Part 3

Construction of 2-D Vertical Shear-wave Velocity Field by the Multichannel Analysis of Surface Wave Technique

2-D Vertical S-wave Velocity Map

- Introduction
- The Method
- Examples
  - Mapping bed rock, Olathe, Kansas
  - Imaging a steam tunnel, Lawrence, Kansas
  - Mapping bed rock, Joplin, Missouri
  - Mapping dissolution features, Damascus, Alabama
  - Locating a pit site, Raleigh, North Carolina
- Conclusions
- Acknowledgements

INTRODUCTION

A Three-phase Research Project

1) acquisition of high-frequency broad band ground roll
2) creation of efficient and accurate algorithms to extract Rayleigh wave dispersion curves from ground roll
3) development of stable and efficient inversion algorithms to obtain near-surface S-wave velocity profiles

INTRODUCTION (continued)

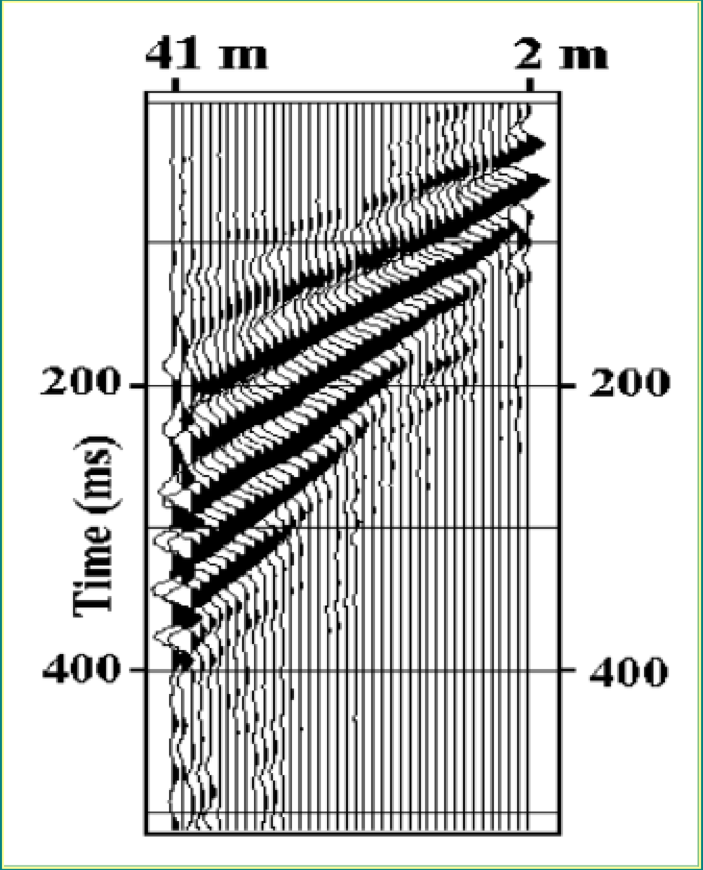
A 2-D S-wave Velocity Section

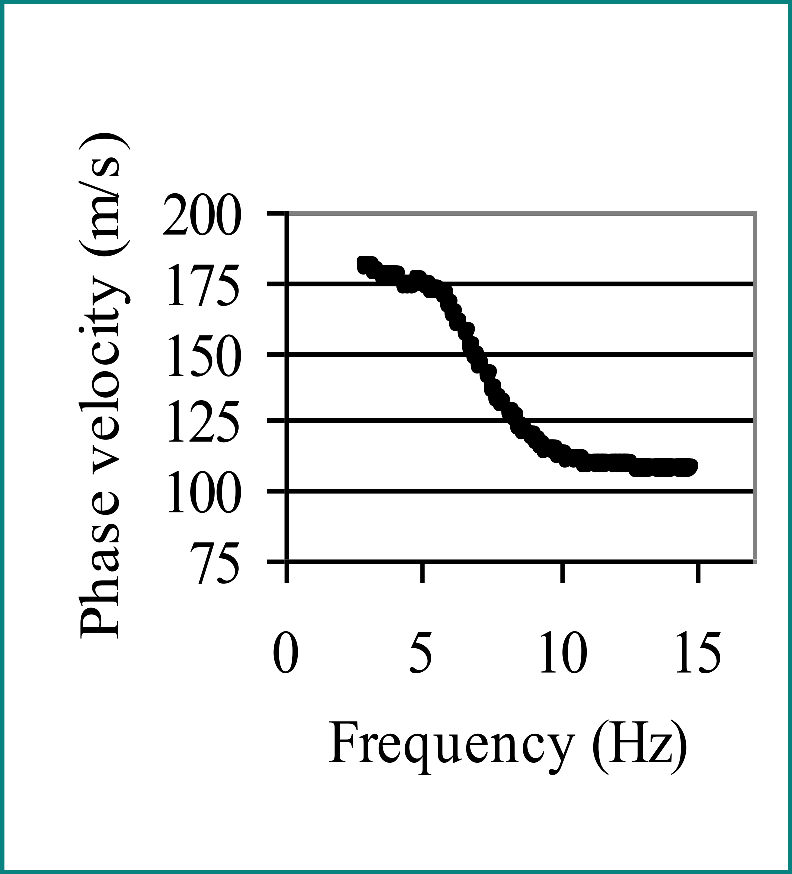
A combination of inverted S-wave velocity and the standard CDP roll-along acquisition format to generate a two-dimensional S-wave velocity section

THE METHOD

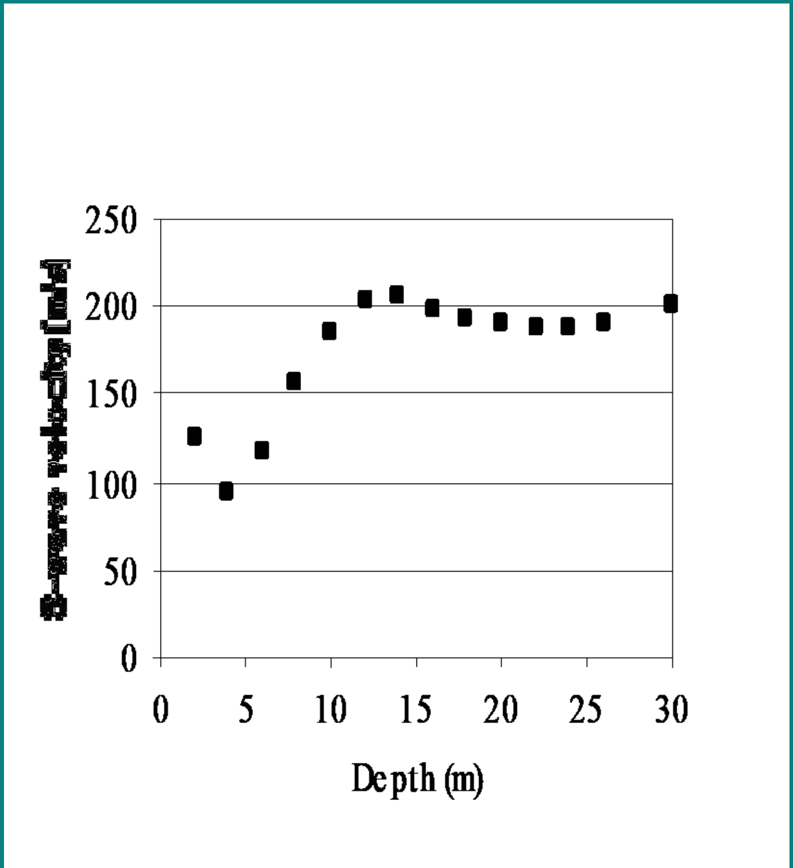
- Acquiring data in CDP acquisition format
- Extracting phase velocities of ground roll from each shot gather
- Generating a 1-D S-wave profile for each shot
- Contouring a 2-D section of S-wave velocity field

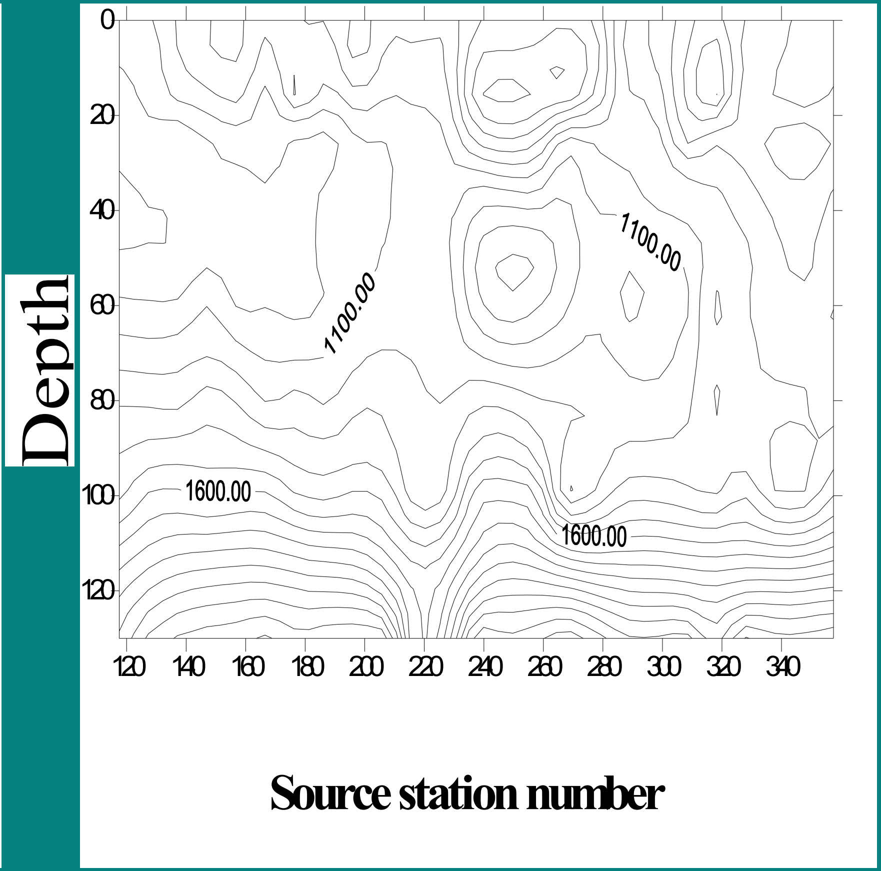
THE METHOD (continued)





THE METHOD (continued)





THE REAL WORLD EXAMPLES

1. Mapping Bedrock (<30 ft) in Olathe, Kansas

Source: a 12 lb hammer and a 1 ft by 1 ft plate

Source spacing: 4 ft

Geophone: single, 4.5 Hz vertical component geophone

Geophone spacing: 2 ft

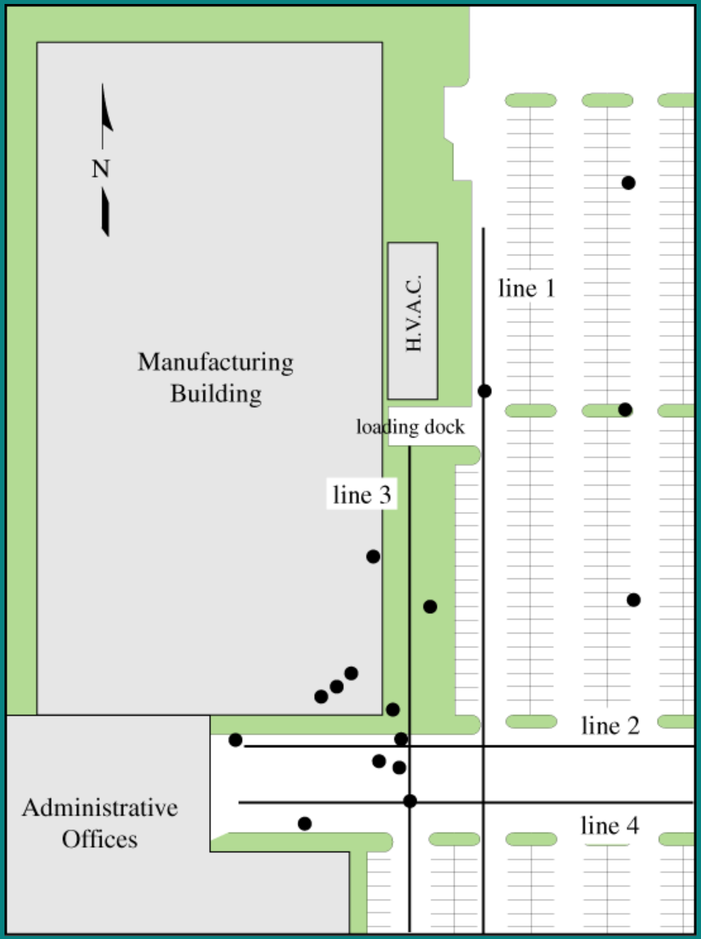
Nearest source-geophone offset: 8 ft

Olathe Example

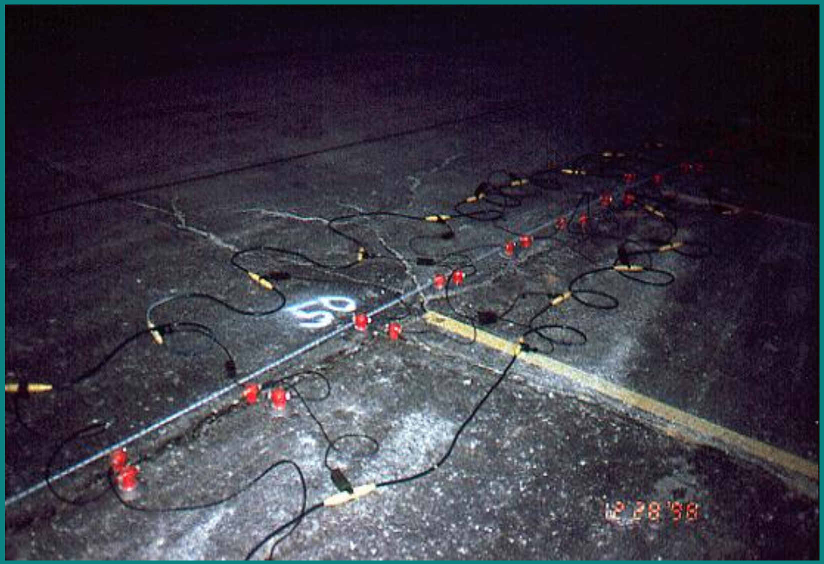
Traces per shot: 48

Sampling Rayleigh waves: 2 to 94 ft

Length of four lines: 1400 ft



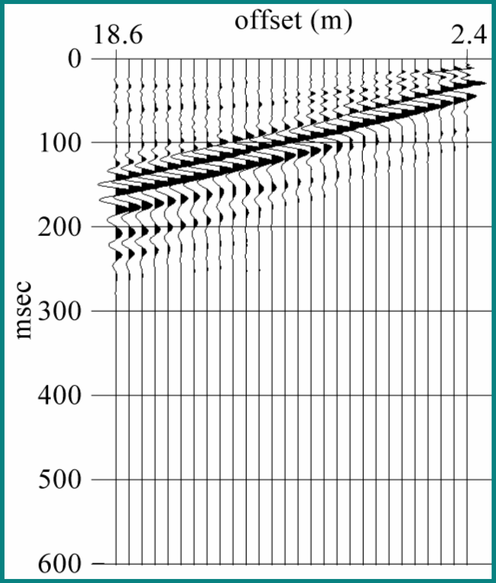
Geophones with spikes, baseplates, or baseplates with sandbags



