A Digital Processing & Data Compilation Approach for Using Remotely Sensed Imagery to Identify Geological Lineaments In Hard-rock Terrains: An Application For Groundwater Exploration In Nicaragua

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Background

• **Lineament**: a surface expression of fracturing (geologic structure) in the form of:
  - Alignments of topography and drainages
  - Linear trends in vegetation and soil-moisture anomalies
  - Truncation of rock outcrops

• Lineaments are indicative of *secondary porosity*
  - Potential to supply large and reliable quantities of water
  - Relationship exists between lineaments and greater well productivity

• Lineaments can be identified using remotely sensed imagery
  - Tone, color, texture, pattern
  - Low-cost, non-invasive approach for improving groundwater exploration
Background

Adapted from http://www.globalsecurity.org/
Objectives

1. Develop an approach for using lineament analysis techniques for groundwater exploration in Pacific Latin America

2. Compare the abilities of a broad assortment of imagery types, combination of imagery types, and image processing techniques

3. Establish an appropriate method to remove false lineaments and evaluate lineament interpretations
Study Area

Source: www.cia.gov

Legend:
- Q
- Qal
- TOC1
- TOC2
- TOC3
- Ti
- Tmc
- Tmc2
- Tmm
- Tmm1
- Tmc3
- Tpc1
- Tpc2
- Tpc3
- Fault

Created by: Jill Barbour 4/25/07
Source: Maps Geologica, Government of Nicaragua
Methods

- Select Imagery Types
- Digital Image Processing
- Initial Evaluation of Image Products
- Lineament Interpretation
- GIS Analysis
- Ground-truth Lineament Map
- Image Evaluation

= 5 scenes

- Satellite sensors: complementary in both spectral and spatial resolutions
- DEM (derived from topographic map)

Methods

- Digital image processing to enhance fracture
  - Tried *several* processing techniques – generated numerous products
  - Which products should be interpreted for lineaments?
  - Which products should be chosen for fusion?

> 100 scenes (“products”)
RADARSAT-1 → Orthorectify and Geolocate → Stack and Subset → Despeckle

ASTER → Stack and Subset → PCA

QuickBird → Band Combination 4, 3, 1 with Standard Deviation (2) Stretch

Manual digitizing of topographic lines → Interpolation → Hillshade

RADARSAT-1 → Stack of 1st PC from each Despeckle Level (1-3)

RADARSAT-1 and ASTER → Stack of RADARSAT-1 PCA Despeckle #2, RADARSAT-1 Change Detection, and ASTER Band 1

- Original
- Despeckle #2
- PCA Despeckle #2
- Change Detection
- Despeckle #3
- PCA Despeckle #3
- Original VNIR
- PCA VNIR
- QuickBird
- DEM hillshade
- Composite #1
- Composite #2
Methods

- Lineament Interpretation
  - Visual observations of lineament features
  - Digitized in ArcGIS
  - Total of 12 interpretations

Select Imagery Types
Digital Image Processing
Initial Evaluation of Image Products
Lineament Interpretation
GIS Analysis
Ground-truth Lineament Map
Image Evaluation

= 12 interpretations
Methods

- **GIS Analysis**
  - **Goals:**
    - Synthesize large data set (12 interpretations)
    - Generate a means to remove false lineaments
    - Final product from which to confidently draw a lineament map
    - Iterative process – trial and error
How to determine if lineaments from multiple interpretations are identifying the same feature?

- Represent lineaments as areas rather than thin lines (Krishnamurthy et al. 2000)
- Buffered lineaments – 172 m width

GIS Analysis
GIS Analysis

- Addition of buffered lineaments from each interpretation
  - Raster file format
  - Raster calculator

= Coincidence Raster
Coincidence Level
- High: 12
- Low: 2
Methods

- Ground-truth Lineament Map
  - Visual inspection of lineaments
    - Identified lineament like features
    - No location guidance from lineament interpretation map
  - Pumping tests (Gross 2008)
    - Nine wells tested
    - Results analyzed to estimate well productivity
    - Correlation to lineament map?
Results

- Ground-truth Lineament Map
- Visual inspection of lineaments
- 21 of 42 field-observed lineaments correspond with mapped lineaments (50%)
Products

- Bruning gave a presentation at (March) 2009 Annual Conference of the American Society of Photogrammetry & Remote Sensing
- Manuscript for submission to this society’s *International Journal of Photogrammetry & Remote Sensing*
- Publicity
Increasing Profile of International Science

- NSF Highlight
- Popular News
- Two MS Thesis Awards at MTU
- Upcoming *EARTH* Article on PCMI
Collaborative Scheme for QAS Characterization

UCE & EPN
(M.S. Students & Professors)
VES reinterpretation
Hydraulic Analysis
Hydrochemistry

EMAAP-Q
(Technical Staff)
Provide Archived Data
Field Logistics

Montpellier Univ.
Isotope Lab Analysis
Sharing data

MTU
(MR, JSG, & ATT)
Remote Sensing
Regional Analysis
Surface Geophysics

CLIRSEN
Remote Sensing Data
Remote Sensing Outreach

IRD, INAHMI
Use similar methodologies in other regions of Ecuador
Undergraduate Preparations for Quito 2009

- Fall Geophysics Practice
- International Programs Office Visit
- Field and Logistical Planning