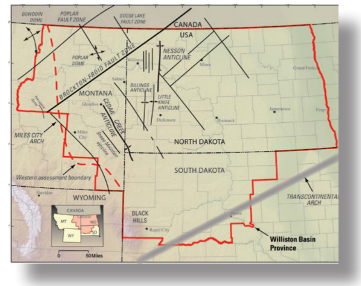
Chapter 6
Williston Basin Province—Interpretation of 2-D Seismic Data, Mountrail County, North Dakota



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By Lawrence O. Anna, John J. Miller, and Ofori N. Pearson

Chapter 6 of 7
Assessment of Undiscovered Oil and Gas Resources of the Williston Basin Province of North Dakota, Montana, and South Dakota, 2010

By U.S. Geological Survey Williston Basin Province Assessment Team

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Introduction

Six seismic reflection lines from Mountrail County, N. Dak., were acquired to document the relation between mapped surface lineaments and to interpret structure related to oil and gas production. The longest line, 100-14W/100-14E, extends east–west over the Parshall producing area (fig. 1), which produces from the Bakken Formation. Line 100-14E is an eastern extension of line 100-14W and extends over Plaza and Wabek fields that produce from the Mississippian Mission Canyon Formation. Both lines were merged during reprocessing (fig. 1). Line 100-9 is a north–south line that ties with lines 100-14E and 100-14W. Lines NEW-228, GR-414, and 100-13 (fig. 1) were used to supplement structural and stratigraphic interpretations of the study area.

Interpretation

The history of the Precambrian basement of the Williston Basin is critical to understanding the basin's evolution, structural configuration, and sedimentation and thermal patterns. Geophysical methods used to map Precambrian structures include gravity and magnetic surveys, which define large-scale Precambrian fault blocks (Brown and Brown, 1987; Anna, 1986) including their orientation and block length that are important attributes to help interpret structural and sedimentation trends. Seismic data were used to refine the gravity and magnetic interpretations. Interpretation of the six, two-dimensional (2-D) seismic lines included the delineation of the Red River Formation, Bakken Formation, Madison Group, and Spearfish Formation (figs. 2–7), and the mapping of numerous faults, most of which are thought to be rooted in Precambrian basement. These faults were interpreted as approximate or inferred because net offsets are small and are difficult to map at the seismic scale. There is also uncertainty as to how far the faults propagate upward through the stratigraphic section. A minor number of structural anomalies may be attributed to salt dissolution.

The positions of the Stanley and Lonetree-Glenburn lineaments (fig. 1) (Anna, 1986) are interpreted from seismic lines, as well as the location of two major producing areas in Mountrail County, N. Dak. (North Dakota Oil and Gas Commission, 2009). Although the Parshall and Sanish producing areas straddle the two lineaments, it is unclear if the lineaments create an area of enhanced reservoir quality. Laterals from horizontal wells trend northwest–southeast, which indicates that operators are attempting to intercept northeast–southwest structural features.

Seismic Reflection Data Acquisition and Processing

Data Acquisition

The seismic data consist of six multichannel seismic reflection lines that the U.S. Geological Survey (USGS) purchased by contractual agreement from Seitel Data, Ltd., in 2007. Two of the lines (100-14W and 100-14E) were combined during reprocessing and interpreted as a single line (line 100-14W/100-14E; fig. 3). The data were originally acquired between 1974 and 1984 by Pacific West Exploration Company, Kemp Geophysical Corp., and Sefel Geophysical, Ltd. (table 1). The lines form a loose network covering a large part of Mountrail County, N. Dak. In total, 67 line-miles of data were purchased. The acquisition agreement for these data by the USGS included limited publication rights. Table 1 gives the field acquisition parameters for all of the lines.

Data Processing

The seismic reprocessing by the USGS was conducted to emphasize reflectors in the sedimentary column and to convert the seismic time structure into depth coordinates. This reprocessing consisted of a standard sequence of (1) automatic gain-control scaling, single-design window-spiking

