An interpretive study of multi-component seismic data over a Cardium oil reservoir in the Carrot Creek field of West Central Alberta

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INTRODUCTION

The use of multi-component seismic data is presently believed, by many, to be the next logical step in the evolution of seismic exploration. The purpose of this study is to undertake the analysis and interpretation of a set of multi-component seismic data obtained over the Carrot Creek oilfield of West Central Alberta. One of the unique features of this data set are the presence of converted shear-wave amplitude anomalies corresponding to the position of producing sandstone and conglomerate bodies of the Cardium Formation. The objective of this study is to obtain an understanding of the origins of these anomalies, and to draw conclusions about the usefulness of multi-component seismic data in identifying Cardium and other, similar clastic plays.

GEOLOGICAL SETTING

The Carrot Creek field of West Central Alberta is located within townships 51-53 ranges 11-14 west of the 5th meridian, just N.W. of the giant Pembina oilfield (Figure 1). Initially discovered in 1963, it produces from several sandstone and conglomerate bodies of the Cardium Formation, which is of Turonian age. Present estimates of reserves for the field are placed at approximately 7 million barrels of initially recoverable oil and a further 2 million barrels of oil recoverable through waterflood (Bergman and Walker, 1987).

In the subsurface the Cardium Formation extends over a large portion of Western Alberta (Figure 1). It shows a west to east thinning from about 100m in the foothills to less than 30m in the plains (Bergman and Walker, 1987).

The Cardium Formation of the Carrot Creek field occurs at a depth of 1560m. It is underlain by the dark shales of the Blackstone Formation and overlain by the shales of the Wapiabi Formation (Williams and Burk, 1964). Krause and Nelson (1984) recognize two lithostratigraphic units within the Cardium Formation itself, namely the Pembina River Member and the Cardium Zone Member (Figure 2). Although this stratigraphy is based on lithologies recorded in the Pembina field, they are consistent with the the lithology found in the Carrot Creek field.

The Pembina River Member corresponds to a coarsening- upward sequence of sediments. This member is variably thick throughout the Carrot Creek field and may reach a maximum thickness of 30m. The sediment grades from silty mudstone at the base of the member through sandstone and into conglomerate (Krause and Nelson, 1984), as shown in Figure 3. These sandstone and conglomerate units act as the reservoir rocks for the field. The conglomerate is found in bodies possessing an asymmetric lensoid shape quite similar to those of modern shelf sand ridges. This conglomerate is found in thicknesses of up to 20m. The orientation of these oil producing conglomerate bodies show a northwest-southeast trend (Figure 4).

The top of the Pembina River Member is marked by an abrupt change from conglomerates to the mudstones of the overlying Cardium Zone Member. The Cardium Zone Member possesses a maximum thickness of 10m throughout the Carrot Creek field and is capped by a chert pebble and nodular siderite layer.

Generally the Cardium Formation is best known as an oil reservoir with production from fine-grained sandstone, interpreted as having been deposited in a shallow marine environment. The transport mechanisms and depositional environments of these conglomerate bodies are however more difficult to explain. Many geologists are still puzzled by the seeming contradiction of having coarse conglomerates contained wholly within what is believed to have been offshore muds. Presently it is believed that the conglomerates in this field were deposited in a series of shelf ridges during a time of low sea-level and transported by a combination of storm induced geostrophic currents, and wave action (Joiner, 1989).

DATA BASE

The CREWES Project has obtained five seismic lines within the Carrot Creek field (Figure 4). Two of these lines (CC-SW-01 and CC-SW-02) consist of three-component seismic data with the remaining three lines (CR851, CR852 and CR853) consisting of conventional vertical-component data only.

Figure 4 also shows that considerable well control is available in the Carrot Creek field. Over 300 wells are present, of which greater than 100 have been cored. Samples from well 6-12-53-13W5 have undergone analysis to obtain the elastic properties of the conglomerate and sandstone units of the Cardium Formation. These results can be seen in Appendix A.

PROPOSED WORK

Presently the processing of the vertical and radial components of lines CC-SW-01 and CC-SW-02 has been undertaken using Western Geophysical's seismic processing software. The results can be seen in Figures 5 and 6. The processing of the transverse component has yet to be undertaken, but visual inspection of the shot records show that little if any coherent signal is present.

The three vertical-component lines (CR851, CR852 and CR853) also have yet to be processed but upon inspection of the shot records (Figure 7) significant signal can be seen and therefore the final processed sections should be of quite high quality.

Figures 5 and 6 show that amplitude anomalies can be seen along the Cardium reflector. These correspond well to the producing pools shown in Figure 4. Although this increase in amplitude is visible in both the vertical and radial components, it is more prominent on the radial section (Figure 8). During this study it is hoped that the origin of this anomaly can be determined and in doing so determine if other Cardium and similar clastic plays can be identified in this way. This will be accomplished through detailed logging of cores, and seismic modelling using Sierra, Landmark and GMA modeling software. Constraints on Vp/Vs over the zone of interest will be provided from petrophysical measurements on core samples. Some initial work has shown that Vp/Vs for the conglomerate is about 1.75 at reservoir conditions (see Appendix A).

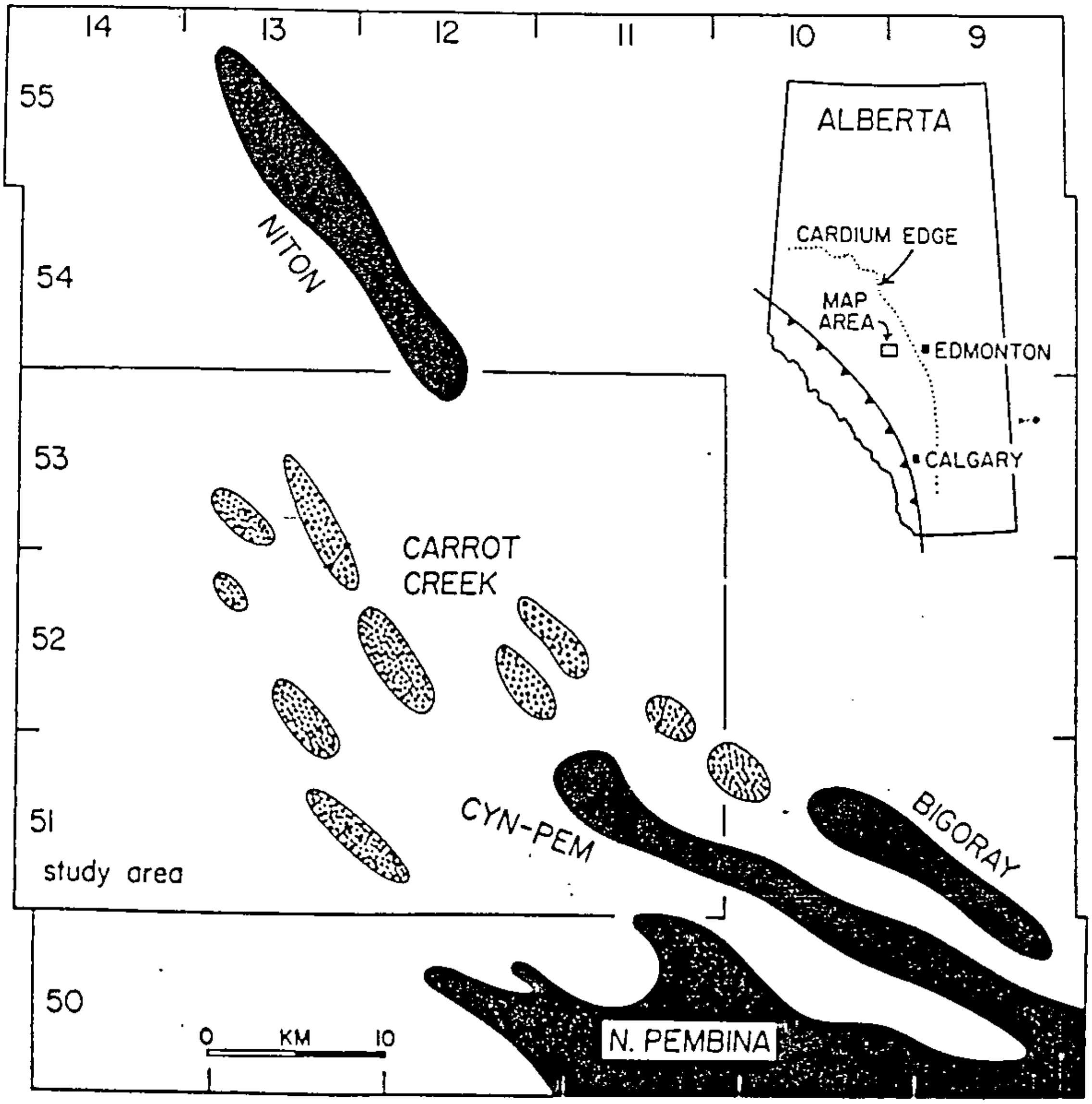


Figure 1: Location map of Carrot Creek field (Bergman and Walker, 1987)

