GC Interpretation Value of Anomalous ('Impossible') Frequencies*

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General Statement

Two constraints can be imposed on the frequency behavior of a digital seismic wiggle trace:

1) Each frequency component of the trace is a positive quantity. Frequencies can have a negative algebraic sign in some mathematical operations, such as Fourier transforms, but when the oscillatory behavior of an actual wiggle trace is visually examined to estimate seismic frequency, the frequency estimate is always a positive number. The situation is much like trying to dial a radio to a negative frequency to listen to music. Negative frequencies are just not a part of the real world.

2) No frequency component can exceed the Nyquist limit f_N, which is defined as:

$$f_N = 1/(2\Delta t),$$

where Δt is the time sample interval of the digital data in units of seconds.

Because of these constraints, when an instantaneous frequency attribute is calculated along the time extent of a seismic trace, the frequency value should never be negative at any time coordinate, nor should the value ever exceed the Nyquist limit.

Instantaneous frequencies, however, always exhibit negative values and values greater than Nyquist at numerous locations throughout a 3-D seismic data volume. The term "impossible frequencies" is used in this article to refer to these anomalous frequency values that violate the constraints just stated.

Example

Figure 1 shows an example of impossible frequencies occurring in a 3-D seismic volume; the surface being analyzed in this instance is a horizon that passes through the Brushy Canyon Formation in an area of the Delaware Basin in New Mexico. At this prospect area, the Brushy Canyon is a sequence of fine-grained siliciclastic units deposited in a deepwater turbidite environment.

The color bar used to display the instantaneous frequency behavior was chosen to emphasize impossible frequencies, with all negative frequencies shown as bright red and all frequencies that equal or exceed the Nyquist limit (125 Hz in this case) shown as darkest black. The arrows positioned along arbitrary lines A, XL91, and XL57 mark where each profile crosses a reasonably continuous trend of these impossible frequencies.

Vertical profiles along lines A and XL57 are displayed as Figure 2 to illustrate the wavelet character that is associated with these impossible frequencies. The position of the attribute surface in Figure 1 is 10 ms below the K horizon along these profiles. The location of each anomalous frequency arrow shown along the map horizon (Figure 1) is indicated by a circle.
At each of these circled coordinates there is a reflection termination or some type of abrupt change in the wave form of the reflection wavelet. Interpreters working with these particular attribute displays concluded that most of these anomalous frequencies were marking stratigraphic pinch-outs or reservoir compartment boundaries. If true, then “impossible frequencies” have great interpretational value.

Applying the assumption that, in this instance, impossible frequencies define boundaries of reservoir compartments, a tentative reservoir-compartment map such as that shown in Figure 3 can be constructed. The compartments on this map were created by drawing boundaries along trends suggested by the alignments of the impossible frequencies. Each boundary defined by this “connect-the-dots” method is arbitrary; other interpreters would connect the dots in different ways and cause some compartments to have sizes and shapes that differ from those shown on this map.

Is the assumption that impossible frequencies define compartment boundaries valid in this case? At this prospect, there is circumstantial evidence that the answer is “yes.”

1) Drilling has confirmed that wells in area A (Figure 3) penetrate small reservoir compartments at this stratigraphic level – the same principle implied by the frequency-based map.

2) A horizontal well drilled across area B has been the most prolific Brushy Canyon producer across a broad area of the basin, confirming that the well penetrated a large compartment, as indicated by the compartment map.

Conclusion

Will impossible frequencies be valuable indicators of stratigraphic terminations and/or compartment boundaries in other areas and in other depositional environments? Always consider the possibility that they will.

Incidentally, some commercial interpretation software arbitrarily deletes the negative algebraic sign of any negative frequencies created by their algorithms, a practice that may not be a desirable thing to do. Those negative frequencies can be important information.