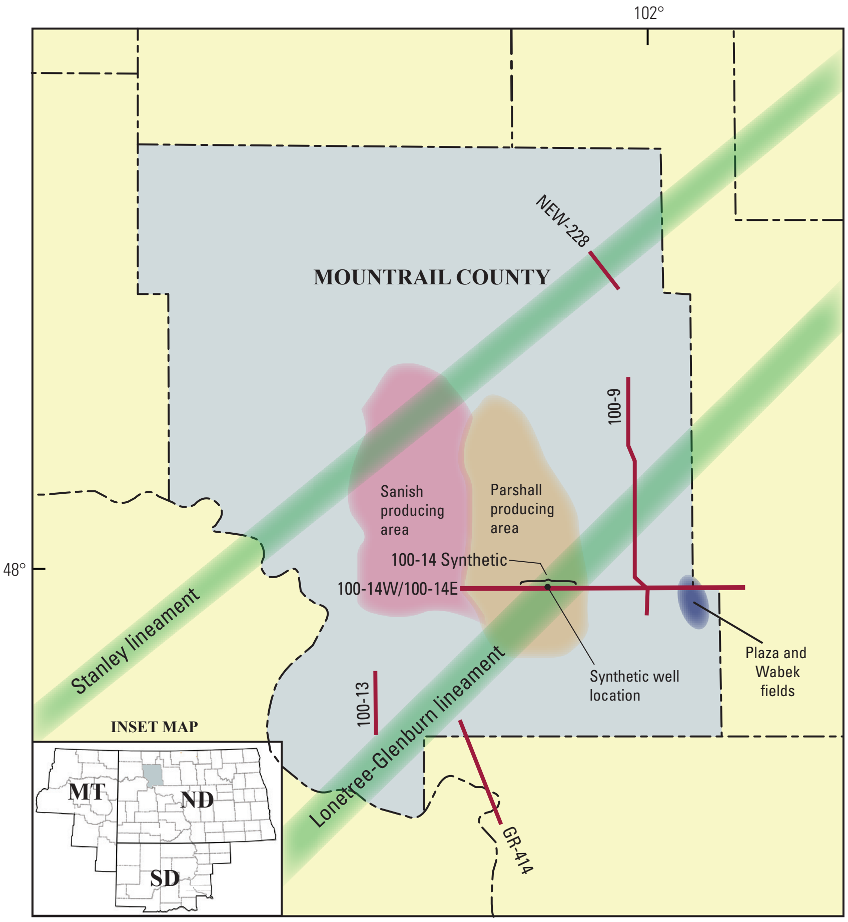

Figure 1. Seismic lines, major producing areas, and major lineaments. Inset map is the Williston Basin Province. Line 100-14 Synthetic is a shortened version of line 100-14W/100-14E as shown by the brace.

deconvolution, datum statics using smoothed surface elevations, velocity analysis, and surface-consistent residual statics; (2) a second velocity analysis; (3) normal move-out and stack; (4) shift to a horizontal datum equal to the average elevation of the line; (5) migration using a smoothed stacking velocity field and automatic gain control scaling; and (6) second-zero-crossing predictive deconvolution, and bandpass filter. Depth conversion was performed using the same smoothed stacking velocity field used for migration. After depth conversion, all seismic lines were shifted to an elevation datum of 2,100 ft above sea level.

Because the seismic lines were recorded by different companies, using different energy sources and recording parameters, the processing parameters used for each line were data dependent and were selected based on extensive testing. For example, the seismic energy sources were Vibroseis, dynamite, and land airgun (table 1), which made it necessary to vary deconvolution and bandpass filter parameters significantly. Another problem we encountered was that, although lines 100-14W and 100-14E overlapped, they were recorded in different years using a different geophone group interval, which resulted in different horizontal trace spacing. Migration requires constant trace spacing, so to solve this problem each line was processed separately up to the point of migration and then combined. Before combining the lines, the trace spacing of line 100-14E was adjusted to match that of 100-14W by means of a Fourier trace interpolation algorithm. This allowed us to migrate the combined lines as a single line.

Identification of Reflectors

To tie the seismic data to well data, we created a synthetic seismogram using a sonic log recorded in Lear Petroleum, #1 School District, located in T. 152 N., R. 90 W., sec. 3. The location of this well is about 52,800 ft east of the west end of line 100-14W and a few feet north of the line at the location shown on figure 1. We were able to identify reflectors with a high degree of confidence between 3,500 and 12,500 ft depths. The synthetic seismogram was embedded in line 100-14 Synthetic (figs. 1 and 2), a shortened version of line 100-14W/100-14E (figs. 1 and 3).

