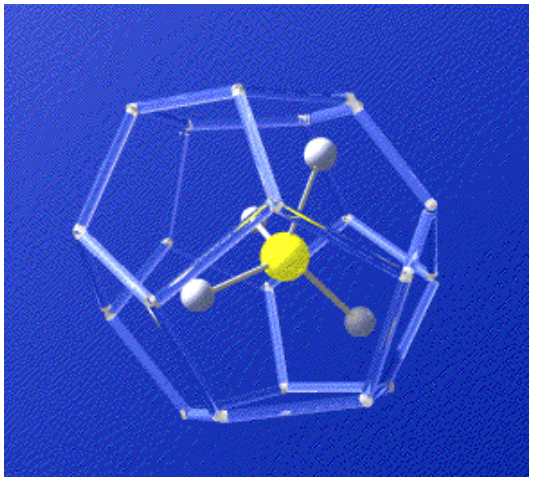

Thermophysical Properties of Gas Hydrates

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High Temperature Materials Laboratory

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

UT-BATTELLE

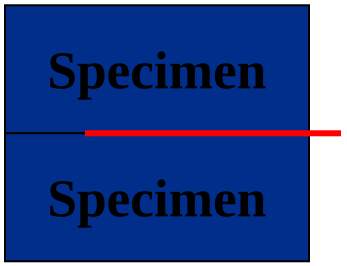
HTML Provides Measurement Capabilities of Thermophysical Properties on Gas Hydrates

- **Thermal diffusivity and conductivity**
- **Heat capacity, specific heat (DSC)**
- **Thermal expansion**
- **Temperature mapping: high speed IR imaging**

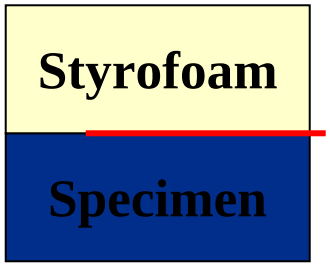
HOT DISK THERMAL CONSTANTS ANALYZER

- **Transient Plane Source (TPS) method**
- **Direct thermal conductivity measurement**

