Equivalence of SV-P and P-SV Images

Basic Concept

Companion brochures establish the principle that all P sources (vertical vibrators, vertical impacts, and buried explosives) produce both direct-P and direct-SV illuminating wavefields. (Fig. 1). As a result, both vertical and horizontal geophones deployed around a P source record two independent sets of reflections (Fig. 1). This brochure focuses on the equivalence of P-source SV-P images (recorded by vertical geophones) and P-source P-SV images (recorded by horizontal geophones).

SV-P and P-SV Velocities and Reflectivities

When SV-P and P-SV images span the same coordinates in image space, a SV-P (converted-P) image recorded by vertical geophones is identical to its companion P-SV (converted-SV) image recorded by horizontal-geophones. Raypaths involved in P-SV positive-offset and negative-offset imaging with a P source and horizontal geophones are shown in Fig. 2a, and companion SV-P raypaths recorded by vertical geophones are illustrated in Fig. 2b. Note the lengths of P and SV raypaths in each velocity facies are identical for both P-SV and SV-P imaging, and the coordinates of P-SV and SV-P image points are identical when imaging involves interchanged source-receiver stations. Fig. 3a displays P-SV and SV-P reflectivity curves for the tops of Tully limestone and Marcellus shale, Appalachian Basin, as functions of opening angle (the sum of incident angle and reflected angle). The magnitude of SV-P reflectivity at most interfaces tends to be slightly less than the magnitude of P-SV reflectivity as illustrated in this example. P-SV and SV-P synthetic seismograms calculated from Vp, Vs, and rho logs spanning Marcellus geology are displayed as Fig. 3b. Only the Vp log is shown. Calculated P-SV and SV-P reflection data are identical across the entire depth interval except P-SV reflections have slightly larger amplitudes.

Real Data Comparisons of SV-P and P-SV Images

SV-P and P-SV brute stacks made from data generated by buried explosives and recorded by surface geophones are shown as Figure 4. These early-stage images are identical except the SV-P image is larger than the P-SV image. Image sizes differ because these data were acquired using a (2-mi) X (2-mi) receiver grid centered inside a (3-mi) X (3-mi) source grid. Because a SV-P image point is closer to the source than to the receiver (Fig. 2b), this SV-P image tries to fill the larger source space.

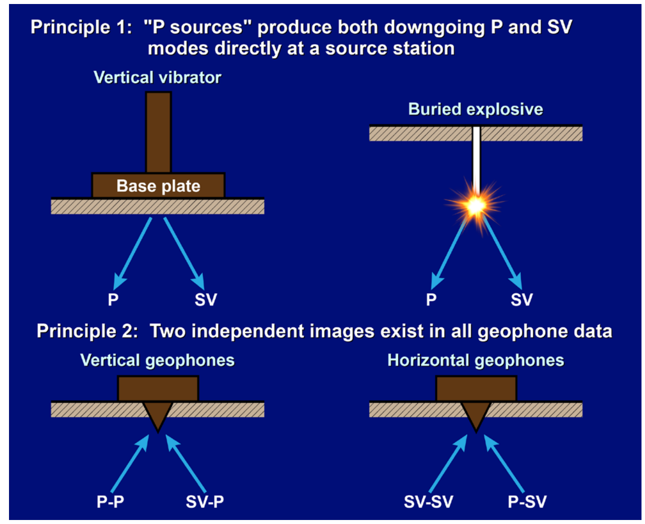


Fig. 1

P-SV Positive and Negative Offsets: Vertical-Force Source and Horizontal Geophones