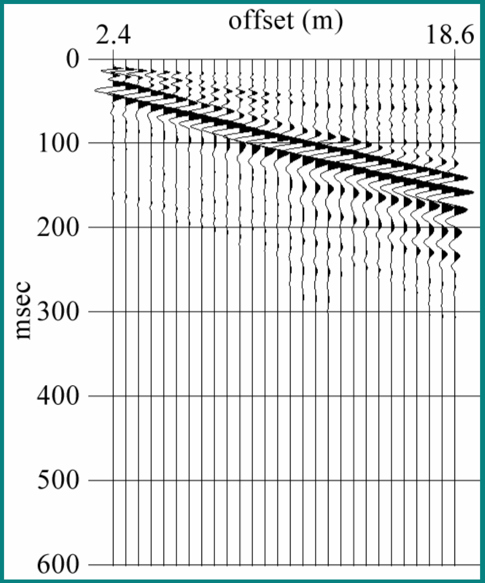
Geophones with spikes and baseplates

Geophones with baseplates and baseplates with sandbags

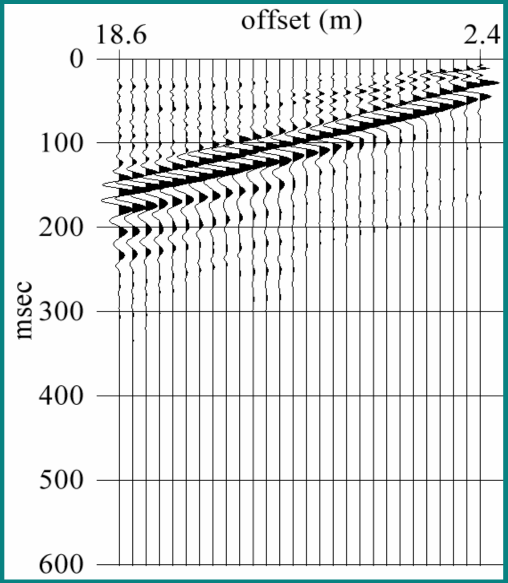
Geophones with spikes, baseplates, or baseplates with sandbags



spikes

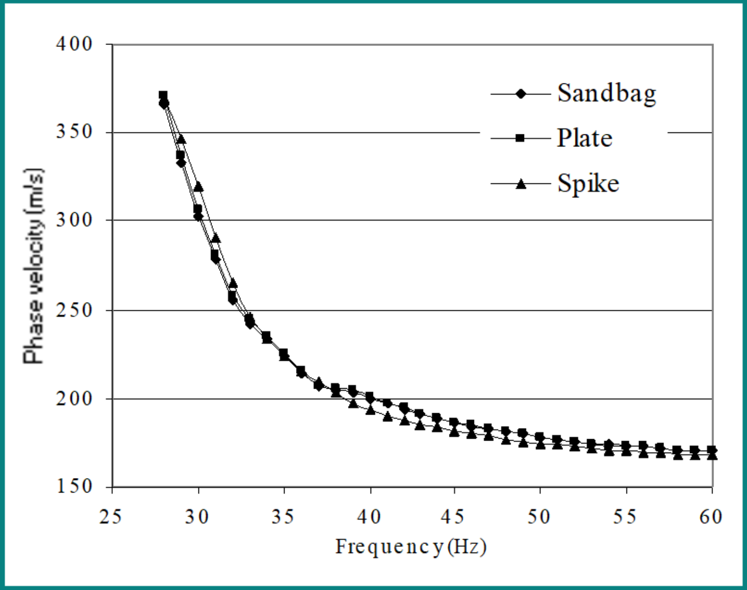


baseplates

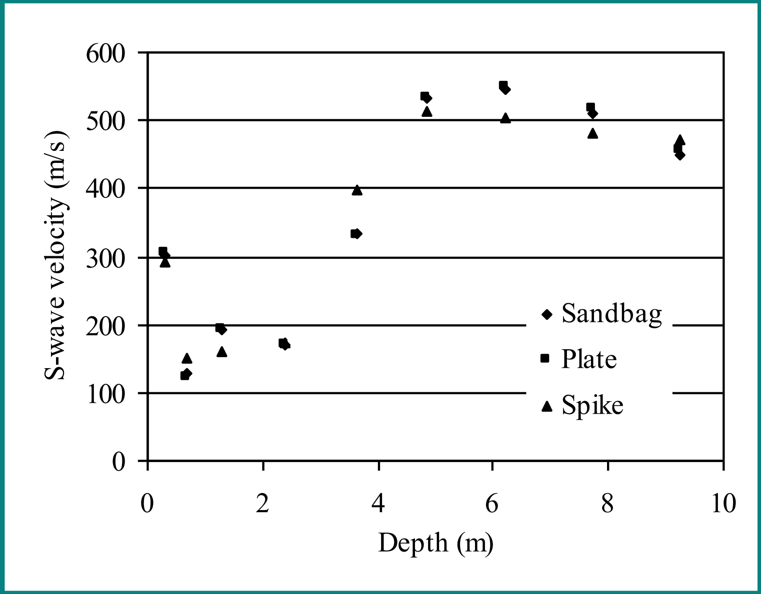


baseplates
with sandbags

Geophones with spikes, baseplates, or baseplates with sandbags



Dispersion curves



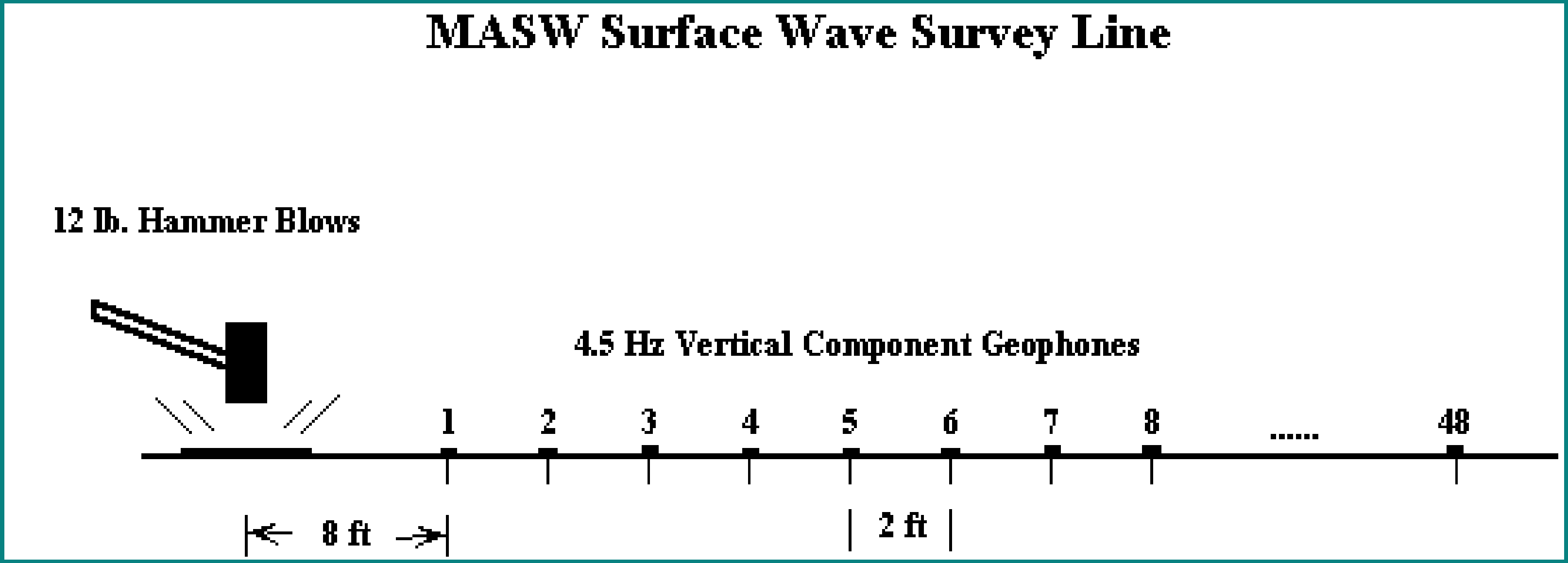
Inverted S-wave velocities

Olathe (continued)

4.5 Hz geophone
with baseplate

12 lb hammer and
1 ft by 1 ft steel plate

Olathe (continued)



Olathe (continued)

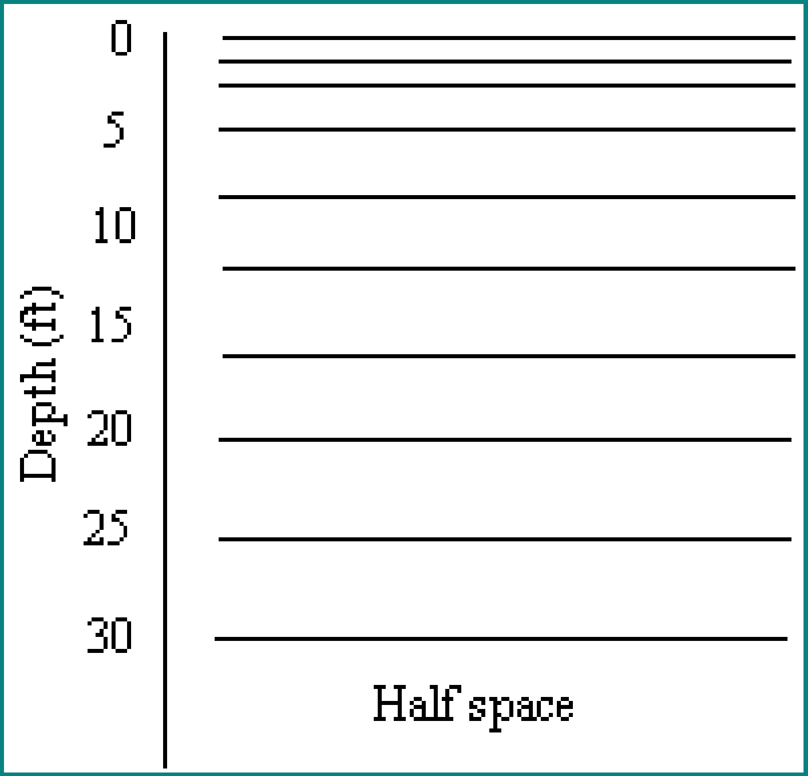
Observed frequency of Rayleigh waves:

20 to 60 Hz

Observed wavelength of Rayleigh waves:

9 to 50 ft

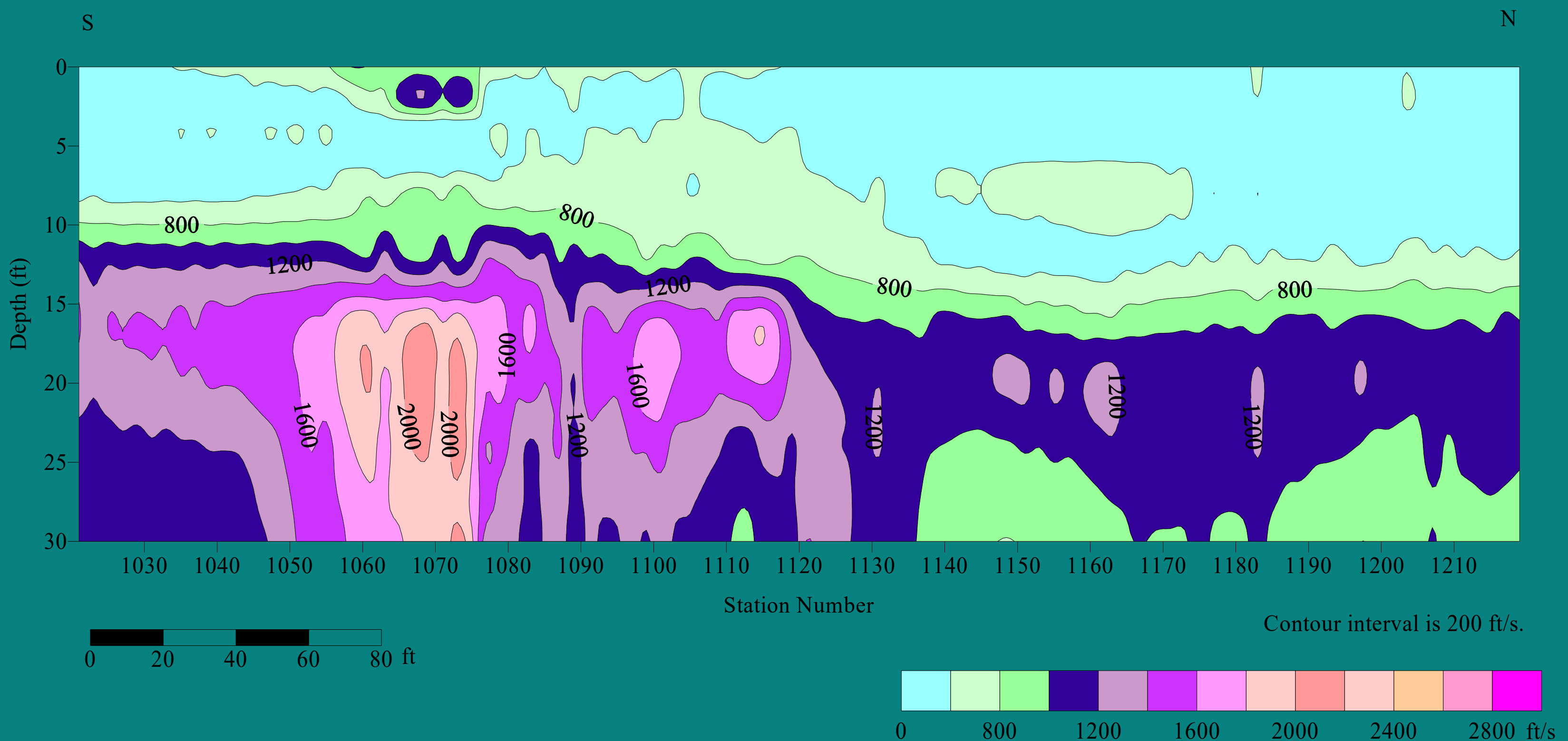
A ten-layer model



Line 1, on asphalt parking lot

Olathe (continued)