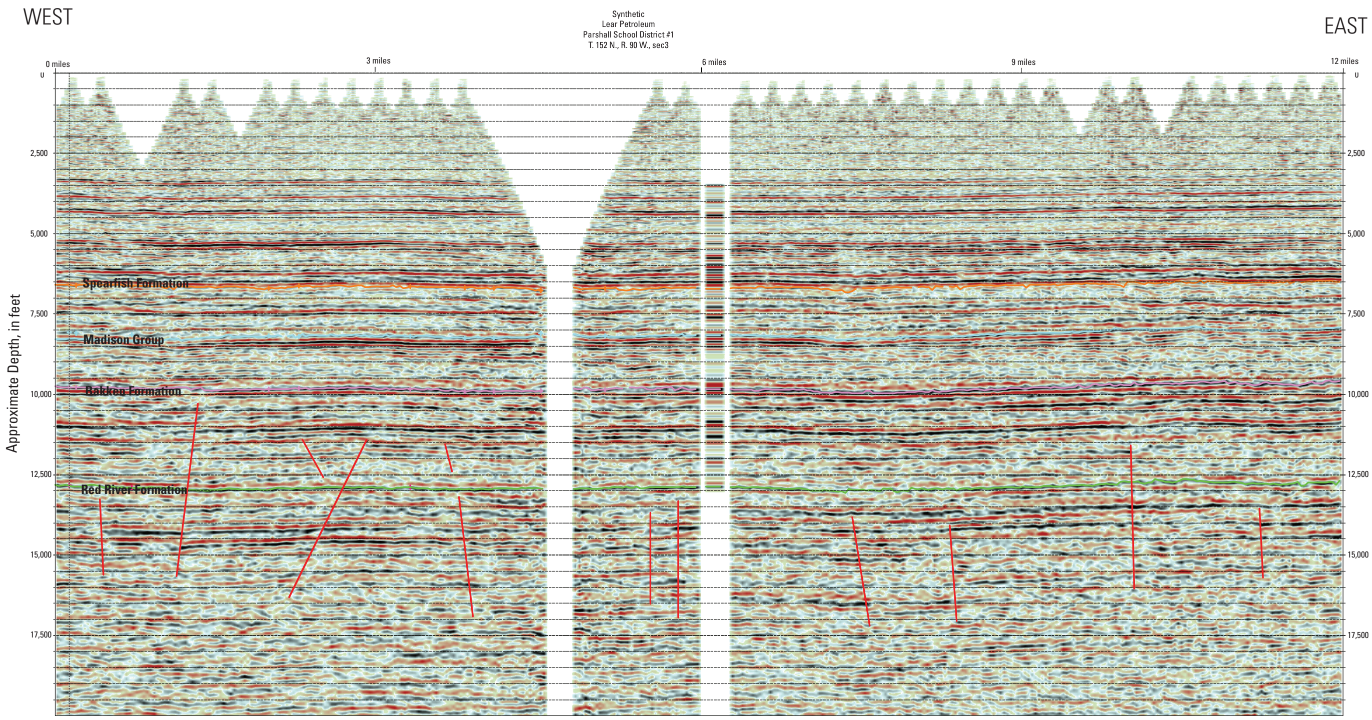

Figure 2. Seismic line 100-14 Synthetic and includes synthetic seismogram. This west–east line includes part of line 100-14W/100-14E. Red lines are interpreted faults.
(***Click here to open full-size, high-resolution image.***)

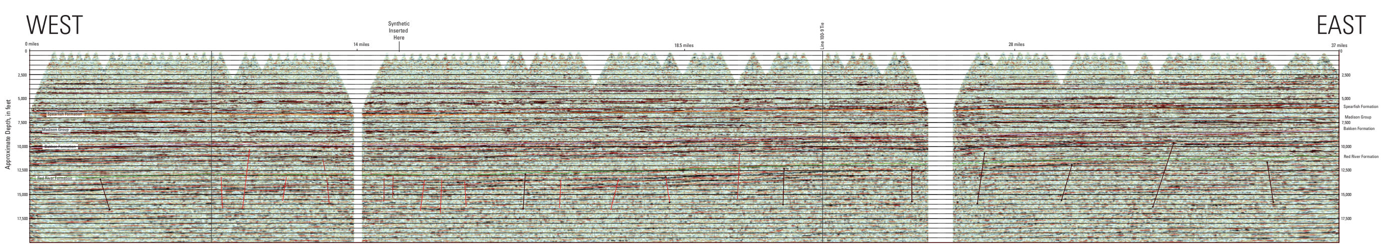

Figure 3. Seismic line 100-14W/100-14E. This west–east line is combined from line 100-14W and line 100-14E and ties with line 100-9. Red lines are interpreted faults.
(***Click here to open full-size, high-resolution image.***)

