MASW DETERMINATION OF SURFACE LAYER THICKNESS AND VS RECONCILED WITH MICROTREMOR RESONANCE ANALYSIS - GREENE COUNTY, OHIO

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ABSTRACT

Multi-channel analysis of surface waves (MASW) was used to define the thickness and shear-wave velocity (Vs) structure of glacial drift at a site in Greene County, Ohio, where glacial drift varies from 10 m to 30 m thick and overlies limestone bedrock. The results were compared to that of microtremor resonance analysis of three-component passive seismic data collected with broadband seismometers at the same site. Both MASW and microtremor analyses resolved the Vs structure and apparent depth to bedrock to depths of ~20m. However, modeling experiments by J. Ivanov (SEG, 2011) suggest that settings such as this, with a low velocity surface layer over high velocity bedrock, require MASW data with larger source offsets than is conventional. It was suggested that longer source offsets are required to distinguish the dispersion of the fundamental and higher modes at longer periods. This phenomenon does not appear to pose a problem for these data. However, additional data are being collected with longer source offsets which will be analyzed to address this question.

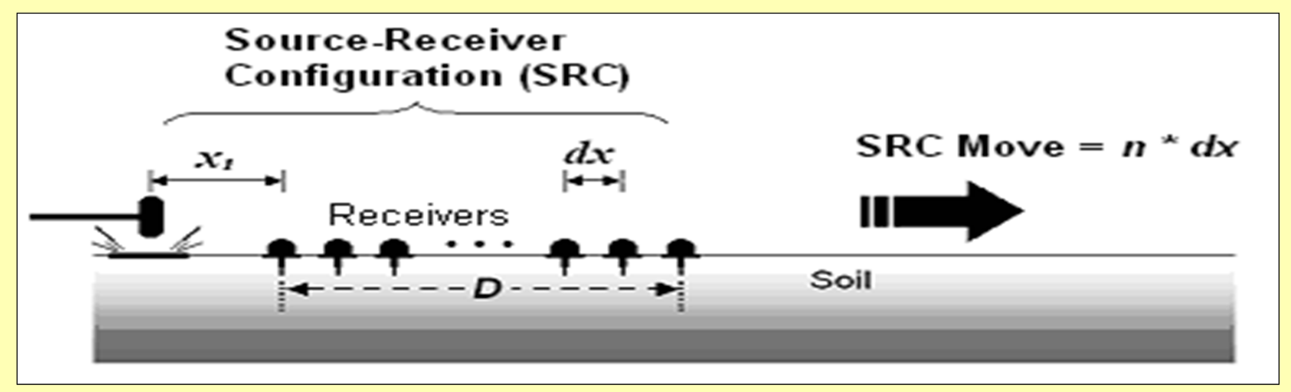
OBJECTIVES

- Define the depth to bedrock at all three seismic stations on the Federal Rd Traverse.
- Define the shear wave velocity of the glacial till and limestone bedrock at all four seismic stations.
- Does a longer source offset allow one to better distinguish between the fundamental and harmonic mode used to define depth to bedrock and Vs structure?
- Compare depth to bedrock and Vs structure determined by both MASW and the microtremor resonance analysis of broadband three-component passive seismic data.

METHODS

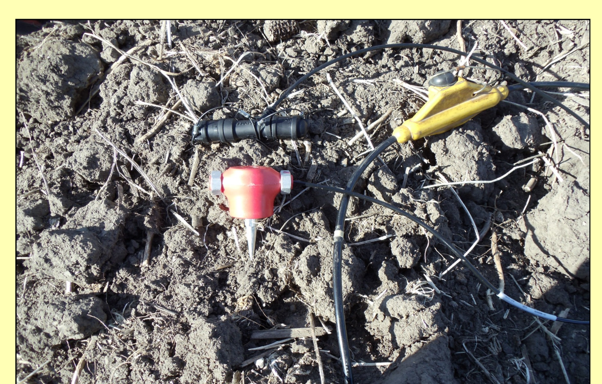
The Active Source MASW Method was used at all three survey locations on Federal Rd. Each survey employed a 10lb sledge hammer as the weight drop and an impact plate. We collected data on a Geometrics Strataview Seismograph using 4.5 Hz vertical geophones. The steps below describe the general procedure for acquisition and analysis.