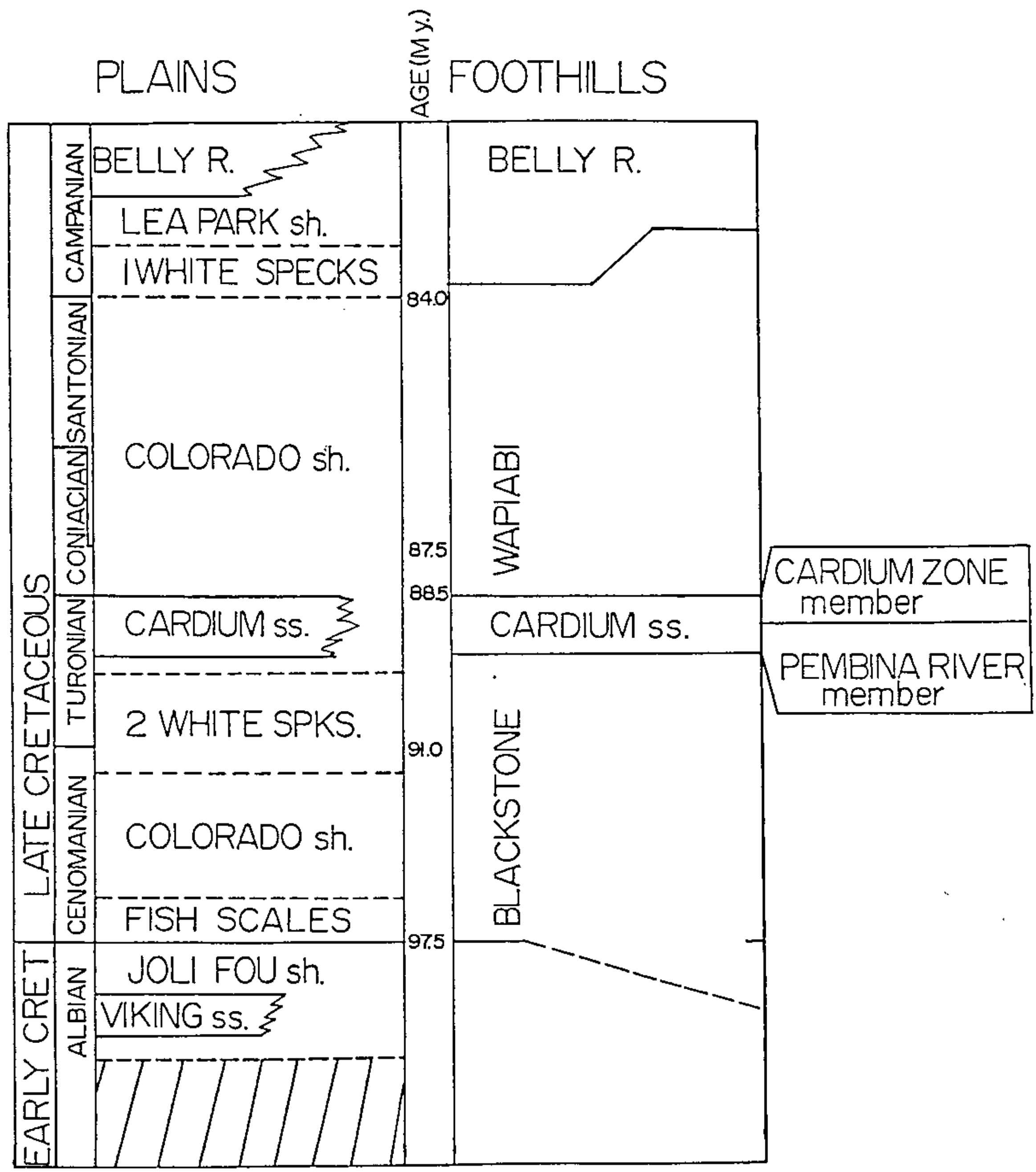


Figure 2: Stratigraphic age and correlation chart for Carrot Creek field (Krause and Nelson, 1984)

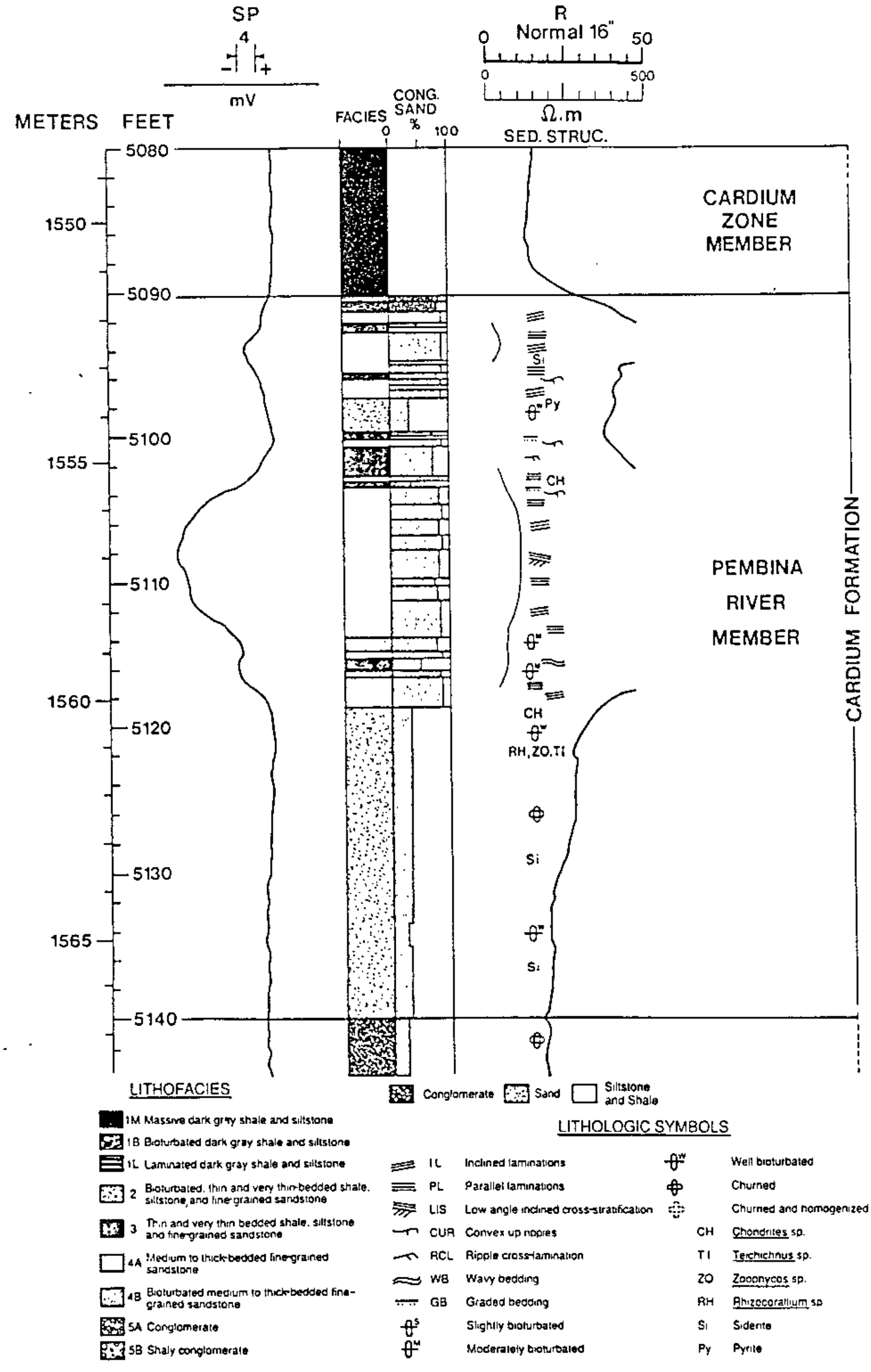


Figure 3: Lithologies of the Cardium Zone and Pembina River Members (Krause et al, 1987)

