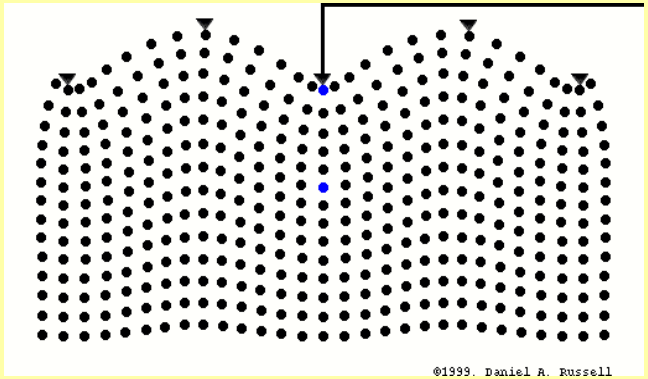
Ground-roll Inversion for S-wave Velocity: Meteor Crater, Arizona



by
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Allied Geophysical Laboratories (AGL) Meeting and Research Day

University of Houston

29th April, 2011

Overview

Motivation and Objective

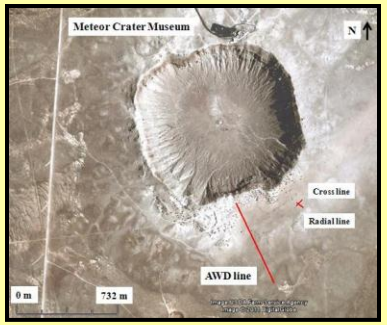
- Near-surface problems

Methodology

- Frequency based ground-roll inversion method

Barringer (Meteor) Crater, Arizona

- Geological Setting
- Seismic experiments



Results and Interpretations

- S-wave velocities (V_S) and identifying geological features

Applications and Future works

- Density prediction - S-wave statics - 3D Tomography

Motivations and Objectives

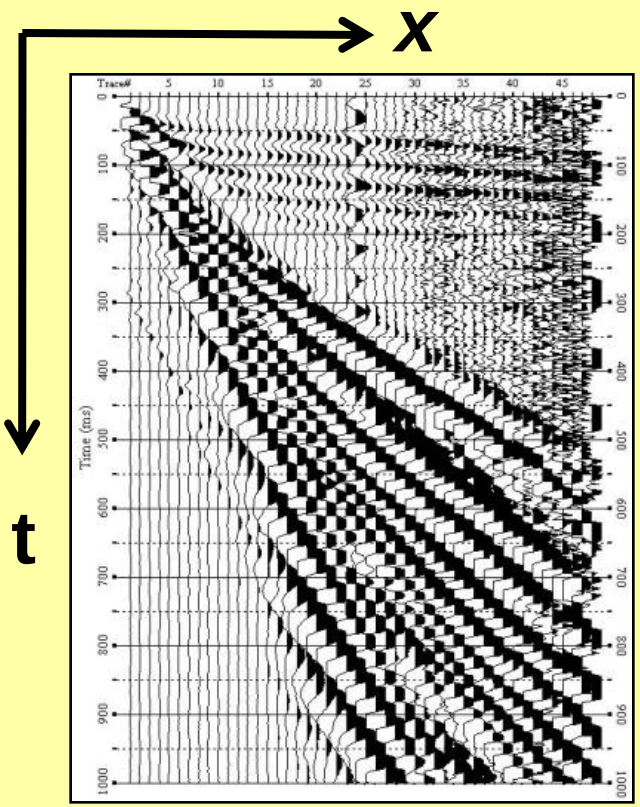
- **Study of the near-surface velocity structure**
  - **Low-velocity, unconsolidated layers**
  - **Near-surface effects propagate deeper**
- **A good estimation of V_S required for multicomponent seismic analysis**
- **Identify geological features using estimated V_S variations**
  - **Thickness of a low-velocity, unconsolidated layer at Meteor Crater, AZ**
  - **Correlation of the results with known information**
- **Time delays in seismic waves (Statics problem)**

