SV-P Imaging with P Sources

History of SV-P Imaging

Previous to 2010, the year when SV-P imaging with P sources was initiated at the Bureau of Economic Geology, only one example of a SV-P image existed in geophysical literature. That example is shown in Fig. 1 with its companion P-SV image. The illuminating SV wavefield used to make this one-and-only SV-P image was produced by a horizontal vibrator, not by a P-wave source. Principles illustrated in Fig. 1 are:

- P-SV and SV-P images show equivalent geology.
- Even though P-SV and SV-P images should be exactly the same, the quality of a P-SV image is often inferior to the quality of its companion SV-P image, as it is in this example.

Comparison of P-SV and SV-P Images

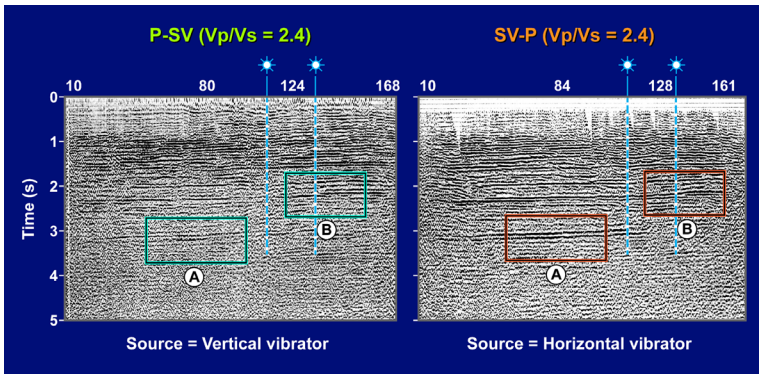


Fig. 1 (Frasier and Winterstein, 1990)

Comparison of SV-P Images Made by a Vertical Vibrator and a Horizontal Vibrator, Wellington Field, South Central Kansas

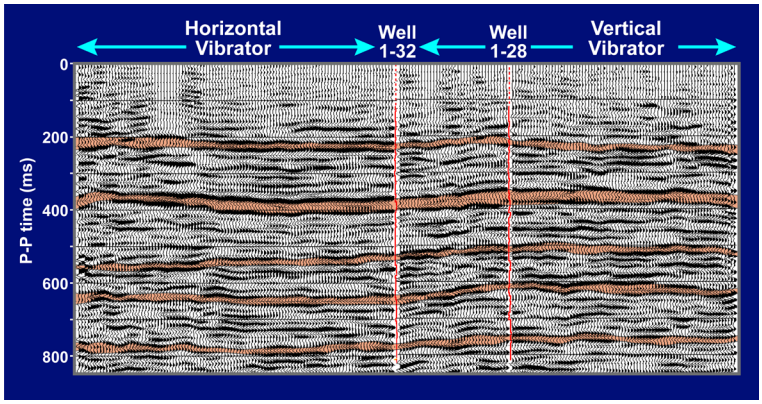


Fig. 2

SV-P Imaging with P Sources

Fig.2 compares SV-P images made with a vertical vibrator (right-side half of the profile) and a horizontal vibrator (left-side half of the profile). These images match at the tie point and have equivalent signal quality. This example is the only known comparison of vertical-vibrator and horizontal-vibrator SV-P images and provides evidence that SV-P imaging can be done with P sources and vertical geophones. The vertical-vibrator portion of Fig. 2 is repeated as the third panel in Fig. 3 where it is compared with its companion P-P and P-SV image windows along the same profile. The SV-P image shows continuous reflection events similar to those in the reliable P-P image. The P-SV image is the poorest quality image of this 3-image set. In P-source studies done to date, P-SV image quality has usually been inferior to SV-P image quality, even though in theory, SV-P and P-SV images should be identical. In no study done to date has SV-P image quality been inferior to P-SV image quality.

Why Are P-SV Images Often Inferior to SV-P Images

Theoretical calculations that lead to the conclusion that P-SV and SV-P images should be identical are based on assumptions that illuminating P and SV wavefields are equal strength, and that vertical and horizontal receivers are equally coupled to the earth. However, modeling studies of P and SV radiation produced by P sources show that SV illuminating wavefields are almost always greater amplitude than P illuminating wave-fields, so there is usually an advantage to SV-P data over P-SV data on the source-side of P-source imaging. On the receiver-side of the imaging process, the question is whether vertical and horizontal geophones are equally coupled to the earth. In VSP data acquisition, one can assume that vertical and horizontal geophones are, to first-order accuracy, equally coupled to the earth. Studies to date show that P-source P-SV and SV-P images constructed from VSP data are equal quality. A comparison of VSP-based P-SV and SV-P images is shown in Fig. 4. The image quality equivalence of these images implies that the difference in P-wave and SV-wave illumination strengths is not the cause of the deterioration of surface-based P-SV image quality. This implication leaves receiver coupling as the most likely cause of differences observed in surface-based SV-P and P-SV images.

