GC Passive Seismic Techniques*

By
Bob Hardage[1]

Search and Discovery Article #40319 (2008)
Posted August 1, 2008

*Adapted from the Geophysical Corner column, prepared by the author, in AAPG Explorer, July, 2008, and entitled "Is the Future of Seismic Passive?". Editor of Geophysical Corner is Bob A. Hardage. Managing Editor of AAPG Explorer is Vern Stefanic; Larry Nation is Communications Director.

[1]Bureau of Economic Geology, The University of Texas at Austin (bob.hardage@beg.utexas.edu)

General Statement

Passive-seismic technology encompasses any procedure by which seismic data are recorded without the use of an active seismic source. When passive-seismic data are acquired, there is no vibrator vehicle, no shothole explosive, no impact source, and no air gun. Instead, seismic wavefields are generated by natural phenomena such as wind, microseisms, ocean waves, or by human-made noises such as moving vehicles, passing aircraft, or mechanical vibrations of operating machinery.

One passive-seismic application that is gaining attention is the acquisition and analysis of low-frequency natural seismic wavefields that seem to indicate the presence of subsurface oil and gas accumulations. In this application, data are acquired using high-sensitivity three component geophones deployed across the earth's surface. Data are recorded for time periods of many minutes to days in order to have data that are appropriate for analysis.

Examples

An example of this low-frequency, passive-seismic application is shown as Figure 1, in which responses of vertical geophones at sites 1 and 2 along a profile are displayed. Site 1 is atop a hydrocarbon producing area; site 2 is not. Data analysis usually focuses on the amount of seismic energy between 1 and 6 Hz in order to distinguish the presence of hydrocarbons – but tests now imply that there is a narrow frequency band extending from approximately 1 Hz up to about 4 Hz that often is the most diagnostic indication of the presence of hydrocarbons for the data sets acquired to date.

Restricting data analysis to this narrow frequency band:

1) Rejects energy created by ocean waves, which tend to have frequencies less than 0.2 Hz.
2) Also rejects energy created by anthropogenic sources (human activity), which tend to have frequencies greater than 4 Hz.

Ocean-wave energy is ubiquitous and can be observed in the interior of continents far from coastlines. The amount of anthropogenic energy varies from site to site, depending on the nature of human culture from area to area.

To emphasize a hydrocarbon response in this narrow, low-frequency band, one data-analysis procedure is to integrate the frequency spectrum to amplify and smooth the data signal. An example of a frequency-spectrum integration of data acquired by vertical geophones is displayed as Figure 2.

Although the data behaviors illustrated in these figures seem to imply the presence of hydrocarbons, the data do not provide information about depth to the hydrocarbon accumulation or about the size of the reservoir. These shortcomings are now being addressed by reverse time modeling of passive-seismic data, a process in which seismic events are extrapolated back to their points of origin.

An example of one such reverse-time model is displayed as Figure 3. When shown in this format, passive-seismic data can be compared with other hydrocarbon-sensitive data and, more importantly, can be subjected to a rotary lie-detector test (the drill bit).

Question/Conclusion

What is the source of the hydrocarbon signal? The big question is *why are hydrocarbon reservoirs associated with these natural-source, low-frequency responses?* This is an active area of research at ETH Zurich, where both meso-scale scattering and pore-scale rock physics mechanisms are being considered. What is known is that empirical evidence is accumulating from the Middle East, North Africa, Europe, Brazil, and North America that implies a relationship between low-frequency passive-seismic responses and the presence of subsurface hydrocarbons.

There is nothing wrong with utilizing empirical rules in hydrocarbon exploitation. Empirical relationships between seismic attributes and reservoir properties are used daily by explorationists to interpret hydrocarbon systems. Maybe we now have another empirically based attribute that can be used: low-frequency, passive-seismic amplitude anomalies.

Author’s Note

At present, I have no experience in using passive-seismic data in the manner described here. However, my responsibility is to alert readers to new techniques that warrant consideration for energy-resource exploitation. If you desire more information about the applications of natural-source passive-seismic technology, contact the author for references to contractors who provide passive-seismic data-acquisition and data-analysis services.