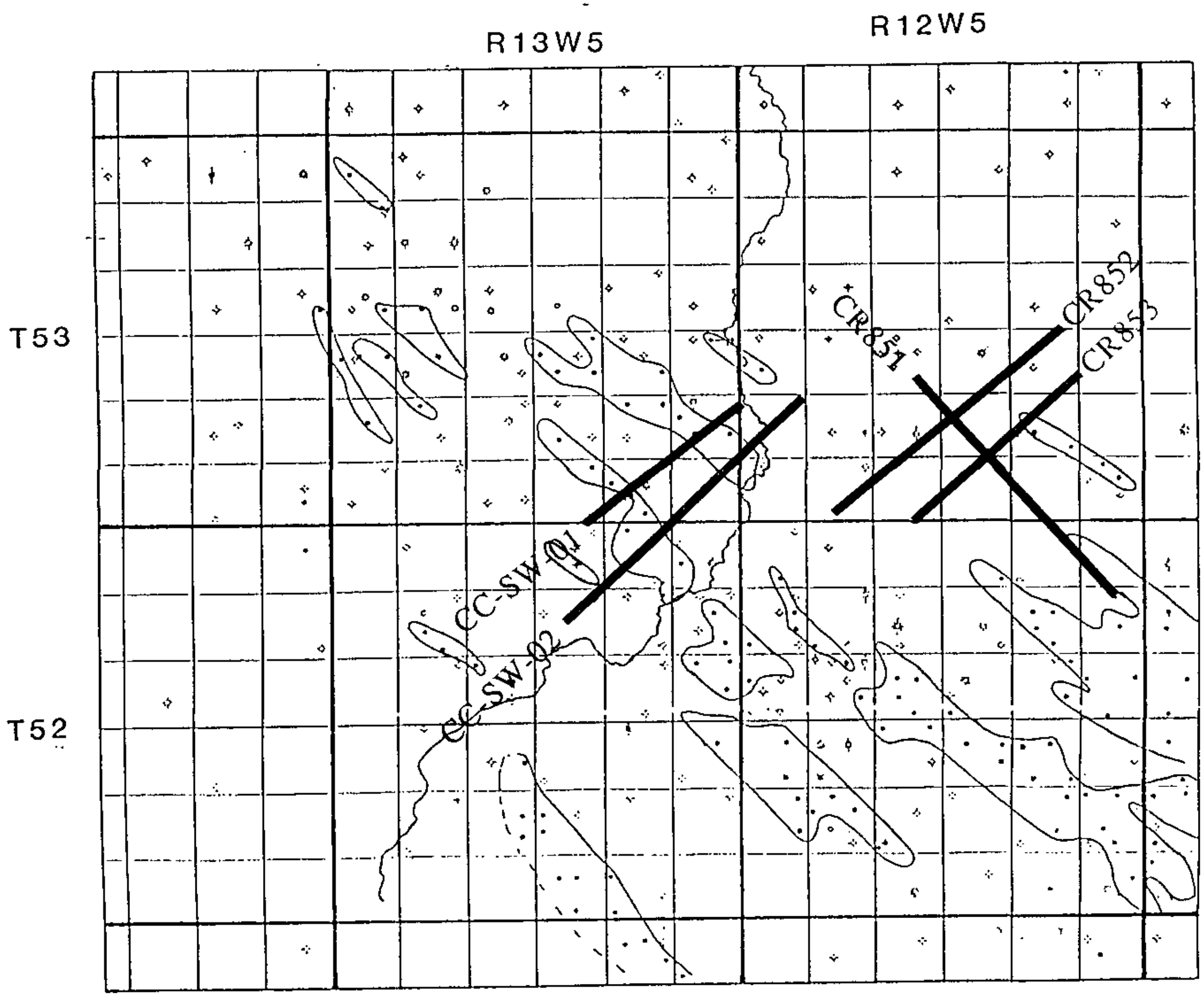
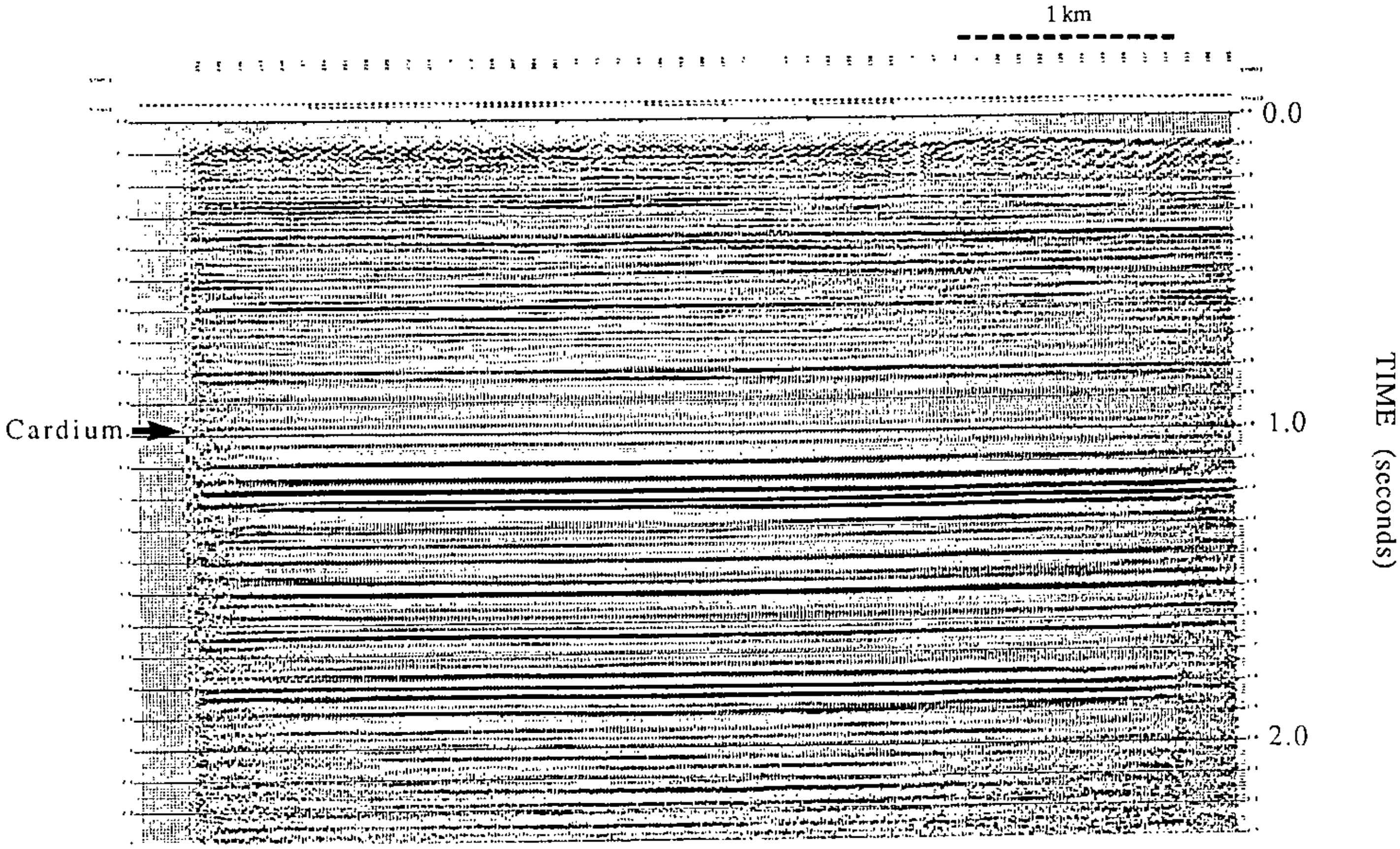


Figure 4: Well and seismic line locations in the Carrot Creek field, producing conglomerate bodies outlined (Joiner, 1989)



