CHAPTER 8 – THE LOWER CRETACEOUS

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INTRODUCTION

In this chapter the geological characteristics and the seismic signatures of selected Lower Cretaceous hydrocarbon reservoirs are illustrated. These data were selected objectively, in order to display a variety of Lower Cretaceous reservoir types in the basin.

The introduction to the chapter consists of six parts: 1) introduction; 2) geological setting of the Lower Cretaceous; 3) stratigraphy and nomenclature; 4) depositional mode and lithologies; 5) economic significance; and 6) reservoir types. Following this introduction are 17 individual subsections which are presented in a south to north and east to west order of occurrence. In each of these subsections a selected pool is described under the headings: 1) an introduction; 2) reserves and productivity; 3) geological cross-section; 4) seismic section; and 5) conclusions.

For several reasons, but primarily due to data availability and data response these examples focus largely on Alberta with some very significant reservoirs such as deep basin gas, tar sands and the disturbed belt being omitted.

GEOLOGICAL SETTING OF THE LOWER CRETACEOUS

Lower Cretaceous sedimentary rocks form a nearly complete record of Neocomian, Aptian and Albian stages in the subsurface of Western Canada (Rudkin, 1965). The strata as illustrated in Figure 8.1 are intricately subdivided by area and units. However, these subdivisions, as shown by Jackson (1985), can be interrelated when studied as facies or environmental variations of major depositional cycles (or sea level variations).

The pre-Cretaceous unconformity and the base of the Fish Scales marker which form the stratigraphic boundaries of the Lower Cretaceous, are generally well-defined by lithological changes and/or well log responses in the subsurface. The lower boundary of the Cretaceous is a major low angle unconformity. Pre-Cretaceous rocks, which subcrop at the unconformity, dip to the southwest except where affected by regional structure associated with the Williston Basin, Sweetgrass Arch, Peace River Arch or the disturbed belt of the Rocky Mountain Foothills (Fig. 8.2). Erosion at the unconformity has exposed progressively older rocks from west to east and south to north. Wright et al. (1984) cross-sections C - C' and D - D' (in Introduction to this volume) show rocks from Jurassic to Cambrian exposed at this surface. Pre-Mesozoic strata in Western Canada are largely carbonates in comparison to the dominantly clastic lithologies of the Mesozoic and younger strata. This contrast of lithologies generally makes subsurface identification easy, but problems do invariably occur where pre-Cretaceous clastics are present such as areas of subcropping Devonian shales or Triassic, Jurassic and Mississippian clastics. These problems will be discussed in the specific examples of this chapter.

The pre-Cretaceous unconformity has a characteristic seismic signature in the basin which is normally a strong peak in the log-normal polarity convention utilized herein (where a positive acoustic impedance generates a peak). This seismic event often shows the characteristic undulating relief of the pre-Cretaceous unconformity in the basin. This relief is significant in that it is a principal factor in controlling drape, onlap, compaction, and drainage patterns in the Lower Cretaceous. A compilation of major relief and drainage features of the Lower Cretaceous strata in Western Canada is shown in Figure 8.3 and is based on the work of Christopher (1980), Hayes (1986), Jackson (1985), McLean (1977) and Williams

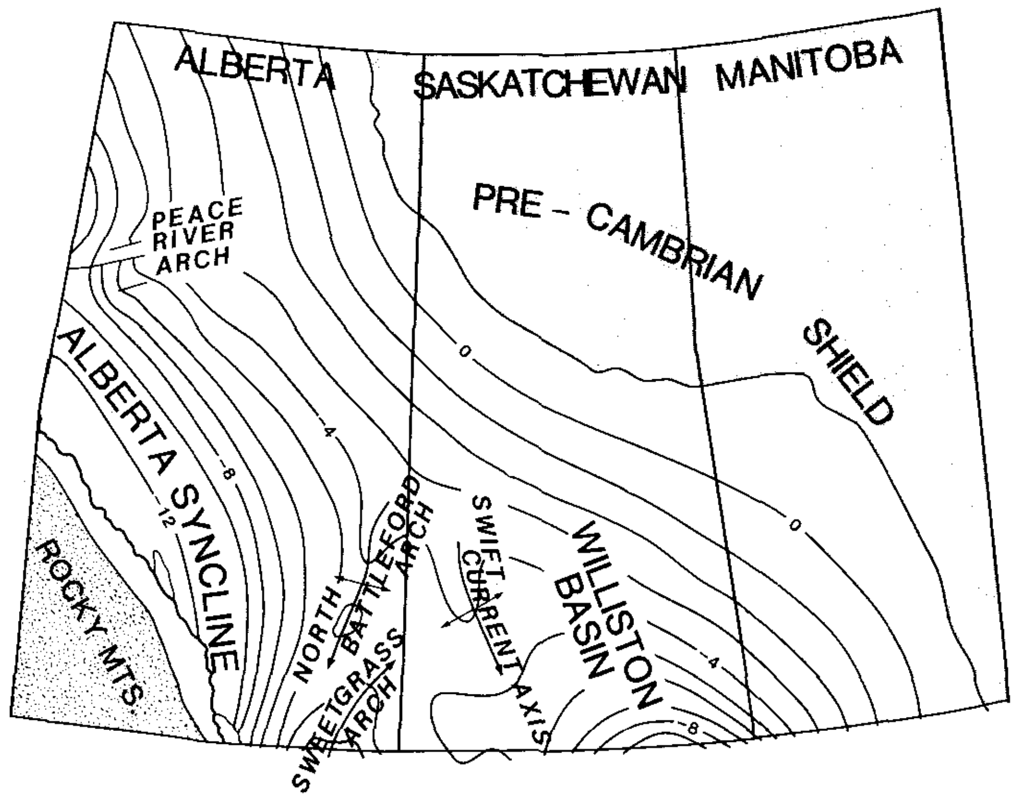

Figure 8.2. Major structural elements of the Western Canada Sedimentary Basin, as defined by structure contours on the pre-Cambrian surface (from Herbally, 1974).

ACKNOWLEDGEMENT

An Acknowledgement of corporate and individual contributors to this project are presented in the Preface to this Atlas. Unfortunately, a total description of these varied contributions would not be practical, and can only be partially attempted. However, the spirit of cooperation, overwhelming enthusiasm, and character displayed by virtually every individual and corporation contacted in regards to this project attests to the strength of the two societies, and these members should be justifiably proud. The contents of this chapter are largely those of the members of the CSPG and CSEG and the author can only be credited with organizing and annotating this material. However, the responsibility for misinterpretations or misrepresentations made herein cannot be relinquished and as such, any errors are those of the author. Thanks are extended to April Dawn Weiss of Poco Petroleums Ltd. who typed the manuscript and to Drs. N.L. Anderson and L.V. Hills who provided constructive editing and reassurance. The author gratefully acknowledges the many helpful suggestions of Mr. William H. Petrie, Dr. Gerry Reinson, Mr. Barry Dick and the assistance of Mr. Chuck S. Briere and Mr. J. Beric Evans who aided with the synthetic models. We also note with gratitude the individuals who reprocessed much of the presented data: Mr. Michael A. Broome, Mr. Paul Chernoff, Mr. Edward W. Vermeulen, Mr. Ken A. Titchkosky, Mr. William E. Hodgan, and their respective firms. A sincere thank you must also be extended to the management of Poco Petroleums, particularly Mr. Ray Robertson, Mr. Tom MacKay, Mr. Rob Shugg, and Mr. Peter Kurceba for their patient understanding and assistance in all possible modes.

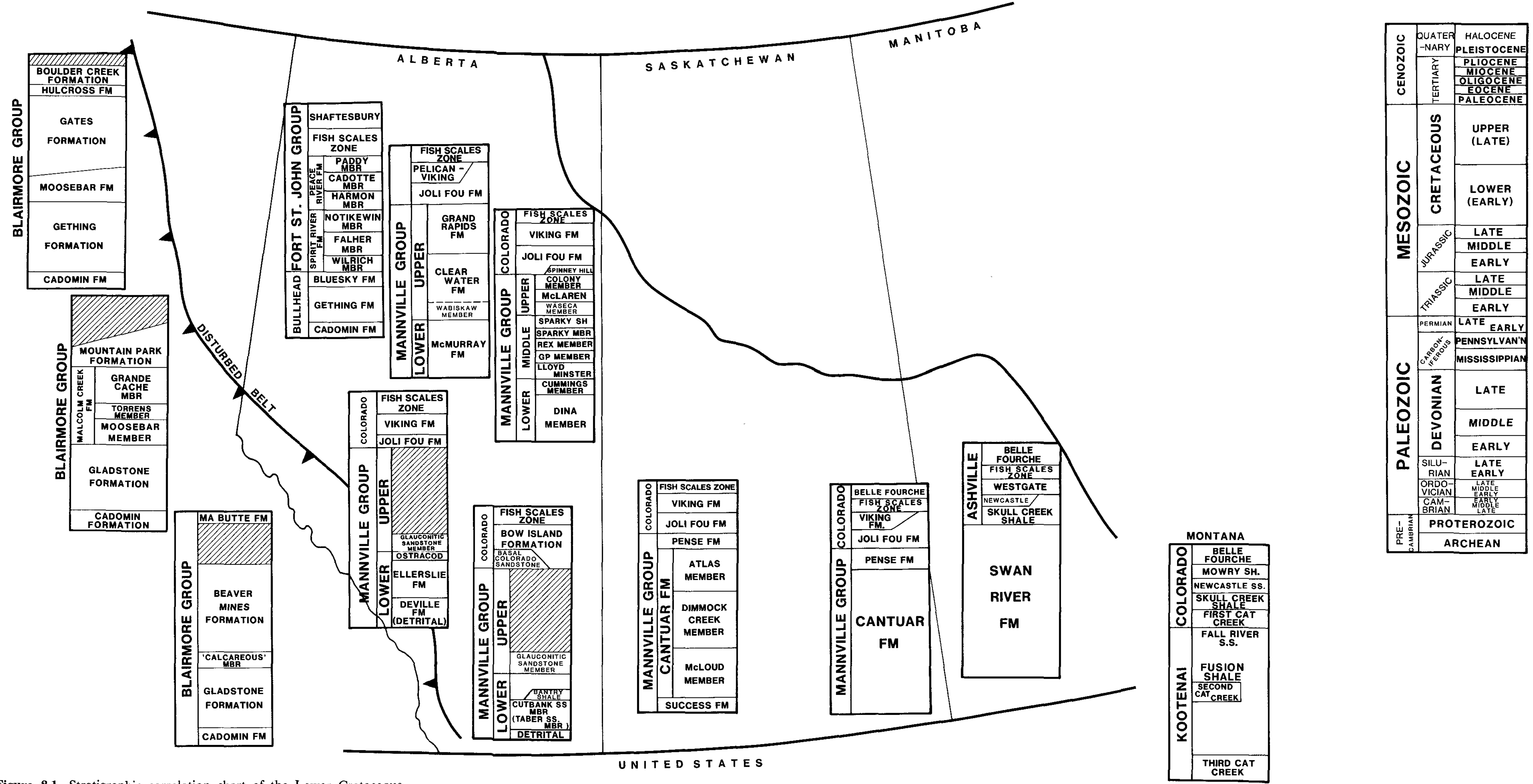

Figure 8.1. Stratigraphic correlation chart of the Lower Cretaceous strata of the Western Canadian Sedimentary Basin.

(1963). Note, however, that the author has liberally attached the previously referenced outlines to Figure 8.3 which is 8th order residual of the base of the Fish Scales zone to pre-Cretaceous interval. Figure 8.3 traces only the zero line between the positive and negative residuals and thus indicates the general trend of thick and thin areas of sediment in the Lower Cretaceous.

The boundary between the Lower Cretaceous and the Upper Cretaceous is conformable and is commonly recognized and set at the base of the Fish Scales zone. This widespread synchronous marker is a shale encased zone of fish remnants which occasionally grades to a silt or very fine-grained sandstone. The zone has a characteristic gamma ray shift (on geophysical well logs) which is discernible in virtually every part of the basin where Lower and Upper Cretaceous rocks are in contact. The Fish Scales zone has no significant reflection coefficient and thus has no prominent seismic signature associated with it. However, the two underlying widespread and uniform stratigraphic units, the lowest shale of the Colorado Gp and the Viking Fm and their lateral stratigraphic equivalents commonly show a significant positive velocity contrast at their contact. In practice the seismically interpreted top of the Lower Cretaceous is assumed to lie a few milliseconds above the Viking Fm event, which is normally a peak in the polarity convention utilized in this work. The lateral equivalents of the Viking Fm, the Bow Island Fm and Paddy and Cadotte members have a similar signature. A discussion of the Viking to Paddy-Cadotte relationship is presented by Stelck (1958), and Workman (1958).

The Viking event is generally followed by a trough and peak which represent the Joli Fou and Mannville events respectively. The Joli Fou Fm commonly has a lower sonic velocity than either the overlying Viking Fm or the underlying Mannville Gp (ie. Figs. 8.78 and 8.79), however this statement should be regarded as a generalization as many exceptions occur. The seismic response to the Mannville Gp is highly variable with respect to time thickness, time structure and character. This variability is demonstrated by the 17 incorporated examples of this chapter.

STRATIGRAPHY AND NOMENCLATURE

Stratigraphic subdivisions of the Lower Cretaceous in Western Canada are diverse, often have only local application and are poorly defined in aerial extent. A review of regional literature such as Christopher (1974), Glaister (1959), Nauss (1945), Jackson (1985), Mellon (1965), Putnam (1982), Rudkin (1965), Vigrass (1968, 1977) and Williams (1963) is key to understanding the development and interrelationships of this nomenclature. Much of this work, however, is consistent with the concepts of Glaister (1959) who described the relationship, correlations and lithologies of the Blairmore Gp (of the southern Alberta Foothills) to the Colorado and Mannville groups of southern Alberta, central Alberta and portions of the northern United States. He correlated the Blairmore section with the lower portion of the Colorado Gp and Mannville Gp (Fig. 8.1), stating that there was a need for differential nomenclature based on lithologies. Upper and Lower Blairmore subdivisions were suggested and set at the "Calcareous member".

Glaister also recognized and subdivided the Lower Cretaceous of central Alberta, in ascending order, as the Mannville Gp, Joli Fou and Viking formations plus the lowest shale of the Colorado Gp (to base of Fish Scales zone). The Mannville Gp was informally subdivided into upper and lower units with the contact being set at the top of the "Calcareous member" or "Ostracod member" (Fig. 8.1). This subdivision is recognized throughout much of the subsequent literature and is based on recognizable lithological characteristics. Furthermore this subdivision is compatible with major sea level changes during the Lower Cretaceous (Jackson, 1985) and defines the time boundaries of major depositional changes.

Figure 8.1 summarizes formational nomenclature utilized in this text for the Lower Cretaceous strata. This figure is a compilation of stratigraphic nomenclature which follows that of the Alberta Energy Resources Conservation Board (ERCB) Table of Formations, the Saskatchewan Department of Mineral Resources Stratigraphic Correlation Chart, and the British Columbia Department of Mines and Petroleum Resources Stratigraphic Correlation Chart (1976).

An exception to the nomenclature of Figure 8.1 is noted in the naming of several examples. The pool names as applied by the above mentioned agencies occasionally contain informal terms, however these names have been retained in the titling of the following examples, as they refer to very specifically defined pool boundaries and horizons (as of January 1, 1988).

The following specific adjustments are applied to the compilation of Figure 8.1: 1) The informal lower and upper subdivisions of the Mannville Gp of Glaister (1959) are utilized, and are retained as informal units; 2) The informal threefold Mannville Gp subdivisions of Vigrass (1977) for the Lloydminster area are utilized, and retained as informal units. Similarly, the ninefold member sub-divisions of the Mannville Gp are retained as informal; 3) The formal term Ellerslie Fm is utilized in preference to the informal term Basal Quartz; 4) The informal Bantry shale of southern Alberta is utilized, consistent with description of Farshori (1983) and Hopkins et al. (1982); 5) The informal term Glauconitic Sandstone member is utilized, consistent with the usage of Jackson (1985); 6) The informal term Taber Sandstone member is locally utilized in the description of subsection 8-6, and is consistent with the informal Cutbank member as described by Hayes (1986); 7) The informal term Ostracod member is utilized, and indicates the top of the lower Mannville, consistent with the usage of Glaister (1959); and 8) The terminology of McLean (1982) is utilized in Figure 8.1 for the Foothills areas of the basin.

Descriptive informal terms such as the "Glauconitic Sandstone member" refer to stratigraphic units which may contain many lithologies.

DEPOSITION OF THE LOWER CRETACEOUS SEDIMENTS

A description of Lower Cretaceous clastic deposition in Western Canada is preceded here by a description of the Mannville Gp and post-Mannville strata as they occur in central Alberta. In doing so, other areas of Lower Cretaceous strata (Fig. 8.1) can be related to as depositional variations of their stratigraphic equivalents in central Alberta.

LOWER MANNVILLE

The lower Mannville of central Alberta and indeed for much of Western Canada is comprised of predominantly non-marine clastics. The source of clastic material is dominantly from the west, however a shield provenance (eastern source) is recognized for the eastern and northeastern portions of the basin (Williams, 1963). During lower Mannville time, lithic material from both eastern and western sources was carried to and deposited in a centralized drainage system which trended from south to north (Fig. 8.3). Paleotopography on the pre-Cretaceous unconformity, which may have been on the order of 150 m, controlled the pattern of drainage. Lower Mannville strata are present in the lows, but are often depositionally absent across pre-Cretaceous highs, due to onlap. A transgression at the close of lower Mannville time resulted in brackish to marine conditions in which carbonates, shales, siltstones and fine-grained sandstones of the Ostracod member were widely deposited.

UPPER MANNVILLE

Transgression of the Lower Cretaceous sea from the north, resulted in the deposition of strata which progressively onlap southward. A strong marine influence, particularly in the Glauconitic Sandstone member of central Alberta and the Bluesky Fm of northern Alberta are indicative of the prevailing marine conditions. To the south the Glauconitic Sandstone member contains both lacustrine sediments and channel sandstones (Farshori, 1983; Hopkins et al. 1982; Hopkins, 1987). The balance of the upper Mannville sediments are a series of sandstones, shales and coals which were deposited during several minor fluctuations in sea level. Most of the undivided upper Mannville sediments appear to be nearshore or continental in deposition and are not as well studied as the lower Mannville strata. Discussion of the upper Mannville strata in central Alberta are generally confined to the Bluesky Fm or Glauconitic Sandstone member and their equivalents. Within the Lloydminster heavy oil area of Alberta and Saskatchewan the equivalent of the central Alberta upper Mannville is further subdivided into middle and upper units (Vigrass, 1977; Putnam, 1982). This subdivision recognizes the separation of nearshore marine strata of the middle Mannville from channel and related sediments of the upper Mannville within the heavy oil area. A discussion of the upper Mannville deposition in the Deep Basin Gas area is presented in Jackson (1985) and Masters (1985).

POST MANNVILLE DEPOSITION

At the end of Mannville time a widespread marine transgression allowed the Gulfian and Boreal seas to merge. This terminated the continental to nearshore deposition of the Mannville Gp and resulted in the uniform deposition of a marine shale, the Joli Fou Fm, being deposited across much of Western Canada. Stelck (1958) concluded that this contact marks the change in basin influence from the Arctic seas to the Gulf of Mexico seas. Furthermore, he suggested that the Basal Colorado sandstones of southern and central Alberta and the Colony member are post-Mannville units. The Joli Fou Fm is a uniform dark grey marine shale ranging from 0 to 35 m in thickness (Workman et al., 1960, Glaister, 1959). In southern Alberta the Joli Fou Fm equivalent is grouped with the Bow Island Fm, whereas to the west it thins and becomes inseparable from the Blairmore Gp.

The overlying Viking Fm of Slipper (1918) is a widespread coarsening upwards sandstone. Reinson (1985) defined the regional facies of the Viking Fm for his study area as being characterized by four or five coarsening upward bioturbated sandy mudstone to

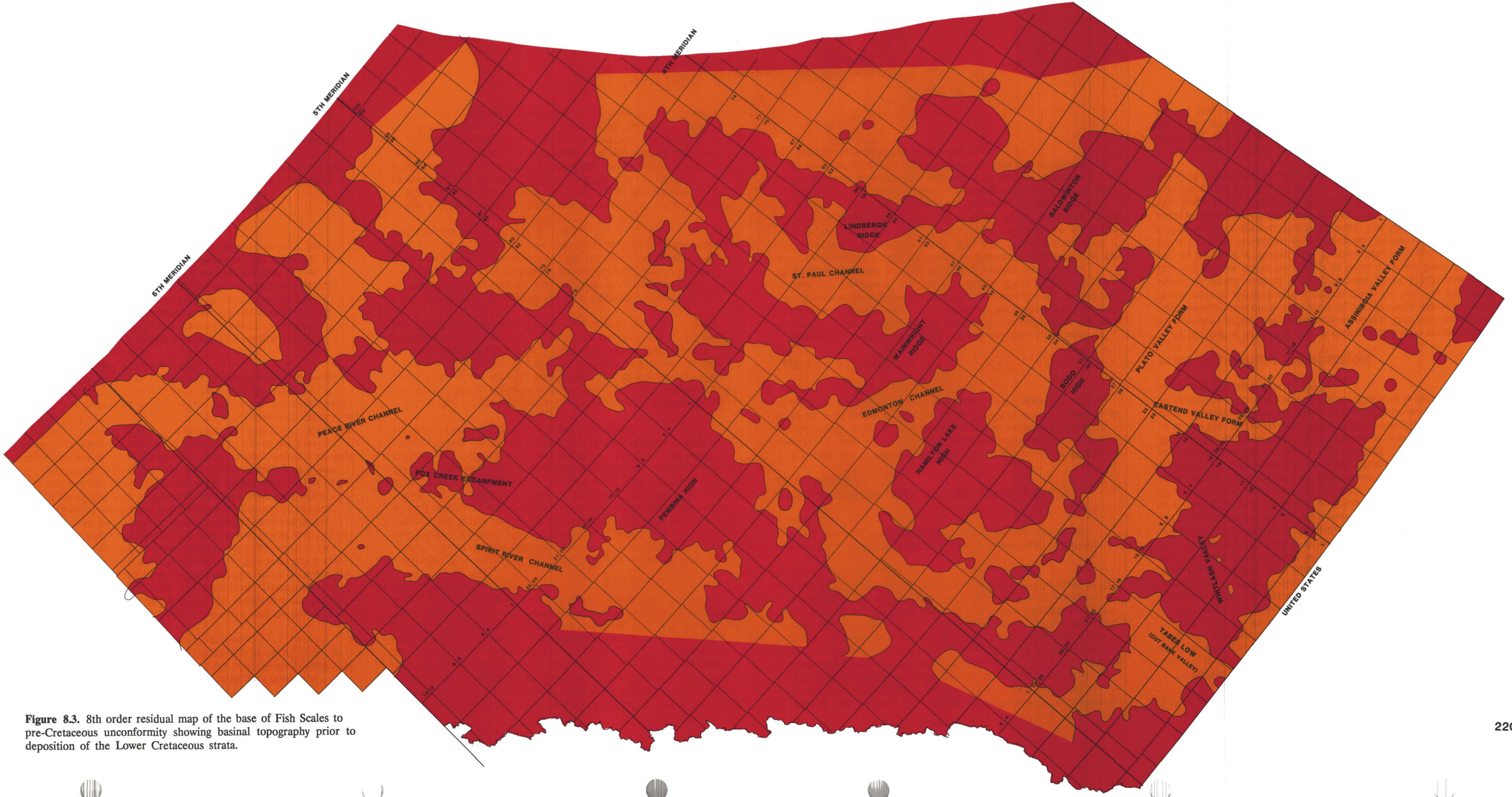

Figure 8.3. 8th order residual map of the base of Fish Scales to pre-Cretaceous unconformity showing basinal topography prior to deposition of the Lower Cretaceous strata.

muddy sandstone sequences. The uppermost cycle occasionally grades to a clean fine-grained shoreface bar sandstone. He interpreted the regional facies of the Viking Fm to be due to the progradation of nearshore sediments. The Viking Fm of central Alberta is correlative with the Bow Island Fm of southern Alberta (Workman et al., 1960). The Bow Island Fm, which includes the Joli Fou Fm, grades westerly into the Blairmore Gp (Fig. 8.1). To the north the Viking Fm is generally correlated to the Paddy and Cadotte members. At the close of Viking Fm time a return to deep water sedimentation resulted in the deposition of the thick uniform marine shale which is bounded by the Fish Scales zone and the Viking Fm. This unit is commonly unnamed in the literature, but is part of the Lloydminster shale (Nauss, 1945), Alberta shale (Hume, 1930) or Colorado Gp (Hayden, 1876). The upper boundary of the Lower Cretaceous is set at the base of the Fish Scales zone. Glaister (1959), Stelck (1958), and Workmen (1959) provide further discussions of the relationship of the Viking Fm to the Bow Island Fm, Paddy and Cadotte members (Peace River Fm), and the Upper Blairmore.

ECONOMIC SIGNIFICANCE OF THE LOWER CRETACEOUS AND THE ROLE OF THE SEISMIC REFLECTION METHOD

Recoverable oil and gas reserves for the Lower Cretaceous of Alberta are shown in the Tables presented in the Introduction to this volume.

Excluding the nonconventional reserves of the Peace River, Wabiskaw and Cold Lake Oil Sands and the Athabasca Tar Sands, the Lower Cretaceous contains some 1921 x $10^6 m^3$ of oil in place. Average pool recovery is on the order of 7% giving an estimated 245 x $10^6 m^3$ recoverable oil for the Lower Cretaceous of Alberta (ERCB, 1987). Initial established reserves of Lower Cretaceous gas are some 1,153 TCM of producible gas.

For many years the Lower Cretaceous was considered a secondary target which paled in economic comparison to the Devonian reefs of Western Canada. Rapid variations in facies, poor resolution of older low frequency seismic data, low recovery factors and smaller reserve potential made this interval less attractive for exploration than the lucrative carbonate plays. The advent and application of improved seismic shooting, recording and processing techniques has resulted in more accurate geophysical and geological mapping of the Lower Cretaceous, which in turn has resulted in economically successful exploration.

Geophysical exploration of the Lower Cretaceous in Western Canada is now oriented towards stratigraphic interpretation rather than to a purely structural approach. The integration of geological and geophysical models in an attempt to predict facies development, is now a powerful method used by explorationists. Drape across channel facies, lateral termination of seismic reflections against post-depositional channels or pre-Cretaceous highs, and certain lithological changes can be confidently identified on seismic data. Future development of shear wave and amplitude/offset techniques could improve the seismic method to a point where lithological variations may be predicted with consistency.

The most significant recent advance in geophysical hydrocarbon exploration has been the application of seismic modelling techniques. Modelling allows the interpreter to set the geological dimensions and acoustic parameters of strata and to view their seismic response. The iterative process of modelling wellbore data to a seismic response has provided a direct link between geology and geophysics, making the interpreter more effective at recognizing the seismic signature of various geological features. This technique has also resulted in a better understanding of what can reasonably be defined with a seismic data set and aid in the modification of acquisition parameters accordingly.

Since the late 1960's the reserves of the average new oil and gas well drilled in Western Canada has fallen. This fact is primarily due to the maturity of carbonate plays. Reserves in major carbonate plays such as the Nisku, Leduc, Keg River formations or Beaverhill Lake Gp (which have sizeable per well reserves) are being replaced by less spectacular Upper and Lower Cretaceous reserves, which although small on a per well or per pool basis, form an ever increasing portion of Western Canada's hydrocarbon reserves.

The Lower Cretaceous of Western Canada contains few conventional world class giants (ie. excluding tar sands deposits). However, the reserves of the many small pools (15,000 gas and 1900 oil pools in Alberta) are a substantial portion of Canada's hydrocarbon reserves and production base. Through innovative engineering techniques (such as high volume lift, thermally enhanced recovery schemes, and improved completion procedures for low permeability reservoirs) previously non-economic hydrocarbon reservoirs have become lucrative exploratory targets. Similarly, the combination of market proximity, transportation infrastructure, reasonable depth, cost, and reserves, make the Lower Cretaceous a mainstay of exploration activity in Western Canada.

RESERVOIR TYPES

Lower Cretaceous reservoirs in Western Canada are almost exclusively clastic in nature, with the exception of the Ostracod member of the lower Mannville. The Ostracod member can be in the form of coquina or shell banks. (Carbonate material normally occurs only as a secondary cement or as lithic fragments in the Lower Cretaceous.) Reservoirs of virtually every clastic depositional mode known occur in the Lower Cretaceous strata. Reservoir encasement is commonly by shales, but can be by coals as is the case of the Lloydminster member in the Provost area. Grain sizes range from silts to conglomerates with sandstone sizes forming the vast majority of reservoirs.

The Western Canada Sedimentary Basin has few major structures, such as large scale diapirism, slump or growth faults, and block faulting that occur in other major petroleum provinces. Therefore, much of the conventional Lower Cretaceous reserves are trapped by a combination of depositional facies and regional dip, with some reservoirs being exclusively stratigraphic. Major structural trapping of oil occurs in the Cold Lake - Athabasca Tar Sands belt of eastern Alberta and western Saskatchewan, where the Lower Cretaceous crosses the dissolutional edge of the Prairie Evaporite Fm salt. Structural traps due to dissolution of Devonian salts (Tangleflags, subsection 8-7 this chapter), drape across Devonian reefs (Peavey, subsection 8-14 this chapter), and karsting (Taber, subsection 8-6 this chapter) can and do occur, however they often have a stratigraphic element as well.

Depositional environments tend to fall within a range of meander belt continental, to shallow and intermediate water depth deposits. Very coarse clastic environments (such as alluvial fan deposits) are described for some of the more westerly areas, particularly in the deep basin gas area (Jackson, 1985).

CRITERION FOR SELECTION OF EXAMPLES

Seventeen examples were selected in order to portray the seismic signatures of a representative suite of Lower Cretaceous reservoirs in Western Canada. It would be impossible to make a complete representation in that there are in excess of 15,000 Lower Cretaceous gas reservoirs in Alberta alone, representing an unknown number of trap types. However, type examples of structural and stratigraphic traps, continental and marine deposits, gas and oil pools and unique traps eg. due to salt dissolution or drape across reefs are presented. Areas of limited seismic use where seismic data is not applicable, or of nonconventional reserves have been omitted (ie. Cold Lake, Wabiskaw, Deep Basin and the accumulations in the disturbed belt). These data are presented sequentially, progressing from: 1) southern Alberta; 2) heavy oil of Alberta and Saskatchewan; and 3) central and northern Alberta.

8–1: BOW ISLAND GLAUCONITE A POOL

The Bow Island Glauconite A pool which is located approximately 230 km southeast of Calgary, Alberta (Fig. 8.4) was discovered in January of 1985 with the drilling of the Petrorep et al. Bow Island 14-2-10-13 W4M well. The Bow Island Glauconite A pool illustrates the geological characteristics and seismic image of a Mannville Gp channel. The channel deposited sediments are interpreted to be part of the Glauconitic Sandstone member, however this is not immediately obvious due to the absence of lower Mannville sediments in the vicinity of the pool. The Bow Island Glauconite A pool is significant in that it is one of the few Glauconitic Sandstone unit oil

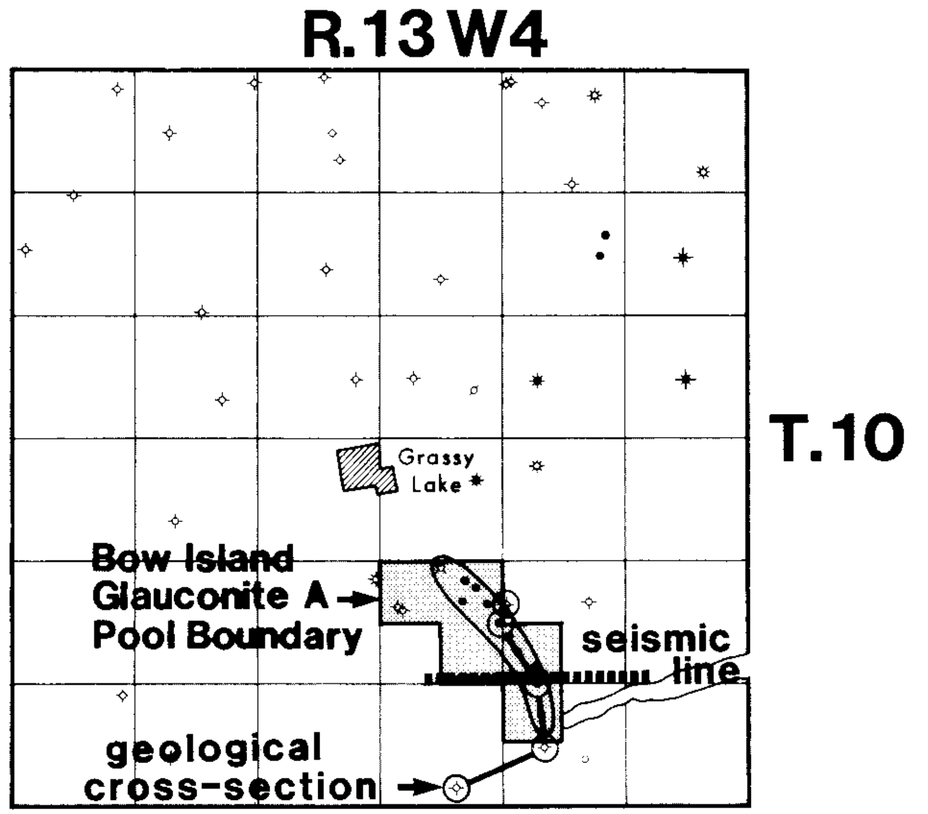

Figure 8.4. Location map, Bow Island Glauconite A pool (courtesy, The Geobase Company Ltd).

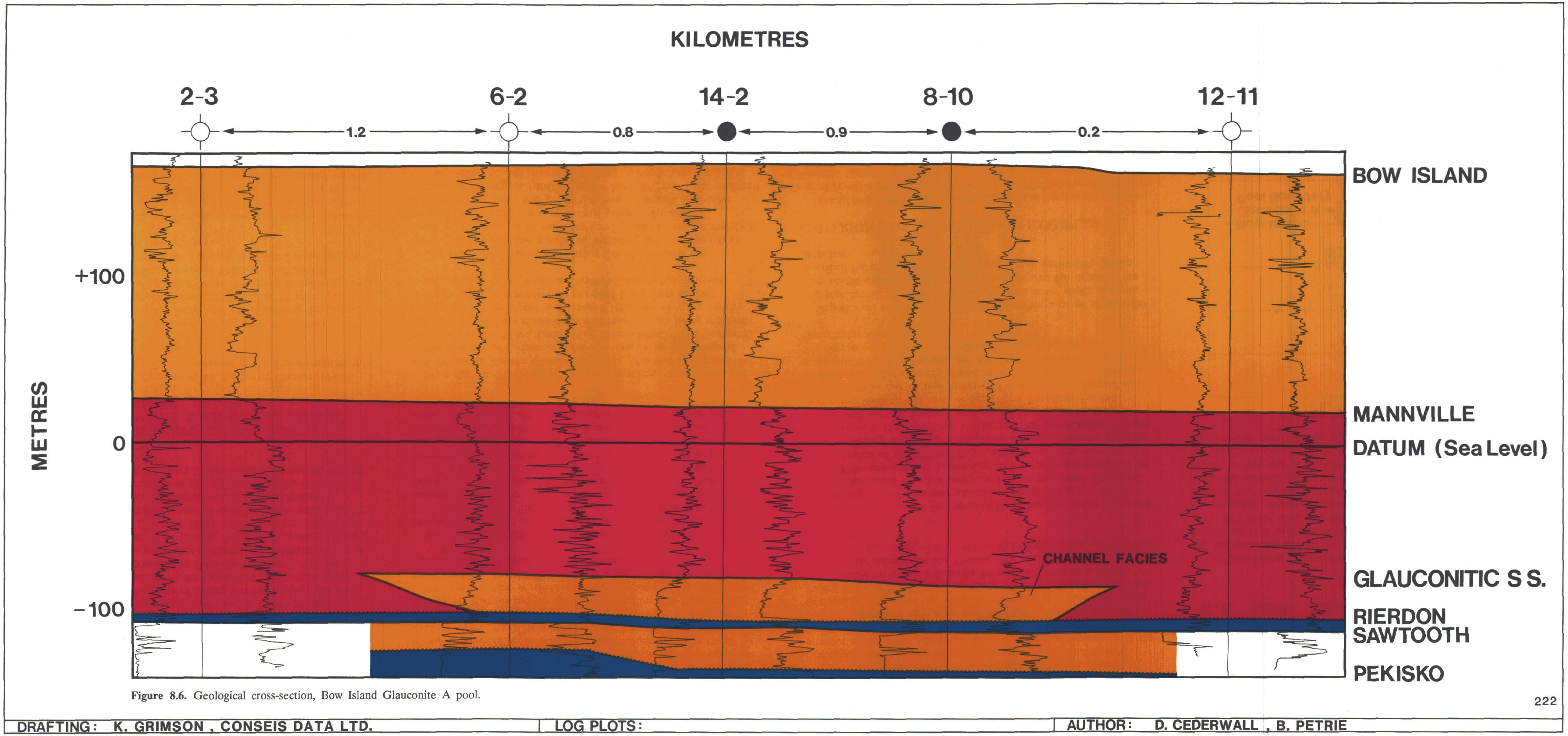

Figure 8.6. Geological cross-section, Bow Island Glauconite A pool.

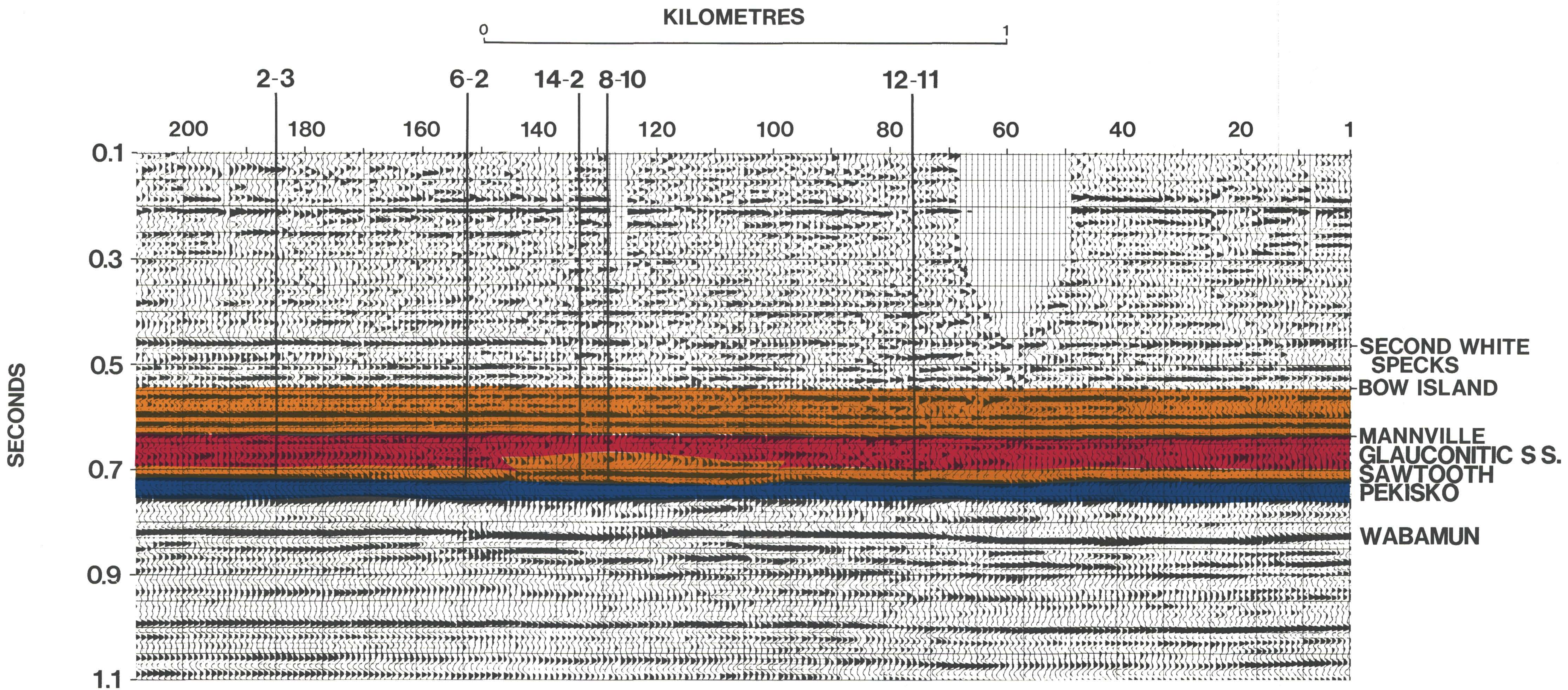

Figure 8.7. Seismic section, Bow Island Glauconite A pool.

DONOR: POLYSEIS RESEARCH INC. | PROCESSOR: | AUTHOR: D. CEDERWALL, R. LUNDBERG pool in the Hays - Grand Forks - Bow Island trend which can be confidently delineated with seismic data. Glauconitic Sandstone member reservoirs of the Grand Forks field (T11-R13 W4M) and the Hays field (T12-R13 W4M) commonly have indistinct or weak seismic signatures (B. Stuart, pers. comm., 1987).