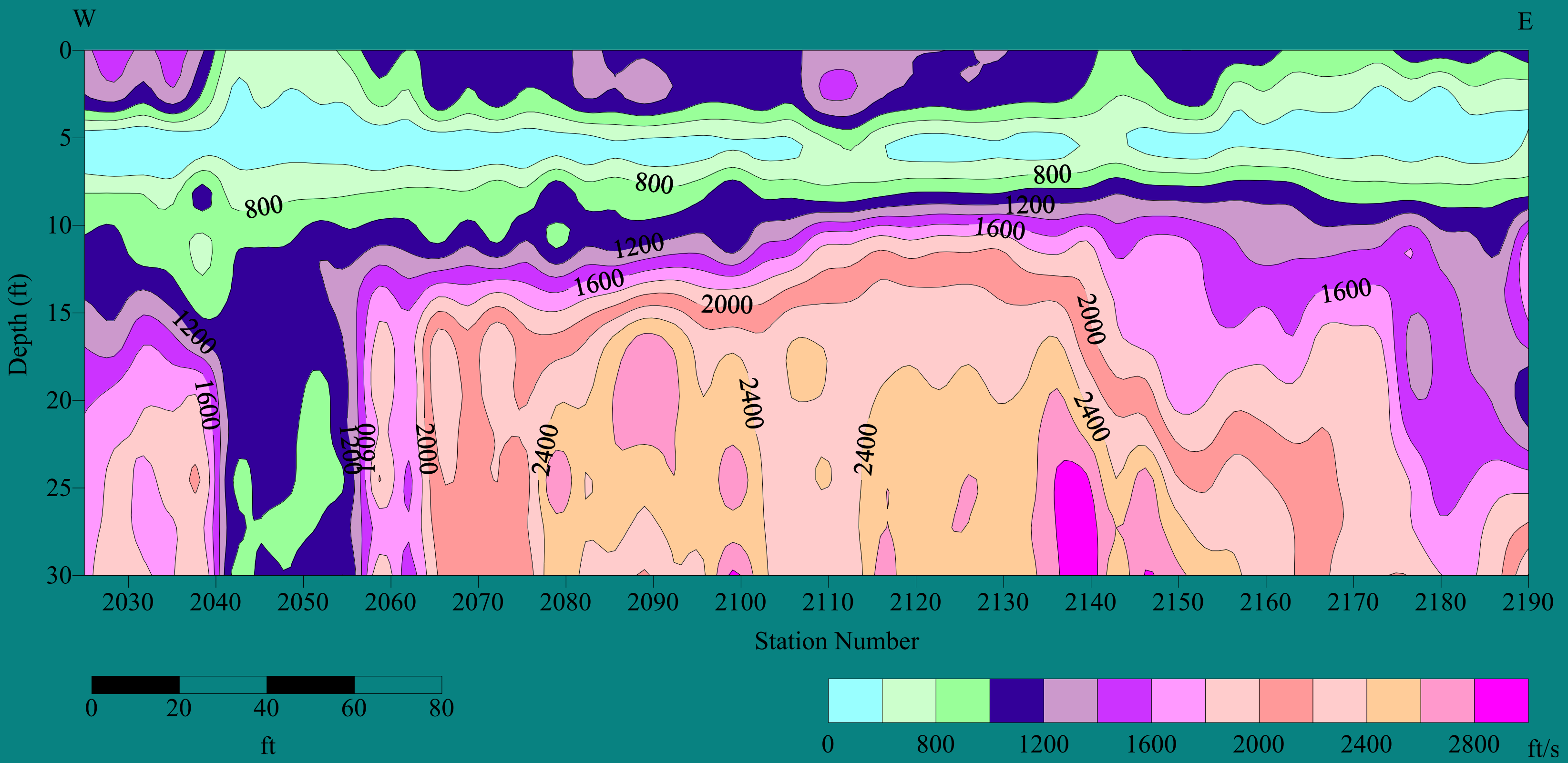
A 2-D S-wave velocity map of line 1, Olathe, Kansas



Line 2, on asphalt parking lot

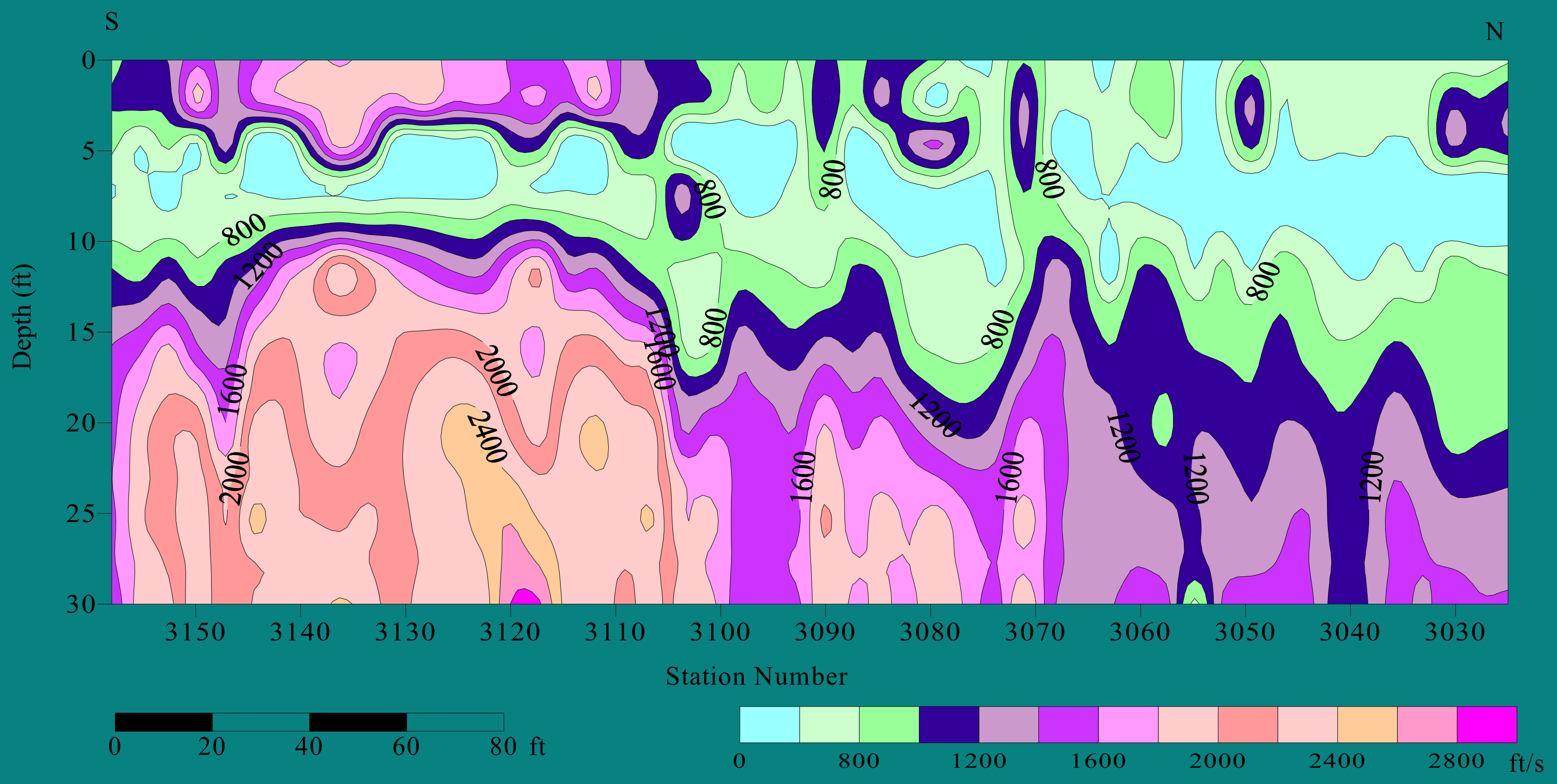
Olathe (continued)

A 2-D S-wave velocity map of line 2, Olathe, Kansas



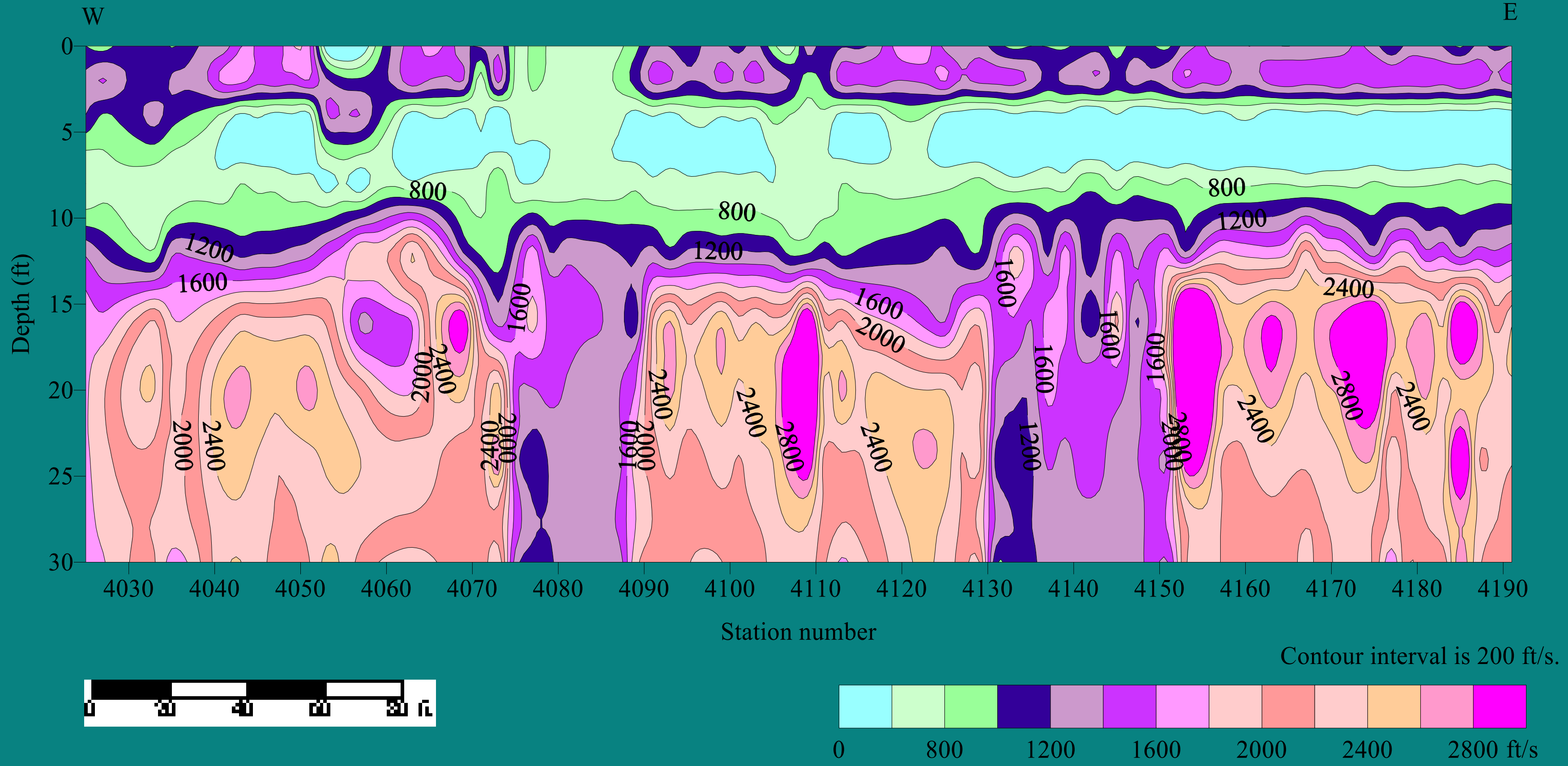
Olathe (continued)

A 2-D S-wave velocity map of line 3, Olathe, Kansas

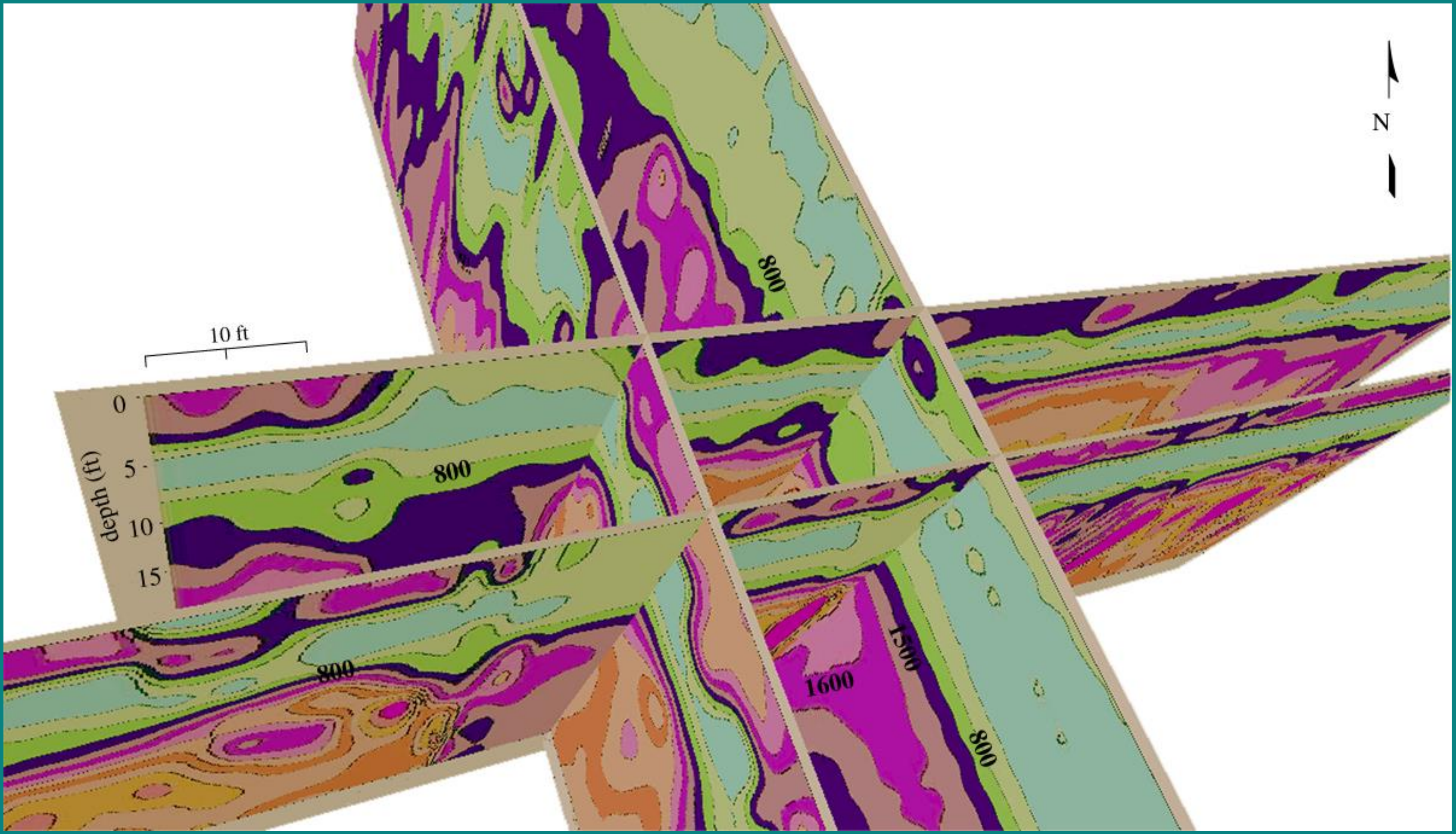


Olathe (continued)

