[GC]Reservoir Compartments Can Challenge Logic*

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General Statement

All oil and gas reservoirs are compartmented to some degree. Lateral barriers to fluid flow sometimes exist because faults disrupt and vertically displace hydrocarbon-bearing units. More common causes of reservoir compartment boundaries are lateral and vertical flow barriers created by depositional processes and post-deposition diagenesis. In this article, we look at a reservoir compartment analysis done across a fluvial depositional system in South Texas. The story involves a bit of humor, provides a dose of soberness, and serves as a case history that illustrates the challenges of reservoir characterization.

Example

The Situation

The logs displayed in Figure 1 describe some of the sandstone units involved in this study, in which the objective was to develop exploitation strategies across a prolific gas-producing system. Wells 175 and 202 on this log cross section were near the center of a planned 3-D seismic survey and were separated by only 200 feet.

Stratigraphers intended to use the logs from these two close-proximity wells to start a reservoir compartment model that could be extended across 3-D seismic image space. They had the options of constructing a reservoir compartment model in which unit A in well 175 connected to only unit B in well 202, or connected to only unit C, or connected to both units B and C.

The Humor

To test which of these three possibilities was correct, pressure tests were done between the two wells:

- A pressure pulse was applied to the perforations across unit A in well 175.

- Packers were set in well 202 to isolate unit B.

- The pressure response in unit B was measured.

The packers were then set to isolate unit C in well 202, the same pressure pulse was again applied in well 175, and the response in well 202 was again recorded. The test results are displayed as Figure 2 – as exhibited by the upper curve of this figure, no pressure variation was observed in either unit B or C.

The stratigraphers claimed the engineers could not do simple pressure-interference tests; the engineers claimed the stratigraphers could not correlate logs. The outcome of the debate was that the pressure test program was redone. The result after considerable time and cost was the repeat pressure-interference tests produced exactly the same curves shown on Figure 2. When these repeat test data confirmed the existence of an interwell compartment boundary between wells 175 and 202, friendly relations were restored to the project team and soberness began to pervade the study effort.

The Reason for Soberness

The possibility of a compartment boundary between wells 175 and 202 was not considered initially because of the close proximity of the wells. It was naively assumed these two wells had to penetrate the same reservoir compartment because they were only 200 feet apart. However, the pressure test data are compelling evidence that an interwell compartment boundary is present.

If a compartment boundary cannot be recognized with log data spaced only 200 feet apart, how can a compartment boundary be predicted using logs acquired in wells at greater separation distances, which is the common well spacing strategy used in reservoir exploitation? This sobering thought must be kept in mind when doing reservoir characterization studies.

Applying Seismic Technology

Geophysicists were challenged by their geological and engineering colleagues to image this elusive compartment boundary between wells 175 and 202. The later-to-come 3-D survey had already been designed and contracted to create 110-foot by 110-foot stacking bins, meaning the interwell space of 200 feet would be spanned by less than two image bins (that is, less than two image traces).

Thus, rather than relying on these 110-foot-bin seismic data for the analysis, a vertical seismic profile (VSP) was acquired that allowed the interwell space to be imaged with stacking bins having a width appropriate for resolving fine detail. The resulting VSP image is displayed as Figure 3.

One advantage of VSP imaging is that the distance between image traces can be adjusted to any desired value during data processing to enhance lateral resolution. In this instance the trace separation was arbitrarily set at 25 feet to produce eight image traces between wells 202 and 175, which allowed a more rigorous interpretation of interwell geology than could be achieved by relying on only two images traces from the 110-ft-bin 3-D seismic volumes used in this study.

Conclusion

These VSP data show a significant change in reflection waveshape for the thin-bed interval spanning units A, B and C that begins in the stacking-bin positioned approximately 150 feet (six image traces) away from well 202. This variation in reflection waveshape, indicated by the highlighted circle, is assumed to mark the compartment boundary between the two wells. Now when I get engaged in a reservoir characterization study, I look at the photo displayed as Figure 4 to keep focused on the complexity of reservoir compartmentalization.