Standard Measurement

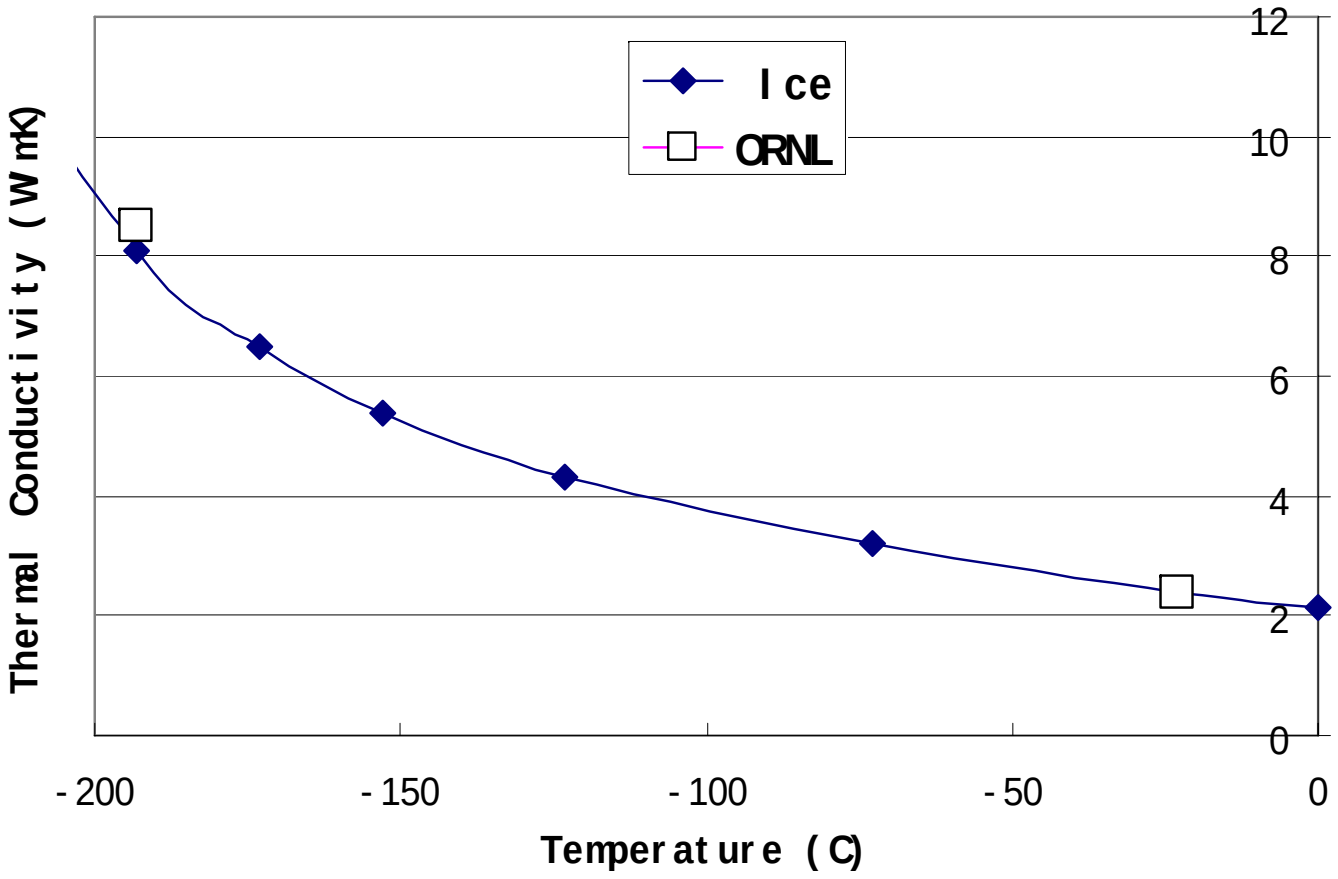


Single-side Measurement



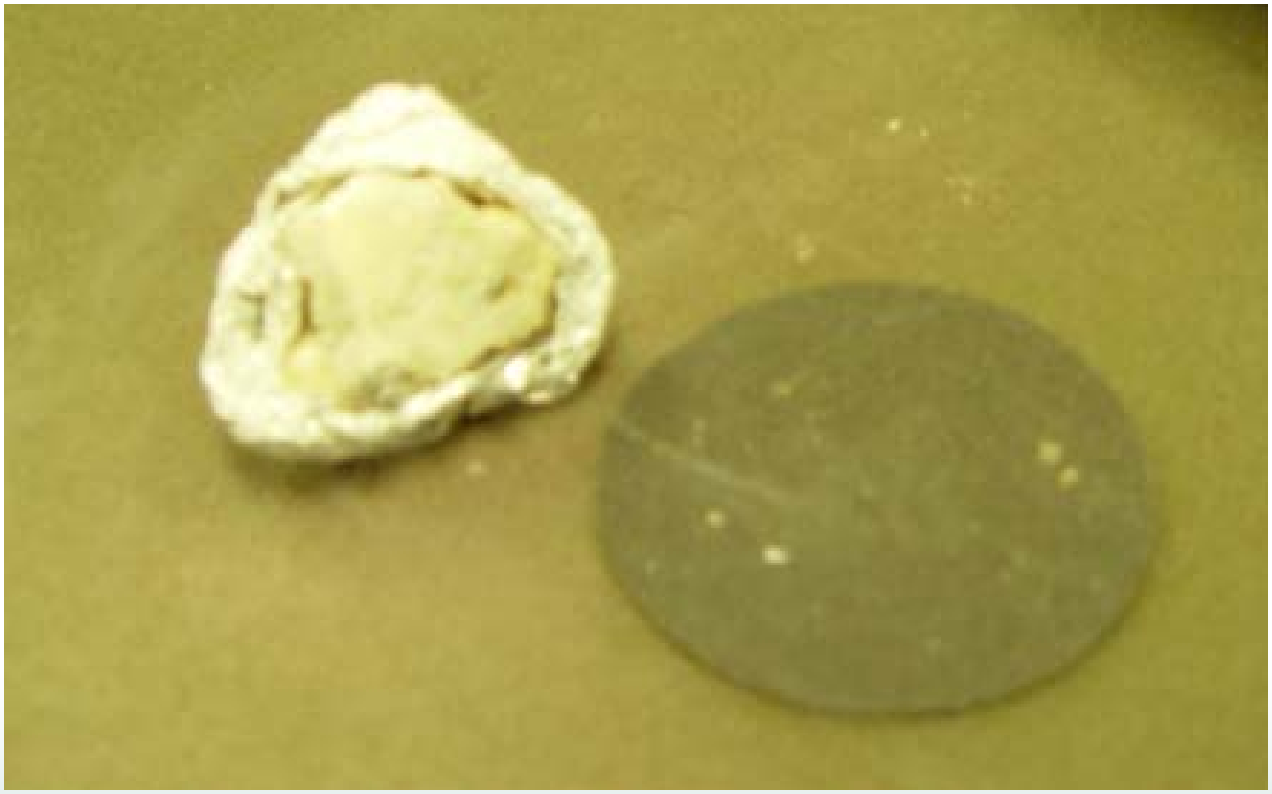
Liquid Nitrogen Tests