$$t_{Statics} = \sum \Delta z_i / V_i$$

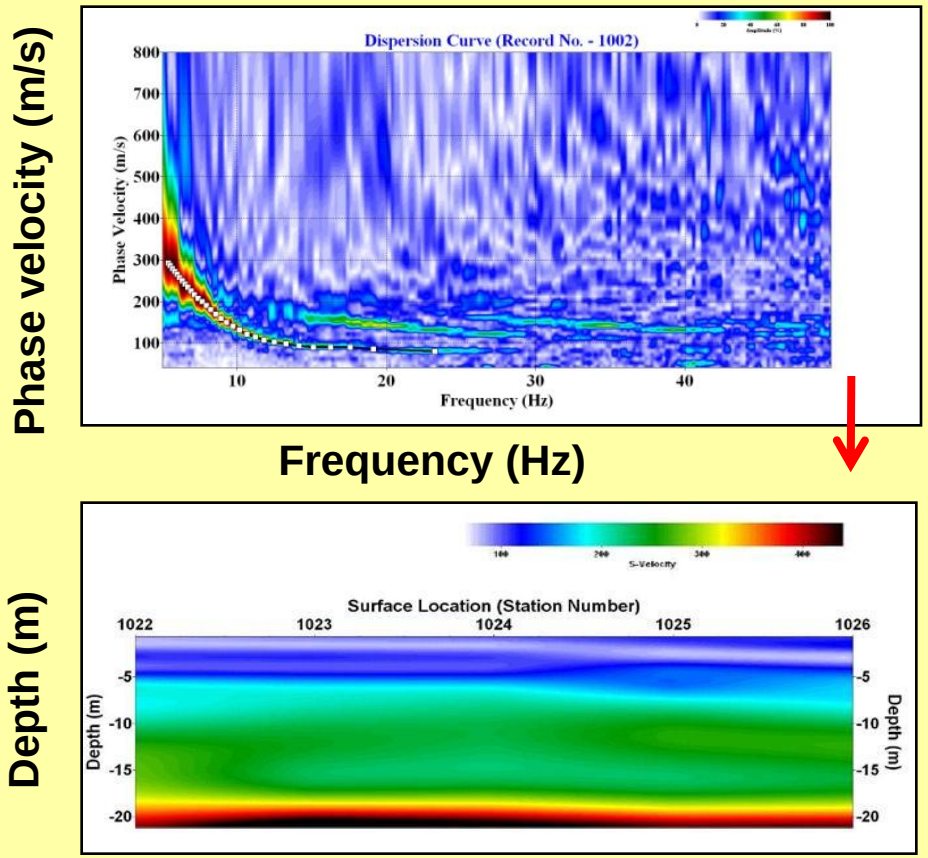
Methodology

- **Multichannel Analysis of Surface Waves (MASW)**
  - **Generation of dispersion curves (phase velocity versus frequency plots)**
  - **Inversion of dispersion curves to estimate V_S**

(Park et al., 1998; ibid 1999; Xia et al., 1999)



Raw shot gather: La Marque, TX

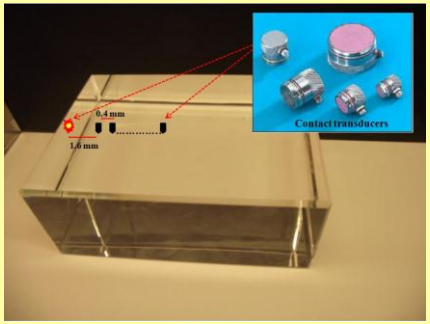


Different Seismic Data Sets

Modeling data

- **Numerical modeling:**
  Finite-difference elastic modeling (Manning, 2007)

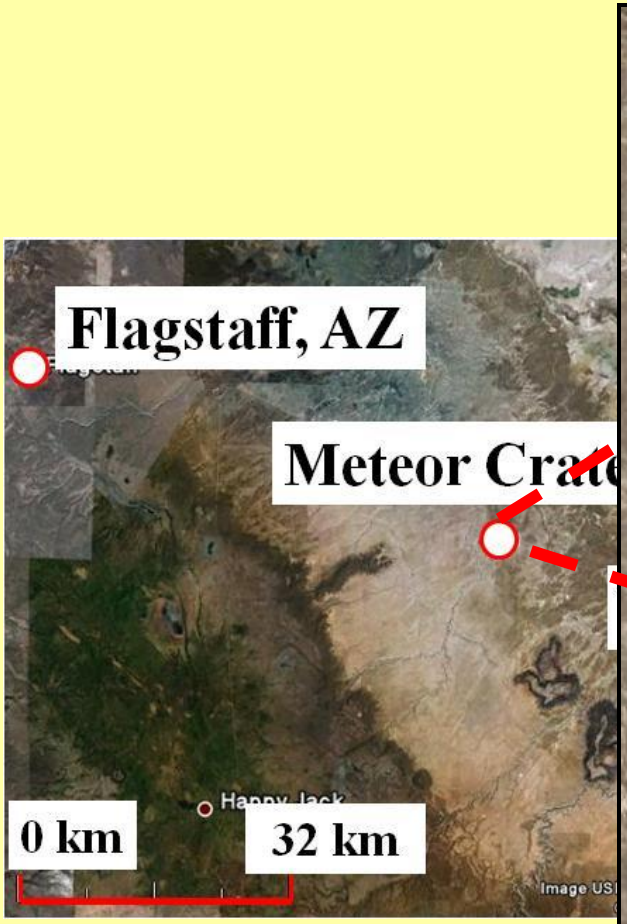
- **Physical modeling:**
  Ultrasonic measurements on glass model