A 2-D S-wave velocity map of line 4, Olathe, Kansas



Olathe (continued)



EXAMPLES (continued)

2. Imaging a Steam Tunnel (<20 ft), Lawrence, Kansas

Source: an IVI minivib with a 10 second linear up-sweep (10 to 150 Hz)

Source spacing: 4 ft

Geophone: three 10 Hz vertical component geophones wired in series

Geophone spacing: 4 ft

Nearest source-geophone offset: 80 ft

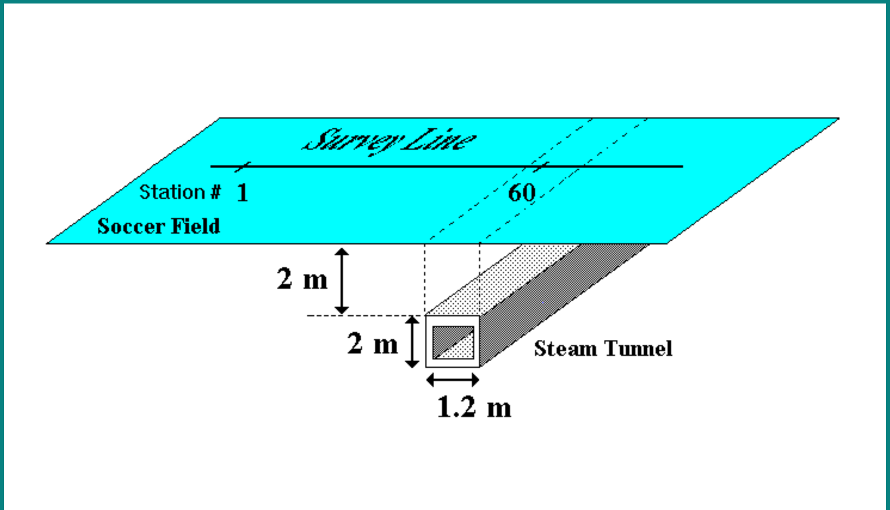
Steam Tunnel Testing Site

Steam Tunnel (continued)

Traces per shot: 30

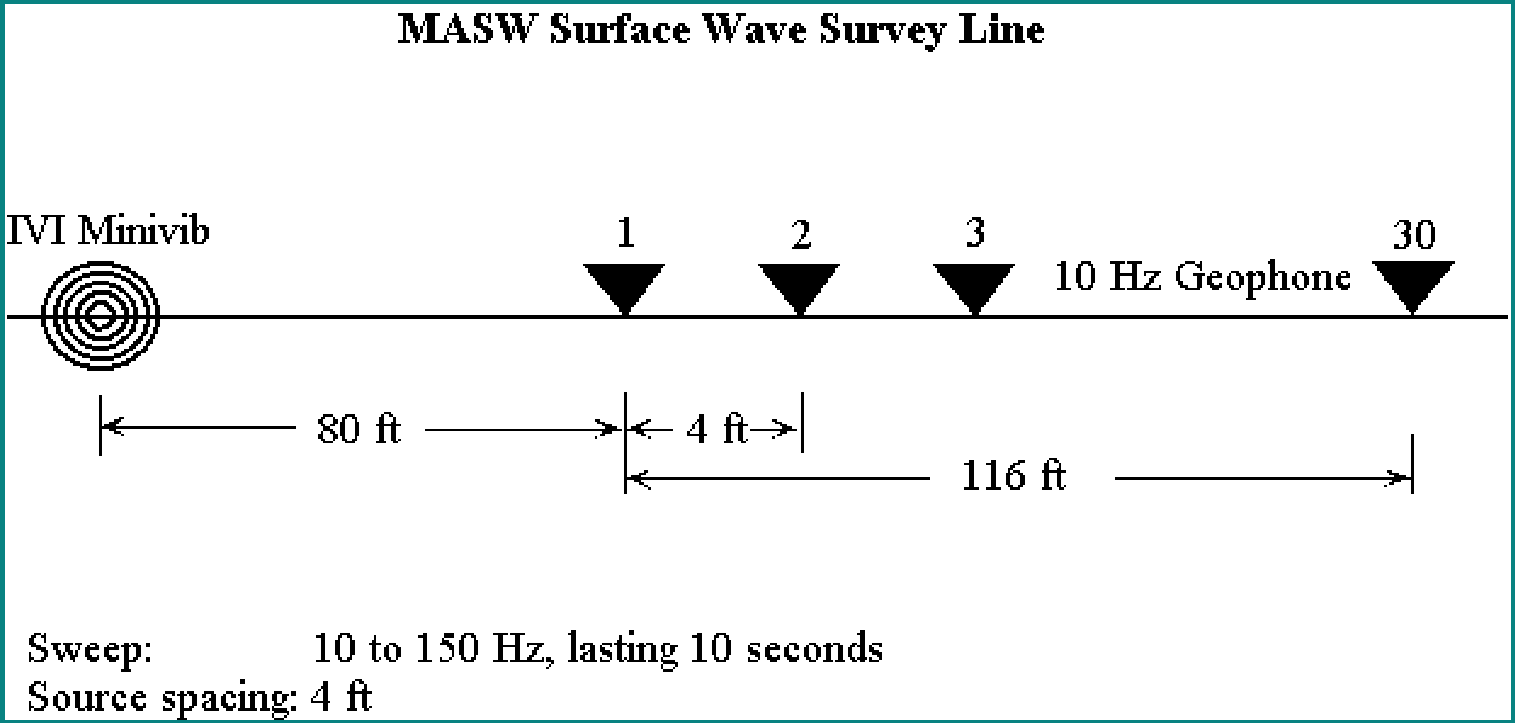
Sampling Rayleigh waves:
4 to 116 ft

76 shots along a line



IVI Minivib

Steam Tunnel (continued)



Steam Tunnel (continued)

The observed frequency of Rayleigh waves:

10 to 50 Hz

The observed wavelength of Rayleigh waves:

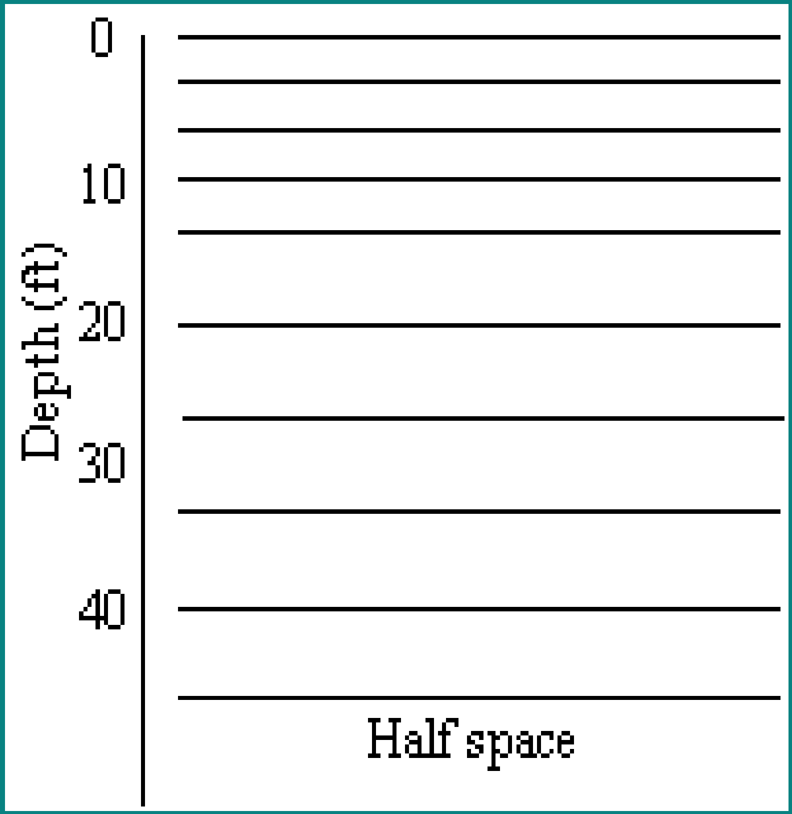
4 to 65 ft

Thickness of the layers

First four layers: 3.3 ft each

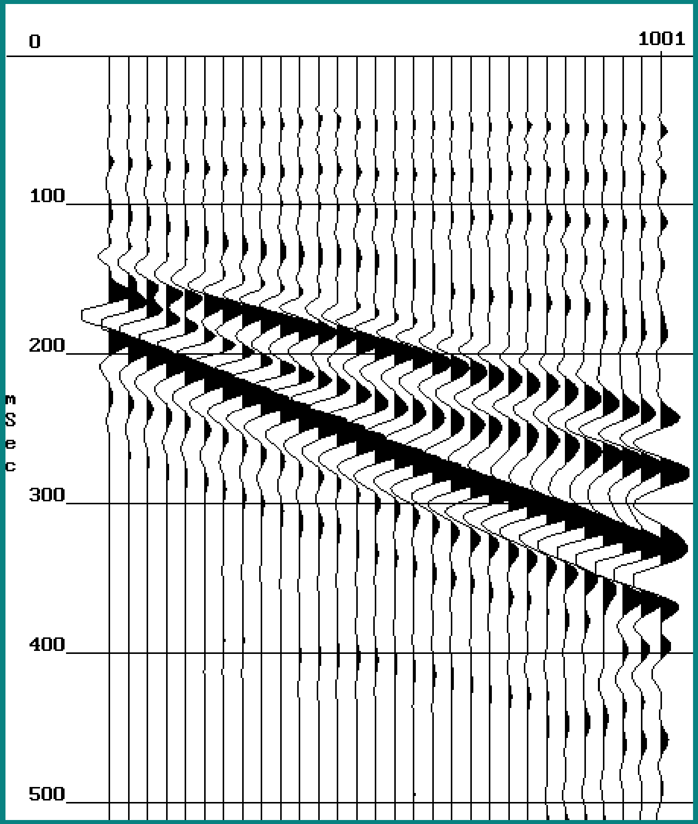
Last five layers: 6.6 ft each

A ten-layer model

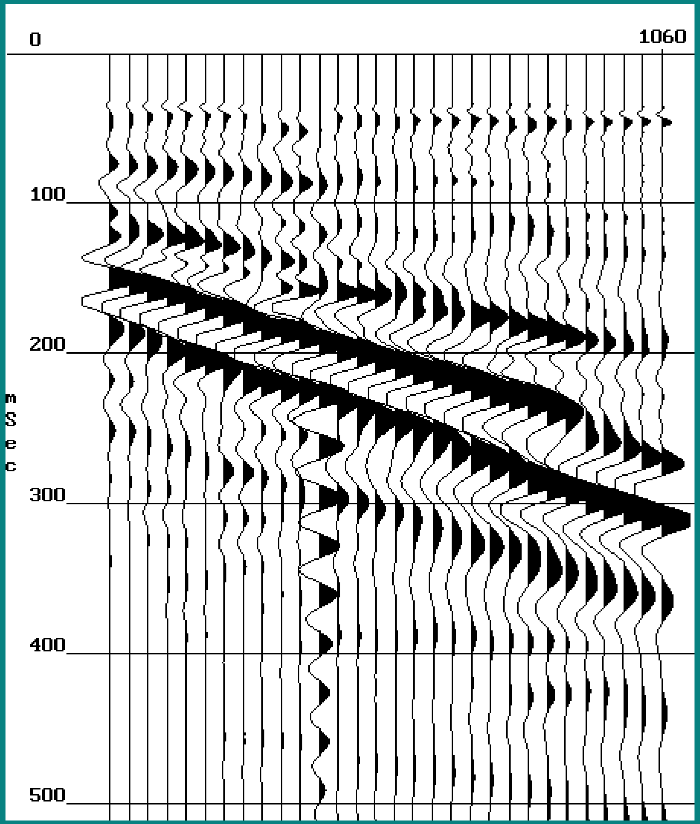


Steam Tunnel (continued)

At beginning of line



At top of tunnel

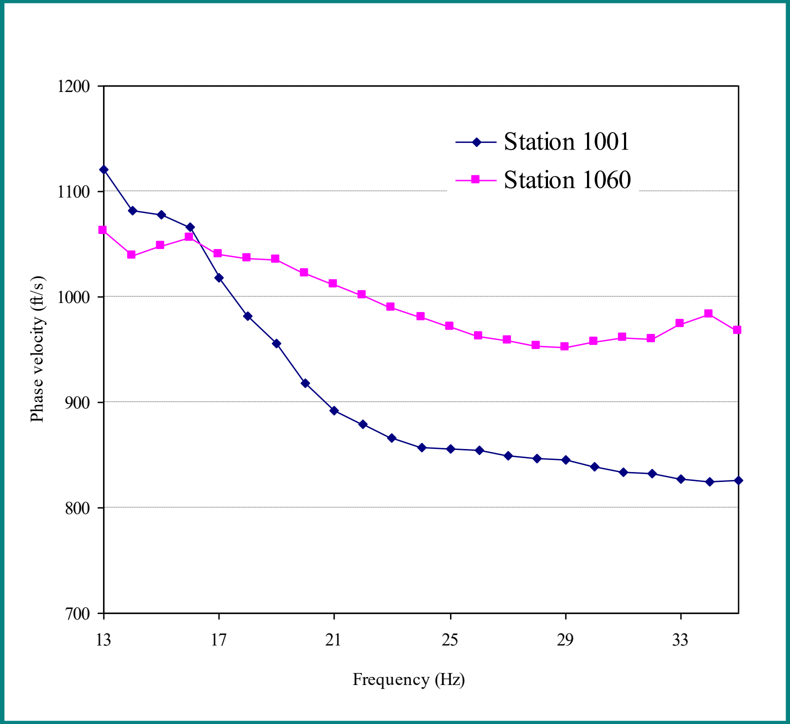


Steam Tunnel (continued)

