

# **A Pitfall in Shallow Shear-wave Refraction Surveying**



**An Interesting Real-World Example**

# Outline

- Introduction

- A Real World Example

  - SH-wave Refraction Survey*

  - P-wave Refraction Survey*

  - Explanation*

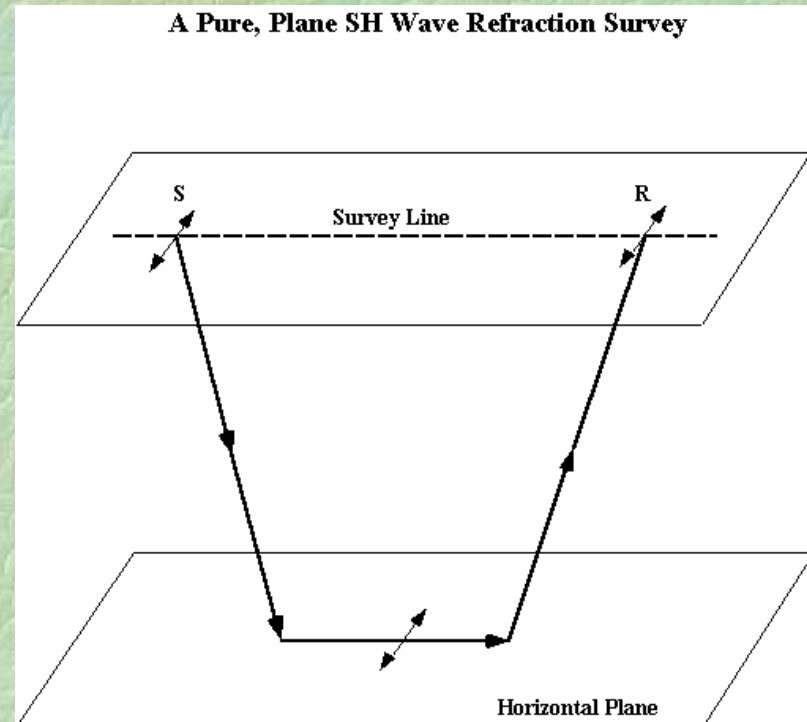
- MASW—An Alternative for Determining S-wave Velocity

- S-wave Velocity from Suspension Logging

- Conclusions

# Introduction

For *a series of horizontal layers*, a pure, plane SH wave refracts and reflects only SH waves. There is no wave-type conversion.



## Introduction (continued)

However, complex near-surface geology may not fit into the assumption of *a series of horizontal layers*. That a plane SH wave undergoes wave-type conversion along an interface in an area of non-horizontal layers is theoretically inevitable.