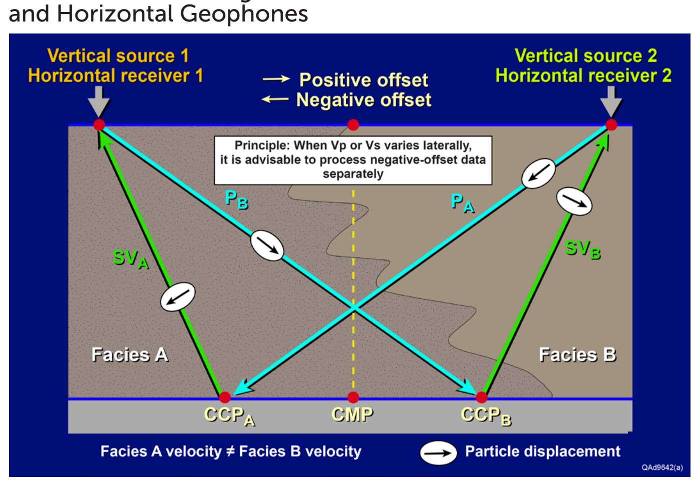


Fig. 2a

SV-P Positive and Negative Offets: Vertical-Force Source and Vertical Geophones

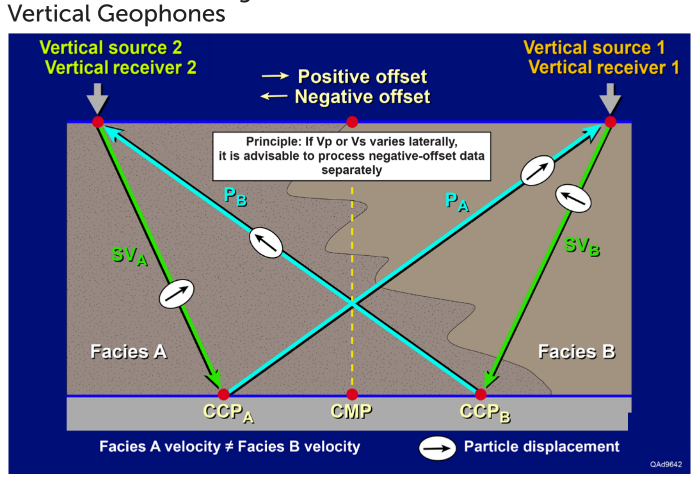


Fig. 2b

In contrast, a P-SV image point is closer to a receiver than to a source (Fig. 2a), so this P-SV image tries to limit its image space to the smaller area spanned by receiver stations. This SV-P brute stack is compared to a P-SV image made from a VSP well positioned on this profile in Fig. 5. The source that generated the VSP data was a vertical vibrator. The two images match quite well at the VSP well location. Significant conclusions are:

1. SV-P and P-SV images are identical in that portion of image space where they overlap (Fig. 4).
2. When data acquisition and processing are done correctly for different P sources across an area, a P-SV image made from source 1 can be substituted for the SV-P image made by source 2 (Fig. 5; SV-P image via buried explosives and P-SV image via vertical vibrator).

