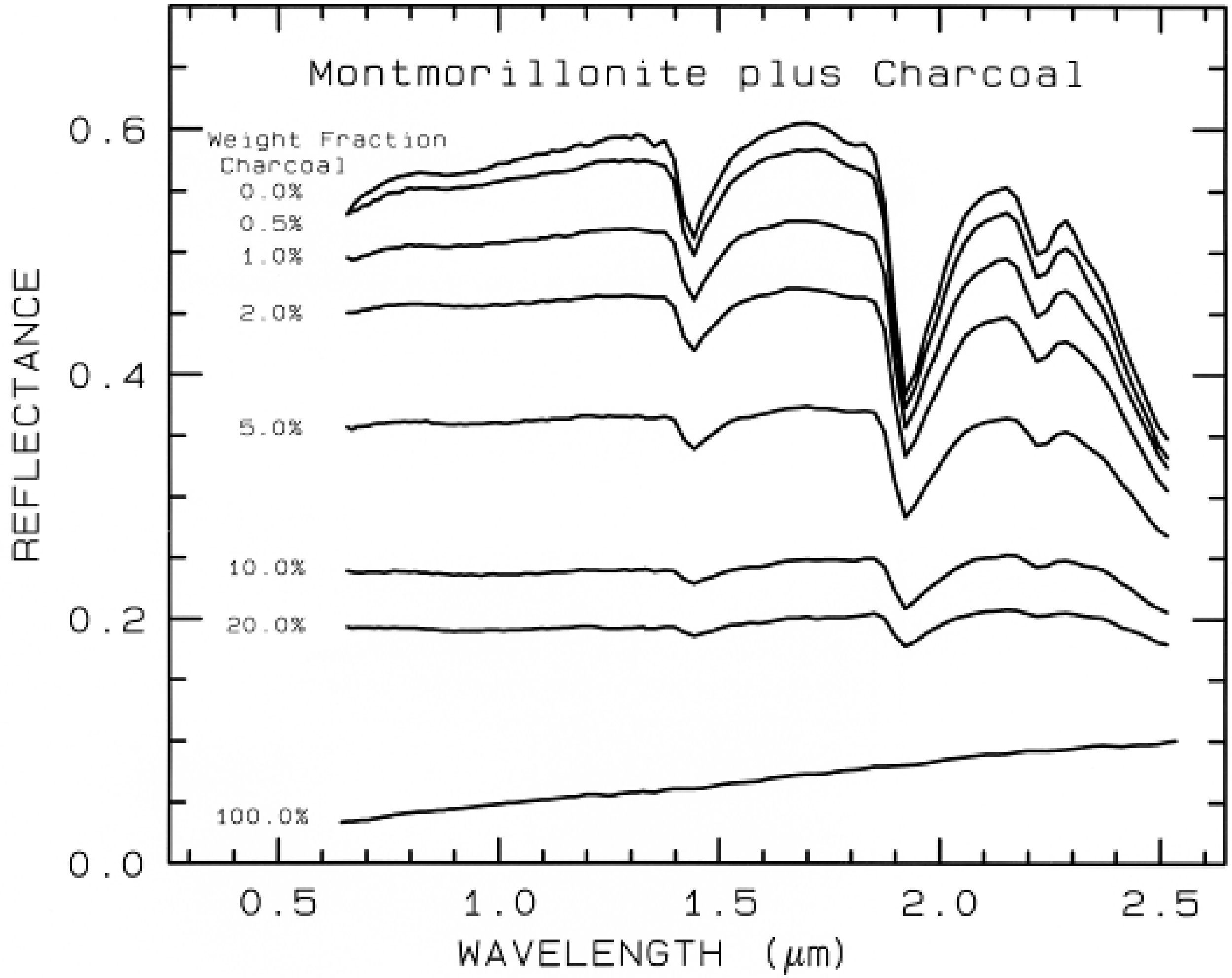
***4)Molecular Mixtures*.** Molecular mixtures occur on a molecular level, such as two liquids, or a liquid and a solid mixed together. Examples: water adsorbed onto a mineral; gasoline spilled onto a soil. The close contact of the mixture components can cause band shifts in the adsorbate, such as the interlayer water in montmorillonite, or the water in plants.

