Mon. Feb. 12, 2018

• Landsat Orbits
• Landsat Instrument Overview
• Landsat interpretation
  – Bands and typical uses
  – Various display options
  – Thermopolis
  – Atlas Mountains – details
  – Arabian Arch (see also pg. 346-355)
Landsat Spacecraft

• Landsat 1, 2, 3 First generation (1972, 1975, 1978)
  – Multispectral Scanner (MSS)
  – Thematic Mapper (TM)
  – #5 Will be retired shortly -- has problems.
• Landsat 7 Second+ generation (1999)
  – Enhanced Thematic Mapper ETM+
  – Still running, with some hardware glitches
• Landsat 8 (Landsat Data Continuity Mission =LDCM)
  – Launched Feb. 2013. Nominal 5 year life

Figure 3-1 Reflectance spectra of vegetation and sedimentary rocks, showing spectral ranges of Landsat MSS and TM bands.
Landsat Orbits

- Near-Polar – so it covers all the earth
- Sun synchronous (precesses once per year to keep local time constant)
  - Landsat passes S over US ~10 AM
  - Many other satellites in the “AM Constellation” or “AM Train”
  - Others in the “PM” Train

Sabins, Fig. 03-12 & -13
Landsat Path and Row

- Earth rotates E by 
  \[\sim 100 \text{ min} \times 1000 \text{ MPH} = 1700 \text{ miles} \sim 2700 \text{ km} \text{ between orbits.}\]

- Landsat has swath width of \(~185 \text{ km}\)

- Over 16 day cycle it fills in gaps between the orbits, so it covers all the earth

- Number of paths: 
  \[233 \approx 16 \text{ days} \times 14.5 \text{ orbits/day}\]

- Spaced at \(~165 \text{ km}\) to provide \(~7.6\%\) overlap at equator, more at higher latitude

- Renumbered “PATHS” increase consecutively to the W

- N/S data “continuous” but break into “ROWS” also spaced at 165 KM

- Given PATH,ROW specifies given location on earth: LA: Path 41, Row 36

- Orbits (and PATH,ROW system slightly different for earliest 3 Landsats

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Figure 3-14 Path-and-row index map of the southwestern United States for Landsats 4 and 5. Image A at path 41, row 36 covers Los Angeles. Image B on path 40 between rows 31 and 32 is located with an optional shift of 50 percent to the south.

Sabins, Fig. 03-12 & -13
Color combinations of Landsat TM bands, Thermopolis, Wyoming.

**Display colors**

- **1-2-3**: Normal color image. Optimum for mapping shallow bathymetric features.
- **2-3-4**: IR color image. Moderate spatial resolution.
- **4-5-7**: Optimum for humid regions. Maximum spatial resolution.
- **2-4-7**: Optimum for temperate to arid regions. Maximum spectral diversity.

*TM bands are listed in the sequence of projection colors: blue-green-red.*
Thermopolis Landsat
2-4-7 = RGB Display

D. IR plus visible color. Bands 2-4-7 = BGR.

H. Interpretation map. Stippled areas are outcrops of Chugwater red beds.
### Table 3-6: Formations in the Thermopolis TM 2-4-7 subscene

<table>
<thead>
<tr>
<th>Formation</th>
<th>Age</th>
<th>Lithology</th>
<th>Image signature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvial deposits</td>
<td>Quaternary</td>
<td>Soil in floodplains of major streams. Flat valley floors with irrigated fields.</td>
<td>Bright green.</td>
</tr>
<tr>
<td>Fort Union Formation</td>
<td>Early Tertiary</td>
<td>Resistant sandstone with minor shale beds. Prominent, eroded dipslopes.</td>
<td>Dark pink.</td>
</tr>
<tr>
<td>Meeteetsee and Lance Formations</td>
<td>Late Cretaceous</td>
<td>Nonresistant shale and sandstone. Broad valley with minor ridges.</td>
<td>Medium pink.</td>
</tr>
<tr>
<td>Mesaverde Formation</td>
<td>Late Cretaceous</td>
<td>Resistant sandstone with shale and coal beds. Alternating ridges and valleys.</td>
<td>Medium pink.</td>
</tr>
<tr>
<td>Cody Shale</td>
<td>Late Cretaceous</td>
<td>Nonresistant shale. Broad valley with minor ridges.</td>
<td>Light pink.</td>
</tr>
<tr>
<td>Frontier Formation</td>
<td>Late Cretaceous</td>
<td>Alternating sandstone and shale. Narrow ridges and valleys.</td>
<td>Dark pink.</td>
</tr>
<tr>
<td>Undifferentiated Formations</td>
<td>Early Cretaceous</td>
<td>Alternating sandstone and shale. Narrow ridges and valleys.</td>
<td>Dark pink and light blue.</td>
</tr>
<tr>
<td>Chugwater Formation</td>
<td>Triassic</td>
<td>Red sandstone and siltstone. Alternating ridges and valleys.</td>
<td>Yellow and orange.</td>
</tr>
</tbody>
</table>

D. IR plus visible color. Bands 2-4-7 = BGR.
Thermopolis Landsat Detailed Map

Figure 3-8 Interpretation map for the Thermopolis subscene.
Figure 3-8 Interpretation map for the Thermopolis subsence.
Atlas Mountains
TM 2,4,7  Plate 6
Atlas Mountains
TM 2,4,7 Plate 6

