[GC]Depth Registration of P-Wave and S-Wave Images*

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Introduction

Hardage and Aluka (2006) introduced the concept of elastic wavefield seismic stratigraphy, a seismic interpretation technology that expands traditional P-wave seismic stratigraphy into the emerging world of multicomponent seismic technology.

Two assumptions are involved in elastic wavefield seismic stratigraphy:

- Across some stratigraphic intervals, one mode of an elastic wavefield will exhibit different seismic sequences and/or seismic facies than will its companion wave modes.
- S-wave seismic sequences and facies are just as important in geologic interpretation as are traditional P-wave seismic sequences and facies.

Once these two assumptions are accepted, a serious interpretational challenge is immediately encountered: Depth registration of P and S images. An interpreter must be confident a targeted data window in P-wave image space is depth equivalent to a data window selected from S-wave image space before the seismic sequences and facies in these respective windows can be used in an elastic wavefield seismic stratigraphy analysis. Until depth-equivalent P and S data windows are defined, no meaningful geological interpretation of P and S seismic sequences or facies can be done.

Techniques seismic stratigraphers use to define depth-equivalent coordinates in P-wave and S-wave image spaces include:

- P-wave and S-wave synthetic seismograms.
- Multicomponent VSP data.
- Map and section views of P and S images of structure and stratigraphy.

Only the latter two options are discussed here.

Multicomponent VSP Data

Multicomponent vertical seismic profile (VSP) data allow rigorous and accurate depth registration of P and S images -- if the VSP data are acquired with receiver stations distributed over a large vertical interval.

The depth origin of a seismic reflection can be determined precisely only if closely spaced receivers span the interface that produces that reflection. The longer the vertical array of receiver stations used in VSP data acquisition, the larger the number of reflecting interfaces spanned and the more depth-equivalent P and S reflections identified.

Examples of nine-component (9-C) VSP data used to define depth origins of P, SH, and SV reflections across an interval of Morrow channel deposition are shown in Figure 1. These data are examples of depth-based VSP imaging.

The three VSP wells shown in Figure 1 are in three different states: Texas, Kansas, and Colorado. The images show that at each well, each elastic wave mode produces a reflection sequence and a seismic facies character across the targeted Morrow interval that are different than what its companion wave modes produce. The different stratal surfaces imaged by each wave mode form the basic architectural elements of elastic wavefield seismic stratigraphy.