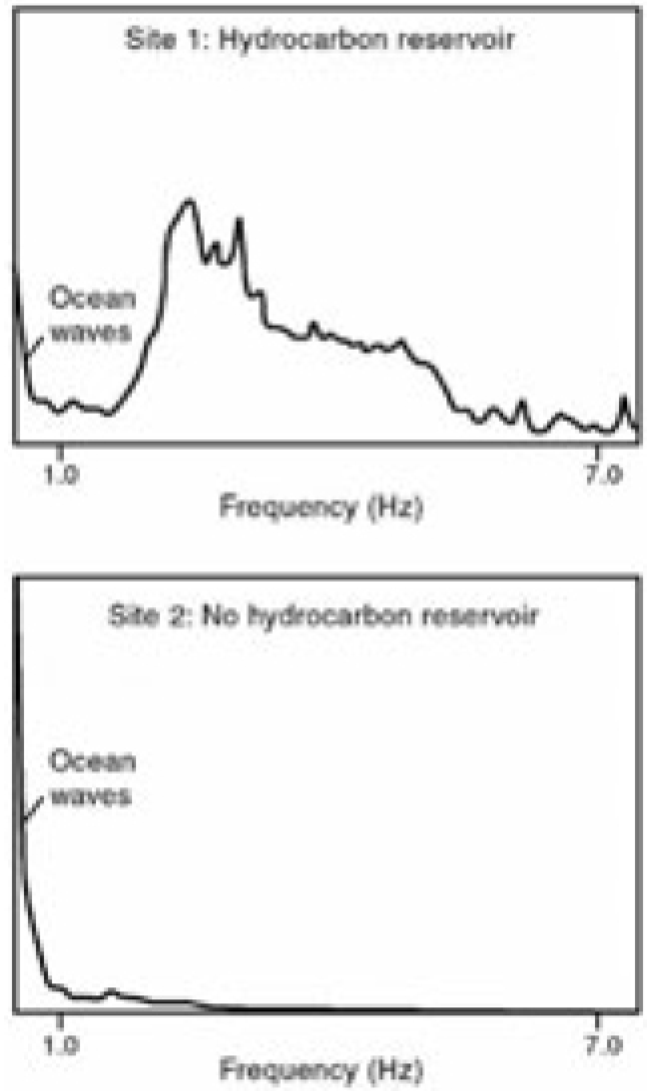

Figure 1. Natural-source seismic wavefields appear to exhibit higher amplitude responses in the frequency range between 1 and 4 Hz when measured above hydrocarbon reservoirs (top) than when measured above areas with no hydrocarbons (bottom). These data are the responses of surface-based vertical geophones.