# **Introduction (continued)**

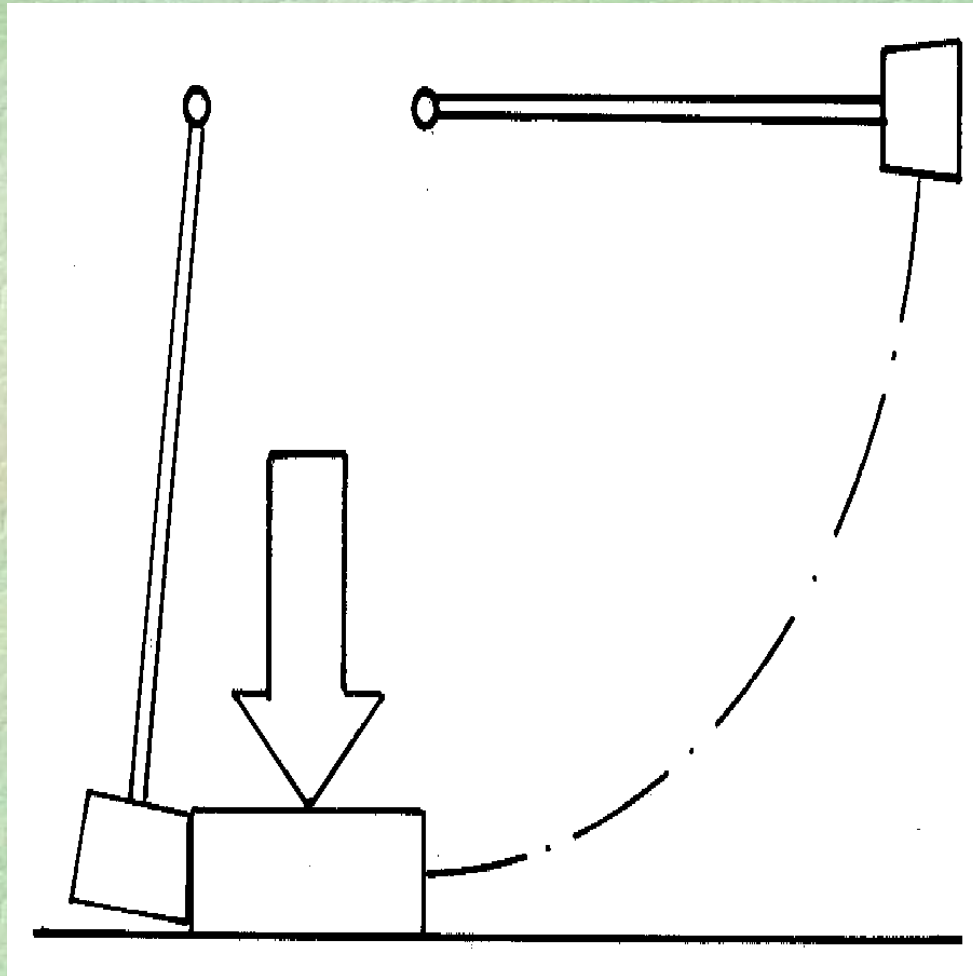
**Can we recognize converted waves?**

**How do we find true S-wave velocities if wave-type conversion really occurs?**

## **A Real-World Example**

A shallow SH-wave refraction survey was conducted in Wyoming during the fall of 1998 to determine shear-wave velocities in near-surface materials up to 7 m deep.