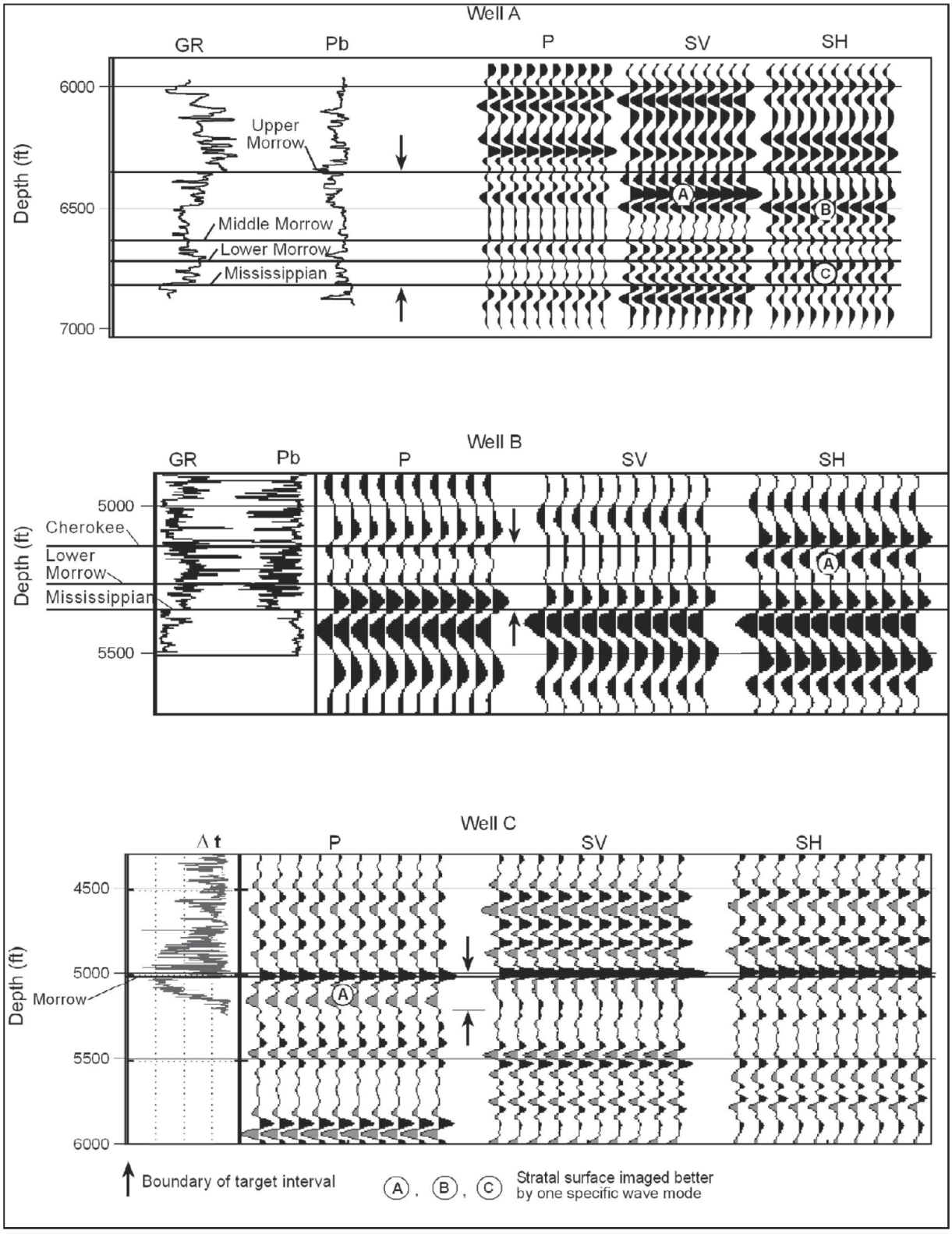

Figure 1. Depth-based P, SV, and SH images constructed from nine-component VSP data acquired in three wells penetrating Morrow-channel environments. One wave mode often reveals a key stratal surface within a target interval that its companion wave modes do not. Examples of such surfaces are labeled A, B, and C.

Map Views and Section Views of P and S Stratigraphy

An example of horizontal time slices through P and S coherency volumes used to define depth-equivalent stratigraphy is illustrated as panels (a) and (b) of Figure 2. The P-P image shows a system of several intertwined channels. The P-SV image shows only one channel, but that channel tracks one of the P-P channels, leading to the conclusion that the P-P and P-SV data are imaging the same stratigraphy. The channel architecture shown on these two images persists for a narrow vertical range of only two to three time samples in each image space.

Two important conclusions can be made:

- P-P image time 796 ms (a) is depth equivalent to P-SV image time 1,964 ms (b).
- P-P and P-SV modes often show significantly different sequence and facies pictures of the same stratigraphic interval.

This latter conclusion is a fundamental premise of elastic wavefield seismic stratigraphy. There is much yet to understand about rock and pore-fluid properties that cause P-P and P-SV images to differ as much as these examples.

Shown in panels (c) and (d) of Figure 2 are vertical slices through these P and S data volumes along highlighted profile 2100. The horizontal yellow line across each vertical slice shows where the horizontal slice from the corresponding data volume was taken.

Using only vertical displays of P-P and P-SV data, an interpreter would have to have great courage to claim the two yellow lines are depth equivalent. In contrast, few interpreters seem to object to the statement that the two map views in panels (a) and (b) are depth equivalent.

Acknowledgment

These examples lead us to the conclusion that map views of thin stratigraphy can be a rather precise option for depth registering two elastic mode images, whereas depth registration is usually more difficult using vertical section views.

Reference

Hardage, Bob A., and I.J. Aluka, 2006, Elastic wavefield seismic stratigraphy: Search and Discovery Article #40184 (2006).