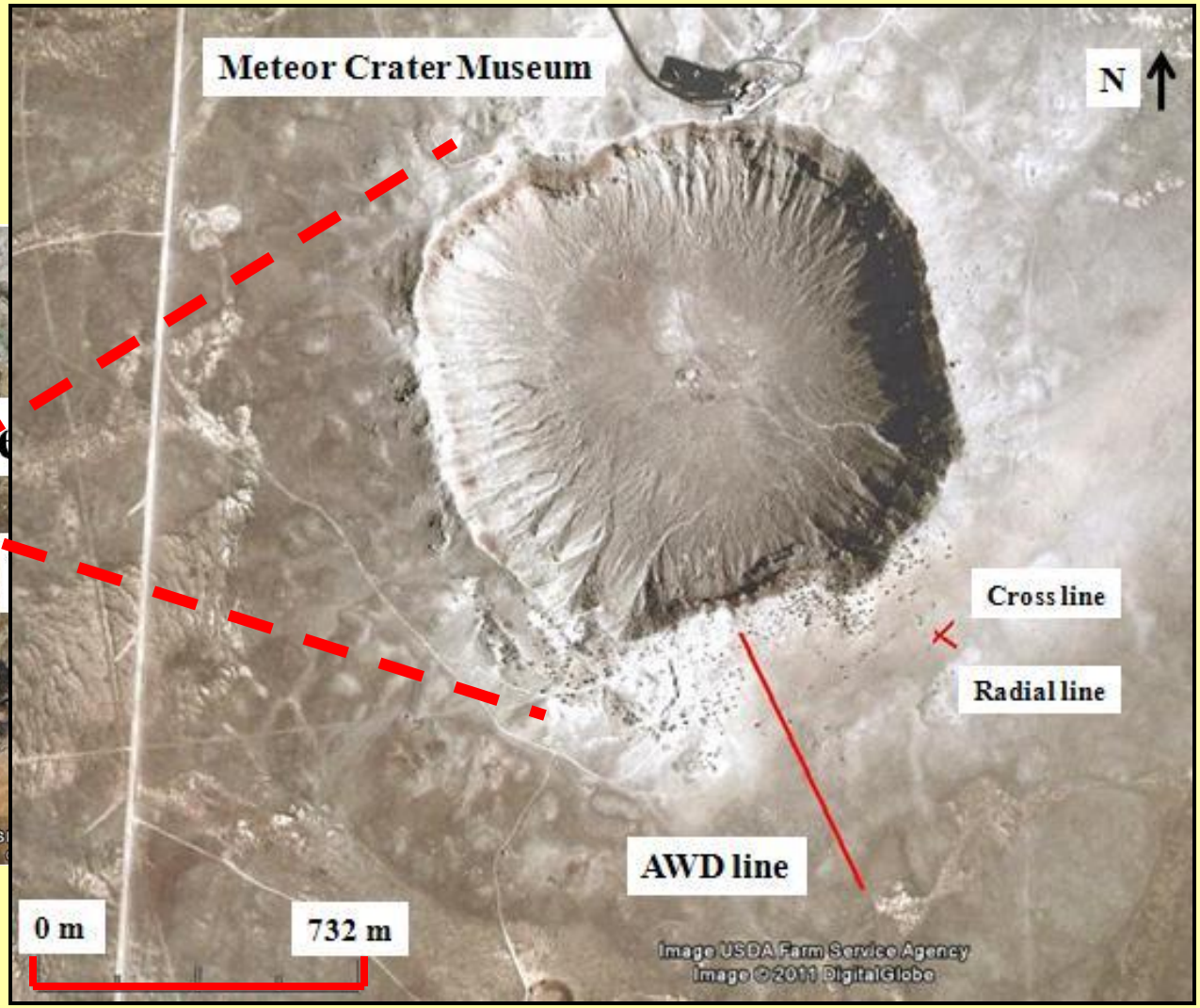


Field data

- **Barringer (Meteor) Crater, AZ**
- **La Marque Geophysical Observatory, TX**
- **Yellowstone-Bighorn Research Association (YBRA), MO**