Thermal Conductivity of Ice

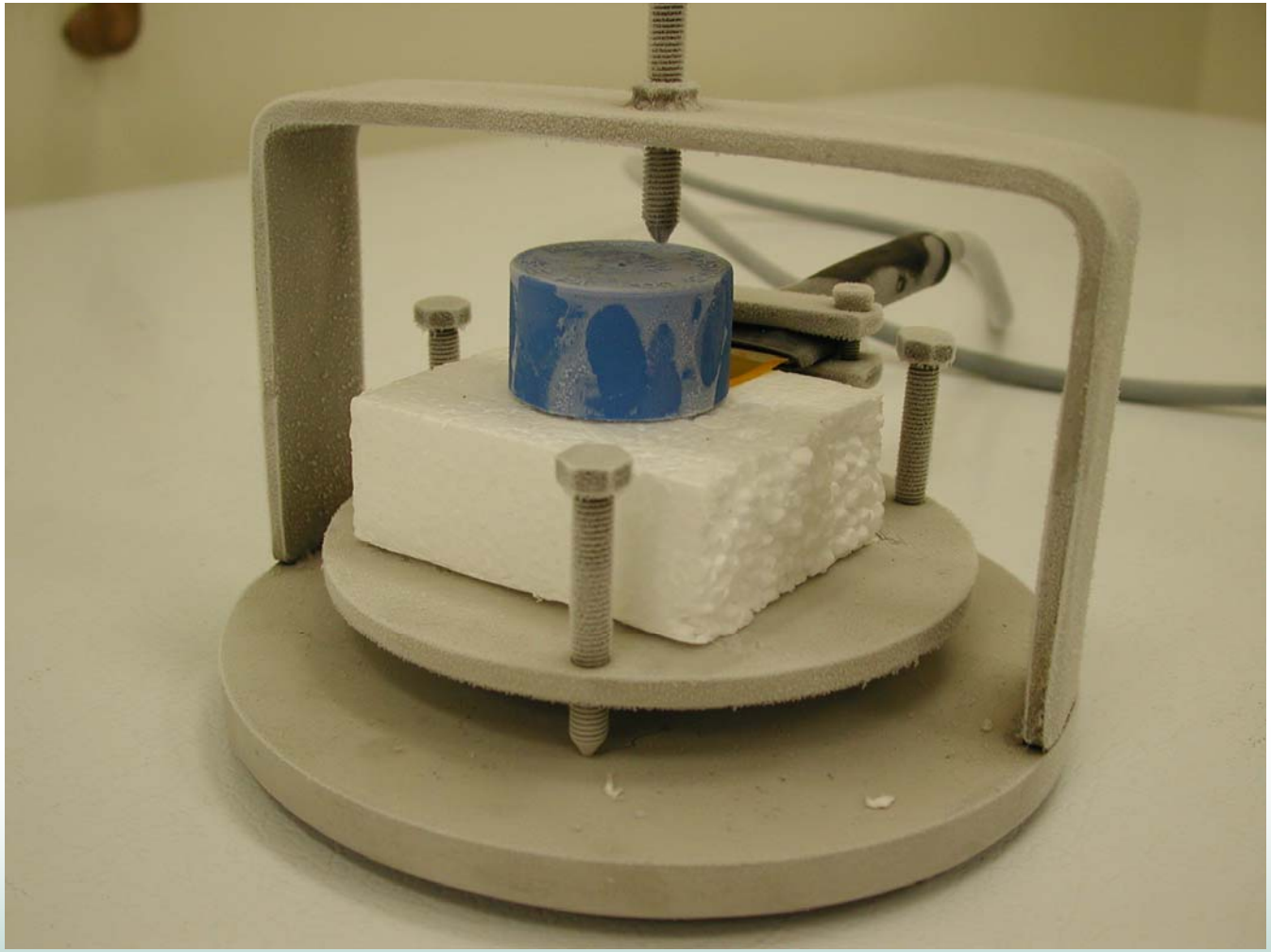


Reference: G.A. Slack, "Thermal Conductivity of Ice", Physic. Rev. B. 22(6), 3065-3071, 1980