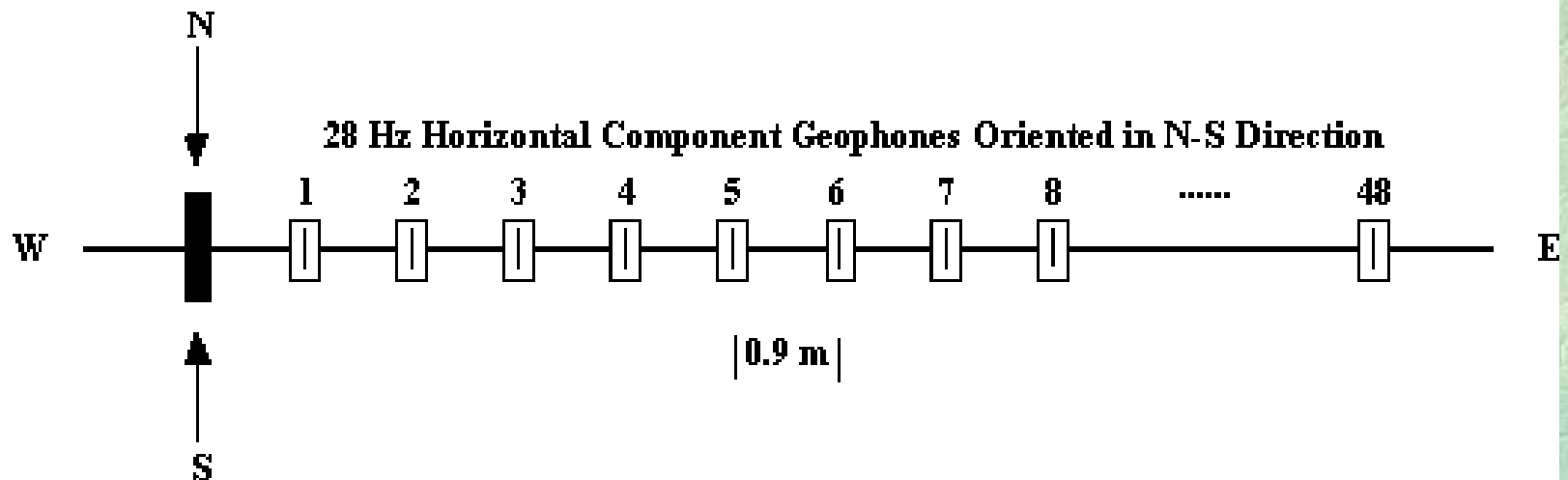
# SH-wave Source



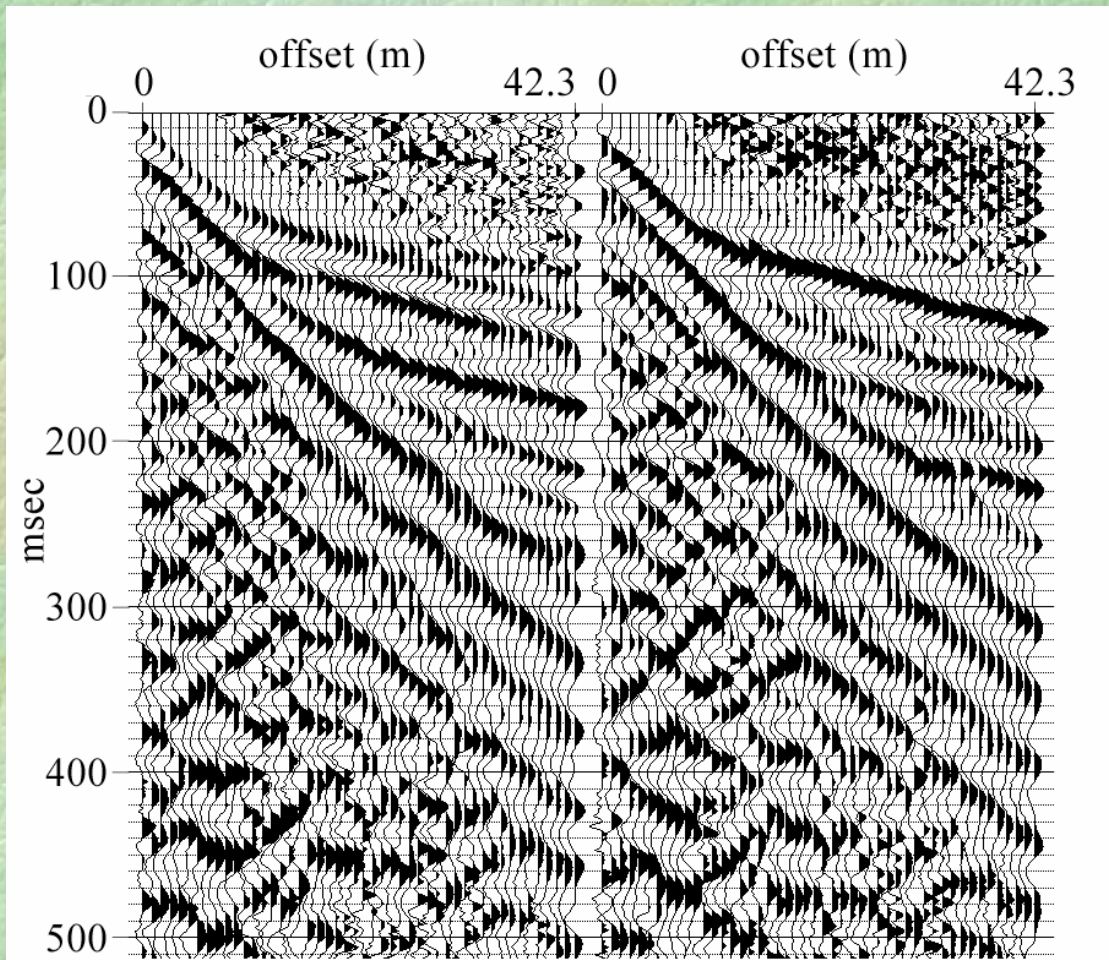
# Field Layout for SH-wave Refraction Survey

## Plan View of SH-wave Refraction Survey Line

Direction of 6.3 kg Hammer Blows



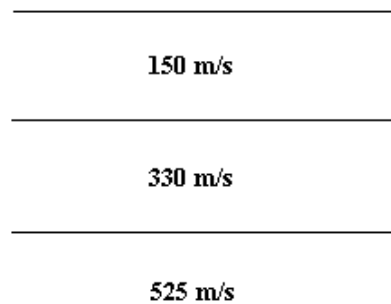
# SH-wave Refraction Data



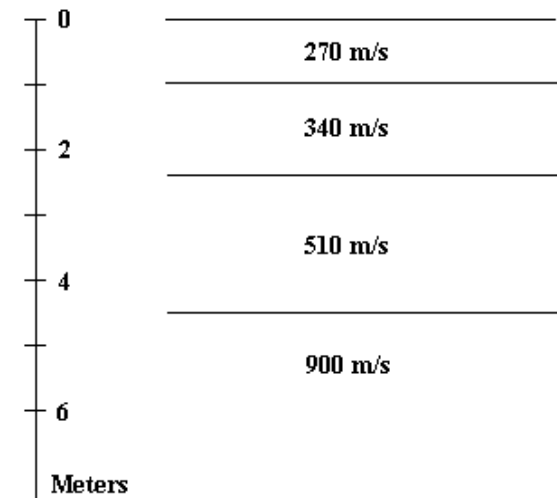
# A Layer Model from SH-wave Data

Compared with the SH-wave velocity of the first layer, the SH-wave velocity of the second layer is more than double.

