GC Reflection Events and Their Polarities Defined by the Hilbert Transform*

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*Adapted from the Geophysical Corner column, prepared by the author, in AAPG Explorer, June, 2010, and entitled "Thin Is In: Here's a Helpful Attribute". Editor of Geophysical Corner is Bob A. Hardage (bob.hardage@beg.utexas.edu). Managing Editor of AAPG Explorer is Vern Stefanic; Larry Nation is Communications Director. Please see closely related article "Instantaneous Seismic Attributes Calculated by the Hilbert Transform", Search and Discovery article #40563.

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General Statement

Previously we introduced the concept of a complex seismic trace ("Instantaneous Seismic Attributes Calculated by the Hilbert Transform", Search and Discovery article #40563); here we'll show how a complex trace provides a rigorous way to set the boundaries of data windows associated with distinct seismic reflections – and we'll define the polarities of each of those reflection events. This complex trace application is important because it is necessary to determine the polarity of every reflection event that spans a layered system in order to determine whether impedance increases or decreases from layer to layer – which in turn provides insight into the lithology, porosity and type of pore fluid in each rock layer.

The principal problem involved in determining the polarity of a seismic reflection event is the challenge of deciding what part of the seismic response represents the reflection event. Questions that have to be answered include:

- Where does the reflection event start and stop?

- How many peaks and troughs are embedded in the reflection event?

- Which peak or trough of a reflection event should be used to define reflection polarity?

The amplitude-envelope function determined from a complex seismic trace provides a way to define the start time, stop time, wavelet character and polarity of overlapping – but distinct – reflection events.

Defining Reflection Events

An example seismic trace, its complex-trace equivalent and the associated amplitude envelope are shown as Figure 1: the amplitude envelope of a complex seismic trace is an oscillating function that has alternating maxima and minima. The data window between two successive minima of an amplitude-envelope function defines a distinct packet of seismic energy. Terms that have been used to describe this interval between successive amplitude-envelope minima are energy packet, wavelet packet and reflection event. Once you equate the term "reflection event" with energy packet (or with wavelet packet), you can then ask the question: "How many reflection events occur between time coordinates A and B on Figure 1?"

You will get the definitive answer "13." A wavelet packet such as any of those defined on Figure 1 may be a reflection from a single interface, or it may be a composite of several reflections from closely spaced interfaces. In either case, a wavelet packet represents the shortest-time concentration of reflection of energy that can be recognized in a seismic response. Because amplitude-envelope minima can be determined numerically after an amplitude envelope is calculated, the start time, stop time and time extent of a reflection event can be defined with mathematical rigor, as shown by each of the labeled "events" on Figure 1, and do not have to be left to interpreter judgment. The basic seismic wavelet that is embedded in the seismic trace on the left of Figure 1 is shown in the center part of the figure. A reader can compare this wavelet with its associated reflection trace on the left of the display to attempt to decide how many reflection events exist across the time interval A to B. In classroom and workshop exercises, people have tended to conclude that the number of reflection events ranges from a low of five or six to a high of 17 or 18. Using the mathematical concept of amplitude-envelope minima to define the boundaries of a reflection event, the correct answer is 13 reflection events (right-hand panel) as already stated.

Defining Reflection Polarity

When a reflection event is defined by this energy packet concept, the polarity of the reflection event can be defined as the algebraic sign of the real-trace extremum (either peak or trough) that is closest to the maximum of the amplitude-envelope that encompasses the energy packet. Using this concept, the polarity of reflection events 5 and 10 on Figure 1 are positive, and the polarities of reflection events 7 and 12 are negative. Thus a complex-trace allows seismic reflection polarity to be defined with the same mathematical rigor that defines the time extent of each reflection event.

A second illustration of energy packets being used to define distinct reflection events and their polarities is provided as Figure 2. In this case, there are excellent examples of energy packets distinguishing overlapping reflection events (events 7 and 8, and events 11 and 12) and defining the data windows spanned by faint, low-amplitude reflections (events 2 and 3).