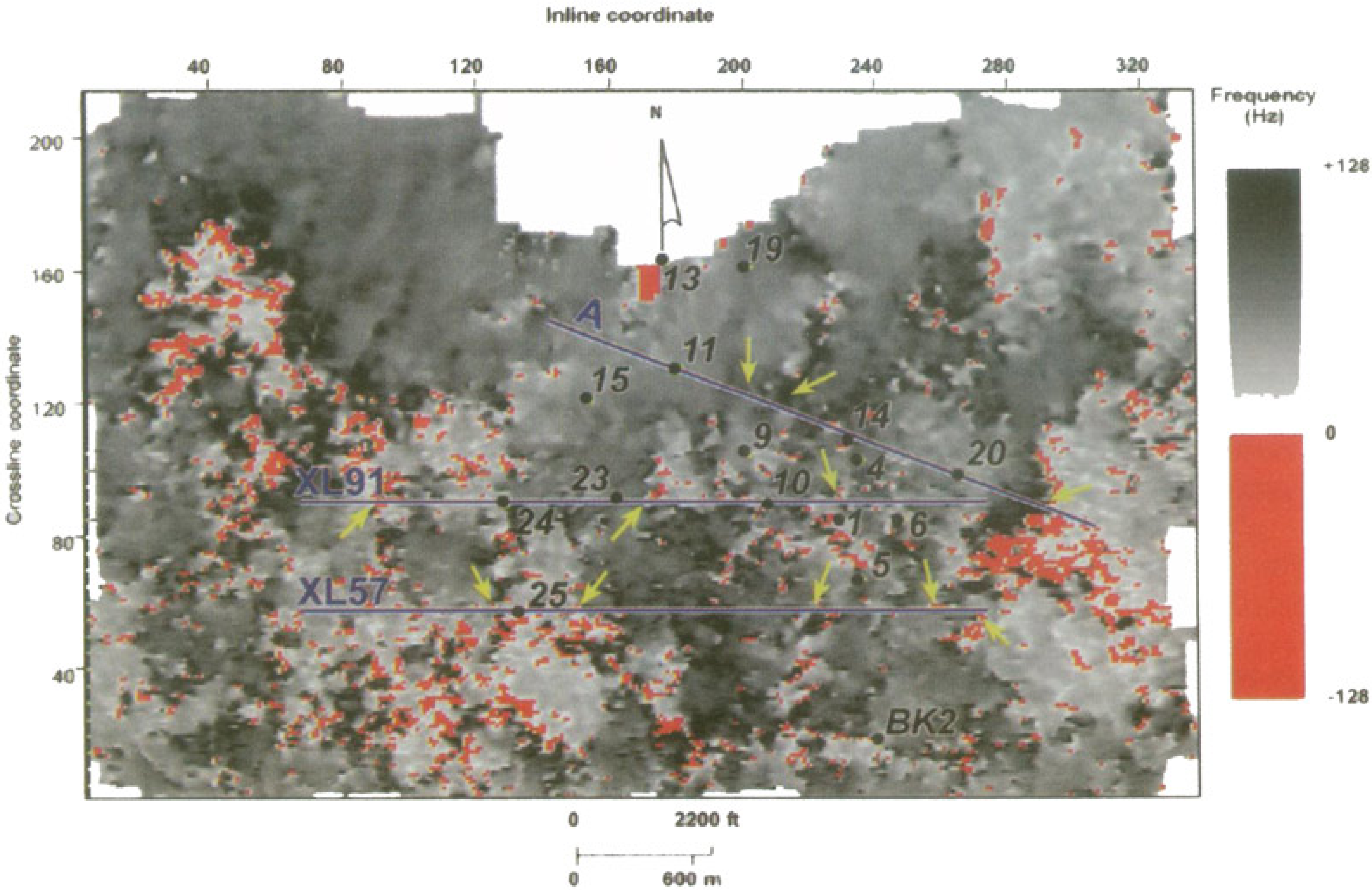

Figure 1. Map of instantaneous frequency behavior across a thin-bed turbidite system. Negative frequencies (red) and frequencies greater than Nyquist (darkest black) are impossible frequency values but are commonly created by software that generates instantaneous seismic attributes. Arrows show where three arbitrary profiles intersect trends of impossible frequencies.