1.Acquiring multichannel records.



2.The deployment of 4.5 Hz geophones in a linear array.

- 24 or 48 Channels.
- Source offset (x1) varies for each site
- Suggested (x1) as discussed by Ivanov (2011) of 10m, 20m, and 40m
- Receiver spacing (dx) is 2m in all cases.
- Spread Length (D) is 48m (24 channels) or 96m (48 channels).


Low Frequency Geophone (4.5 Hz)


Field Acquisition: Striking the impact plate

3.Extracting the fundamental-mode dispersion curves.

- Raw data (SEG2) is converted to KGS format for analysis using the seismic processing software called Surfseis3.
- Surfseis3 processes the seismic data by comparing phase velocities of waves at different frequencies.
- A best fit curve based on amplitude and signal-to-noise (S/N) ratio is selected for inversion.

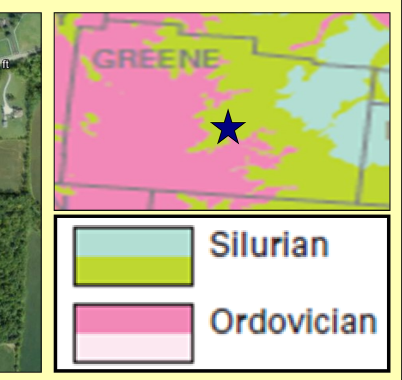
4.Inverting these curves to obtain 1-D (depth) Vs.

- Setup 3 layer model with equal weighting of layers.
- Assume a fixed Poisson's Ratio of 0.4.
- Iterate through a series calculated dispersion curves for a 3-layer model to converge upon a match with the empirical dispersion curve.
- Least squares method.

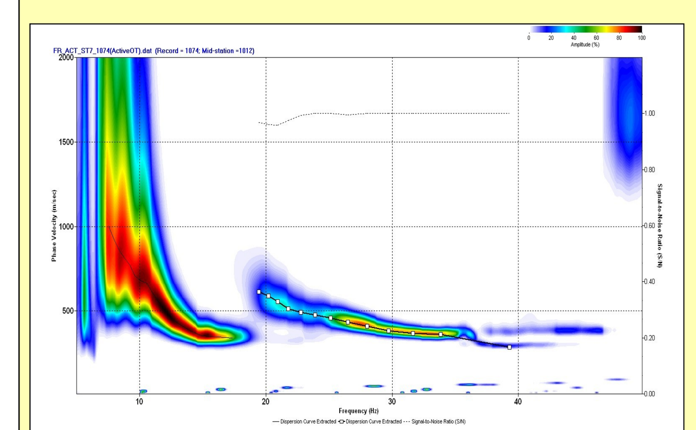
RESULTS

In this study the Vs for the glacial drift defined by Surfseis3 inversion is 400-450 m/s and consistent at all three seismic stations. These results agree with NEHRP Classification Index of stiff soil (366-762 m/s).

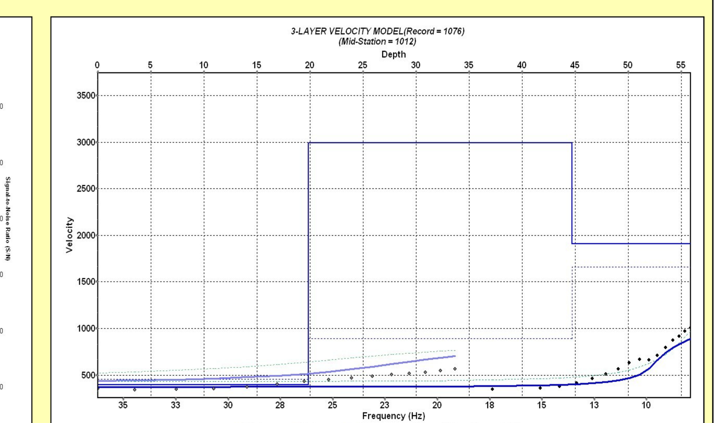
According to the NEHRP Classification Index a hard rock should be greater than 1524 m/s. The Vs defined by Surfseis3 Inversion for the local limestone bedrock falls between 2200-3000 m/s, which is consistent at all three seismic stations and agrees with NEHRP classifications.