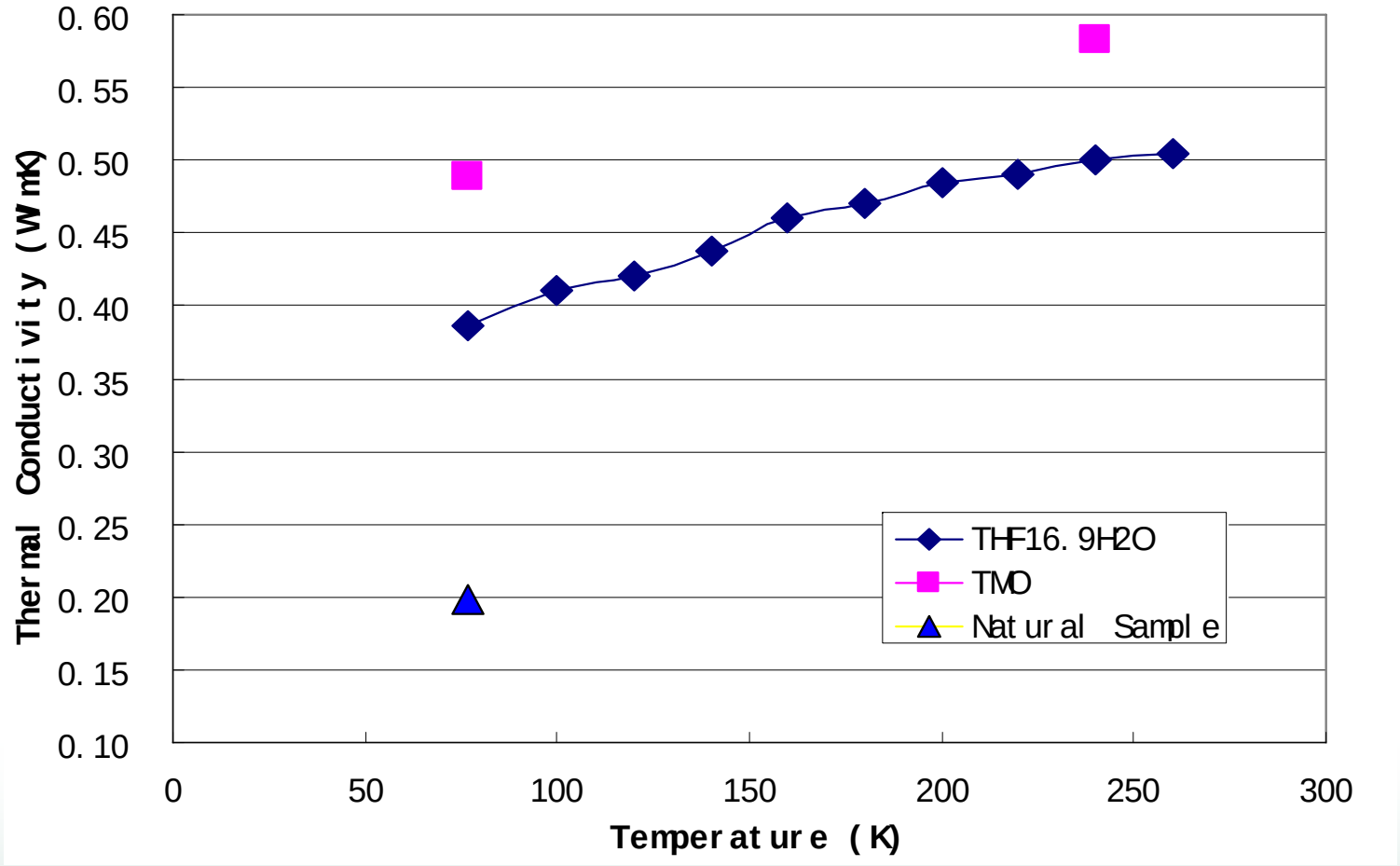
Using Sand Paper to Get a Flat Surface from Natural Sample



TMO and Natural Sample Holder



Thermal Conductivity of TMO-I



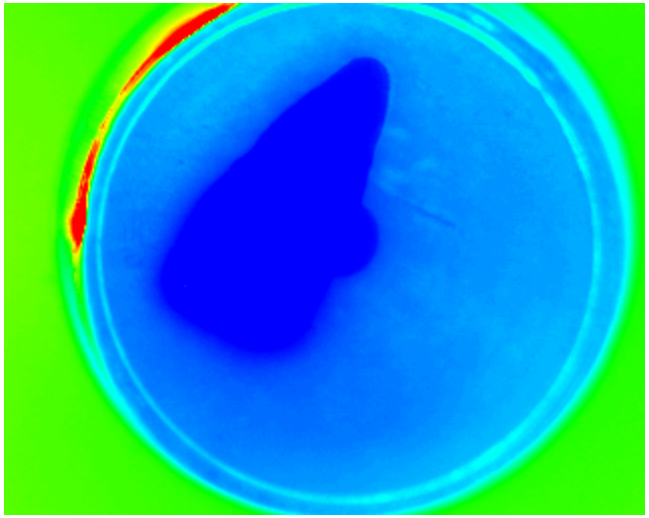
Reference: H. Suga, "Calorimetric Studies of Some Energy-related Materials", Thermochimica Acta, 328, 9-17, 1999