Dispersion curves for imaging beginning of line and top of tunnel

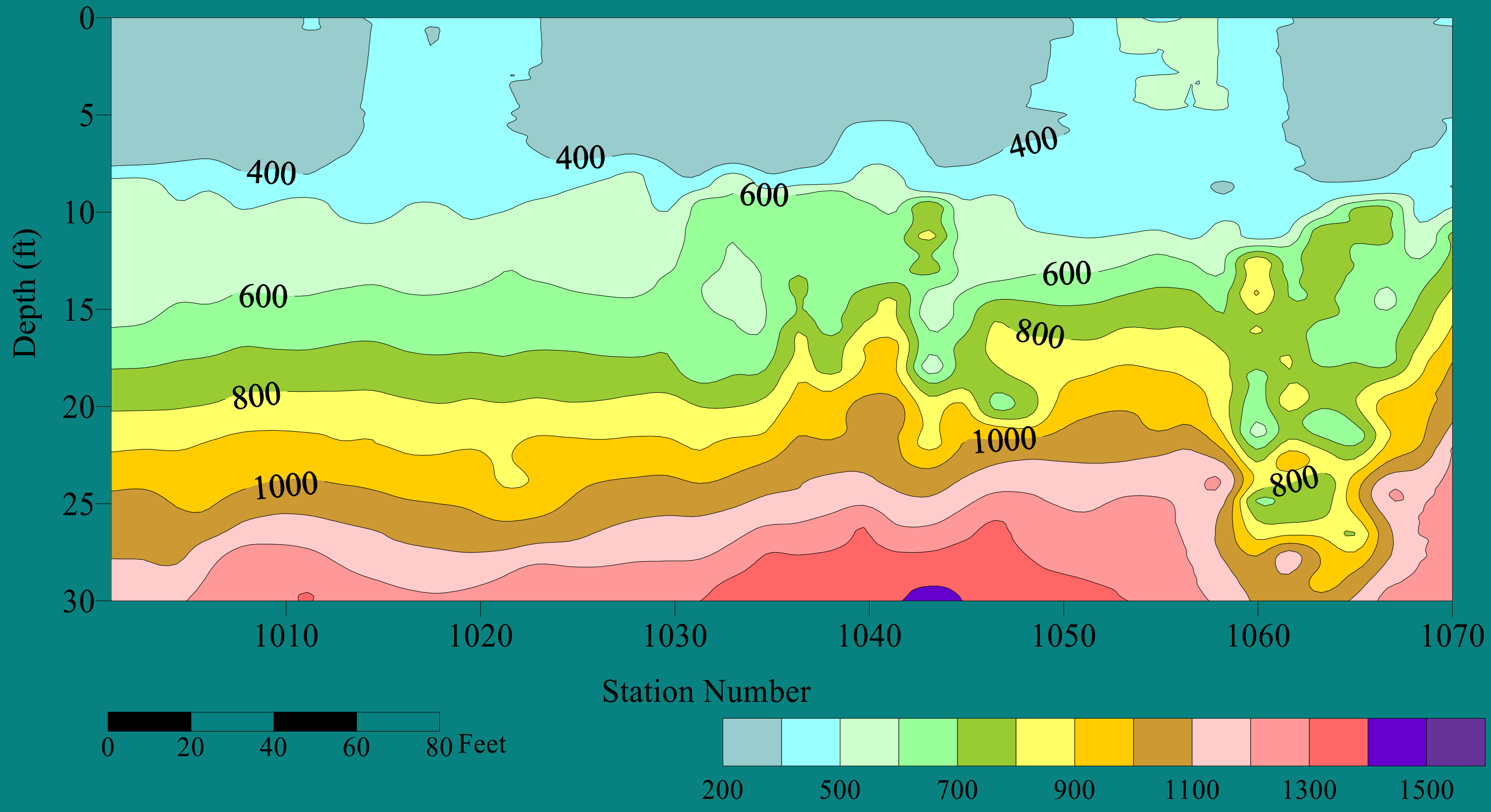
The difference between the two dispersion curves indicates the existence of an anomalous subsurface.

Relatively lower phase velocity (pink line) in lower frequencies (< 17 Hz) suggests low S-wave velocity at a relatively deeper depth. Relatively higher phase velocity in a range (> 20 Hz) suggests very shallow materials are compacted.



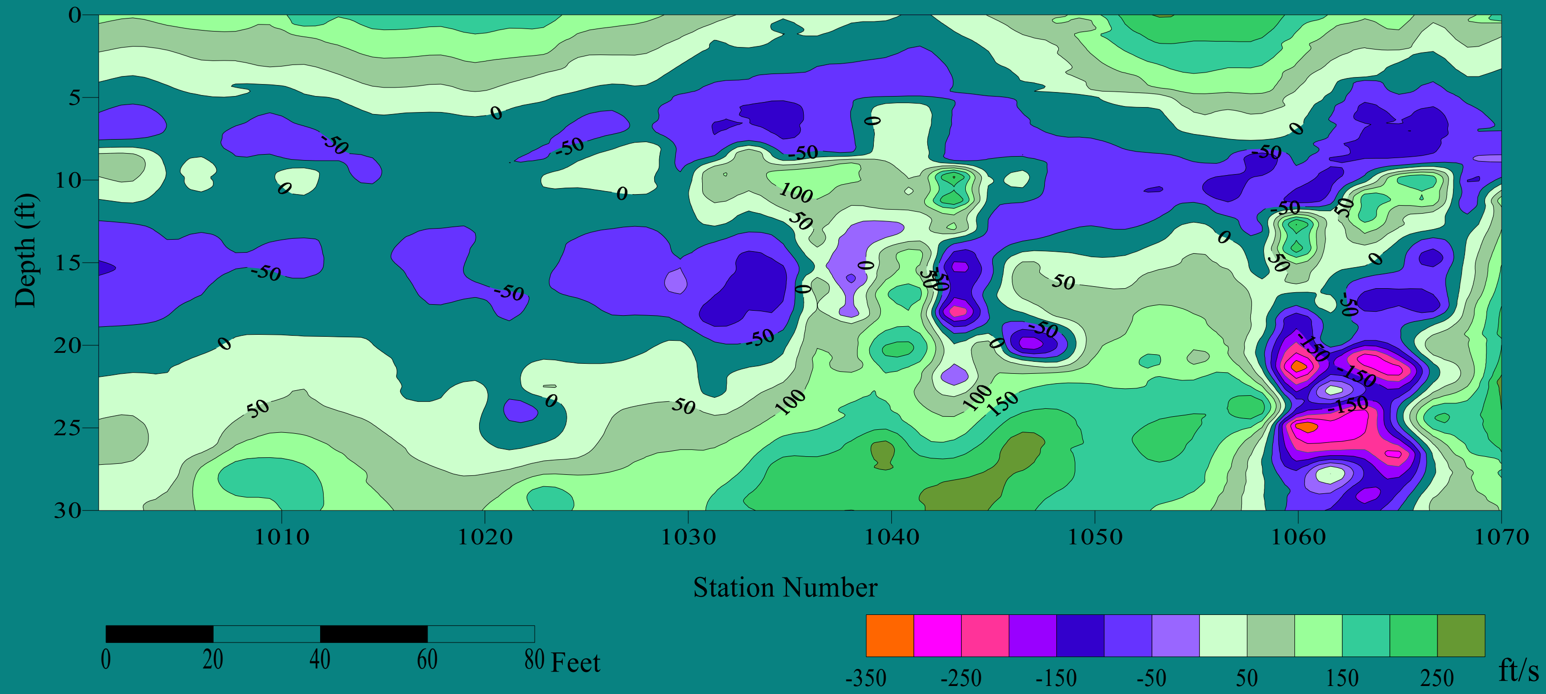
Steam Tunnel (continued)

S-wave velocity map, Steam Tunnel at KU



Steam Tunnel (continued)

Residual S-wave velocity, first-order trend removed, Steam Tunnel, KU



EXAMPLES (continued)

3. Mapping Bedrock Surface (<100 ft), Joplin, Missouri

(Two parallel lines total 364 shots)

Source: an IVI minivib with a 10 second linear down-sweep (100 to 10 Hz)

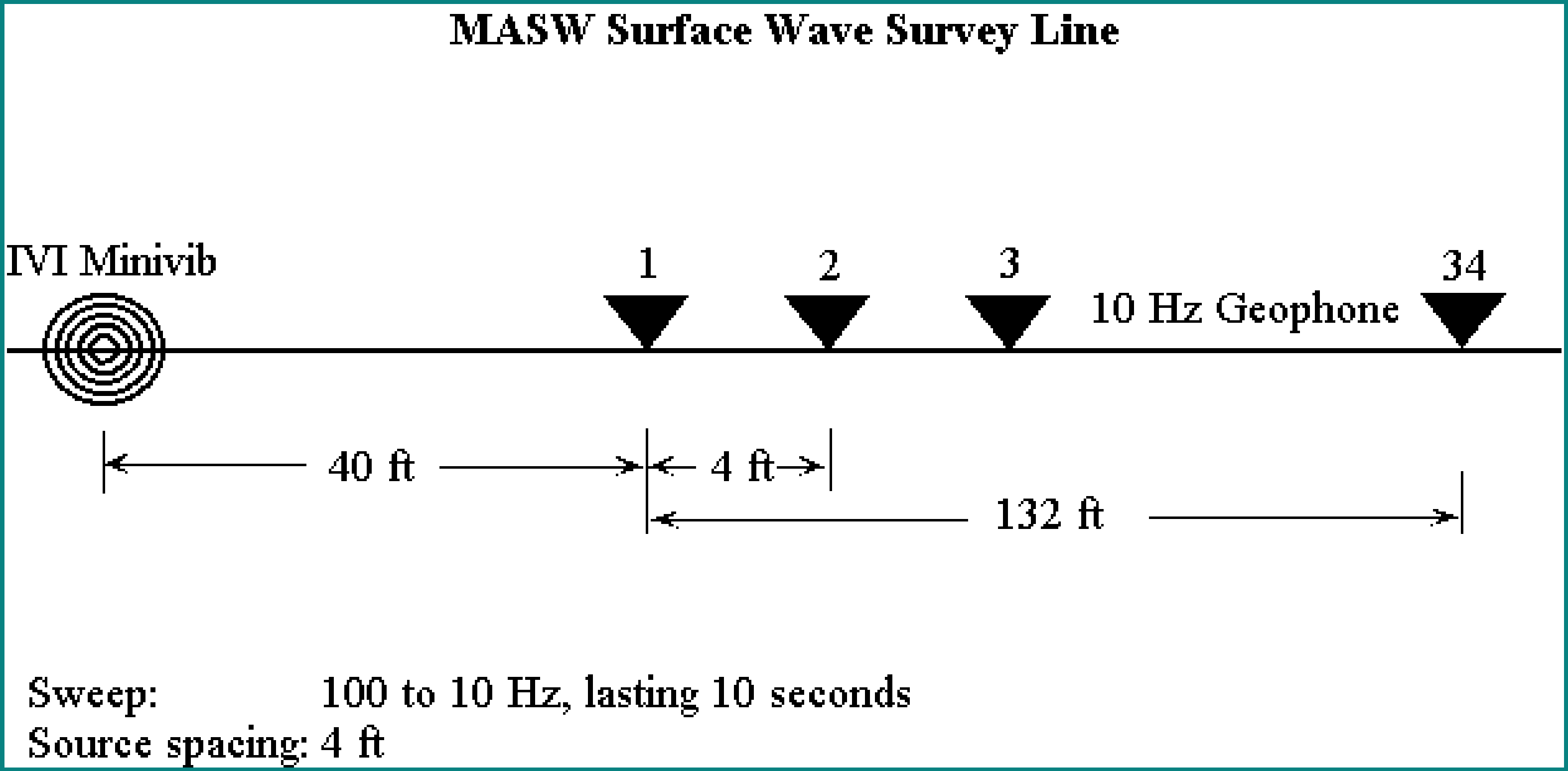
Source spacing: 4 ft

Geophone: three 10 Hz vertical component geophones wired in series

Geophone spacing: 4 ft

Nearest source-geophone offset: 40 ft

Joplin Example



Joplin (continued)

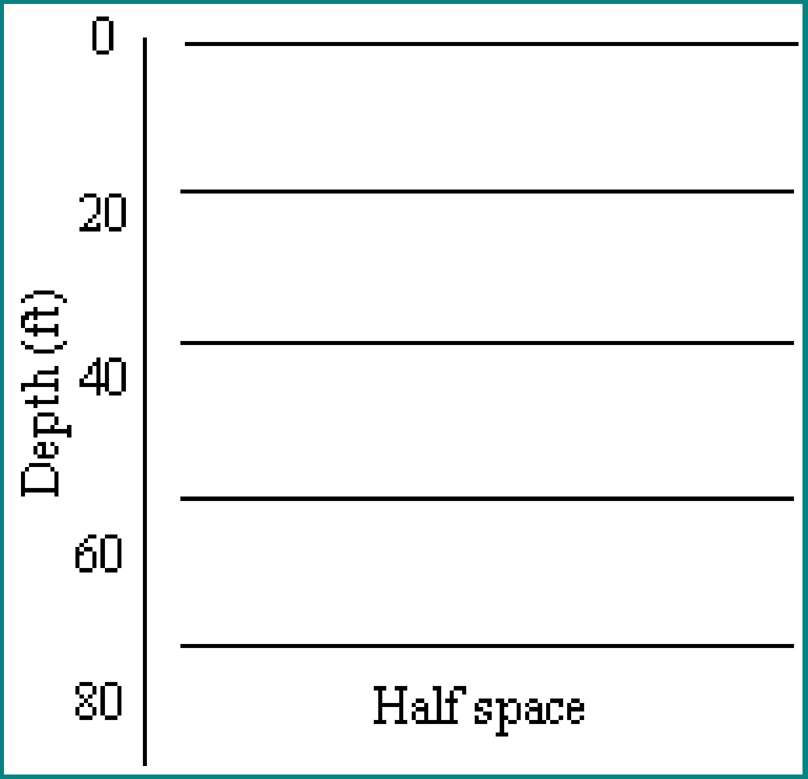
Traces per shot: 34

Sampling Rayleigh waves:
4 to 132 ft

Observed frequency of
Rayleigh waves: 10 to 25 Hz

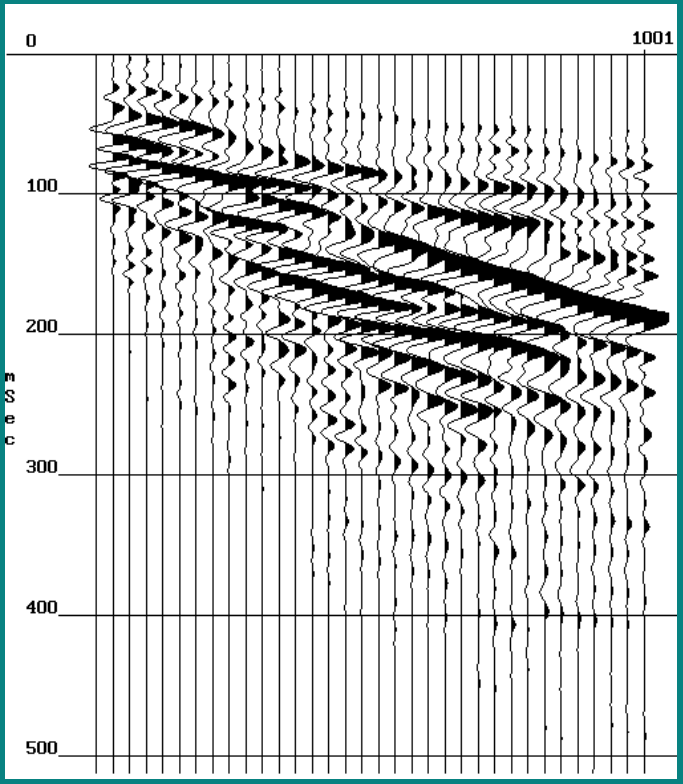
Observed wavelength of
Rayleigh waves: 40 to 100 ft