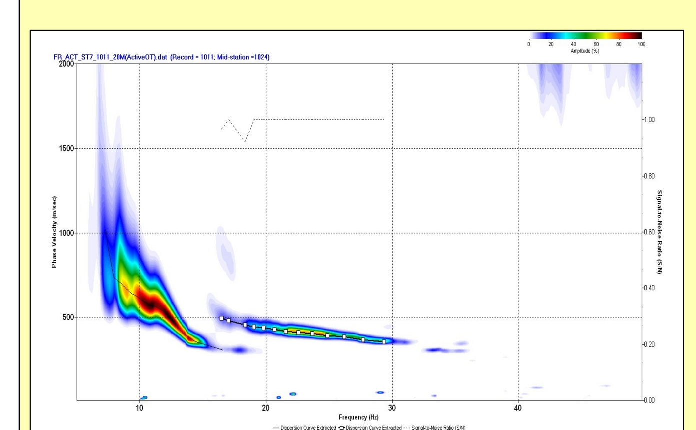
Results for Site 5 at different source offsets (10m, 20m, 40m)



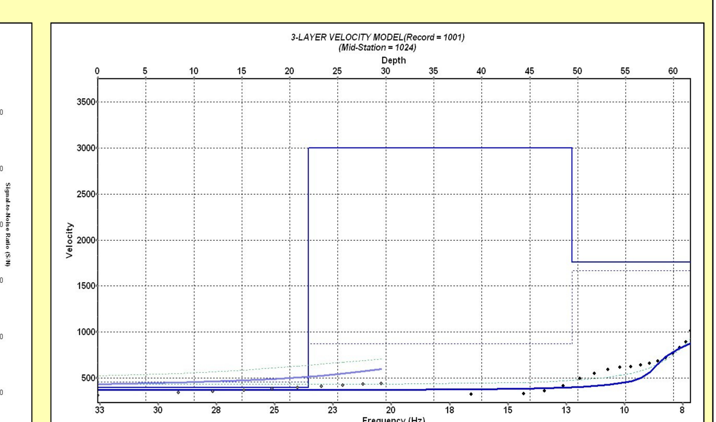
Source Offset (x1) =10m.
Receiver spacing (dx) = 2m. (SurfSeis3)
Spread Length (D) = 96m



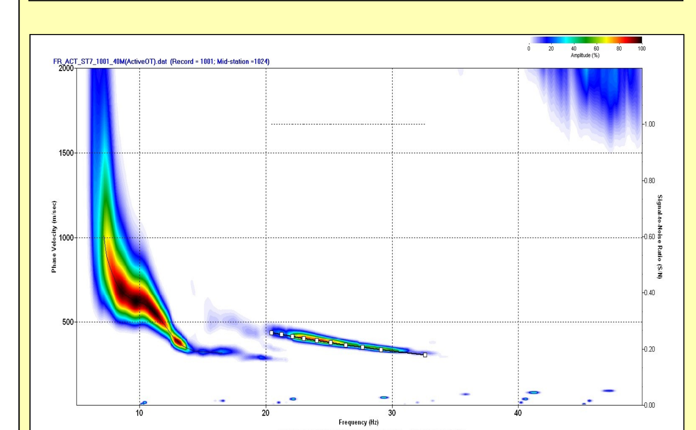
Bedrock (Vs) =3000 m/s.
Glacial Till (Vs) = 400 m/s. (SurfSeis3)
Depth to Bedrock (m) = 20m



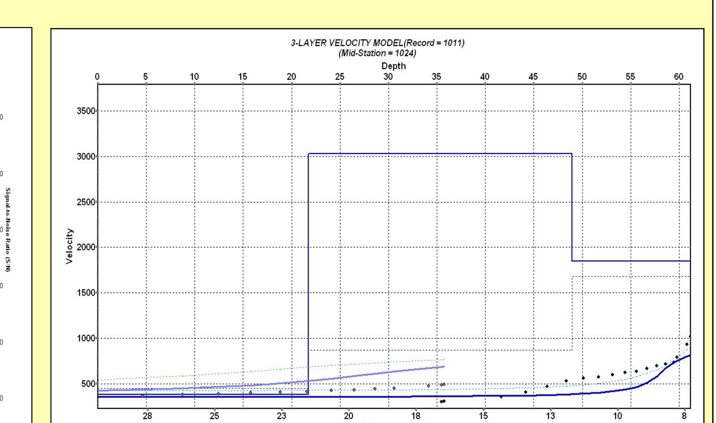
Source Offset (x1) = 20m.
Receiver spacing (dx) = 2m. (SurfSeis3)
Spread Length (D) = 96m