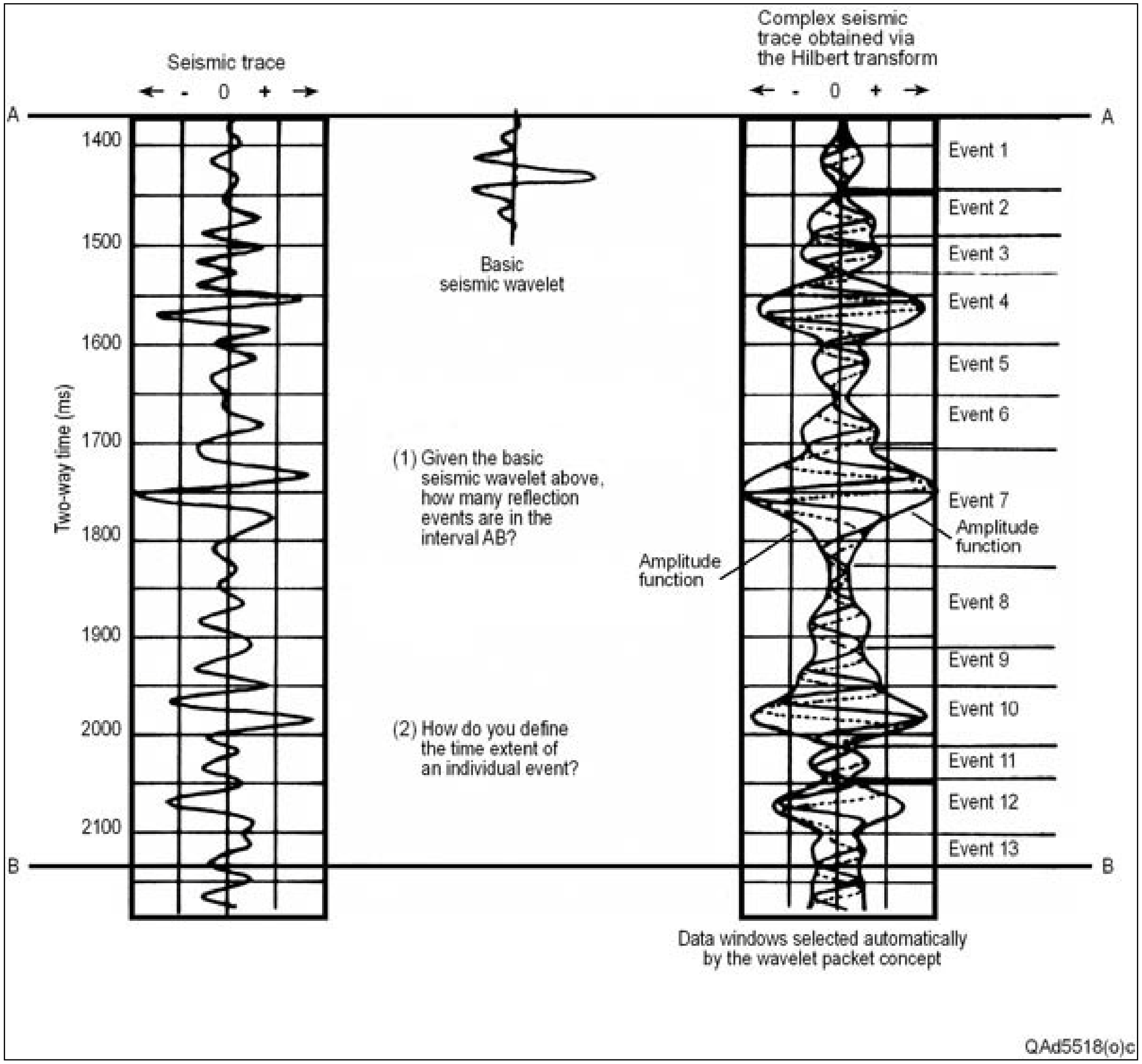

Figure 1. The concept of an energy packet (or wavelet packet) being used to define the time extents and polarities of reflection events. The wavelet that illuminates the geology is shown in the center. The resulting reflection trace is displayed on the left. The display on the right is a complex seismic trace consisting of a real part (which is the real trace on the left repeated as a solid-line wiggle) and an imaginary part (the Hilbert transform of the real trace shown by the dash-line wiggle). The amplitude envelope is the function that bounds this complex trace on the left and right so as to touch every positive and negative extremum of the real and imaginary parts of the complex trace.