Glauconitic Sandstone member reservoirs in this area typically have abrupt basal contacts with high angle cross-stratified sandstones, fining and shaling upward sequences, and an absence of both fauna and burrowing, all of which are suggestive of a continental channel regime (Berry, 1974). The Bow Island Glauconite A pool is classified as a channel deposit based on physical dimensions and well log signature and correlation. This is consistent with the description of the Glauconitic Sandstone member of the Little Bow area (Hopkins et al., 1982) who note a diachronous relationship between the regional and channel facies of the Glauconitic Sandstone member.

A threefold subdivision for the Glauconitic Sandstone member is defined here to aid in the discussion of the seismic data related to the southern Alberta Mannville pool (subsections 8-1 to 8-5).

These generalized subdivisions are referred to as the: 1) regional facies; 2) channel facies; and 3) non-reservoir channel facies.

1) REGIONAL FACIES (Interchannel Facies)

The regional facies is relatively widespread and consists of a coarsening upward sequence of interbedded shales, siltstones and sandstones. These dominantly argillaceous strata are often horizontally bedded and bioturbated. These strata are usually interpreted as shallow marine or coastal plain deposits (Jackson, 1985; Hopkins et al., 1982). This facies can form a reservoir under certain trapping conditions (ie. Badger Upper Mannville B pool).

2) CHANNEL FACIES

The channel facies are of high reservoir quality and are characterized by abrupt basal contacts, a fining upwards sequence, rip up clasts and high angle cross-stratification.

3) NON-RESERVOIR CHANNEL FACIES

The non-reservoir channel facies were deposited within the confines of the channel cut, similarly to the previously described facies, but are often of poor reservoir quality and are usually non productive.

Log analysis shows the Bow Island pool to be a shale free reservoir in its lower part with shale increasing and porosity decreasing vertically. Oil production is taken in conjunction with high volumes of water, a situation typical of many heavy and medium density oil pools in Western Canada.

Reserves for the pool, and the principal reservoir characteristics are shown in Table 8.1. Productivity data for this pool are displayed in Figure 8.5.

Table 8.1: Reserves and significant reservoir parameters, Bow Island Glauconite A pool. (ERCB, 1987)

Initial Oil Volume in Place	5230 x 10^3m^3
Primary Assigned Recovery Factor	10%
Primary Recoverable Reserves	523 x 10^3m^3
Cumulative Production to 1/1/88	64.4 x 10^3m^3
Area	288 ha
Average water Saturation	23%
Oil Density	20 kg/m^3
Average Depth	911.3 m
Average Pay	9.55 m
Average Porosity	26%
Discovery Year	1985

GEOLOGICAL CROSS-SECTION

A west to east structural cross-section of the Bow Island Glauconite A pool (Figure 8.6) runs roughly perpendicular to the northward plunging nose of the Sweetgrass Arch and perpendicular to the axis of the Glauconitic Sandstone member channel. The section which is datumed at sea level incorporates pre-Jurassic to Bow Island Fm sediments. The lowest strata identified on the cross-section are Mississippian carbonates of the Pekisko Fm which are laterally persistent, clean, tight, limestones which are separated from the overlying Sawtooth Fm by an erosional surface. The Sawtooth Fm strata are typically very clean, coarsening upward quartzose sandstones, which are overlain by the shales of the Rierdon Fm. Sawtooth Fm sandstones appear to have a higher attendant sonic velocity than the channel facies of the Glauconitic Sandstone member in this vicinity. This contrast which could be due to the occurrence of a secondary cementation of the Sawtooth sandstones not observed in the channel facies is partially responsible for the seismic response of the channel facies.

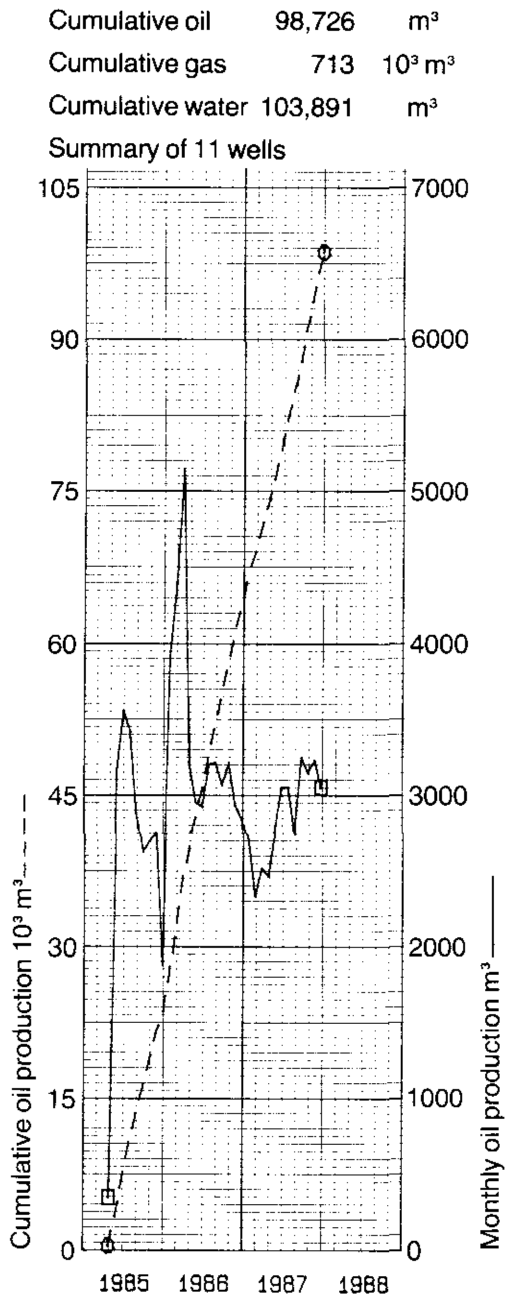

Figure 8.5. Production data, Bow Island Glauconite A pool.

The Rierdon Fm is the subcropping pre-Cretaceous formation in this area. Both the Sawtooth and Pekisko formations are exposed in subcrop to the Lower Cretaceous, to the north. The Sawtooth Fm sandstone, generally thickens in pre-Jurassic erosional lows on the Mississippian unconformity.

The overlying Glauconitic Sandstone member shown on the cross-section in the 14-2 and 8-10 wells (Fig. 8.6) is interpreted as channel strata. These fluvial sediments (the channel facies) are thought to have been deposited unconformably against the regional facies strata. The regional facies are shown in the 2-3 and 12-11 wells. The boundary between the Glauconitic Sandstone member and the Rierdon Fm is the pre-Cretaceous unconformity and may represent a significant period of non-deposition or erosion (Jackson, 1985). Most or all of the lower Mannville strata (Ellerslie Fm) are absent in the area, presumably due to emergence of the area at that time. As a result, the Glauconitic Sandstone member and Rierdon Fm are separated by only a few metres of strata. This interpretation is supported by Hayes (1986) who shows a thin Rierdon Fm and no lower Mannville sediments in the pool area (Fig. 8.29). Berry (1974) showed that the channel facies of the Glauconitic Sandstone member (Grand Forks Field, T11-R13 W4M) can occur in direct contact with the Rierdon Fm or locally with the Sawtooth Fm. In some areas there is evidence that the reservoir sandstones are sourced from the erosion of predating lower Mannville and or the Sawtooth Fm (B. Dick, pers. comm. 1988). The occurrence of a high velocity interval separating the channel facies sandstone from the Rierdon Fm may be of significance in the seismic detection of this reservoir. However, the major anomalous velocity contrast appears to be generated by the aggregate low velocity of the channel facies sandstones plus the Rierdon Fm to the higher velocity Sawtooth Fm sandstones (Fig. 8.6). In this example, the thin high velocity zone at the channel base is partially responsible for an extra peak, however, it is unclear as to whether this unit is due to a channel lag deposit or remnant lower Mannville strata (ie. the Calcareous member or Ostracod member).

The pool trends southeast - northwest with paleodrainage being to the north. Figure 8.4 indicates that the pool is approximately 500 m in width and 2.5 km in length, and is arcuate on a radius centered to the west of the pool. These characteristics are analogous to a modern point bar sequence of a meandering stream. The southernmost producing wells in the pool, particularly the 11-2-10-13 W4M show a marked increase in shale content and may be correlative with the inside of a point bar sequence. Channel facies sandstones in excess of 20 m in thickness are noted in the 4-11-10-13 W4M well. An oil-water contact, but no apparent gas cap are observed on well logs. The balance of the cross-section shows the capping upper Mannville sediments and the Bow Island Fm sandstones, neither of which drape across the Glauconitic Sandstone member channel facies.

SEISMIC SECTION

The displayed seismic line (Fig. 8.7) was acquired in 1985 after the discovery of the pool and was part of an experimental study on seismic source response in southern Alberta conducted by Polyseis Research Inc. Four seismic methods; vibroseis, airgun, plus single and multi-hole dynamite shot patterns were applied over the same line location. The displayed section, the log normal polarity vibroseis source line, gave the best response of the four test sources, (R. Lundberg pers. comm., 1987). The original processing of the section by Geo-X Ltd. has been utilized, and only a portion of the line has been displayed in order to maximize the display size of the channel facies of the Glauconitic Sandstone member.

The deepest reflection identified is the Wabamun event. Below this horizon are the Devonian Winterburn, Woodbend, Beaverhill Lake and Elk Point groups as well as Cambrian aged sediments. The stratigraphy of these units in southern Alberta is described at length by Herbaly (1974). These units and the regional position of the pool are shown on the Wright et al. (1984) cross-section F - F' in the introduction to this volume.

The laterally continuous peak identified as the Pekisko event is the Jurassic - Mississippian unconformity. This reflection shows moderate amounts of relief due to pre-Jurassic differential erosion and is three or four milliseconds structurally low in the vicinity of the Glauconitic Sandstone member anomaly, (trace 100-145). A small Mississippian high occurs to the east of the anomaly (trace 1-50).

The next labelled and laterally continuous reflection represents the pre-Cretaceous unconformity. This trough is the reflection from the contact of the eroded Jurassic (Rierdon and Sawtooth formations), and the Lower Cretaceous. These events are also identified on the synthetic seismic trace of Figures 8.8 and 8.9.

The anomalous feature between traces 100 and 145 is correlative with the producing Glauconitic Sandstone member oil wells of sections 2, 10 and 11-10-13 W4M. The principal laterally anomalous characteristic is the appearance of an extra cycle, trough through peak in which the peak is sharper than the overlying trough. The onset of the broad trough is correlative with the shaly low velocity top of the channel facies, and the sharp, underlying high frequency peak is correlative with the channel base. The time-thickness of the trough is therefore related to the thickness of the channel facies sandstones. Note also that the anomaly dips slightly to the east, possibly indicating the cutbank side of a channel which is laterally accreting to the east. This model would also be consistent with the arcuate shape of the pool in plan view.

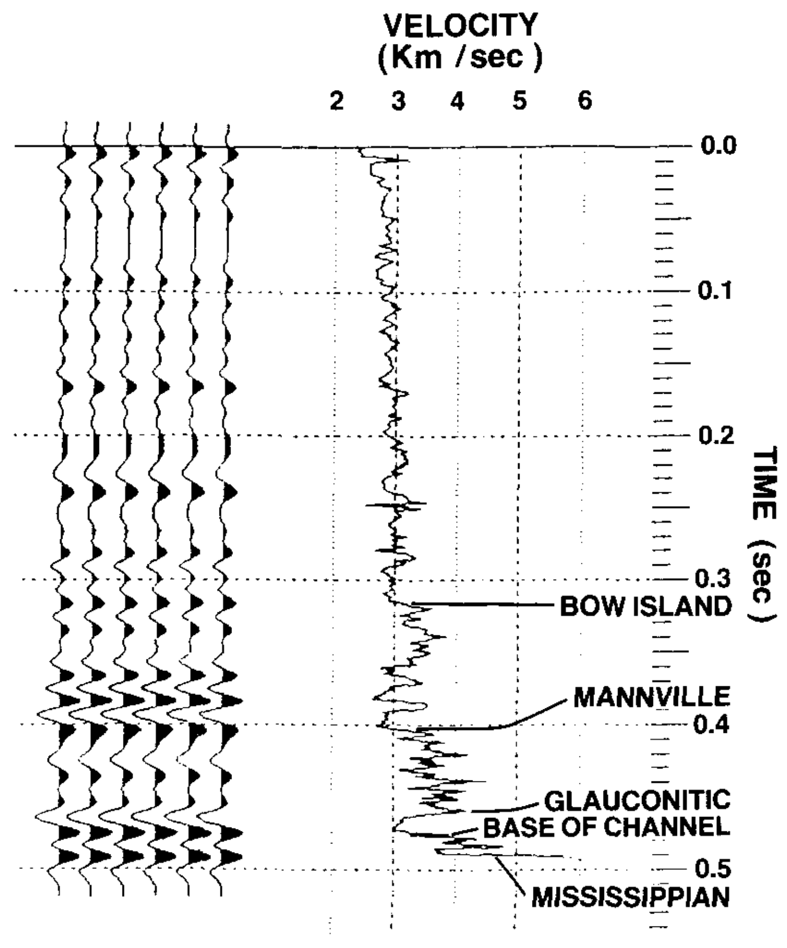

Figure 8.8. Single well synthetic seismic trace, Bow Island Glauconite A pool.

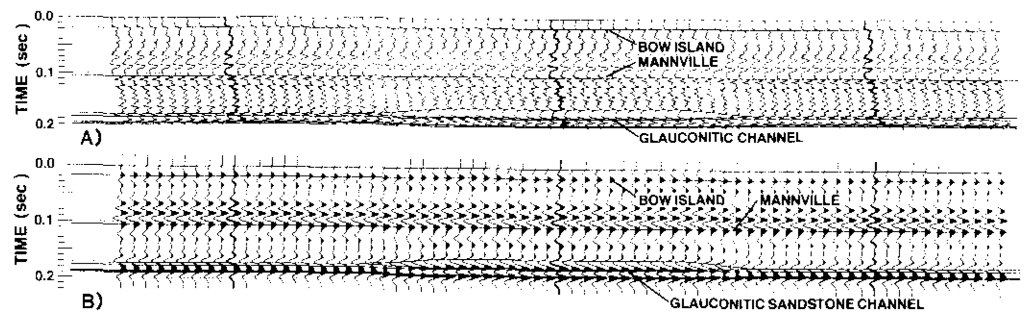

Figure 8.9. Multiwell synthetic seismic model, Bow Island Glauconite A pool.

Little or no drape occurs along the events overlying the Glauconitic Sandstone member channel, suggesting that the laterally offsetting beds predate channel sandstone deposition and were relatively well compacted prior to channel incision. No evidence of a rim or levee and overbank deposit is evident from either the geological cross-section or the seismic line.

Figure 8.8 is a seismic model which utilizes the sonic logs of the 10-11 and 14-2-10-13 W4M wells. This model closely approximates the observed signature of Figure 8.7.

CONCLUSIONS

The Bow Island Glauconite A pool is an upper Mannville oil pool with a mappable seismic signature. The dimensions, arcuate shape, sedimentological features and geophysical signature of the pool indicate that it is a back filled channel which had been cut into strata which had undergone compaction. Furthermore, the channel facies sandstones were deposited in an area devoid of lower Mannville strata. The seismic signature of the channel facies is principally due to the marked contrast of clean low velocity sandstones with the underlying higher velocity pre-channel strata.

8–2: GRAND FORKS SAWTOOTH WW POOL

INTRODUCTION

The Grand Forks Sawtooth WW Pool is located 200 km southeast of Calgary, Alberta in T12-R13 W4M(Fig. 8.10). This prolific (heavy to medium gravity) oil producing area has been extensively developed under reduced well spacing and high volume lift techniques. These techniques have led to high volumetric recoveries for moderate gravity crudes (Table 8.2).

The principal reservoir in the Grand Forks area is the Glauconitic Sandstone member channel complex (Berry, 1974). This south to north trending reservoir is reported as having variable seismic definition in the pool area which is dependent on the velocity contrast with the underlying strata (B. Stuart pers. comm., 1987). A portion of the Grand Forks Upper Mannville B pool which is formed by the Glauconitic Sandstone member is shown on the two left justified well logs on Figure 8.14. The second target horizon and subject of this example, the sandstones of the WW pool are controversial in their stratigraphic identification. This reservoir is currently defined by the ERCB (1987) as the Sawtooth WW pool, however, it was designated as the Lower Mannville II pool until

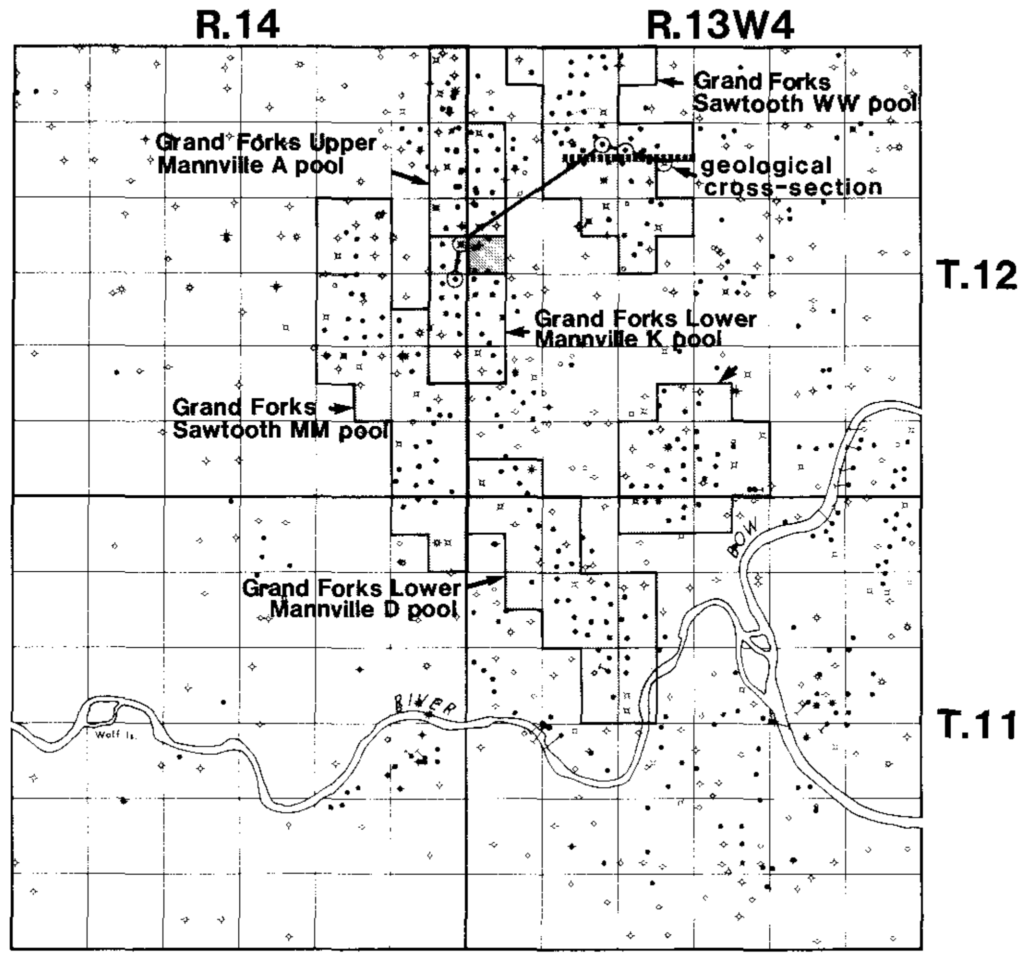

Figure 8.10. Location map, Grand Forks Sawtooth WW pool (courtesy, The Geobase Company Ltd).

1986. This sandstone unit which occurs in the pre-Glauconitic - post-Mississippian interval is variously identified in the area as lower Mannville or Jurassic. Throughout much of the field area the pre-Cretaceous subcrop is formed by the Jurassic sandstones of the Sawtooth Fm which are difficult to distinguish from adjacent lower Mannville strata in the subsurface. However, distinction of lower Mannville from Jurassic strata can be inferred with the assumption that the former are dominantly coarsening upwards units whereas the latter strata are commonly fining upwards fluvial sandstones. These data depict the geology and seismic definition of a pool where Jurassic Sawtooth Fm sandstones are truncated and sealed by adjacent lower Mannville strata. Interpretation of the stratigraphy of this area is further complicated by erosion from the upper Mannville Glauconitic Sandstone member which locally incises lower Mannville and Jurassic strata and thus the combination of three closely spaced erosional surfaces leads to numerous possible combinations of formations at stratigraphic interfaces.

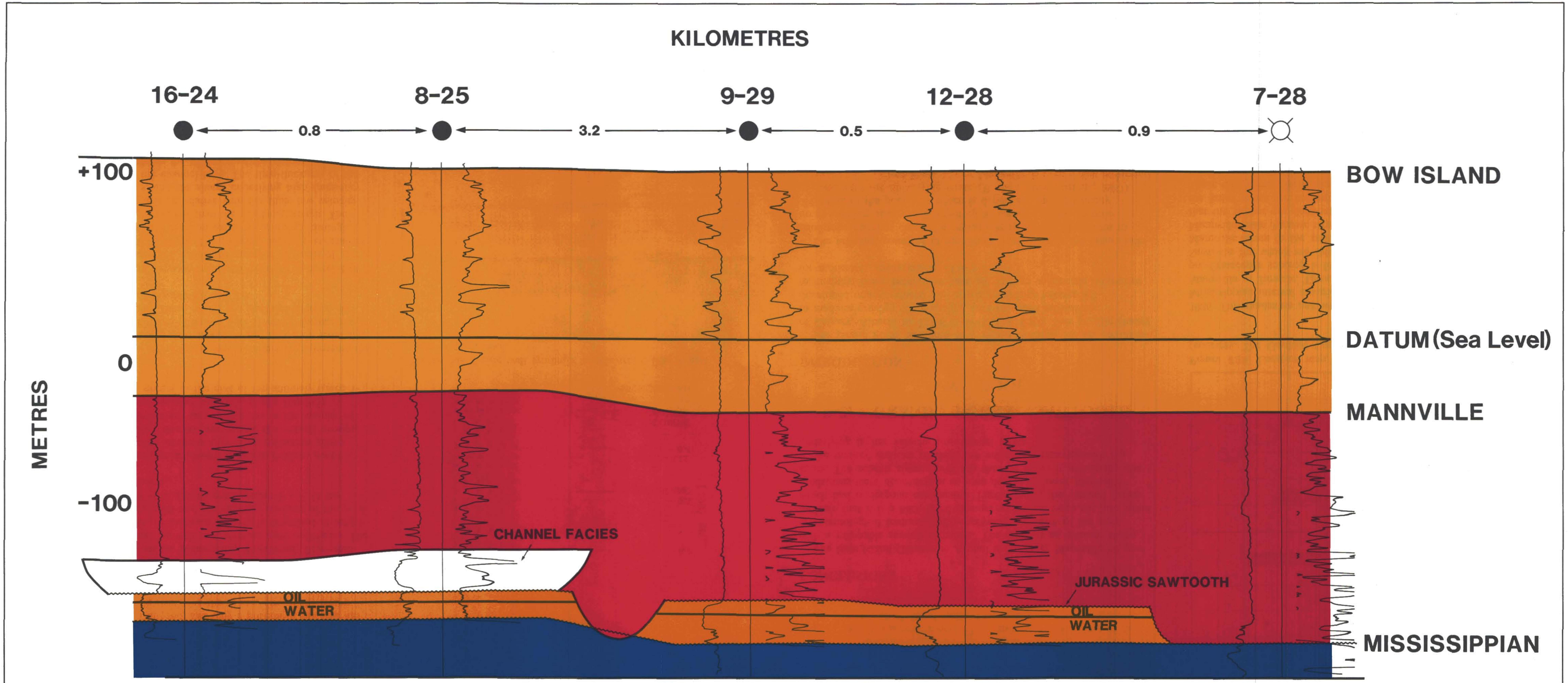

Figure 8.12. Geological cross-section, Grand Forks Sawtooth WW pool.

DRAFTING: K. GRIMSON | LOG PLOTS: | AUTHOR: D. CEDERWALL

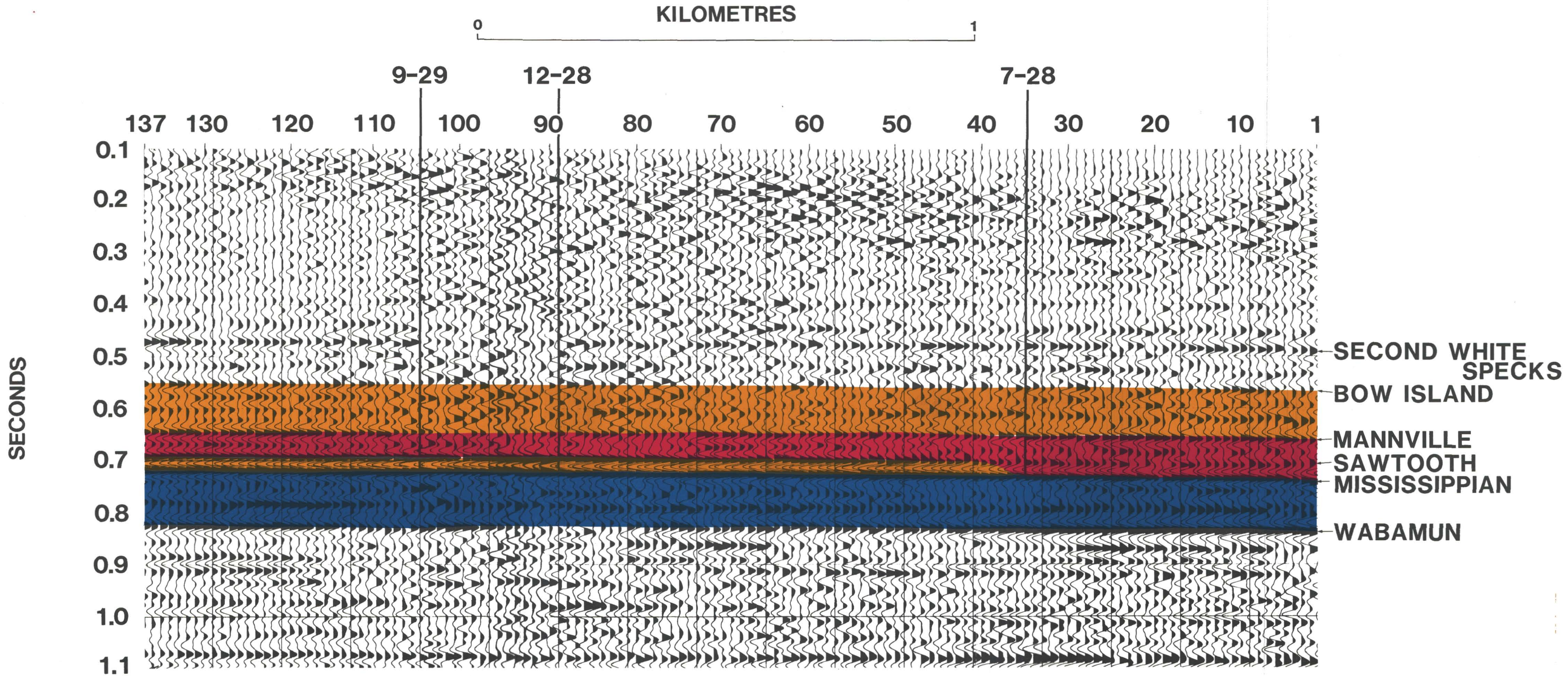

Figure 8.13. Seismic section, Grand Forks Sawtooth WW pool.

DONOR: OAKWOOD PETROLEUM LTD. | PROCESSOR: | AUTHOR: D. CEDERWALL, B. STUART

Reserves and significant reservoir parameters of the Sawtooth WW pool are shown in Table 8.2. Production data for the pool are depicted in Figure 8.11.

Table 8.2: Reserves and significant reservoir parameters, Grand Forks Sawtooth WW pool (ERCB, 1987)

Initial Oil in Place	3030 x 10^3m^3
Primary Recovery Factor	20%
Additional Secondary Recovery Factor	25%
Initial Established Reserves	1,240 x 10^3m^3
Production To Date	535 x 10^3m^3
Remaining Reserves	704 x 10^3m^3
Area	560 ha
Average Pay	3.41 m
Average Water Saturation	33%
Average Porosity	25%
Oil Density	885 kg/m^3
Average Depth	926.9
Discovery Year	1983

GEOLOGICAL CROSS-SECTION

The west to east geological cross-section Figure 8.12 depicts strata from the Mississippian aged Pekisko Fm through the Lower Cretaceous, Bow Island Fm. The cross-section more or less parallels the seismic section through sections 28 and 29-12-13 W4M and also covers the Grand Forks Upper Mannville B Pool to the west. The two left justified, B pool wells depict the relationship of the Glauconitic Sandstone member channel to the Sawtooth Fm sandstone. In these wells the Glauconitic Sandstone member channel facies incises the Sawtooth Fm and could in fact share a common aquifer. Both of these wells display the bell shaped fining upwards sequence of the Glauconite Sandstone member channel facies in contrast to the coarsening upwards character of the Sawtooth Fm. A separation of the Sawtooth Fm between the 8-25 and the 9-29 locations is interpreted, based on independent oil-water contacts. The Sawtooth Fm is laterally persistent up to the location of the 7-28-12-13 W4M well where the zone has been eroded and later replaced with lower Mannville strata. Two wells, 9-29 and 12-28-12-13 W4M are typical of oil wells in the WW pool, which averages 3.4 m of oil pay over water. No associated gas cap occurs with this Sawtooth Fm oil pool.

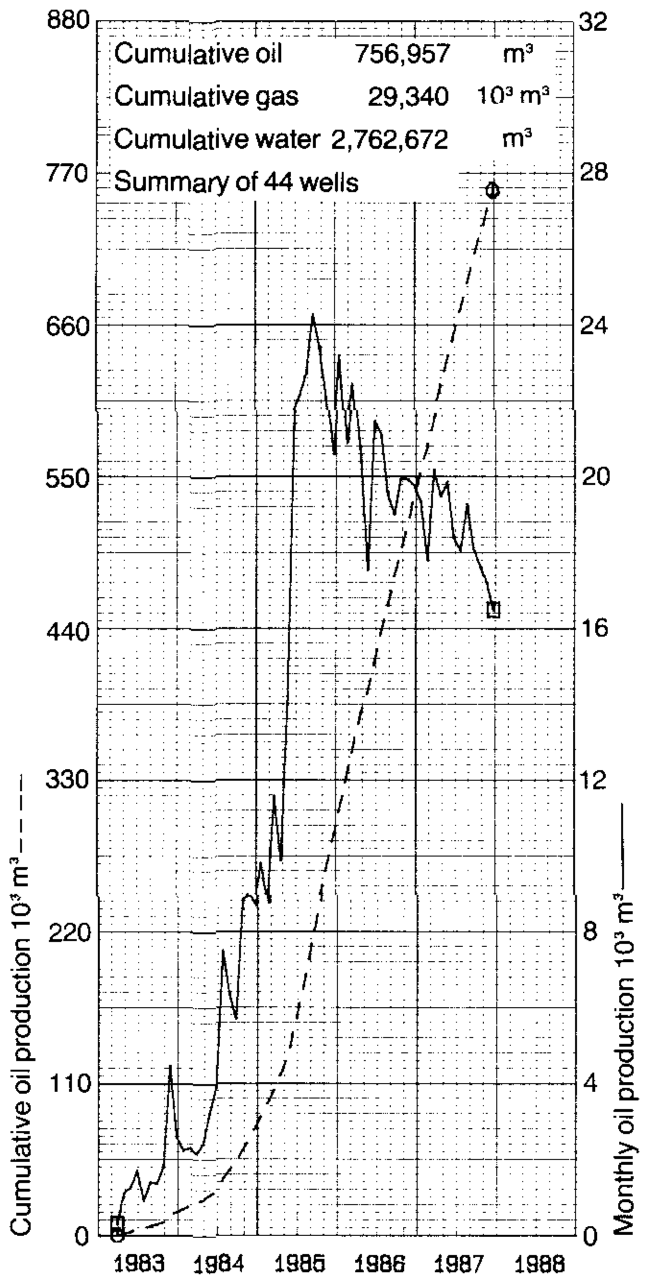

Figure 8.11. Production data, Grand Forks Sawtooth WW pool.

SEISMIC SECTIONS

The seismic data shown in Figure 8.13 were donated by Oakwood Petroleums Ltd., and are displayed under original processing. Identified on this west to east line are the Wabamun, Mississippian, Sawtooth, Mannville and Bow Island events. Of particular interest on this data is the lateral character change of the Sawtooth event near trace 50. This peak weakens and cannot be confidently correlated east of this point. This lateral character change correlates with the west to east truncation of the Sawtooth Fm illustrated in Figure 8.12 and thus the absence of the peak at 700 ms is thought to be indicative of pre-Cretaceous erosion of the Sawtooth Fm, as described for the geological cross-section. Little or no drape is detected associated with this feature and the seismic signature is principally one of lateral character variation. Identification for the events on this data are shown on Figure 8.14.

Figure 8.15 is a seismic model which was generated utilizing the sonic log from the 8-29 location plus a modification of this log which attempts to replicate the stratigraphy of the 7-28 location. A reasonable comparison between the model of Figure 8.15 and the seismic section of Figure 8.13 is observed. Note, however the diminished amplitude of the Mississippian event on the model where the Sawtooth Fm is absent.

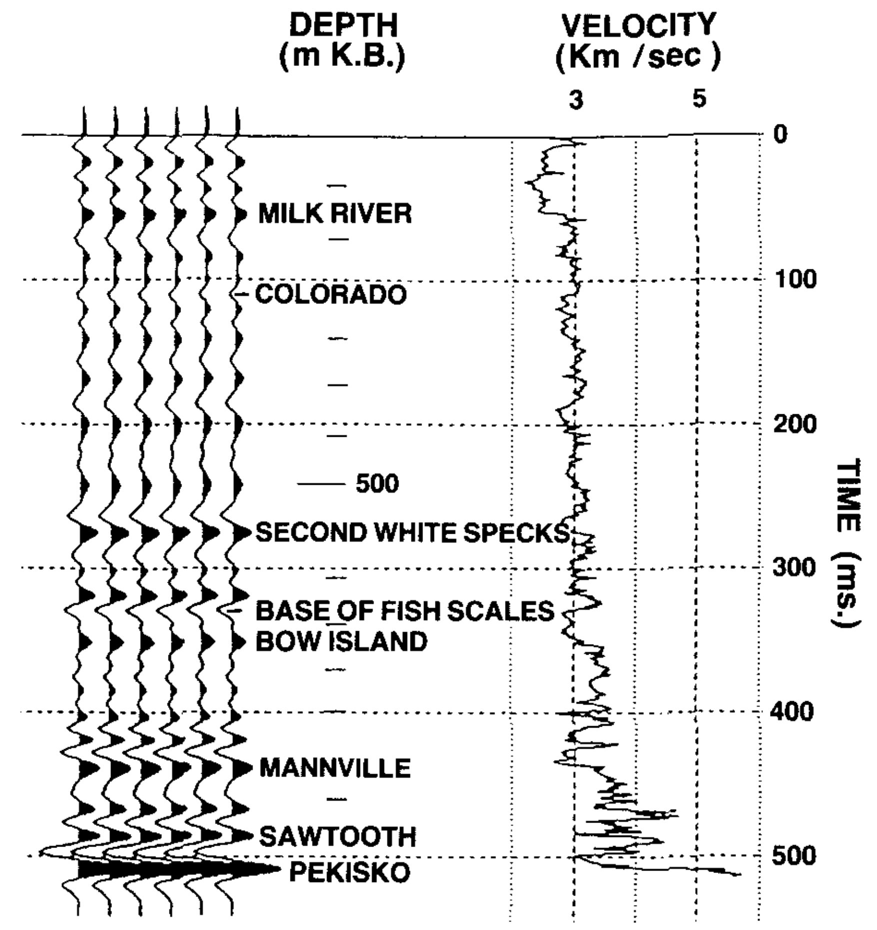

Figure 8.14. Single well synthetic seismic trace, Grand Forks Sawtooth WW pool.

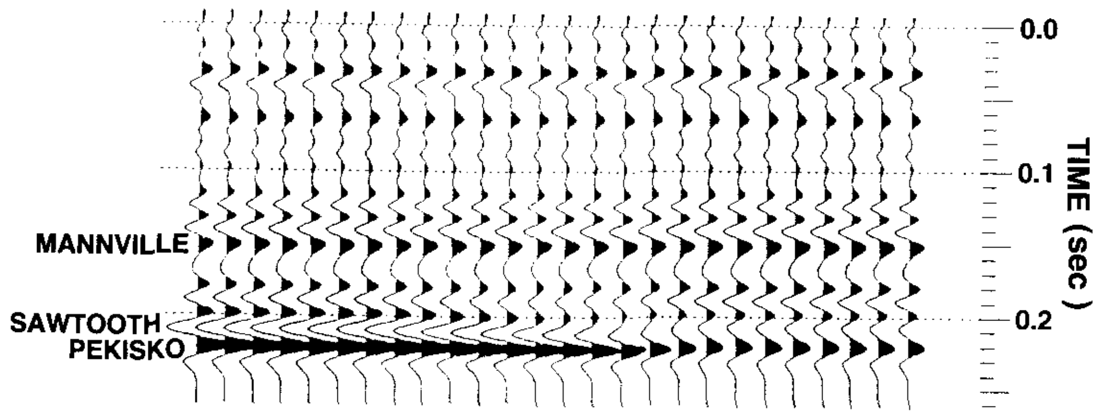

Figure 8.15. Multiwell synthetic seismic model, Grand Forks Sawtooth WW pool.

CONCLUSIONS

The Grand Forks Sawtooth WW pool is formed by a coarsening upwards sandstone which is likely of marine origin. On the assumption that the Sawtooth Fm sandstones are predominantly formed by a marine coarsening upwards sequence, in contrast to the dominantly fining upward fluvial sandstones of the Glauconitic Sandstone member channel facies this pool is classified as Jurassic in age. The ERCB has recently reassigned this and several other pools of the Grand Forks field to the Sawtooth Fm. Recognition of: 1) coarsening upwards cycles as indicative of the marine Sawtooth Fm; and 2) fining upwards sequences as representative of Mannville strata permits a plausible interpretation of the geophysical and geological data.

The seismic signature of the Grand Forks Sawtooth WW pool is provided by a lateral character variation of the data in response to the lateral termination of the Sawtooth Fm sandstones by lower Mannville erosion.

8–3: THE COUNTESS UPPER MANNVILLE D POOL

INTRODUCTION

The Countess Upper Mannville D pool is located in T18 - R15 W4M, 145 km southeast of Calgary, Alberta, within the confines of the Countess field (Fig. 8.16). The 1965 discovery of this pool was the result of a major statistical well commitment to freehold lessors

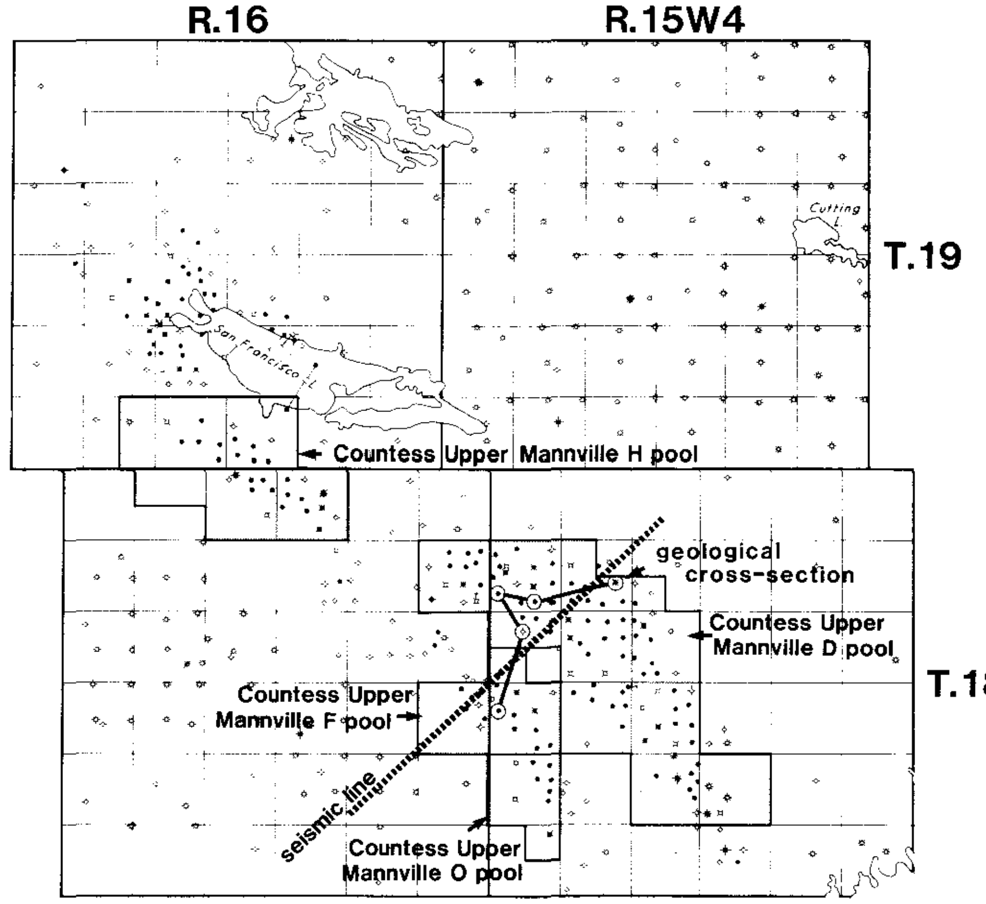

Figure 8.16. Location map, Countess Upper Mannville D pool (courtesy, The Geobase Company Ltd).

in an area where geological studies had shown significant potential (McCoy and Moritz, 1982). Their study consisted of a 26 township area (2500 km^2) containing about one well for every 16 sections. The authors state that geophysical methods available at that time were of little help in delineating the subtle clastic stratigraphic traps they envisioned.