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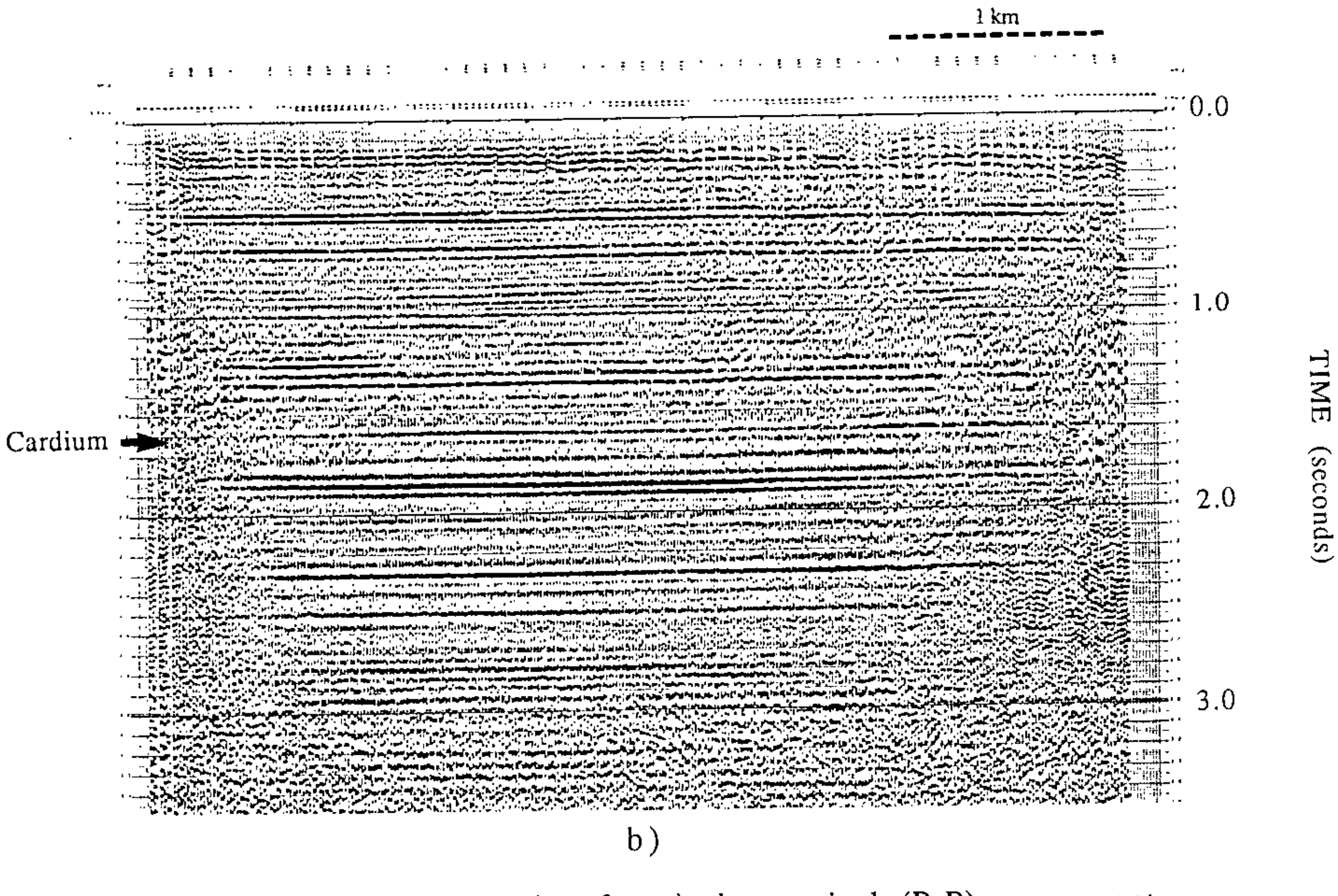
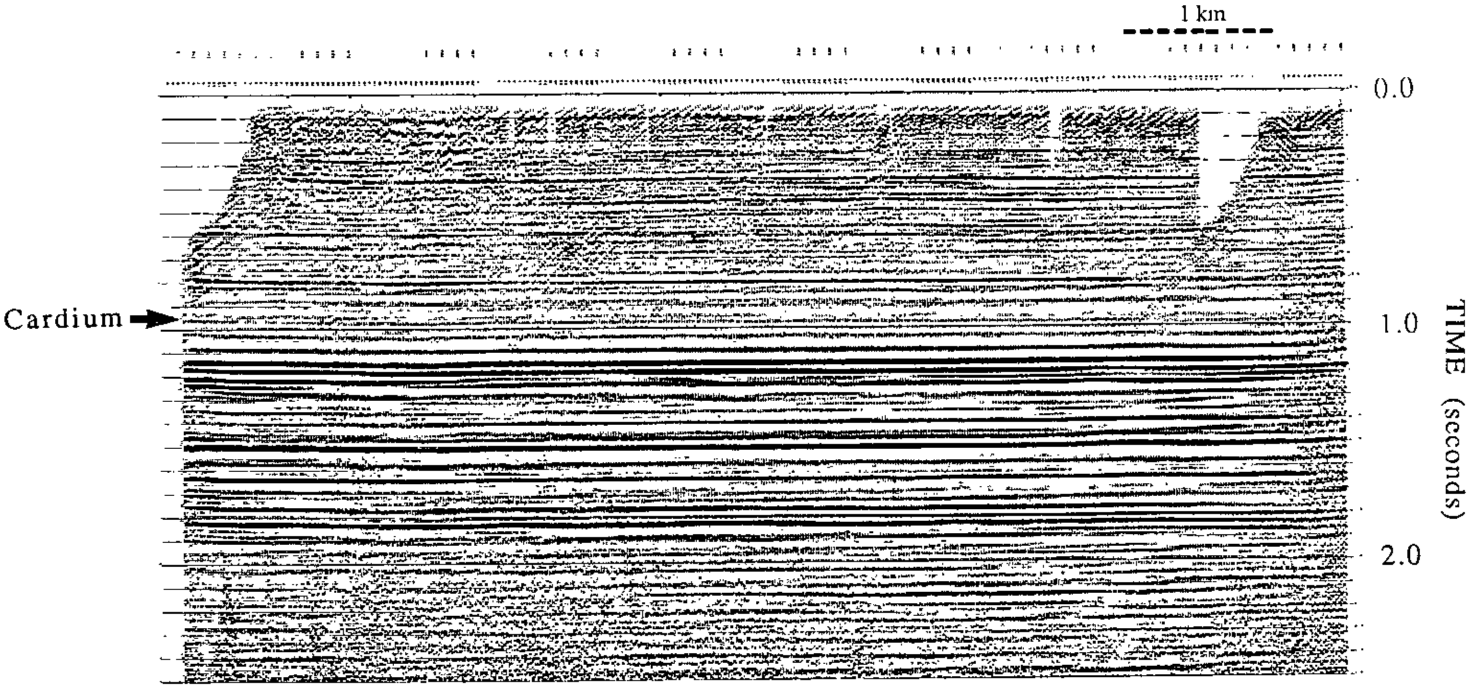
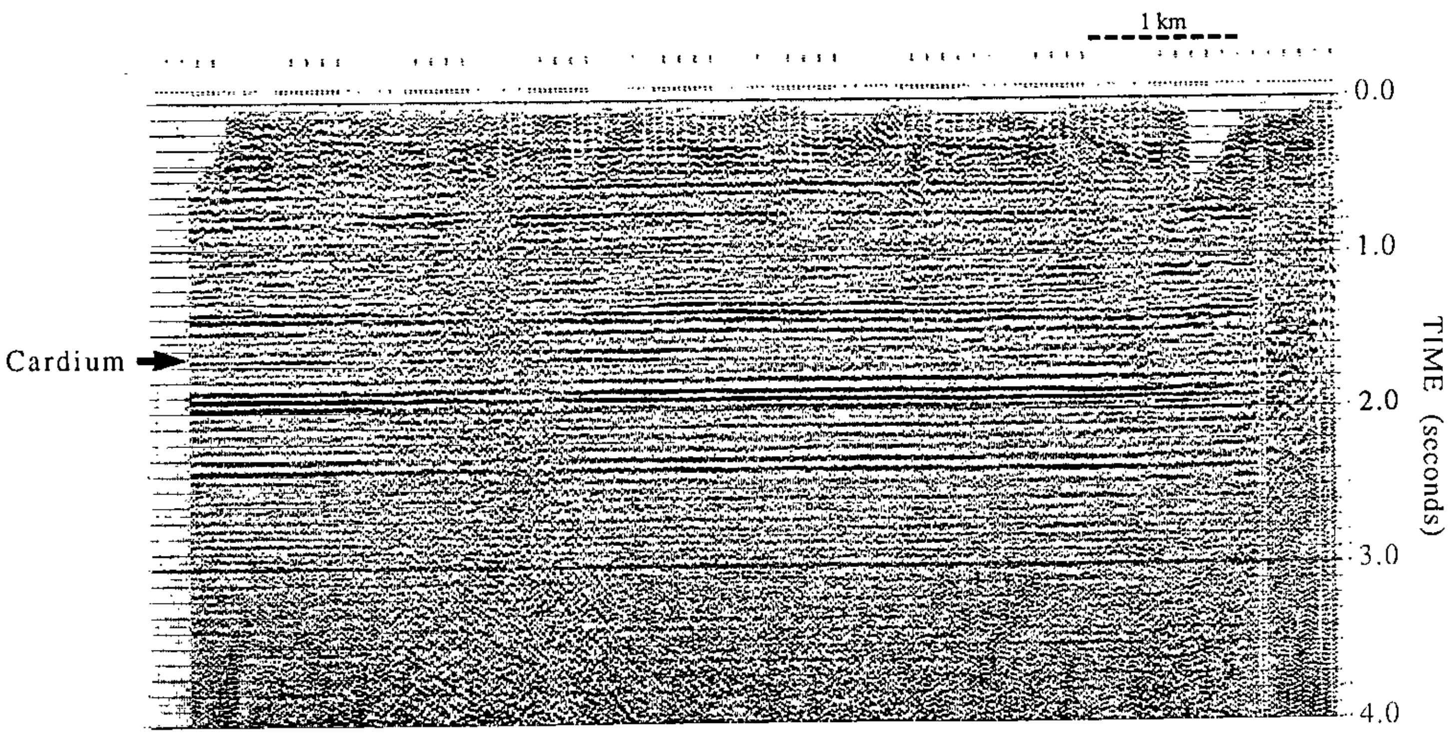


b)

Figure 5: Final stack section for a) the vertical (P-P) component data and b) the radial (P-SV) component data of line CC-SW-01



a)



b)

Figure 6: Final stack section for a) the vertical (P-P) component data and b) the radial (P-SV) component data of line CC-SW-02