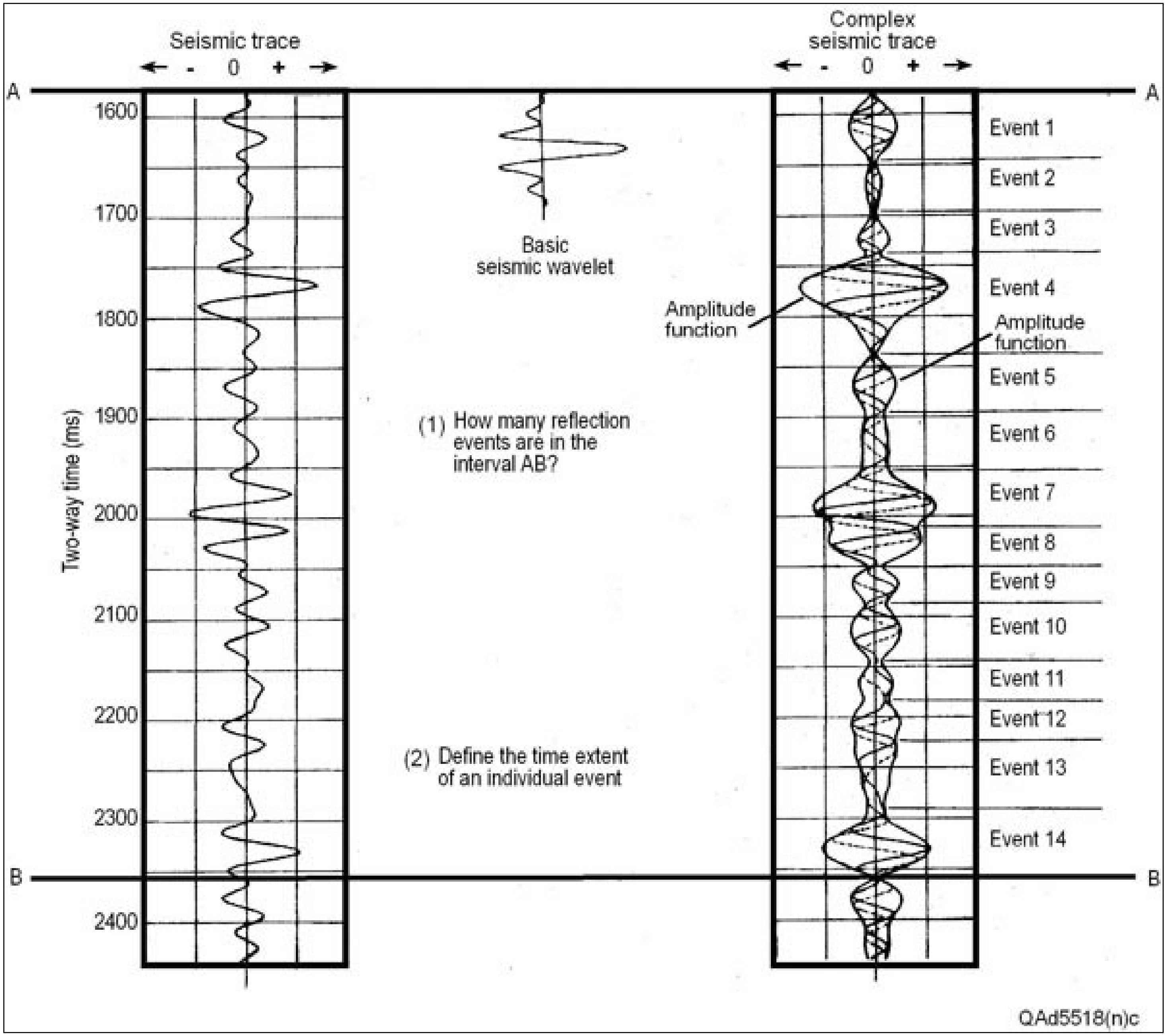

Figure 2. Example 2 of energy packets being used to define distinct reflection events in the seismic trace on the left and also the polarities of those reflections.