The upper Mannville, Glauconitic Sandstone member of the D pool is described by Farshori (1983) and Herbaly (1974) as channel facies sandstones, although McCoy and Moritz (1982) considered the pool to be marine in deposition. Significant economic potential and excellent geological control make this pool an attractive exploratory model, although direct detection of the reservoir with geophysics is not demonstrated here. However, the geological structure and interval thickness which are coincident to the pools occurrence are delineated. Areas of Mannville, particularly lower Mannville thinning over pre-Cretaceous highs appear to be favorable to deposition of reservoir strata and hydrocarbon entrapment.

In the immediate vicinity of the pool, cuesta like relief is formed by erosion of the Pekisko Fm. Localized thinning of the lower Mannville indicates that the Pekisko Fm was subaerially exposed during a portion of lower Mannville time. Present day dip of the pre-Cretaceous unconformity is to the northwest, plunging away from the northwest flank of the Sweetgrass Arch (Fig. 8.1).

Reserves and significant reservoir parameters for the Countess Upper Mannville D pool are shown in Table 8.3. Productivity data for the pool are shown in Figure 8.17.

Table 8.3: Reserves and significant reservoir parameters, Countess Upper Mannville D pool (ERCB, 1987)

Initial Oil in Place	12900 x $10^3 m^3$
Primary Recovery Factor	10%
Additional Secondary Recovery	33%
Total Recoverable Reserves	5410 x $10^3 m^3$
Cumulative Production to Date	4899.8 x $10^3 m^3$
Remaining Established Reserves	510 x $10^3 m^3$
Area	1538 ha
Average Pay	4.9 m
Average Porosity	25%
Average Water Saturation	20%
Oil Density	904 kg/m^3
Average Depth	1122 m
Discovery Year	1967

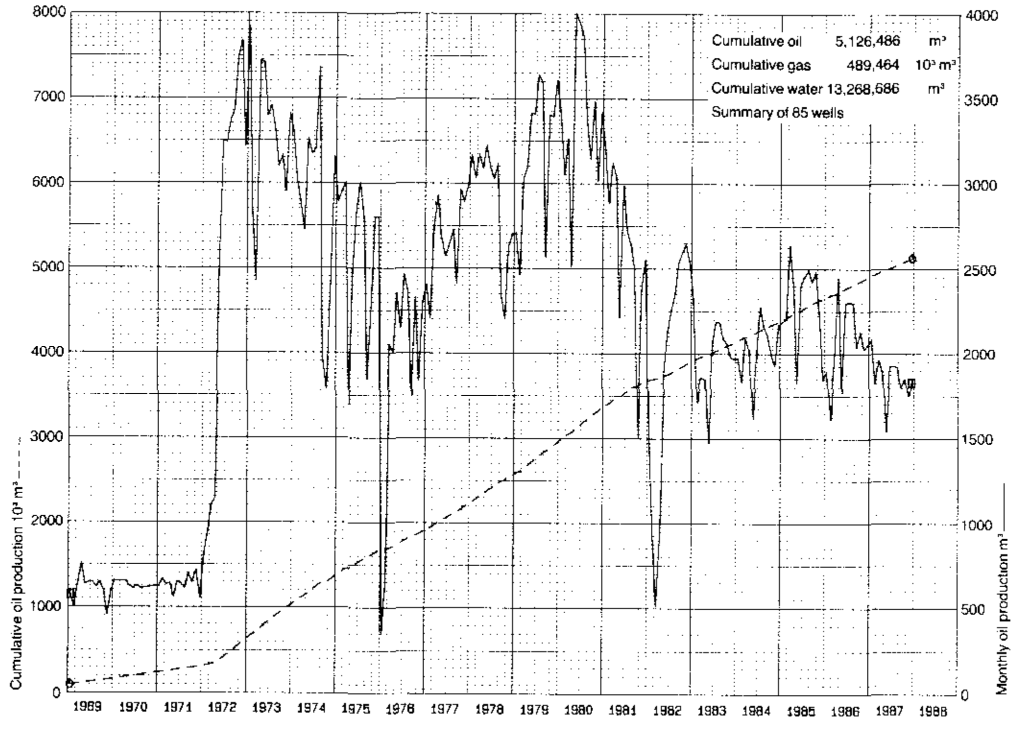

Figure 8.17. Production data, Countess Upper Mannville D pool.

GEOLOGICAL CROSS-SECTION

The geological cross-section (Fig. 8.18) parallels both the schematic section of McCoy and Moritz (1982) and the presented seismic section (Fig. 8.19). This cross-section crosses the Countess Upper Mannville D and O pools perpendicular to their depositional strike and to regional dip. Due to space restrictions the well logs have not been spaced directly over their respective locations along the seismic line.

The lowest identified formation on the cross-section is the Pekisko Fm. Local structural relief is 20 m on the unconformity beneath parts of this pool and results in proportionate lower Mannville thinning. Regional mapping of the Mannville Gp thickness shows the pool to be located on a moderate thin of 130 m as opposed to areas of severe pre-Cretaceous erosion which show Mannville Gp isopachs approaching 190 m. Extreme lower Mannville thinning occurs at the 12-18 location where the Bantry shale lies almost directly on the Pekisko Fm.

Farshori (1983) used a fourfold subdivision of the Ostracod (A,B,C & D) and a twofold subdivision of the channel facies sandstones to describe the pool and its setting. He described cycle A through D as representing a regressive sequence which resulted from the infilling of an extensive "Ostracod" lake in southern Alberta. Cycle A is the Bantry shale, a bentonitic, low velocity shale. Cycle B is a brown fossiliferous limestone, which is commonly referred to as the Ostracod member, while cycles C and D are a bioturbated shale and white sandstone respectively. The units are interpreted as a regressive sequence of sedimentation: 1) below wave-base; 2) lower shoreface; 3) middle shore; and 4) upper shoreface. The C and D cycles of Farshori (1983) are considered to be part of the regional facies of the Glauconitic Sandstone member here.

Farshori (1983) subdivided the Glauconitic Sandstone member into an upper and lower unit based on textural characteristics and mineralogy. He described a distinct channel facies for both of the sandstone units, and suggested deposition occurred in a northwest draining channel system, approximately one kilometre wide and 3 to 12 m deep.

Due to lack of core study in this subsection the subdivisions suggested by Farshori (1983), cannot be replicated. However, the lowermost unit (A cycle or Bantry shale) is shown in all wells on the cross-section. The two off-channel wells are thought to represent a complete and uninterrupted A through D Ostracod sequence, whereas the three displayed channel wells represent the upper and lower Glauconitic Sandstone member channel facies sandstone units with an undetermined portion of the B, C and D Ostracod member units having been eroded.

SEISMIC SECTION

The seismic data (Fig. 8.19) were donated by PanCanadian Petroleum Ltd. and reprocessed courtesy of Exploration Seismic Services Ltd. The line is oriented southwest to northeast, perpendicular to the strike of the Upper Mannville D pool (Fig. 8.16). Identification for the line is shown on the synthetic seismic trace of Figure 8.20. The lowest event indicated on the seismic section is the Pekisko Fm. Paleozoic strata in this area are exposed to the Mannville Gp rather than Jurassic strata. The top of the Pekisko event is identified as a peak, and is characterized by erosional relief. This event is 5 to 10 ms time-structurally high in the vicinity of the D pool (traces 100 - 220) and occurs with coincident Mannville thinning.

Coincident with this relief there is a notable variation in the trough overlying the peak marking the Pekisko Fm. This event

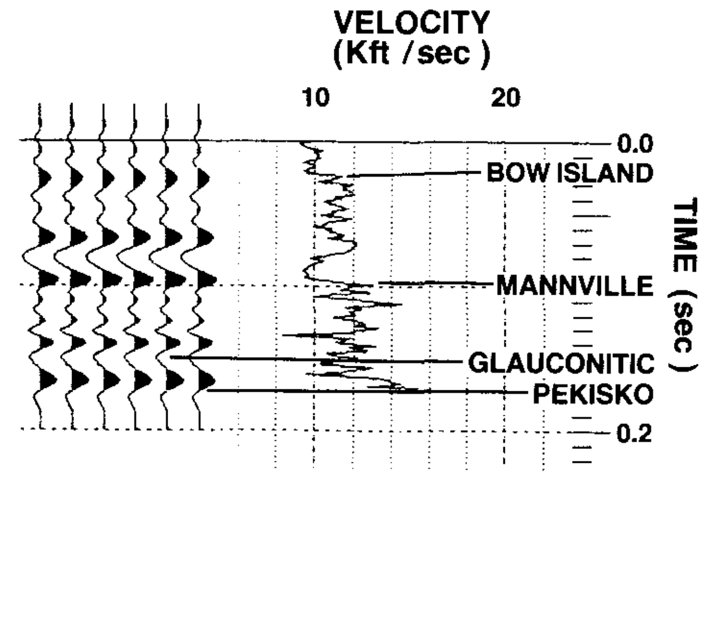

Figure 8.20. Single well synthetic seismic trace, Countess Upper Mannville D pool.

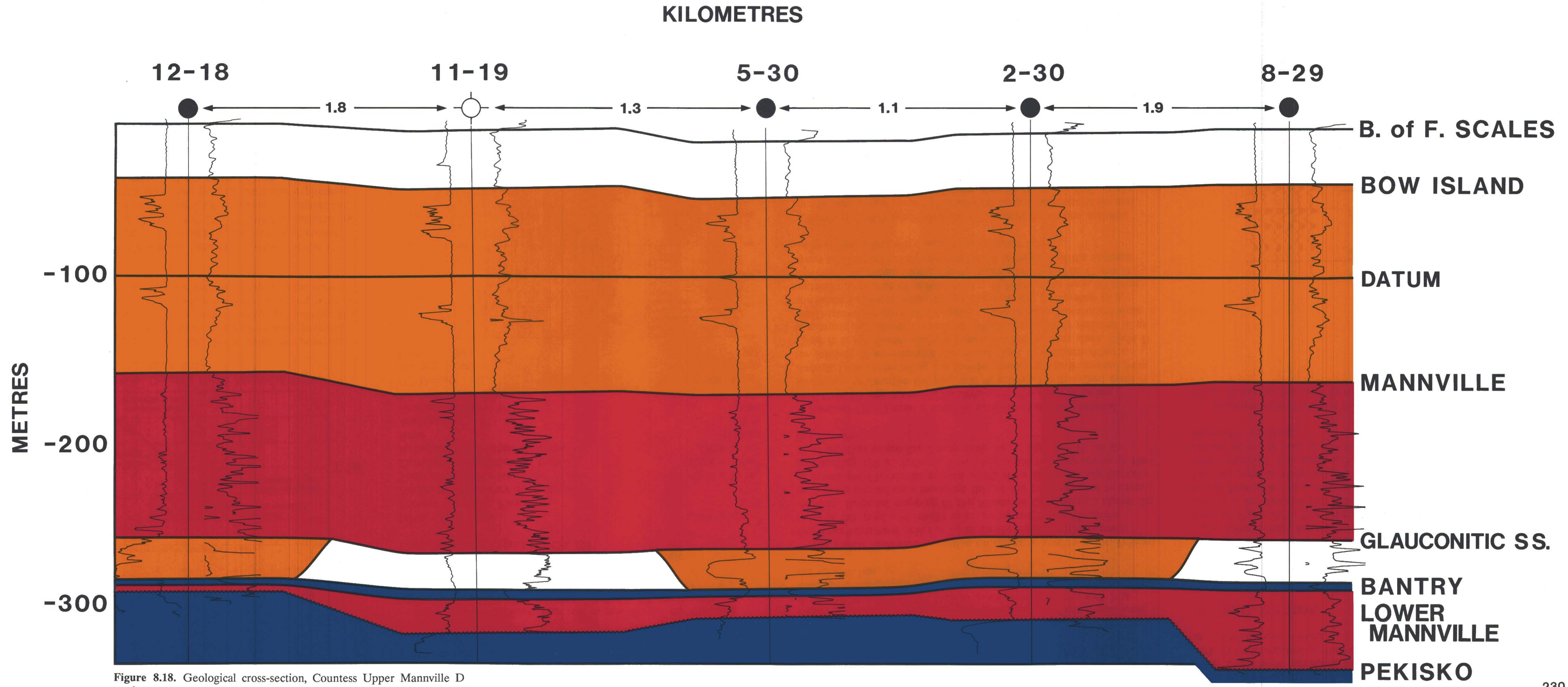

Figure 8.18. Geological cross-section, Countess Upper Mannville D pool.

DRAFTING: K. GRIMSON | LOG PLOTS: | AUTHOR: D. CEDERWALL

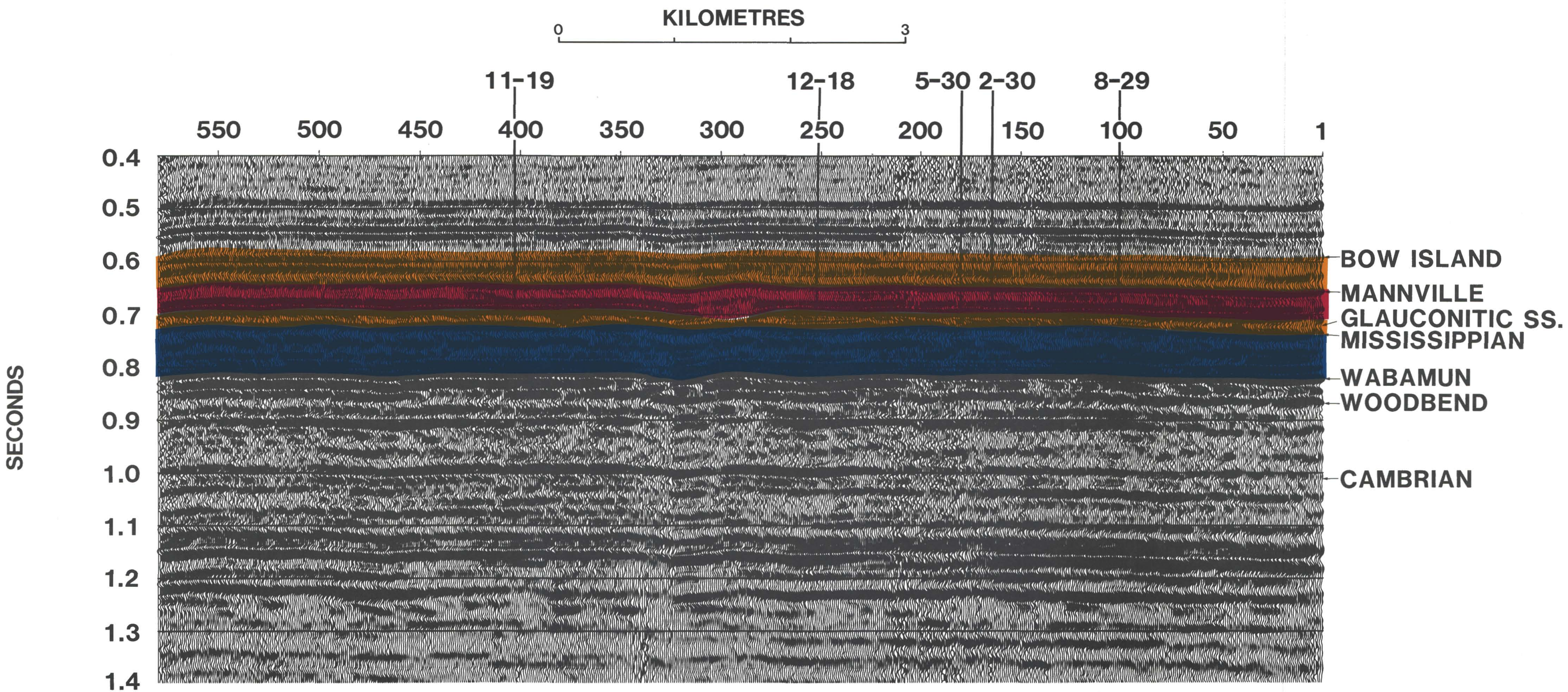

Figure 8.19. Seismic section, Countess Upper Mannville D pool.

DONOR: PANCANADIAN PETROLEUM LIMITED | PROCESSOR: EXPLORATION SEISMIC SERVICES LTD., M. BROOME | AUTHOR: D. CEDERWALL, C. BRIERE

changes from a broad doublet to a single trough across the high, as a result of lower Mannville thinning. Unlike the Bow Island Glauconite A pool and Badger Upper Mannville B pool of this chapter, the channel facies of the Glauconitic Sandstone member does not have a significant seismic signature. This is attributed to the lateral uniformity of the Bantry shale beneath the reservoir, and the absence of a velocity contrast between regional facies and channel facies strata. However, the lateral character change from trace 290 to 310 may be representative of an area where the Bantry shale is absent. The positioning of the previously noted character change and the time-structural low between traces 290 through 310 could be significant in identifying the O pool, which shows less thinning of the Mannville than the D pool.

Some time structural relief on the Mississippian and corresponding lower Mannville thinning, occurs from trace 330 to 440 on the data. The time structure is not of the magnitude expected on examination of the 12-18 well log, and is likely due to the off-line position of the well location.

CONCLUSIONS

The Countess Upper Mannville D pool occurs in an area with marked relief on the pre-Cretaceous unconformity and corresponding lower Mannville thinning across a paleotopographic high. These features are mappable with seismic data. Unlike the Bow Island Glauconite A (8-1) and the Badger Upper Mannville B (8-4) pools, the reservoir itself has no diagnostic seismic signature. Lateral velocity contrast between regional facies and channel facies sandstones observed in examples 8-1 and 8-4 are not observed in this example. This absence of a lateral velocity contrast could be due to shale content, secondary cementation or compaction of the reservoir sandstones.

8–4: BADGER UPPER MANNVILLE B POOL

INTRODUCTION

The Badger Upper Mannville B pool is located in T16 - R18 W4M some 140 km southeast of Calgary, Alberta (Fig. 8.21) and produces 940 kg/M^3 oil from the Glauconitic Sandstone member. The reservoir, which is in a channel facies, is analogous to the adjacent Little Bow and Retlaw fields (Hopkins et al. 1982). A threefold subdivision of: 1) regional facies; 2) channel facies; and 3)

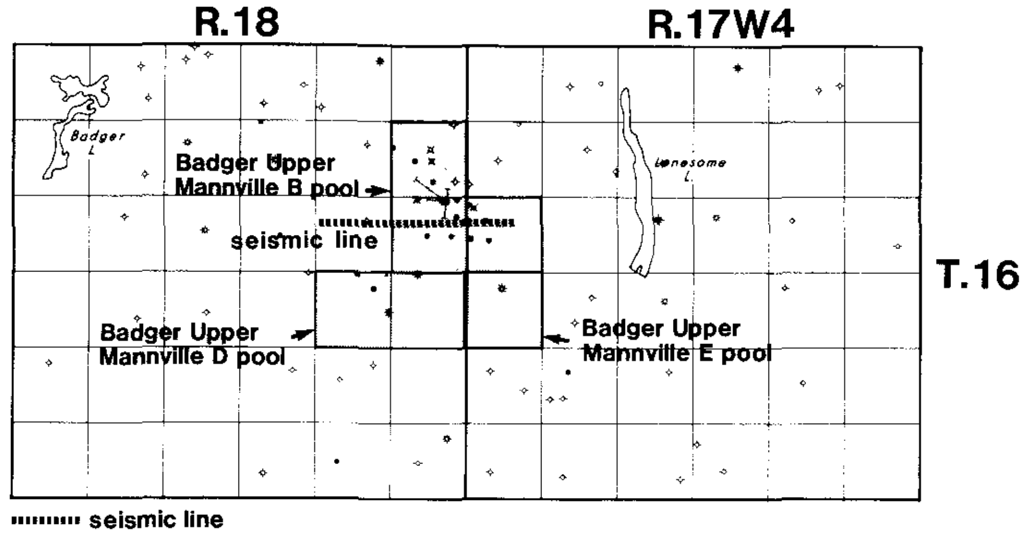

Figure 8.21. Location map, Badger Upper Mannville B pool (courtesy, The Geobase Company Ltd).

non-reservoir channel facies is utilized in the description of the Glauconitic Sandstone member at Badger. A definition of these facies is given in subsection 8-1 of this chapter. The reservoir sandstone at Badger is a part of a laterally extensive channel fill which is dominated by non-reservoir strata. This major channel variably cuts through the Bantry shale, Ostracod member and the thinly bedded regional facies of the Glauconitic Sandstone member. Vertical incision of the channel may be restricted to only post Bantry strata, or may cut well into lower Mannville and Mississippian strata (Fig. 8.22). The Badger Upper Mannville B pool occurs on the western flank of one such cut. The majority of the producing wells in the pool do not show the channel facies to have eroded below the Bantry shale. However, the Bantry is absent in producing wells such as 16-25-16-18 W4M. East of the pool, the Bantry shale is absent along a southeast to northwest trend. Strata at the Glauconitic Sandstone member interval in these wells are not correlative with the regional facies or the channel facies reservoir sandstones and are interpreted as non-reservoir channel fill. This sequence is diagrammatically represented in Figure 8.22. Several wells immediately west of the channel facies produce from the thin sandstones of the regional facies. It is uncertain as to whether these wells are in hydraulic communication with the channel facies or if the channel acts as a trap.

The Badger Upper Mannville B pool is located on the northwest flank of the Sweetgrass Arch, north of the subcrop of the Sawtooth and Rierdon formations. Subcrop in this area is formed by carbonates of the Pekisko Fm which is moderately high in the pool area. The pool trends northwest to southeast with the reservoir (the channel facies) being roughly one kilometre wide and contained within a 4 to 6 km wide non-reservoir channel facies. The length of the reservoir channel facies is indeterminate from present well control, but appears to be more than five kilometres. A gas cap is present in the 10-18-16-17 W4M well and an oil-water contact occurs in the downdip wells of section 24-16-18 W4M. The best producing wells in the pool occur where neither fluid interface is intersected by the wellbore. The Badger Upper Mannville B Pool contains 2350 x 10^{3}M^3 of oil in place, of which some 656 x 10^{3}M^3 are recoverable. Recovery factors which are estimated at 13% primary, plus 27% secondary under water flood (ERCB, 1986), are good for a reservoir containing 940 Kg/m^3 oil. Porosity of the reservoir sandstone averages 23% and can be as great as 29%. The sandstone unit has a characteristic sharp basal contact, and tends to increase in shale content vertically. Additional reserves and reservoir parameters of the Badger Upper Mannville B pool are given in Table 8.4. Productivity data for the pool are shown in Figure 8.23.

Table 8.4: Reserves and significant reservoir parameters, Badger Upper Mannville B pool (ERCB, 1987)

Initial Oil in Place	2350 x 10^{3}m^3
Primary Recovery Factor	13%
Addition Secondary Recovery Factor	27%
Initial Established Reserves	656 x 10^{3}m^3
Production to Date	46.7 x 10^{3}m^3
Remaining Established Reserves	609.3 x 10^{3}m^3
Area	273 ha
Average Pay	6.4 m
Average Porosity	23%
Average Water Saturation	24%
Oil Density	940 kg/m^3
Average Depth	1114 m
Discovery Year	1983

GEOLOGICAL CROSS-SECTION

Electric logs from five wells across the Badger Upper Mannville B pool area are displayed on a west to east structurally datumed cross-section (Fig. 8.24). The area covered on the geological cross-section is significantly longer than that of the seismic section, (Fig. 8.25) in order to illustrate the relationship of the regional facies

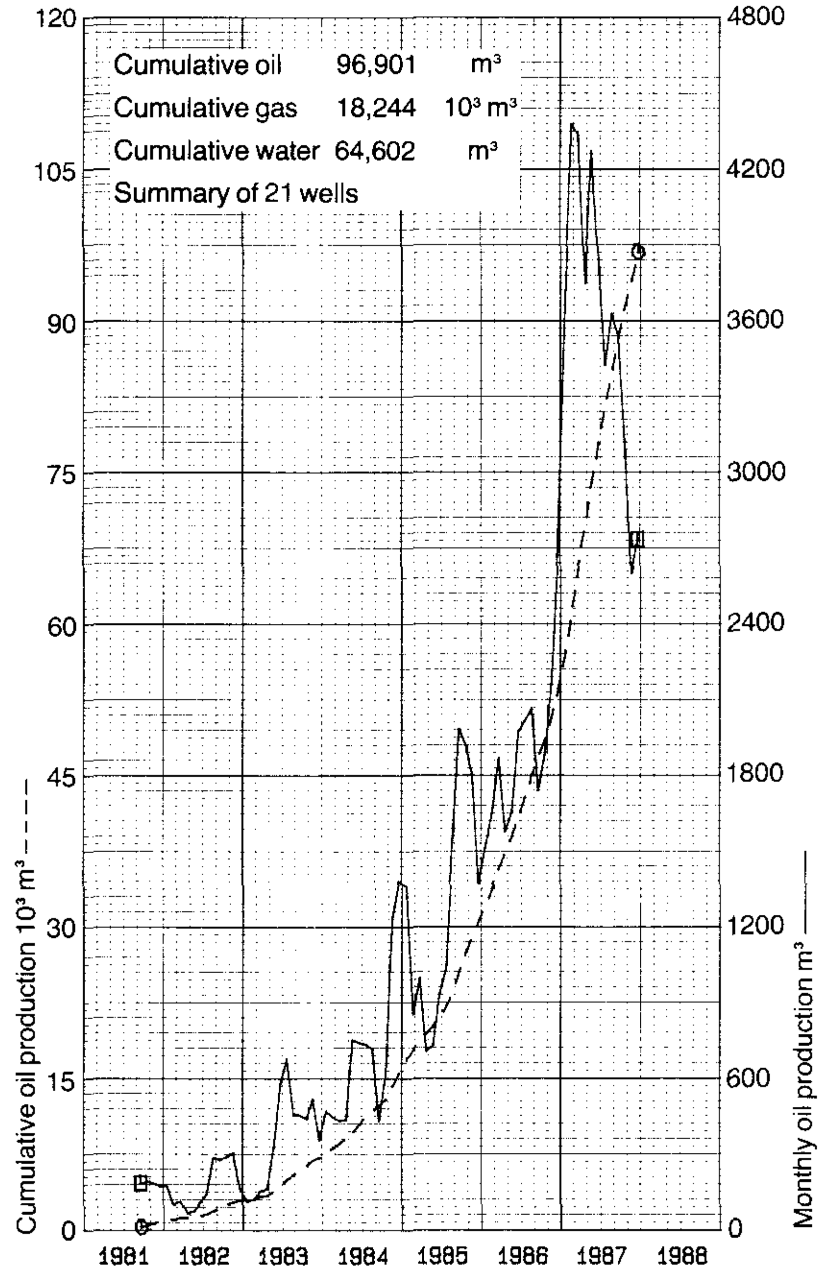

Figure 8.23. Production data, Badger Upper Mannville B pool.

to the channel facies and non-reservoir channel facies of the Glauconitic Sandstone member.

The 10-24 and the 6-19 wells of Figure 8.24 are typical of producing wells within the channel facies, whereas the 11-19 well is interpreted as occurring on the channel edge. The non-reservoir channel facies is schematically represented on the section and occurs in a laterally extensive area between the 11-19 and 7-24 locations. This area is typified by an absence of the Bantry shale, indicative of

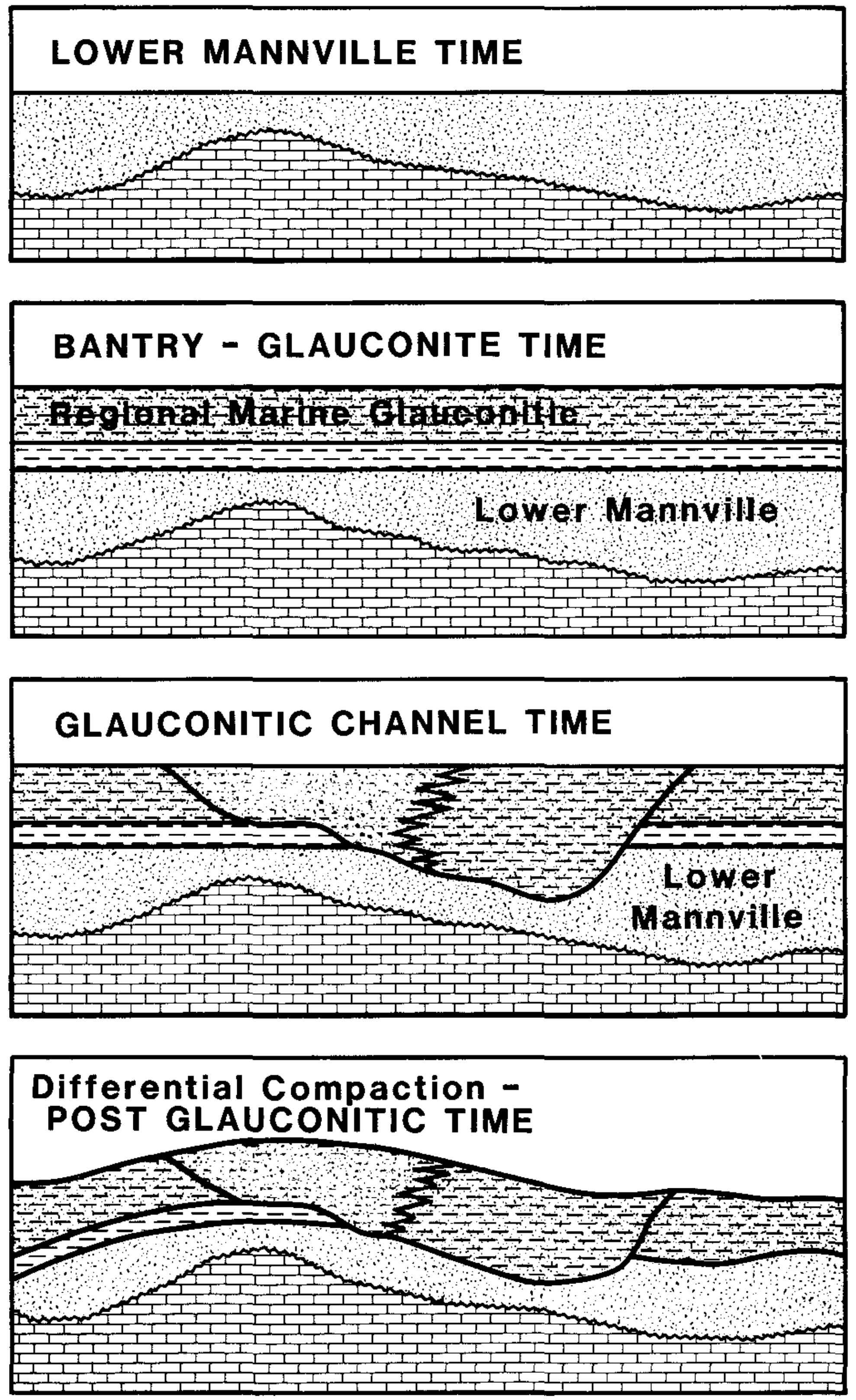

Figure 8.22. Schematic geological cross-section in the area of the Badger Upper Mannville B pool.

upper Mannville channeling. The Glauconitic Sandstone member in the non-reservoir channel facies does not exhibit the same porosity and permeability as the sandstones of the channel facies and are generally shaly and silty sandstones. No direct relationship is observed between pre-Cretaceous structure and the location of the channel facies. However, post-depositional structure at the Glauconitic Sandstone member level is controlled by compaction of the underlying lower Mannville strata across the pre-Cretaceous unconformity.

Further discussion of deposition of the Glauconitic Sandstone member is presented inHopkins et al. (1982) and Hradsky and Griffin (1984).

SEISMIC SECTION

Seismic data for the Badger Upper Mannville B pool were donated by Bow Valley Industries Ltd. and are displayed in reprocessed format courtesy of Poco Petroleums Ltd. The seismic line (Fig. 8.25) is oriented west to east along the southern edge of section 24-16-18 W4M. This line crosses the regional facies, the channel facies, and possibly the non-reservoir channel facies of the Glauconitic Sandstone member. Identification of the seismic events are shown on Figures 8.26. The regional facies which is characterized by the presence of the underlying Bantry shale, consists of thinly bedded marine sandstones and shales. The seismic signature of this unit is recognized to the west of trace 145 (at about 700 ms) and in descending order, consists of a weak peak (regional facies event), followed by a strong trough (lower Mannville event) and strong peak (Mississippian event).

The channel facies anomaly occurs between traces 145 and 57 and is characterized by both the absence of the regional facies event and a broad trough at the Glauconitic - Bantry - lower Mannville event. Both effects are due to the additive low velocities of the channel facies and the Bantry shale. East of trace 57 the signature of the non-reservoir channel facies is illustrated. This seismic signature is not distinguishable from the regional facies, and an absence of well control on this portion of the line leaves some uncertainty as to the existence of the non-reservoir channel facies at this location.

Time structural relief of 5 to 10 ms is observed along the Mannville Gp reflection, on the eastern portion of the line (Fig. 8.25). This structure is not coincident with the occurrence of the previously described channel facies anomaly. Time structural relief also occurs along the Pekisko Fm reflector (peak at 800 ms)

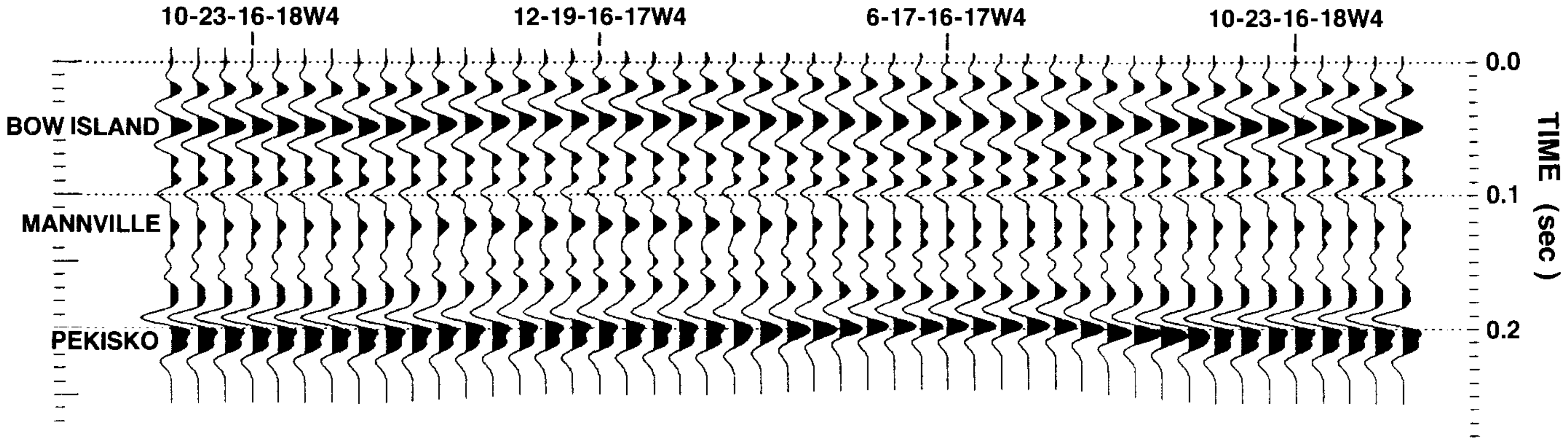

Figure 8.26. Multiwell synthetic seismic model, Badger Upper Mannville B pool, and corresponding geological model.

coincident with the pool. This observed time relief occurs in conjunction with a character change along the Pekisko reflector and could be partially generated by tuning.

A seismic model utilizing sonic logs for wells in the regional facies, channel facies and non-reservoir channel facies is shown in Figure 826. This model replicates the anomalous feature observed on the seismic section (Fig. 8.25).

CONCLUSIONS

The Badger Upper Mannville B pool is formed by an upper Mannville channel sandstone which is detectable with seismic data. Recognition of the reservoir is dependent on the frequency content and more importantly proper phase correction of the seismic data. The seismic signature is due to the lateral contrast of low velocity channel facies sandstones with higher-velocity regional facies strata, and the constructive interference of the low-velocity channel facies and the low-velocity Bantry shale reflection.

8–5: TABER MANNVILLE A POOL

INTRODUCTION

The Taber Mannville A pool is located in T9 - R17 W4M, about 180 km southeast of Calgary, Alberta (Fig. 8.28) within a wide pre-Cretaceous erosional cut and illustrates the entrapment of oil in the lower Mannville, Taber Sandstone member channel. These sandstones fill a north to south trending pre-Cretaceous low termed the Cut Bank Valley (Hayes, 1986). This valley trends northward and could join the Spirit River valley of McLean (1977), as suggested by Jackson (1985, p. 65, Fig. 19). The informal term "Taber Sandstone

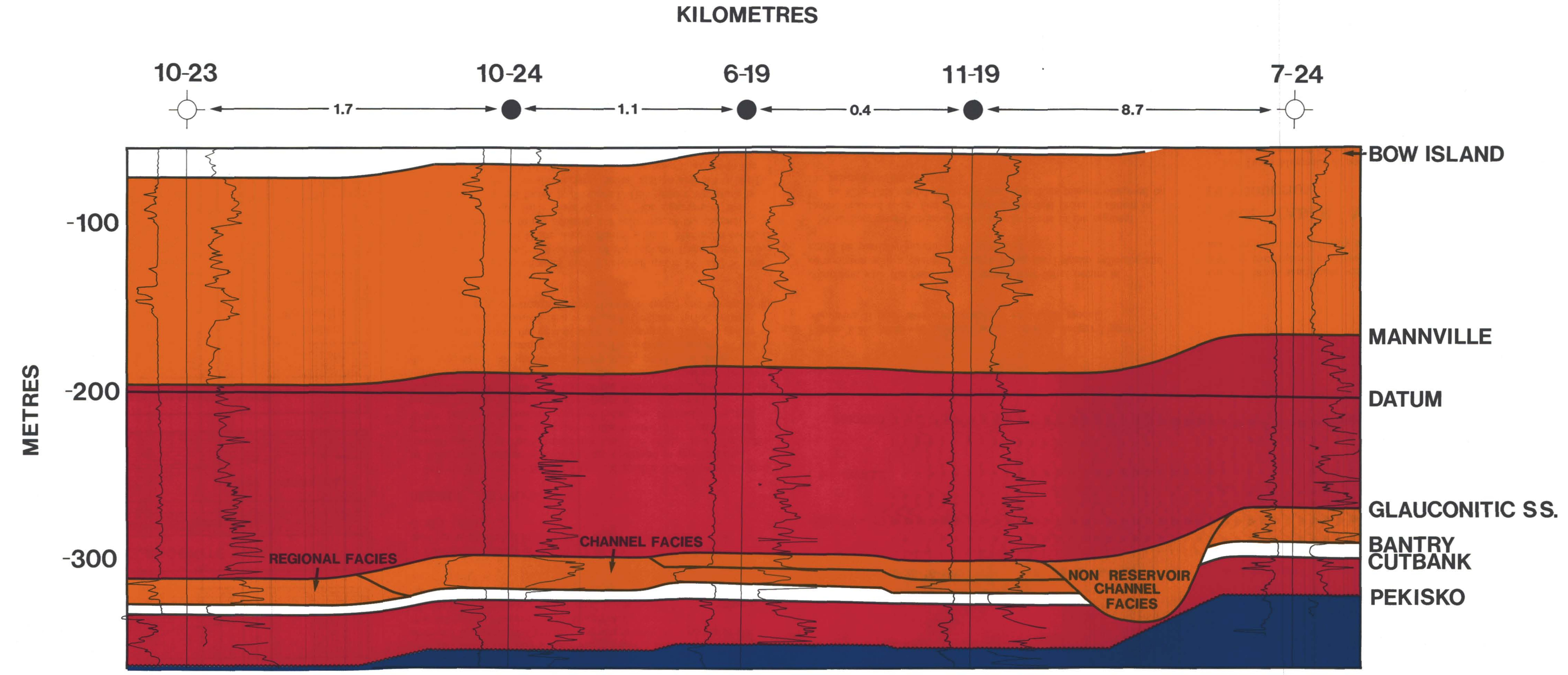

Figure 8.24. Geological cross-section, Badger Upper Mannville B pool.