Map patterns

<table>
<thead>
<tr>
<th>Rock units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ridge. Light and dark blue</td>
</tr>
<tr>
<td>2. Slope. Dark red and purple. Resistant key bed</td>
</tr>
<tr>
<td>3. Ledges. Light to dark pink and red.</td>
</tr>
<tr>
<td>4. Slope. Largely covered with sand and gravel of various hues.</td>
</tr>
<tr>
<td>5. Ledge. Light blue.</td>
</tr>
<tr>
<td>Qay. Younger alluvium.</td>
</tr>
</tbody>
</table>

Figure 3-17 Stratigraphic column for interpreting the TM image in the Saharan Atlas Mountains, Algeria.
Interpretation Steps

1. Establish sequence of mappable units, from literature or directly from image.
2. Determine attitude of beds (dipslopes, antidip scarps, etc.)
3. Interpret folds and faults (based on outcrop patterns and attitudes)
4. Prepare cross section to accompany interpretation map
5. Check interpretation in the field.

(from Sabins, pg. 89)
Rule of V's

- Block images from Marli Miller's website at University of Oregon
  - <http://pages.uoregon.edu/millerm/>
- Block models originally by John Lewis at Colorado College

- In a “constant profile” valley across otherwise flat terrain:
  - A horizontal bed would show as two lines along the side of the valley
  - A vertical bed would show as a straight line
  - A dipping bed would show a v pointing in the direction of dip
Rule of V's

– Often we have steep topography here
  • If beds are horizontal then as seen from above outcrops look like contours
    – The v will point upstream on tributaries
  • Becomes a question of whether dip of bed is steeper or shallower than the surface slope
  • Following also from <<http://pages.uoregon.edu/millerm/>>
Central Arabian Arch
TM 2,4,7  Plate 4

Plate 4  Analog mosaic of the Central Arabian Arch compiled from Landsat TM 2-4-7 prints.

See also pg. 346-355
Interpretation Steps

1. Establish sequence of mappable units, from literature or directly from image.
2. Determine attitude of beds (dipslopes, antidip scarps, etc.)
3. Interpret folds and faults (based on outcrop patterns and attitudes)
4. Prepare cross section to accompany interpretation map
5. Check interpretation in the field.

(from Sabins, pg. 89)
# TM band combinations

**Table 3-4** Landsat thematic mapper (TM) spectral bands

<table>
<thead>
<tr>
<th>Band</th>
<th>Wavelength, µm</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.45 to 0.52</td>
<td>Blue-green. Maximum penetration of water, which is useful for bathymetric mapping in shallow water. Useful for distinguishing soil from vegetation and deciduous from coniferous plants.</td>
</tr>
<tr>
<td>2</td>
<td>0.52 to 0.60</td>
<td>Green. Matches green reflectance peak of vegetation, which is useful for assessing plant vigor.</td>
</tr>
<tr>
<td>3</td>
<td>0.63 to 0.69</td>
<td>Red. Matches a chlorophyll absorption band that is important for discriminating vegetation types.</td>
</tr>
<tr>
<td>4</td>
<td>0.76 to 0.90</td>
<td>Reflected IR. Useful for determining biomass content and for mapping shorelines.</td>
</tr>
<tr>
<td>5</td>
<td>1.55 to 1.75</td>
<td>Reflected IR. Indicates moisture content of soil and vegetation. Penetrates thin clouds. Provides good contrast between vegetation types.</td>
</tr>
<tr>
<td>6</td>
<td>10.40 to 12.50</td>
<td>Thermal IR. Nighttime images are useful for thermal mapping and for estimating soil moisture.</td>
</tr>
<tr>
<td>7</td>
<td>2.08 to 2.35</td>
<td>Reflected IR. Coincides with an absorption band caused by hydroxyl ions in minerals. Ratios of bands 5 and 7 are used to map hydrothermally altered rocks associated with mineral deposits.</td>
</tr>
</tbody>
</table>

**Display colors**

<table>
<thead>
<tr>
<th>Display colors*</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2-3</td>
<td>Normal color image. Optimum for mapping shallow bathymetric features.</td>
<td>Lower spatial resolution due to band 1. Limited spectral diversity because no reflected IR bands are used.</td>
</tr>
<tr>
<td>2-3-4</td>
<td>IR color image. Moderate spatial resolution.</td>
<td>Limited spectral diversity.</td>
</tr>
<tr>
<td>4-5-7</td>
<td>Optimum for humid regions. Maximum spatial resolution.</td>
<td>Limited spectral diversity because no visible bands are used.</td>
</tr>
<tr>
<td>2-4-7</td>
<td>Optimum for temperate to arid regions. Maximum spectral diversity.</td>
<td>Unfamiliar color display, but interpreters quickly adapt.</td>
</tr>
</tbody>
</table>

*TM bands are listed in the sequence of projection colors: blue-green-red.
Linear Features

- Linear: Adjective
- Lineation: 1-D fabric in a rock
- Lineament: Linear or curvilinear feature on a map or image

Figure 3-24 Landsat MSS band 4 image of the Peninsular Ranges, southern California. From Lamar and Merifield (1975, Figure 3). Courtesy P. M. Merifield, UCLA.
Albedo vs. Topography

- Snow cover can actually improve study of structure, by suppressing albedo effects.