P and SV Radiation Patterns Produced by Vertical Vibrators

Source Station with No Local Anisotropy

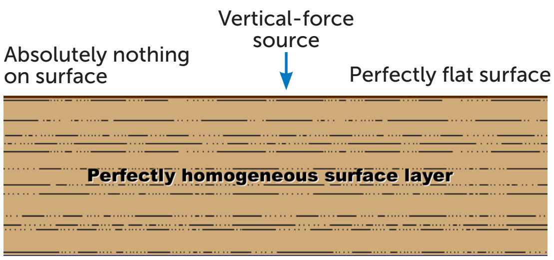


Fig. 1a

Introduction

For decades, only the downgoing P wave produced by vertical vibrators has been used in seismic reflection seismology. The result is that vibrator-generated reflection data have been limited to the P-P mode when receivers are vertical geophones, and to only P-P and P-SV modes when 3C geophones are deployed. This brochure emphasizes that vertical vibrators also produce a direct-SV illuminating wavefield that is effective for practicing S-wave reflection seismology. The use of this direct-SV mode expands vertical-vibrator imaging options to SV-P and SV-SV modes.

1950's Calculations of P and SV Radiation Patterns

Figures 1a and 1b illustrate Earth modeling done in the 1950s to calculate P and SV radiation patterns produced by a surface-based, vertical-displacement source (either a vertical vibrator or a vertical impact). In this modeling, the Earth's surface is assumed to be flat and have no vegetation, and the Earth's interior is assumed to be isotropic and homogeneous (Fig. 1a). This modeling showed that a vertical vibrator produces more SV illuminating energy than P energy (Fig. 1b). The problem regarding this direct-SV illumination is that only a small fraction of SV energy travels at takeoff angles inside the illumination cone extending from +30 to -30 degrees from vertical. As a result, it was assumed that essentially all SV energy produced by a vertical vibrator would refract at shallow interfaces and not illuminate deep geologic targets. This conclusion has caused the direct-SV mode produced by vertical vibrators to be ignored as an option for SV reflection seismology for decades.

P and SV Radiation Produced by a Vertical-Force Source
(Theoretical Calculation circa 1950s)

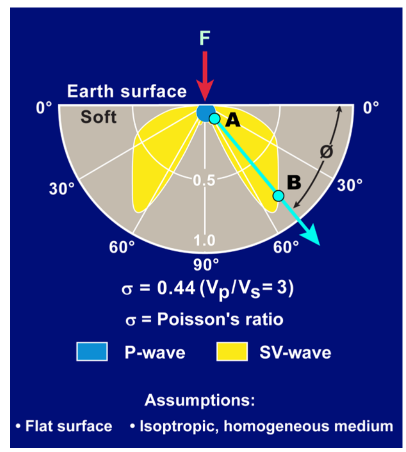


Fig. 1b

Common Source-Station Irregularity

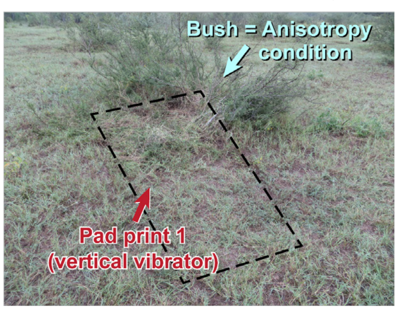


Fig. 2a

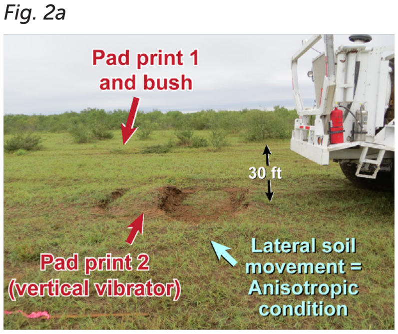


Fig. 2b

Real-Earth Source Stations

An appropriate question is "does the model in Fig. 1a represent Earth conditions at real-earth source stations?". Photographs in Fig. 2a and 2b depict irregularities that occur at real source stations. In Fig. 2a, one corner of a vibrator baseplate was atop a mesquite bush. Roots of bushes and trees create volumes of material that are stiffer than that in shallow-root grass areas near source stations. In Fig. 2b, soil at a station only 9-m (30-ft) from the station in Fig. 2a is weak enough to flow laterally away from a baseplate imprint. There is no visible evidence on the surface that indicates such a difference in soil stiffness coefficients exists at these two proximal stations. Many examples of such near-source irregularities could be shown. In short, the simplified earth model used to produce the radiation patterns in Fig. 1b is rarely, and maybe never, found at real-earth source stations

Modern Finite-Difference Modeling

Today we are not constrained to use simple earth models as researchers were in the 1950s because we can implement finite-difference or finite-element modeling techniques using large computational resources. A finite-difference model that allows small

