GC Chronostratigaphic Surfaces and Seismic Reflections*

By

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General Statement

A fundamental premise of seismic stratigraphy is that seismic reflections follow chronostratigraphic surfaces, not lithostratigraphic surfaces.

In 1993, Tipper published an intriguing paper (Geological Magazine, v. 130, no. 1, p. 47-55) in which the following question was posed: "Do seismic reflection events necessarily follow chronostratigraphic surfaces?" Simple earth models and forward seismic modeling were used to illustrate basic and important interpretation principles.

The editor of this monthly column (Hardage) has observed increased interest in seismic interpretation among graduate students when they have been asked to analyze this Tipper paper, so repeating some of its concepts here seems appropriate.

Stratigraphic and Seismic Models

We use the stratigraphic model in Figure 1 as a demonstration. This model shows five units deposited at five different geologic times -- T1 through T5. These five chronostratigraphic bodies are shown in the top panels of Figures 2-4 as stacked, overlapping targets that are to be imaged. This five-layer stack is then illuminated with seismic wavelets having varying resolution properties.

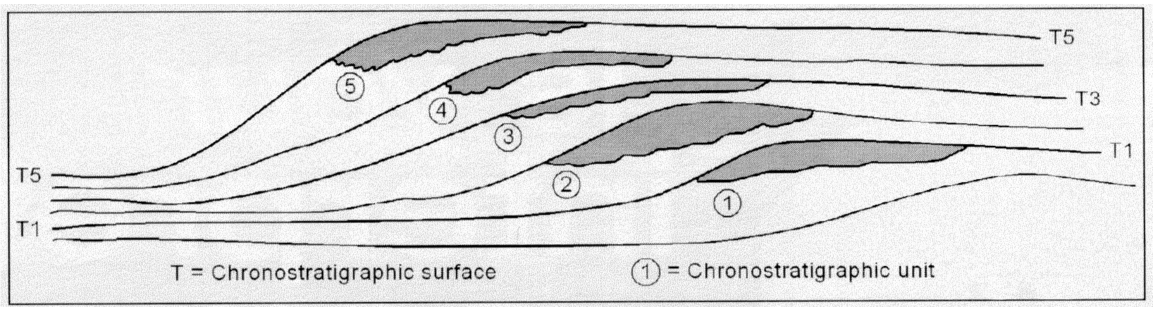

Figure 1 – Our Earth model: Five stratigraphic targets (bodies 1 through 5) deposited at five different geologic times, T1 through T5.