Zoeppritz Reflectivity Calculations

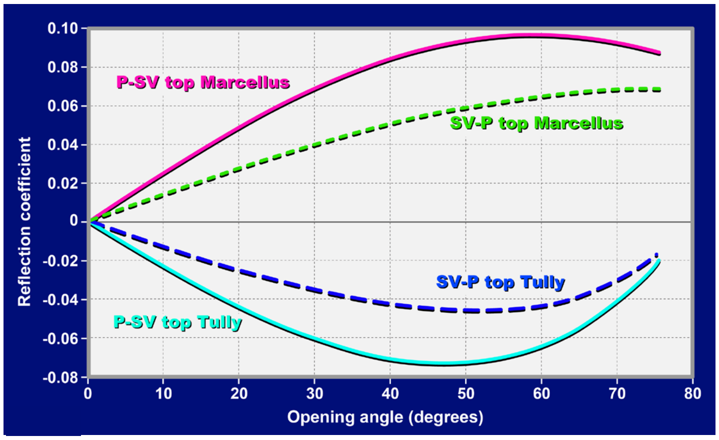


Fig. 3a

Comparison of P-SV and SV-P Reflectivities

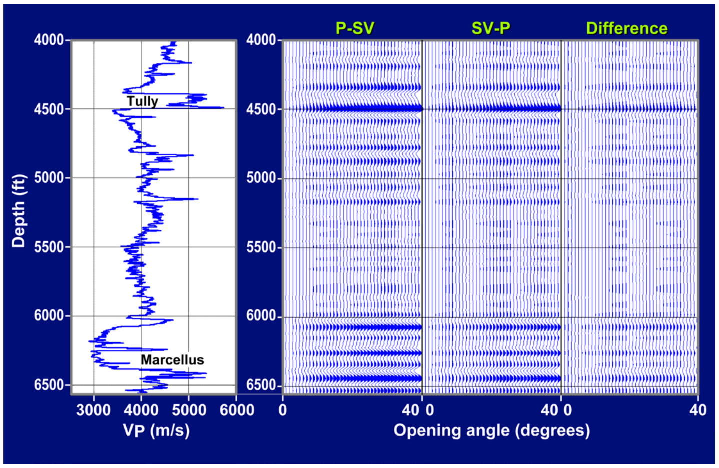


Fig. 3b

Comparison of Brute Images

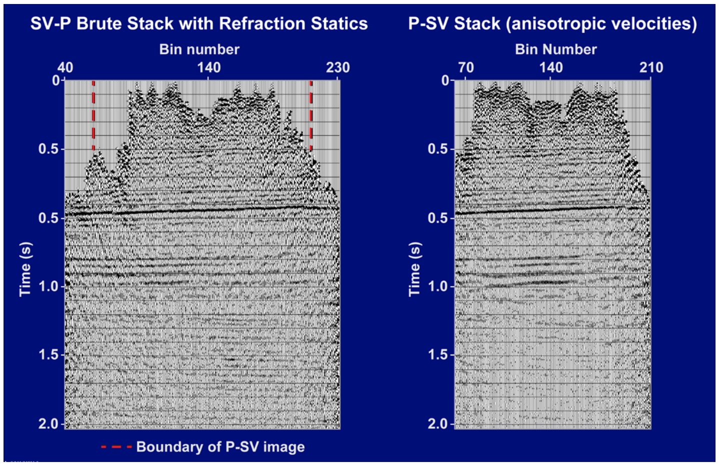


Fig. 4

Implications

1. A large amount of unused S-wave data exists in legacy, P-source data stored in digital data libraries.
2. P sources are a low-cost way to acquire all P and SV wave modes.
3. Software is needed that can 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).

Correlation of P-SV VSP Image and Surface-Based SV-P Brute Stack (Appalachian Basin)

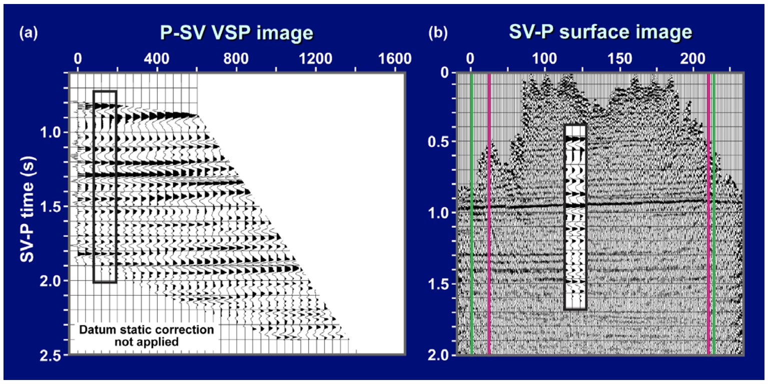
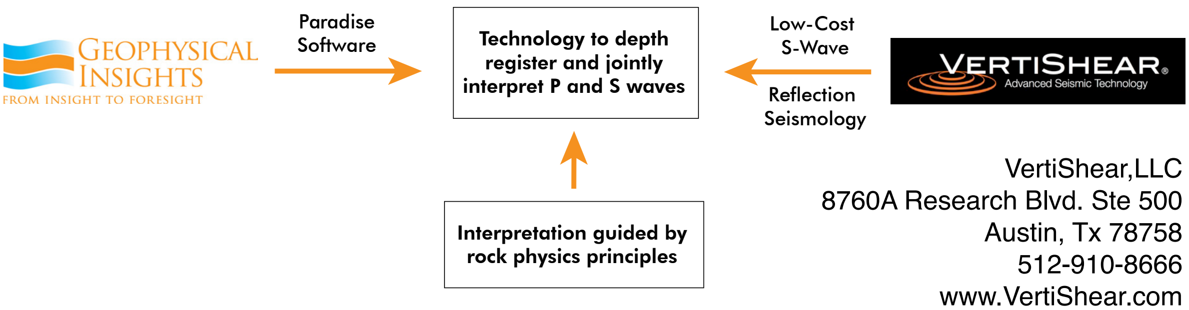


Fig. 5



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