DRAFTING: K. GRIMSON | LOG PLOTS: | AUTHOR: D. CEDERWALL, B. PETRIE

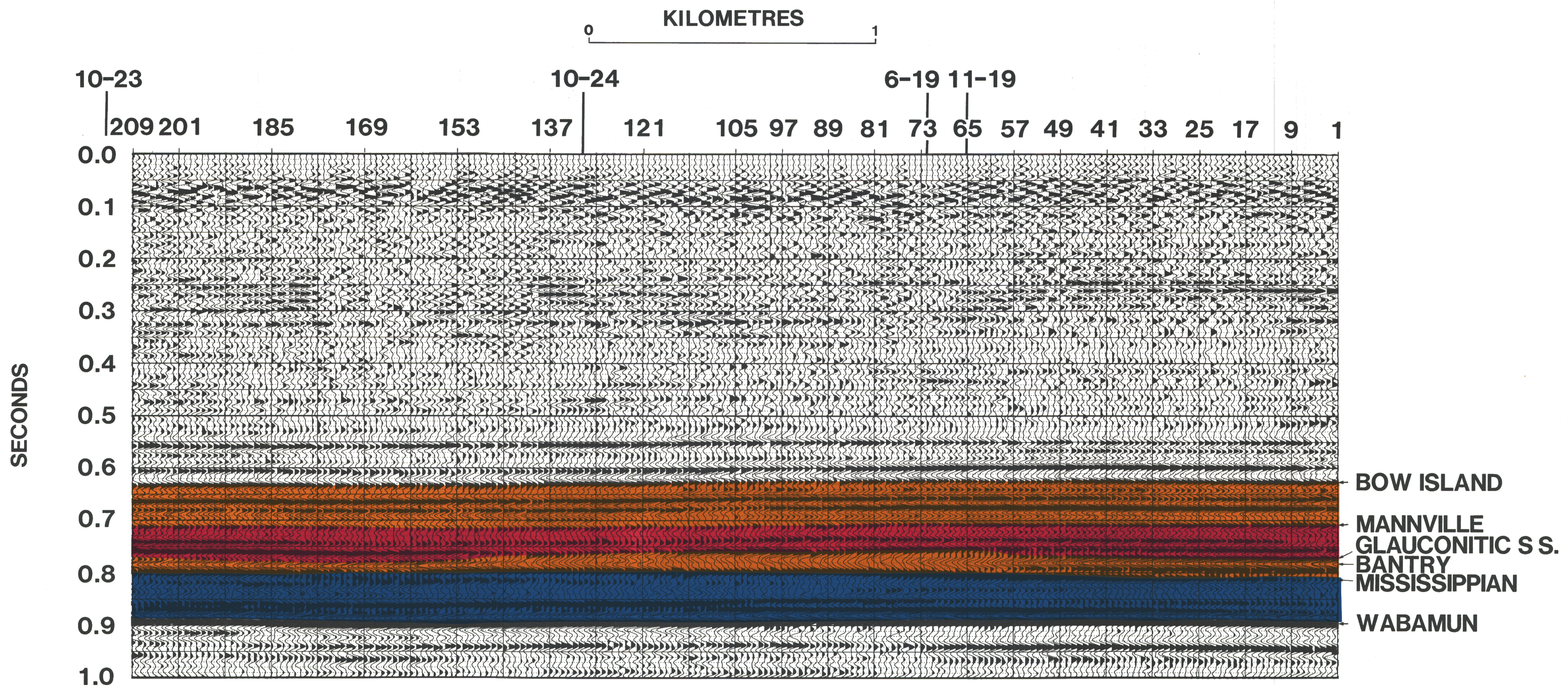

Figure 8.25. Seismic section, Badger Upper Mannville B pool.

DONOR: BOW VALLEY INDUSTRIES LTD. | PROCESSOR: POCO PETROLEUMS LTD. | AUTHOR: D. CEDERWALL, B. EVANS, I. BAKER

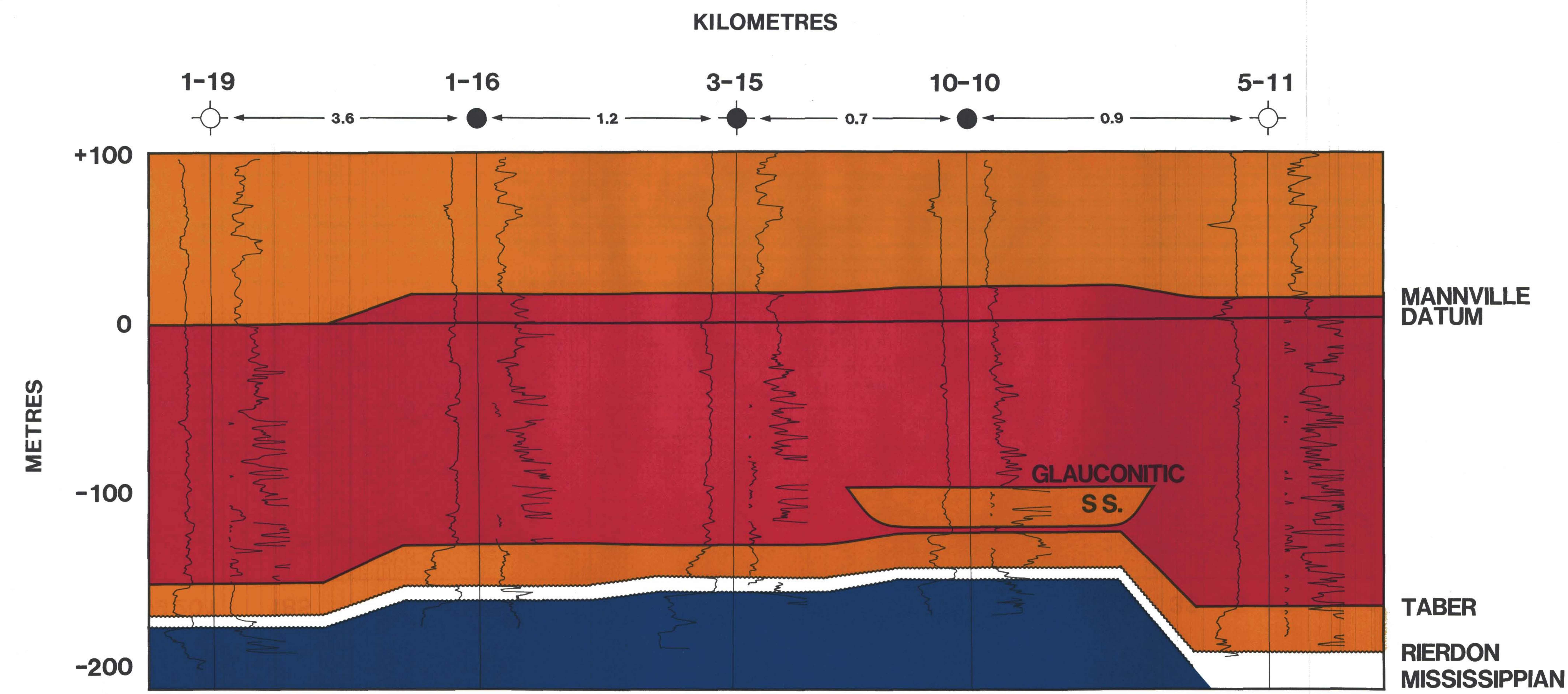

Figure 8.31. Geological cross-section, Taber Mannville A pool.

DRAFTING: K. GRIMSON | LOG PLOTS: | AUTHOR: D. CEDERWALL

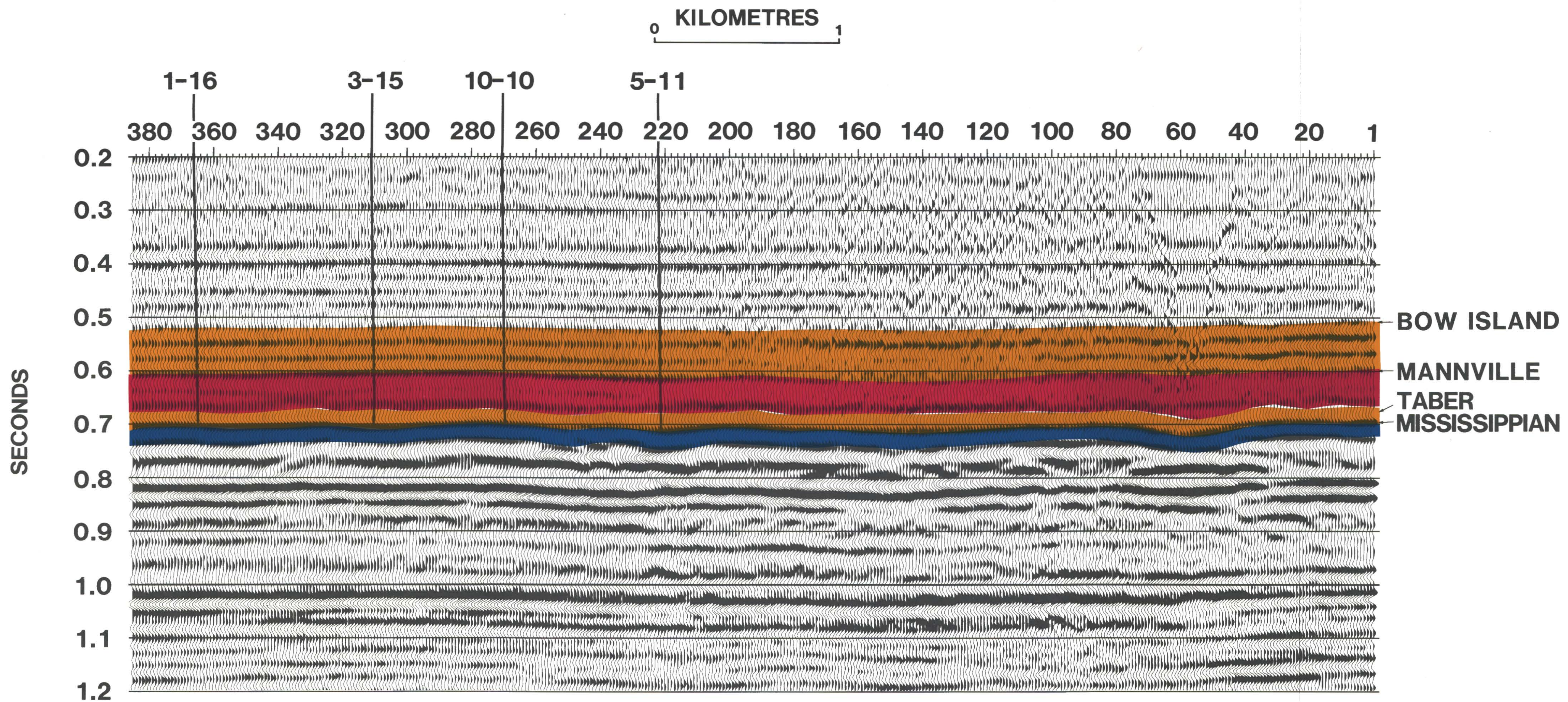

Figure 8.32. Seismic section, Taber Mannville A pool.

DONOR: | PROCESSOR: DATASPAN TECHNOLOGY LTD., P. CHERNOFF | AUTHOR: D. CEDERWALL

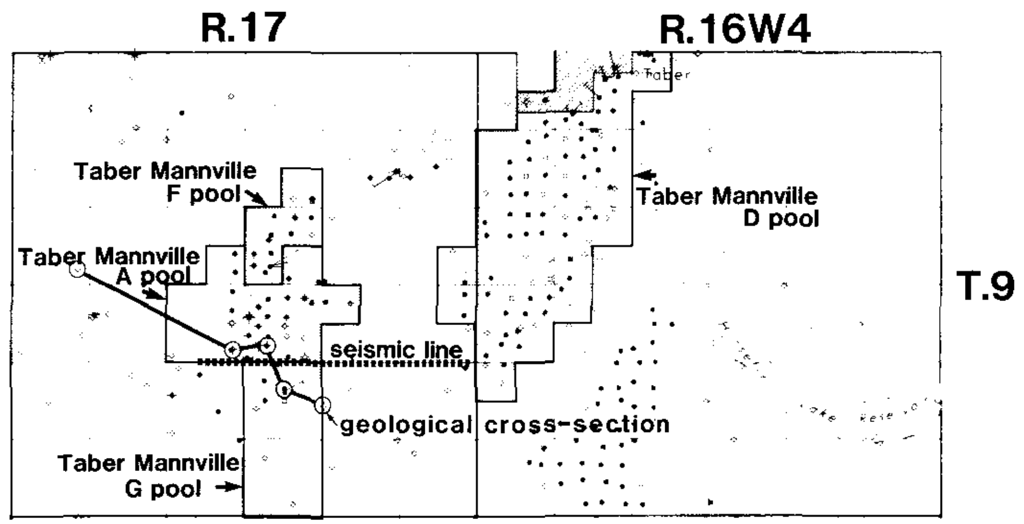

Figure 8.28. Location map, Taber Mannville A pool (courtesy, The Geobase Company Ltd).

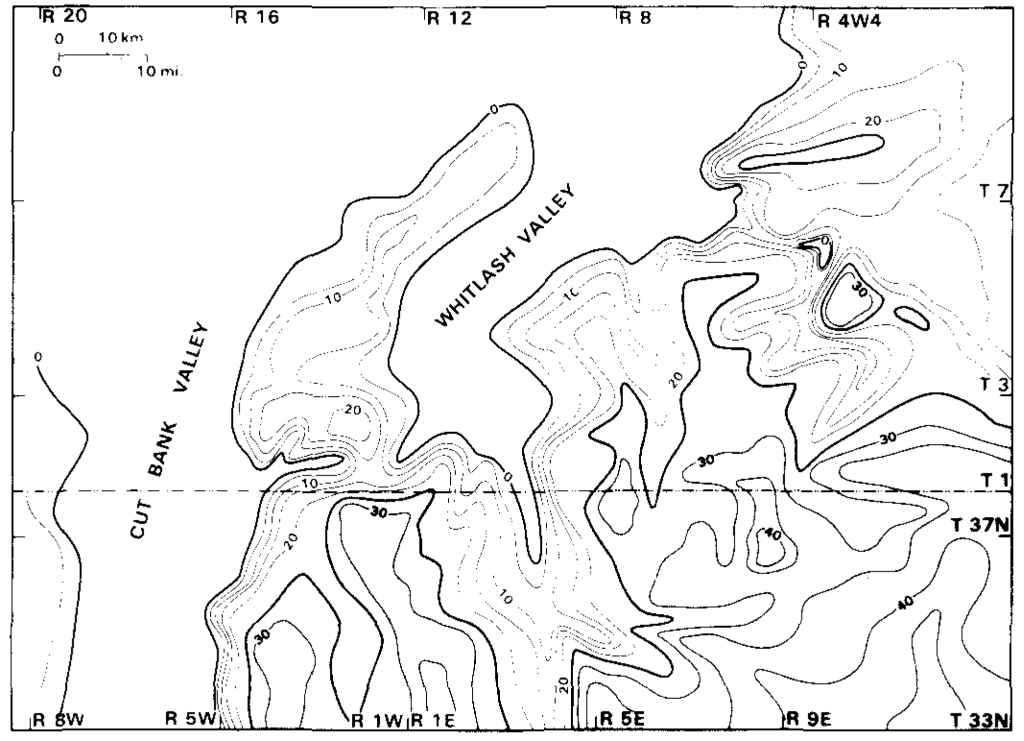

Figure 8.29. Isopach of the Taber Sandstone member in the vicinity of the Taber Mannville A pool (from Hayes, 1986).

member" is utilized in this subsection and is considered to be the equivalent of the informal "Cutbank member sandstone" described by Hayes (1986). Four styles of hydrocarbon traps are recognized for the Taber Sandstone member in this area. The first style, as illustrated by the A pool, is structural closure on the Taber Sandstone member which is post-depositional in age. Other economically significant reservoirs occur where the Taber Sandstone member is truncated in an updip position by the non-reservoir channel facies of the Glauconitic Sandstone member or are terminated by pinchout against the valley edge. Hradsky and Griffin (1984) also described trapping by lateral facies changes within the Taber Sandstone member due to late channeling and associated non-reservoir channel facies strata. The Taber Mannville A pool is positioned near the central axis of the Cut Bank Valley (Hayes, 1986). His mapping showed that the pool is located in an isopach thick where the lower Mannville and Taber Sandstone member isopachs are 40 and 25 m respectively (Fig. 8.29). Subcrop in the area of the pool is formed by the Rierdon Fm. The Swift Fm, which is absent in the vicinity of the pool, is preserved to the east where it forms the edge of the Cut Bank Valley (Hayes, 1986).

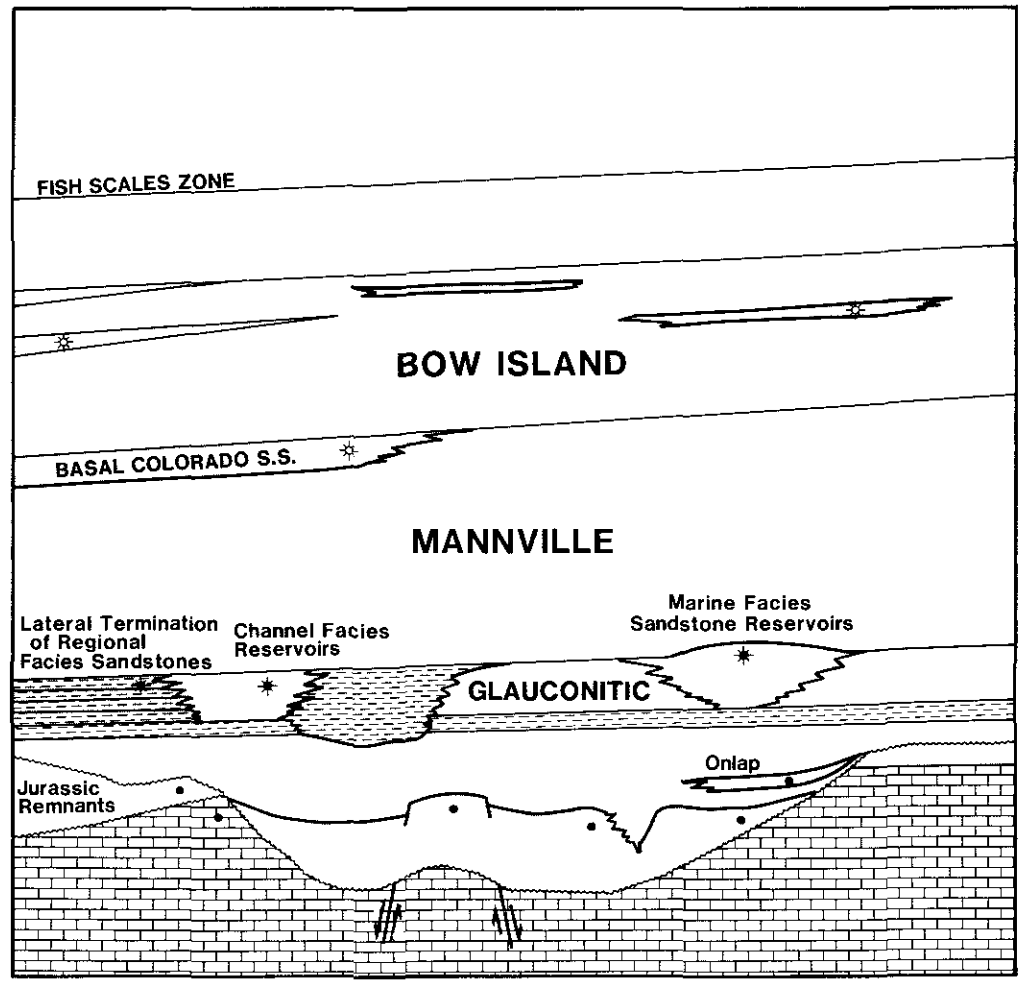

Figure 8.30. Schematic geological cross-section of the Lower Cretaceous strata in the vicinity of the Taber Mannville A pool.

Taylor (1984) described a significant Mississippian low and lower Mannville thick in this area which he termed the Taber Low. This low is slightly narrower than that described by Hayes (1986). Taylor's data supports pre- and post-Taber karsting of Mississippian or older strata as a cause of the valley and source of local structure within the channel. This postulated trapping mechanism is schematicaly depicted in Figure 8.30.

Strata of the Taber Sandstone member are described by Hayes (1986) as "predominantly quartz and chert sandstone, most commonly medium-grained but ranging from very fine to coarse with conglomerate beds, a lack of marine fossils, locally abundant mudstone rip up clasts, a predominance of massive bedding and planar cross bedding, abundant scouring and fining upward sequences". Hradsky and Griffin (1984), proposed a braided stream environment for this unit. Reserves and significant reservoir parameters for the Taber Mannville A pool are shown in Table 8.5. Production data for the pool are shown in Figure 8.33.

Table 8.5: Reserves and significant reservoir parameters, Taber Mannville A pool (ERCB, 1987)

Initial Oil in Place	1140 x 10^3m^3
Primary Recovery Factor	20%
Total Established Recoverable Reserves	228 x 10^3m^3
Cumulative Production	209.8 x 10^3m^3
Remain Established Reserves	18.2 x 10^3m^3
Area	264 ha
Average Pay Thickness	3.37 m
Average Porosity	21%
Water Saturation	35%
Oil Density	921 kg/m^3
Mean Formation Depth	983 m
Discovery Year	1944

GEOLOGICAL CROSS-SECTION

Five electric logs from T9-R17 W4M are arranged in a west to east sequence, Figure 8.31, showing structural closure of the lower Mannville, Taber Sandstone member across the subject pool. The section incorporates strata from the Mississippian Turner Valley Fm through the Lower Cretaceous Bow Island Fm. The Turner Valley Fm is overlain by the shale of the Rierdon Fm and of note is the absence of the sandstones of the Sawtooth Fm which occur to the east in this area. The Rierdon Fm is overlain by the Taber Sandstone

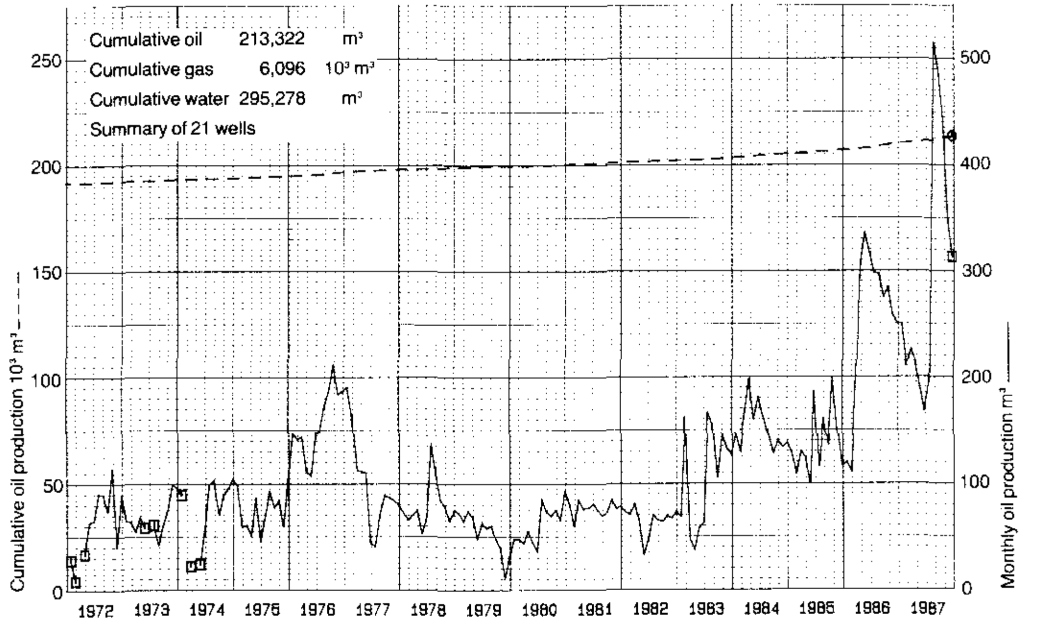

Figure 8.33. Production data, Taber Mannville A pool.

member which is roughly 20 m in thickness across this section. The Taber Sandstone member is surprisingly uniform in thickness in spite of substantial pre-Cretaceous relief. This suggests that much of the present day structure on the Taber Sandstone member postdates its deposition. It appears to be a fining upwards unit particularly in the 3-15-9-17 W4M well. Evidence for localized channeling in the Glauconitic Sandstone member interval is present in the 10-10-9-17 W4M well, however this non-reservoir channel facies does not appear to cut into the Taber Sandstone member.

SEISMIC SECTION

Seismic data for the Taber Mannville A pool (Fig. 8.32) were donated by Gordon Capital Ltd., and reprocessed by Dataspan Technology Ltd. The location of the seismic section and the geological cross-section are shown in Figure 8.28. These data do not extend to the eastern edge of the Cut Bank Valley or Taber Low, however they do show the rugged relief on the Mississippian similar to that described by Taylor (1984). Identification of the seismic events of Figure 8.32 are shown on the synthetic seismic section of Figure 8.34.

Notable on the line is the relatively uniform thickness of the Taber Sandstone member interval over structure on the pre-Cretaceous unconformity. Mississippian strata, particularly the units which occur from 700 to 800 ms along the line, show numerous lateral structural and character variations. These features do not

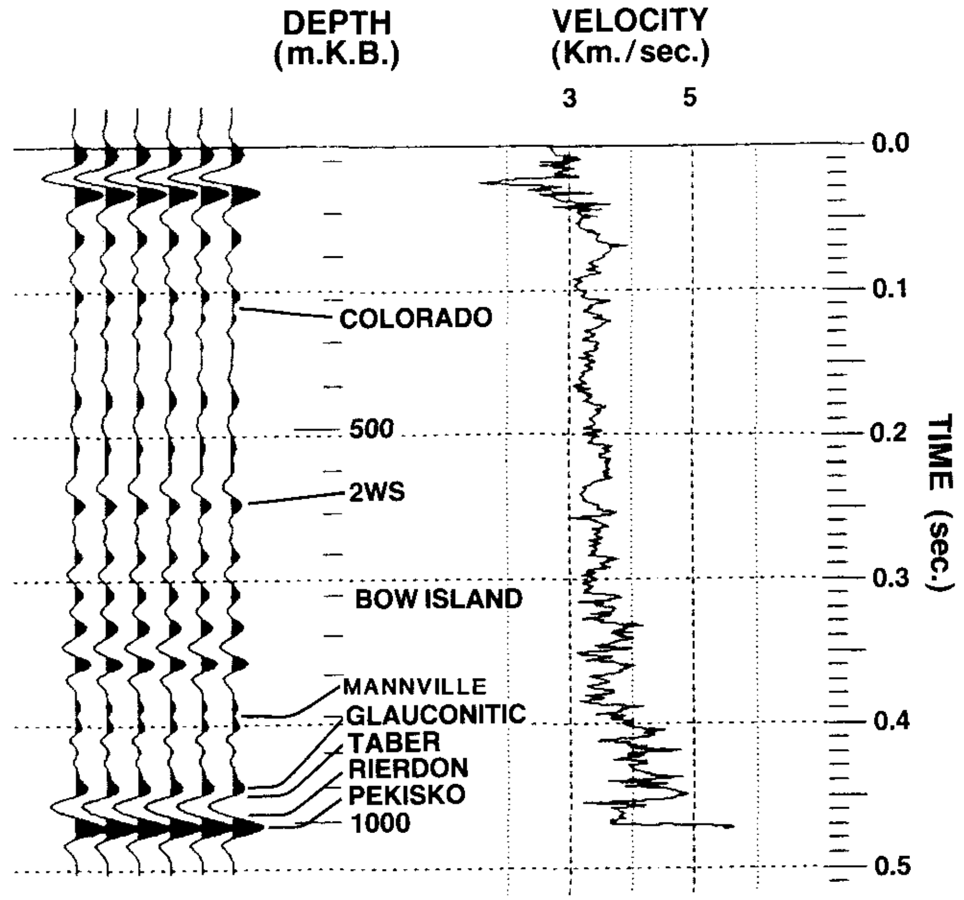

Figure 8.34. Single well synthetic seismic trace, Taber Mannville A pool.

appear to be deep seated in origin (ie. pre-Mississippian), nor do any associated salts occur in the Mississippian section which could cause what appears to be dissolutional structures. It is concluded, that the observed lateral character and time-structural variations of the Mississippian event are caused by dissolution of the Mississippian carbonates. Much or all of these structures postdate the Taber Sandstone member because it does not onlap them but continues across them.

CONCLUSIONS

The Taber Mannville A pool is located in a substantial north to south trending low termed the Cut Bank Valley (Hayes, 1986). This valley, which formed a drainage axis in post-Jurassic time, contains fluvial sediments of the Taber Sandstone member. An isolated structural closure is mapped on the Taber Sandstone member across the pool. This closure is likely due to a remnant Mississippian high in an area of post-Taber dissolution of Mississippian carbonates, and is one of four types of trapping mechanisms which occur in the Taber Sandstone member of this area.

8–6: WESTHAZEL G.P. SAND POOL

INTRODUCTION

The Westhazel G.P. Sand pool is located in T50 - R22 W3M approximately 75 km east of Lloydminster, Saskatchewan (Fig. 8.35). The pool illustrates the trapping of heavy oil where the normal monoclinal southwestern dip is locally reversed as a result of dissolution of the underlying Prairie Evaporite Fm salt. This pool is an excellent model in that it illustrates the relationship between the period of salt dissolution and the resultant lateral thickening of overlying strata.

The Westhazel pool, (specifically sections 33,34 and 35-50-22 W3M) produces from the sandstones of the General Petroleums (G.P.) and the Sparky members (Mannville Gp). The G.P. member (Fig. 8.1) is placed in the informal middle Mannville Gp subdivision of Vigrass (1977) and Putnam (1982). Their subdivision which includes the Sparky, Rex, G.P., and Lloydminster members in the middle Mannville, is based on the conclusion that all of these strata share a dominantly marine genesis. This example is not an exception

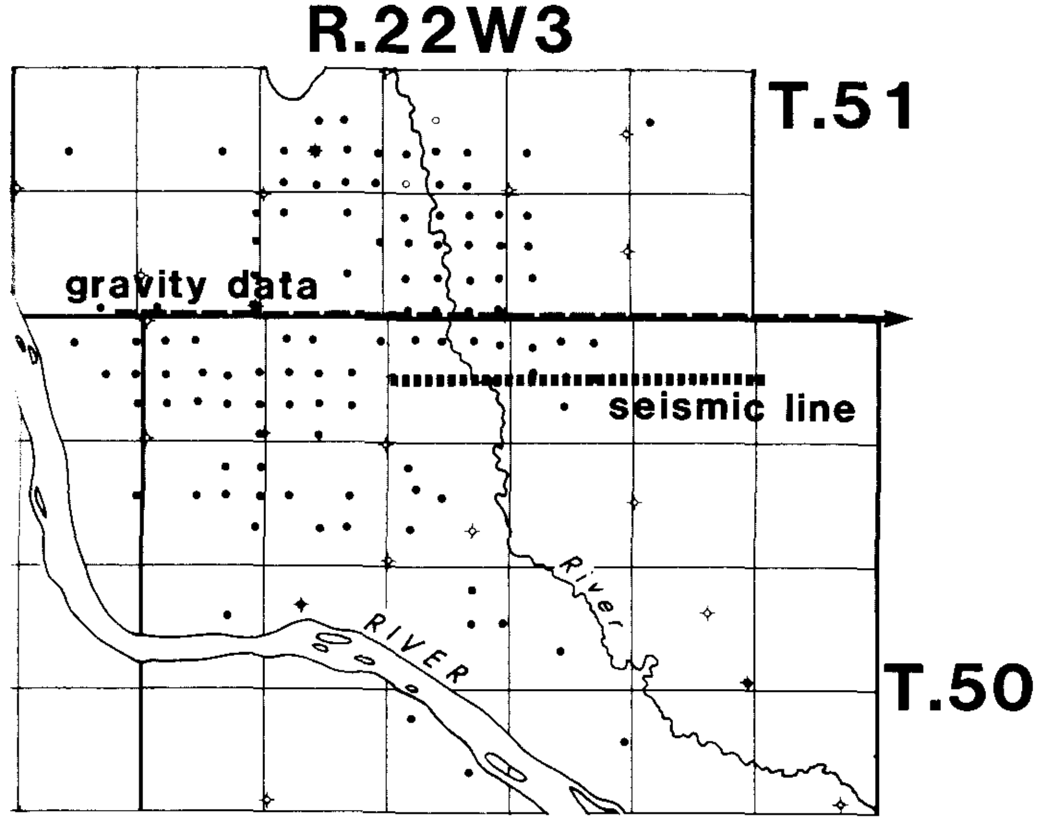

Figure 8.35. Location map, Westhazel G.P. Sand pool (courtesy, The Geobase Company Ltd).

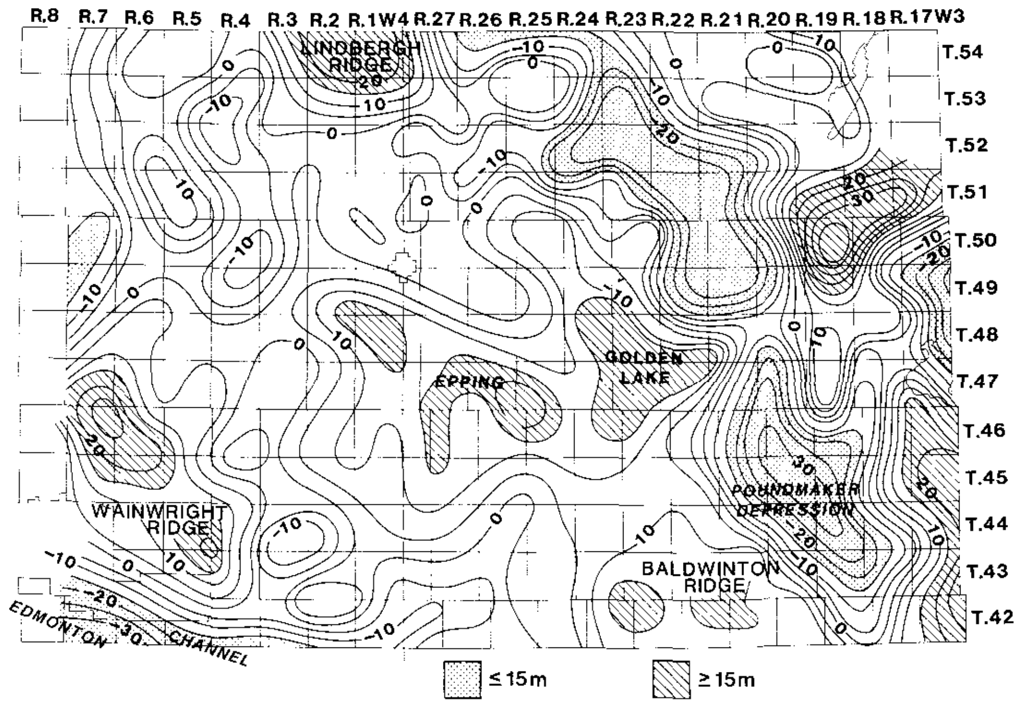

Figure 8.36. Second order residual map of the pre-Cretaceous unconformity surface, Lloydminster area (adapted from Smith, van Hulten and Young, 1984).

in that the G.P. member shows a coarsening upward (marine) sequence on well logs. The G.P. member (although locally interrupted by a shale filled channel) shows little or no thickening over the present day main salt dissolutional edge (Fig. 8.36), suggesting that dissolution did not occur in this area during middle Mannville time. Further, it is concluded that the G.P. member was deposited as a relatively flat lying marine sandstone, and that no trapping mechanism was in place until some time after deposition. A section of the Prairie Evaporite Fm salt is preserved west of the pool, whereas it is absent to the east. This absence of salt corresponds with some thickening of post-G.P. member units. Lateral thickening of overlying strata relative to a location where thick salt is preserved, is therefore an estimate of the amount of salt dissolution during deposition of those strata, providing that they have not been erosionally removed at an unconformity. This method of determining the period of dissolution has been utilized by Hriskevich, (1970) in dating dissolution of Black Creek Mbr salts of the Rainbow Basin. He reported a direct relationship between salt dissolution focused by the Upper Keg River Reef Mbr and formational thickening of overlying units.

While dating the dissolution of the Prairie Evaporite Fm in this area it was observed that the structure is post-Mannville and possibly Upper Cretaceous or later in origin. On this basis it was concluded that most of the oil entrapped in the G.P. member migrated into place in post-Mannville time. Possible traps could therefore occur in other areas of Saskatchewan where porous Devonian and Mississippian strata cross this dissolutional edge. Broughton (1978) indicated that Paleocene coals are thickest over areas of salt dissolution and concluded that dissolution of the Prairie Evaporite Fm continued until at least post-Paleocene in southern Saskatchewan.

A summary of the reserves and significant reservoir parameters for the Westhazel G.P. Sand pool are given in Table 8.6. Production data for this pool are displayed in Figure 8.37.

Table 8.6: Reserves and significant reservoir parameters, Westhazel G.P. Sand pool (After Saskatchewan Energy and Mines Miscellaneous Report 86-1)

Original Oil in Place	6.031 x 10^3m^3
Estimated Primary Recovery	4.1%
Initial Established Reserves	247 x 10^3m^3
Production to Dec 31/85	55 x 10^3m^3
Remaining Reserves	192 x 10^3m^3
Developed Area	324 ha
Average Pay	8.0 m
Average Porosity	35%
Average Water Saturation	30%
Oil Density	977 kg/m^3
Average Depth	485 m
Discovery Year	1971

GEOLOGICAL CROSS-SECTION

Figure 8.38 is a west to east five well cross-section from the Westhazel G.P. Sand pool. A significant structural feature noted on the cross-section is the eastern dip of the Mannville Gp strata which is in contrast to the general southwestern dip of the Western Canada Sedimentary Basin. This dip reversal is attributed to dissolution of the Prairie Evaporite Fm salt.

Sandstones of the G.P. member are uniformly thick on well logs except in the 12-34 location where it is replaced by a post G.P. member shale filled channel, similar to that described by Vigrass (1977). This erosional feature is not essential to the trapping of

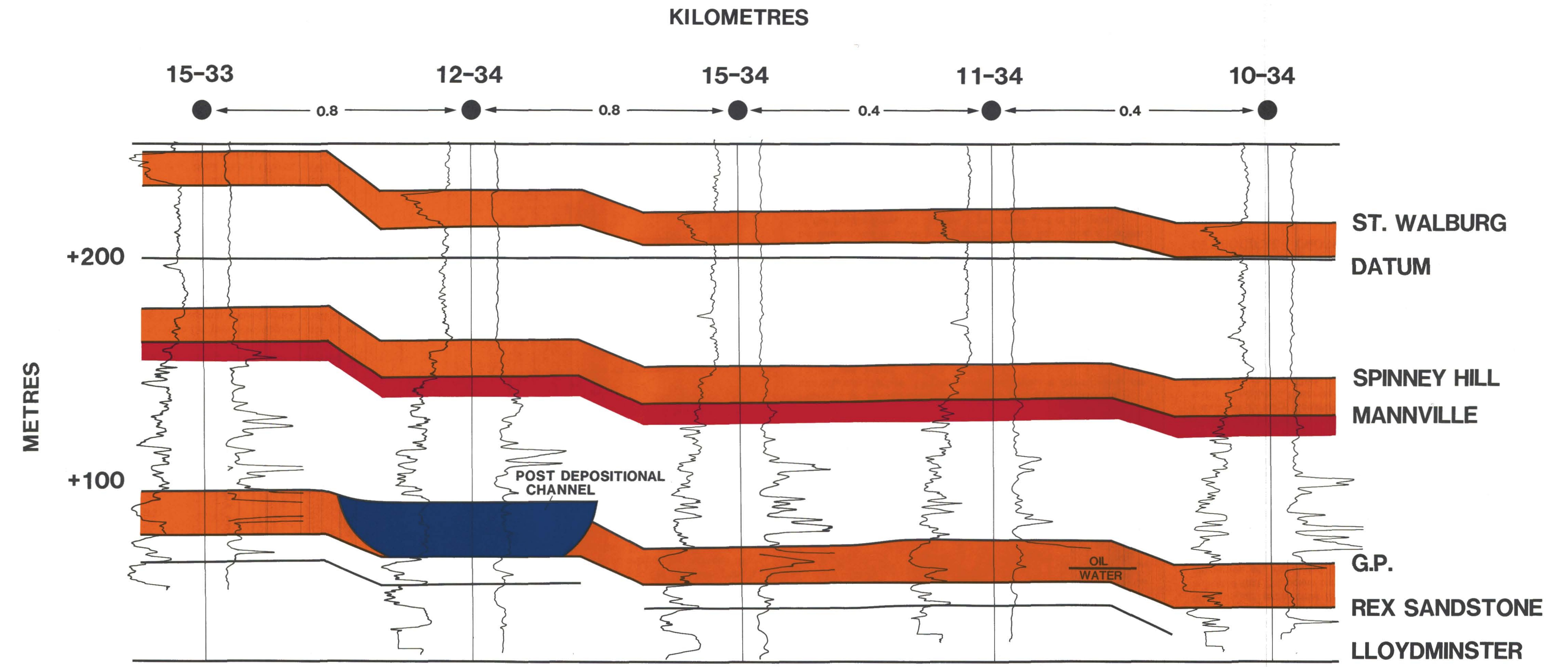

Figure 8.38. Geological cross-section, Westhazel G.P. Sand pool.