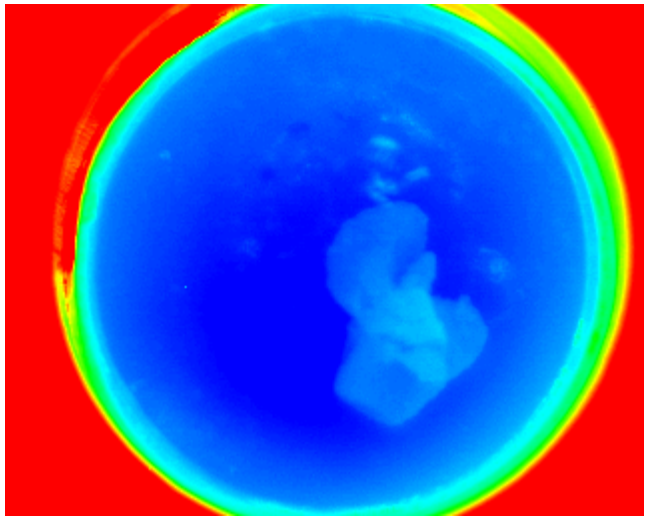
Thermography Facility at ORNL

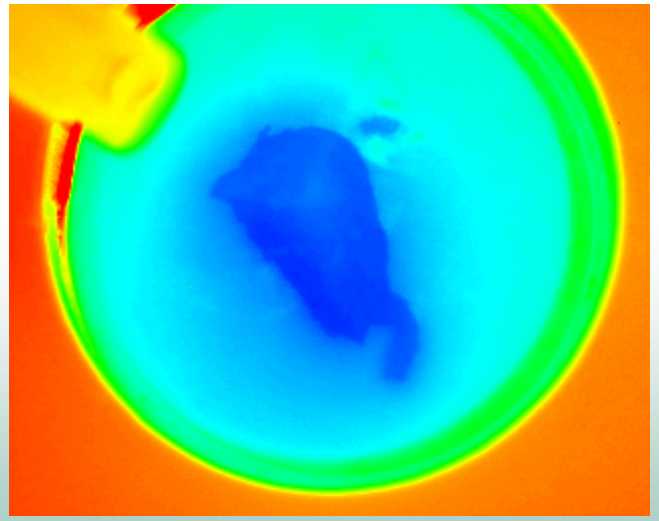
- **Five infrared cameras:**
  - **Indigo Phoenix Near IR**
  - **Indigo Phoenix Mid IR**
  - **Indigo Alpha**
  - **Indigo Omega**
  - **Raytheon Radiance HS Mid IR**
- **Spectral Imaging (3-5 microns)**
- **Spectrometers: UV-IR**
- **Single-point IR detectors: one color and two-color detectors**
- **Features: High-speed: 346Hz to 38kHz; high-sensitivity: 0.015 K; spatial resolution from 5 μm/pixel**

IR Images of Melting (-70 to 50ºC)