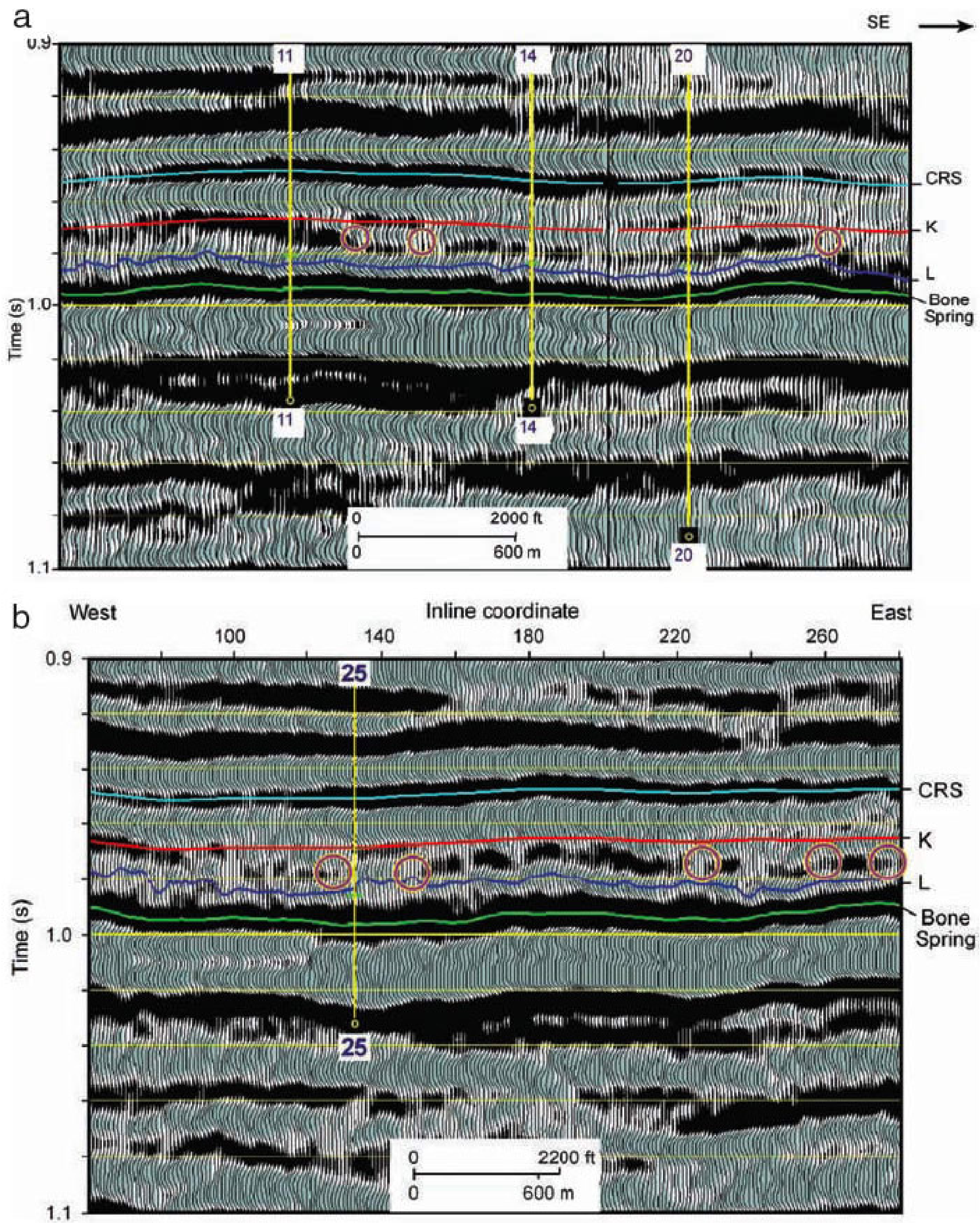

Figure 2. Vertical seismic section along profiles (a) A and (b) XL57 (Figure 1). The map in Figure 1 is 10 ms below and conformable to horizon K. Circled locations show where the profile crosses a trend of impossible frequencies.