Bedrock (Vs) =3000 m/s.
Glacial Till (Vs) = 400 m/s. (SurfSeis3)
Depth to Bedrock (m) = 22m



Source Offset (x1) = 40m.
Receiver spacing (dx) = 2m. (SurfSeis3)
Spread Length (D) = 96m



Bedrock (Vs) =3000 m/s.
Glacial Till (Vs) = 400 m/s. (SurfSeis3)
Depth to Bedrock (m) = 22m

RESULTS

H/V Analysis

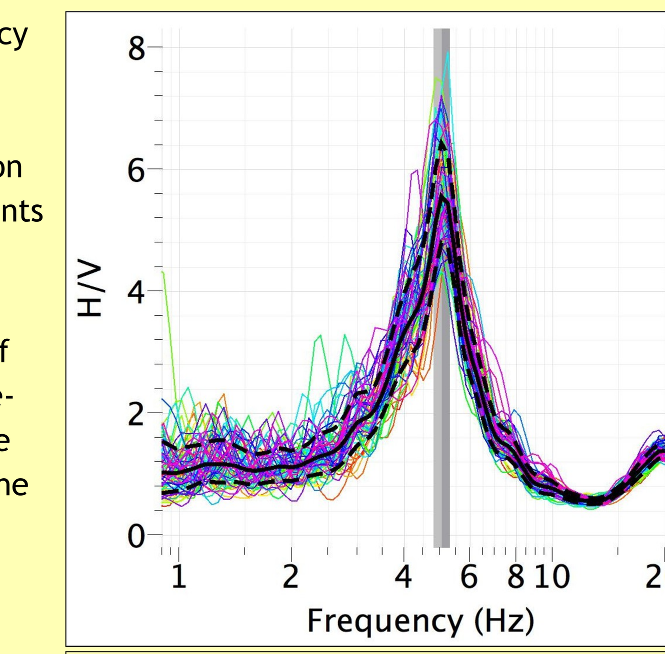
The data used to make the H/V vs frequency plot to the right are from a 3-component broadband seismometer (60s-50Hz Guralp CMG-3ESPCD) previously deployed at Station 5. The peak at **5.0 Hz** on this plot represents the constructive resonance of shear waves within the surface layer (glacial drift).

The frequency of constructive resonance of shear waves in a surface layer should be related to the Vs and thickness of the surface layer, as determined independently from the MASW analysis, according to the following equation: $F_0 = Vs / 4 \times \text{OVERBURDEN THICKNESS}$

Station 5 predicted frequency from MASW:

F_0 Hz = 400 m/s / 4 * 20m

F_0 = **5 Hz**



H/V for Station 5 -1/2 hour (0700-0730 MT2:30am Local) on Dec 30, 2009.
Geopsy was used the complete the H/V analysis

CONCLUSIONS

Depth to bedrock from SurfSeis3 agree with that determined from local water well data from ONDR records and increases from W to E.

- Station (5) bedrock depth of 18m-20m.
- Station (7) bedrock depth of 20m-22m.
- Station (9) bedrock depth of 25m-30m.

The concerns by Ivanov (2011) regarding source offsets needed to address a high contrast velocity model appear valid. This study found higher quality dispersion in the 20m source offset (x1) in comparison to the 10m offset, however, the 10m and 20m offsets appear to allow for more complete development of the Rayleigh wave along the recording profile than the 40m offset data.

Comparing the 3-component broadband seismometer and MASW data we can see that the resonant frequency displayed is equal.

REFERENCES

Park, C.B., Miller, R.D., and Xia, J., 1999, Multichannel analysis of surface waves (MASW); Geophysics, 64, 800-808

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Donat Fah, Fortunat Kind, Domenico Giardini. "A theoretical investigation of average H/V ratios." Geophy. J. Int. (2011): 535-549.

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