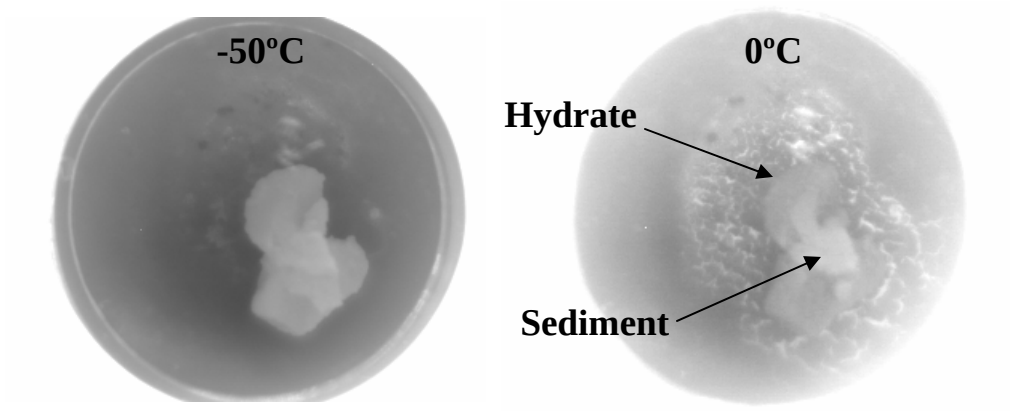
ICE





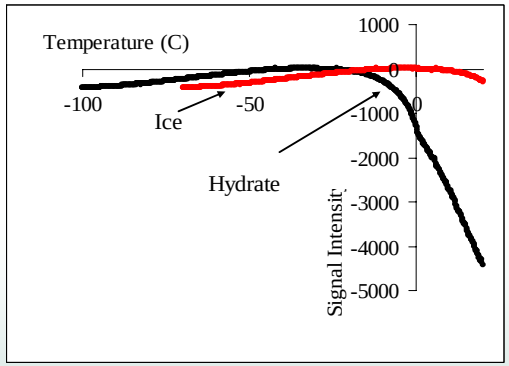


Infrared Thermography reveals the location of hydrate in natural samples.



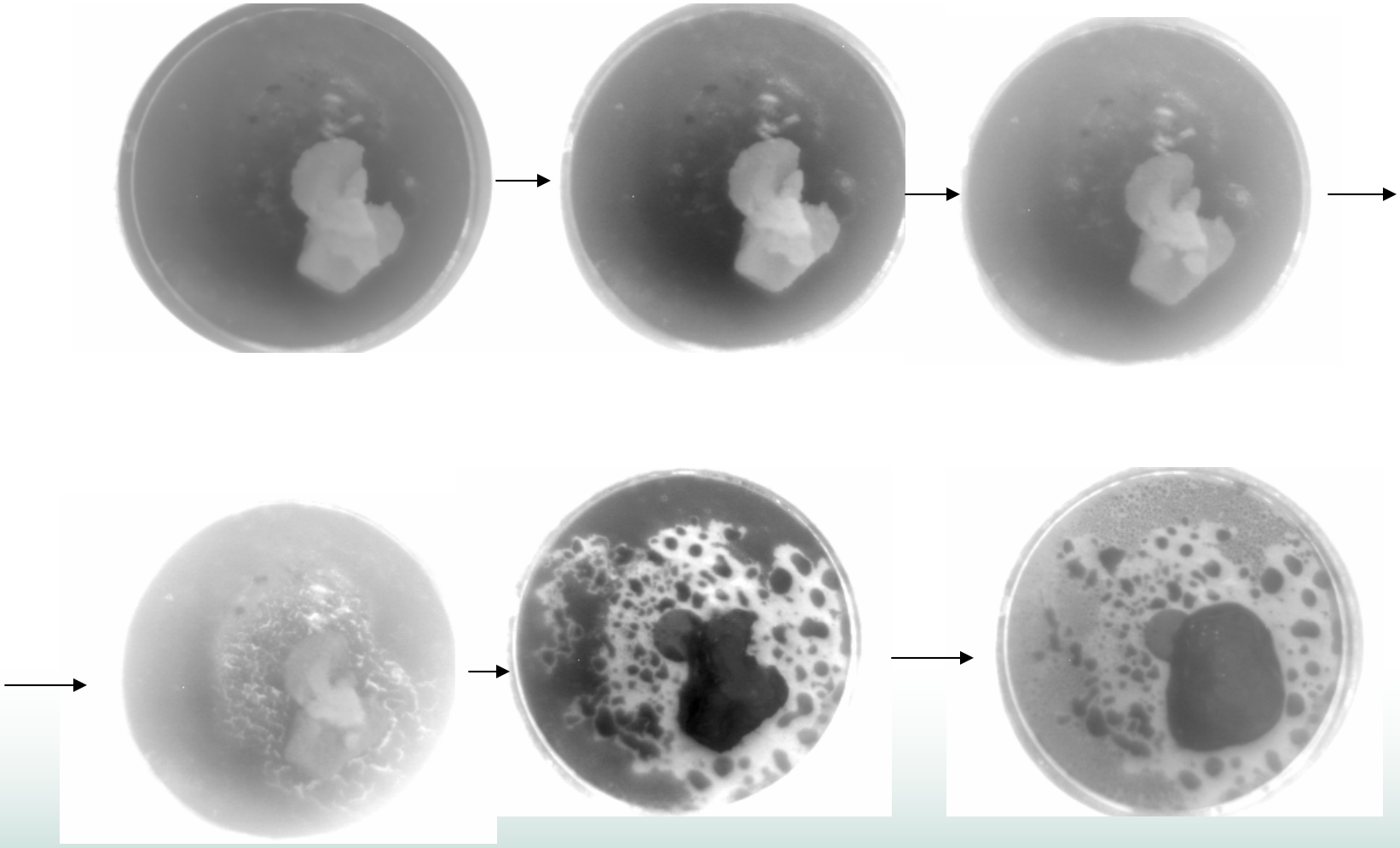
Raman Microscopy revealed both Structure I and II containing both methane and ethane from natural samples recovered from Green Canyon in the Gulf of Mexico.