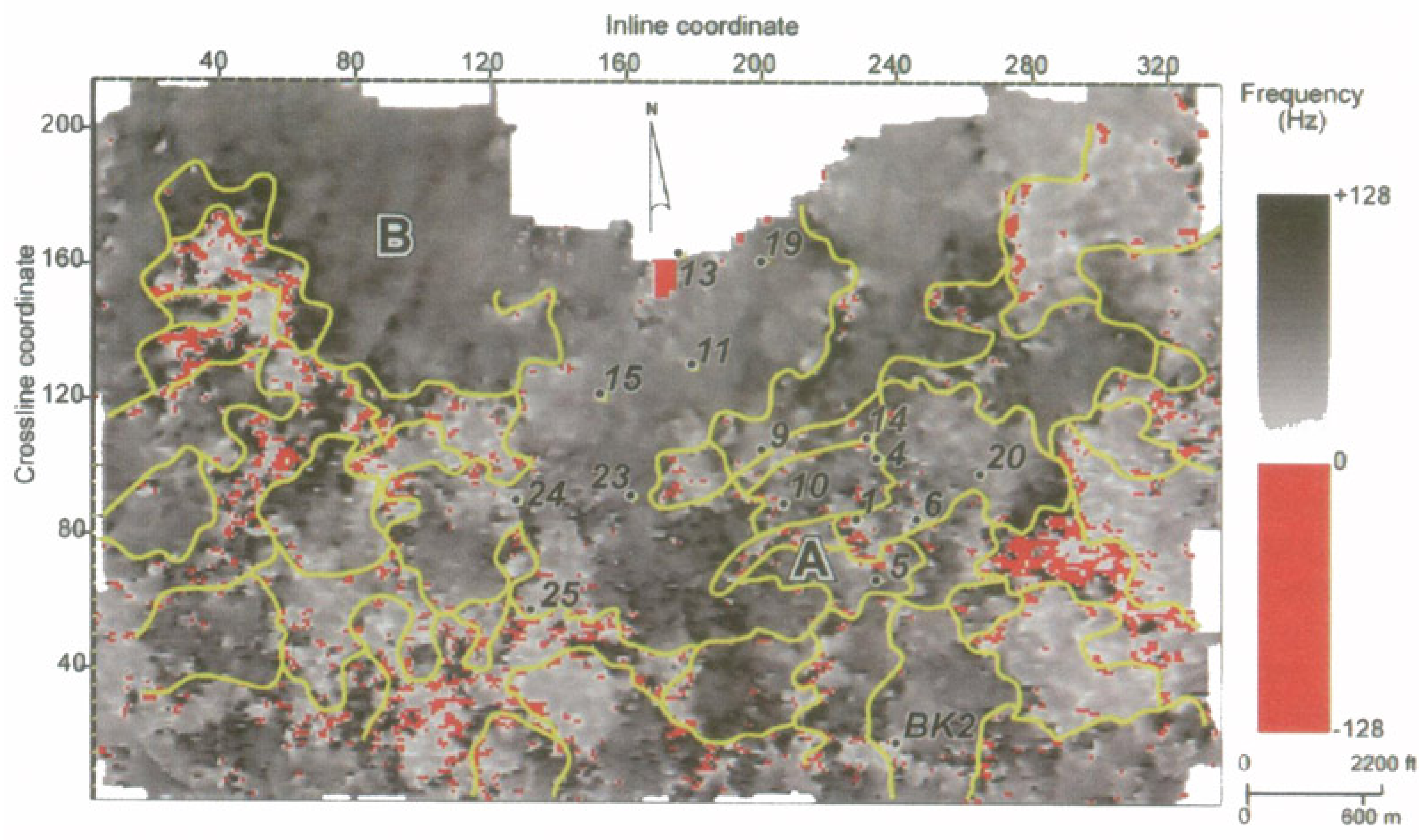

Figure 3. Map of hypothetical reservoir compartment boundaries that follow trends of impossible frequencies. The map implies that area A has small reservoir compartments and area B is a large reservoir compartment.