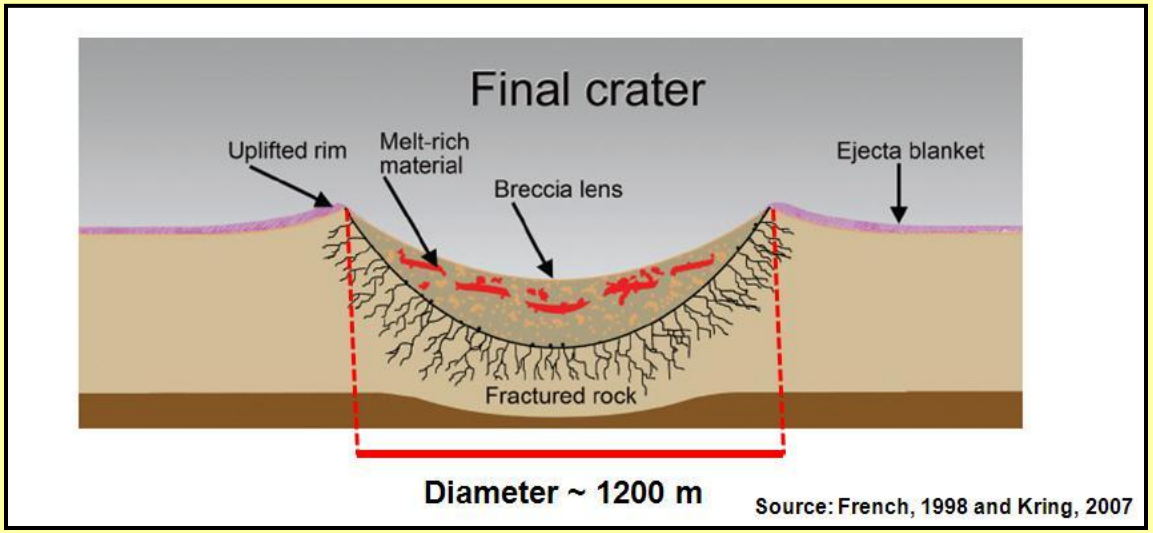
Barringer (Meteor) Crater, AZ





Source: Satellite image from Google Earth

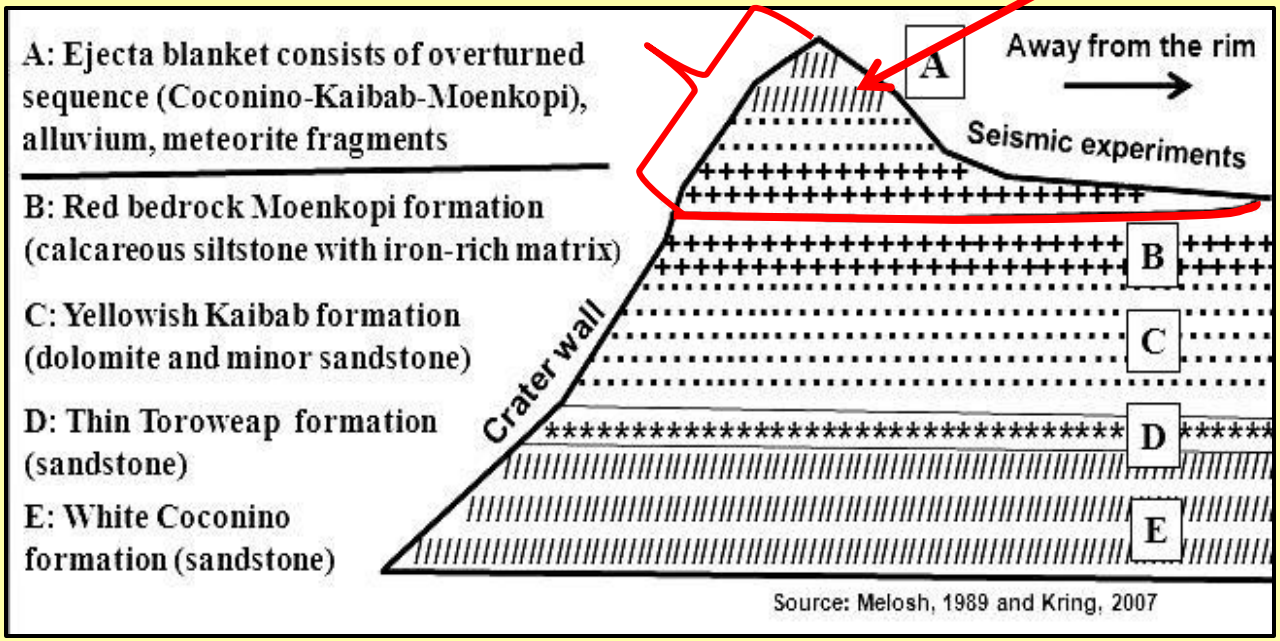
Meteor Crater: An Unique Astrobleme



Meteorite Craters in Texas:

- **Odessa Crater**
- **Sierra Madera Crater**

Overturned sequence

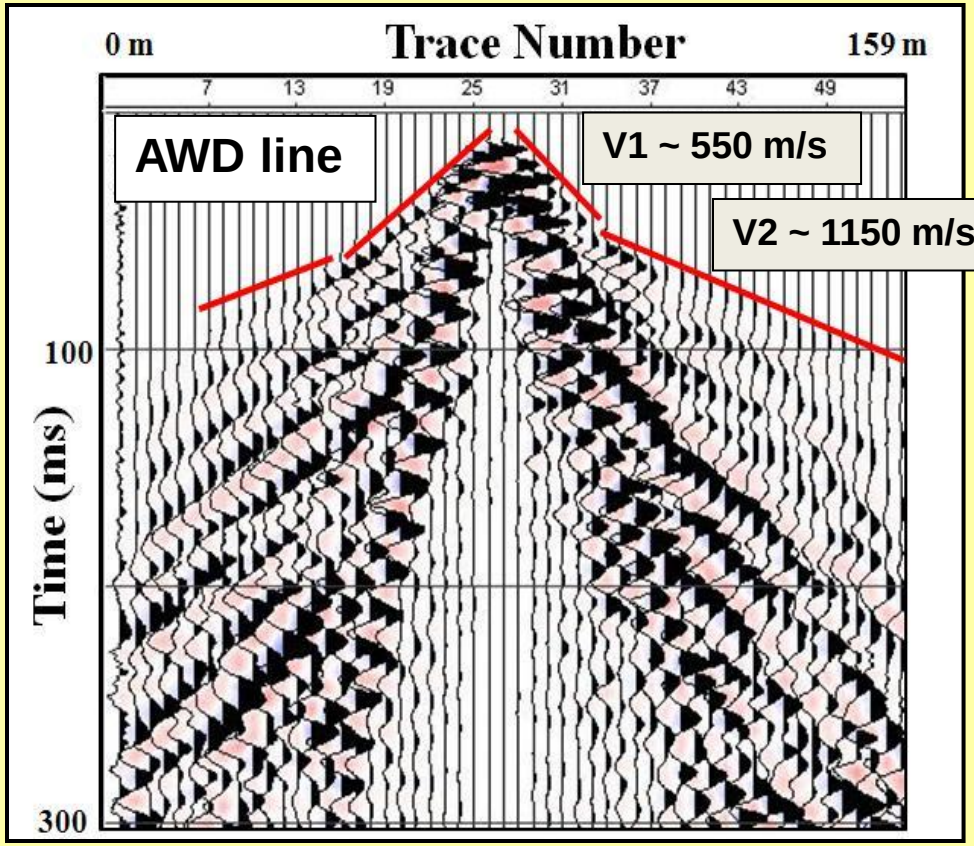


Seismic Experiments at Meteor Crater

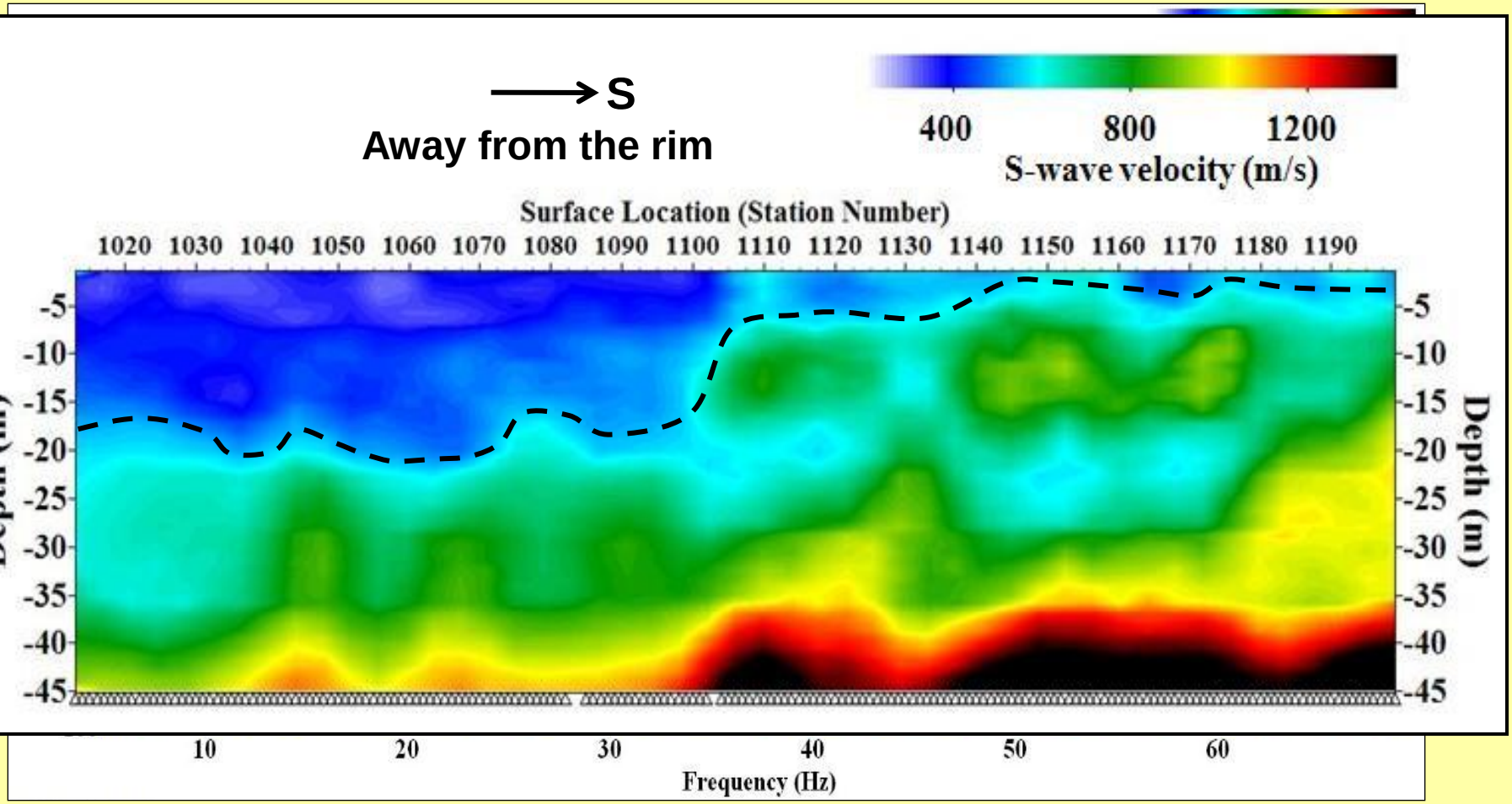
- **Source interval: 2-3 m**
- **Receiver interval: 2-3 m**
- **Source type: 10 lb sledgehammer, Accelerated Weight Drop**

Ultrasonic Measurements

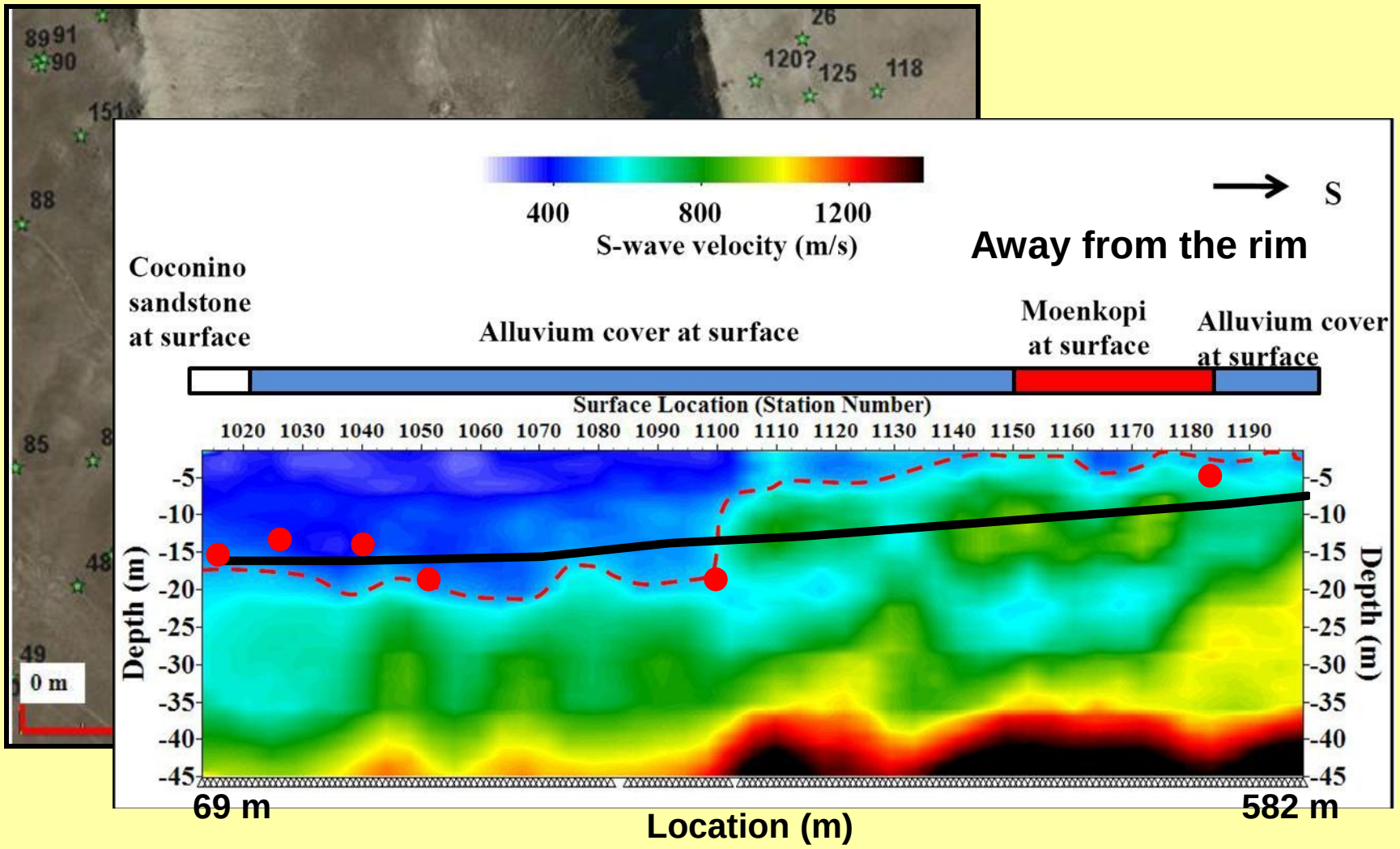
Rock Formation	Range of P-wave velocity (m/s)
Moenkopi 1	815 ± 33
Moenkopi 2	1255 ± 106
Moenkopi 3	1570 ± 89
Kaibab 1	3705 ± 81
Kaibab 2	2560 ± 210



