P and SV Radiation Patterns Produced by Buried Explosives

Common View of Buried-Explosive Sources

Buried explosives are commonly viewed as pure-P sources because an explosion is basically a volume of expanding high-pressure gas (Fig. 1a). This view means that no direct-SV illuminating wavefield is produced at a shot cavity, and that any illuminating S wavefield produced by a buried explosive has to be a P-to-SV mode conversion at the earth surface. This brochure will show that a robust direct-SV mode is produced at a shot cavity and that a buried explosive is not a pure-P source.

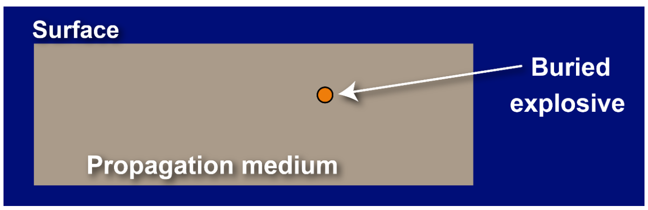


Fig. 1a

Finite-Difference Modeling

The popular earth model in Fig. 1a is not appropriate for buried explosives because it does not account for physical conditions that must be present. For example, where is the shot-hole, where is the physical container that holds the explosive material, how do elastic properties of the earth and explosive material differ, etc.? The importance of these real-world conditions can be determined by utilizing finite-difference modeling that includes a shot-hole of loose fill (Model 1, Fig. 3a), and then a shot-hole with explosive material positioned at the base of the hole in a stiff, rigid container (Model 2, Fig. 3a). When the simplified model in Fig. 1a is used in finite-difference modeling, the result is the traditional answer that shows the source is pure-P, there is no direct-SV mode, and a converted-SV mode is produced at the earth surface. When model conditions include a realistic shot hole, converted-SV modes are produced at the surface, and robust, vertically traveling, direct-SV energy is also produced at the shot cavity (Fig. 3b). When the model includes a shot hole and also an explosive container, the resulting direct-P and direct-SV wavefronts cause particularly robust SV illumination to travel in vertical and near-vertical takeoff angles from a buried shot (Fig. 3c).

Evidence of Direct-SV Mode Produced by Buried Explosives

A photograph of an excavated shot cavity is shown in Fig. 1b. The fracturing surrounding the cavity is visual evidence that intense shearing is associated with cavity formation, which means a direct-SV mode has to be produced. The field test illustrated in Fig. 2a is an easy way to demonstrate that buried explosives produce direct-SV illumination. In this test, explosives are detonated at different depths in a shot hole and downgoing wavefields are recorded by a deep receiver. As a shot moves deeper, a direct-SV mode arrives at a deep receiver at earlier times because shot-to-receiver travel paths shorten as shot depth increases. In contrast, SV modes produced at the earth surface arrive at later times as shot depth increases because shot-to-surface distances increase. This difference in travel-time behavior allows direct-SV and surface-generated SV modes to be identified in these test data (Fig. 2b).

Vertical Plane Passing Through Cavity Created by a Buried Shot

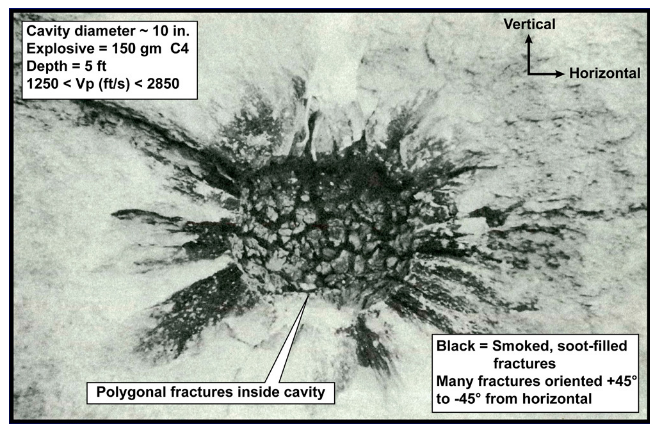


Fig. 1b (From Kusubov, 1976)

Field Test Data Showing Evidence That Buried Explosives Create Direct-SV Wavefields