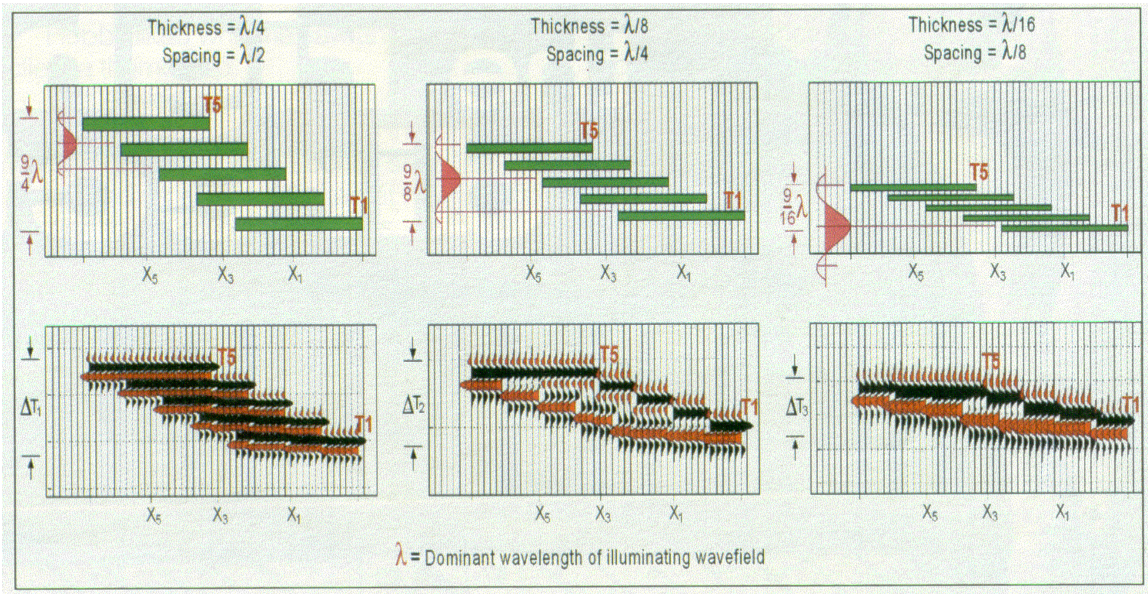

Figure 2 – Top row: synthetic models approximating the Earth model in Figure 1. Bottom row: images produced by forward modeling using the wavelet shown in each model (top). Here the lateral overlap from unit to unit is seven dominant wavelengths (7λ). X5 marks the center of depositional unit 5; X3 the center of depositional unit 3, and X1 the center of unit 1. Labels T1 through T5 show the positions of depositional times T1 through T5 as defined in Figure 1.

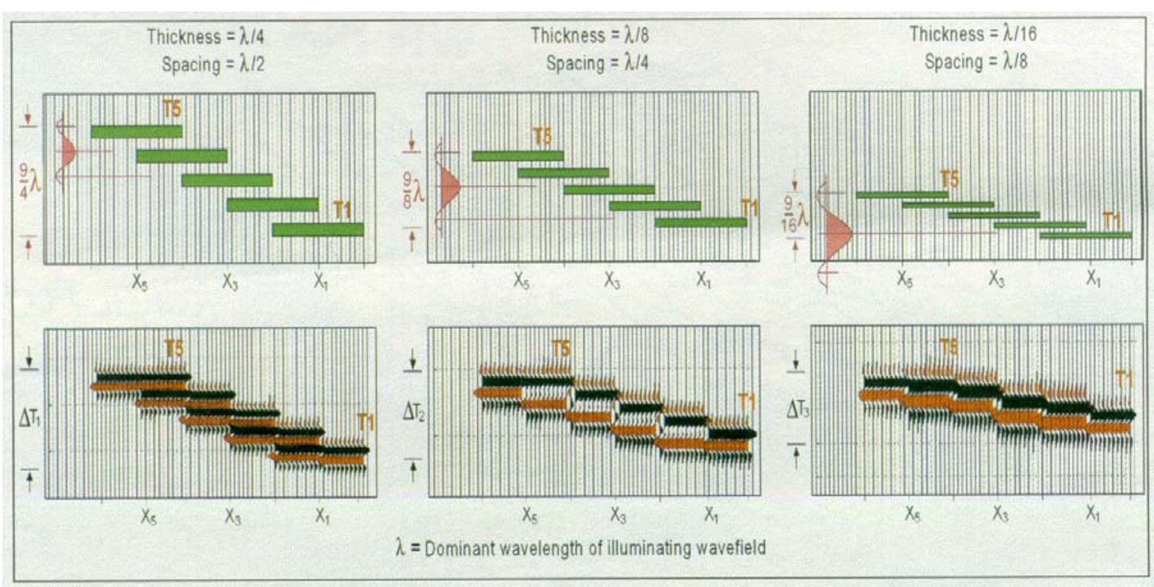

Figure 3 – Same modeling exercise described in Figure 2, except the lateral overlap from unit to unit is decreased to five dominant wavelengths (5λ).