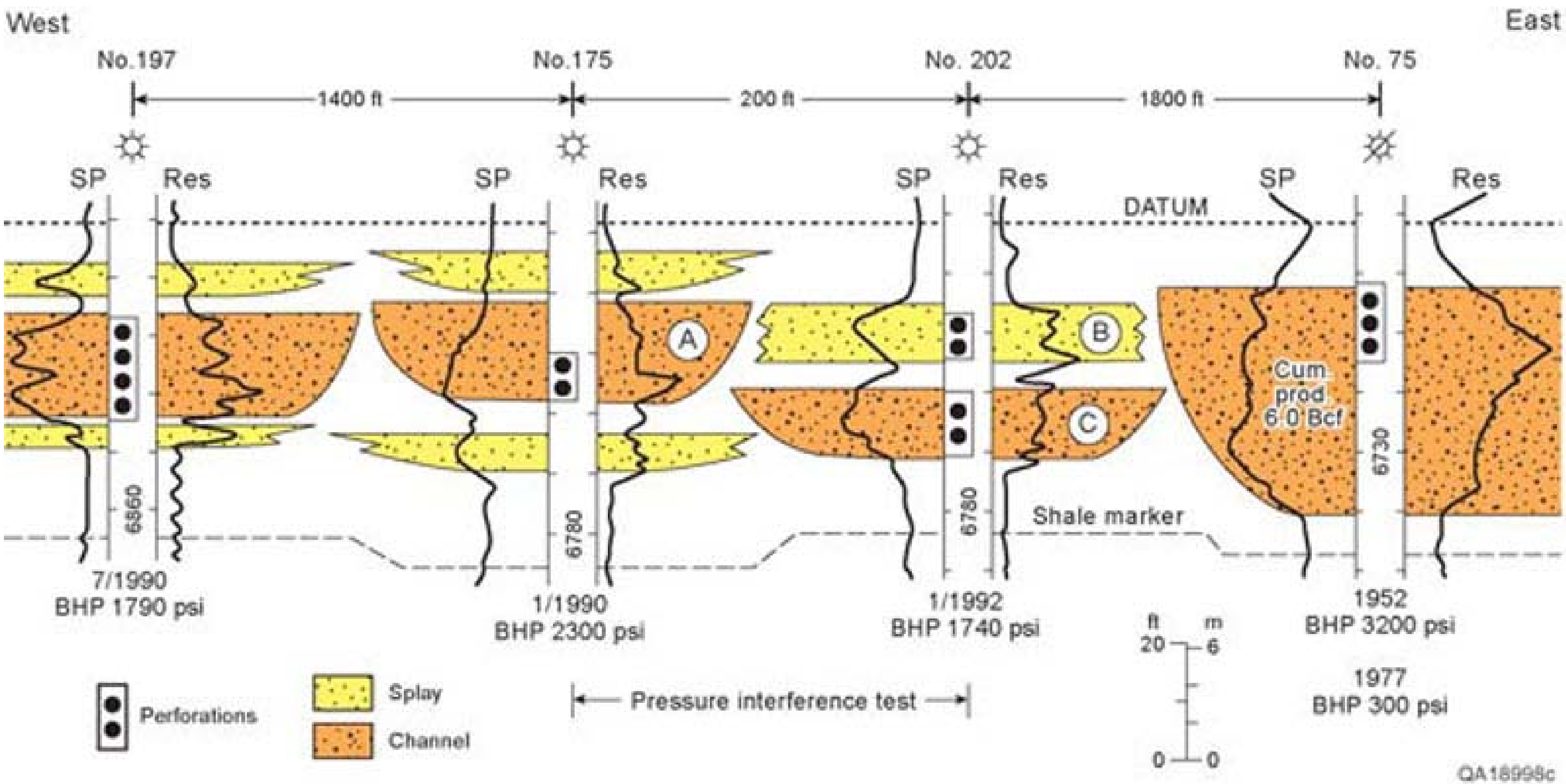

Figure 1. Well logs acquired in wells where a reservoir characterization study was done. Note wells 175 and 202 are separated by only 200 feet. BHP = bottom hole pressure; 1/1990 = January of 1990.

