INFEERENCE OF GROUNDING-ZONE PROPERTIES FROM RADAR BASAL REFLECTIVITY, DIELECTRIC MODELING, AND BASAL-ECHO ANALYSIS

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(Horgan et al., 2013b)
WISSARD
Grounding-Zone Survey
Seismic results

Determining basal reflectivity
- Estimating englacial attenuation
- Estimating basal reflectivity

Interpreting basal reflectivity
- Hydropotential and basal reflectivity
- Basal reflectivity and englacial features
- Bed-echo analysis
- Dielectric modeling

Conclusions
EMBAYMENT SEISMIC LINE: ACTIVE SEDIMENTATION LIKELY; NO WEDGES
Depth-averaged englacial attenuation rate: 16.6±2.4 dB/km
Why are floating areas so dim?
THE SIMPLE CASE: REFLECTIVITY AT A SUBGLACIAL PENINSULA
A MORE COMPLEX CASE: REFLECTIVITY IN SUBGLACIAL EMBAYMENT
BASAL REFLECTIVITY AND FOLD IN RADAR INTERNAL LAYERS
Why so dim?

- System fault
- What is the interface?
  - Appearance of basal interface, roughness, temperature
  - Two layers or more?
  - Attenuation/skin depth
- Reflectivity modeling
- Synthetics

Water Depth Distribution

Embayment Reflectivity Distribution

Seismically-inferred Depth

Water Depth (m)

Basal Reflectivity (dB)

Subglacial water flowpath

DInSAR inland flexure limit
DInSAR seaward flexure limit
**BASAL REFLECTIVITY CONUNDRUM**

Why so dim?
- System fault
- What is the interface?
  - Appearance of basal interface, roughness, temperature
  - 2-layers or more?
  - Attenuation/skin depth

**Reflectivity modeling**
**Synthetics**

**WATER DEPTH DISTRIBUTION**

**EMBAYMENT REFLECTIVITY DISTRIBUTION**

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**Table 1.** Dielectric properties of common subglacial materials at for a 5 MHz radar wave

<table>
<thead>
<tr>
<th>Material</th>
<th>Permittivity</th>
<th>Conductivity (S m⁻¹)</th>
<th>Power</th>
<th>Reflectivity (dB)</th>
<th>tan δ</th>
<th>Skin Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater</td>
<td>79.7</td>
<td>1 \times 10⁻⁶</td>
<td>-3.5</td>
<td>0.002</td>
<td>225</td>
<td></td>
</tr>
<tr>
<td>Seawater</td>
<td>79.7</td>
<td>2.7</td>
<td>-0.23</td>
<td>11.3</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td>Groundwater</td>
<td>79.7</td>
<td>3.1 \times 10⁻²</td>
<td>-2.4</td>
<td>1.4</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Unfrozen till (40% gw)</td>
<td>18</td>
<td>4.1 \times 10⁻³</td>
<td>-6.3</td>
<td>0.82</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Unfrozen till (15% fw)</td>
<td>12</td>
<td>3.3 \times 10⁻⁵ to</td>
<td>-9.9</td>
<td>0.01 to 0.1</td>
<td>12 to 39</td>
<td></td>
</tr>
<tr>
<td>Unfrozen till (45% fw)</td>
<td>30</td>
<td>8.3 \times 10⁻⁴</td>
<td>-5.9</td>
<td>0.01 to 0.1</td>
<td>7.8 to 25</td>
<td></td>
</tr>
<tr>
<td>Unfrozen bedrock (15% gw)</td>
<td>6.6</td>
<td>7.5 \times 10⁻⁴</td>
<td>-14</td>
<td>0.41</td>
<td>8.2</td>
<td></td>
</tr>
<tr>
<td>Frozen (40% gw ice)</td>
<td>2.8</td>
<td>2.7 \times 10⁻⁵</td>
<td>-30</td>
<td>0.035</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>Frozen bedrock (15% gw ice)</td>
<td>2.7</td>
<td>1.7 \times 10⁻⁵</td>
<td>-27</td>
<td>0.022</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>Marine ice</td>
<td>3.43</td>
<td>4.8 \times 10⁻⁵</td>
<td>-35</td>
<td>0.05</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>2.6</td>
<td>1.1 \times 10⁻⁵</td>
<td>-25</td>
<td>0.015</td>
<td>68</td>
<td></td>
</tr>
</tbody>
</table>
TWO OR THREE LAYERS?

\[ R_{ab} = 20 \log_{10} \left| \sqrt{\varepsilon_a - \varepsilon_b} \sqrt{\varepsilon_a + \varepsilon_b} \right| \]

\[ R_{abc} = 20 \log_{10} \left( r_{ab} + t_{ab}r_{bc}t_{ab} \frac{\exp(-2ik_b\delta)}{1 - r_{bc}r_{ab} \exp(-2ik_b\delta)} \right) \]

(Whillans Ice Plain, Ross Ice Shelf)

- till wedge
- primary bed echo
- off-nadir echoes
- multiple bed echo

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Conductivity (S m^{-1})
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<th>Skin Depth (m)</th>
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<td>Freshwater</td>
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(MacGregor et al., 2011)
BASAL REFLECTIVITY: TWO- and THREE-LAYER MODELS

2-LAYER MODEL

ICE/WATER/SEAWATER

ICE/WATER/SALTY TILL

ICE/BRACKISH WATER/SALTY TILL
SYNTHETIC MODELING

Conductivity is ~0.001–0.01 S/m (brackish; ~10% sediment)
Dim reflectivity indicates large area of brackish water?
- ~10% sediment content
- Brackish

Lagged water exchange in shallow water column
- Abruptly brightens in other areas and seaward of embayment
- Lobe ~10 m step, would take us out of a node; stepped basal topography
- Tidal anomaly larger seaward of reflectivity step
- Regional geologic control?

Low basal-melt rate
- No strong plume circulation
- No subglacial channel melted into ice
- No accommodation space for wedges–flat deposits imaged by reflection seismology