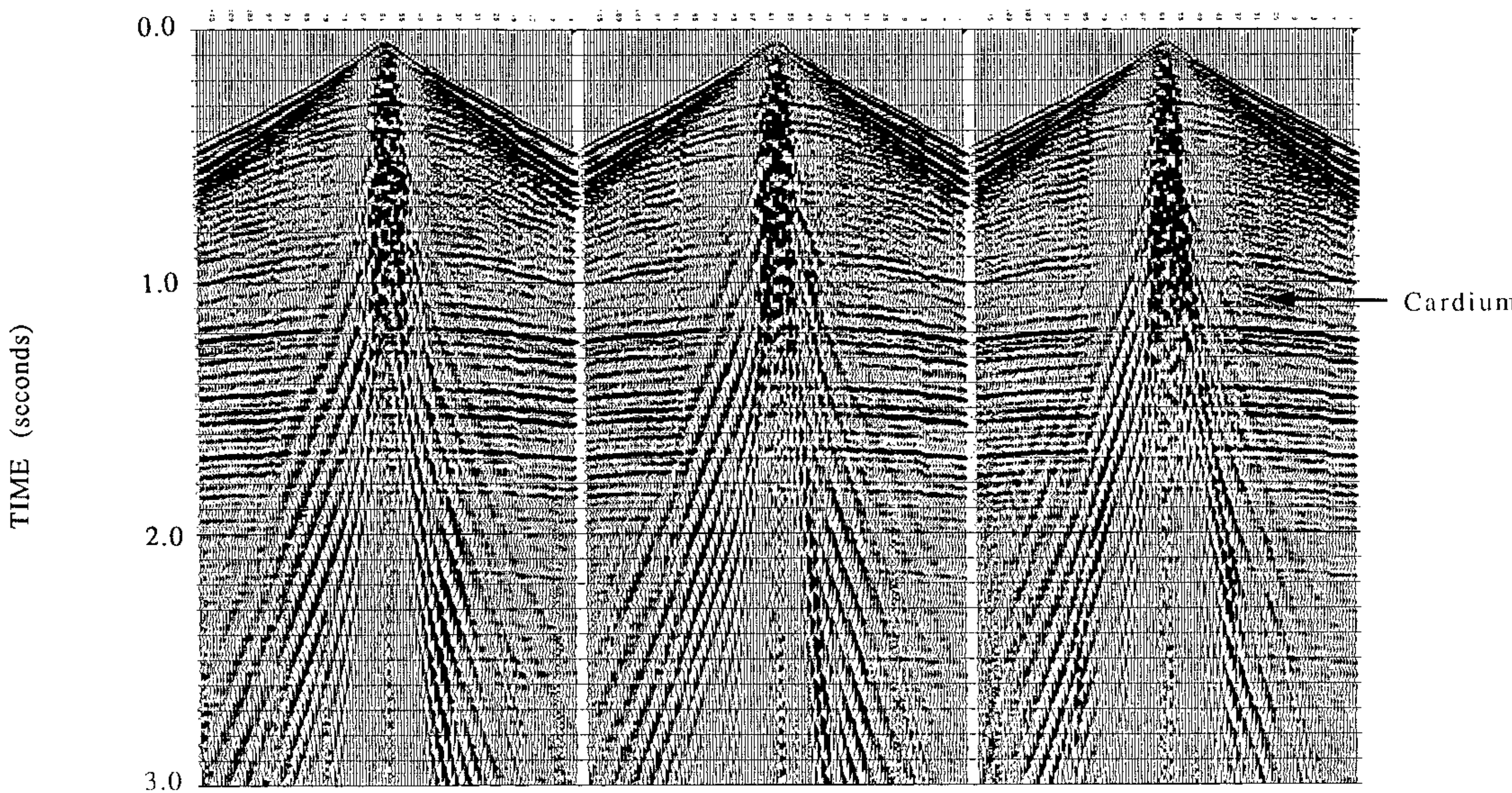
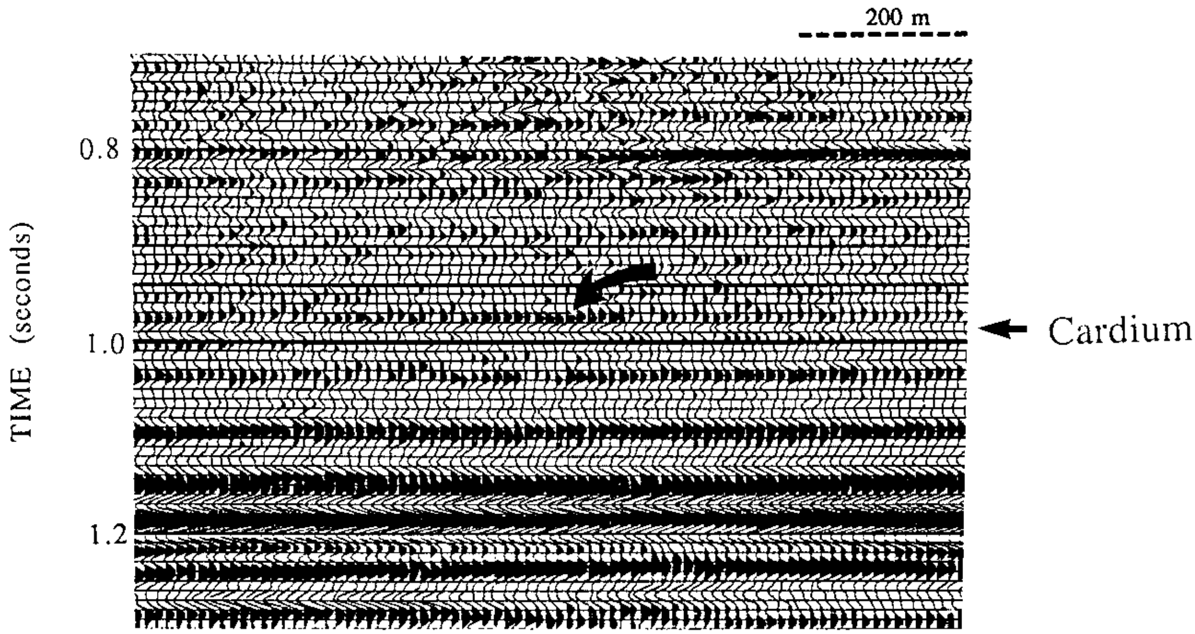


Figure 7: Sample shot records for the conventional vertical (P-P) component data from line CR851



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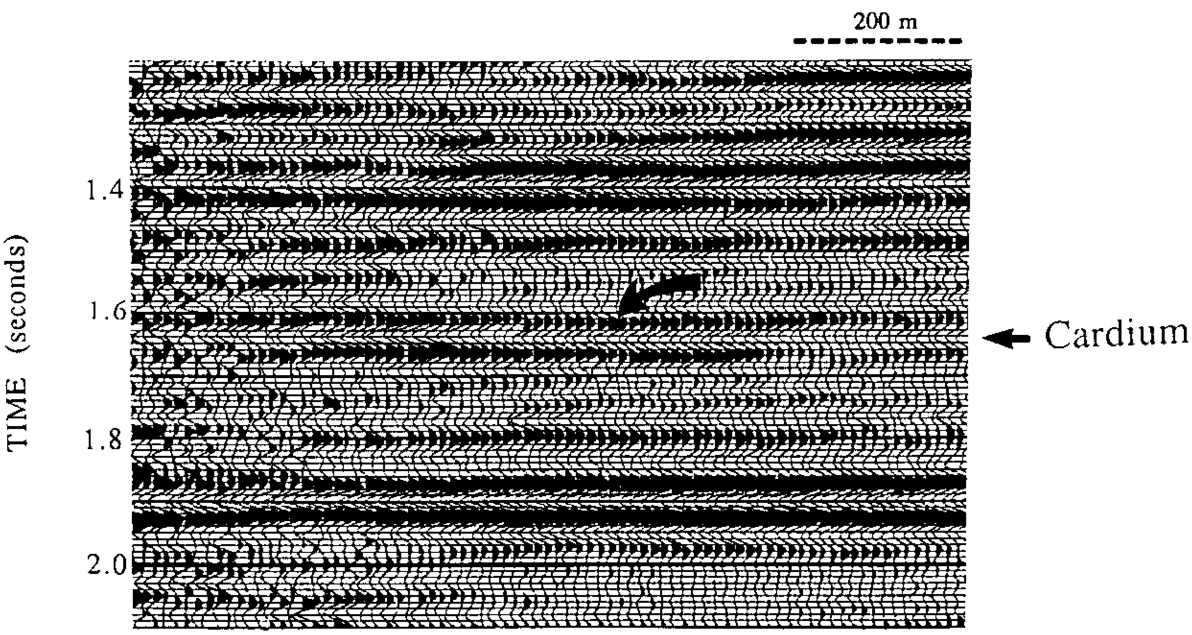

b)

Figure 8: Amplitude anomalies on a) the vertical (P-P) and b) the radial (P-SV) components of line CC-SW-02

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REFERENCES

Bergman, K.M. and Walker, F.G., 1987, The importance of sea-level fluctuations in the formation of linear conglomerate bodies: Carrot Creek Member of the Cardium Formation, Cretaceous Western Interior Seaway, Alberta, Canada: Journal of Sedimentary Petrology, 57, 651-665.

Harrison,M., 1989, Three-component seismic data processing: Carrot Creek Alberta: in this volume.

Joiner, S., 1989, Sedimentology and ichnology of the Cardium Carrot Creek field, West Central Alberta, Course work: Geology 701, University of Calgary.

Krause, F.F., Collins, H.N., Nelson, D.A., Machemer, S.D. and French, P.R., 1987, Multiscale anatomy of a reservoir: geological characterization of the Pembina-Cardium pool, West Central Alberta, Canada: The American Association of Petroleum Geologists Bulletin, 71, 1233-1260.

Krause, F.F. and Nelson, D.A., 1984, Storm event sedimentation: lithofacies formation in the Cardium Formation, Pembina area, West Central Alberta, Canada: in Stoth, D.F. and Glass, D.J. eds., The Mesozoic of Middle North America, C.S.P.G. Memoir 9, 485-511.

Slatt, M.R., Robinson, J.C., Lighty, K.A. and Moore, G.F., 1987, Seismic reflection character analysis of stratigraphic traps in Cretaceous Cardium Formation, Alberta, Canada: The American Association of Petroleum Geologists Bulletin, 71, 298-307.

Swagor, N.S., Oliver, T.A. and Johnson, B.A., 1976, Carrot Creek field, Central Alberta: in Lerand, M.M. ed., Sedimentology of selected clastic oil and gas reservoirs in Alberta: Canadian Society of Petroleum Geologists, 4th Core Conference, pp125.

Wang, Z., 1989, Carrot Creek core analysis: Core Laboratories, Calgary.

Williams, G.D. and Burk, C.F. Jr., 1964, Upper Cretaceous: in McCrosson, R.G. and Gallister, R.P. eds., Geological History of Western Canada, A.S.P.G., Calgary, Alberta, 169-189.

APPENDIX A

Following are the results of the core analysis carried out upon the samples from the well 6-12-53-13W5 as obtained by Wang (1989). These results include; P and S-wave velocities, Vs/Vp ratios, shear moduli, bulk moduli and Young's moduli for various confining pressures under gas and oil-saturated conditions.