Result: Dispersion curve and S-wave velocity



Interpretation: Meteor Crater



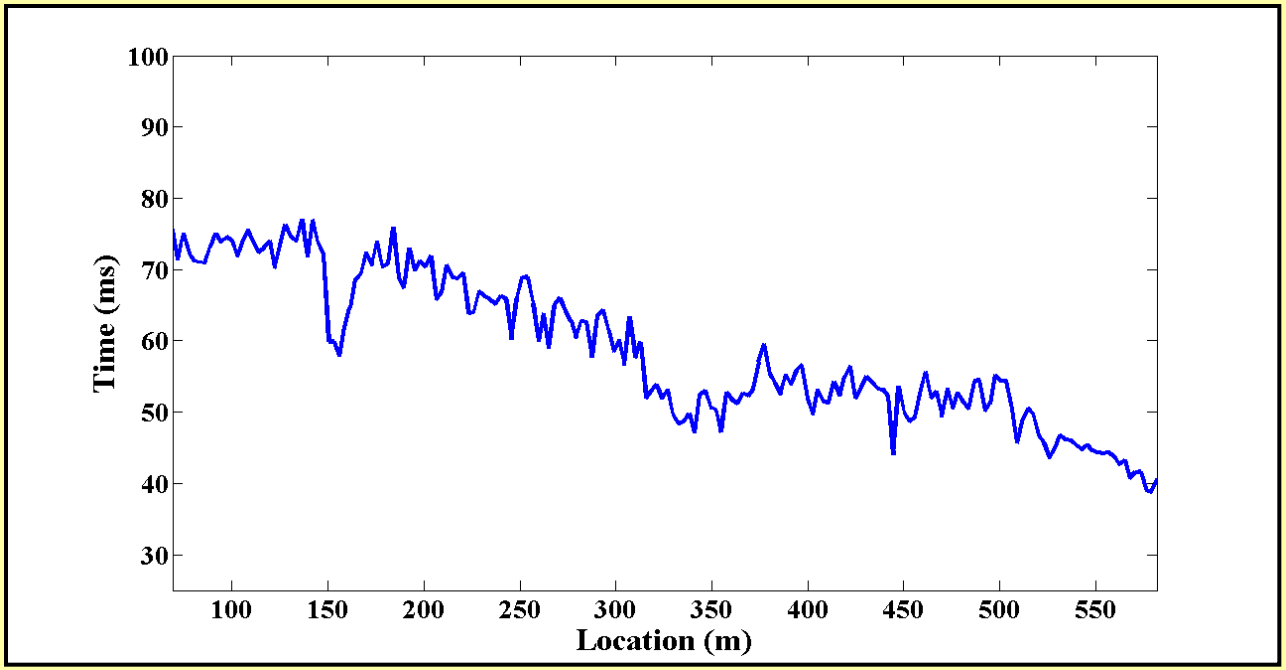
Conclusions

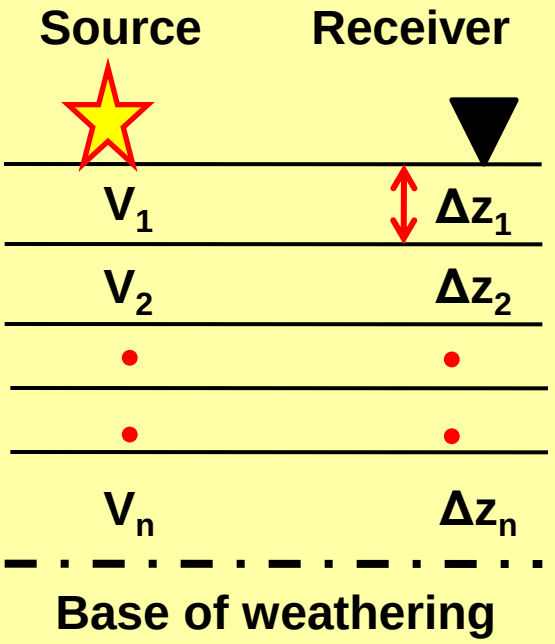
- **Ground-roll inversion is a simple, robust, noninvasive, and low-cost method**
- **2D S-wave velocity structures can be obtained**
- **A broad range of S-wave velocities are estimated:**