Linear and intimate mixtures



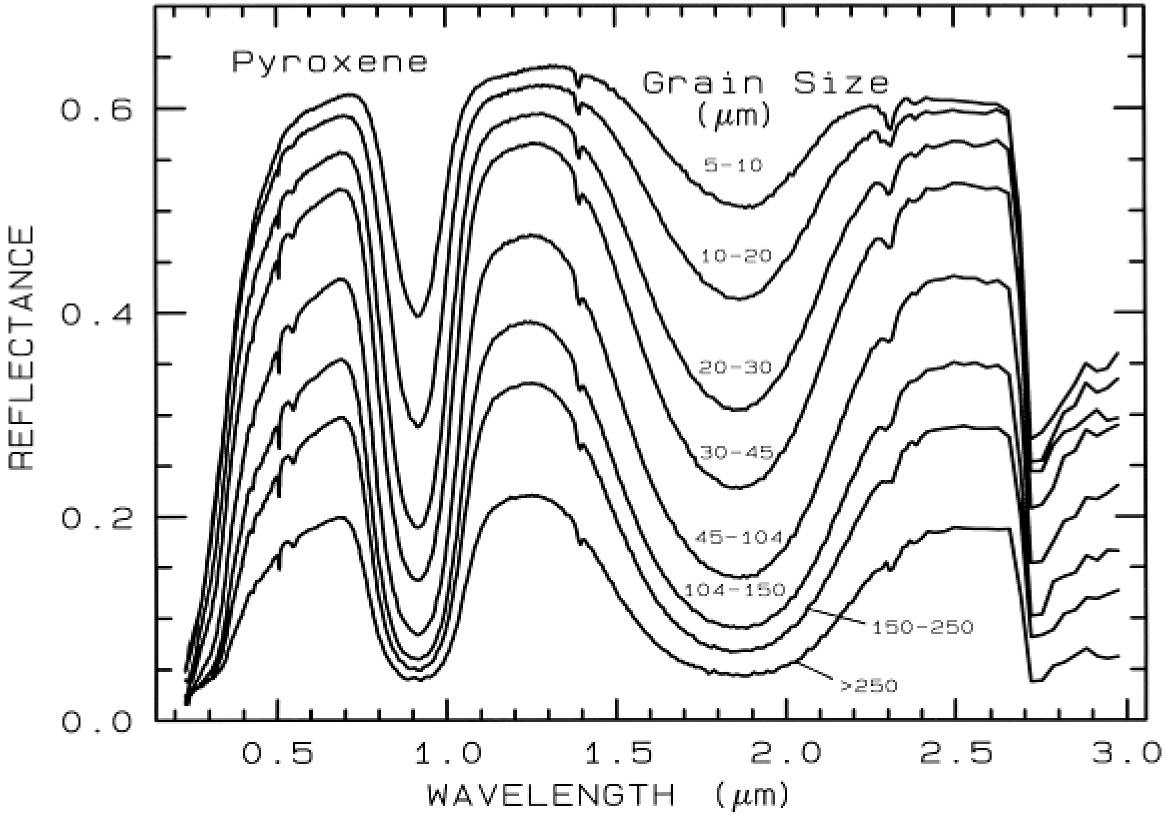
- Two mixture types are shown: intimate and areal. In the intimate mixture, the darker of the two spectral components tends to dominate, and in an areal mixture, the brighter component dominates. The areal mixture is a strictly linear combination.

Intimate mixing



- Reflectance spectra of intimate mixtures of montmorillonite and charcoal illustrates the non-linear aspect of reflectance spectra of mixtures. The darkest substance dominates at a given wavelength.

