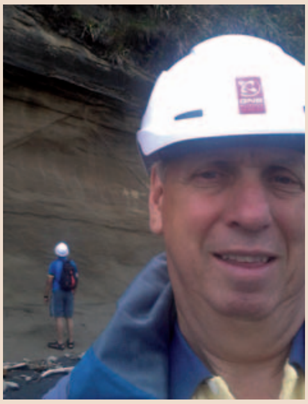
10.1071/PVv2017n187p39

Seismic window



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Seismic resolution

Seismic resolution is a term that is often misunderstood, but it is quite a simple concept that has its origins in physics. Resolution is defined as the ability to separate two features that are very close together, or to show two features as separate rather than blended together. In optical physics the Rayleigh criterion defines the minimum resolvable detail, and it is half a wavelength. For seismic data the limit of resolution is the tuning thickness, which is a quarter of a wavelength (because the energy travels through the layer twice). At this separation the reflection from one event and the first side lobe of the preceding or following event are aligned, and only one reflection is seen. My own experience demonstrates how seismic resolution is commonly misunderstood.

First, I often hear the term 'sub-seismic' in meetings, usually when an imaginary fault is randomly placed on a map in order to close a prospect or to explain the strange performance of a production well. When pressed, the user of the term usually describes the fault as having a throw less than tuning thickness and, therefore, below seismic resolution. Using this logic, and if it is assumed that the dominant wavelength is 60 m, faults with a throw of less than 15 m would be sub-seismic. Actually sub-seismic faults are much smaller.

Second, I was lucky enough to spend a few days on a field trip along the Taranaki coast in New Zealand earlier this year. Here the cliffs reveal sediments deposited in environments ranging from deep water fans and slope fans to upper slope feeder channels. In the shallower environments there were channels everywhere and, while discussing the inadequacies of seismic data, someone remarked that most of the channels were less than 15 m and would not be seen on seismic.

Figures 1 and 2 show two channels in the cliff face. The channel in Figure 1 is quite large, maybe 100 m across and up to 5 m deep. Figure 2 shows a much smaller channel about 1 m deep. Both these channels were deposited in a much larger channel system that is 2 km across. Therefore, at least three channels are present, varying in size by an order of magnitude or two. Which, if any, of these three channels can be detected by seismic?

If the data has a high signal to noise ratio and high frequency content I would be tempted to say maybe all of them. This gets to the point of this article. Detection and resolution are not the same thing and semantics are important. Something below seismic resolution can still be detected and identified as a channel, even if we are unable to determine the thickness. Figure 1 shows a quarter wavelength for a typical seismic wavelet (60 m wavelength). This is much larger than the channel so the top and base reflections would not be resolved. But, the channel is detectable and would appear as a change of seismic amplitude, possibly meandering across the area of interest.

Detection can be described as sensing or measuring the presence of something. For seismic data the limit of detection is often quoted as 1/30th of a wavelength, which in this example is 2 m (I suggest it would have to be exceptional data to detect the small channel in Figure 2). The same limits are similar for faults. There are many attributes that use phase to identify faults and a 15 degree lateral change of phase is visually discernible by most interpreters. Computers can probably pick a 10 degree difference, which is 1/36th of a wavelength. So, using this logic, sub-seismic faults are less than 2 m.

Two metres is quite small, but the fine scale variations in geology are much smaller than the seismic method can measure. There can be quite rapid changes in geology over very short distances, and I found the real value in the Taranaki field trip was the recognition that geology can change rapidly both vertically and horizontally, and how much of this detail is not captured by seismic data.