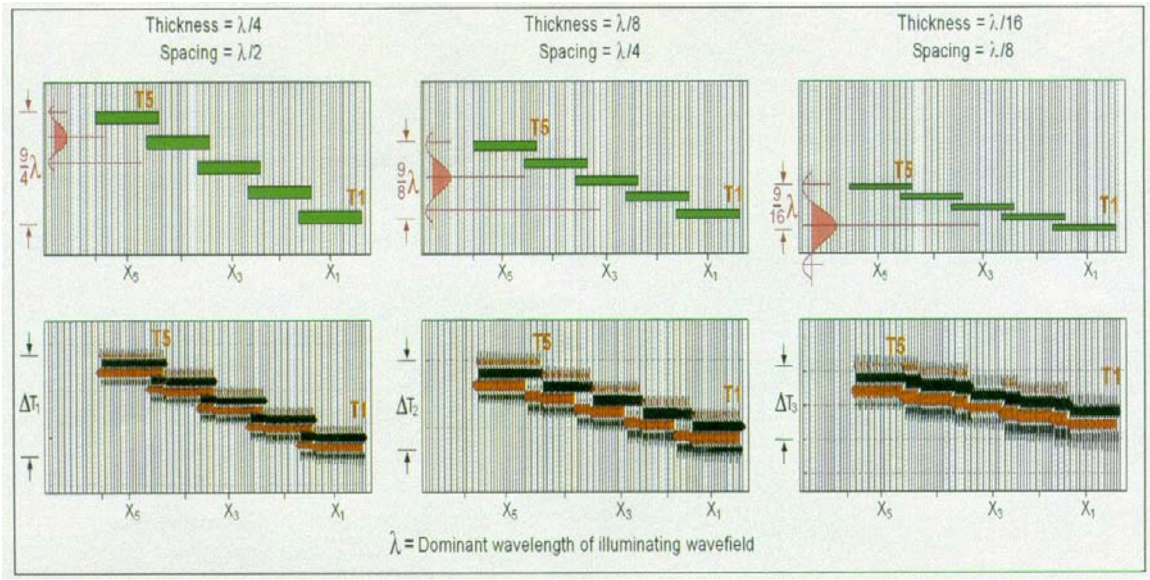

Figure 4 – Same modeling exercise described in Figure 2, except the overlap of the units is decreased to two dominant wavelengths (2λ).

In these figures, the left column shows the illumination created by a high-resolution wavelet; the center column uses a moderate-resolution wavelet for the imaging; and the right column documents the image produced by a low-resolution wavelet. The illuminating wavelet is shown beside each five-layer model for easy comparison of wavelet length with bed thicknesses and bed spacings.

Modeling calculations are done in a dimensionless way in which all aspects of the model (bed thickness, bed spacing, bed overlap) are defined in terms of the dominant wavelength of the illuminating wavelet. This approach allows one person to think of the analysis as “the wavelet is the same in all cases, but the stratigraphic units have different thicknesses and spacings,” while another person can view the picture as “the unit thicknesses and spacings are always the same, but the wavelet varies.” Either view is correct. Use the one that is less taxing to the brain.

Relationships between wavelet length, bed thickness, and bed spacing are defined at the top of each column. The amount of unit-to-unit overlap decreases as modeling proceeds from Figures 2 to 4.

What does this modeling exercise tell us? With λ to represent the dominant wavelength of the illuminating wavelet, some key points are:

- When bed thickness is λ/4 or greater and bed spacing is λ/2 or more, there is an individual reflection event for each stratal surface T1 through T5 (left columns).
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In this case, seismic reflections follow chronostratigraphic surfaces, and unit-to-unit relationships within the five-layer system can be interpreted from the seismic response.

- When bed thickness is λ/16 or thinner and bed spacing is λ/8 or less (right columns), the five-layer system is represented by a single, slightly erratic peak/trough response that cuts across depositional time lines T1 through T5.

In this case, the seismic reflection response is a diachronous event, not a chronostratigraphic event. We lose the ability to analyze the internal architecture of the layered system, and seismic reflections no longer follow chronostratigraphic surfaces.

- Between these two imaging options is the situation in the center column, where imaging indicates that there is a separate unit positioned at each depositional time, T1 through T5, although no image shows the correct lateral dimensions of the depositional bodies. The part of each unit that is overlapped by a younger unit is not imaged.

Even though the imaging is not 100 percent correct, there is a reflection event for each chronostratigraphic surface. In this case, we can say that each image in the center columns consists of chronostratigraphic, but incomplete, seismic reflections.

Conclusion

Whether seismic reflections follow chronostratigraphic surfaces depends on:

- The relative magnitude of the dominant wavelength of the illuminating wavelet compared with the bed thickness deposited at each geologic time.
- The vertical spacing between successive chronostratigraphic surfaces.
- The amount by which younger beds overlap older beds.

Probably all reflection possibilities illustrated in these models occur within any single 3-D seismic volume. Our recommendation is that the premise that seismic reflections follow chronostratigraphic surfaces is sound and should be applied as a first principle of seismic interpretation.

However, in critical prospect areas, modeling similar to what is illustrated here should be done to determine whether the assumption that seismic reflections are chronostratigraphic needs to be abandoned in a few local areas, even though the concept is correct in a general sense.

Reference

Tipper, John C., 1993, Do seismic reflections necessarily have chronostratigraphic significance?: Geological Magazine, v. 130, p. 47-55.

Acknowledgment

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