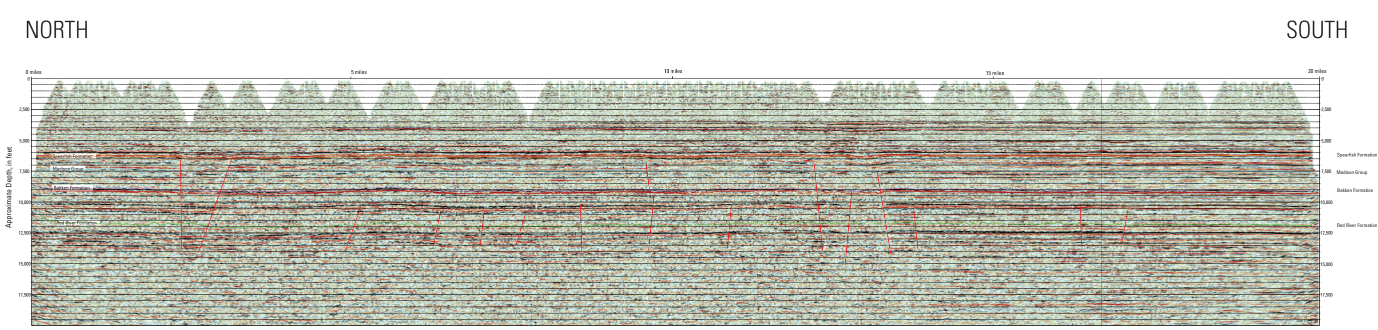

Figure 4. Seismic line 100-9. This north–south line ties with Line 100-14W/100-14E. Red lines are interpreted faults.
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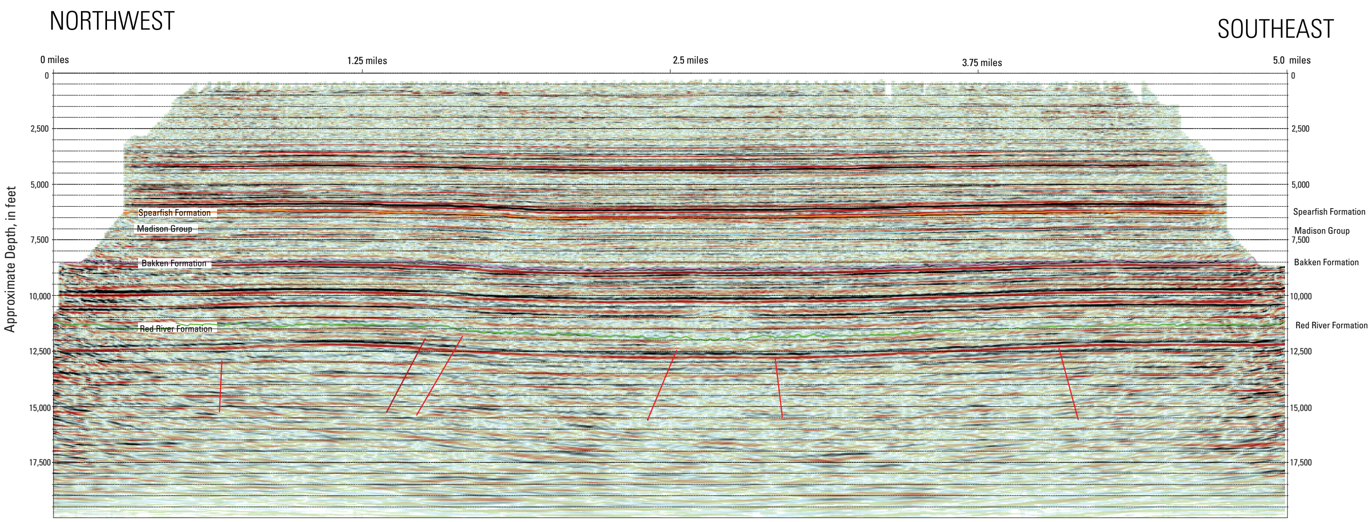