University of Calgary Oct. 21, 1989

Carrot Creek Sample 6-12-53-13 w5

Velocity Test

Porosity = 5.8% Perm. = 0.85 md Grain Density = 2.73 g/cm^3

length = 10.695 cm

T = 60° C

gas-saturated pore pres.= 0

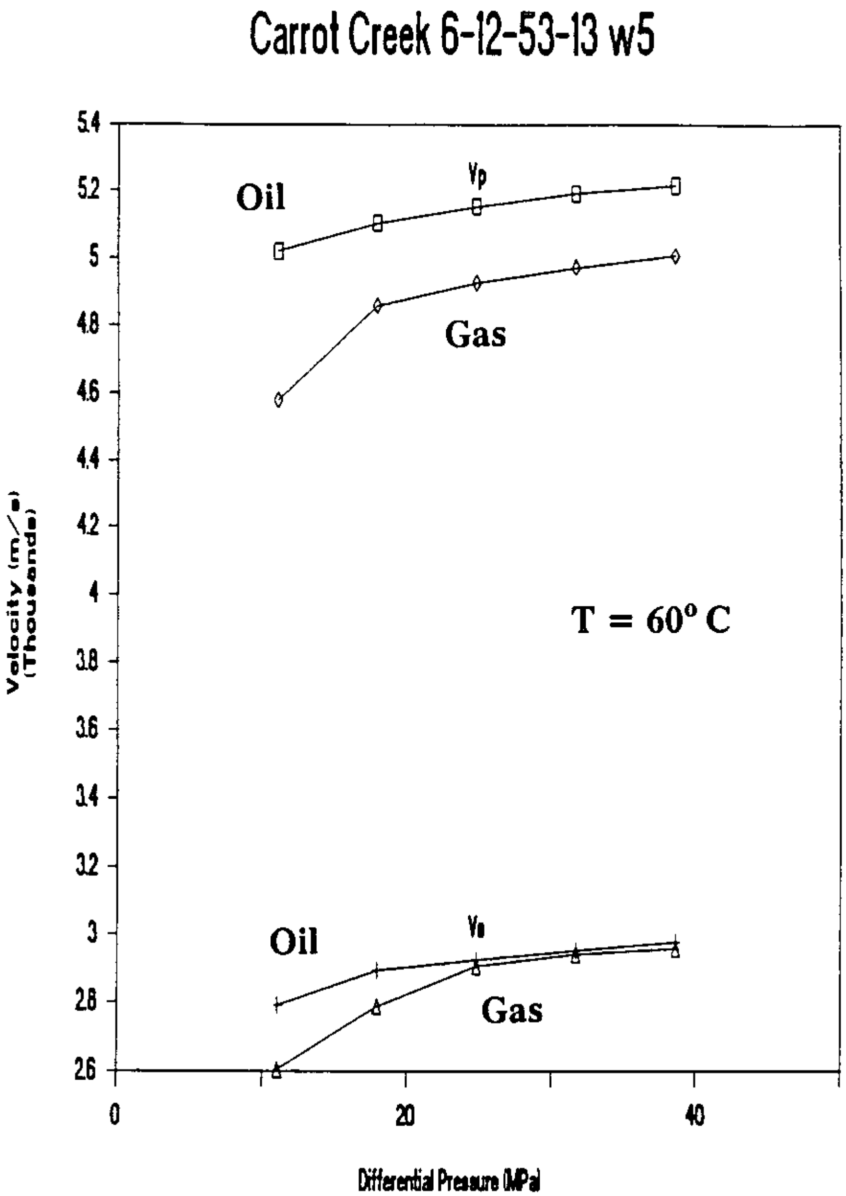
Confining (psi)	Pressure (MPa)	P-Wave Time	S-Wave Time	P-Wave Vel. (m/s)	S-wave Vel. (m/s)	Vp/Vs Ratio	Poisson's Ratio
1600	11.0	33.85	63.15	4580	2605	1.758	0.261
2600	17.9	32.5	60.45	4861	2789	1.743	0.255
3600	24.8	32.2	58.9	4929	2906	1.696	0.233
4600	31.7	32	58.45	4974	2942	1.691	0.231
5600	38.6	31.85	58.25	5009	2959	1.693	0.232

Shear Modulus (GPa)	Bulk Modulus (GPa)	Young's Modulus (GPa)
17.5	30.7	44.0
20.0	34.1	50.2
21.7	33.5	53.6
22.3	34.0	54.8
22.5	34.5	55.5

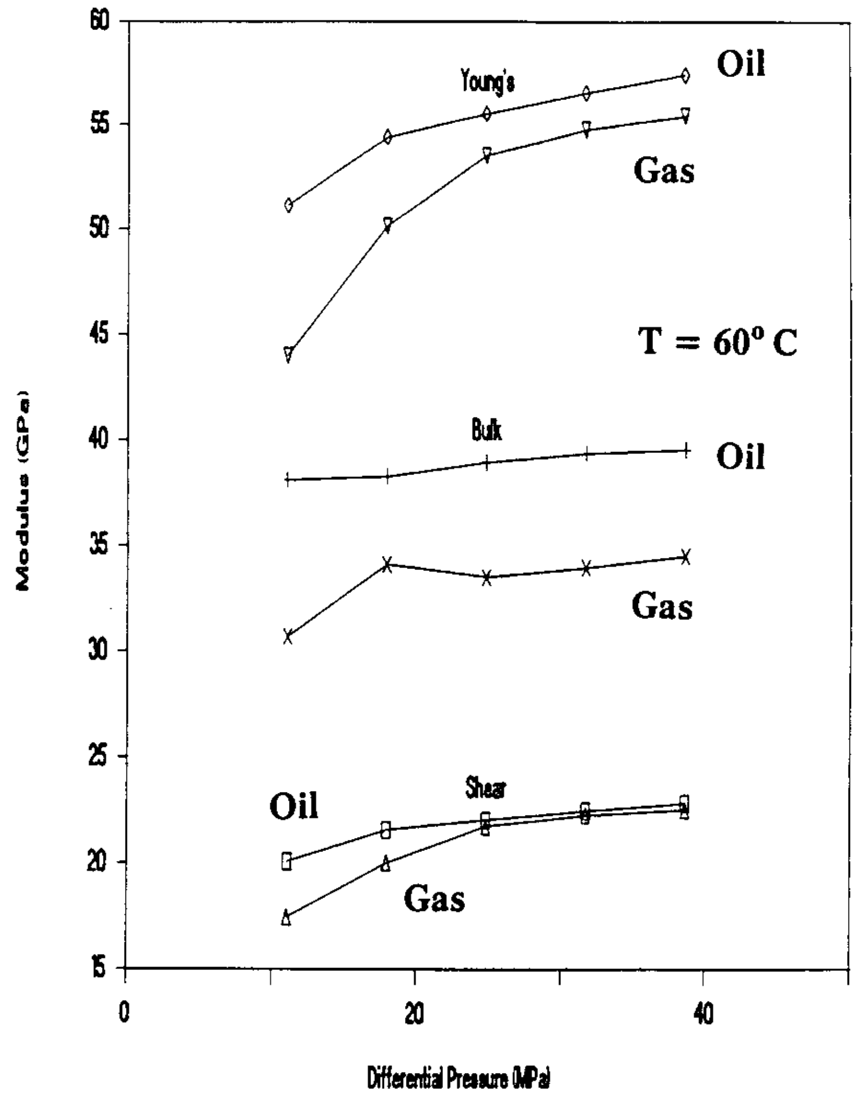
oil-saturated pore pres.= 1425 psi (9.83 MPa)

Confining (psi)	Pressure (MPa)	P-Wave Time	S-Wave Time	P-Wave Vel. (m/s)	S-wave Vel. (m/s)	Vp/Vs Ratio	Poisson's Ratio
3025	20.9	31.8	60.4	5021	2792	1.798	0.276
4025	27.8	31.45	59.05	5105	2894	1.764	0.263
5025	34.7	31.25	58.65	5154	2926	1.761	0.262
6025	41.6	31.1	58.3	5192	2954	1.757	0.261
7025	48.4	31	58	5217	2979	1.751	0.258

Shear Modulus (GPa)	Bulk Modulus (GPa)	Young's Modulus (GPa)
20.1	38.1	51.2
21.5	38.3	54.4
22.0	39.0	55.6
22.4	39.4	56.6
22.8	39.6	57.4


Carrot Creek 6-12-53-13 w5
Velocity (m/s) (Thousands)
Differential Pressure (MPa)
Oil
Vp
Gas
T = 60° C
Oil
Vs
Gas
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
0
20
40

Carrot Creek 6-12-53-13 w5



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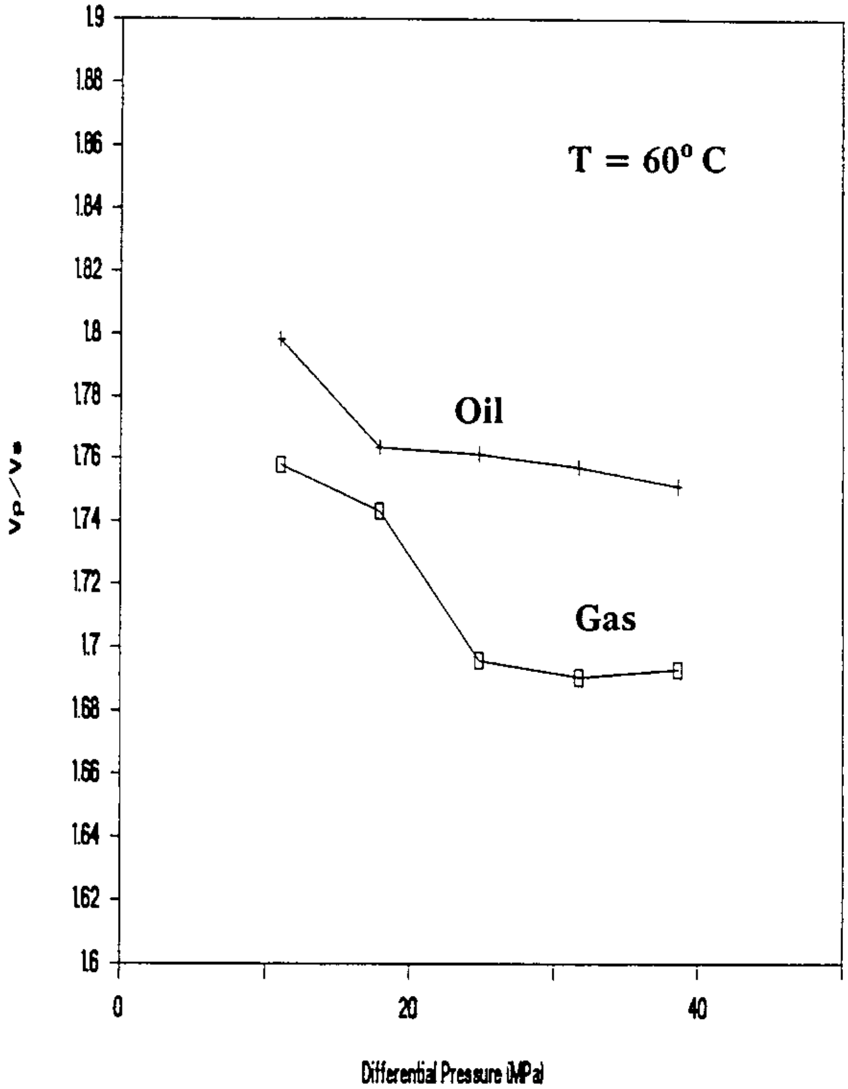
Carrot Creek 6-12-53-13 w5