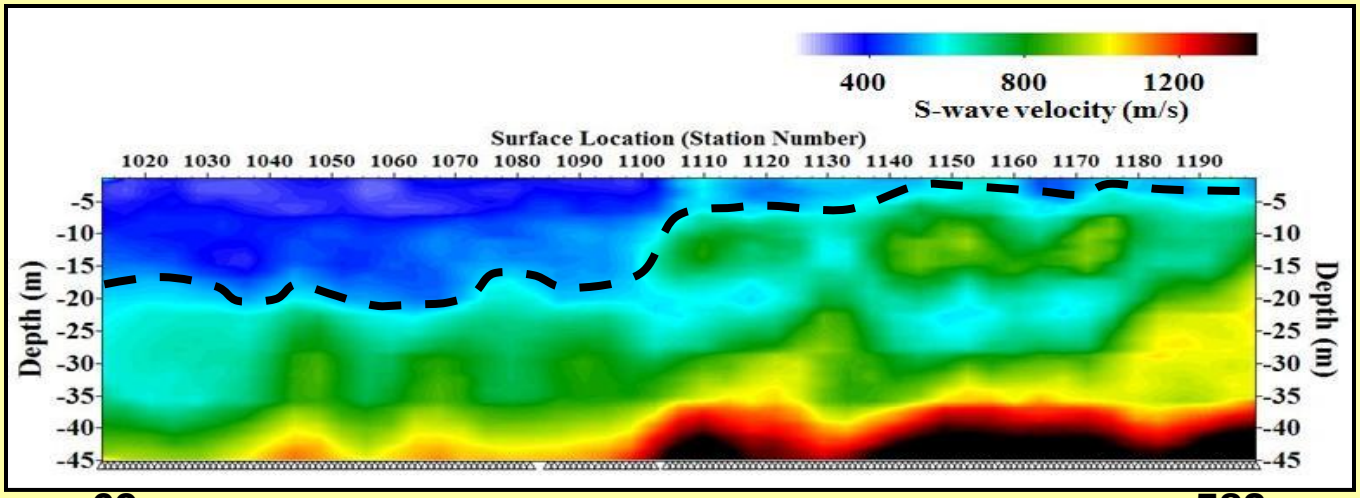
Vs (m/s)	Numerical Model	Physical model	YBRA, MO	La Marque, TX	Meteor Crater, AZ
Known	500-740	3400	300-900	N/A	N/A
Ground-roll inversion	450-800	3200-3500	300-1000	100-500	200-1000

- **Geological structures are identified based on the estimated S-wave velocity variations**

Application: S-wave Low-velocity Statics







$$t_{Statics} = \sum \Delta z_i / V_i$$

Application: Density from S-wave velocity

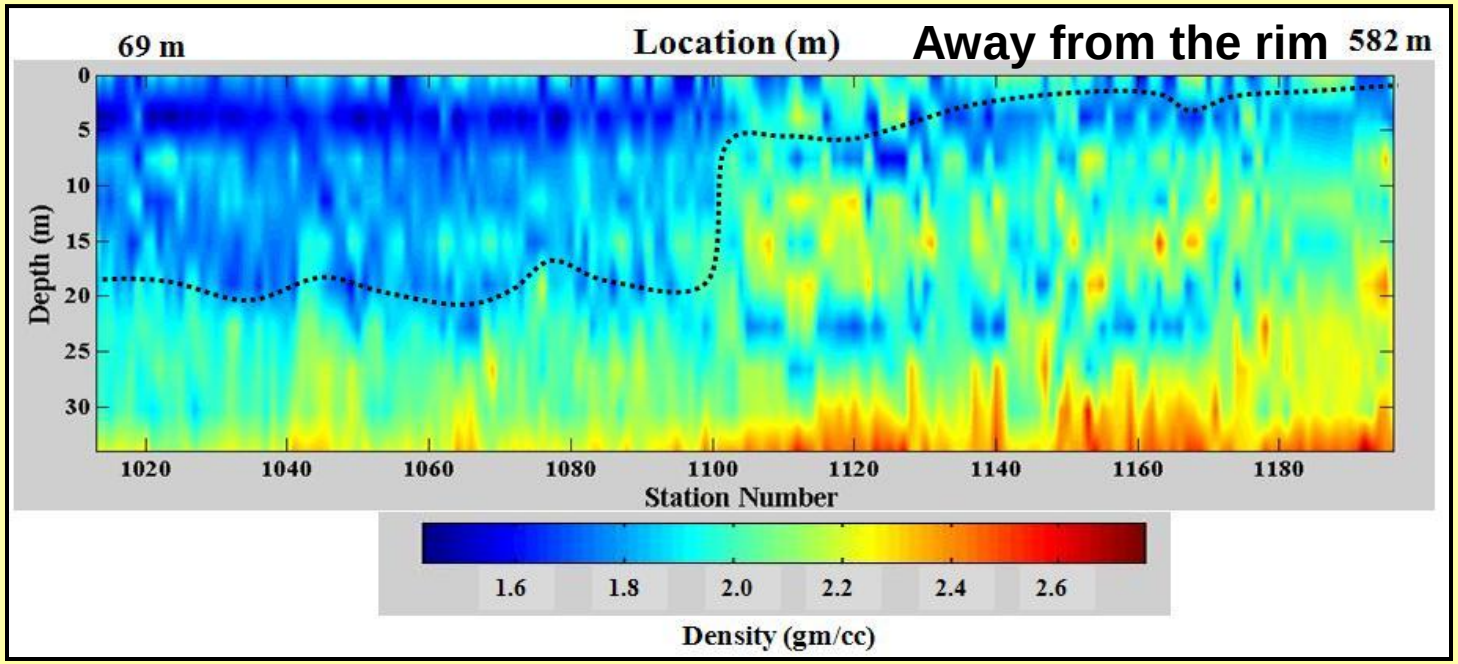
Gardner's Equation for S-wave: $\rho = 0.37\ V_S^{0.22}$