DRAFTING: K. GRIMSON | LOG PLOTS: | AUTHOR: D. CEDERWALL, D. NICOUD

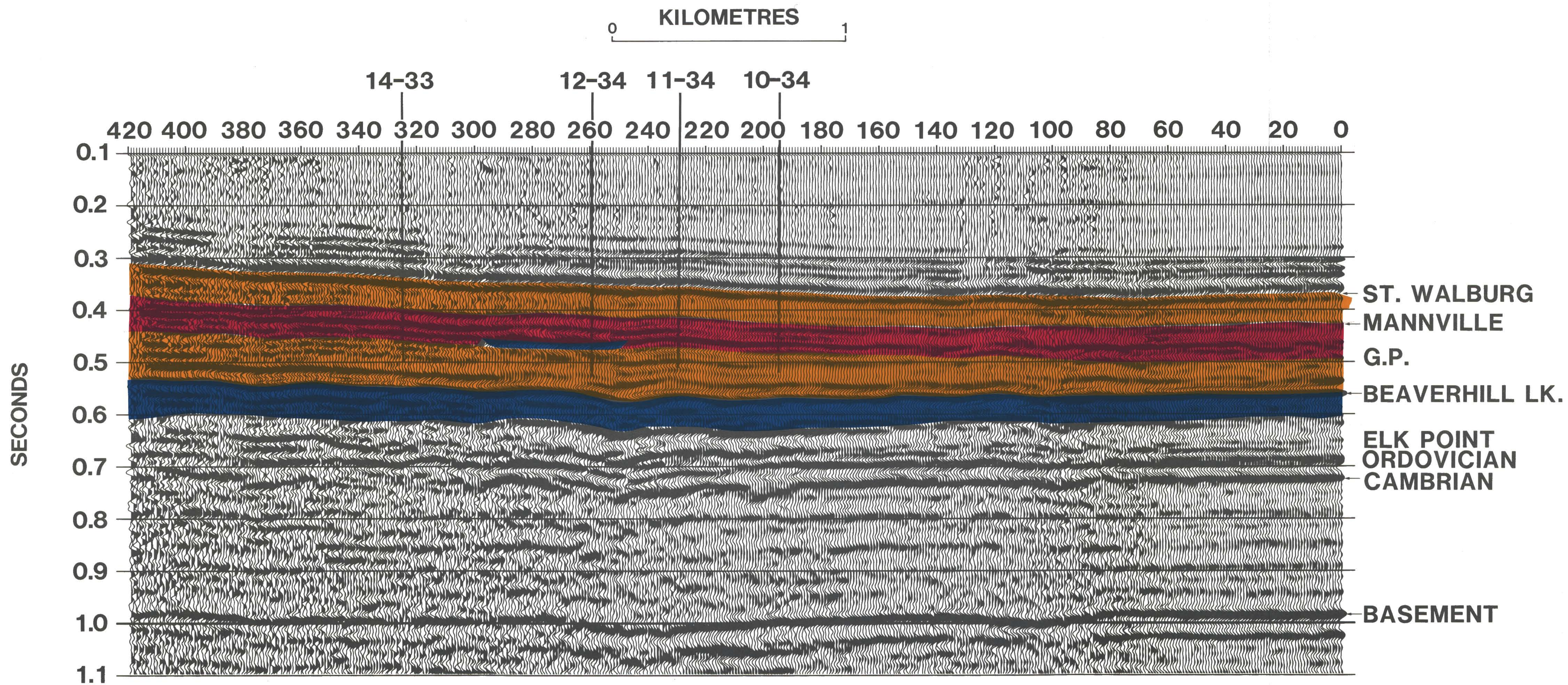

Figure 8.39. Seismic section, Westhazel G.P. Sand pool.

DONOR: HUSKY OIL OPERATIONS LTD. | PROCESSOR: SEIS-STAR GEOPHYSICAL LTD. | AUTHOR: D. CEDERWALL, D. NICOUD

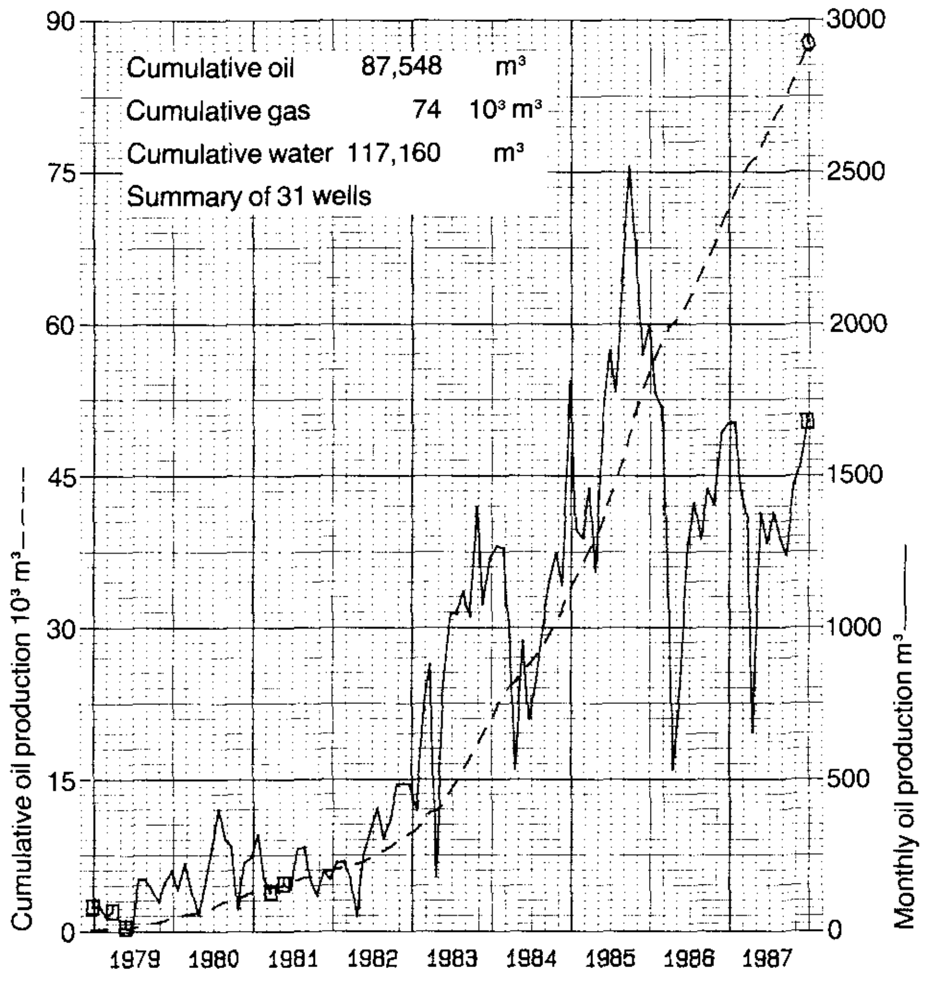

Figure 8.37. Production data, Westhazel G.P. Sand pool.

hydrocarbons at Westhazel, but could be the cause of some inter-pool separations. The 15-33, 12-34 and 11-34 wells all produce from the G.P. member at approximately 100 m above sea level. The downdip (eastward) 10-34 well is wet, but produces from a secondary horizon.

The uniformity of bed thickness and uniform depositional style noted in the Mannville Gp on this cross-section are evidence that these strata were deposited in a flat and relatively stable environment. On the basis of these observations it is concluded that present day structure is principally post-depositional in origin. Furthermore, the absence of interwell unit thickening at the Spinney Hill and St. Walburg intervals suggests that the structure probably postdates the deposition of these units.

SEISMIC SECTION

The seismic data for the Westhazel pool (Fig. 8.39) were donated by Husky Oil Operations Ltd. and reprocessed by Seistar Geophysical Ltd. This 5 km long line (24 fold, P-shooter energy source) was acquired in 1985 to aid in the exploration and development of the Westhazel pool. The line is divided into three portions on the basis of character patterns: 1) east portion; 2) west portion of the line (Paleozoics); and 3) west portion (Mesozoics). Event identifications are shown on the synthetic seismic trace of Figure 8.40.

A) EAST PORTION

The eastern portion of this line (traces 1-190) illustrates the total dissolution of the Prairie Evaporite Fm salts. The Prairie Evaporite event is absent on the right side of the line, but is present and labelled on the left hand side of Figure 8.39. The eastern portion of the line is typified by normal monoclinal dip to the southwest with no significant localized interval changes.

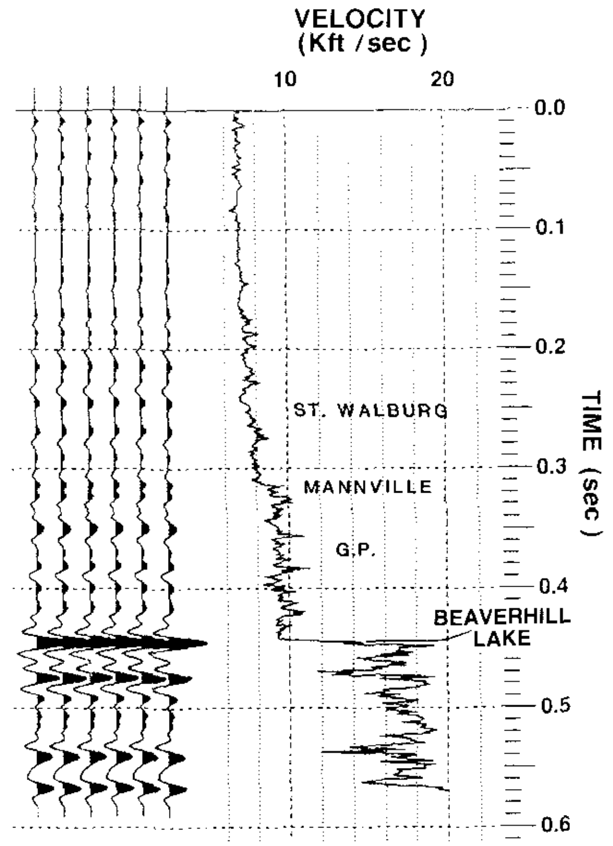

Figure 8.40. Single well synthetic seismic trace, Westhazel G.P. Sand pool.

B) WEST PORTION - PALEOZOIC

Paleozoic sediments on the west portion of the line (520 to 990 ms, traces 190-420) gradually thicken to the west. A 30 ms change in the total Paleozoic interval indicates the gradual westward thickening of the Prairie Evaporite Fm, and coincides with time-structural relief along the pre-Cretaceous unconformity event. The unconformity exhibits local undulating relief at the subcropping Beaverhill Lake Gp, and dip reversal (dip to the east over the larger area (traces 190-420, Fig. 8.39). This dip reversal is the structural element which provides closure for the Mesozoic clastics. The numerous rapidly changing events and diffractions in the 650 to 750 ms interval are associated with the partial dissolution of the Prairie Evaporite Fm salts and the resulting collapse features.

C) WEST PORTION - MESOZOICS

The Mesozoic interval on the western portion of this line (Fig. 8.39, above 520 ms and traces 420-200) shows dip reversal similar to that previously described for the Paleozoic. Of note is the absence of significant lateral thickening within the Mannville Gp interval along this line, suggesting that structure due to dissolution is post-Mannville in origin.

A minor feature is noted at the G.P. interval (traces 290-250 at 530 ms) which is coincident with the 12-34 well (Fig. 8.38). This feature is the seismic expression of a shale filled G.P. channel.

GRAVITY DATA

Figure 8.41 is a gravity line covering the same area as the seismic section of Figure 8.39. These data whose location is shown in Figure 8.35 were donated by Wild Rose Gravity Exploration and were interpreted by Dr. J. T. Sallomy of that firm. Shown with the data of Figure 8.39 are the regional gravity envelope interpreted for a full salt and a no salt section. Note the gradual change in the gravity response over the dissolutional area and the similarity of this slope to the dip measured by the seismic data. This style of dissolutional edge is very similar to that of Smith et al. (1984) shown in Figure 8.42.

CONCLUSIONS

The Westhazel G.P. Sand pool illustrates the structural trapping of hydrocarbons in Lower Cretaceous strata as a result of dip reversal due to salt dissolution. These data also illustrate the seismic

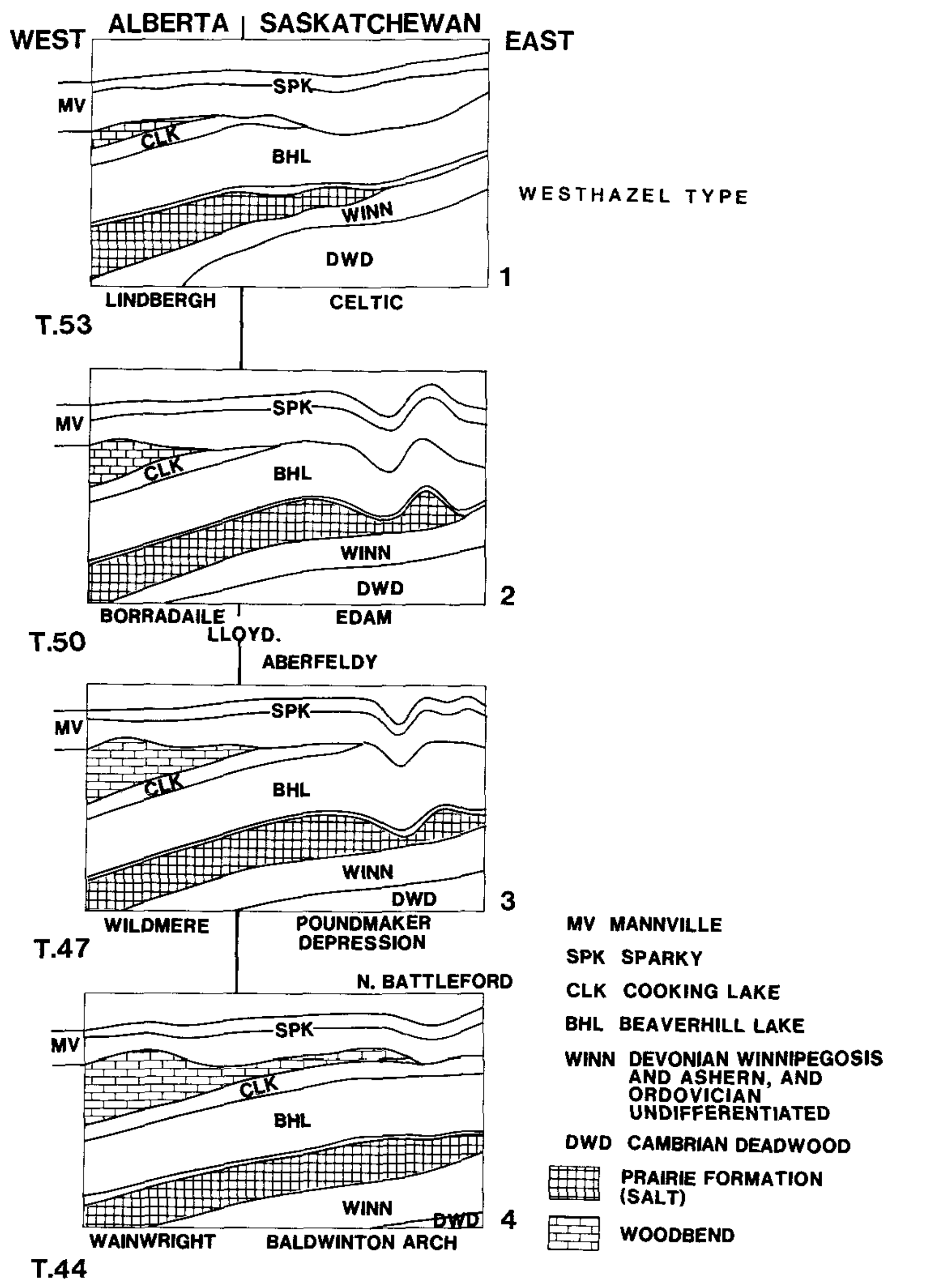

Figure 8.42. Schematic geological cross-section of dissolution of the Prairie Evaporite Fm in the Lloydminster area. (adapted from Smith, van Hulten and Young, 1984).

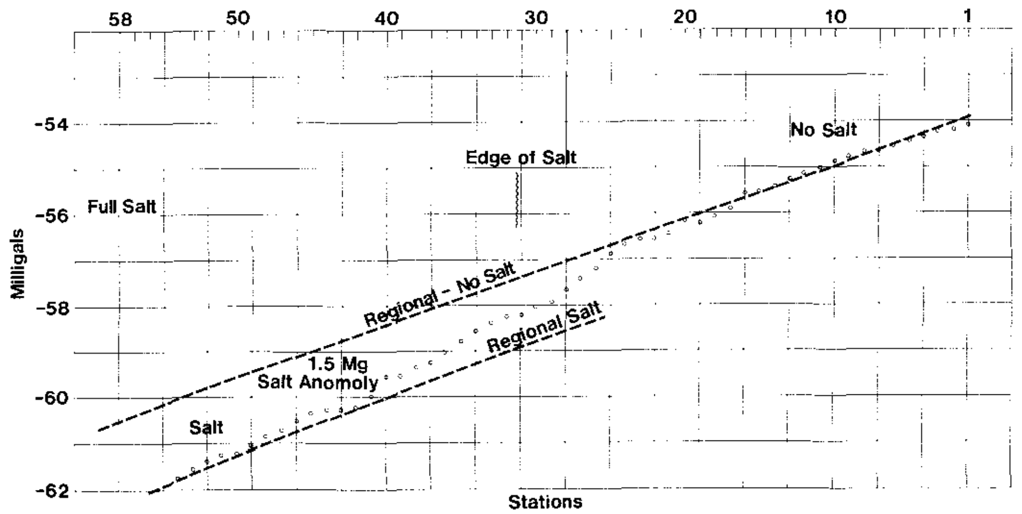

Figure 8.41. Gravity data, Westhazel G.P. Sand pool (courtesy, Wild Rose Exploration Services Ltd).

signature of an intra-Mannville shale filled channel similar to that described by Vigrass (1977). The dissolution of Prairie Evaporite Fm salt in this area is variable with respect to age, rate, and extent. Seismic data is an aid in determining the dissolutional history, present day structure, and depositional style of an area. Mapping of the dissolutional edge of the Prairie Evaporite Fm with conventional ground level gravity data is demonstrated, showing the applicability of regional gravity work in this area.

8–7: PROVOST UPPER MANNVILLE BB POOL

INTRODUCTION

The Provost Upper Mannville BB pool is an upper Mannville channel facies reservoir located in T38 - R1 W4M, some 400 km east of Calgary, Alberta (Fig. 8.43). The pool is part of a channel facies trend which is mapped southeast to northwest through T36, T37 and T38 R1 W4M. These strata, which are also known as the McLaren member (Gross, 1980), are part of the informal upper Mannville subdivision of Vigrass (1977) and Putnam (1982). Putnam and Oliver (1980) concluded that it is difficult to distinguish between the Colony, McLaren and Waseca members of the upper Mannville on a regional basis due to their similarity and therefore a twofold facies subdivision of a singular upper Mannville unit is utilized in describing the seismic signature of the pools of this subsection. They are:

1) Regional facies sandstones - these strata are thought to be the contemporaneous overbank, crevasse splay, swamp, marsh, lake, and marine deposits that accompanied the higher energy channel facies sandstones. These strata are described at length in Putnam and Oliver (1982) who denoted them as the B and C facies of the upper Mannville; and

2) Channel facies sandstones - these strata are the A facies of Putnam and Oliver (1982) and are generally thick, fining upward sandstones with abrupt basal contacts, rip up clasts and high angle cross-stratification. These strata are formed by the stacking of multiple paleochannels (Wrightman et al. 1987). Note however, that the subdivision presented herein is utilized in order to simplify the description of the seismic signature for Provost Upper Mannville BB pool and other examples of this chapter. This subdivision should be regarded as an oversimplification of Wrightman et al. (1987) and Putnam and Oliver (1980).

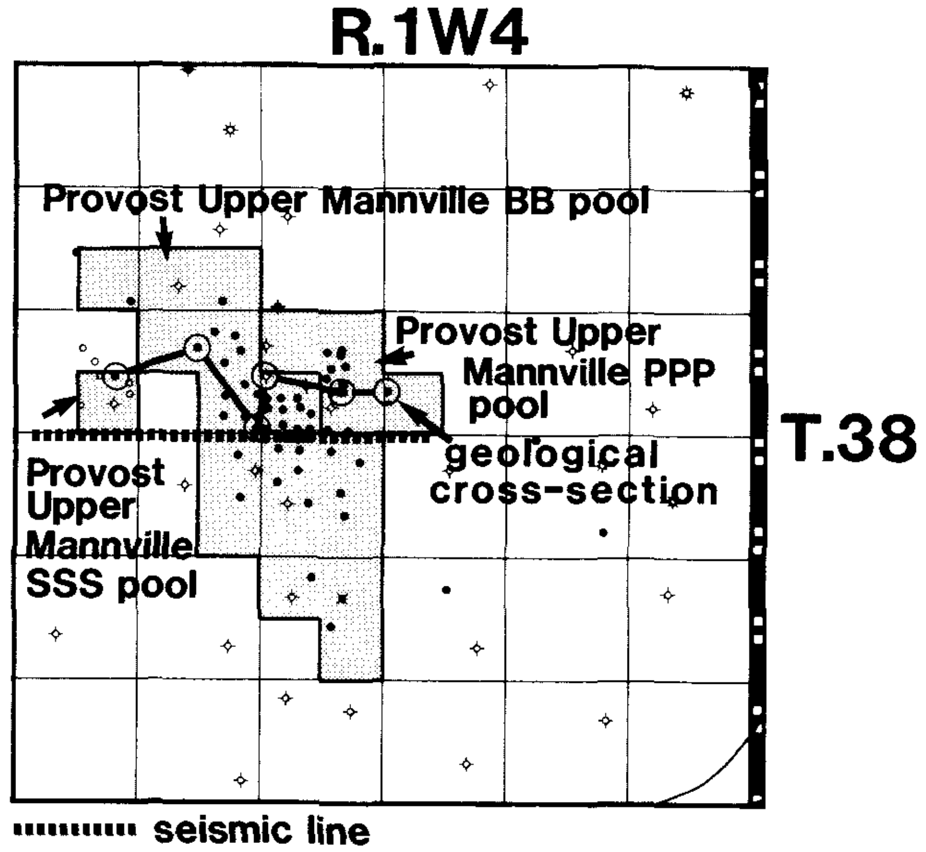

Figure 8.43. Location map, Provost Upper Mannville SSS, BB and PPP pools (courtesy, The Geobase Company Ltd).

Wrightman et al. (1987) in a more complete study showed the upper Mannville channels of eastcentral Alberta to contain facies of "several genetic origins". Their data suggested that the channel deposits of the Hairy Hills area consists of multiple paleochannels. Furthermore, they suggested an increasing marine influence in the eastern portion of their study area and paleodrainage in that direction. Their work, however, does not conflict with the generalization used herein in that they describe contemporaneous deposition of channel and regional strata similar to that of Putnam and Oliver (1982) in contrast to a disconformable channel model such as that of Reinson (1985) for the Crystal Viking A and H pools, and those of examples 8-1 and 8-4 of this chapter.

The pool is located at the northern end of an oil bearing channel trend that is mappable as a single channel facies (the Provost Upper Mannville B Pool) in T36 and T37 - R1 W4M (Gross, 1980). To the north this single channel sandstone splits into three separate, mappable channel deposits which form the Provost Upper Mannville SSS, BB and PPP pools. This threefold separation of the channel deposited sandstones could indicate diversion as the channel flow slows on meeting a shoreline. These pools are all formed by elongated "shoe string" type deposits which are generally less than 1.5 km in width.

The three channel facies pools are located in an area of a Mannville Gp thin, marked by an absence of lower Mannville strata and the Nisku Fm subcrop. This area is referred to as the Bodo high and is accentuated to the north by the lower Mannville Edmonton Channel (Williams, 1963), where a full Dina member sandstone is deposited on subcrop which is eroded down to the Ireton and Leduc formations.

The upper Mannville sediments are separated from the middle Mannville Sparky member by a laterally continuous shale unit and are overlain by the Joli Fou Fm. Laterally the three upper Mannville channel sandstone facies are separated by the sequence of interbedded sandstones and shales of the regional facies. These upper Mannville channel deposits all show abrupt basal contacts and fining upwards sequences which grade upwards to non-reservoir strata. Reserves and significant reservoir parameters for the Provost Upper Mannville BB pool are listed in Table 8.7. Productivity data for this pool is illustrated in Figure 8.44.

Table 8.7: Reserves and significant reservoir parameters, Provost Upper Mannville BB pool (ERCB, 1987).

Initial Oil in Place	7,880 x $10^3 m^3$
Primary Recovery Factor	10%
Total Established Recoverable Reserves	788 x $10^3 m^3$
Cumulative Production	263.7 x $10^3 m^3$
Remaining Established Reserves	534.3 x $10^3 m^3$
Area	448 ha
Average Pay Thickness	8.63 m
Average Porosity	28%
Water Saturation	25%
Oil Density	980 kg/m^3
Mean Formation Depth	753 m
Discovery Year	1977

GEOLOGICAL CROSS-SECTION

Figure 8.45 is a west to east geological cross-section which parallels the seismic line of Figure 8.46. This geological cross-section does not extend to the west to intersect the previously described lower Mannville Edmonton Channel complex, and thus is restricted to an area typified by the Nisku Fm subcrop and the absence of the Dina member.

The upper Mannville channel complex is shown as three distinct channel facies units which are offset by regional facies sediments. Gross (1980) suggests that these off-channel sediments predate the channel cut, noting that the channel of the more southerly B pool (T36 - R1 and T37 - R1 W4M) incises well into the middle Mannville units.

The channel facies outlined in wells of this cross-section (8-19, 1-20, 7-21) all show a characteristic abrupt channel base and evidence of a fining upward sequence on the SP curve. Gross (1980) described these reservoir sandstones as "fine to medium grained, fairly well sorted with shale rip up clasts", and shows that both single and multicycle, laterally accreting deposits occur in different parts of the pool. Note also that the wells of Figure 8.45 do not incise the middle Mannville strata as do some of the wells shown in Gross (1980). The comparatively "shallower" cut depth by the channels illustrated in this subsection may indicate a lower energy regime in the channel complex northward from the area studied by Gross (1980).

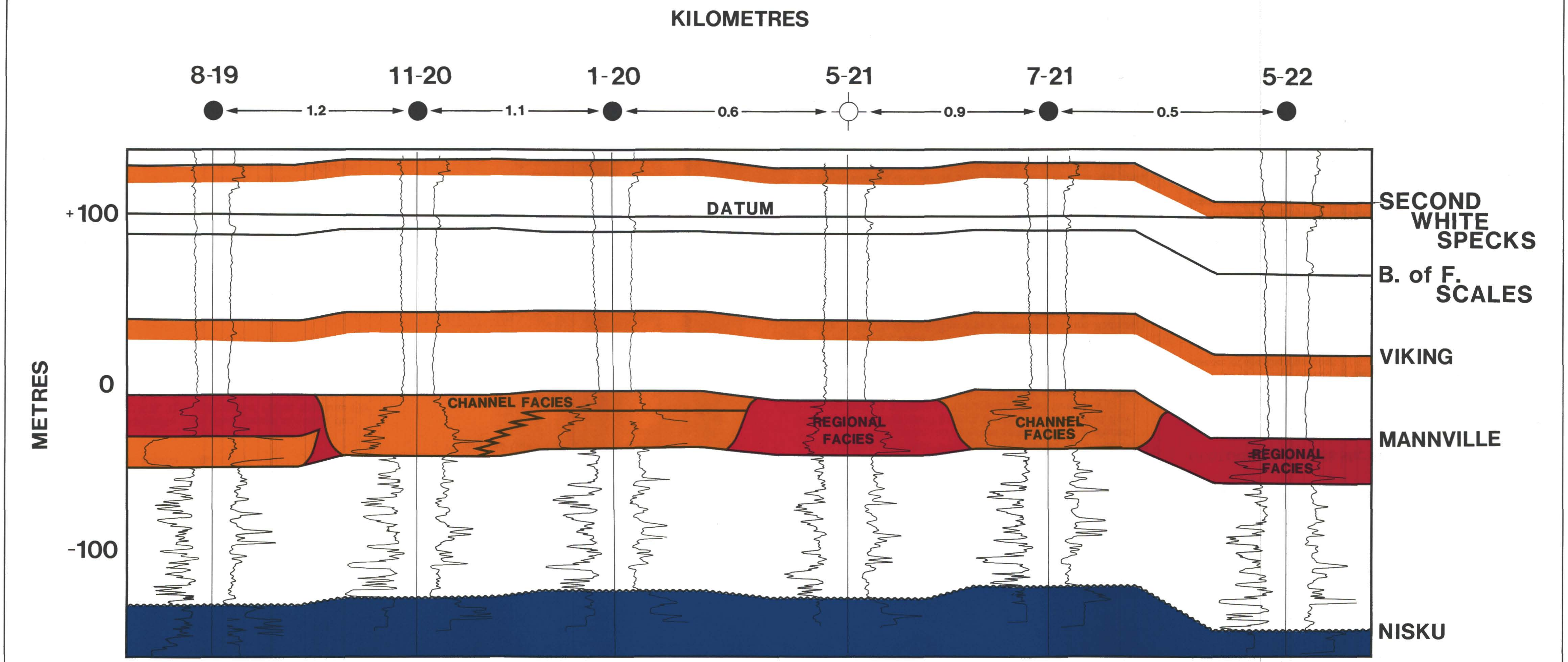

Figure 8.45. Geological cross-section, Provost Upper Mannville SSS, BB and PPP pools.

DRAFTING: K. GRIMSON | LOG PLOTS: | AUTHOR: D. CEDERWALL, L. BALDWIN

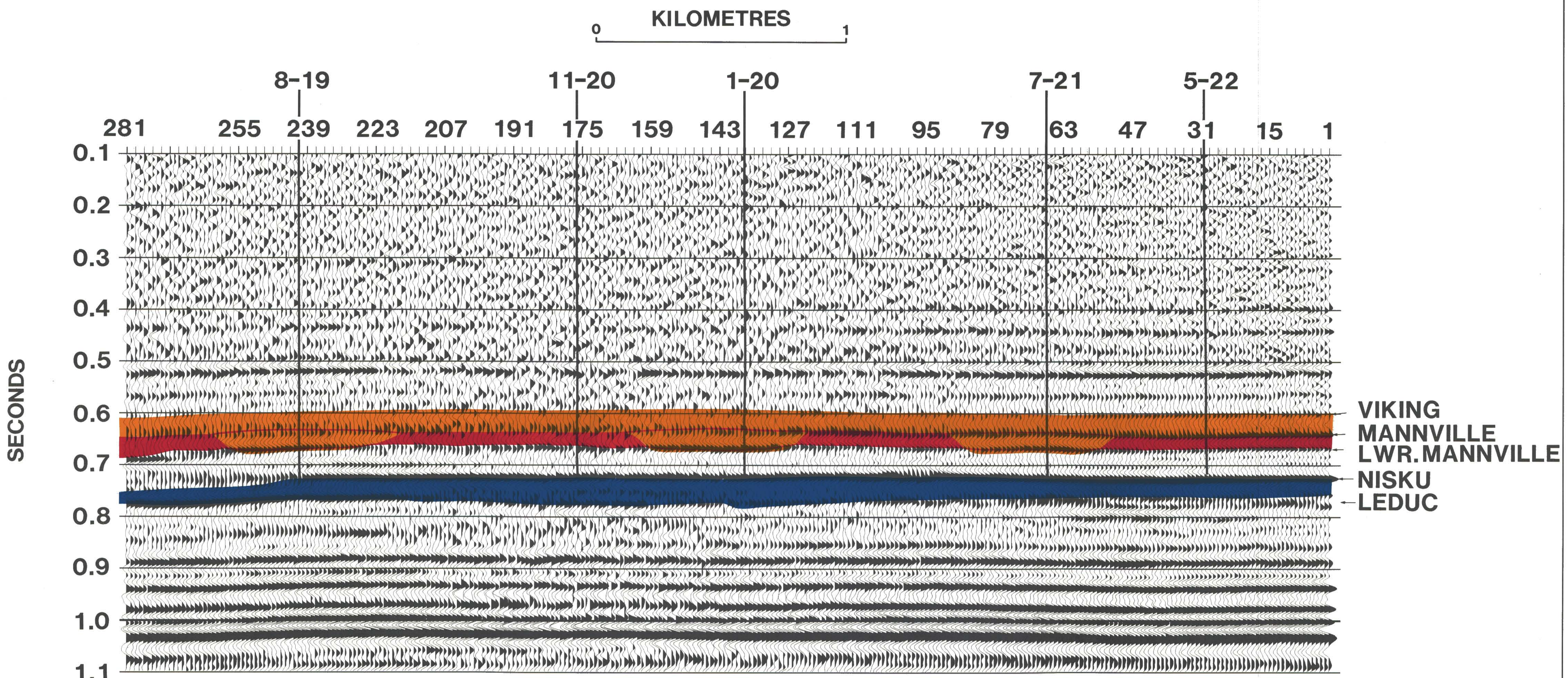

Figure 8.46. Seismic section, Provost Upper Mannville SSS, BB and PPP pools.

DONOR: NORCEN ENERGY RESOURCES LTD. | PROCESSOR: DATASPAN TECHNOLOGY LIMITED, P. CHERNOFF | AUTHOR: D. CEDERWALL, D. DALY

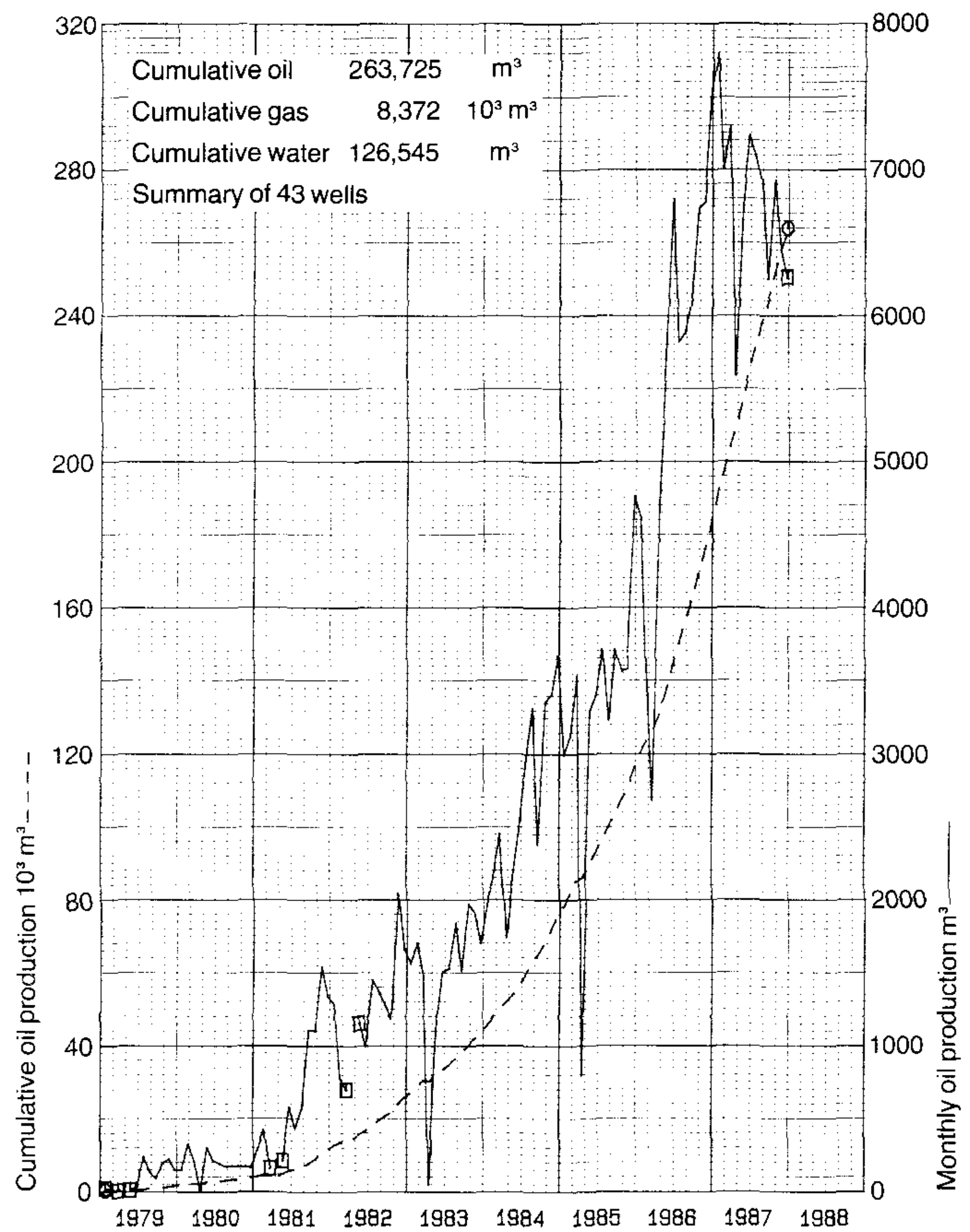

Figure 8.44. Production data, Provost Upper Mannville SSS, BB and PPP pools.

SEISMIC SECTION

This 1200% CDP seismic line was donated by Norcen Energy Ltd. and reprocessed by Data-Span Technology Ltd. The more prominent events are labelled in ascending order on Figure 8.46 as the Nisku Fm, Mannville Gp, and Viking Fm events. Identification of these events is shown in Figure 8.47. With respect to the Paleozoic strata

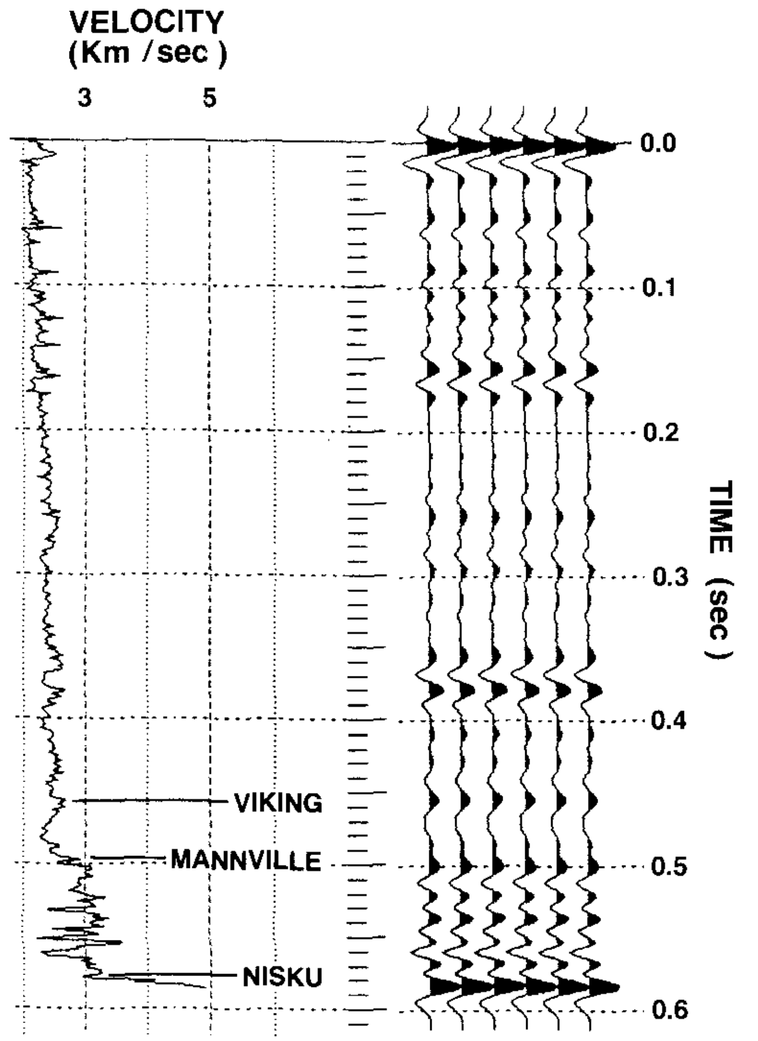

Figure 8.47. Single well synthetic seismic trace, Provost Upper Mannville SSS, BB and PPP pools.

no major time-structural or interval thickening features other than pre-Cretaceous erosional relief are noted. West of trace 287, the pre-Cretaceous subcrop is the Leduc Fm. Mannville interval time thickening here corresponds to the presence of the Dina member. To the east the thinning of the Mannville time interval coincides with the time structural high of the pre-Cretaceous unconformity and the Nisku Fm subcrop.

Three separate channel facies anomalies are observed between traces 237 to 261, 127 to 159 and 57 to 83, which are the seismic signatures of the SSS, BB and PPP pools respectively. These three areas exhibit an increase in both sharpness and amplitude in the trough to peak cycle directly under the Mannville Gp event. The increased amplitude on the peak is due to the velocity contrast between the low velocity channel facies sandstones and the strata which directly underlie the channel facies. Laterally, in the regional facies strata, this velocity contrast is much weaker. A slight upwardly convex shape occurs in the trough to peak sequence of the three anomalies. This effect could be due to differential compaction of channel facies to regional facies strata, with the later showing a higher degree of compaction, however, this structure is not replicated at the Mannville event.