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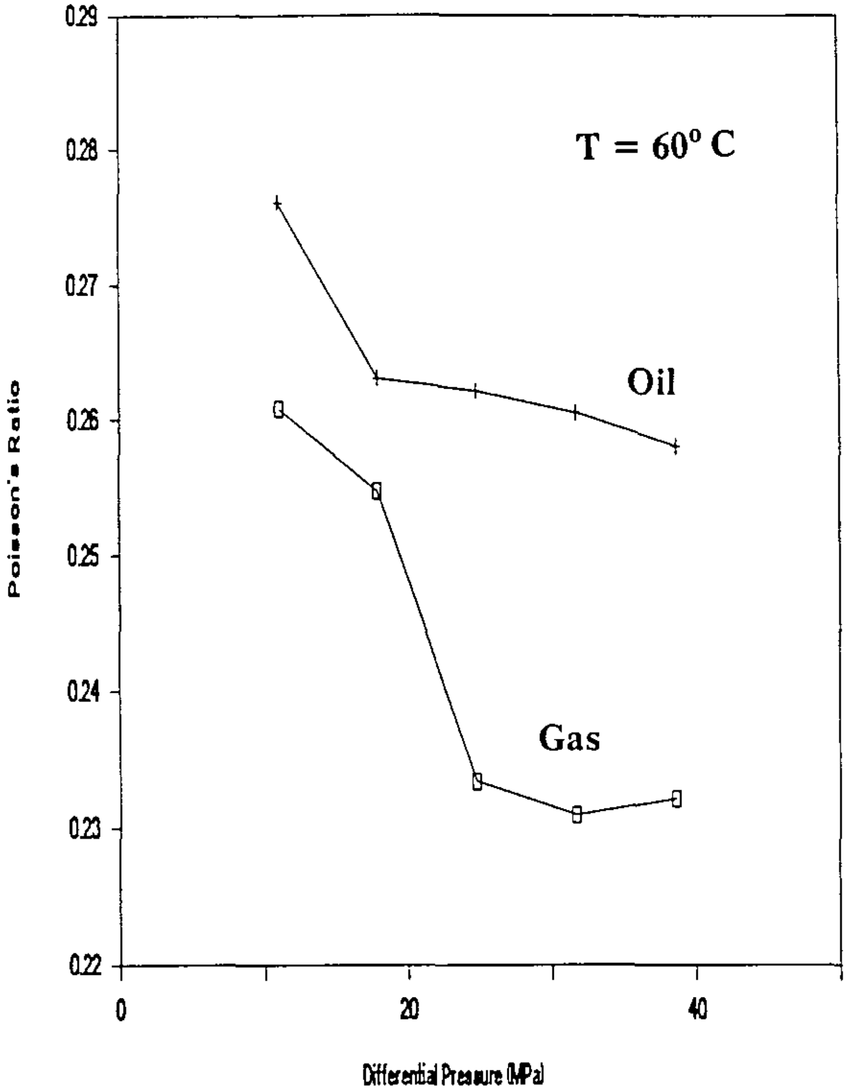

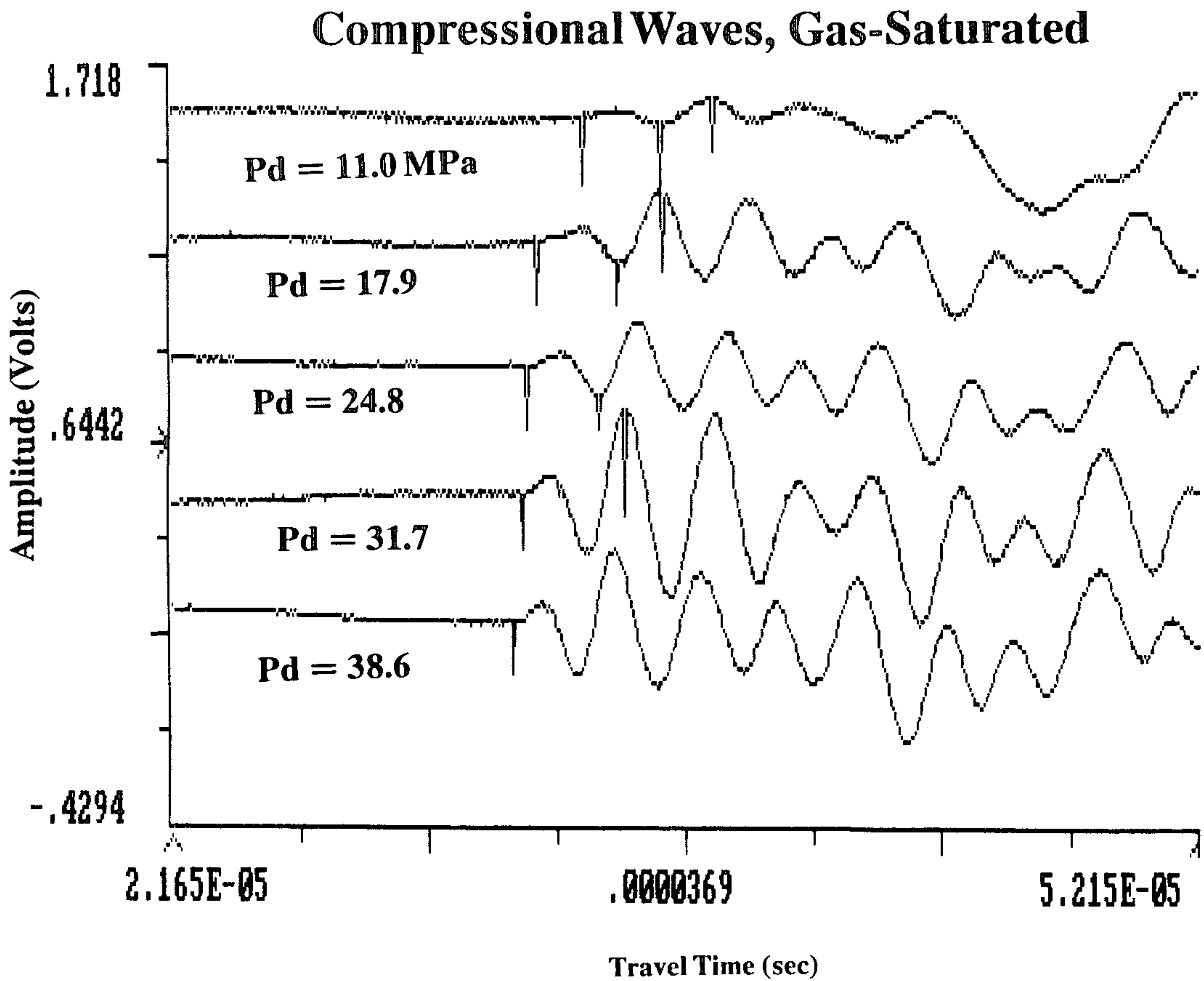

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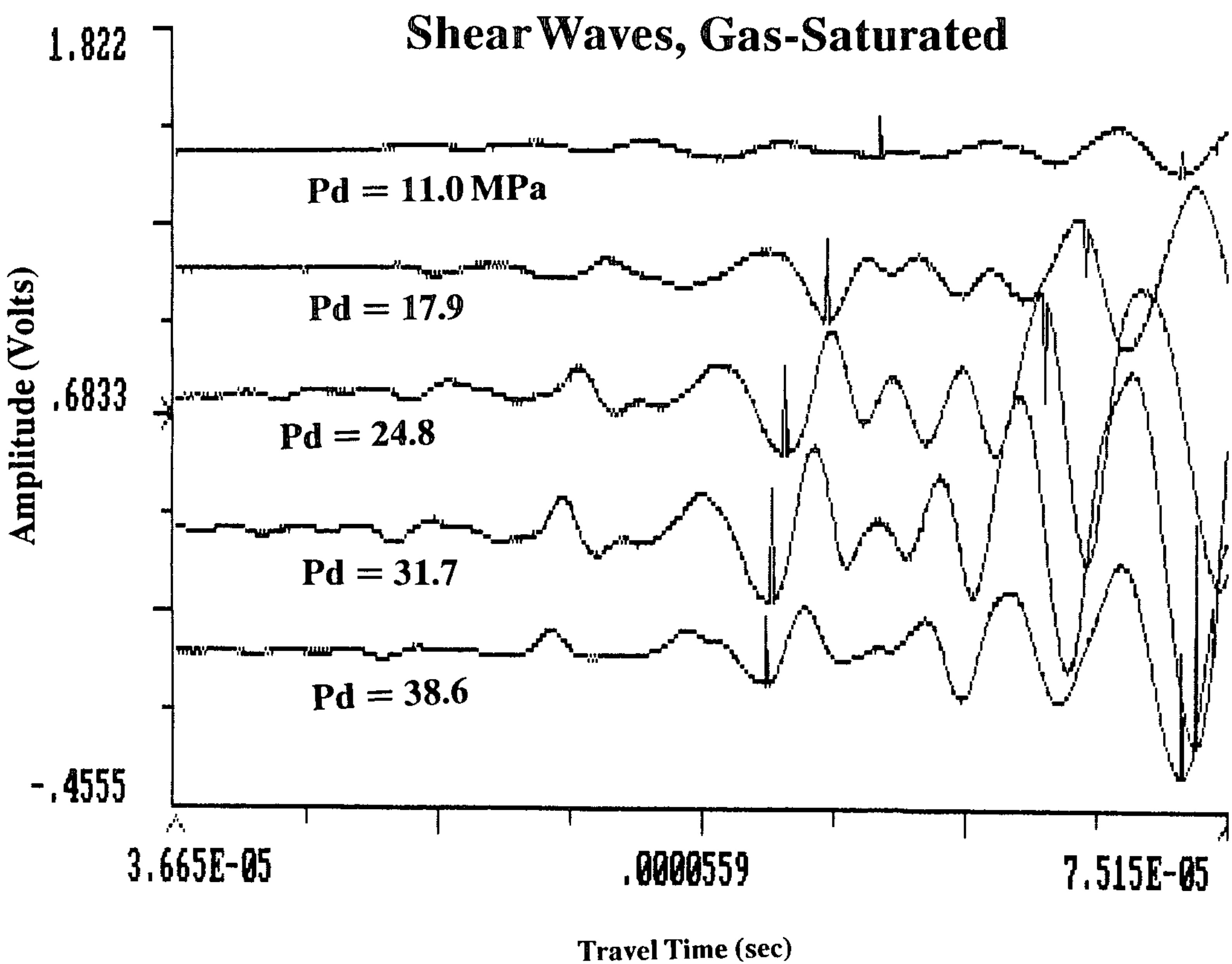