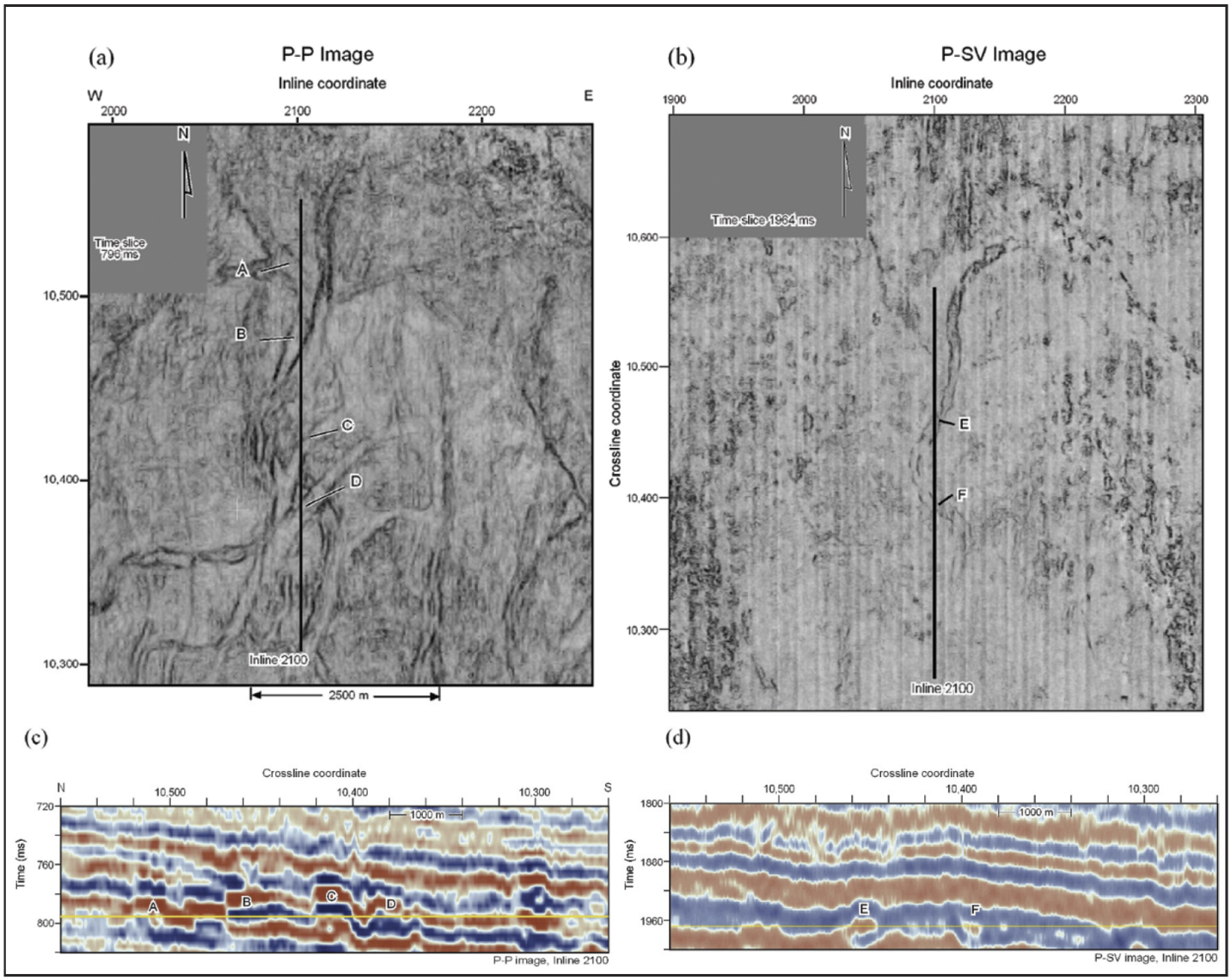

Figure 2. Map views of thin stratigraphy (a) and (b), used to depth register P-P and P-SV images. In map view, equivalence of thin P-P and P-SV channel features results in P-SV time 1,964 ms (b) being defined to be depth equivalent to P-P time 796 ms (a). It is more difficult to determine depth-equivalent image coordinates using 2-D section views (c) and (d) of this same stratigraphy. Horizontal yellow lines across the section views define the positions of the time slices. The vertical sections are positioned along inline coordinate 2100. Channel features A through F on the map views are the same features labeled A through F on the vertical sections.