Hydrate appears much colder than ice as it dissociates.

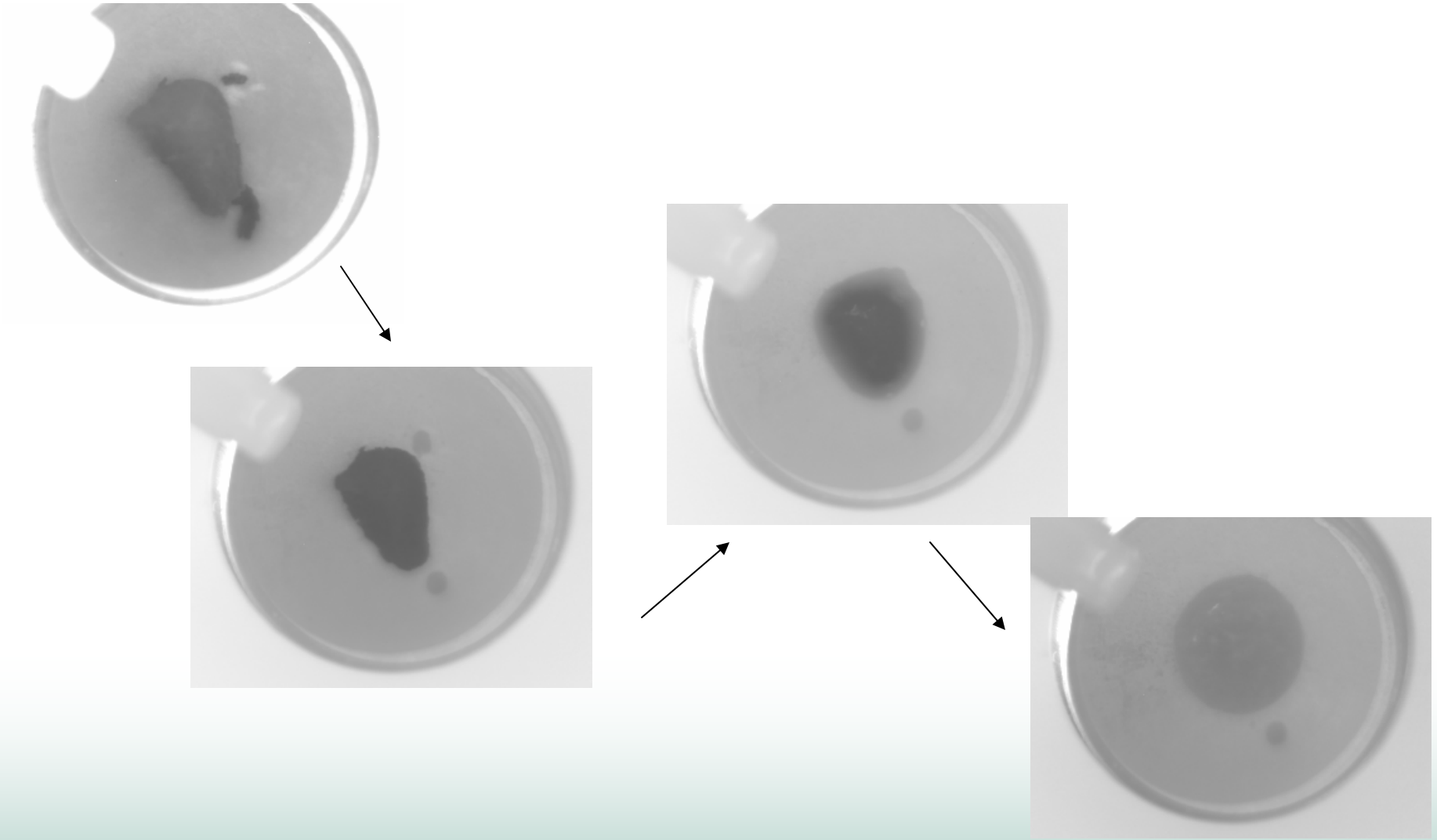


Possible Clathrate 1st Guess	*Measured Peak Position (cm-1)*	*From Literature*
C5 or C6	2868.49	
C5 or C6	2876.71	
C2H6 in SII 5(12)6(2) Large	2884.34	2887.3
CH4 in SII 5(12)6(4) Large	2898.77	2903.72 +/- 0.28
CH4 in SI 5(12)6(2) Large	2901.73	2904.85 +/- 0.33
CH4 in SII 5(12) Small	2912.32	2913.73 +/- 0.76
CH4 in SI 5(12) Small	2917.14	2915.04 +/- 0.58
C2H6 in SII 5(12)6(2) Large	2939.47	2942.3
C2H6 in SI 5(12)6(2) Large	2947.46	2946.2
???	2982.53	