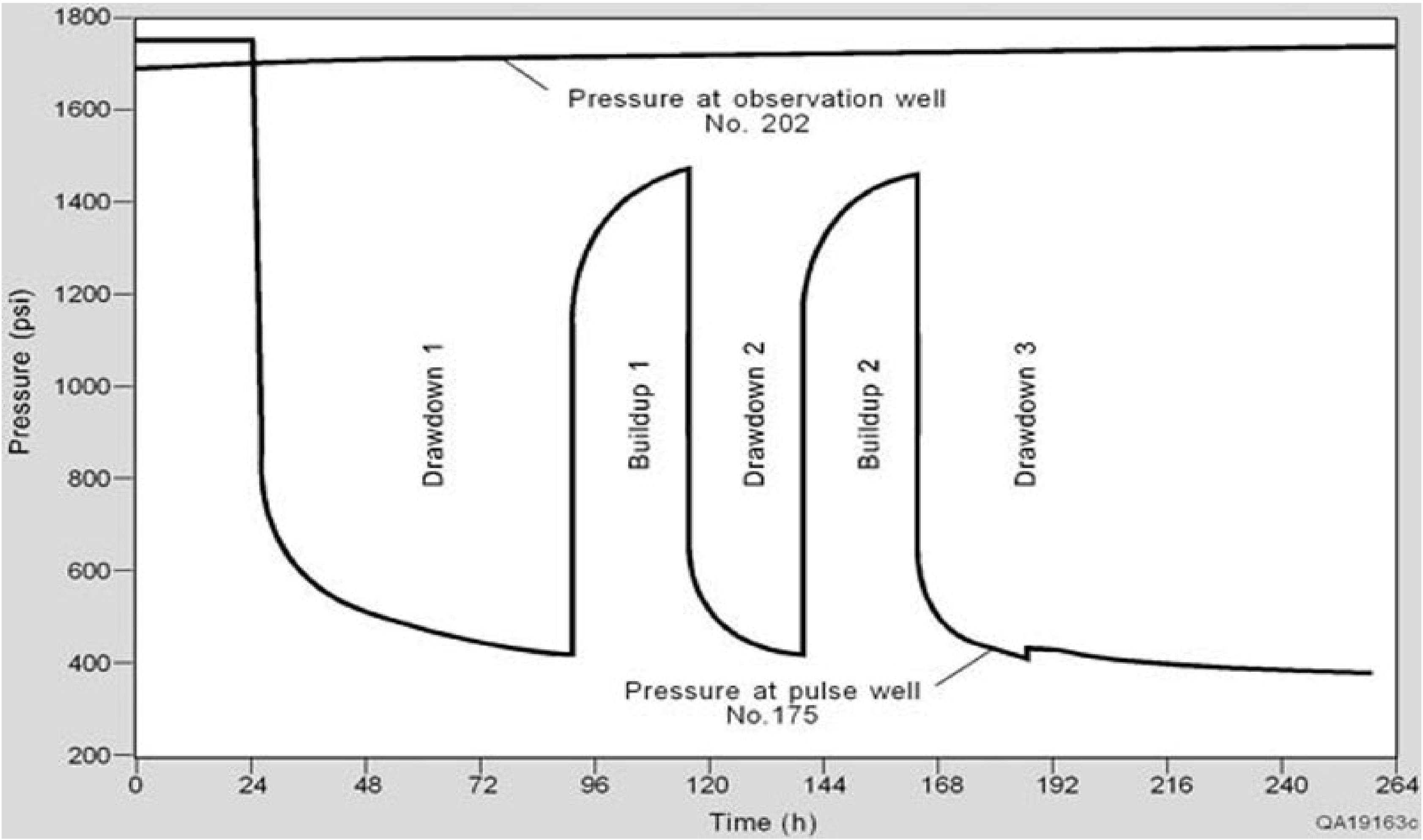

Figure 2. Pressure interference data measured between unit A in well 175 and units B and C in well 202. The lack of a pressure response in well 202 implies a compartment boundary exists in the interwell space between the two wells.