Figure 5. Seismic line NEW-228. Red lines are interpreted faults.
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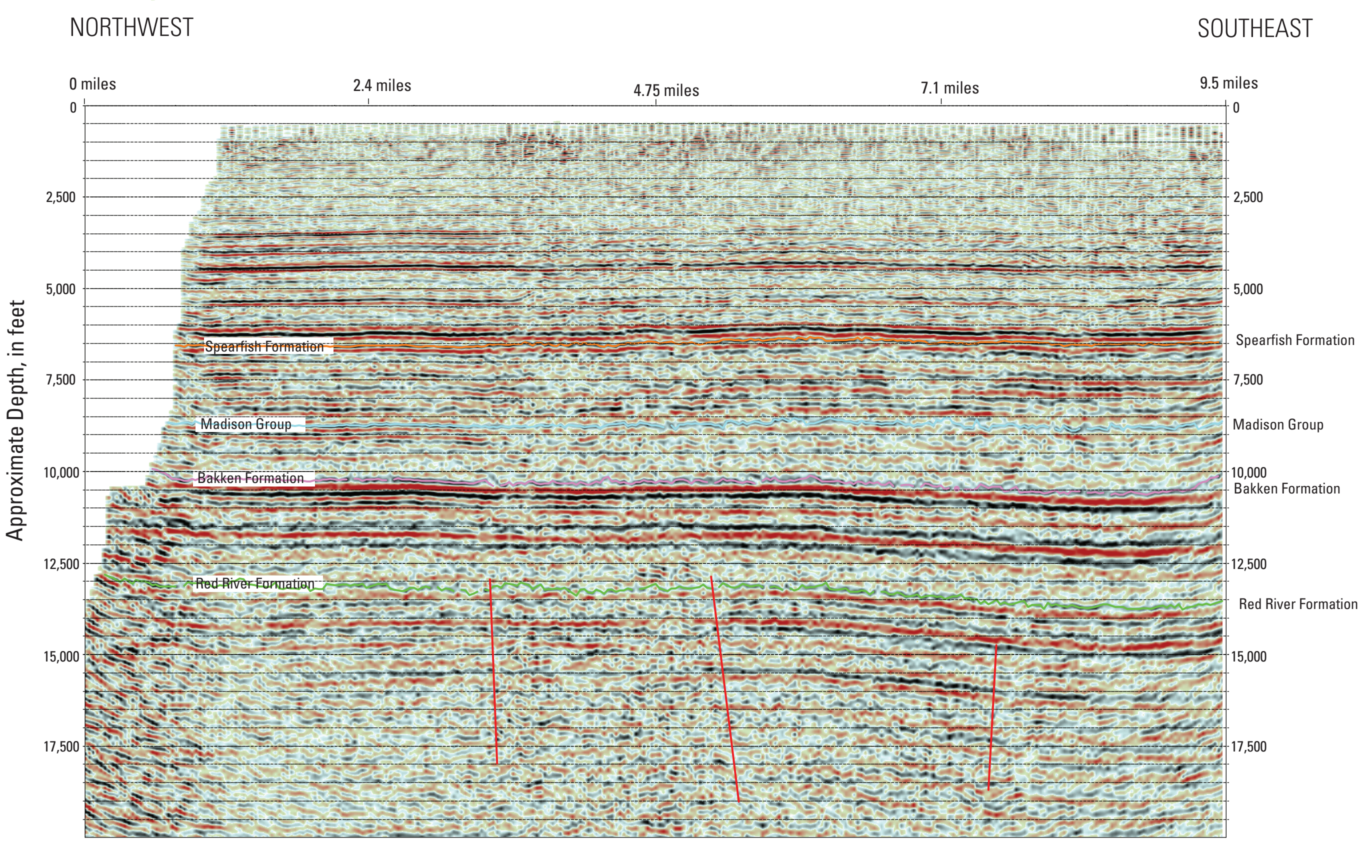