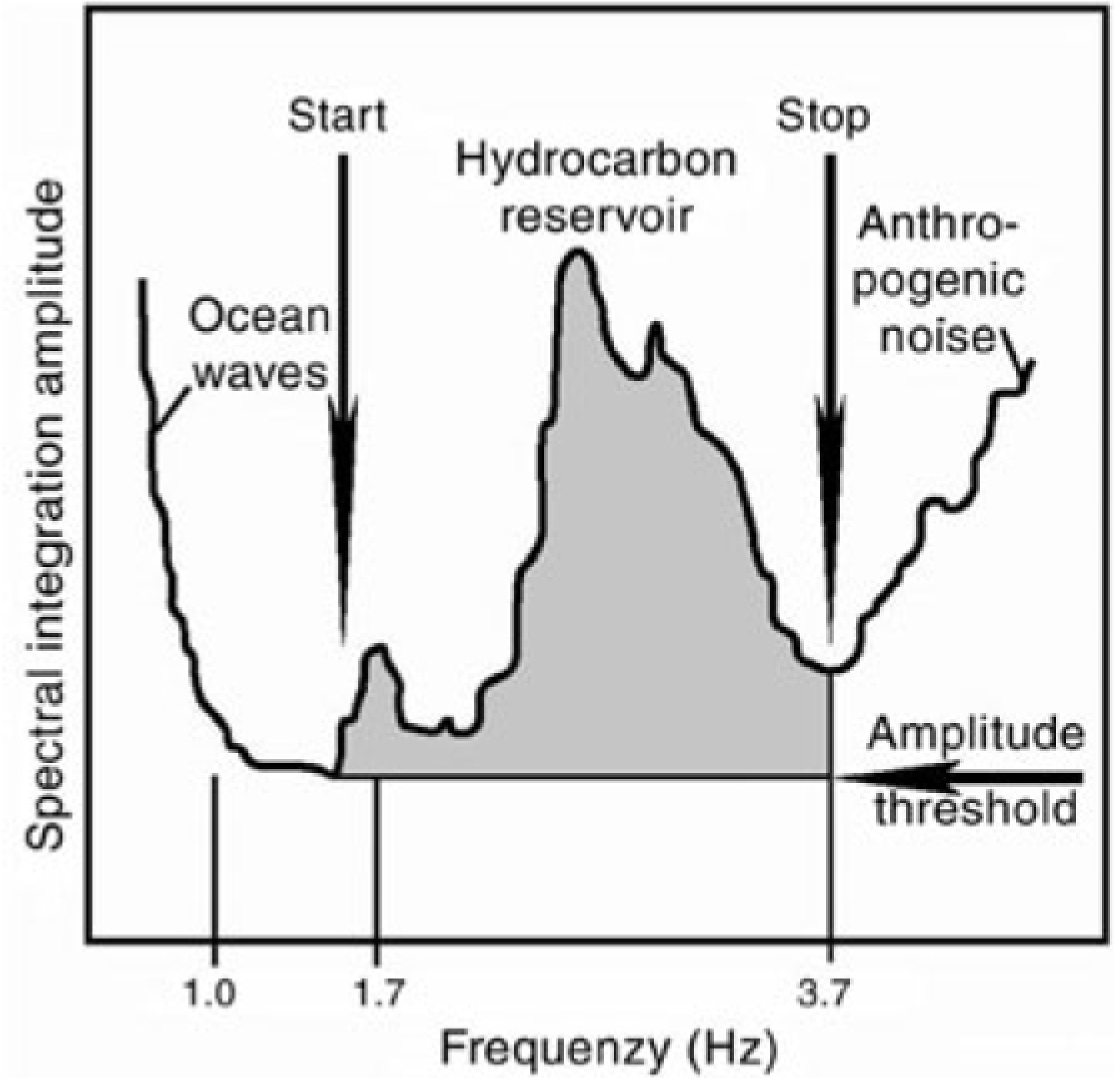

Figure 2. Integrating the frequency spectrum of natural-source seismic data emphasizes and smoothes any signal that appears in the interval between ocean-wave activity (less than 0.2 Hz) and anthropogenic (human) activity (greater than 4 Hz). Some requirements of the data analysis are to define the start and stop frequencies of interest and the amplitude threshold of signals that should be considered.

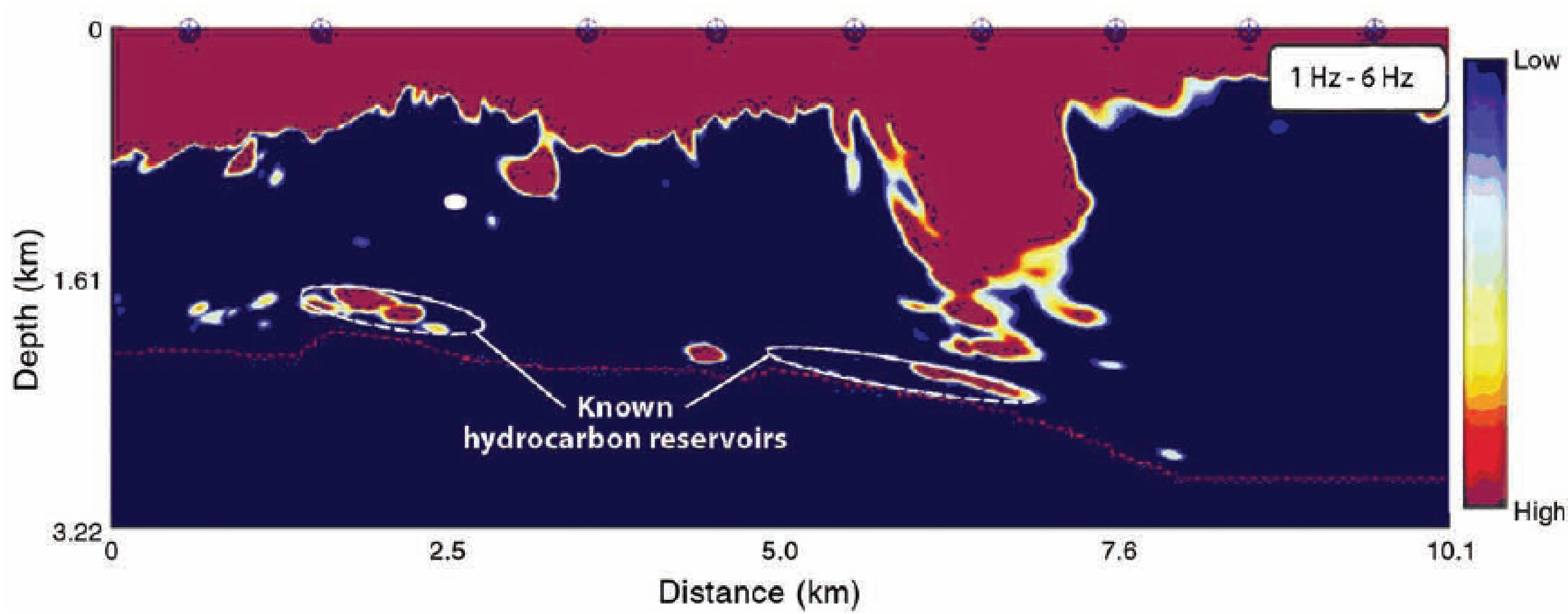

Figure 3. Reverse-time model of passive-seismic data that defines the maximum particle-velocity associated with natural-source frequencies of 1 to 6 Hz along a profile that traverses two known hydrocarbon reservoirs. The data are now in a form that indicates the depths and approximate sizes of the reservoirs.