CONCLUSIONS

The Provost upper Mannville SSS, BB and PPP pools are typical of the upper Mannville channels of eastern Alberta described by Putnam and Oliver (1980) and Gross (1980). The seismic signature, however, is not consistent with that of the Colony member example of this text (Hairy Hills Colony W pool) or the observations of Focht and Baker (1985). Three possible factors which could contribute to this difference are:

1) The channel facies sandstones of this subsection are capped by thicker upper Mannville strata, and are thinner than the previously cited examples. This fact may explain the absence of discernable drape along the Mannville event, (whereas drape is a noted characteristic of the data in Focht and Baker (1985);

2) The channel facies sandstones of this example are oil bearing whereas those of Focht and Baker (1985) are principally gas bearing reservoirs, a fact that could contribute to some character differences; and

3) Near surface geological conditions in the pool vicinity detracted from the data quality of this line and the application of an F/K filter was required to clarify these anomalies.

8–8: HAYTER DINA B POOL

INTRODUCTION

The Hayter Dina B pool straddles the fourth meridian in T40 - R1 W4M approximately 340 km east of Edmonton, Alberta (Fig. 8.48), and occurs within the confines of the Edmonton Channel complex of Williams (1963). The example depicts heavy oil entrapment in the Dina member sandstone of the Mannville Gp. The Dina member is typically a thick sequence of stacked channel facies sandstones whose east to west depositional axis are partially controlled by pre-Cret-

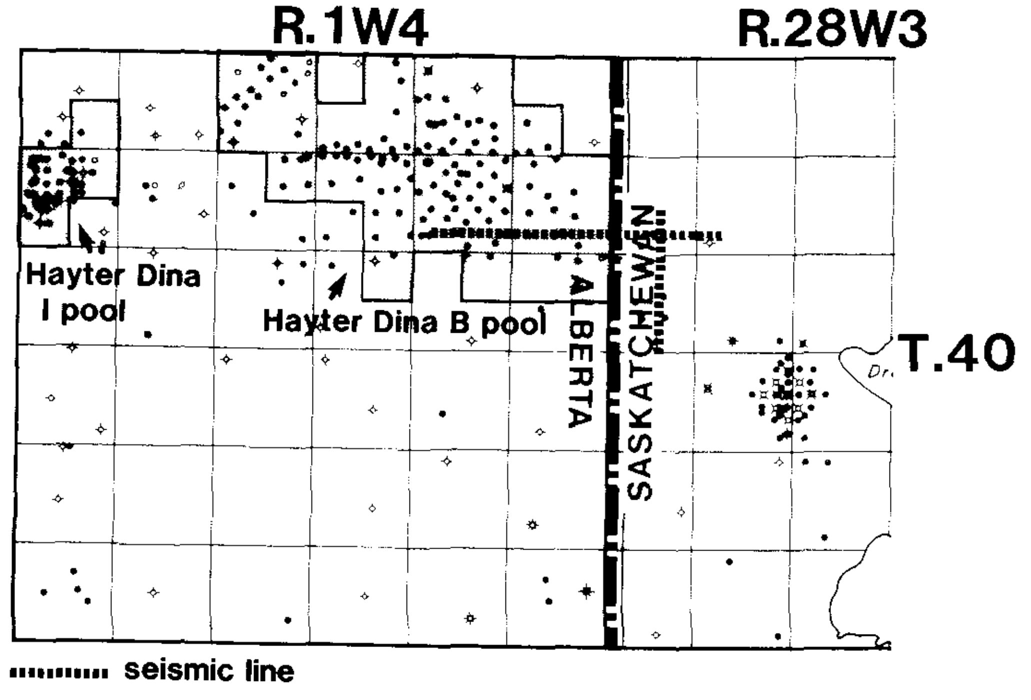

Figure 8.48. Location map, Hayter Dina B pool (courtesy, The Geobase Company Ltd).

aceous relief. The fining upwards characteristic of these sandstones can adversely effect oil production. Porosities of 30% and pay thickness commonly on the order of 15 m lead to volumetrically large in place reserves of 37 630 x $10^3 m^3$ of oil which are subject to a low recovery factor of 2% due to their high viscosity.

One west to east cross-section depicting the reservoir, the trapping mechanism and an adjacent pool to the east (the Eyehill Cummings Sand Pool) is shown. The two seismic sections, one east to west and one north to south, illustrate the seismic signatures of the Dina member and the pool trap. Productivity data for the Hayter Dina B pool are shown in Figure 8.49 and reserves and reservoir parameters are summarized in Table 8.8.

Table 8.8: Reserves and significant reservoir parameters, Hayter Dina B pool (ERCB, 1987)

Initial Oil in Place	37,630 x 10^3m^3
Primary Recovery Factor	2%
Total Initial Established Reserves	753 x 10^3 M3
Cumulative Production	424.3 x 10^3m^3
Remaining Established Reserves	328.7 x 10^3m^3
Area	1384 ha
Average Pay Thickness	11.24 m
Average Porosity	29%
Average Water Saturation	14
Oil Density	965 kg/m^3
Mean Formation Depth	778.5 m
Discovery Year	1969

GEOLOGICAL CROSS-SECTION

Figure 8.50 is a west to east geological cross-section showing the relationships between the Dina member of the Hayter Dina B pool, the pool trapping mechanism and the Eyehill Cummings pool (Fig. 8.48). The lowest horizon identified is the subcropping Leduc Fm. Substantial erosional relief on the Leduc has a direct effect on the thickness and orientation of the Dina member sandstone, however this is not the sole controlling element on deposition of this unit.

Figure 8.50 shows four wells which intersect the Dina member at different depths. A hydraulic separation between the two oil pools is shown on this diagram, but is tenuous in that the oil-water contacts of the two pools are of similar structural elevations. Also note that the mapping of exact oil-water contacts in heavy oil areas is difficult due to the existence of long transition zones across these interfaces.

Two wells, 14-20 and 4-29 (Fig. 8.50) show a near maximum thickness of the Dina member sandstone. The 4-28 location shows a thin Dina sandstone which is capped by shale. The strata are laterally adjacent to thicker Dina sandstone in the 14-20 and 4-29 locations and the shale acts as a seal to create the lateral updip trapping mechanism. Additional closure is provided by differential compaction within the Dina member between strata which have contrasting volumes of shale, a mechanism that is thought to control the north and south limits of the pools as well as interwell structural changes. The westward limit of the pool is controlled by a combination of regional dip and a relative increase in the amount of compaction that occurs in wells that are away from the channel axis.

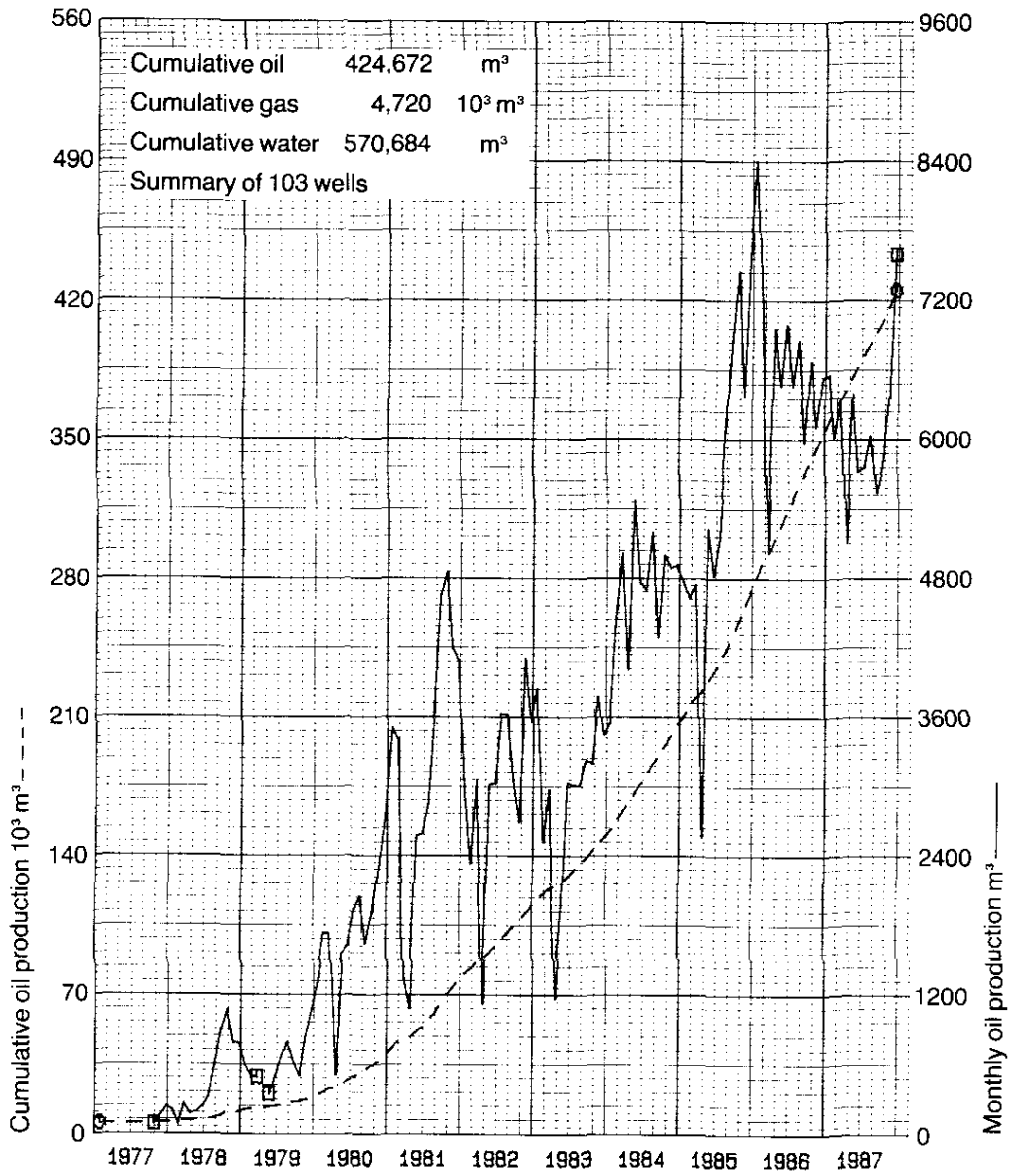

Figure 8.49. Production data, Hayter Dina B pool.

SEISMIC SECTION

The two lines (Fig. 8.51) were donated by Hillcrest Resources Ltd. These 1500% CDP data were acquired in 1984 using a Vibroseis energy source and a spread length of 900 m. Figure 8.51A is the west to east section and Figure 8.51B is the south to north. Identified on both lines are the Leduc, Dina, Sparky, Mannville, and Viking events. The west to east line of Figure 8.51A shows a thick Dina member interval to the west of trace 99. The Dina event correlation is shown on the synthetic seismic trace of Figure 8.52 and is placed at the peak to trough inflection at approximately 720 ms on Figure 8.51B. The seismic signature of the pool trap is shown to the east of

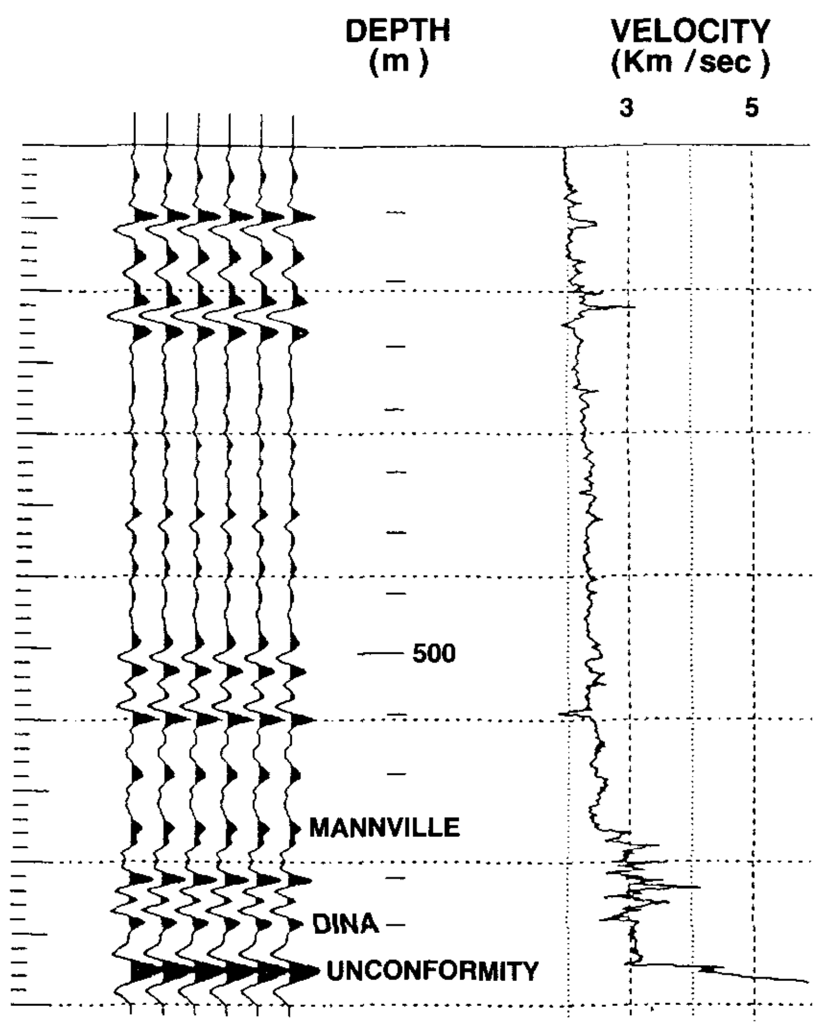

Figure 8.52. Single well synthetic seismic trace, Hayter Dina B pool.

trace 99. These strata are shown by the 4-28 location of the geological cross-section of Figure 8.50 and show the thin Dina member sandstone and thick overlying shale. Within this area (east of trace 99) the top of the Dina member is indicated at 750 ms. Note the lateral continuity of this area where the Dina member sandstone is "replaced" with shale. This lateral continuity is not the expected geometry of a post-depositional cut and fill structure as described for the Provost Basal Quartz C pool, and warrants further sedimentological examination.

A similar feature, indicating the partial lateral termination of the Dina member occurs north of trace 51 on Figure 8.51A. Also notable on this line is a thickening of the Sparky Fm interval and corresponding time structure on the Sparky Fm event [traces 176-307, Fig. 8.51A)]. This time-structure, and thickening corresponds with Sparky member production and is interpreted as being due to the shoaling of this marine middle Mannville unit and resultant better sorted sandstones as described for the following Hayter Sparky A pool.

CONCLUSIONS

The Hayter Dina B pool illustrates heavy oil entrapment in the lower Mannville Dina member sandstone of the Edmonton Channel. The updip trapping mechanism (a seal formed by shale) is mappable with the presented seismic data. Vigrass (1977) has suggested that similar traps are due to the occurrence of intra-Mannville unconformities which the author certainly believes to exist, (ie. Provost Basal Quartz C pool of this chapter). However, the lateral continuity of the shale, suggested from the seismic data of this example, does not conform to a model of post-depositional erosion as an origin for the pool trap and it is unclear as to whether the shale predates, postdates or is concurrent with the deposition of the Dina member sandstone.

A thickening of the middle Mannville Sparky member which is interpreted as due to shoaling and a cleaning of the marine sandstone is definable from the presented seismic data, similar to the Sparky member anomaly of the Hayter Sparky A pool (subsection 8-9).

8–9: HAYTER SPARKY A AND DINA A POOLS

INTRODUCTION

Two coincident reservoirs, the Hayter Sparky A and Dina A pools are illustrated in subsection 8-9 (Fig. 8.53). The pools, located in T41-R1 W4M approximately 340 km southeast of Edmonton, Alberta contain heavy gravity crude in the Lower Cretaceous Mannville Gp at a depth of less than 1000 m. Relatively unrestricted production allowances for this area make these reservoirs attractive exploration targets. The lower Mannville pool of this subsection and those of the Hayter Dina B and Provost Basal Quartz C pools are similar in that all produce from the Dina member yet the inclusion of these data serves to contrast several different trapping mechanisms within the Edmonton Channel trend. Similar to the afore-

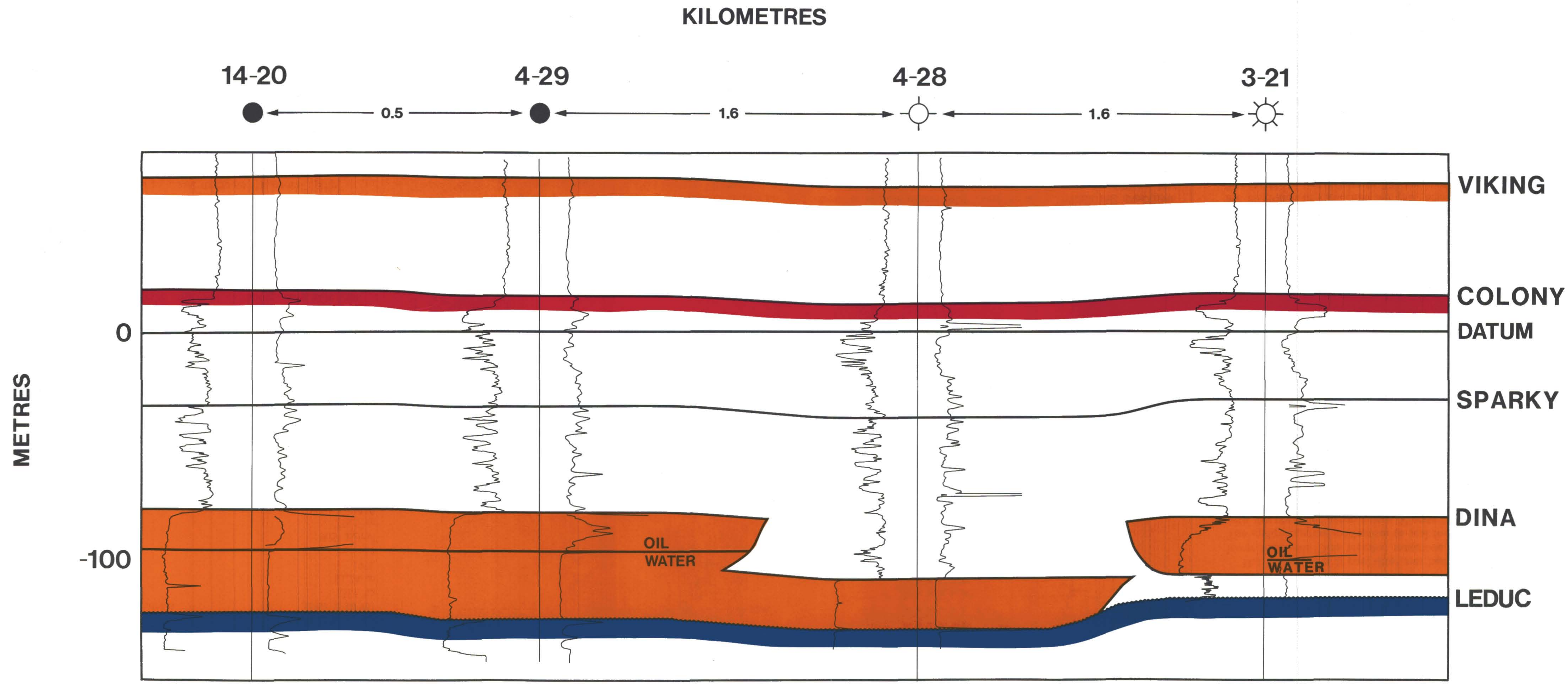

Figure 8.50. Geological cross-section, Hayter Dina B pool.

DRAFTING: K. GRIMSON | LOG PLOTS: | AUTHOR: D. CEDERWALL

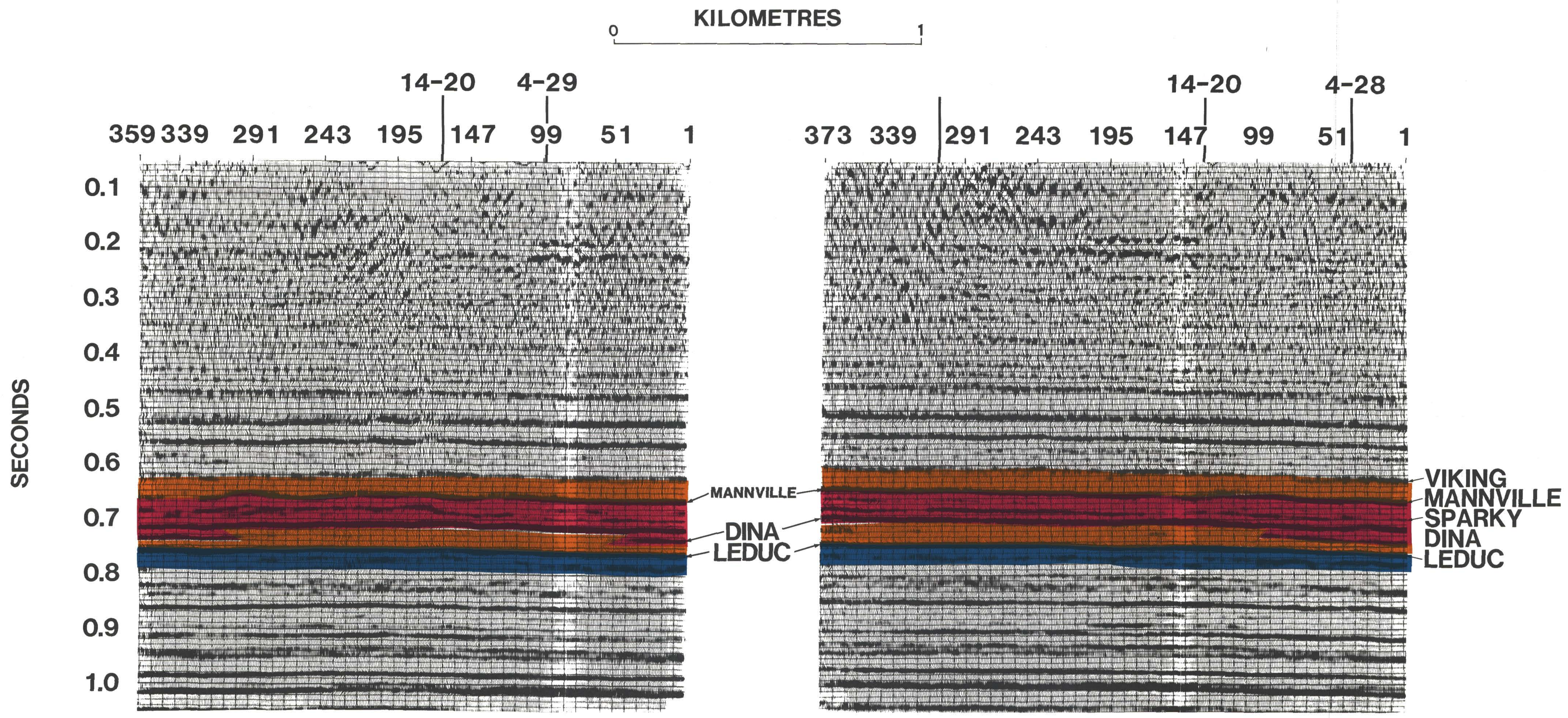

Figure 8.51. Seismic section, Hayter Dina B pool.

DONOR: HILLCREST RESOURCES LTD. | PROCESSOR: | AUTHOR: D. CEDERWALL, M. MANSELL

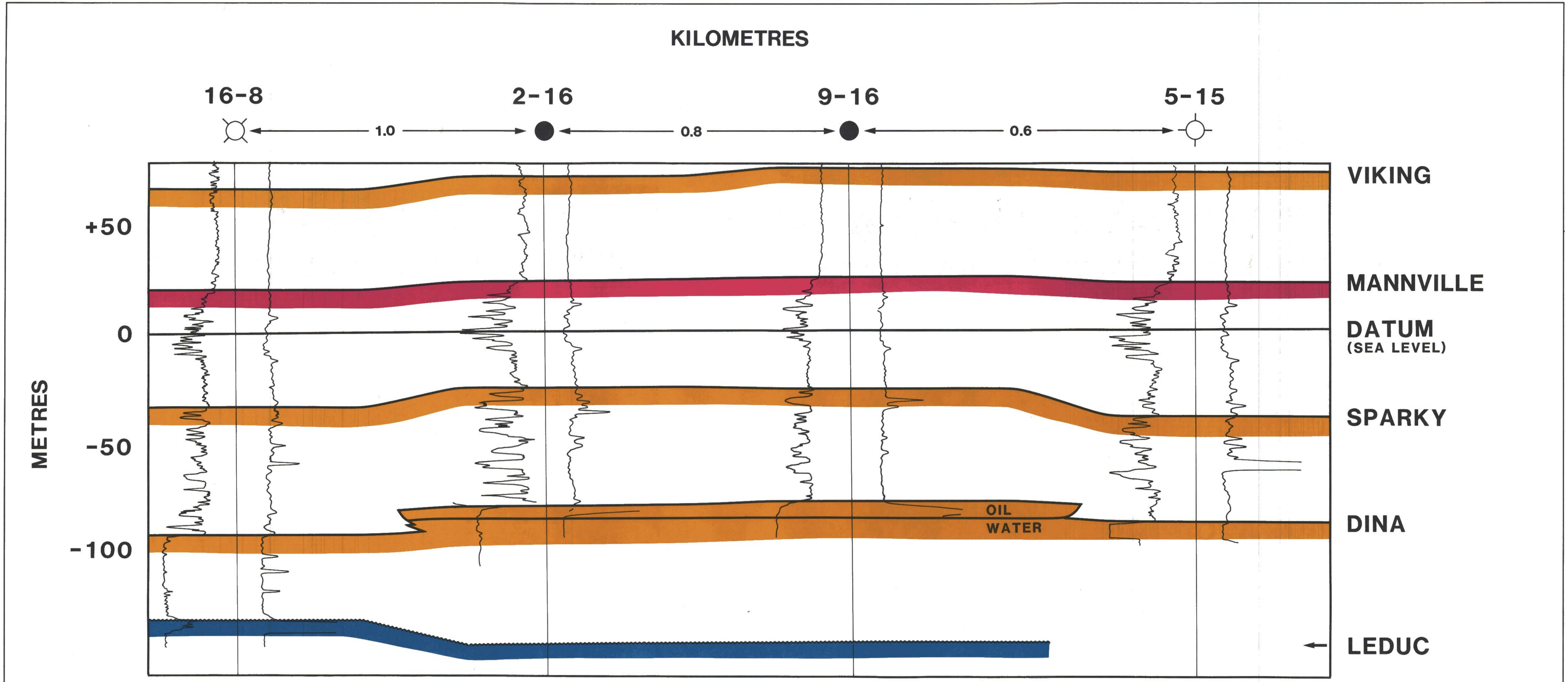

Figure 8.56. Geological cross-section, Hayter Sparky A and Dina A pools.

DRAFTING: K. GRIMSON | LOG PLOTS: | AUTHOR: D. CEDERWALL

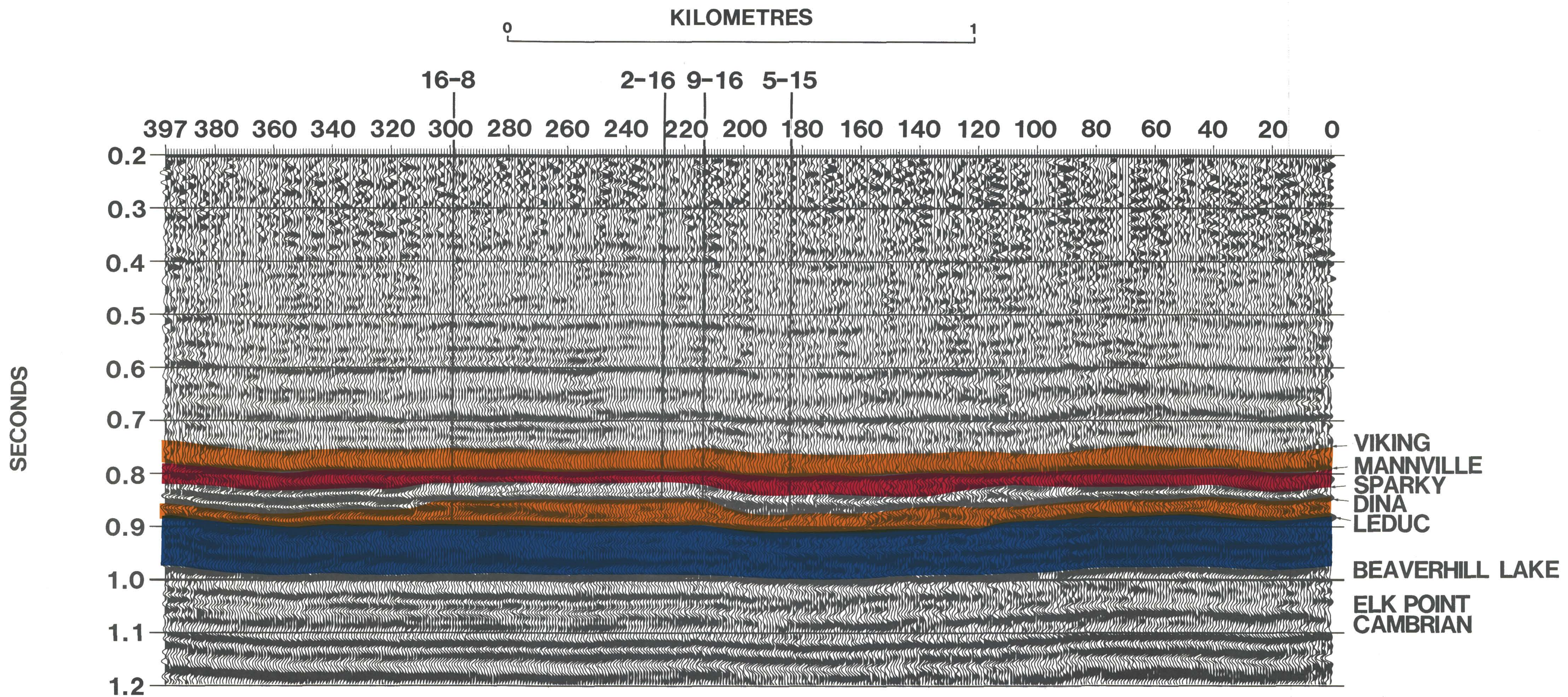

Figure 8.57. Seismic section, Hayter Sparky A and Dina A pools.

DONOR : MURPHY OIL COMPANY LTD. | PROCESSOR : SEIS-STAR GEOPHYSICAL LTD. | AUTHOR : D. CEDERWALL , C. BRIERE mentioned examples, the Hayter Dina A pool is located within an area of a lower Mannville thick. To the north and south of the pool pre-Cretaceous highs known as the Wainwright Ridge and Bodo high are formed by the subcropping carbonates of the Nisku Fm. Subcrop in the area of the pool is formed by the Leduc Fm indicating erosion of both the Nisku and Ireton formations.

Structural closure and facies control of the Sparky member sandstone is provided by pre-existing structural closure on the Dina member. This structural facies control and the closure of the Sparky member shown here are similar to that of the Chauvin and Wainwright fields where the pre-Sparky structure is provided by Devonian carbonates in the absence of the Dina member. Closure on the Sparky member at Hayter is due to differential compaction within the underlying Dina member. Coincident with the structure is a thickening of the Sparky member due to shoaling of the marine sandstone across this pre-existing high. Both the geological and geophysical sections document the thickening of the Sparky and structural closure on the Sparky and Dina members.

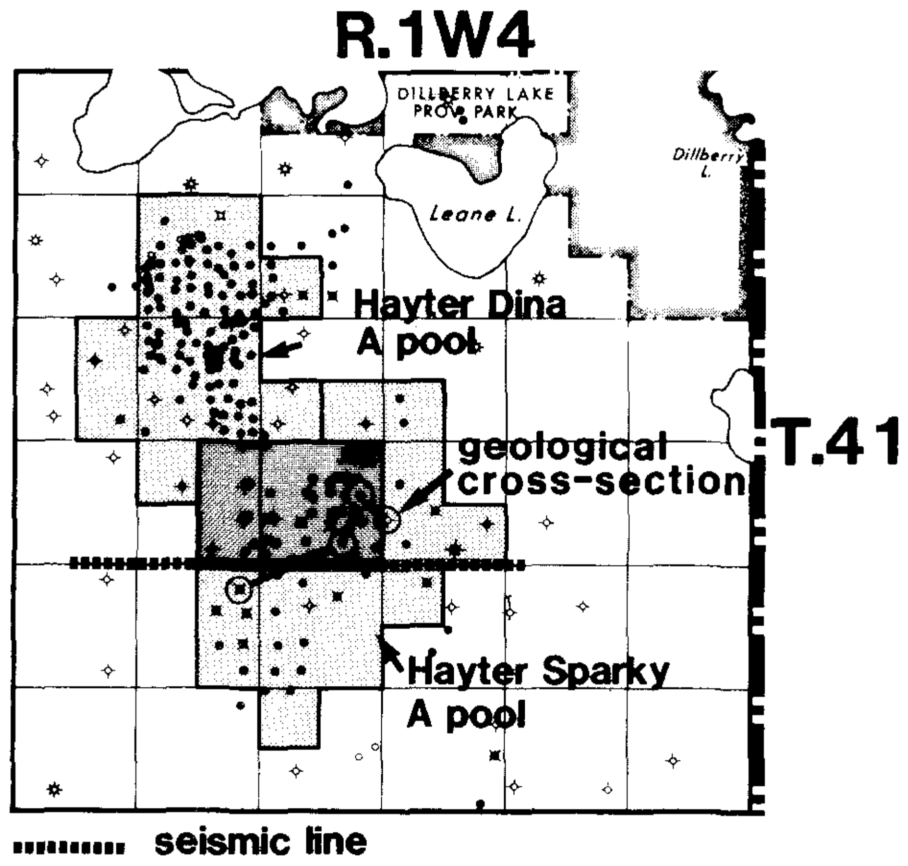

Figure 8.53. Location map, Hayter Sparky A and Dina A pools (courtesy, The Geobase Company Ltd).

Oil recovery from the Dina A pool is substantially better (a total of 17%) than the previously documented Dina B pool (2%), due to lighter and less viscous oil, reduced well spacing and the existence of a water flood. High recovery from the Sparky A pool of 10% of in place oil reserves is possible due to a large lateral distance of the aquifer to the producing wells in the thin sheet sandstone, and water flooding. Additional reserve data and significant reservoir parameters are shown in Table 8.9. Productivity data for the Hayter Sparky A pool is shown in Figures 8.54 and 8.55.

Table: 8.9: Reserves and significant reservoir parameters, Hayter Dina A and Sparky A pools (ERCB, 1987)

	DINA A	SPARKY A
Initial Oil In Place	12,290 x 10^3M^3	3742 x 10^3m^3
Primary Recovery Factor	4%	7%
Secondary Recovery Factor	13%	3%
Total Established Recoverable Reserves	1736 x 10^3M^3	355 x 10^3m^3
Cumulative Production	704 x 10^3M^3	269 x 10^3m^3
Remaining Established Reserves	1032 x 10^3M^3	86 x 10^3m^3
Area	707 ha	1224 ha
Average Pay	8.01 m	7.37 m
Average Porosity	30%	28%
Average Water Saturation	19%	26%
Oil Density	921 kg/M^3	910 kg/m^3
Mean Formation Depth	788.6 m	795 m
Discovery Year	1969	1968

GEOLOGICAL CROSS-SECTION

Figure 8.56 is a west to east geological cross-section which portrays the reservoir sandstones and trapping mechanisms for the Sparky and Dina members (Fig. 8.53). The occurrence of heavy oil in the Sparky member sandstone is coincident with a distinct thickening of the underlying Dina member, which may be due to differential compaction. The Sparky member sandstone grades to a less shaly and more porous sandstone across this high as shown by the comparison of the producing and non-producing wells. This change is attributable to shoaling of the marine Sparky member across the Dina member structure with additional structure due to differential compaction of the Sparky member. Some thinning of the overlying Sparky shale is observed coincident with the structural relief along the Sparky member. As previously mentioned, the primary mechanism for initiating this shoaling is structural relief due

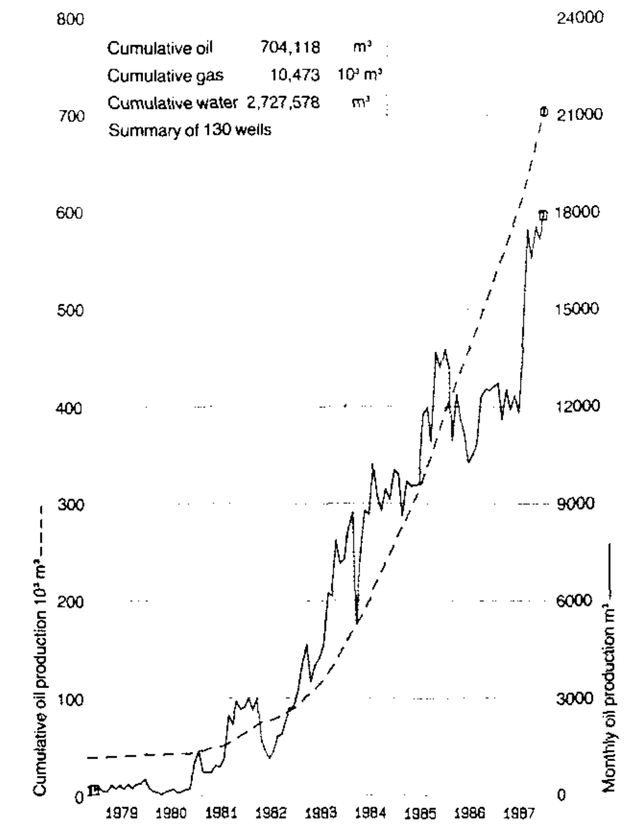

Figure 8.54. Production data, Hayter Dina A pool.

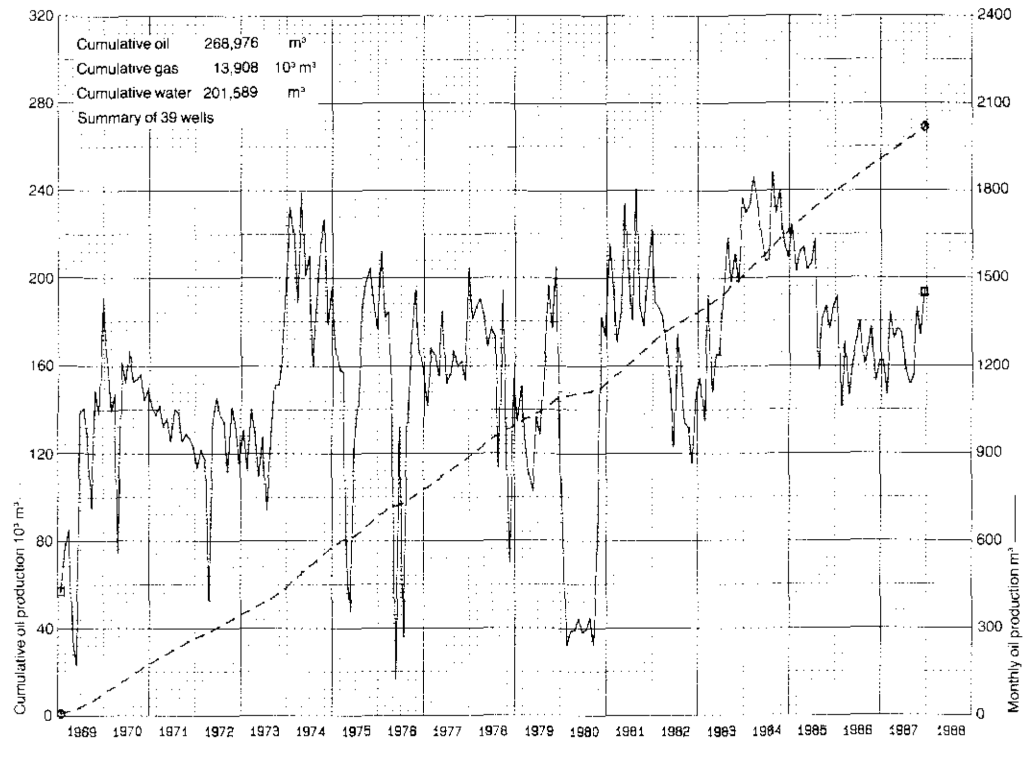

Figure 8.55. Production data, Hayter Sparky A pool.

to compaction within the underlying Dina member. This compactional relief is due to an extra thickness of Dina sandstone which is laterally offset by non-channel Dina member strata. These non-channel strata are differentially compacted in relation to the channel thicks because of this shaly character. A comparison of the 16-8 and 2-16 wells (Fig. 8.56) shows this relationship and corresponding structure. Similarly, at Chauvin, Wainwright and many other locations throughout the Lloydminster area the Sparky member attains reservoir quality and closure coincident with underlying structure. This pre-existing structure is more commonly pre-Cretaceous highs with sandstones of the Lloydminster and G.P. members forming onlap style traps whereas the Sparky drapes over the entire structural highs. Smith et al. (1984) list four trapping mechanisms associated with the Sparky member as follows: A) "Regional Facies" sandstones abutting against shale filled Channel Facies; B) Regional and Channel Facies sandstones trapped structurally, mainly due to dissolution of the Prairie Evaporite Fm salt; C) Sandstones locally developed within the Channel Facies; and D) Lateral pinchout of Regional Facies sandstones.