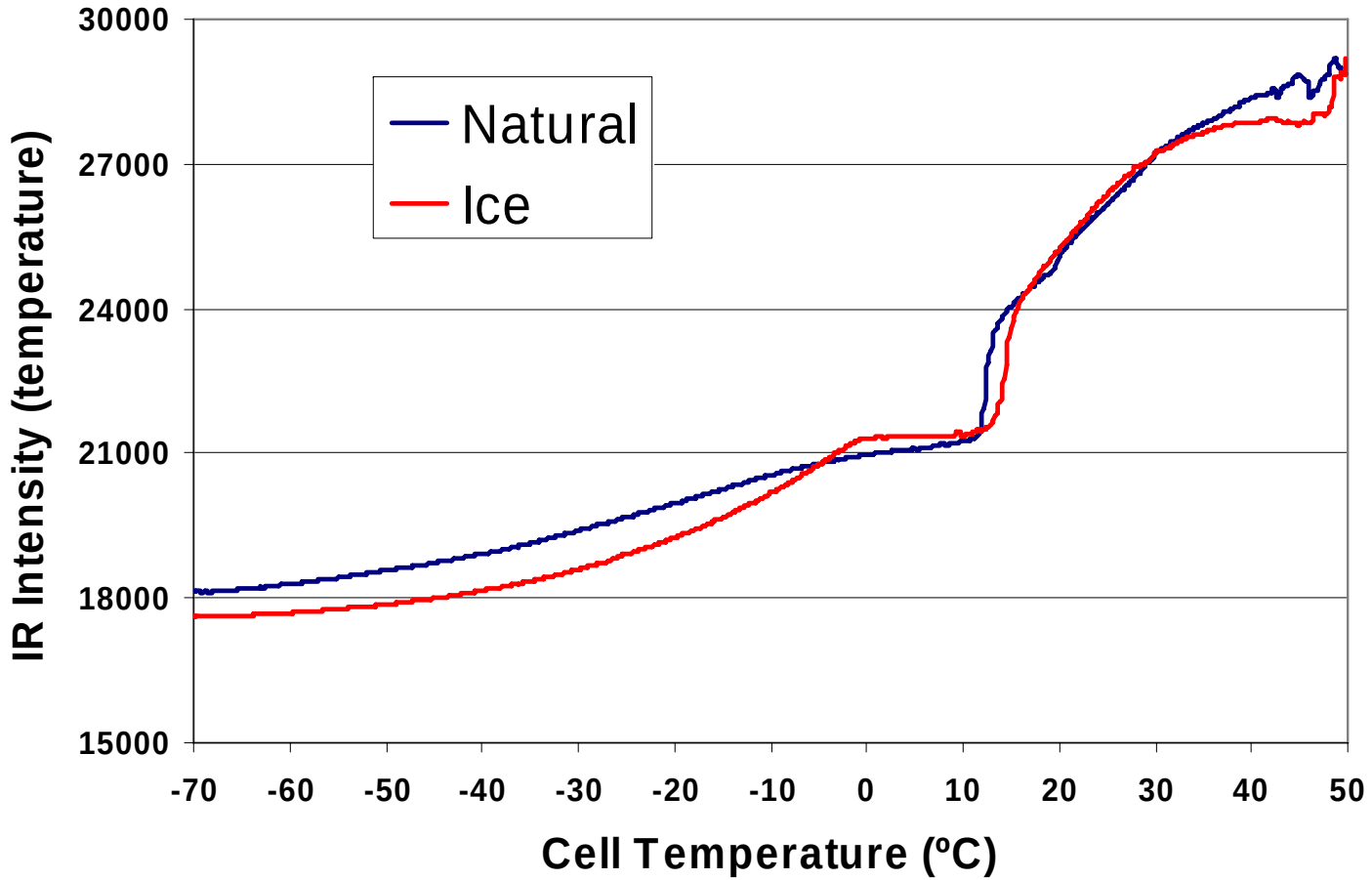
IR Images of a “Dirty” Natural Sample Melting



Natural Sample –70 – 50º C



Cell Temperature Vs. IR Signal



Temperature Differences