**A Layer Model from SH-wave Data**



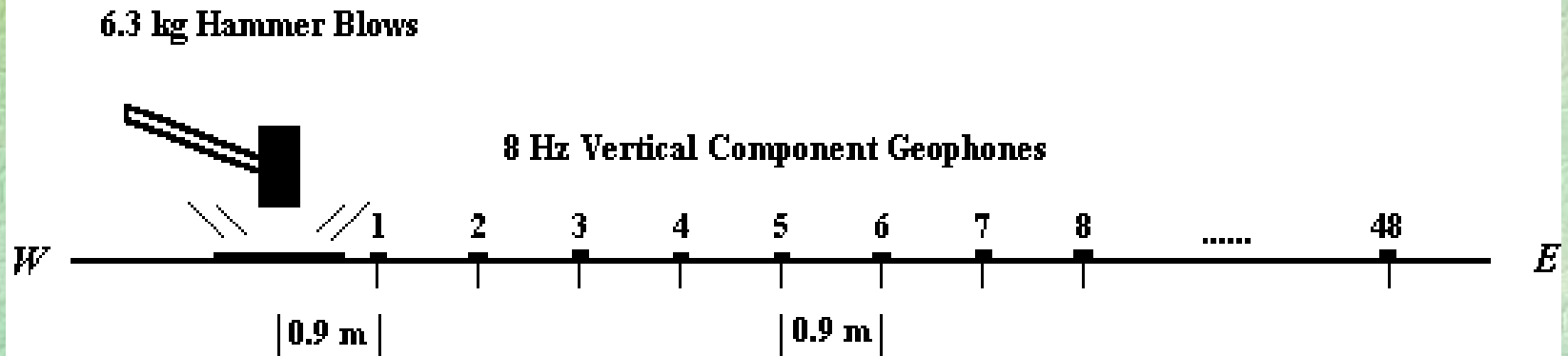
**A Layer Model from P-wave Data**



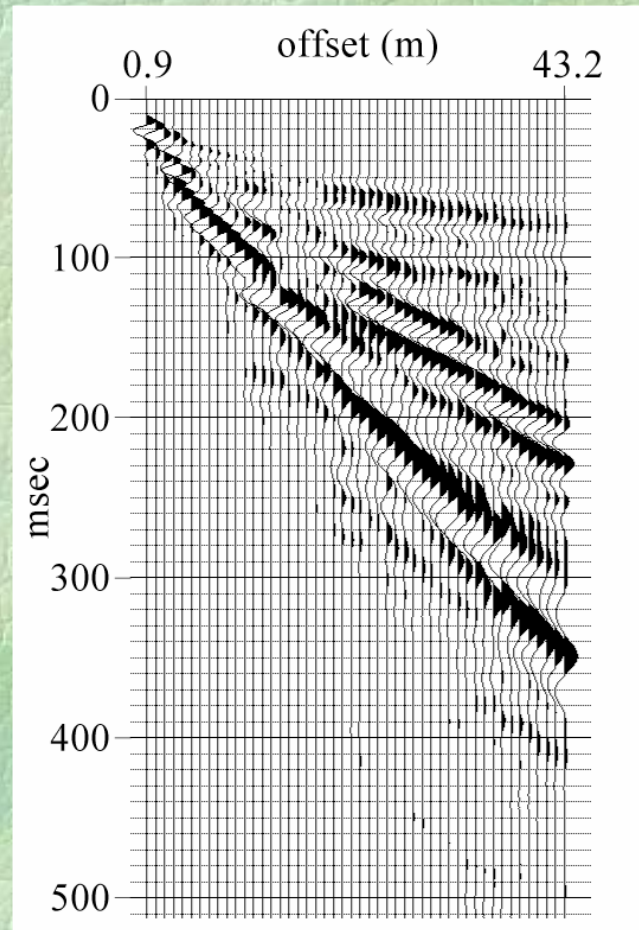
**Are velocities of the second and third layers the true SH-wave velocities, or are they converted P-wave velocities?**

# Field Layout for P-wave Refraction Survey

## P-wave Refraction Survey Line



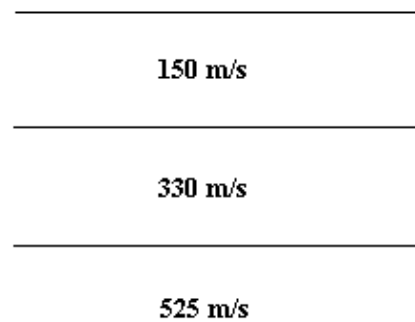
# P-wave Refraction Data



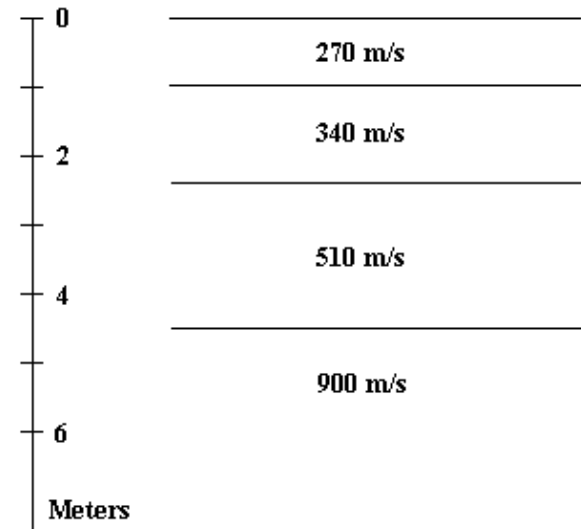
# A Layer Model from SH-wave Data

P-wave velocities of the second and third layers are almost the same as the relevant “SH-wave” velocities.