The Sparky member production of this example are best described by classification "D". This classification could, however, be expanded to note that the regional facies are often structurally and depositionally controlled by pre-Cretaceous structure and or differential compaction of the lower Mannville.

SEISMIC SECTION

The east to west seismic line of Figure 8.57 was donated by Murphy Oil, Canadian Occidental Petroleum, Texaco Canada Resources and Norcen Energy Ltd., and reprocessed by Seistar Geophysical Ltd. The two pools are located between traces 200 and 310 on the line and are typified by significant time-structural relief and character changes.

Significant structural relief is observed along the Dina event between traces 210 and 320 (at 650 ms) and corresponds to an overall thickening of the Dina interval. Coincident with this, but slightly wider in lateral extent is the Sparky member structure at 610 ms. The peak labelled as the Sparky event is interpreted as the interface between the Sparky member shale and Sparky member sandstone and shows time-structural relief of 10 to 15 ms. The Sparky member time-structural relief occurs with some thickening of the Sparky to Dina interval across the pool. Thinning of the Mannville to Sparky interval is also noted over this area.

CONCLUSIONS

The Hayter Dina A and Sparky A pools are an example of stacked or "related" heavy oil reservoirs. The two pools are related in that closure on the Dina member forms the initial structure on which the Sparky member sandstone has developed. This mechanism would require some early stage differential compaction within the Dina member level (ie. by Sparky member time).

This leads to some confusion in that other upper Mannville strata of this area such as Colony member channels appear to be relatively uncontrolled by pre-existing structures. However, note the local thinning of the Sparky member shale across the Sparky and Dina member highs of Figure 8.56 which may have levelled much of the predating structure.

8–10: WAINWRIGHT

INTRODUCTION

The Wainwright subsection illustrates the relationships between the lower Mannville strata and the subcropping Paleozoic highs. Although the example is not specific to any particular pool, reserves are quoted to show the significance of subcropping traps, such as the Wainwright Nisku A pool. Subcrop traps, in this area, require a competent top seal which is generally formed by the middle Mannville strata. The data also show a Colony member channel whose characteristics are discussed in subsection 8-12 of this chapter. A schematic diagram (Fig. 8.59) depicts: 1) the geological setting of this seismic line; 2) several of the previously discussed trap types; and 3) the relationship of the Wainwright Ridge to the Edmonton Channel.

Reserves and significant reservoir parameters for the Wainwright Nisku A pool are shown in Table 8.10. Productivity data for the pool are illustrated in Figure 8.58.

Table 8.10: Reserves and significant reservoir parameters, Wainwright Nisku A pool (ERCB, 1987)

	WAINWRIGHT NISKU A
Initial Oil in Place	3856 x $10^3 m^3$
Primary Recovery Factor	5%
Primary Recoverable Reserves	193 x $10^3 m^3$
Cumulative Production	136.4 x $10^3 m^3$
Remaining Established Reserves	56.6 x $10^3 m^3$
Area	528 ha
Average Pay	6.58 m
Average Porosity	17%
Average Water Saturation	32%
Oil Density	957 kg/m^3
Average Depth	641.5 m
Discovery Year	1982

GEOLOGICAL CROSS-SECTION

The principal features of seismic section (Fig. 8.60) are schematically depicted on the geological cross-section (Fig. 8.59). This diagram also depicts trap types of the Provost Basal Quartz C pool, Hayter Dina A and B pools and the Hairy Hills Colony W pool. The left justified or southern portion represents the area of the Edmonton Channel, whereas the right justified portion represents the area of the Wainwright Ridge. Within the confines of the channel the pre-Mannville erosion has removed Paleozoic strata down to the Leduc Fm, resulting in deposition of a thick Mannville Gp as compared to the area of the ridge. On the ridge note that the Ireton and Nisku formations are preserved and the lower and some middle Mannville units onlap and truncate against the high providing potential hydrocarbon traps. The Nisku Fm is truncated updip by erosion and produces heavy oil (957 kg/m^3) of the Wainwright Nisku A pool of T44 - R5 W4M. Here the Nisku Fm is capped by middle Mannville shales. Several other trap types such as intra-Mannville unconformities, Colony member channels, onlap of the Lloydminster member and shoaling of the Sparky member are depicted here and discussed further within this chapter (subsection 8-8, 8-9, 8-11). Thinning of the Lower Cretaceous strata as they onlap the Wainwright Ridge is shown on the 8th order residual map of Figure 8.61.

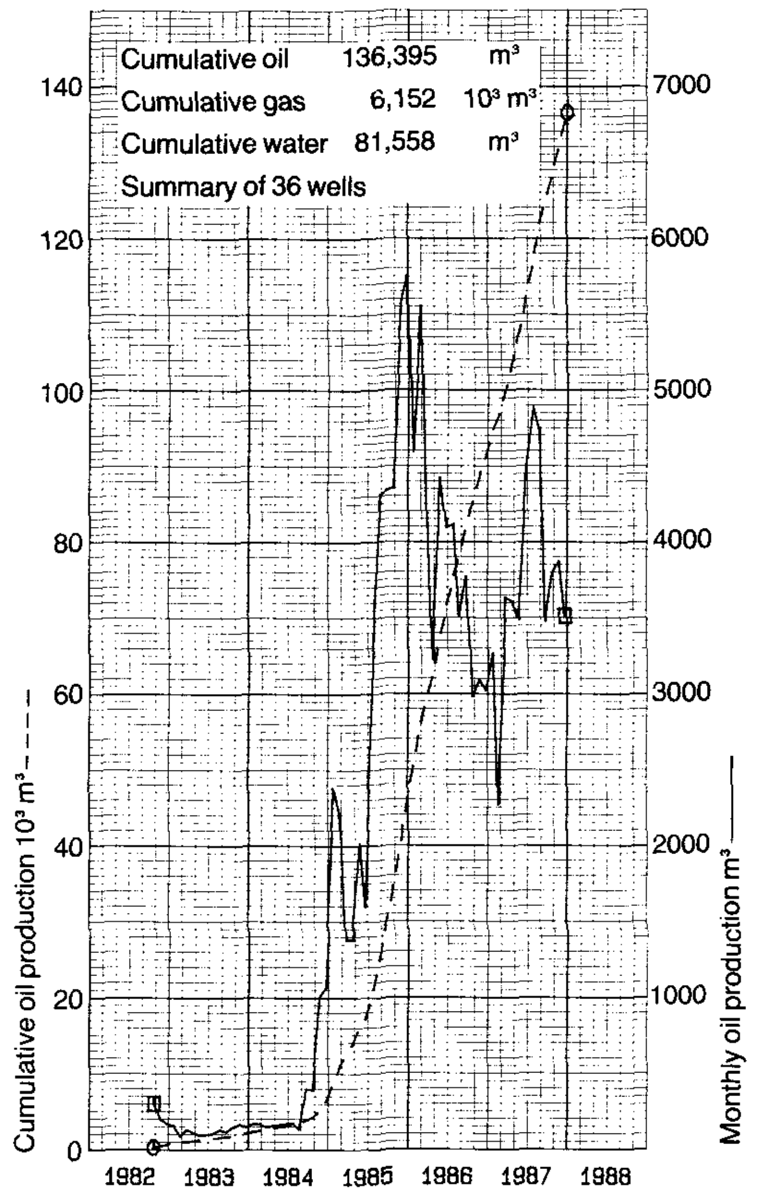

Figure 8.58. Productivity data, Wainwright Nisku A pool.

SEISMIC SECTION

The seismic line of Figure 8.60 is a south to north oriented 800% dynamite line acquired in 1983 and donated by Cabre Exploration Ltd., Bow Valley Industries and Coho Resources Limited. The southern segment of this line, between traces 204 and 718 is representative of the Edmonton Channel. This area is typified by thick Mannville and Dina member intervals. The Dina member appears to gradually thin and pinchout (traces 288-204) against the Wainwright Ridge. The ridge is structurally highest between traces 1

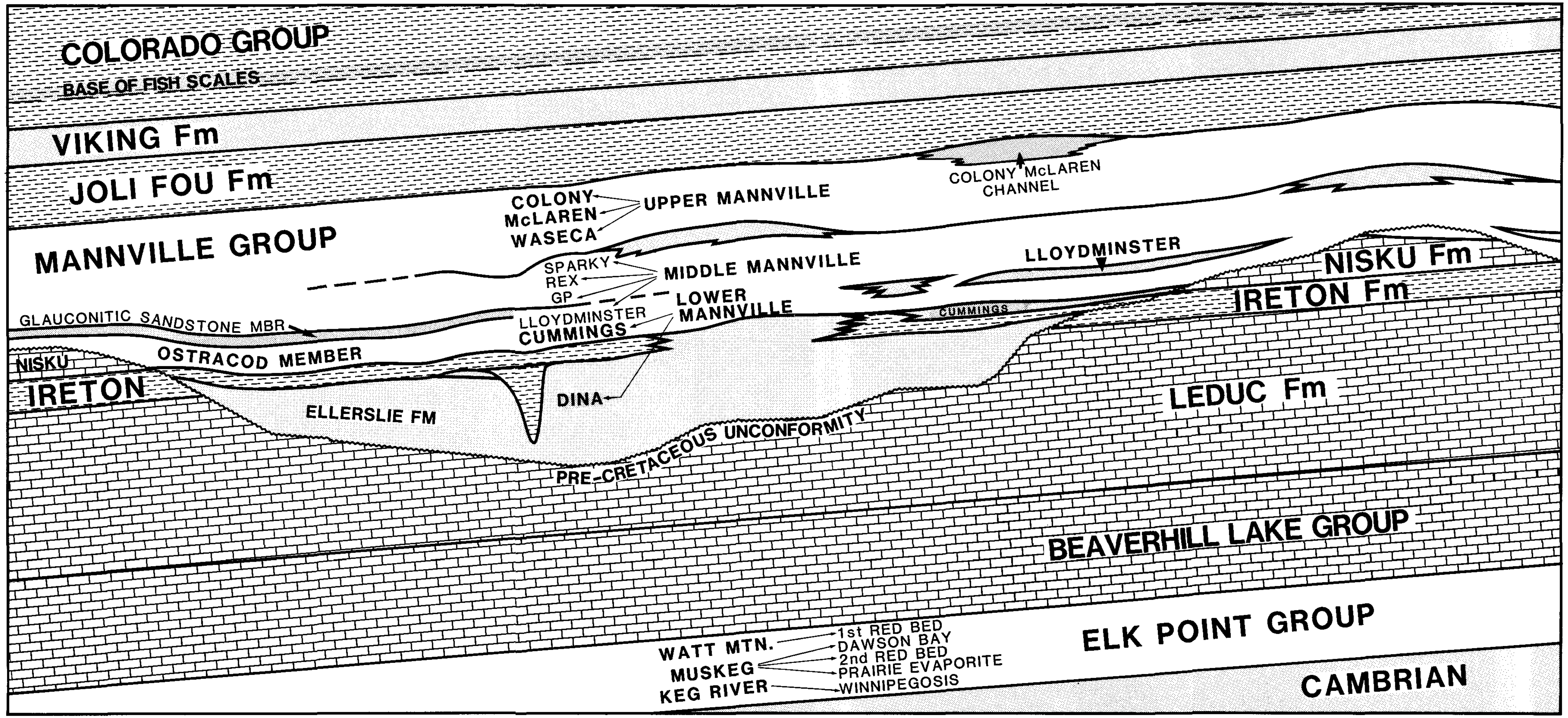

Figure 8.59. Schematic geological cross-section, Wainwright Ridge and Wainwright Nisku A pool.

DRAFTING: K. GRIMSON

AUTHOR: D. CEDERWALL

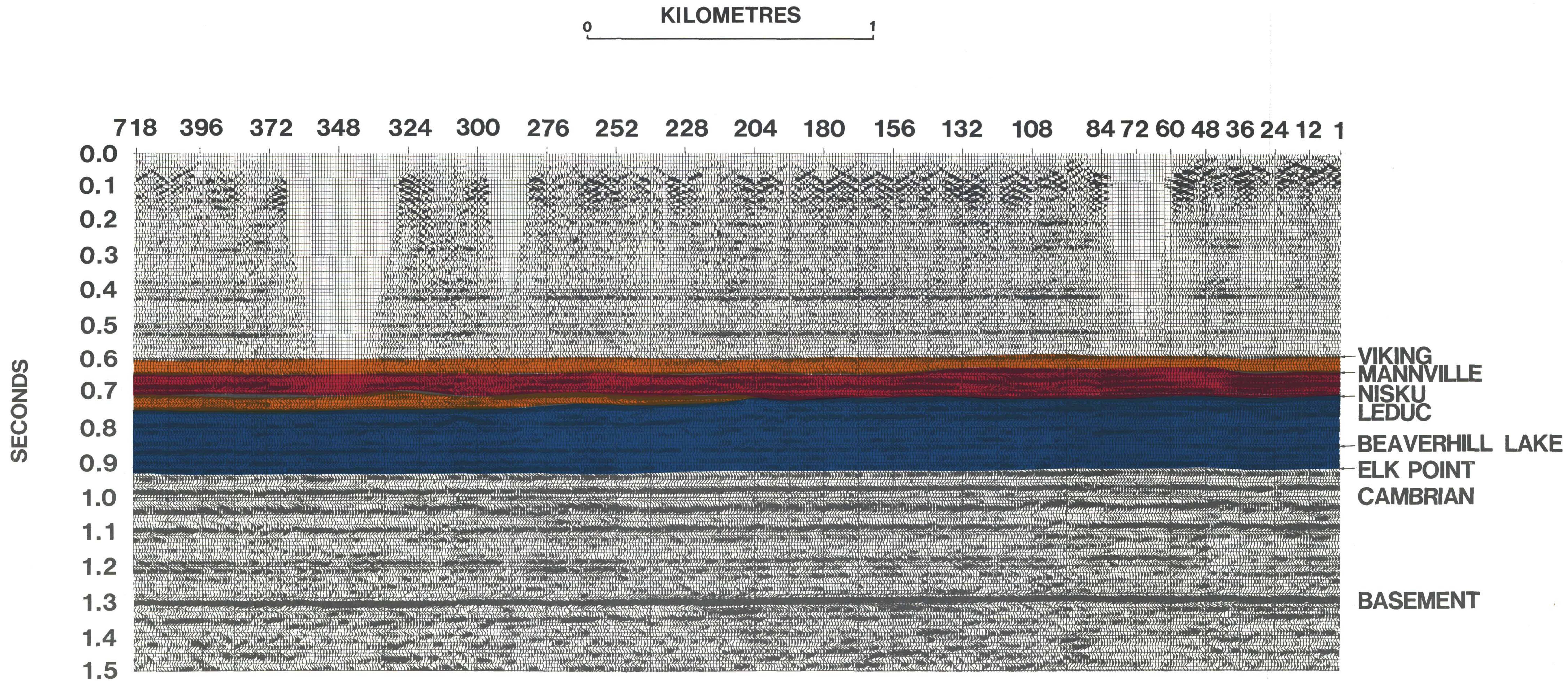

Figure 8.60. Seismic data, Wainwright Ridge and Wainwright Nisku A pool.

CABRE EXPLORATION
DONOR: BOW VALLEY INDUSTRIES LTD. & COHO RESOURCES LIMITED | PROCESSOR: | AUTHOR: D. CEDERWALL, B. MacDONALD

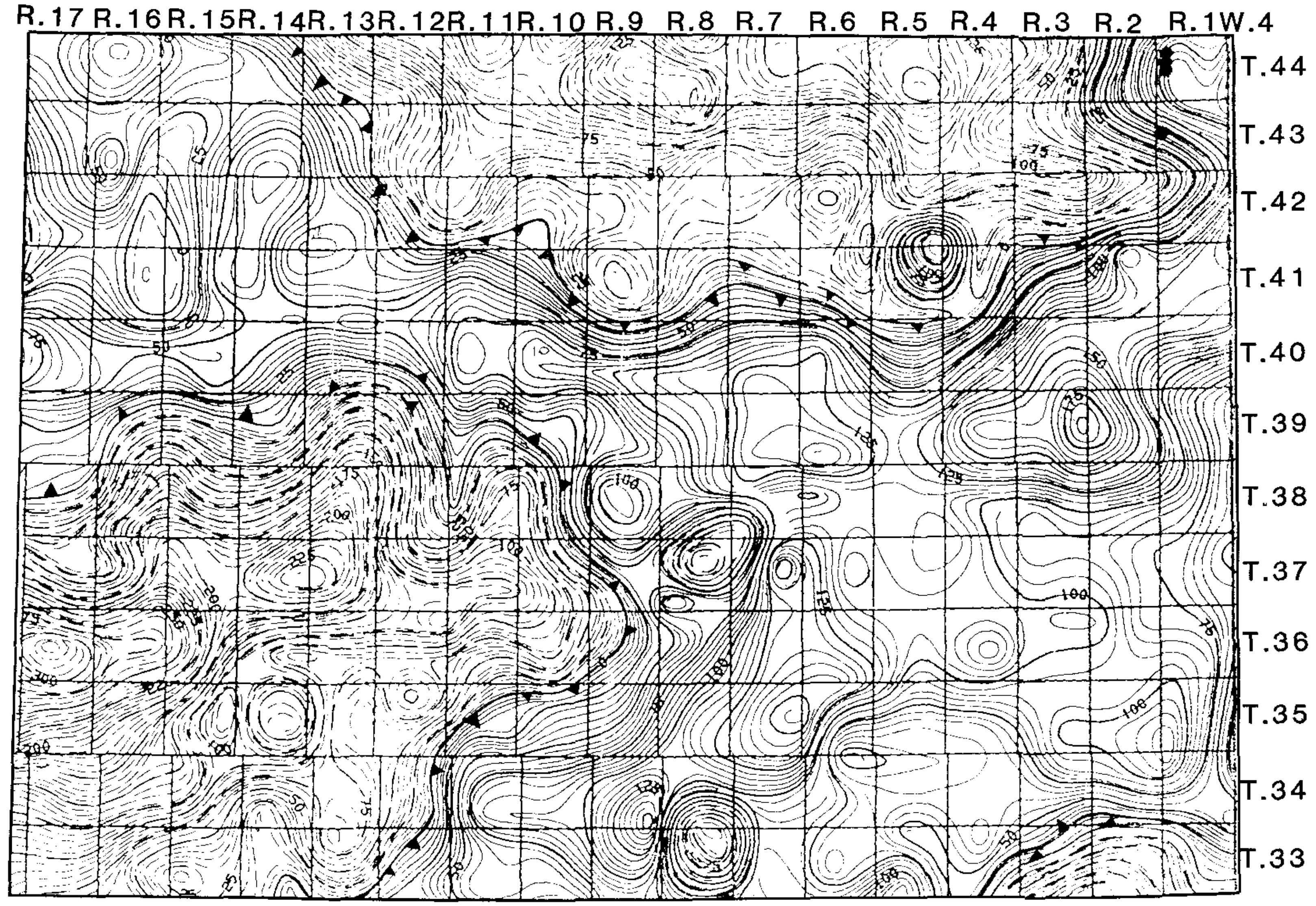

Figure 8.61. 8th order residual map Base of Fish Scales to pre-Cretaceous unconformity, Provost area (courtesy, Poco Petroleums Ltd).

and 204 and is typified by both a thin Mannville interval (640 to 710 ms) and a total absence of the Dina member. The extra trough to peak cycle which occurs near the top of the Paleozoic strata over this area is due to the presence of the Nisku and Ireton formations which are absent due to erosion within the channel area. This extra thickness of Paleozoic strata between traces 1 and 204 creates deeper event pull-up on the order of 10 to 15 ms relative to the same events within the channel area.

An anomalous feature along the Mannville Gp event between traces 36 and 156, is indicative of a Colony member channel. This event shows structural relief along the Mannville Gp and some thickening of the upper Mannville interval. Colony member type anomalies are discussed further in the Hairy Hills Colony W pool of this chapter.

CONCLUSION

Figure 8.60 shows the onlapping relationship between lower Mannville strata and pre-Cretaceous structures of the Wainwright Ridge. This relationship is common in the Western Canada Sedimentary Basin, and is a key to understanding both the deposition of the Lower Cretaceous strata and to explaining the occurrence of many Mannville and pre-Cretaceous subcrop type traps. The seismic data also displays the signature of a Colony member channel facies sandstone.

8–11: PROVOST BASAL QUARTZ C POOL

INTRODUCTION

The Provost Basal Quartz C Pool is located in T40 - R8 W4M in eastcentral Alberta approximately 170 km east of Edmonton, Alberta (Fig. 8.62). This reservoir which is also referred to as the Shorncliffe pool produces oil from the Ellerslie Fm. The pool, which measures approximately 1.5 km east to west by 1 km north to south, lies within the Edmonton Channel complex described by Williams (1963).

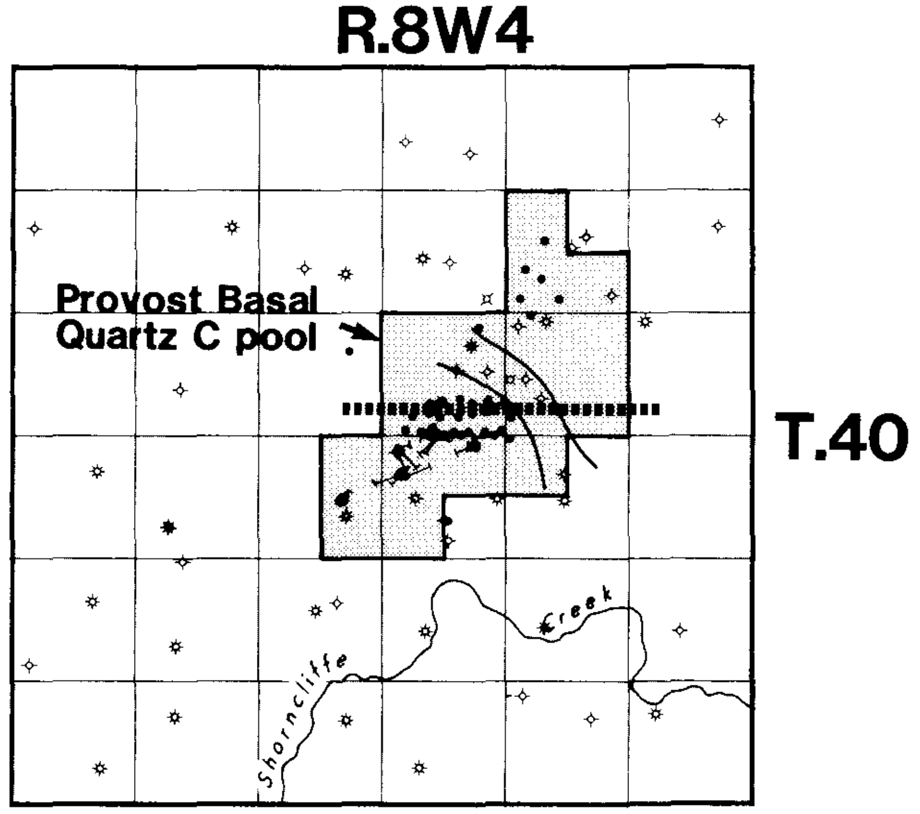

Figure 8.62. Location map, Provost Basal Quartz C pool (courtesy, The Geobase Company Ltd).

The Provost Basal Quartz C Pool is similar to the Hayter Dina B pool in that both produce oil from the top of a thick, lower Mannville sandstone. The two examples, although genetically related, are different with respect to their trapping mechanisms. In the vicinity of this pool clean quartzose sandstones of the Ellerslie Fm consist of a series of stacked channels which may exceed 55 m in gross thickness. An absence of good well-log markers within these sandstones prevent confident division of this unit into sequences and thus the presented subdivision of the Ellerslie Fm in Figure 8.65 should be used with caution. These sandstones are part of an east to west trending Lower Cretaceous valley fill sequence which is bounded to the north and south by Paleozoic escarpments. To the north, resistant carbonates and shales of the Nisku, Ireton and Leduc formations form a high termed the Wainwright ridge. Similarly to the south, Devonian strata form ridges termed the Hamilton Lake and Bodo highs (Fig. 8.3). The valley fill is variable in width, but is commonly on the order of 30 km across. It extends for several hundred kilometres from western Saskatchewan into eastcentral Alberta (Gross, 1980). The petrography of these sandstones (Williams, 1963) and their radiometric age based on contained feldspars (Williams et al., 1962) suggests an eastern source for these sediments. Likely sources are the Pre-Cambrian Shield or the Athabasca Sandstone of Saskatchewan.

This example is primarily stratigraphic in that the updip seal is formed by a very narrow, lower Mannville shale filled channel. This channel which lies to the northeast of the pool is of uncertain origin, but appears to be filled with sediments which postdate the Ellerslie Fm. Shale fill examined in core from a similar trap in T40-R26 W3M shows low energy characteristics (thin, horizontally laminated, and burrowed strata) in contrast to the channel facies of the Ellerslie Fm. This suggests that a rapid abandonment or marine transgression caused open channel systems and/or oxbow lakes to be flooded and filled by overbank deposits or marine sediments, during late lower Mannville (Ostracod) time.

At the Provost Basal Quartz C pool this cut and fill trends southeast by northwest, perpendicular to regional dip, thereby forming a seal for downdip hydrocarbons. This style of trapping mechanism is discussed by Vigrass (1977), who suggested a post depositional model of erosion and filling, due to intra-Mannville unconformities.

The Basal Quartz C Pool produces 921 kg/m^3 oil from an average pay of 13.4 m. The oil is underlain by a thick water zone which provides a drive mechanism in the absence of a gas cap or significant dissolved gas. The reservoir sandstones are relatively unconsolidated, and have average porosity of 30% and permeabilities of several Darcies. Specific reservoir parameters are presented in Table 8.11. Production data for the subject pool are shown in Figure 8.63.

Table 8.11: Reserves and significant reservoir parameters, Provost Quartz C pool (ERCB, 1987)

Initial Oil in Place	5610 x 10^3m^3
Primary Recovery Factor	7%
Initial Primary Recoverable Reserve	393 x 10^3m^3
Production to Date	209.2 x 10^3m^3
Remaining Recoverable Reserves	183.8 x 10^3m^3
Average Porosity	30%
Water Saturation	23%
Average Pay	13.4 m
Oil Gravity	921 kg/m^3
Area	192 ha
Discovery Year	1977

GEOLOGICAL CROSS-SECTION

Five wells are presented in the west to east geological cross-section through the Provost Basal Quartz C Pool (Fig. 8.64), depicting: 1) regional Ellerslie Fm; 2) the reservoir; and, 3) the trap. The section shows strata from the pre-Cretaceous unconformity to the base of the Fish Scales zone.

The lowest strata identified on Figure 8.64 are the subcropping Nisku Fm carbonates, which show local relief due to differential pre-Cretaceous erosion. Overlying this unconformity is the Ellerslie Fm which shows a lateral variation in thickness in Figure 8.64. Well (6-15-40-8W4) penetrates a thick Ellerslie Fm sandstone that shows a fining upwards sequence. This is overlain by thinly bedded coarsening upwards sandstone and shales which may predate the extra thickness of Ellerslie Fm sandstone which occur in the pool wells (15-15 and 16-15). This extra thickness of sandstone is likely the last phase of Ellerslie Fm sedimentation.

The origin of the pre-existing non-channel strata are undetermined, however two unstudied origins are postulated:

1) contemporaneous overbank and floodplain sediments may have been deposited; and

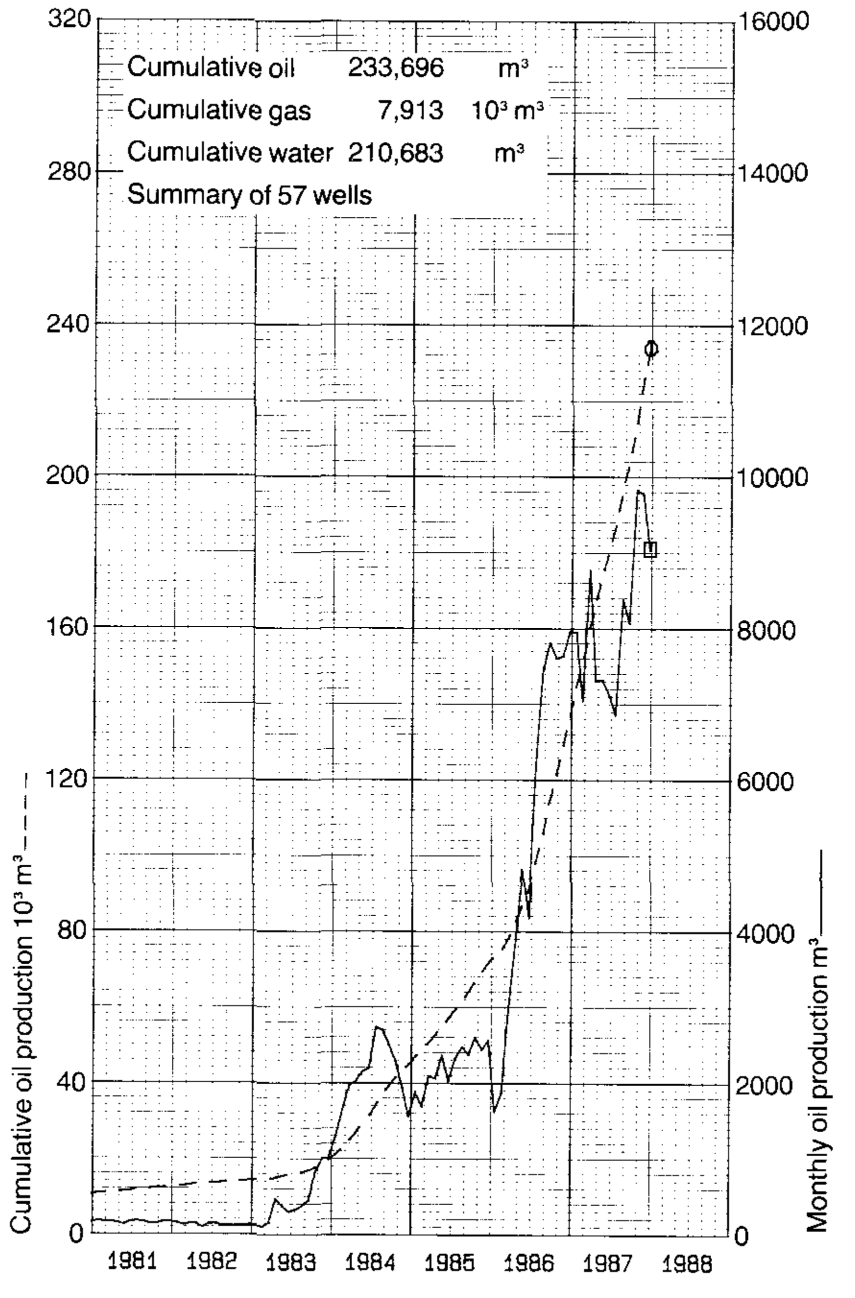

Figure 8.63. Production data, Provost Basal Quartz C pool.

2) marine strata were deposited during Ostracod time and later cut and filled by a diachronous Ellerslie Fm channel that transcended Ostracod time, prograding into the Ostracod sea.

Figure 8.64 shows that a minor amount of structure due to compaction is present along both the Mannville Gp and Viking Fm horizon. Reverse drape or slumping is associated with the cut and shale filled structure.

SEISMIC SECTION

The seismic data shown in Figure 8.65 (loc. Fig. 8.62) were acquired in 1982 to aid in the development of the Provost Basal Quartz C pool. These proprietary data were donated by Coho Resources Ltd., Bow Valley Industries Ltd. and Cabre Exploration Ltd. and were reprocessed by Teknica Resource Development Ltd. The twelvefold coverage, dynamite source data utilized 20 m group intervals along a 960 m by 960 m spread length with shotpoints spaced at 80 m intervals. The three kilometre long, west to east, line covers both the reservoir sandstone and the trap. Identification of the seismic events are shown on the synthetic seismic trace of Figure 8.66.

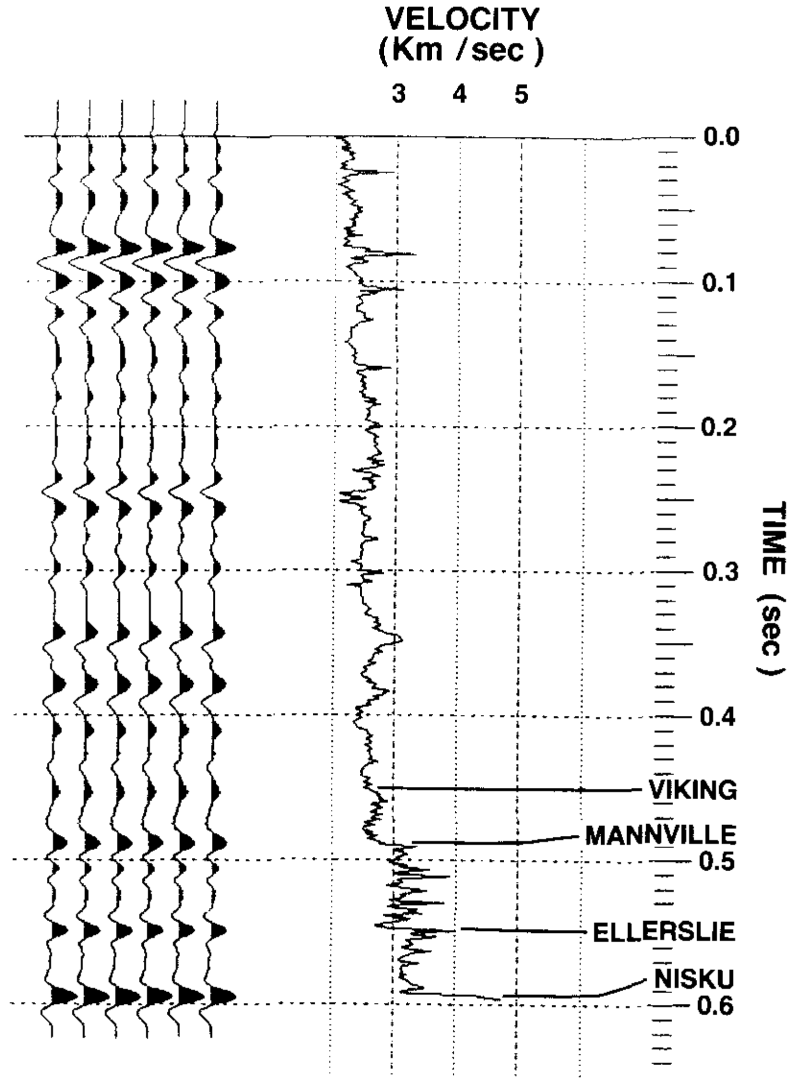

Figure 8.66. Single well synthetic seismic trace, Provost Basal Quartz C pool.

The lowest event identified on the data (Fig. 8.65) is the Elk Point Gp, which in this area consists, in ascending order, of the Winnipegosis, Prairie Evaporite Fm, 2nd Red Bed, Dawson Bay and 1st Red Bed formations. Below the Elk Point Gp are Cambrian sandstones and the pre-Cambrian basement complex.

The overlying unit is the Beaverhill Lake Gp which is a thick, dominantly limestone sequence. The lower unit of the Beaverhill Lake Gp which is likely the Slave Point Fm equivalent is separated by a thin shale from the upper carbonate units. It is capped by a uniform and laterally persistent shale which marks the end of Beaverhill Lake Gp deposition. The Woodbend Gp is dominated by thick Leduc Fm carbonates of the southern Alberta reef complex. This unit is capped by 20 to 30 m of calcareous Ireton Fm shale, and is overlain by the Nisku Fm which is the pre-Cretaceous subcrop in the vicinity of the pool. No salts are present in the Beaverhill Lake, Woodbend or Winterburn groups in the area and no evidence is found for dissolution of the Prairie Evaporite Fm salts.

The Ellerslie Fm event is identified by the peak to trough inflection labelled on the seismic data of Figure 8.65. This inflection represents the interface of the higher velocity capping units to the low velocity porous Ellerslie Fm sandstones. A significant time-structural low, the result of drape due to the compacted shale plug occur between traces 110 and 145. Drape appears to be extended through to the Mannville Gp, Joli Fou Fm and Viking Fm events on the seismic data.

CONCLUSIONS

Several different styles of hydrocarbon traps such as lateral pinchouts, differential compaction and post-depositional erosion with shale fill occur in the Ellerslie Fm of the Edmonton Channel. The Provost Basal Quartz C Pool is an example of the later type and has a discernable seismic signature, which consists of: 1) drape across the reservoir sandstone thick; 2) negative drape due to compaction of the shale fill of the channel cut; and, 3) lateral time-structural and character variation of the Ellerslie event due to the variation in the Ellerslie Fm thickness.

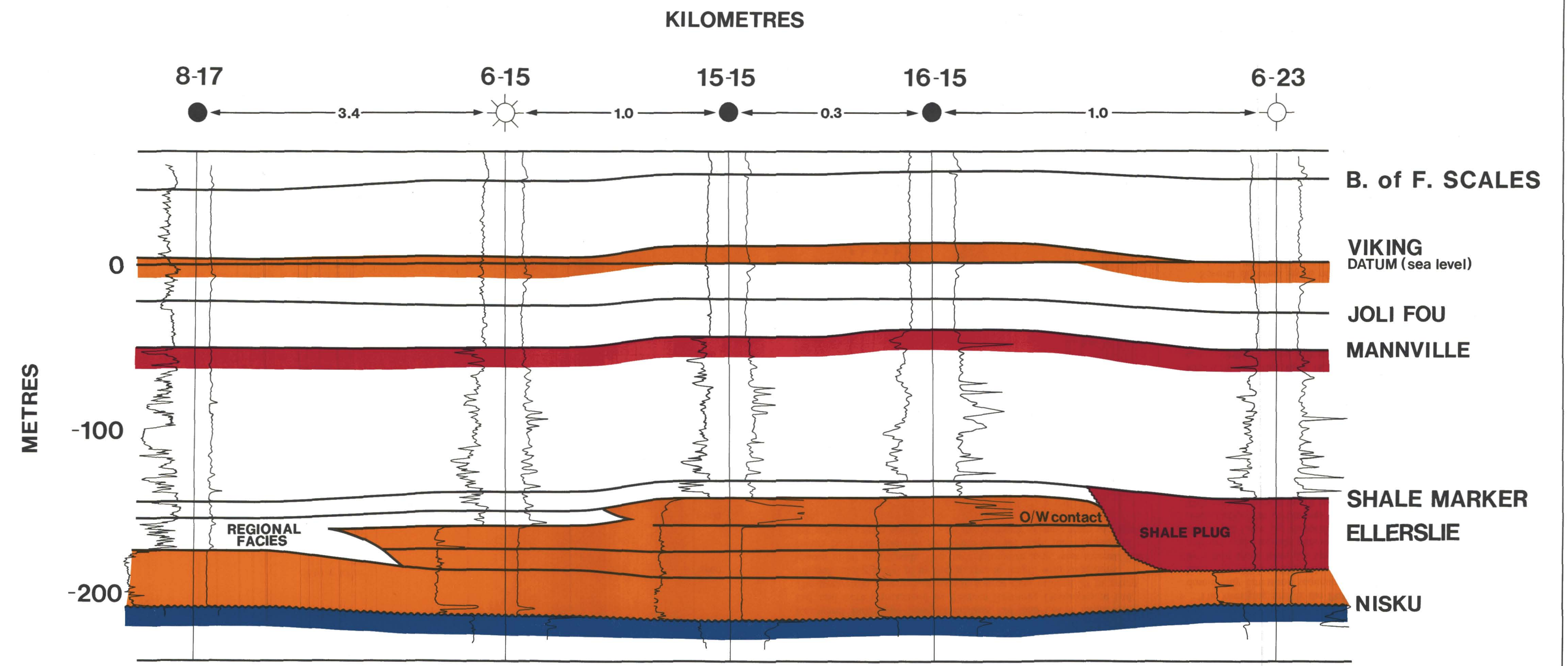

Figure 8.64. Geological cross-section, Provost Basal Quartz C pool.

