“The Effectiveness of Remote Sensing Techniques in Lineament Mapping for Groundwater Exploration in Volcanic Terrains”

- Hard-rock aquifers are only productive where there is secondary porosity
  - Productivity is directly related to the density and distribution of fractures
  - Haphazard well siting is often unsuccessful

- Research Objectives:
  - Develop a comprehensive, standardized approach for using lineament analysis techniques to characterize fractured bedrock aquifers in Pacific Latin America
    - Test various digital image processing techniques
  - Evaluate the approach via simple pump tests and field assessments of lineaments
Data sets:

- Satellite Imagery:
  - Digital Globe
    - QuickBird (1)
      - Optical
      - 0.60 m pixel size
  - ASTER (1)
    - Optical
    - 15 m pixel size
  - RADARSAT-1 (3)
    - Optical
    - 0.60 m pixel size

- 20 m DEM (digitized from topographic map)

- Geological Map
  (1:50,000 scale)
Study Area
Boaco, Nicaragua

- **Terrain**
  - rugged, hilly, vegetated, lots of agricultural influence, several intermittent streams

- **Geology**
  - Tertiary volcanics, some Quaternary alluvium, normal faulting (two dominate directions)
Satellite Imagery Comparison

Optical:  
Radar:

Gamma Rays  X-Rays  U.V. Rays  Visible  Thermal Infrared  Microwave  TV/Radio

Near and Mid Infrared

(㎝) $10^{-10}$ $10^{-9}$ $10^{-8}$ $10^{-7}$ $10^{-6}$ $10^{-5}$ $10^{-4}$ $10^{-3}$ $10^{-2}$ $10^{-1}$ $1.0$ $10$ $100$

Satellite Imagery Comparison (continued)

• Digital Globe QuickBird and ASTER
  – Advantages:
    • Multiple bands and high spatial resolution
  – Disadvantages:
    • Limited by cloud cover and price

• RADARSAT-1
  – Advantages:
    • Uninhibited by atmospheric conditions and time of day
    • Ability to penetrate vegetation
  – Disadvantages:
    • Single bands and complex processing
RADARSAT
Orthorectified Scenes and Stack

February 24, 2007
Dry Season
Ascending Orbit

September 9, 2006
Wet Season
Ascending Orbit

November 7, 1997
Transitional Season
Descending Orbit

Stacked Image
Red = Feb. 24, 2007
Green = Nov. 7, 1997
Blue = Sept. 9, 2006
RADARSAT Principle Components Analysis (PCA)

Stacked Image
Red = Feb. 24, 2007
Green = Nov. 7, 1997
Blue = Sept. 9, 2006

PCA Image
Red = PC #1
Green = PC #2
Blue = PC #3
RADARSAT
Speckle Reduction and Change Detection

Stacked Image
Red = Feb. 24, 2007
Green = Nov. 7, 1997
Blue = Sept. 9, 2006

Speckle Reduction
ERDAS Imagine “Speckle Suppression Function” run iteratively with averaging windows (7 pixels x 7 pixels)

Change Detection
Differences in pixel values between Feb. 24, 2007 (dry season) image and Sept. 9, 2006 (wet season) image
RADARSAT

Displaying

Change detection image *alone*

Transparent display of change detection image with Sept. 9, 2006 (wet season) image in grey scale

Transparent display of change detection image with Nov. 7, 1997 (descending) image in grey scale
Primary Lineament Interpretation Results: QuickBird

Mapped Faults

Single interpreter, multiple trials:

Trial #1
Trial #2
Trial #3

Multiple interpreters, single trial:

Observer #1
Observer #2
Observer #3
Observer #4
Future Work

• Finish processing imagery, fuse processed imagery together
• Complete all lineament interpretations and delineate coincident lineaments
• Field work (March 6 – March 19)
  – Ground-truth coincident lineaments
  – Perform pump test
• Statistical assessment of results