**A Layer Model from SH-wave Data**



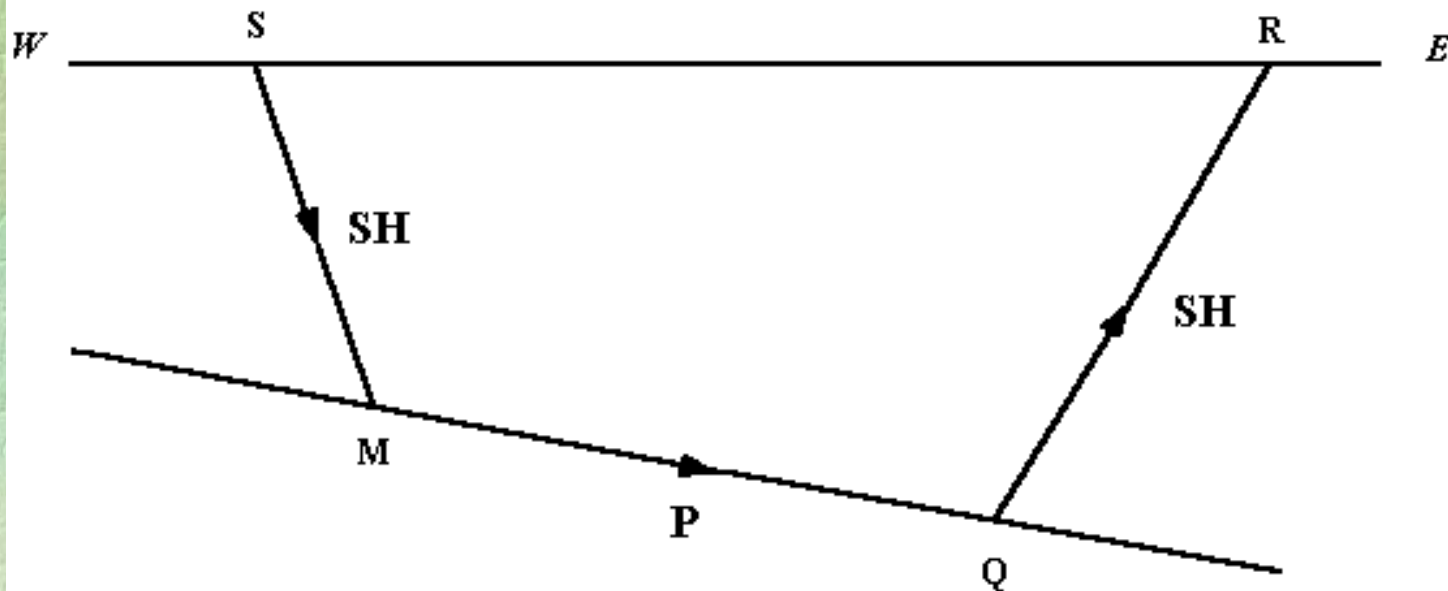
**A Layer Model from P-wave Data**



**Velocities from SH-wave refraction survey actually are converted P-wave velocities.**

# Explanation

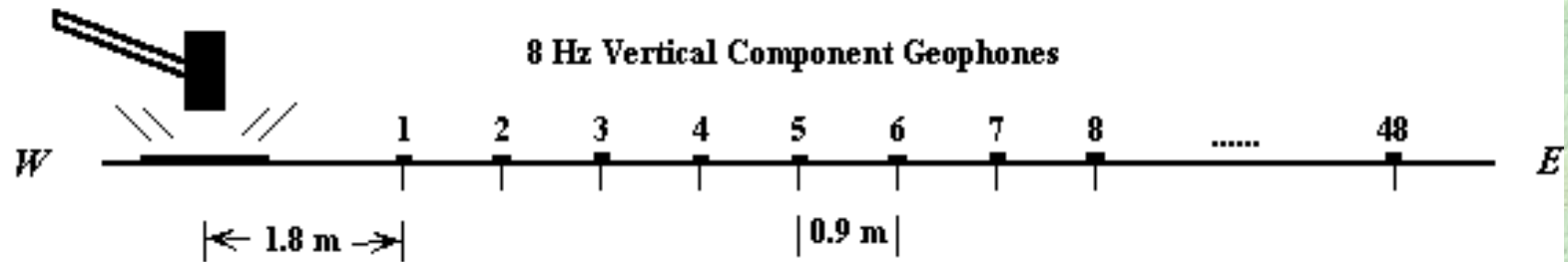
## A Possible Model for SH-P-SH Conversion