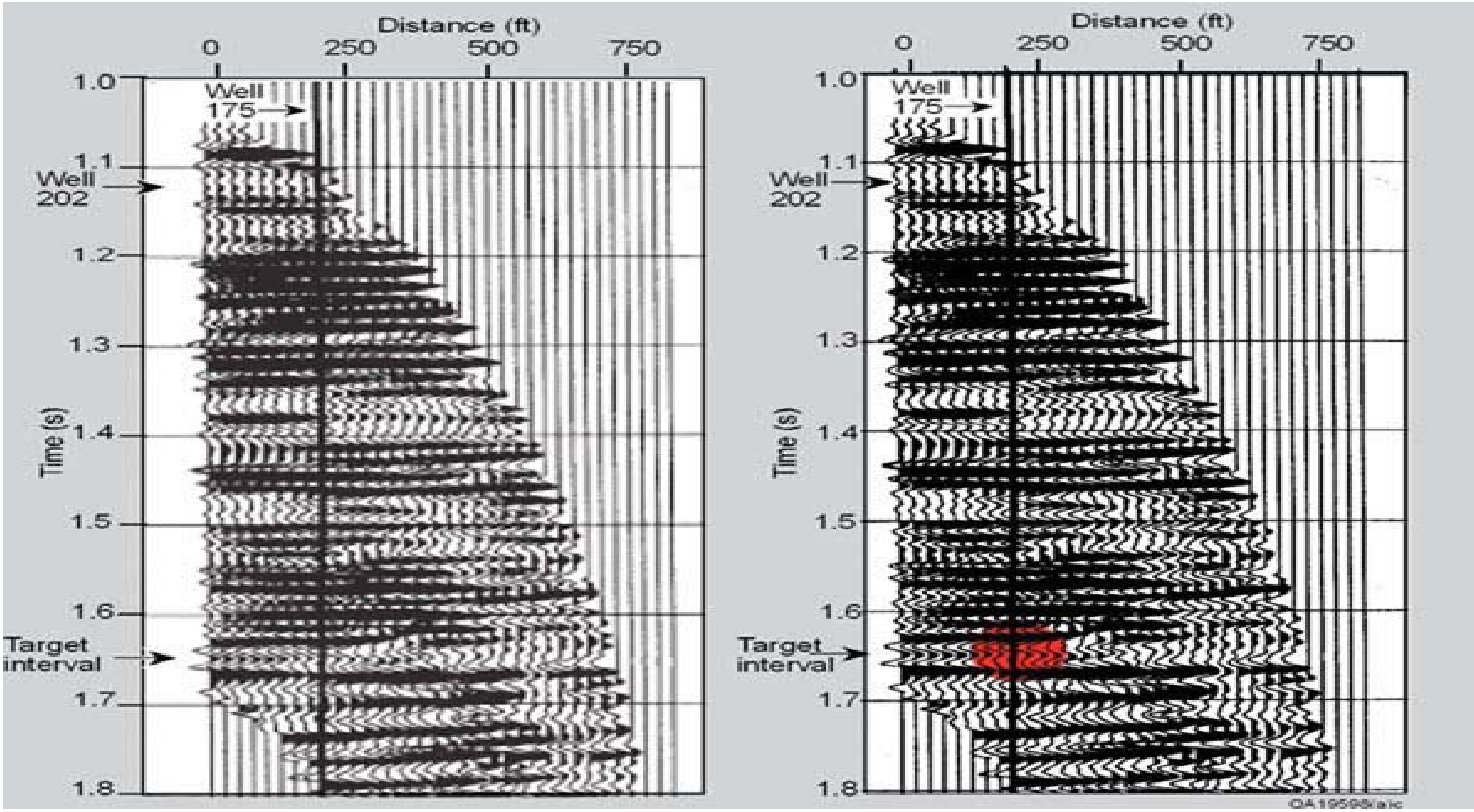

Figure 3. VSP data acquired in well 202 to create an image spanning across well 175. These data have been processed to create stacking bins 25 feet wide. Reservoir units A, B and C defined on Figure 1 are positioned in the reflection peak labeled "Target interval." Well 202, the VSP receiver well,is positioned at the first image trace on the left. The highlighted reflection waveform change that occurs beginning at an image position approximately 50 feet to the left of well 175 is assumed to be the compartment boundary between the two wells.

Figure 4. Photo showing the proximity of wells 175 and 202. It is sobering to think a reservoir compartment boundary occurs in the short interwell distance between these two wells. In this photo, a zero-offset VSP is being acquired in well 175. For the data shown on Figure 3, the receiver system was in well 202 and the vibrator source was far to the north of well 175.