A five-layer model

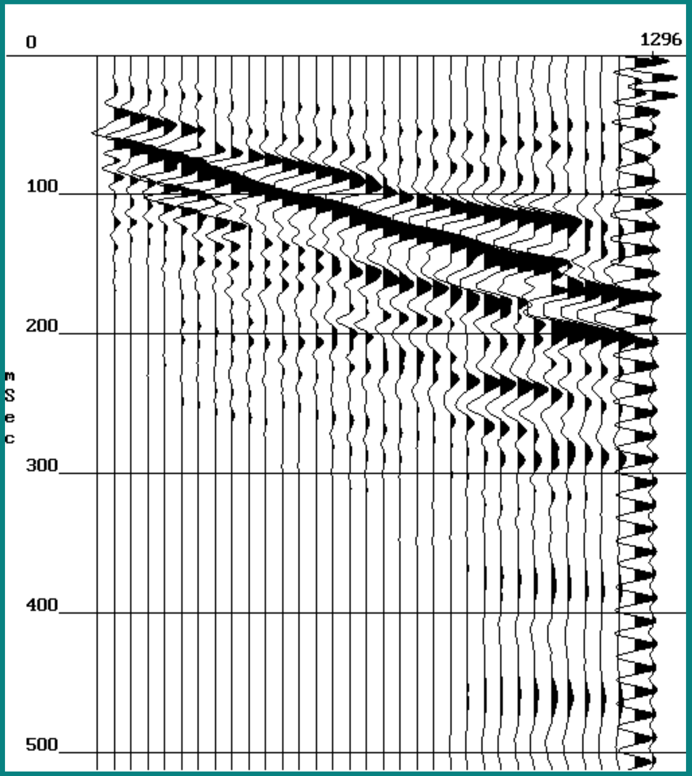


Joplin (continued)

Shot for imaging station 1050



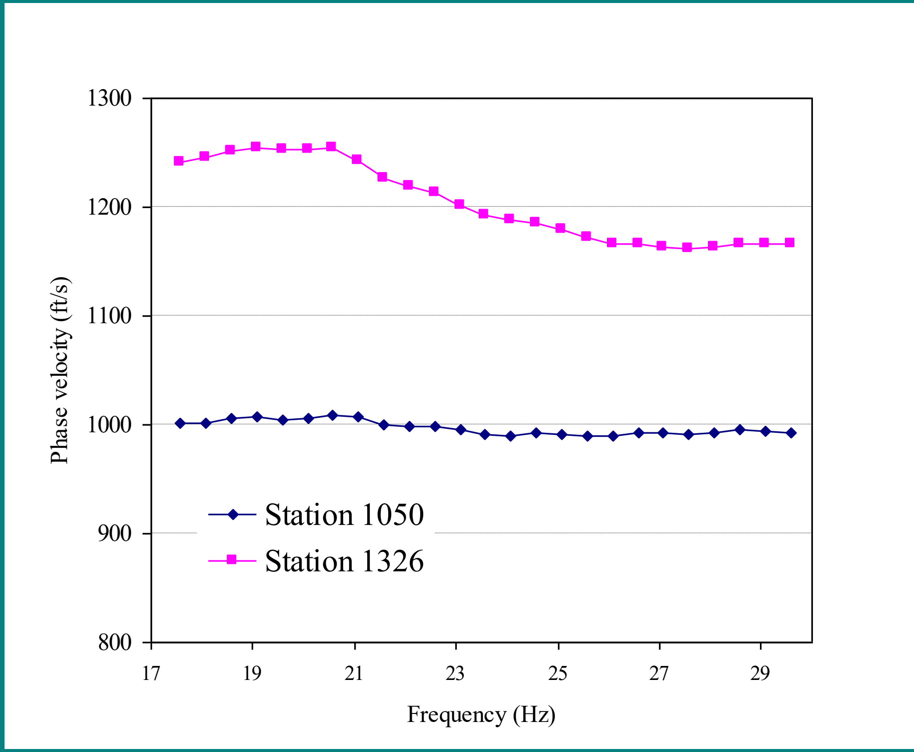
Shot for imaging station 1326



Joplin (continued)

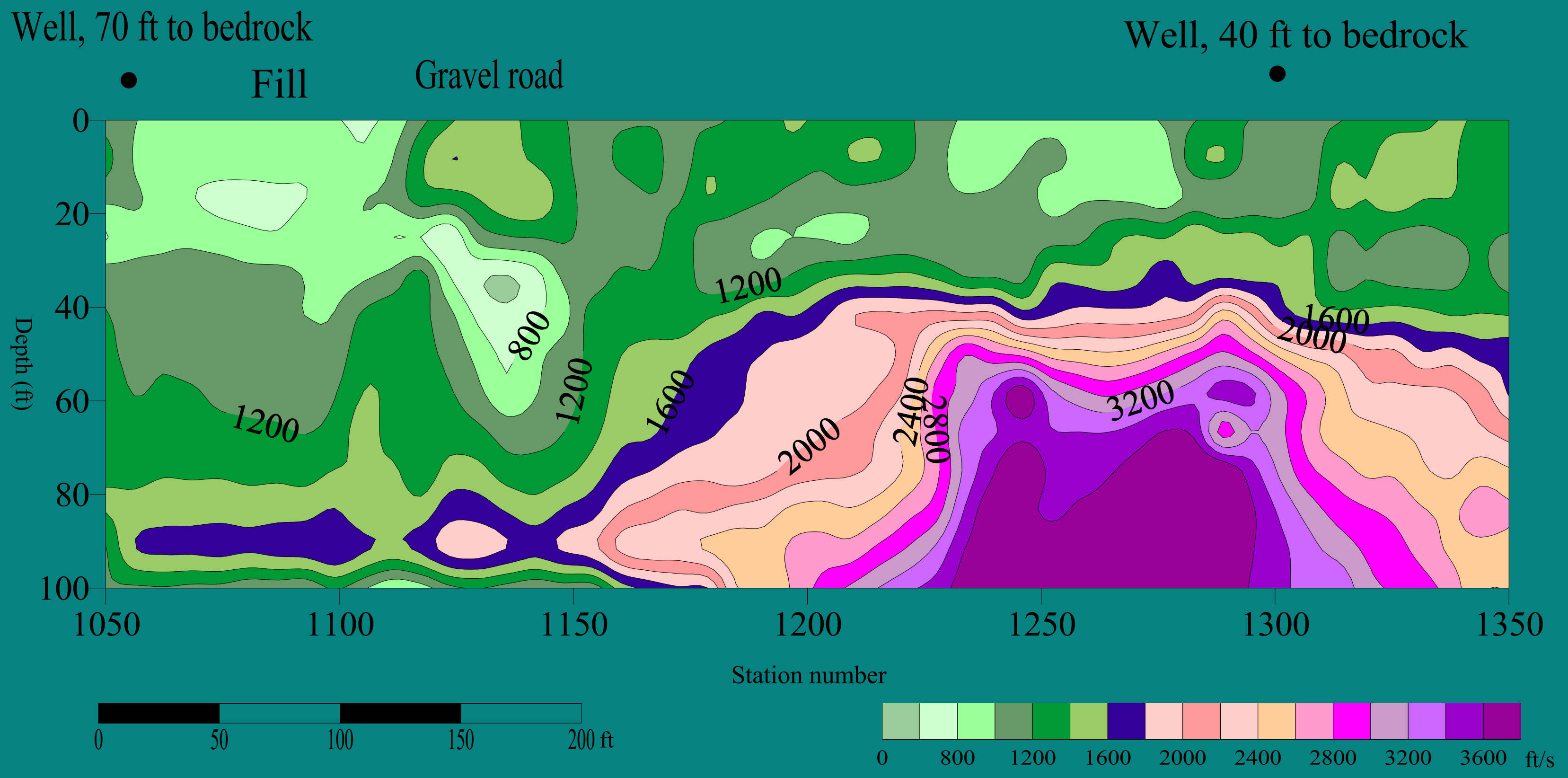
Dispersion curves for imaging stations 1050 and 1326

200 ft/s difference between these two dispersion curves: station 1050 is at the beginning of the line, and station 1326 is at the location of the second well.



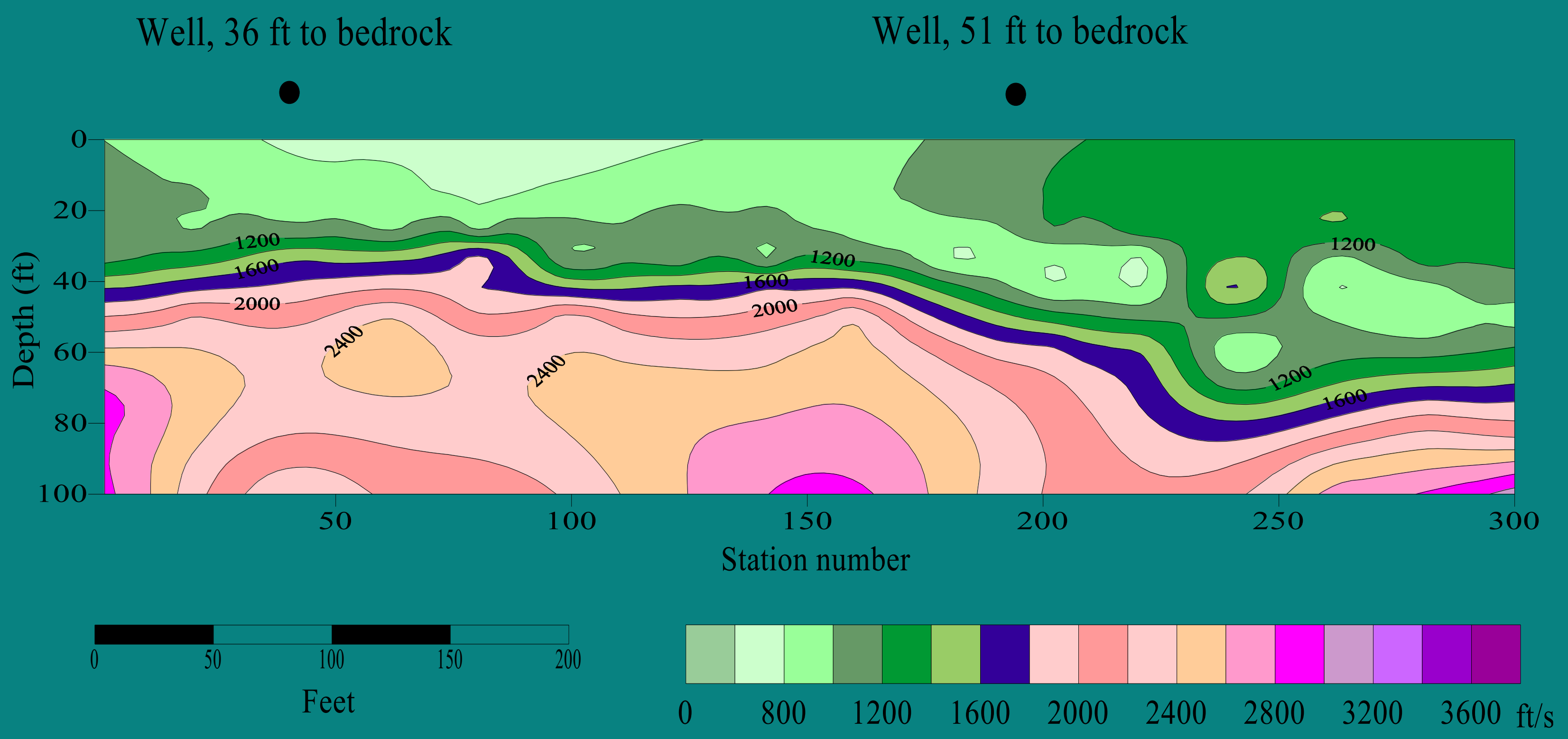
Joplin (continued)

A 2-D S-wave velocity map of line 1, Joplin, Missouri



Joplin (continued)

A 2-D S-wave velocity map of line 2, Joplin, Missouri



EXAMPLES (continued)

4. Mapping Dissolution Feature (<100 ft), Damascus, Alabama

(2,500 shots acquired along thirteen lines)