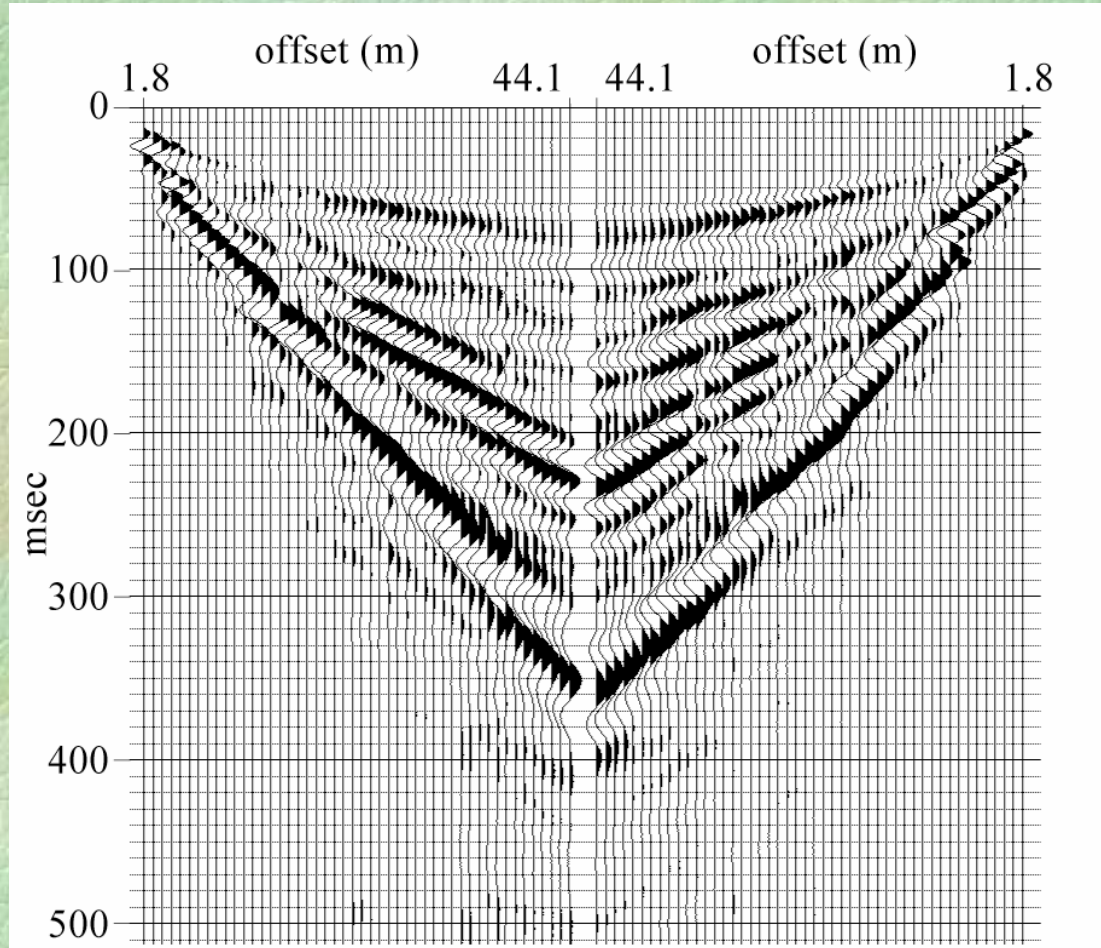
# Field Layout for MASW Survey

## MASW Surface Wave Survey Line

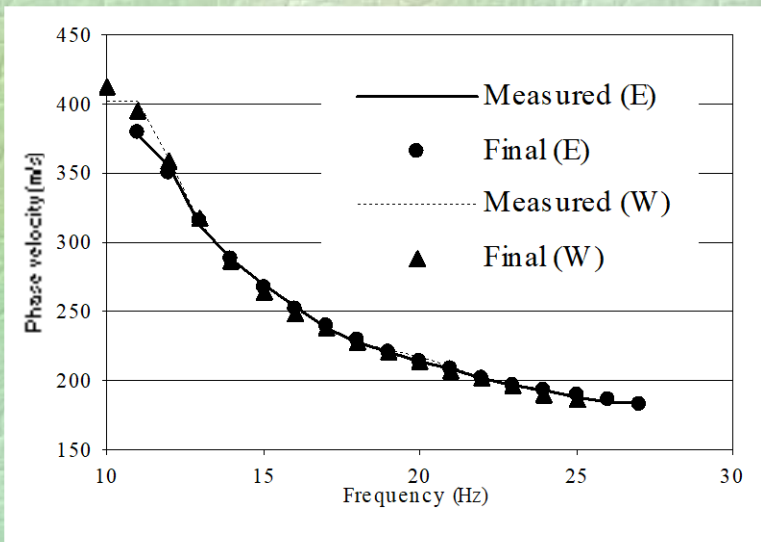
6.3 kg Hammer Blows



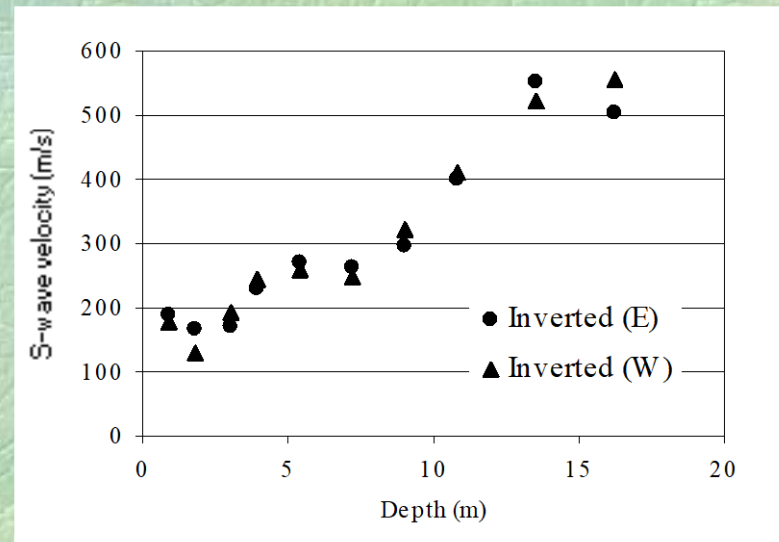
# Surface Wave Data



# Dispersion Curve

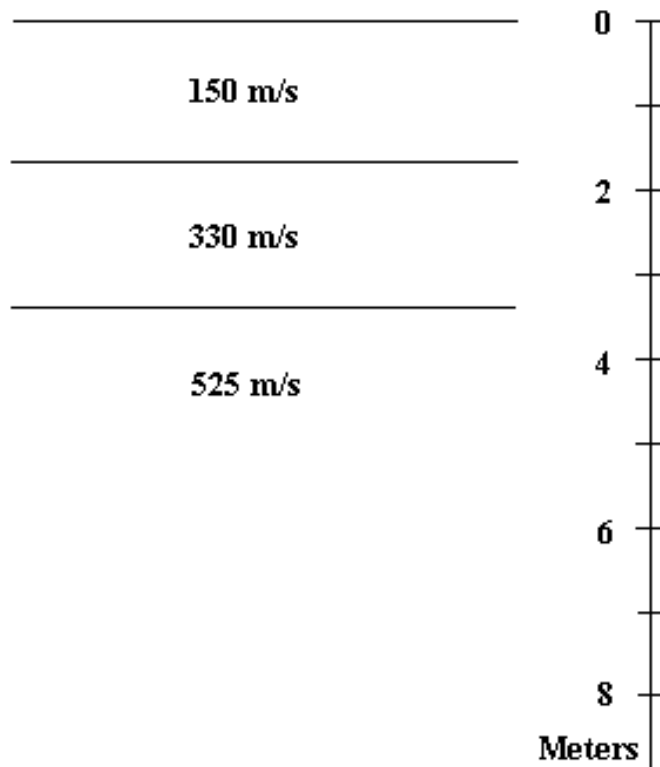


# S-wave Velocity Model

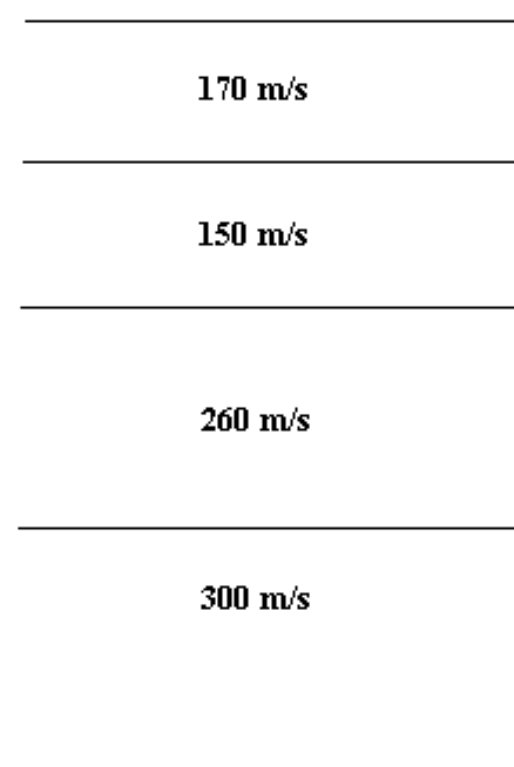


# S-wave Velocities from SH-wave Refraction and MASW

**A Layer Model from SH-wave Data**

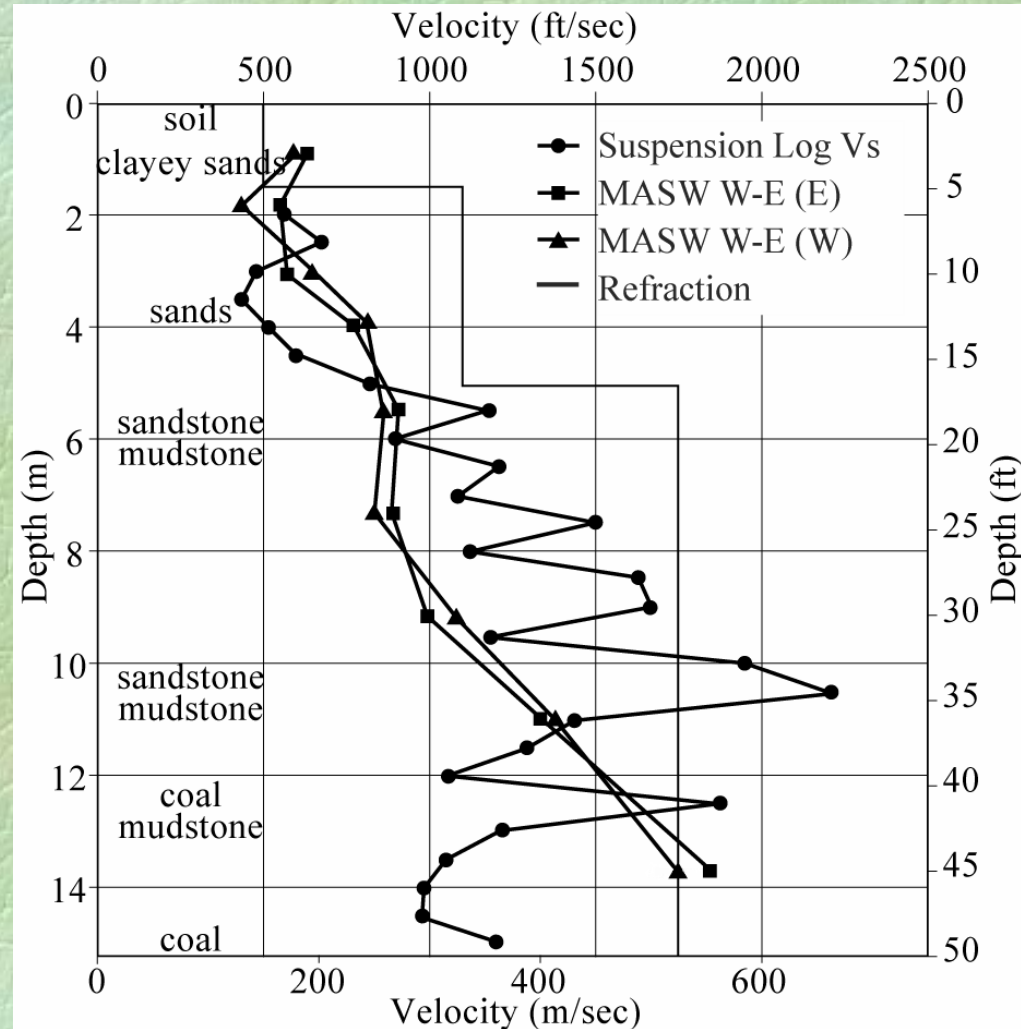


**A Layer Model from MASW Data**



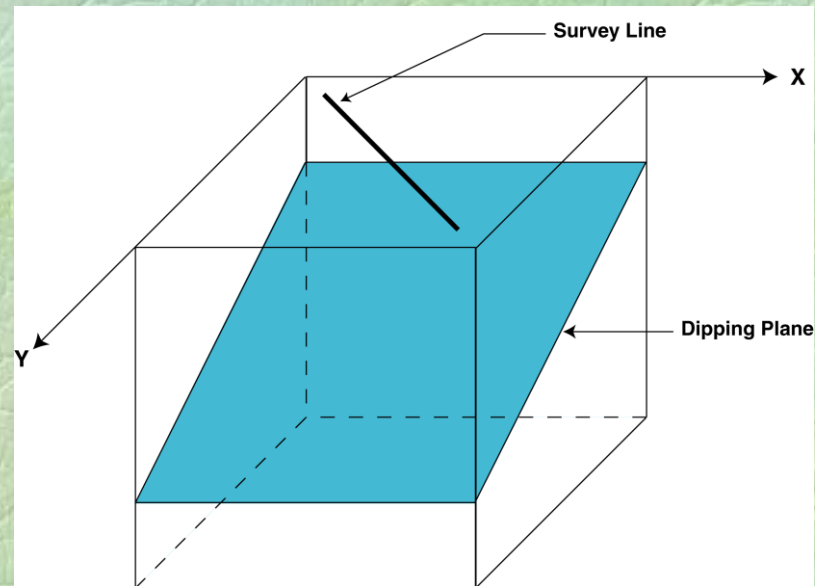
# S-wave Velocity from Suspension Logging

To confirm the inverted S-wave velocity, a borehole was drilled on the site and suspension logging was conducted.



# Be Careful When Doing SH-wave Refraction Surveys

In a case of a dipping layer, SH-P conversion will occur if a survey line is not parallel to *Y* axis.



# Conclusions

- ❑ Shallow shear-wave refraction survey may not provide the true S-wave velocity because of wave-type conversion in an area of non-horizontal layers.
- ❑ To verify if velocities based on shear-wave refraction surveys are velocities of converted waves, an additional P-wave refraction survey is necessary.
- ❑ The best alternative at this time is MASW, which can provide reliable S-wave velocities, even in an area of velocity inversion (a higher velocity layer underlain by a lower velocity layer).

# Acknowledgments

The authors wish to thank Blackhawk Geometrics for their permission to publish the seismic data presented herein. Authors extend their thanks to Bart Hoekstra of Blackhawk Geometrics for acquiring seismic data and to Julian Ivanov for constructive discussions on this topic. The authors also appreciate the efforts of Mary Brohammer and Amy Stillwell in manuscript preparation.