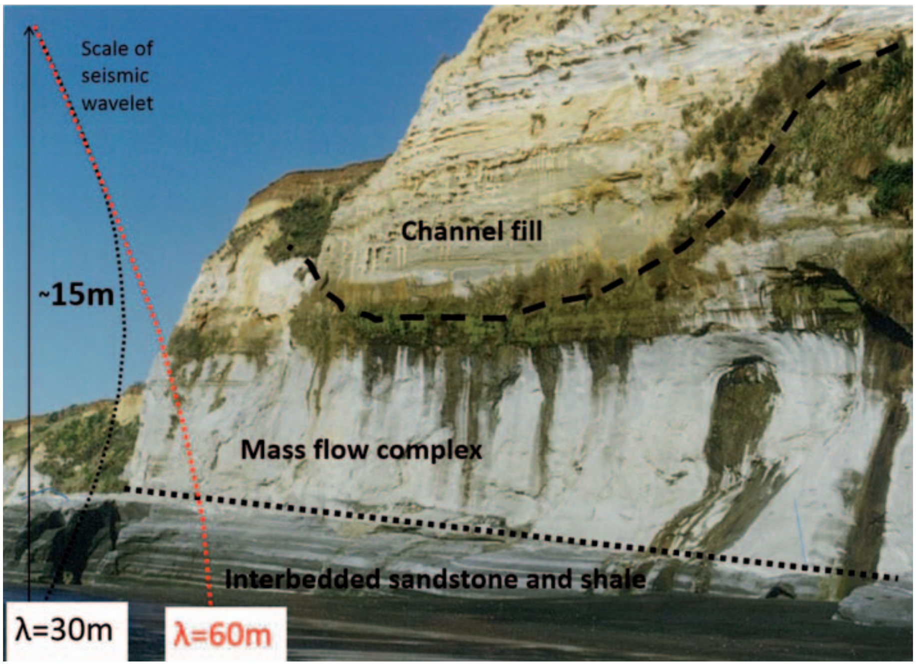

Figure 1. *This channel in the Taranaki cliff face is about 100 m across and 5 m deep and would be detected by seismic, but the top and base of the channel would probably not be resolved in typical seismic (represented by the red curve on the left).*

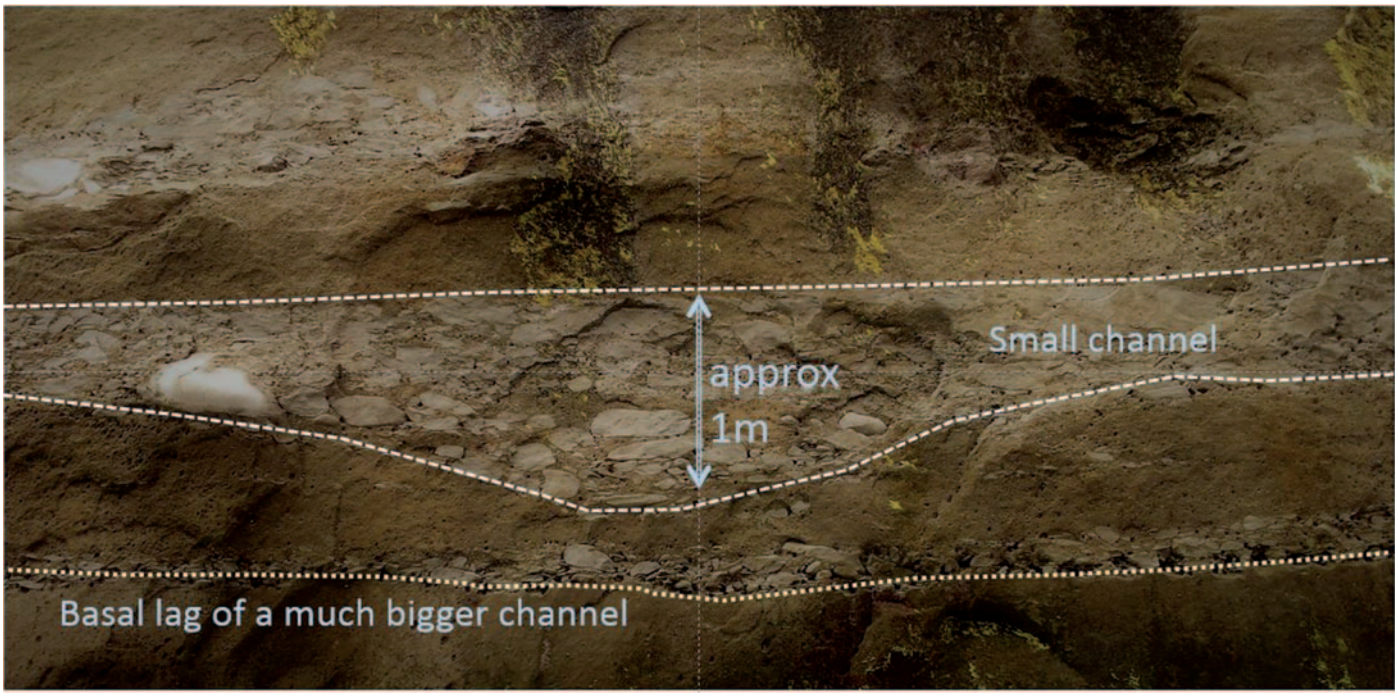

Figure 2. *A small channel approximately 1 m deep. Seismic data would have to be exceptional to detect this feature, which may be important in modelling a reservoir.*