A DIGITAL PROCESSING AND DATA COMPILATION APPROACH FOR USING REMOTELY SENSED IMAGERY TO IDENTIFY GEOLOGICAL LINEAMENTS IN HARD-ROCK TERRAIN:
AN APPLICATION FOR GROUNDWATER EXPLORATION IN NICARAGUA

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Outline

• Background
• Objectives
• Study area
• Methods
• Results
• Conclusions and Future Work
• Acknowledgements
Background

• **Lineament**: a surface expression of fracturing (geologic structure)
  – Indicative of *secondary porosity*
    • Potential to supply large and reliable quantities of water
    • Relationship exists between lineaments and greater well productivity
  – Identified using RS imagery

• Traditional lineament analysis techniques have not proven successful in Boaco
  – Previous lineament analyses generally in ideal settings
  – Various sensors & digital processing techniques have been employed, but not compared
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

• Boaco, Nicaragua
  – Rural community
  – Hard-rock (volcanic) aquifers dominate
  – Proxy for similar regions

Adapted from: www.goshen.edu
Methods

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

• Preprocessing
• Digital image processing to enhance expression of fracturing
  – Several processing techniques generated numerous products

Various Stretch Enhancements on Various Band Combinations
Optimum Index Factor Intensity Hue Saturation Transformation
Texture Enhancement Principle Components Analysis
Normalized Difference Vegetation Index
Tassel Cap Transformation
Edge Enhancements (many directions)
Despeckling (many levels)
Change Detection Dark Image Adjustment
Various Stacks & Fusions
Methods

• Initial image evaluation
  – Qualitatively scored each image product for its ability to exhibit faulting as good, moderate, or poor (Krishnamurthy et al. 1992)
    • 10 image products
    • 2 composites

100+ → 12
Sensor or Source ▸ Processing Flow ▸ End Product

RADARSAT-1 → Orthorectify and Geolocate → Stack and Subset → Despeckle → Level #2 → PCA → Image Subtraction → Level #3 → PCA → Original

ASTER → Stack and Subset → PCA

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

Topographic Map → 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 → Composite #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

• Initial lineament interpretations on each of the 12 products
  – Visual observations of lineament features
  – Digitized in ArcGIS
  – Total of 12 interpretations

• Synthesis of the 12 interpretations
  – Final lineament interpretation
Methods

• Ground-truth Lineament Map
  – Visual inspection of lineaments
    • Identified lineament like features
    • No location guidance from lineament interpretation map
Results

• Final lineament map
  – 9 of 11 mapped faults were observed
  – Observed lineaments correlate to mapped structure
Results

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

- **Image evaluation**
  - RADARSAT-1 products are superior

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Product</th>
<th>% False Identification</th>
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<tbody>
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<td><strong>RADARSAT-1</strong></td>
<td>Original</td>
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<td>Despeckle #2</td>
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<td><strong>ASTER &amp; RADARSAT-1</strong></td>
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# Results

## Image Evaluation

- RADARSAT-1 overcomes shortcomings inherent to optical imagery

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<thead>
<tr>
<th>Problem with Optical Imagery</th>
<th>Overcome by RADARSAT-1</th>
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<tr>
<td>Can’t image through clouds</td>
<td>Penetrates through cloud cover</td>
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<td>Vegetation dominates</td>
<td>Topography dominates</td>
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<tr>
<td>Suppression of topography</td>
<td>Off nadir viewing and paring ascending</td>
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<tr>
<td>due on/near-nadir viewing</td>
<td>and descending orbital scenes</td>
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- Despeckling (smoothing) processing technique
  - Removes noise (backscatter)
Conclusions

• Interpretations based on RADARSAT-1 products are superior to interpretations from other sensor products
  – Successful lineament interpretations in this study area requires:
    • Minimization of anthropogenic features and influences
    • Maximization of topographic features
  – However, no single image type identified ALL lineaments

• Results for Boaco can be applied to similar regions/settings

Future Work

• Examination of the following for lineament detection:
  – Change detection with optical imagery
  – Thermal imagery
  – Various beam modes of RADARSAT-1
  – New imagery
Acknowledgements

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## Methods – data prep.

- Phenomenology Assessment

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### Scene parameters

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<th>Acquisition Time (Local Time, hh:mm:ss)</th>
<th>Solar Azimuth (degrees)</th>
<th>Solar Elevation Angle (degrees)</th>
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Study Area

Legend:
- Q
- Cai
- TQM
- TQMI
- TQM2
- TpI
- Tmc
- Tmca
- Tmpd
- Tmm
- Tammi
- Tmms
- Tmpb
- Tmpcc
- TpcI
- Tpcik
- Fault

Source: Mapa Geologica, Government of Nicaragua