Where, ρ in gm/cc and V_S in ft/s - (Potter and Stewart, 1998)

Target units	Bulk density (gm/cc) from drill cores
Ejecta blanket	1.87-2.17
Moenkopi	2.19-2.48

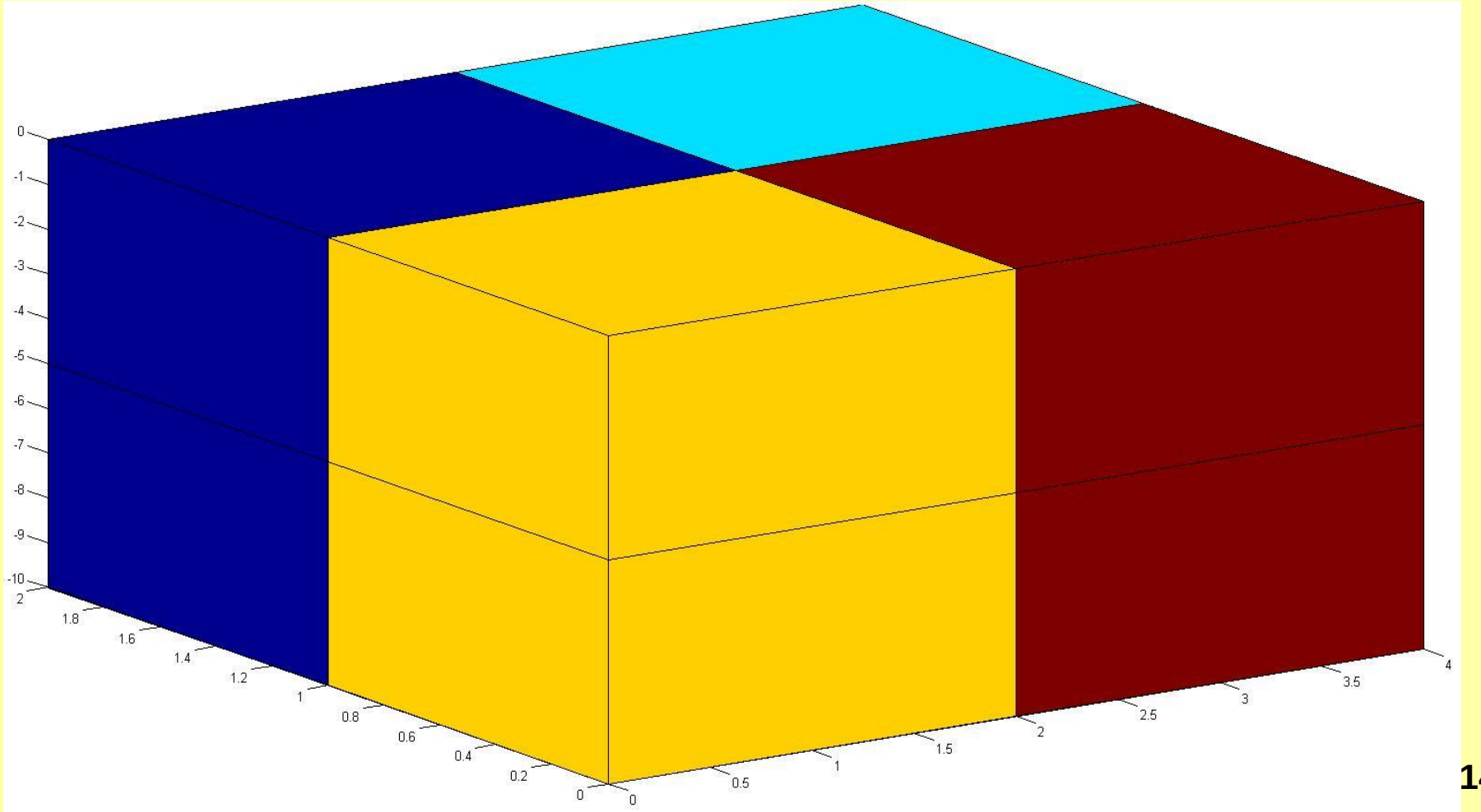
(Walters, 1966, Watkins *et al.*, 1966, and Kring, 2007)

S



Future work: 3DTomography

- **Construction of a picture of the internal values of an object from sum of those values**
- **Finding an integrand from various integral values (Stewart, 1991)**



Acknowledgement

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- **My colleagues at AGL**
- **Dr. D. A. Kring (Lunar and Planetary Institute)**
- **Meteor Crater Museum**
- **Kansas Geological Survey**

Allied Geophysical Laboratories

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