Source-Receiver Geometry for Calculating P and SV Radiation Patterns

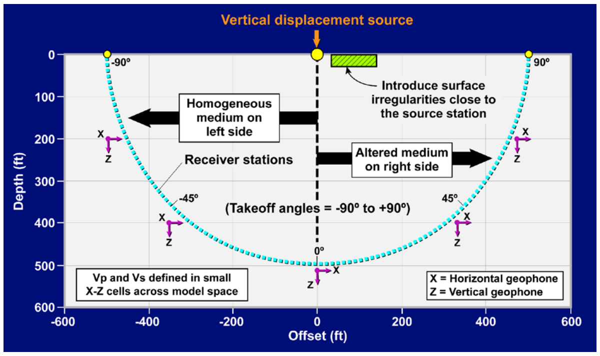


Fig. 3a

irregularities to be near source stations is displayed in Fig. 3a. The direct-P and direct-SV radiation patterns that result when simple earth irregularities are close to a source station are displayed in Fig 3b (irregularity is stiffer than the remainder of the medium) and in Fig. 3c (irregularity is softer than the surrounding medium). In each case, robust direct-SV energy greater than direct-P energy propagates at vertical and near-vertical takeoff angles from the source station, causing a vertical vibrator to be an effective S-wave reflection source as well as an effective P-wave reflection source.

Finite Difference Modeling with Near-Station Velocity Increase in Surface-Exposed Layer

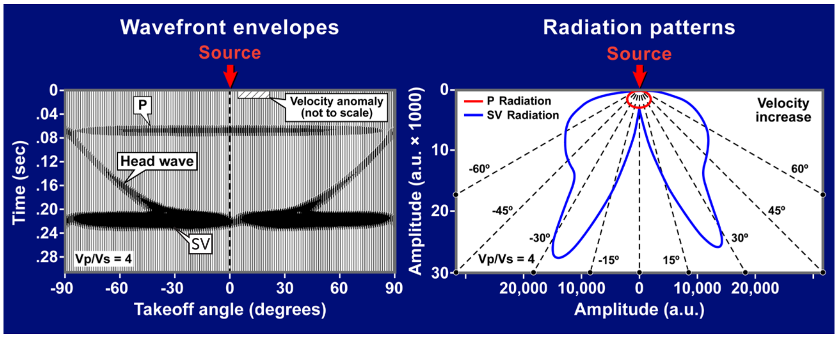


Fig. 3b

Velocity Anomaly

- 30% increase in Vp and Vs
- 5ft from source
- 10ft thick
- 20ft wide

- Red pattern is P Radiation
- Blue pattern is SV radiation

Finite Difference Modeling with Near-Station Velocity Decrease in Surface-Exposed Layer

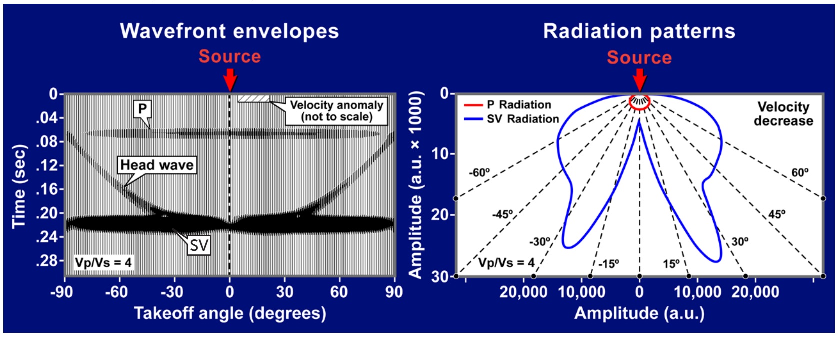


Fig. 3c

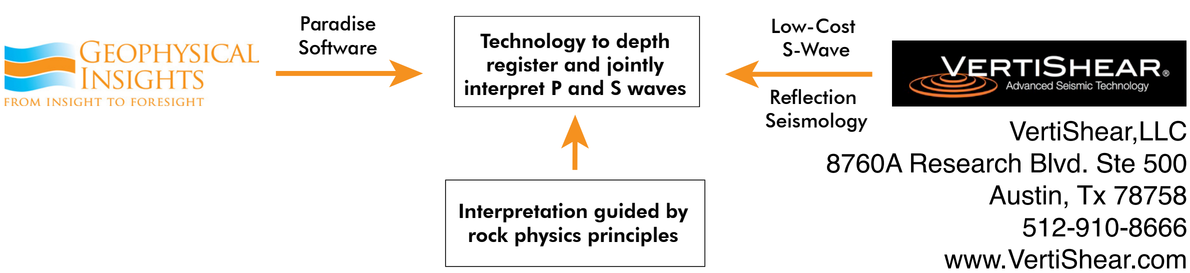
Velocity Anomaly

- 30% decrease in Vp and Vs
- 5ft from source
- 10ft thick
- 20ft wide

- Red pattern is P Radiation
- Blue pattern is SV radiation

Implications

1. A huge amount of unused S-wave reflection data resides in vertical-vibrator, legacy-data libraries.
2. S-wave reflection seismology can be practiced with vertical vibrators.
3. Software is needed that can depth register P and S data produced by vertical vibrators and perform joint interpretation of P and S images of targets illuminated by these data (an expansion of Geophysical Insights Paradise software).



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