Figure 6. Seismic line GR-414. Red lines are interpreted faults.
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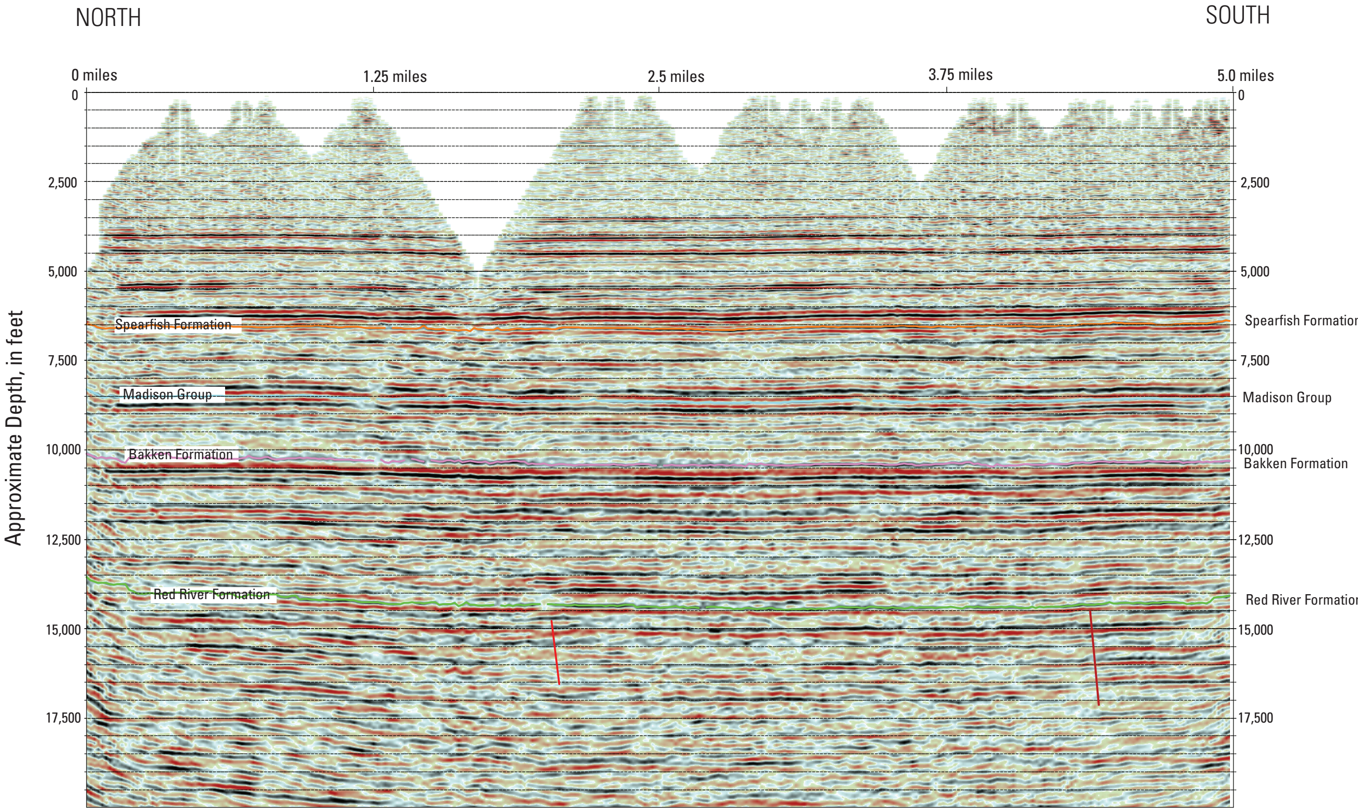

Figure 7. Seismic line 100-13. Red lines are interpreted faults.
(*Click here to open full-size, high-resolution image.)*

Table 1. Seismic acquisition parameters.

Line	Shotpoint number	Geophone interval (ft)	Trace interval (ft)	Line length (mi)	Energy source	Sub-surface fold	No. of channels	Year recorded	Company
GR-414	235–363	330	165	9	land airgun	18	36	1983	Kemp
100-9	656–215	220	110	20.08	dynamite	6	48	1977	Pac West
100-13	877–747	220	110	6.16	dynamite	6	48	1977	Pac West
100-14E	2,274–2,171	165	82.5	3.25	dynamite	6	48	1979	Pac West
100-14W	164–716	220	110	23.0	dynamite	6	48	1974	Pac West
100-14 (E & W combined)			110	26.25	dynamite				
NEW-228	1330–1520	110	55	5.34	Vibroseis 8–100 hz	30	120	1984	Sefel

Acknowledgments

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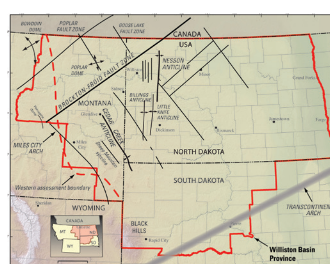

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