A Close Look at Surface-Based 3C Geophones

Fig. 5 illustrates concepts involved in recording reflection data with surface-based 3C geophones. Two deployment strategies, identified as 1 and 2, can be used. In legacy 3C data, the most common deployment seems to be option 1 (spike-planted geophones). The comments in Fig. 5 emphasize that spike-planted vertical geophones (Z) are always better coupled to the earth than are horizontal geophones (X) because the earth-contact area for Z geophones (total base of geophone case) is greater than the contact area for X geophones (only the cross-section of the spike). When a geophone is buried (option 2), the contact area for Z geophones is still larger than the contact area for X geophones for most geophone designs. The key point is that P-SV data are degraded if 3C geophones are not buried with great care, but SV-P data are usually not affected even if 3C geophones are spike planted. An important conclusion is that legacy SV-P data generated by a P source and recorded by vertical geophones should usually have good signal-to-noise quality.

Implications

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

Comparison of P-P and Converted-Mode Images, Wellington Field, Kansas

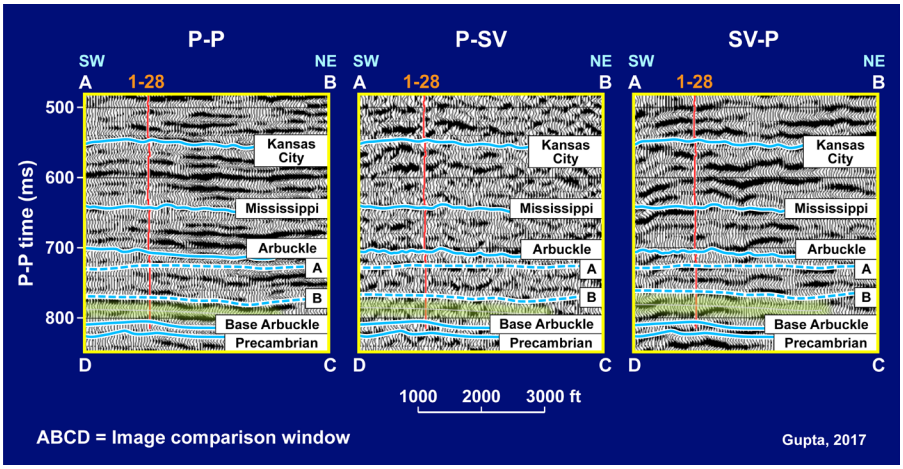


Fig. 3

Combining VSP P-SV and SV-P Images to Extend S-Wave Information Farther From a Receiver Well

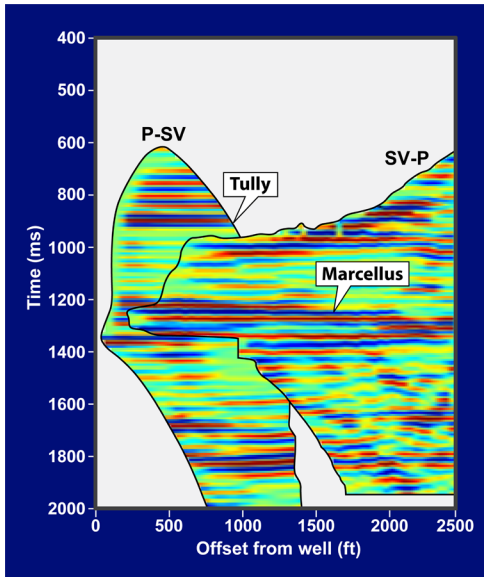


Fig. 4

Why Do SV-P and P-SV Images Differ? Receiver Issues.

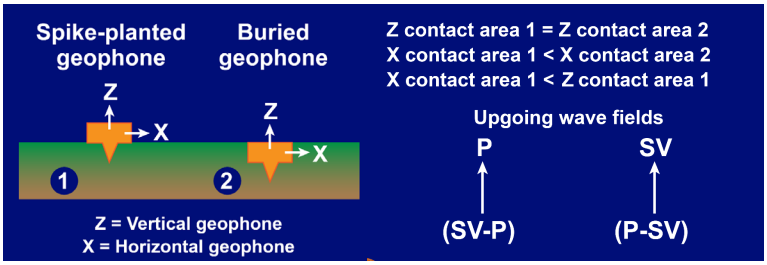
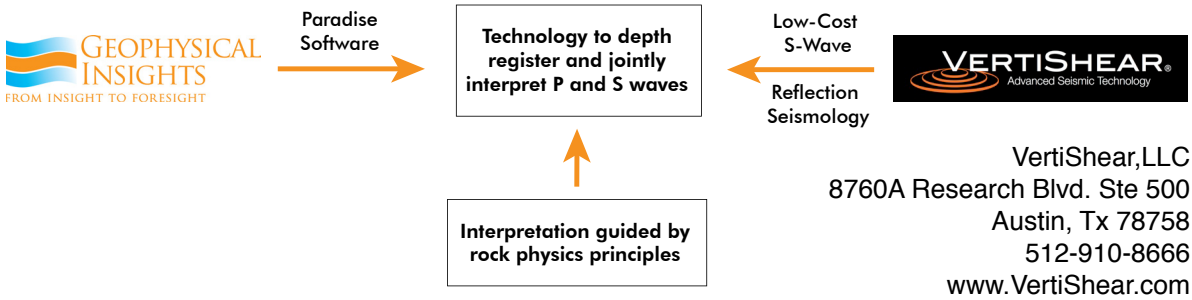


Fig. 5



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