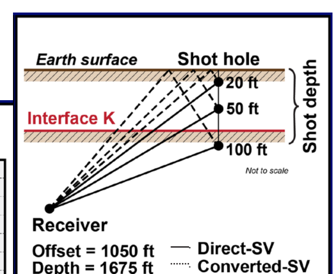


Fig. 2a

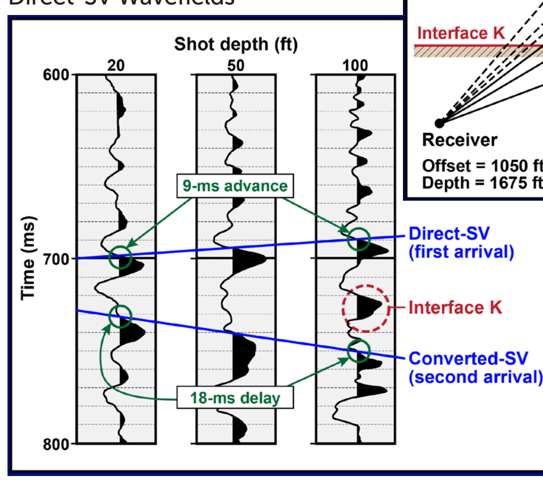


Fig. 2b

Fundamental Physics

It is true that a buried explosive begins its life as a pure-P source. However, in real-earth conditions this pure-P lifetime is measured in fractions of milliseconds. As soon as expanding gas produced by explosive material interacts with physical interfaces associated with the material's confining rigid container and shot hole, shearing is initiated and the source is no longer pure-P. A buried explosion begins its life as a pure-P source, but in a fraction of a millisecond converts to a dual-wavefield (P and SV) source.

Implications

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

Earth Models Used to Calculate P and SV Radiation Generated by a Buried Explosive

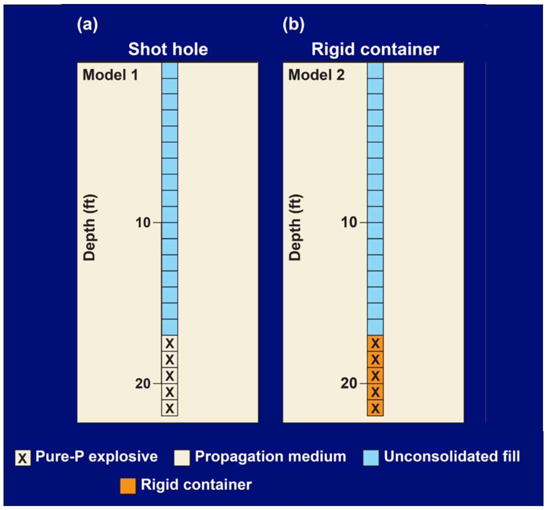
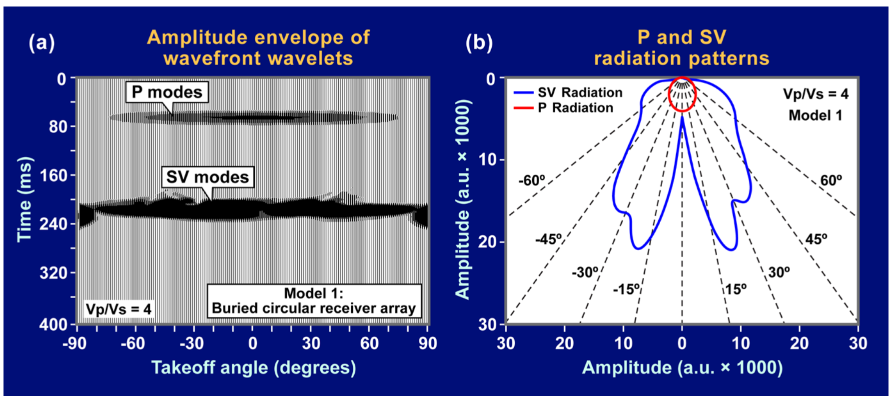
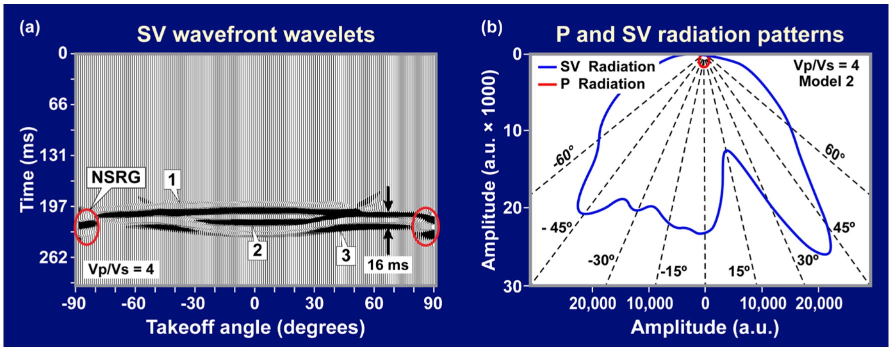


Fig. 3a



Illuminating P and SV Wavefields, Model-1, Pure-P Source Plus a Shot-hole

Fig. 3b



Illuminating P and SV Wavefields, Model-2, Shot-hole Plus Rigid Container

Fig. 3c

Model 2:
Circular receiver array SV response
Five overlapping wavefronts
1 Direct-SV
2 Two surface-generated P-SV modes
3 Two surface-generated SV-SV modes
NSRG = Near-surface receiver geometry

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