Wed. Apr. 11, 2018

• Lunar Geology Intro. for Wed. lab
• Finish “Environmental” Applications (Ocenas)
• Start Hewson paper (if time)

• Reading:
  – Skim Sabins Chapter 10. Oil Exploration
    • (link on class website "Reading List" Page)
Lunar Geology-- Overview

- Maria vs Terrae division
- Basalt vs. Anorthosite
Composition of Mare vs. Highlands

• **Highlands:** ANORTHOSITE
  
  (Ca feldspar)
  
  – Result of very early global magma ocean
    
    • If you melt lunar mantle completely, and let lighter material float to top, that top material will be ANORTHOSITE
  
  – Surface layers are “impact breccias”

• **Mare:** BASALT
  
  – Result of partial (10%) melt of mantle
    
    • First melting component has composition of basalt
  
  – Highly vesicular because because of “low” atmospheric pressure, even with (possible) low volatile abundances

From “The New Solar System” by Beatty et al.
Origin of the Anorthosite?
Bowen reaction series

- Anorthite and olivine are first minerals to crystallize
- Anorthosite is lower density than the melt and will float (especially for dry lunar melts)
- Olivine and pyroxene are denser and will sink
Different composition basalts

- Fe and Ti content vary and control albedo
- May represent changing thermal state of interior, and shifting source regions
Simple Albedo/Color Effects

Edge of Mare Serenitatis is darker, bluer

Several flows of different albedo, color in Mare Tranquillitatis
Spectral mapping

- Lucey et al., based on Clementine images

- Note high Ti abundance in Tranquillitatis and the rim of Serenitatis

Fe abundance  Ti abundance
Spectral angle method for Ti

- Lucey et al., technique, for Ti
- Note that Ti rich basalt is both dark and blue, but neither alone is enough to uniquely measure Ti as both observational measurements can be affected by other properties like Fe abundance, grain size. You need to measure both.
- Samples of constant Ti abundance fall along lines in left plot.
- Calibrated using observations at locations with measured Ti abundance from returned lunar samples, using right plot to convert $\theta$ to Ti abundance
- Note Ti not actually in form of TiO$_2$, but abundances typically given in terms of oxide percent.
Decision Tree Classification

- Create a decision tree where, based on some observed parameter, you first assign each pixel either to Class A or Class B
  - In this case, use NIR Albedo to assign pixel to either highlands or mare
- Continue to add branches to the tree making further decisions based on other observed parameters
  - Here, decide whether a mare pixel is high Ti or low Ti basalt based on a threshold Ti abundance
- Continue adding branches (decision “Nodes”) till you have each pixel fully classified
Determining vertical structure

- Remote vertical stratigraphy by comparing composition of crater walls (shallow material) vs. central peaks (deep material)

Pieters 1993
Ocean Remote Sensing

- Chlorophyll abundance
- Oil slicks
- Side-Scan Sonar
  - WHOI Side-Scan Sonar Search for Air France 447 debris
- Ocean Bottom Topography (bathymetry)
  - WHOI Side-Scan Sonar Search for Air France 447 debris
Modis: Channels for chlorophyll detection

- Follow-on to work described on Sabins pg. 301 Fig 9-4) with earlier CZCS (Costal Zone Sensor)

![Map showing chlorophyll distribution with CZCS bands graph]

- Upwelled spectral radiance (µW cm⁻² srad⁻¹ nm⁻¹)
  - Symbol: mg m⁻³
  - Band 1: 0.09, 0.86, 7.66, 60.40
  - Band 2: 2.67, 0.46, 0.05, 0.04
  - Band 3: 2.00, 1.08, 0.50, 0.36
  - Band 4: 2/3, 2/3, 2/3, 2/3

- Chlorophyll vs Wavelength, µm
  - Values: 0.09, 0.86, 7.66, 60.40
Oil Slicks: Deepwater Horizon Spill 2010

From NASA MODIS (via wikipedia)
Ocean Floor Topography

• Bathymetry -- traditional work limited to ship tracks

• Indirect observations available from ocean surface height
  – Provide global (but low resolution) picture of sea floor

• Side-Scan Sonar – Analogous to synthetic aperture radar but using sound waves rather than EM ones
Side-Scan Sonar

- University of Hawaii System
Overall topography of Hawaiian Islands

Detail in next slide
Side-Scan Sonar

- Data acquired in strips, as side scan sonar towed behind ship
Side-Scan Sonar and Air France 447 Search: Remus 6000

• Results from last spring:
Woods Hole Oceanographic Institution REMUS 6000 ROV's

• Side-Scan Sonar search system

• Can operate to 6000 m (~20,000 ft) Crash side depth is 10,000 ft

• 5 knot speed

• 22 hour mission duration (Li-ion batteries)
Air France 447 Search: Sonar and Photos

• Debris field formed as material settles to depth (Arrows are 600 m x 200 m)
Ocean Floor Topography

- Data from European ERS-1 altimeter and Navy Geosat
Ocean Floor Topography

- Data from European ERS-1 altimeter and Navy Geosat
- Measure height of satellite above ocean using 13 GHz radar
- Accurate to 3 cm
- Track orbit of satellite with GPS and laser systems

Extra gravity from mountain pulls water in from the sides, raising sea level slightly
Ocean Floor Topography

- West pacific subduction zones
- Chains of volcanoes