Source: three ground impacts from a rubber band accelerated weight drop

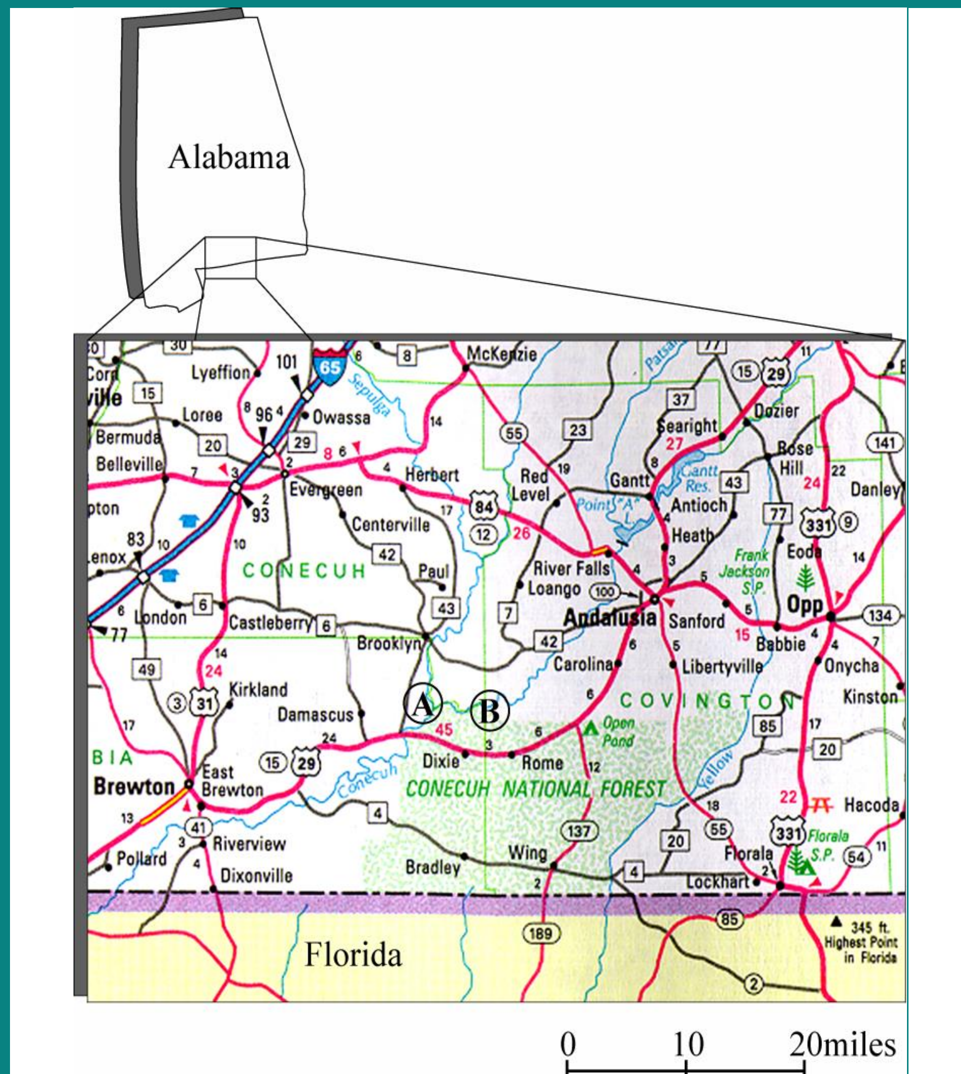
Source spacing: 4 ft

Geophone: Single 4.5 Hz vertical component geophone

Geophone spacing: 4 ft

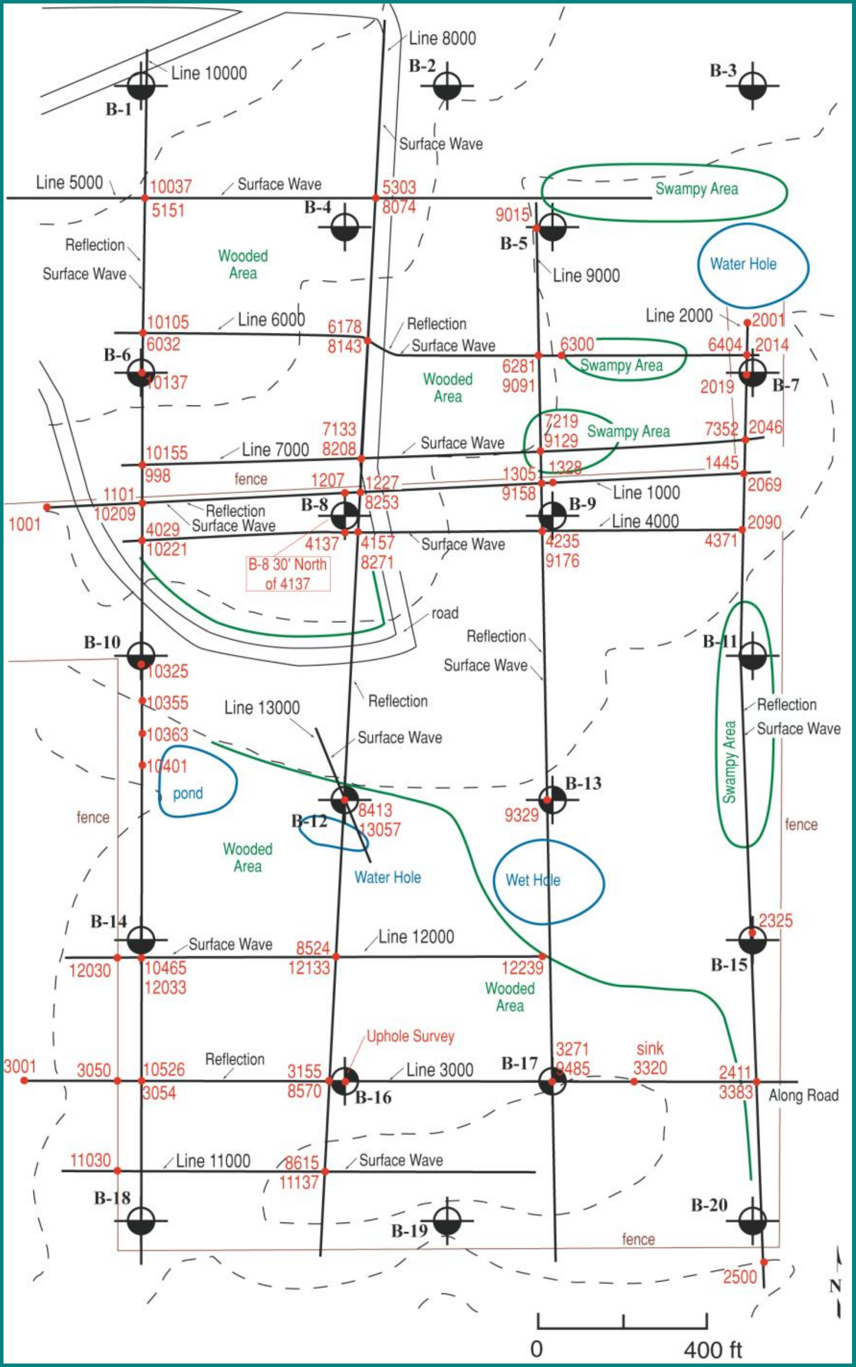
Nearest source-geophone offset: 40 ft

Site Map


Alabama
McKenzie
Lyeffion
Owassa
Loree
Bermuda
Belleville
Evergreen
Herbert
Centerville
Red Level
Gantt
Searight
Dozier
Rose Hill
Danley
Antioch
Heath
Eoda
CONECUH
Paul
River Falls
Loango
Andalusia
Sanford
Opp
London
Castleberry
Brooklyn
Carolina
Libertyville
Babbie
Onycha
Kinston
Kirkland
Damascus
COVINGTON
A
B
Dixie
Rome
Open Pond
Brewton
East Brewton
CONECUH NATIONAL FOREST
Hacoda
Riverview
Pollard
Dixonville
Bradley
Wing
Florala
Lockhart
Florala S.P.
Frank Jackson S.P.
345 ft. Highest Point in Florida
Florida
0
10
20miles

Line Location Map

13 lines
2,500 shots



Working Site

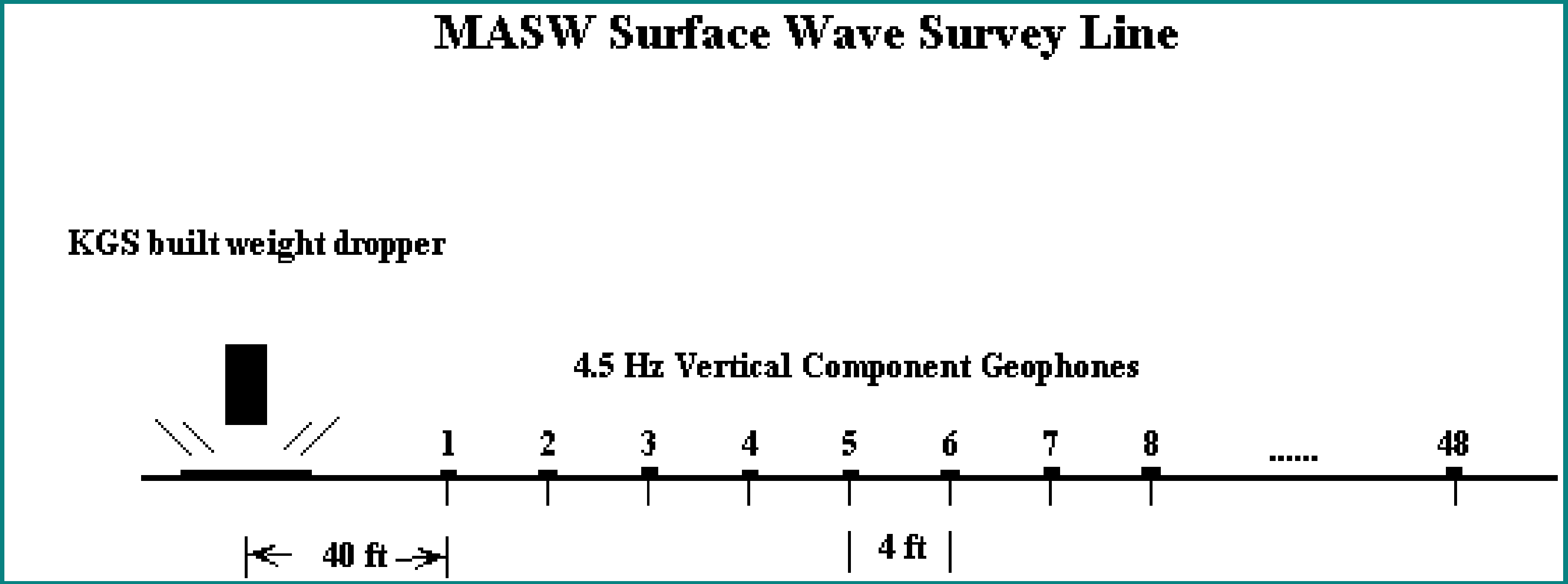
Damascus Example (continued)

A rubber band accelerated weight dropper

Damascus (continued)

A survey line

Damascus (continued)



224 shots along line 1

Damascus (continued)

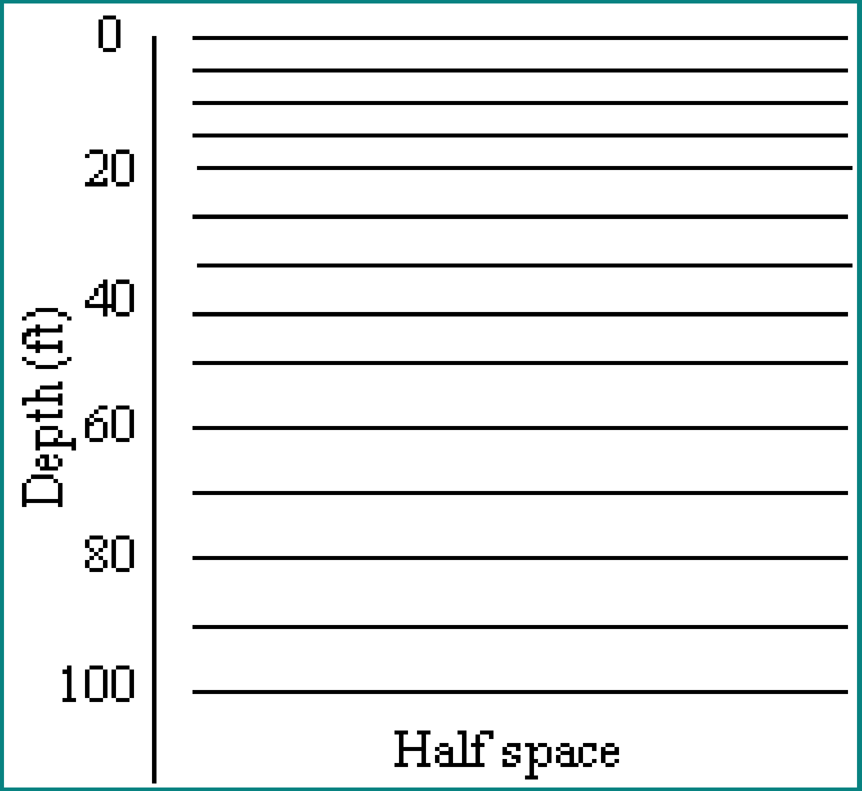
Traces per shot: 48

Sampling Rayleigh waves:
4 to 188 ft

Observed frequency of Rayleigh: 5 to 22 Hz

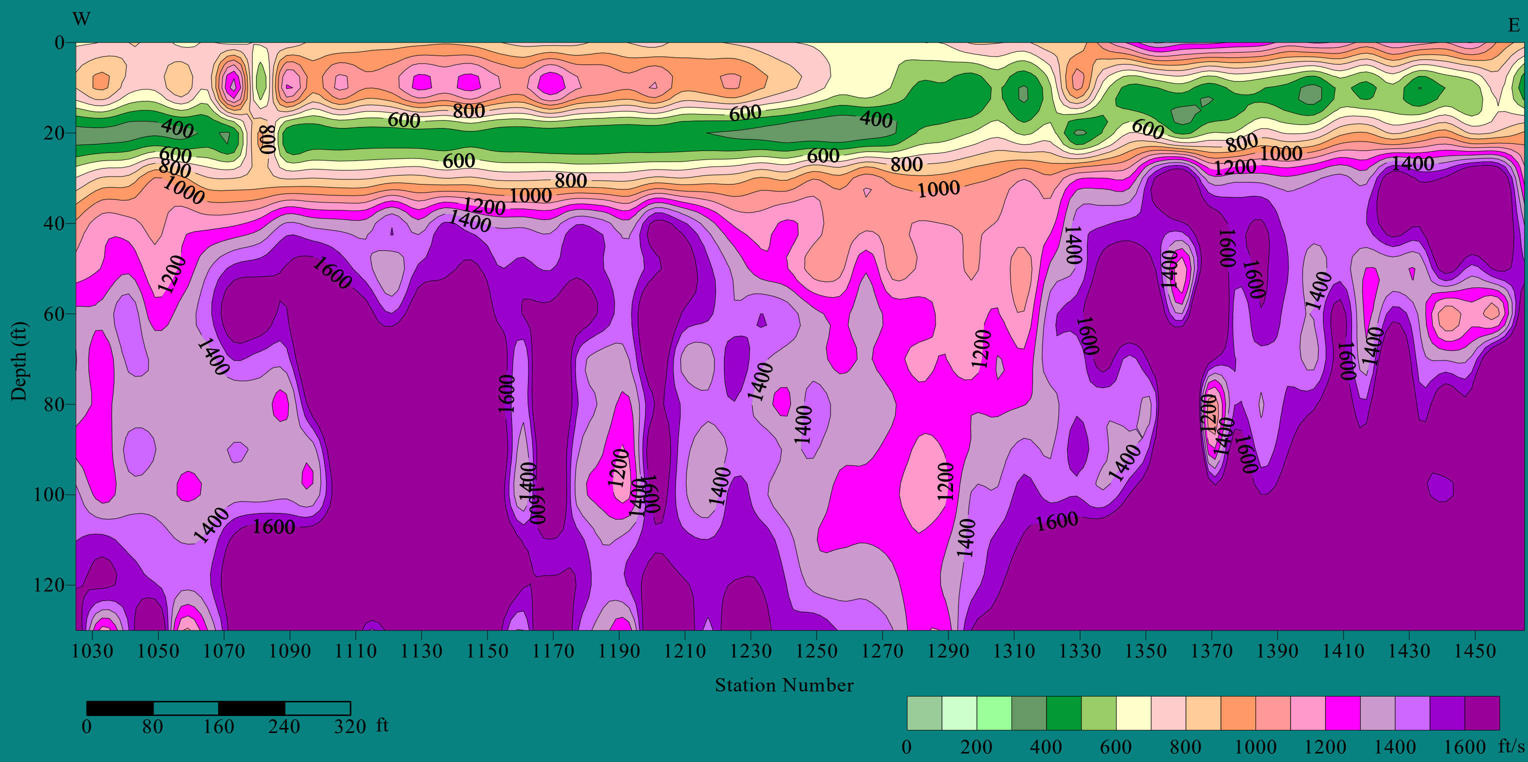
Observed wavelength of Rayleigh waves:
25 to 200 ft