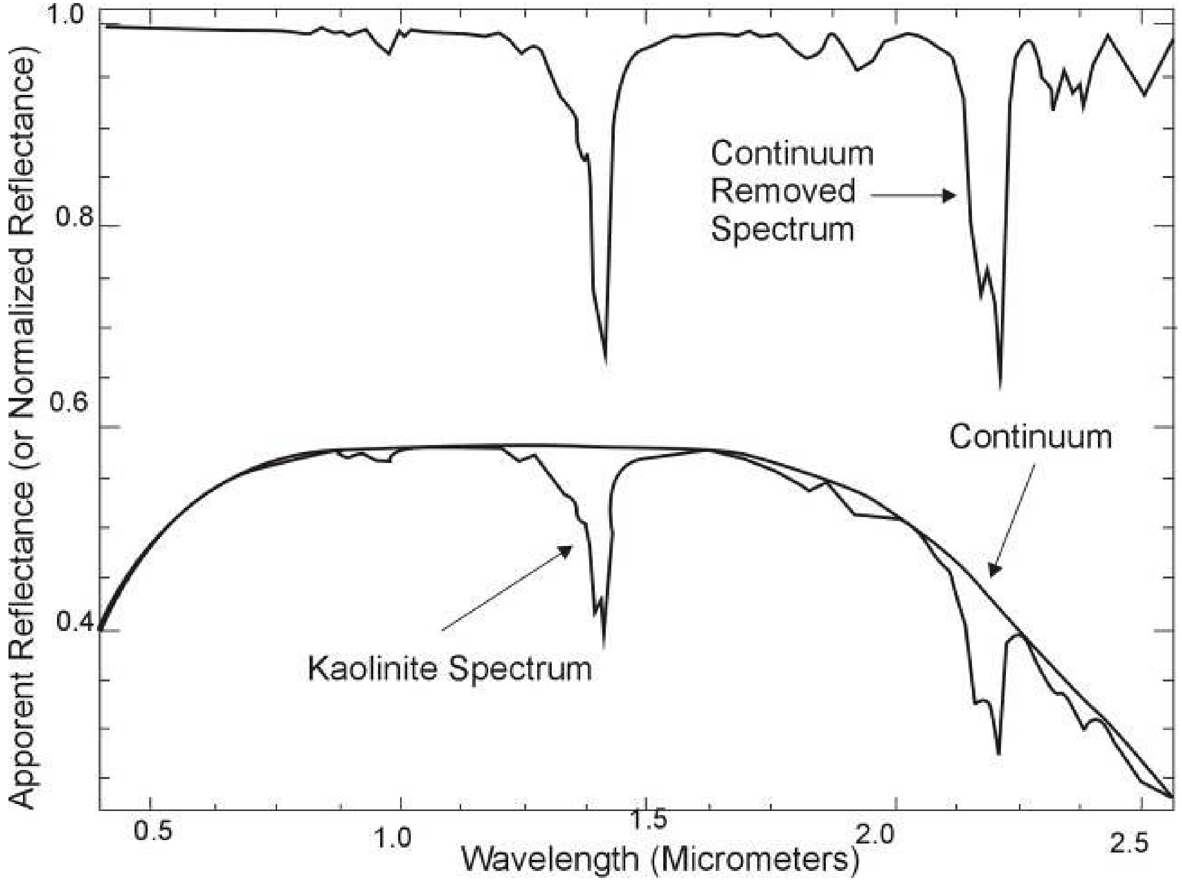
Grain size effects



>size = <albedo and <depth

- Reflectance Spectra of pyroxene as a function of grain size. As the grain size becomes larger, more light is absorbed and the reflectance drops

Continuum removal



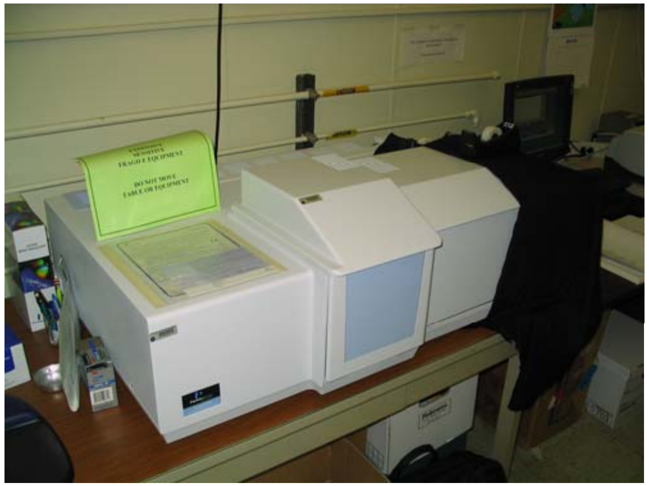
- Continuum removal fits an overall spectrum as 'rubber band' over the spectrum and removes this 'trend' thus leaving after removal only the local details (are absorption features). In this way we can better 'see' these features and we also standardize reflectance to a common continuum.

Spectral libraries

- SLI's are collections of spectra of different surface materials
- Often grouped by surface type (vegetation vs. soils vs. man-made materials etc.) and sometimes by grain size fraction (influence on spectra).

Spectral libraries

- Usually measured under laboratory conditions with excellent spectrometers and by well known USA research institutions (e.g. JPL, USGS, John's Hopkins University, etc.)



Nicolet (TIR) and Perkin-Elmer (UV-SWIR) spectrometers at JPL

Spectral libraries

- Availability
  - publicly available SLI's are included in ENVI
  - ASTER speclib on the internet
  - Create own from field/lab measurements
  - Create own from image (point measurements or average of ROI)

Sources

- Materials from
  - Chris Hecker
  - Freek van der Meer
  - Jelger Kooistra
  - Eduardo García-Meléndez