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128

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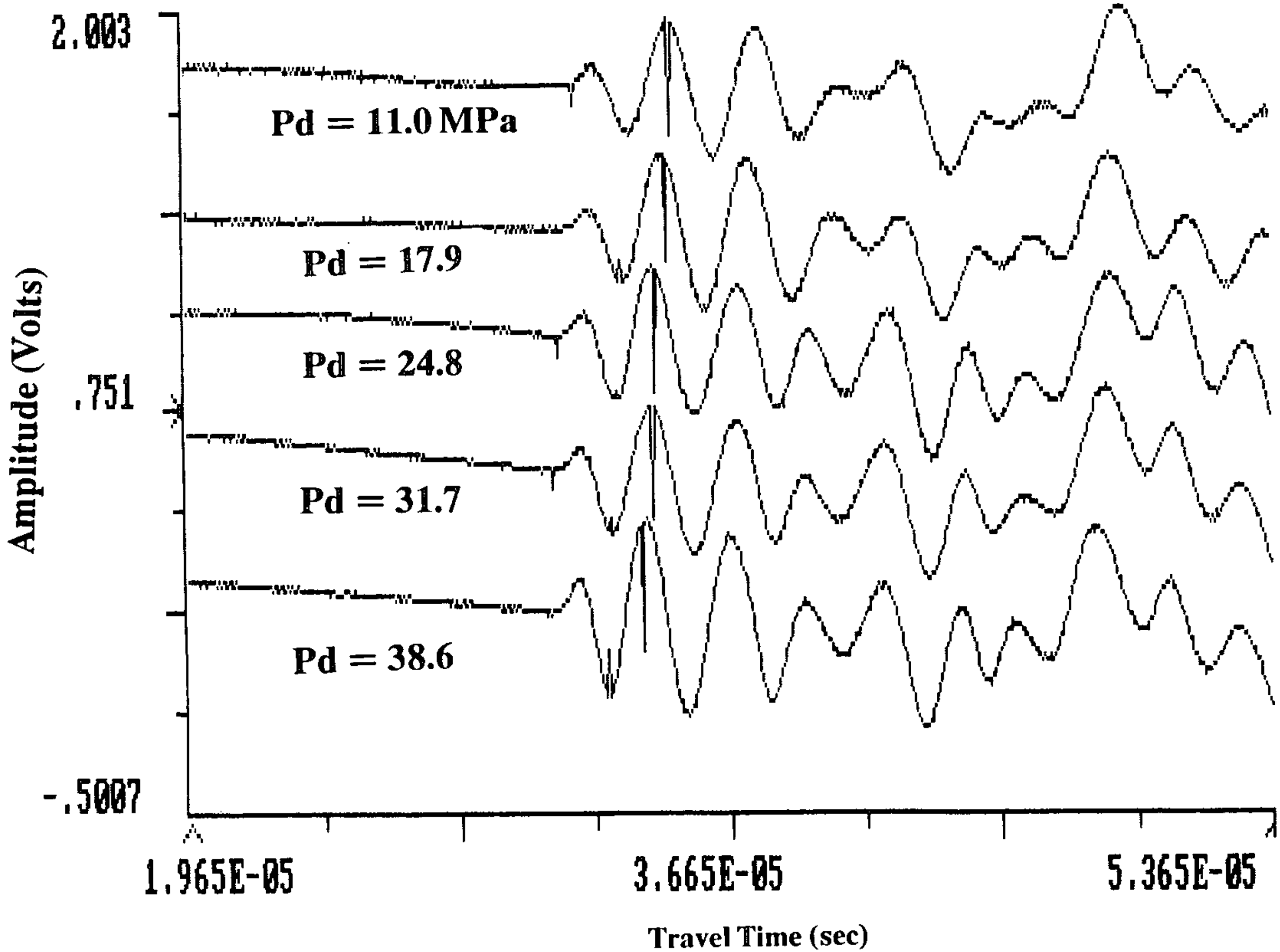
Compressional Waves, Oil-Saturated



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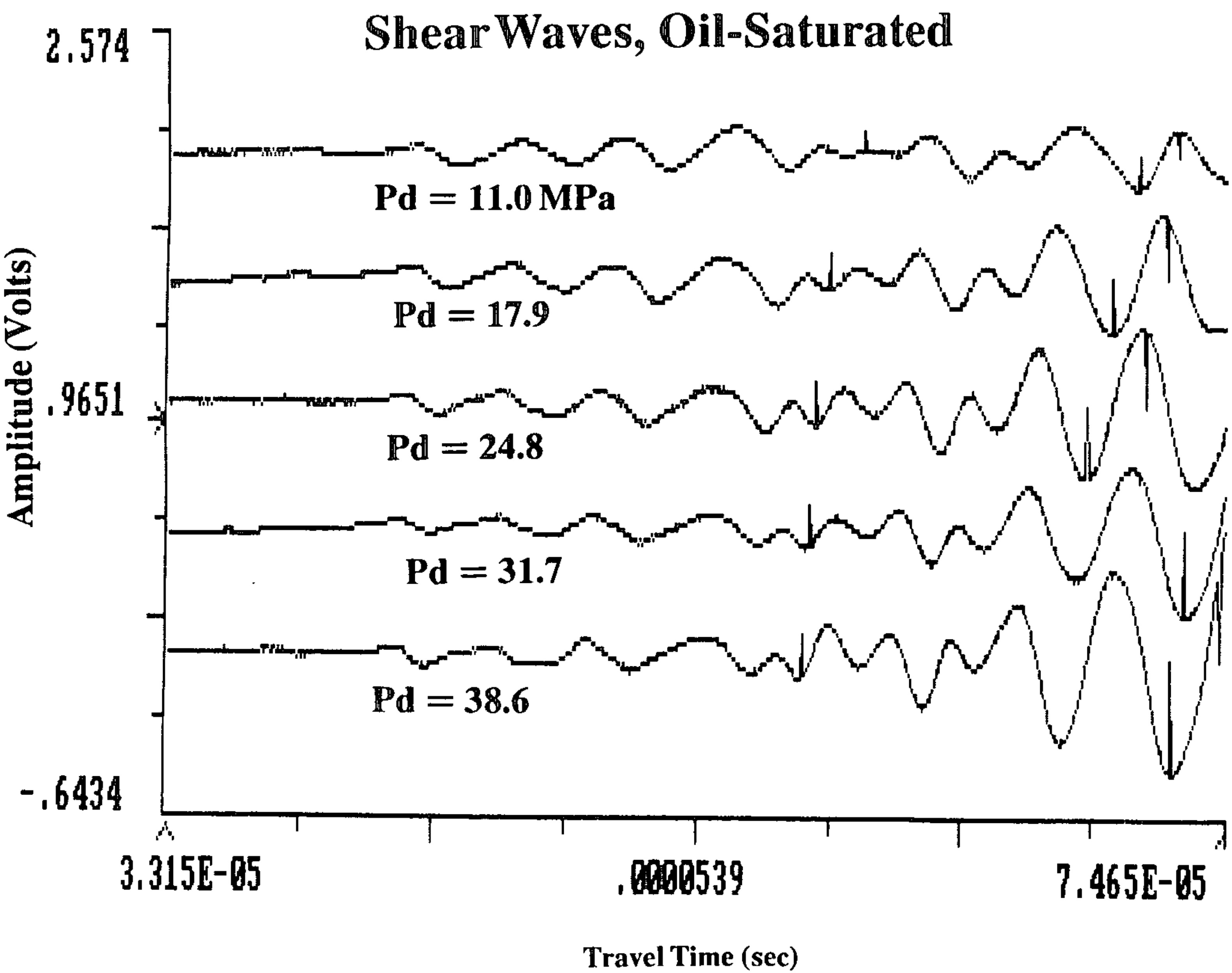

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