A fourteen-layer model



Damascus (continued)

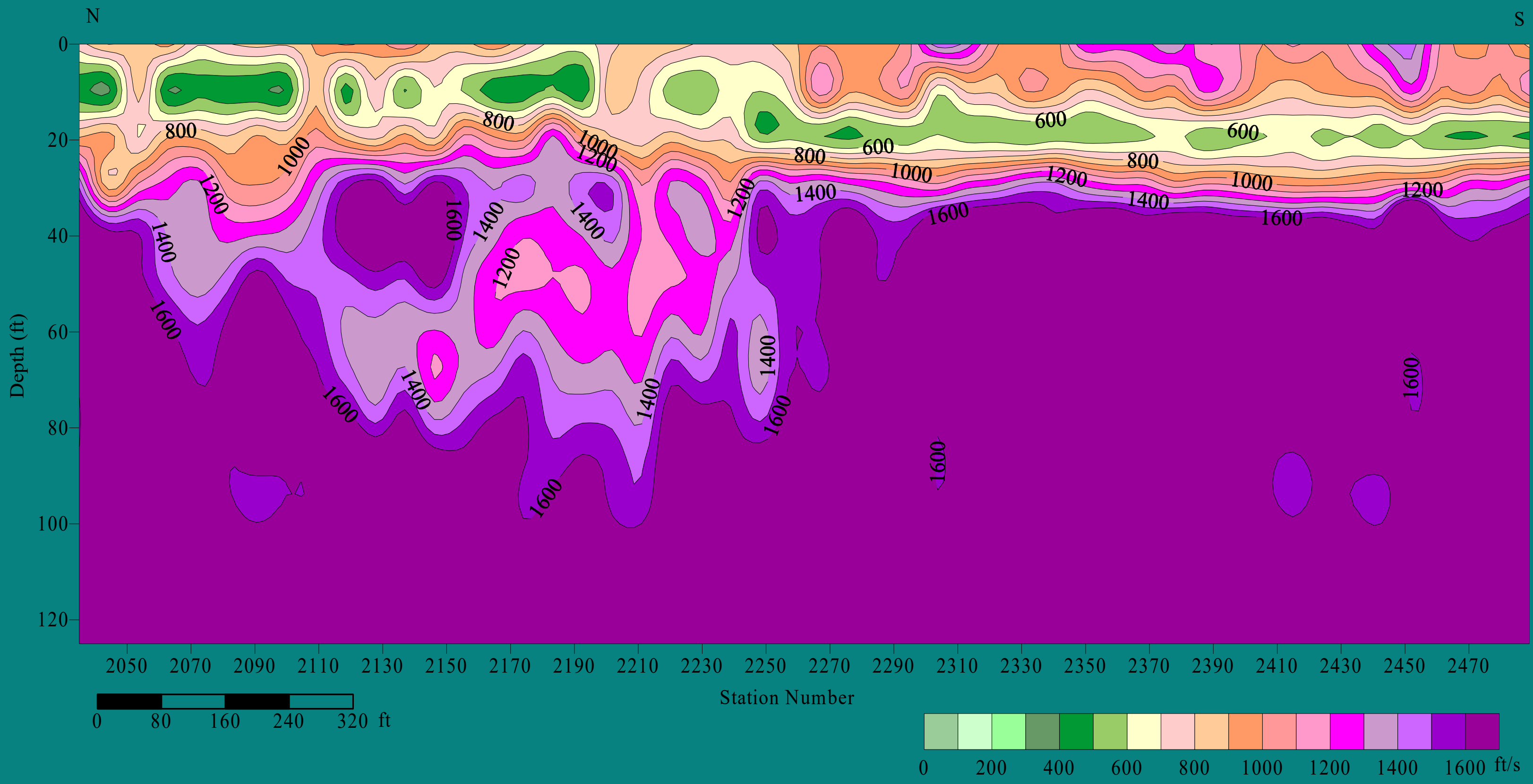
A 2-D S-wave velocity map of line 1



Two distinguished S-wave velocity lows are around stations 1050 and 1270 from 40 to 100 ft depth. The weathered limestone surface is interpreted along the 1,200 ft/s contour line.

Damascus (continued)

A 2-D S-wave velocity map of line 2



EXAMPLES (continued)

5. Pit site location (< 40 ft), Raleigh, North Carolina

(250 shots acquired along two lines)

Source: one ground impacts from 8 lb. hammer

Source spacing: 2 ft

Geophone: Single 4.5 Hz vertical component geophone

Geophone spacing: 2 ft

Nearest source-geophone offset: 24 ft

48-channel *Geometrics StrataView*

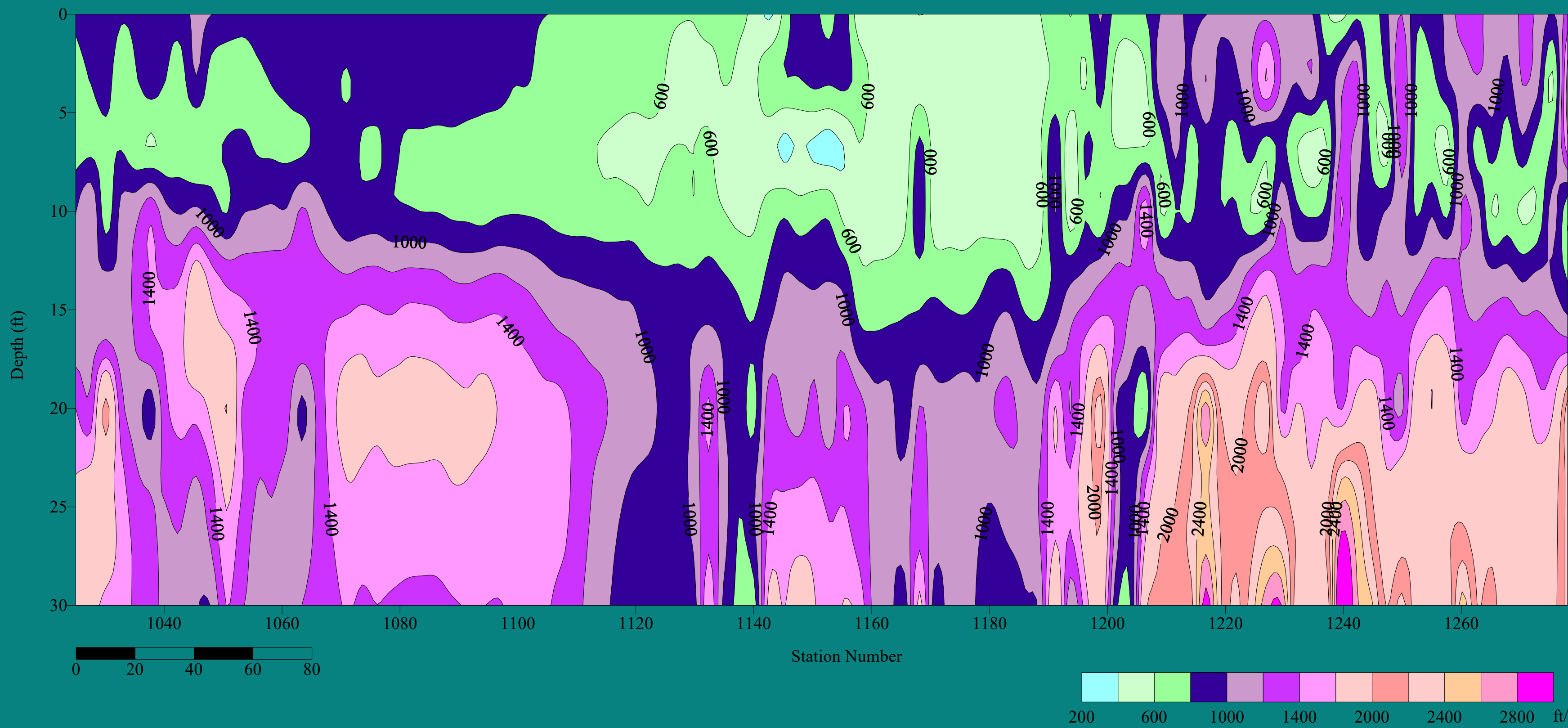
8 lb Hammer and 1 ft by 1 ft plate (DELRIN)

4.5 Hz vertical component geophone

Raleigh, North Carolina

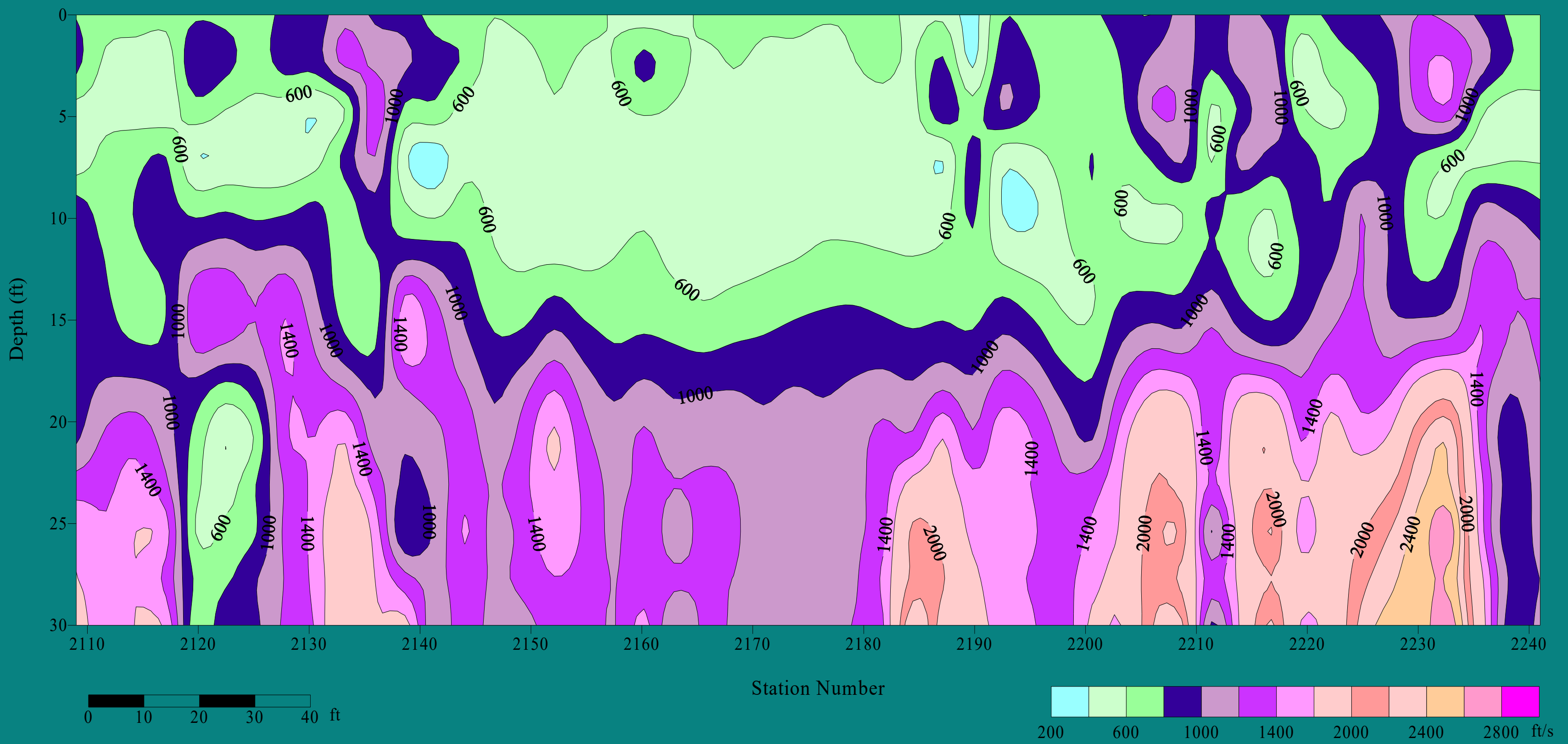
Raleigh, North Carolina

S-wave velocity section of line 1



Raleigh, North Carolina

S-wave velocity section of line 2



CONCLUSIONS

1. Shallower target investigation

   High-frequency (> 2 Hz) ground roll
   Investigation depth from 5 to 100 feet

2. Feasibility in noisy environments

   Ground roll, high signal-to-noise ratio, allowing 2-D images to be obtained in noisy environments

3. Efficiency

   The standard CDP roll-along acquisition method provides an efficient way to acquire large quantities of broadband surface wave data along a line

CONCLUSIONS (continued)

4. Reliability

   The redundancy of the CDP acquisition method provides a reliable way to verify inverted S-wave velocities so that it reduces the ambiguity of inverted S-wave velocities

5. Simplicity

   A contouring software: from a 1-D S-wave velocity profile to a 2-D S-wave velocity map

6. Anomaly enhancement

   2-D data processing techniques can be applied to a 2-D S-wave velocity section to enhance local anomalies

ACKNOWLEDGEMENTS

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