DRAFTING: K. GRIMSON | LOG PLOTS: | AUTHOR: D. CEDERWALL, G. CHARLTON

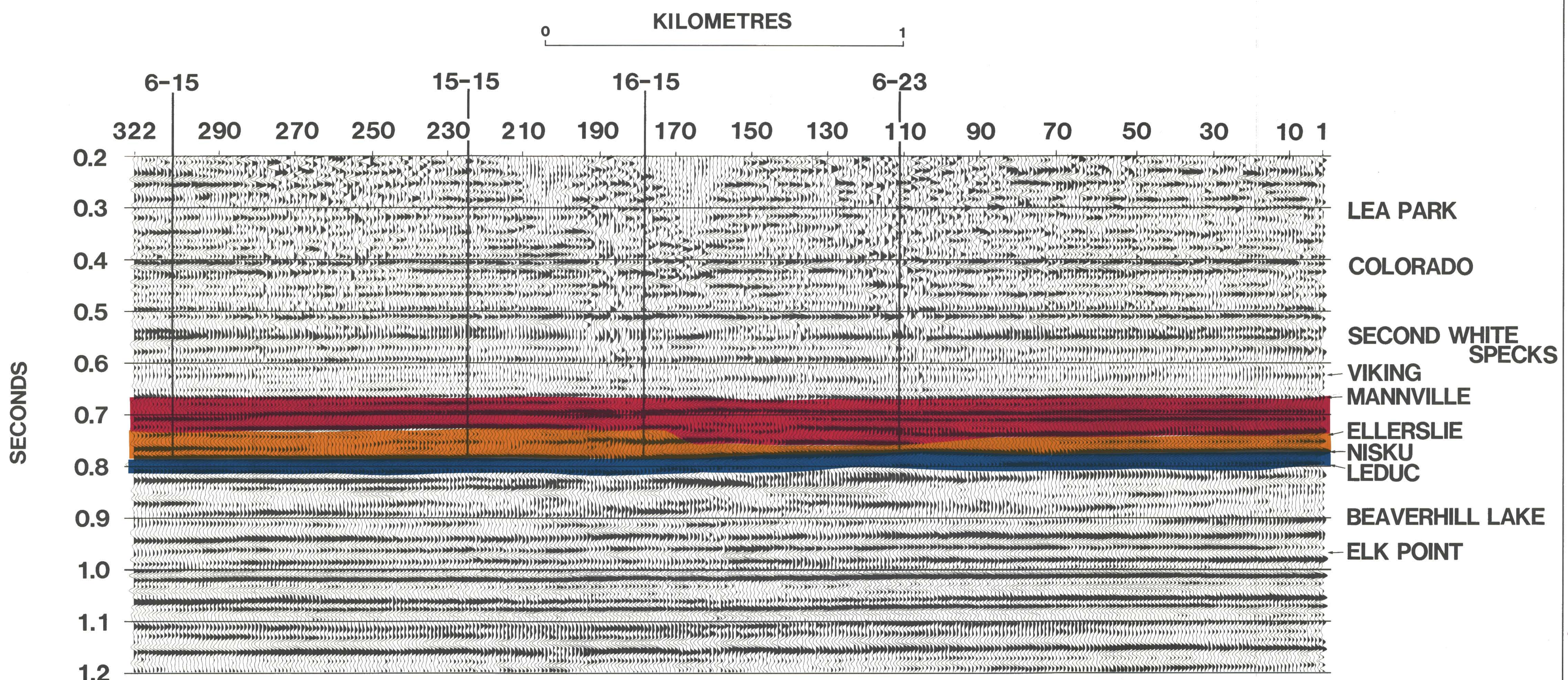

Figure 8.65. Seismic section, Provost Basal Quartz C pool.

DONOR: COHO RESOURCES LIMITED, CABRE EXPLORATION LTD. & BOW VALLEY INDUSTRIES LTD. | PROCESSOR: TEKNICA RESOURCE DEVELOPMENT LTD | AUTHOR: D. CEDERWALL, B. MacDONALD

8–12: HAIRY HILLS COLONY W POOL

INTRODUCTION

The channel sandstone reservoir of the Hairy Hills Colony W pool is typical of the prolific Colony member gas reservoirs of eastern Alberta which have been successfully exploited with the use of seismic data. The Colony member is the uppermost unit of the nine member informal subdivision of the Mannville Gp in the Lloydminster area and consists of shales, siltstones, coals and sandstones. The term Colony member sandstone has a strong genetic connotation as it is commonly associated with thick shoestring channel sandstones which trend south to north and northwest throughout much of east-central Alberta and Saskatchewan (Putnam and Oliver, 1982). Channels in the Colony member are elongated, usually being less than one kilometre wide and several tens of kilometres in length. Reservoir thicknesses in excess of 35 m are known to occur with gas pay typically underlain by water in thicker wells. Wrightman et al.

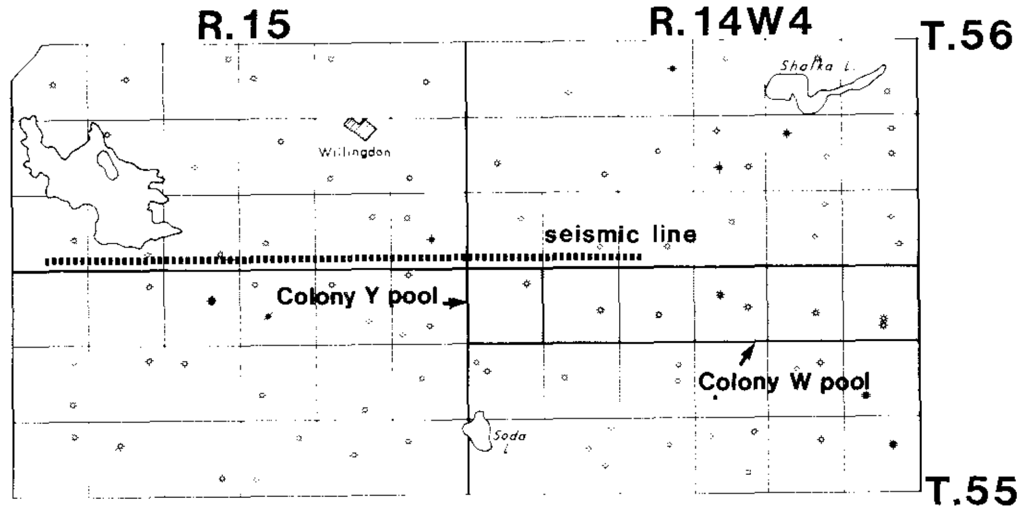

Figure 8.67. Location map, Hairy Hills Colony W pool (courtesy, The Geobase Company Ltd).

(1987) showed that the reservoir sandstones of the Colony member consist of multiple stacked paleochannel deposits. Their work also suggested an eastern basin configuration for the upper Mannville and paleodrainage in that direction.

Putnam (1982), Vigrass (1977), and Wickenden (1948) have suggested a threefold genetic subdivision for the Mannville Gp in the Lloydminster area which incorporates the Colony, McLaren and Waseca members into the upper Mannville (Fig. 8.1). This subdivision allows for a bulk mapping of the upper three members which are extremely difficult to separate in the subsurface with well logs (Putnam and Oliver,1980). In this subsection, usage of the term "Colony member" will infer the deposition of channel facies sandstones, whereas laterally equivalent non-channel facies are referred to as the regional facies. Work by Putnam and Oliver (1980) has lead to the proposal of contemporaneous deposition of the channel sandstones with associated levee, crevasse splays, overbank and other associated deposits. Significant drape across the Colony member channel sandstone anomalies of this example and the examples of Focht and Baker (1985) suggests that most or all differential compaction of the upper Mannville postdates channel deposition. Note that much of the structural drape measured by the time-structural relief along the top of the Mannville event is "apparent" and caused by a change in the phase of the seismic response or "bright spot effect" (B. Dick, pers. comm., 1988). No distinction is made between "phase generated" and "drape generated" structures of the Colony member, channel sandstone anomolies.

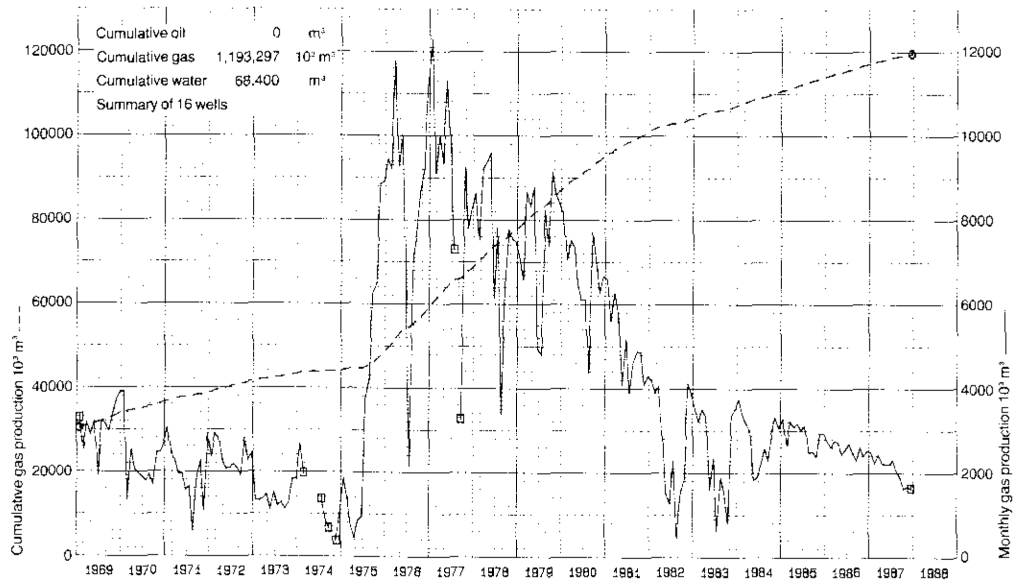

Figure 8.68. Production data, Hairy Hills Colony W pool.

The Colony member channel facies sandstones of this area occur at a depth of approximately 550 m and are unconsolidated to weakly consolidated quartz sandstones. The sandstones exhibit high angle cross-stratification, fining and shaling upward sequences, abrupt bases, and occasionally rip up or slumped clay clasts (Wrightman et al. 1987). Permeabilities of several Darcies are common and porosities commonly average 30%. Reserves and reservoir parameters of the Hairy Hills Colony W pool are shown in Table 8.12. Production data for subsection 8-12 are illustrated in Figure 8.68.

Table 8-12A. Reserve sand significant reservoir parameters, Hairy Hills Colony W pool (ERCB, 1987)

Initial Volume in place	1900 x 10^6m^3
Pool Recovery	72%
Surface Loss	5%
Initial Established Reserves	1300 x 10^6m^3
Net Cumulative Production	1134 x 10^6m^3
Remaining Established Reserves	116 x 10^6m^3
Average Pay Thickness	8.26 m
Average Porosity	30%
Average Gas Saturation	75%
Mean Depth	538 m
Discovery Year	1954

GEOLOGICAL CROSS-SECTION

Five wells are shown in the geological cross-section of Figure 8.69 (loc. Fig. 8.67). The end two wells (3-36 and 10-24) penetrate the Woodbend Gp, whereas the middle three wells penetrate less than 30 m into the Nisku Fm. The section which is datumed at sea level includes the Lower Cretaceous Viking Fm at its top. Interwell distances are not to scale in this diagram in order to optimize the visual display.

The lowest strata shown are the Devonian Leduc Fm (Willingdon reef) and the off-reef Ireton and Duvernay formations. The sediments are overlain by the Nisku Fm which is the subcropping pre-Cretaceous strata in this area. Both the Nisku and Leduc formations contain gas reserves in places. Structural relief occurs on the pre-Cretaceous unconformity between the locations of this cross-section due to: 1) differential erosion along the subcrop; and 2) differential compaction of the Ireton Fm. The area is thought to have been emergent during lower Mannville time as indicated by the absence of the lower Mannville strata.

The three central well logs (10-10, 10-2 and 7-33) show the development of the Colony member channel facies which approaches 40 m in the 10-10 well. All three wells show a blocky SP curve, with abrupt bases and fining upward sandstones. Regional facies strata are represented by the two end wells 10-24 and 3-36. The channel facies wells are shown to be contained in a single channel event, however more detailed examination such as that of Wrightman et al. (1987, p. 199) show the potential for hydraulic separation of closely spaced upper Mannville channels.

SEISMIC SECTION

The seismic section of Figure 8.70 was donated by Chevron Canada Resources Ltd. and reprocessed by Exploration Seismic Services Ltd. The line was part of a regional seismic acquisition program and is segmented to optimize the seismic signature of the pool. Identifications for the seismic events are shown on the synthetic seismic trace of Figure 8.71.

The anomaly shown from trace 90 to 150, identified on Figure 8.69 at approximately 520 ms is interpreted as a Colony member

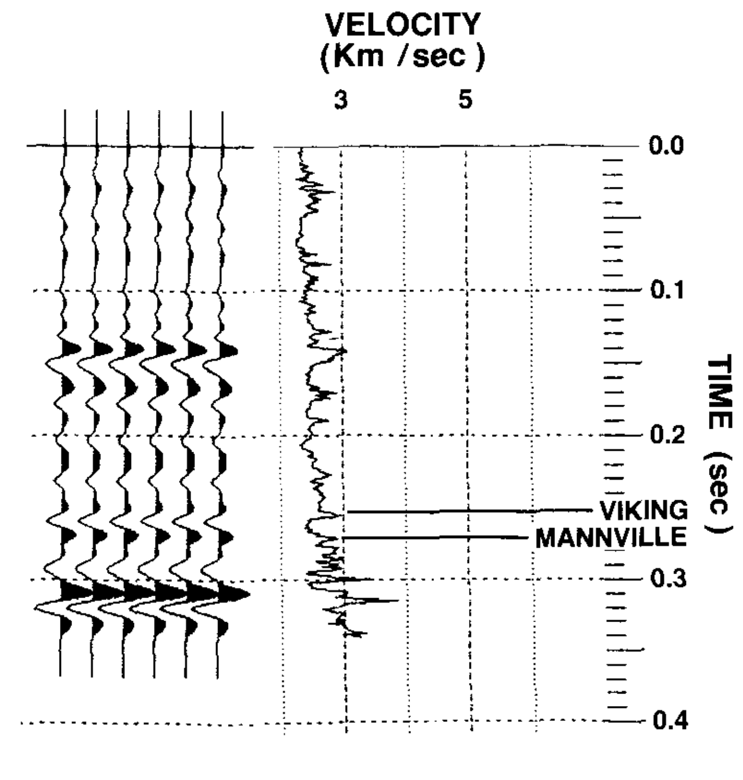

Figure 8.71. Single well synthetic trace, Hairy Hills Colony W pool.

channel facies sandstone. This feature is located at the north end of the Hairy Hills Colony W pool which trends north to south throughout much of T55 - R14 W4M before turning sharply west. The anomaly consists of time-structural relief of some 10 to 15 ms over an approximately 800 m wide channel. A corresponding increase in Mannville time-thickness is noted over the anomalous area. The occurrence of both drape and the increase in Mannville Gp thickness is not readily apparent on the geological cross-section (Fig. 8.69) due to the well spacing. This drape which is observed on the seismic data of Figure 8.70 may suggest that the Colony member channel facies sandstones were deposited contemporaneously with regional facies strata, but are also partially generated by the lateral phase change in the response due to gas saturation in the reservoir.

The deeper anomaly (at 620 ms) between traces 165 and 300 is the signature of the Willingdon D3 - B pool. This Leduc Fm reef is anomalous in its geological setting in that it is far removed from the major Leduc Fm reef trends of Alberta. Pull-up of 40 ms and lateral termination of Ireton Fm events are noted. Drape of the Mesozoic strata across the Leduc Fm reef is not as significant as that determined for more deeply buried Leduc Fm reefs such as those of Chapter 4 (this volume). Most compaction of the Ireton Fm took place prior to the Mesozoic and these strata were erosionally removed. Subsequent Mesozoic deposition was insufficient to overcome previous overburden pressures and therefore drape of the Mesozoic is not a noted feature. A review of Leduc reef compactional features is given in Chapter 4 (this volume), Labute and Gretener (1969) and Gretener and Labute (1972).

CONCLUSIONS

Figure 8.69 illustrates the seismic signature of a Lower Cretaceous, Colony member channel and an underlying Leduc Fm reef. Significant relief on the top of the Mannville Gp event, upper Mannville thickening and a lateral amplitude anomaly are characteristic of the Colony member channel sandstones. The time-relief which occurs across the Colony anomaly is seen as evidence that the Colony member channel facies sandstones were deposited contemporaneously with the laterally adjacent regional facies strata. Comparison of many upper Mannville anomalies by Focht and Baker (1985) shows that differences between coal anomalies and channel sandstones are discernable, and that seismic signatures can be used to estimate gross pay.

8–13: PEAVEY BLAIRMORE POOL

INTRODUCTION

The Peavey Blairmore pool, located approximately 45 km north of Edmonton, Alberta in T56-R24 W4M (Fig. 8.72), produces from the Ellerslie Fm and is of interest in that it overlies the edge of the Morinville Leduc Fm reef. Trapping in the Ellerslie Fm at Peavey is due to structural drape across an underlying reef. This structure is post-depositional and there is no discernable control on Ellerslie Fm sedimentation by the reef structure. The Morinville reef which is located on the northern portion of the Rimbey-Leduc Fm reef chain shows a significant reef edge structure, analogous to the peripheral rim structure of the Redwater reef complex described by Mossop (1972).

Mossop (1972), Labute and Gretener (1969) and Gretener and Labute (1972) respectively, explain the occurrence of reef rim structures and drape of post-reef strata. Their conclusions are used in explaining the occurrence of structural closure at the Ellerslie Fm interval in this example. Mossop (1972), in a reconstruction of original reef structure used formation interval thickness and estimates of reef compaction (recorded in stylolites) to explain the origin of the peripheral rim structure of the Redwater Leduc Fm reef. He concluded that the rim structure is due to the greater compaction of the micritic inner-reef lagoonal facies relative to the

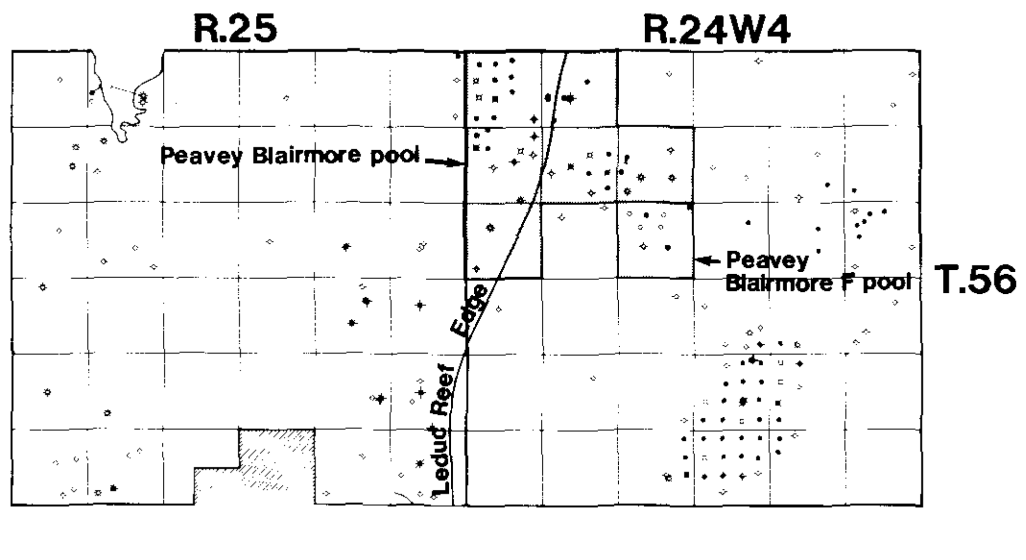

Figure 8.72. Location map, Peavey Blairmore pool (courtesy, The Geobase Company Ltd).

clean carbonates of the reef margins. No evidence was demonstrated for any primary rim structure on the reef edge. Labute and Gretener (1969) examined the degree and timing of the compaction of Ireton Fm shales encasing the Leduc Fm of the Wizard Lake Leduc Fm reef. They concluded that a significant thickness of pre-Cretaceous sediments was eroded from above these reefs. Their conclusion is supported by interval thickness data which show that compaction of the Ireton Fm was interrupted during the pre-Cretaceous hiatus due to the removal of overburden. Further compaction did not recommence until the weight of the Cretaceous strata exceeded that of the eroded Paleozoic sediments. Additional discussion of the differential compaction process and the effects of erosion are given in O'Connor and Gretener (1974a, 1974b), and Labute and Gretener (1969).

The geological and seismic data in this subsection indicate that: 1) structural relief sufficient to trap hydrocarbons is present in the Ellerslie Fm across the rim of the underlying Leduc Fm reef; 2) significant thinning of the subcropping Paleozoic formations does not appear to occur coincident with the reef rim; and 3) the Ellerslie Fm does not appear to be depositionally controlled by the reef. This would lead to the belief that the present structure on the Ellerslie Fm is largely post-depositional in origin.

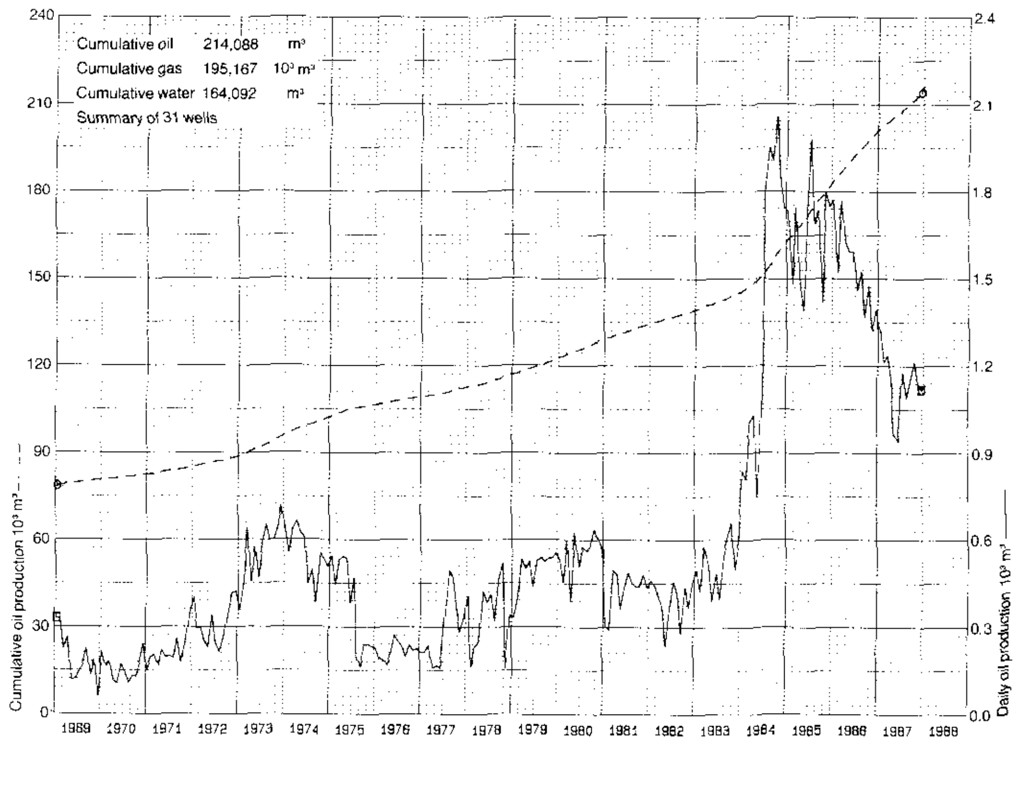

Figure 8.73. Production data, Peavey Blairmore pool.

A summary of the oil reserves and significant reservoir parameters for the Peavey Blairmore pool are shown in Table 8.13. Productivity data for this pool are illustrated in Figure 8.73.

Table 8.13: Reserves and significant reservoir parameters, Peavey Blairmore pool (ERCB, 1987)

Initial Oil in Place	1896 x $10^3 m^3$
Primary Recovery Factor	20%
Additional Secondary Recovery Factor	10%
Primary Recoverable Reserves	379.0 x $10^3 m^3$
Additional Secondary Recoverable Reserves	63.6 x $10^3 m^3$
Cumulative Production to Date	208.6 x $10^3 m^3$
Remaining Established Reserves	234.4 x $10^3 m^3$
Area	272 ha
Average Pay	3.25 m
Average Porosity	20.6%
Water Saturation	23%
Oil Density	876 kg/m^3
Average Depth	1067 m
Discovery Year	1952

GEOLOGICAL CROSS-SECTION

The Peavey Blairmore pool geological cross-section is segmented into two parts. A left justified portion illustrates the Mesozoic strata and the right justified portion illustrates the Paleozoic strata.

Figure 8.74(1)

Figure 8.74(1) depicts the on-reef to off-reef stratigraphic relationships of the Woodbend Gp. The two wells which are stratigraphically datumed show the off-reef thickening of the Calmar, Nisku and Ireton formations, and the off-reef occurrence of the Duvernay Fm. The 2-30 location is common to the 8.74(2) section and illustrates a near maximum structural position along the reef rim.

Figure 8.74(2)

Figure 8.74(2) illustrates the Lower Cretaceous strata in the proximity of the reef rim. The section which is structurally datumed at 220 m below sea level shows the structural closure on the Ellerslie Fm. A downdip water interval is shown by the 6-30 well. An oil interval occurs between the 6-30 well and the interpreted gas cap

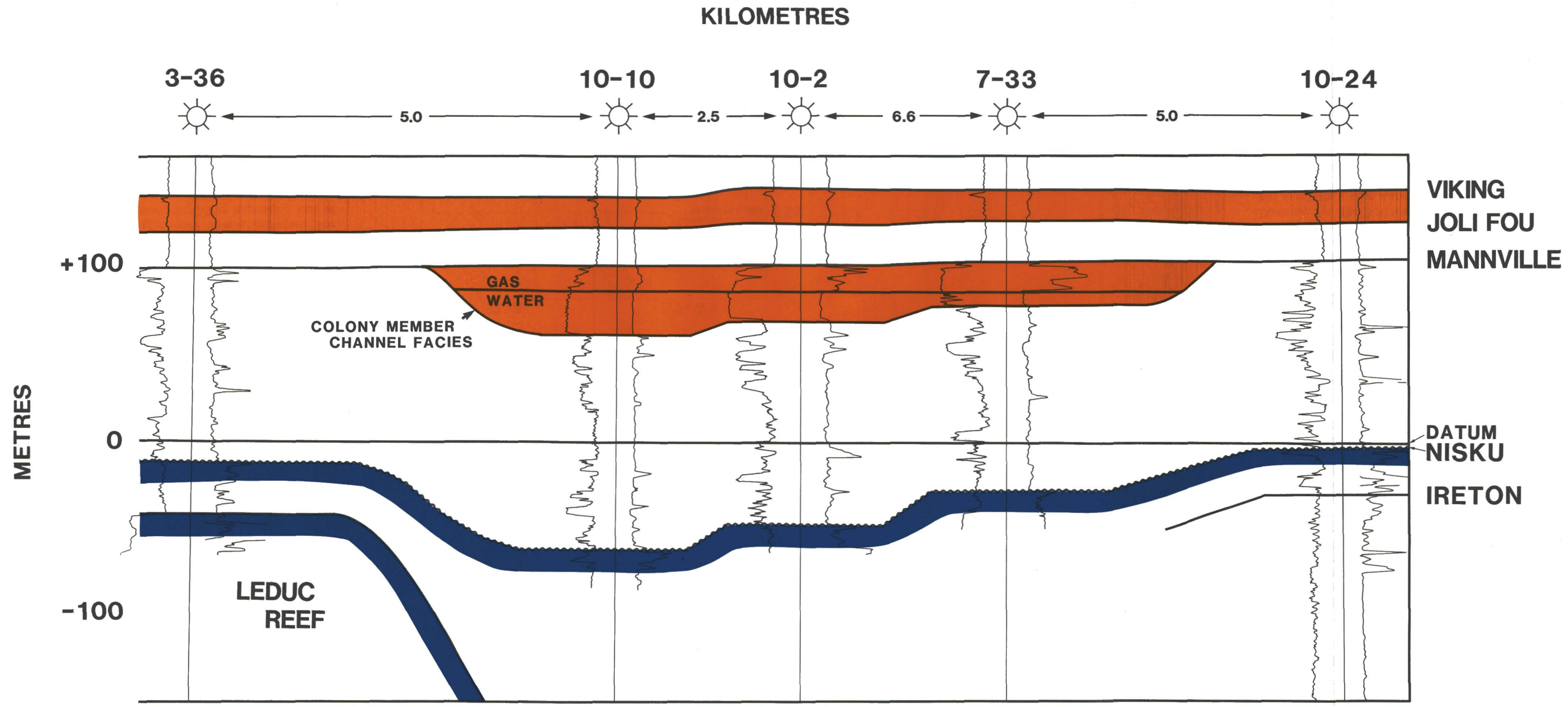

Figure 8.69. Geological cross-section, Hairy Hills Colony W pool.

DRAFTING: K. GRIMSON | LOG PLOTS: | AUTHOR: D. CEDERWALL , C. BRIERE

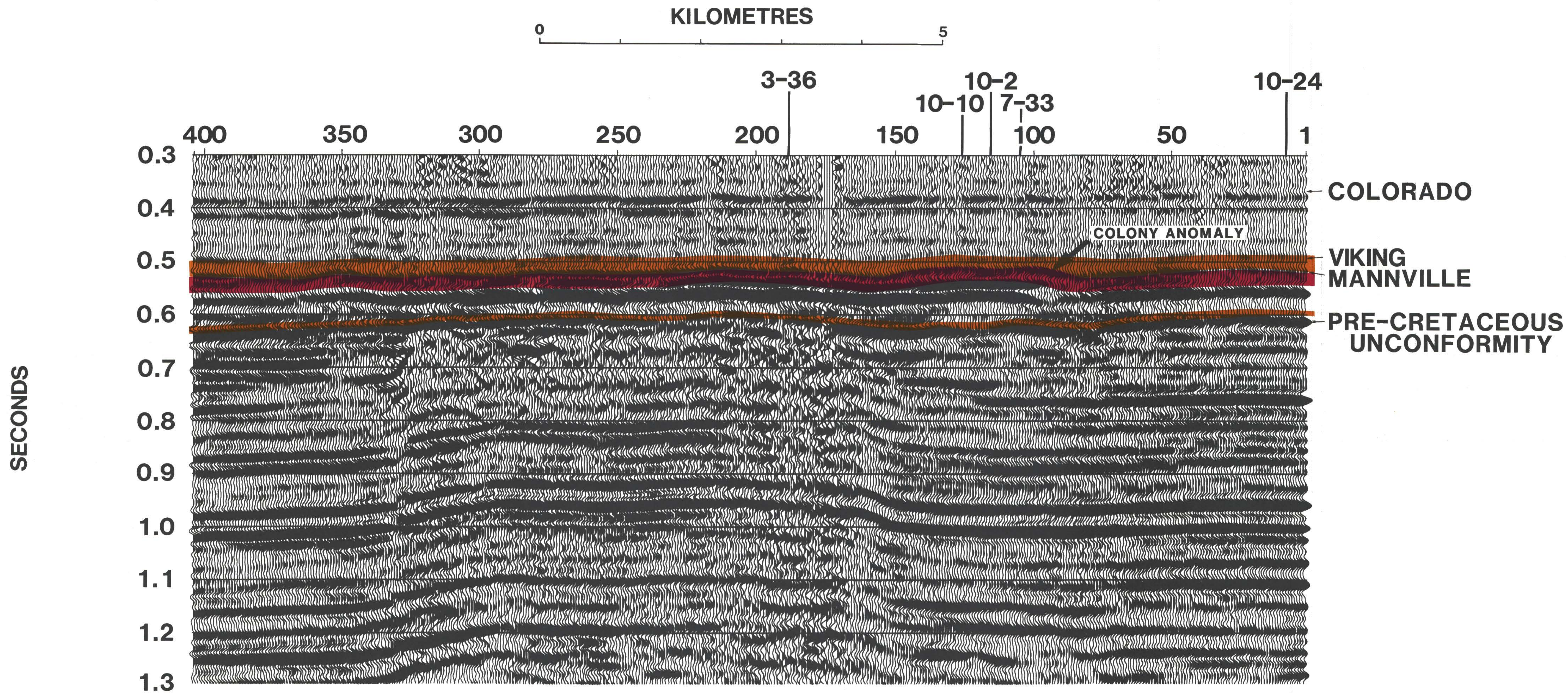

Figure 8.70. Seismic section, Hairy Hills Colony W pool.

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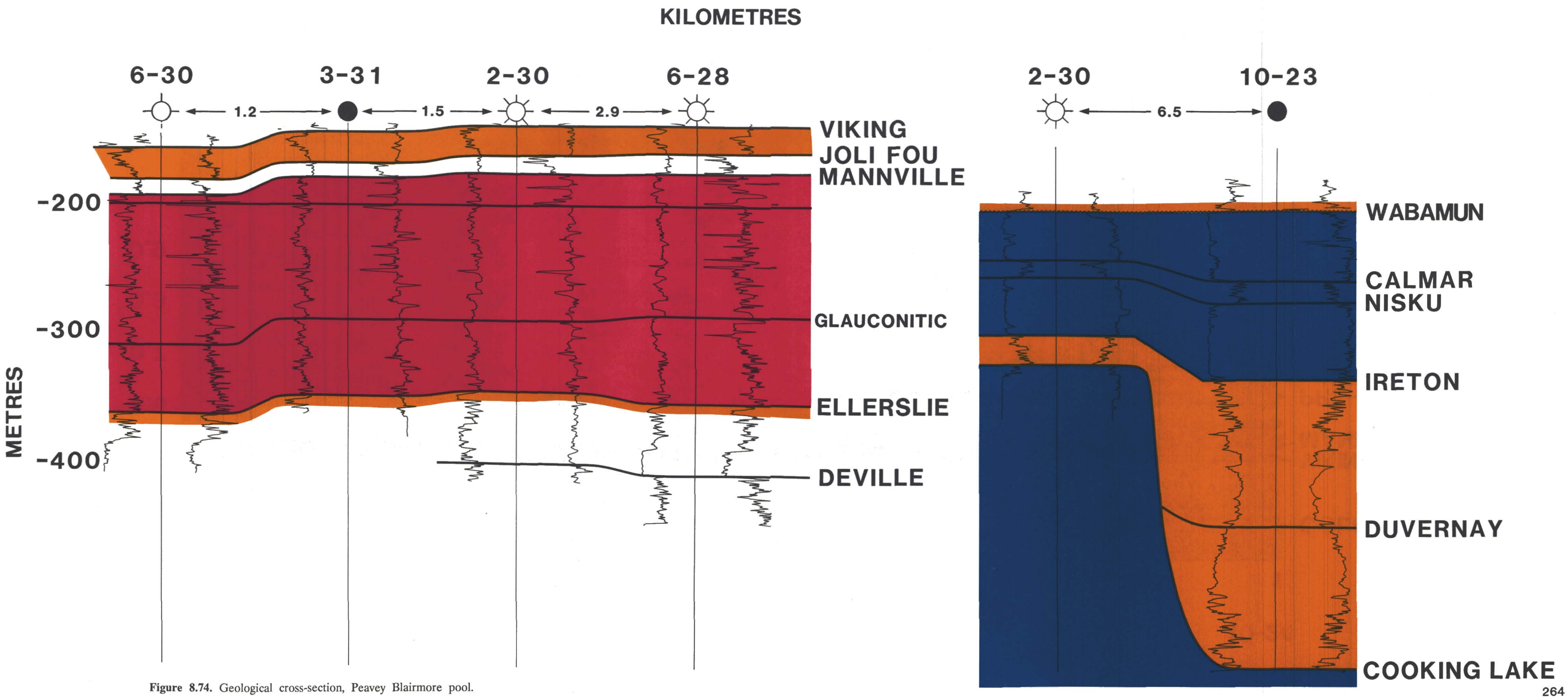

Figure 8.74. Geological cross-section, Peavey Blairmore pool.

DRAFTING: K. GRIMSON | LOG PLOTS: | AUTHOR: D. CEDERWALL, D. WINE

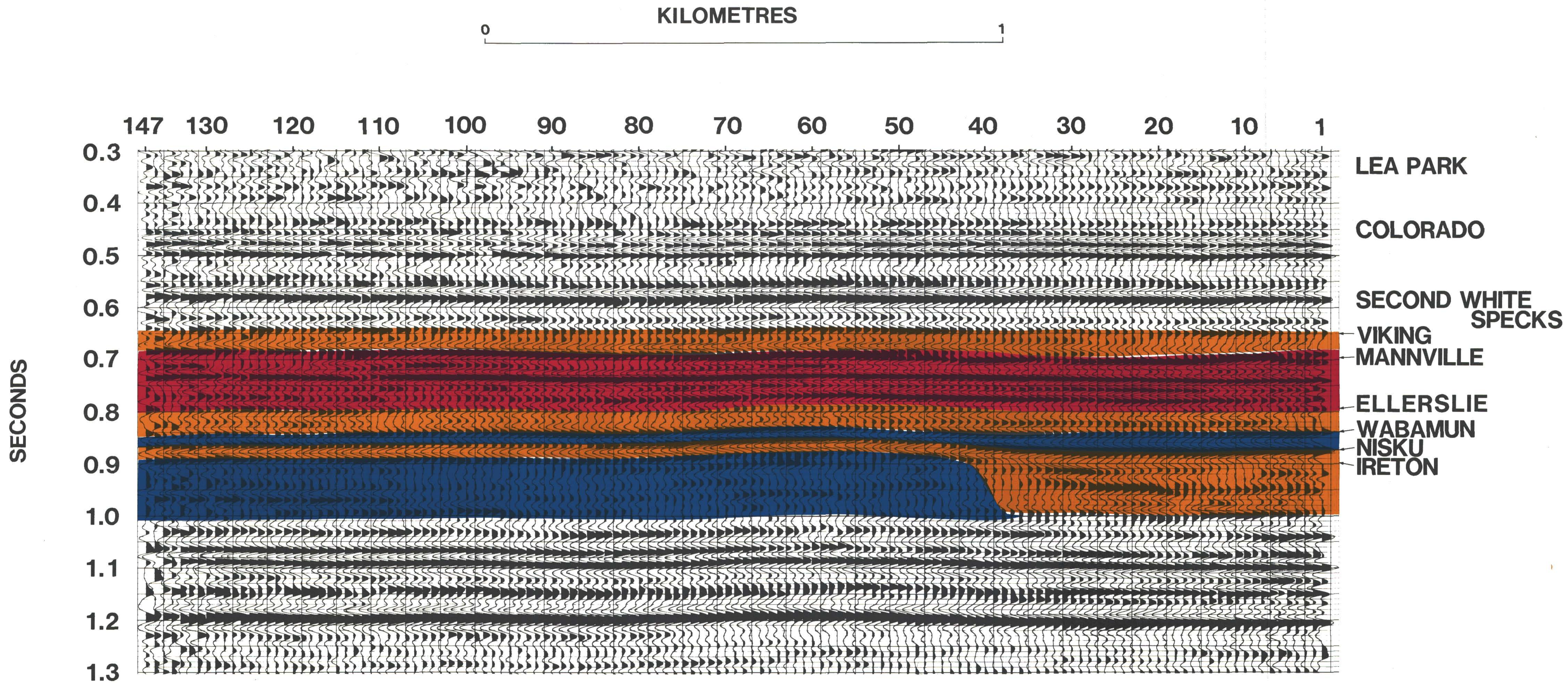

Figure 8.75. Seismic section, Peavey Blairmore pool.

DONOR: MONTNEY RESOURCES LTD. | PROCESSOR: | AUTHOR: D. CEDERWALL, M. MANSELL which is penetrated in the 2-30 well. The continuity of this upper Ellerslie Fm sandstone is not conclusive but considered likely. Directly below the reservoir sandstone, the lower portion of the Ellerslie Fm appears to be in a fining upwards sequence, analogous to the Dina member (Mannville Gp) and Ellerslie Fm channels of the Provost Basal Quartz C and Hayter examples of this chapter. The term Deville Fm is applied here to the detrital facies strata which lie directly on the pre-Cretaceous unconformity.

SEISMIC SECTION

The seismic section of Figure 8.75 was donated by Montney Resources Ltd. and are displayed under original processing. Well ties and the exact location of the line are undisclosed, however it is oriented perpendicular to the reef edge. A visual comparison of the data and the accompanying synthetic trace suggests that this data is slightly out of phase with log normal polarity. The data are twelve-fold Vibroseis source, acquired in 1983 using a 67-m source interval and 33.5-m group interval. Identifications for the seismic events are shown on the synthetic seismic trace of Figure 8.76.

Traces 1 through 30 (0.850 - 1.1 secs) of Figure 8.75 are the signature of the Woodbend Gp in an off-reef position. Traces 1 through 45 of approximately the same time-interval show the reef front, apex of the reef rim and the back-reef slope to the innerreef. The innerreef occurs west of trace 75. Notable features on Figure 8.75, through this time interval, are the time-structure on the Leduc event and apparent pull-up of the deeper events that occur between the on-reef and off-reef positions. Maximum time-structure on the Leduc event and maximum pull-up of deeper events are observed at trace 54. This point is interpreted as the apex of the reef rim. A relative time-structure of 15 ms on the Leduc event is noted between this position and the inner reef. Similar time-structural relief is observable on much of the overlying strata and can be traced up to approximately 550 ms. Note, however, that the magnitude of this time-structure and the magnitude of the closure gradually diminish in the shallower horizons. Note also that the Wabamun to Ireton interval is relatively constant from on-reef to off-reef positions, indicating that time-structure on the top of the Wabamun event is due to differential compaction of the Woodbend Gp, rather than to erosion.

Time-structural relief on the Ellerslie event parallels that of the Ireton event, but is of slightly less magnitude. Dip reversal due to compaction of the off-reef sediments (Ireton Fm) to the east which is replicated in the Lower Cretaceous is the updip trapping mechanism for the Ellerslie Fm. Compaction of the innerreef relative to the reef rim and regional dip are the sources of a structural low to the west of the pool.

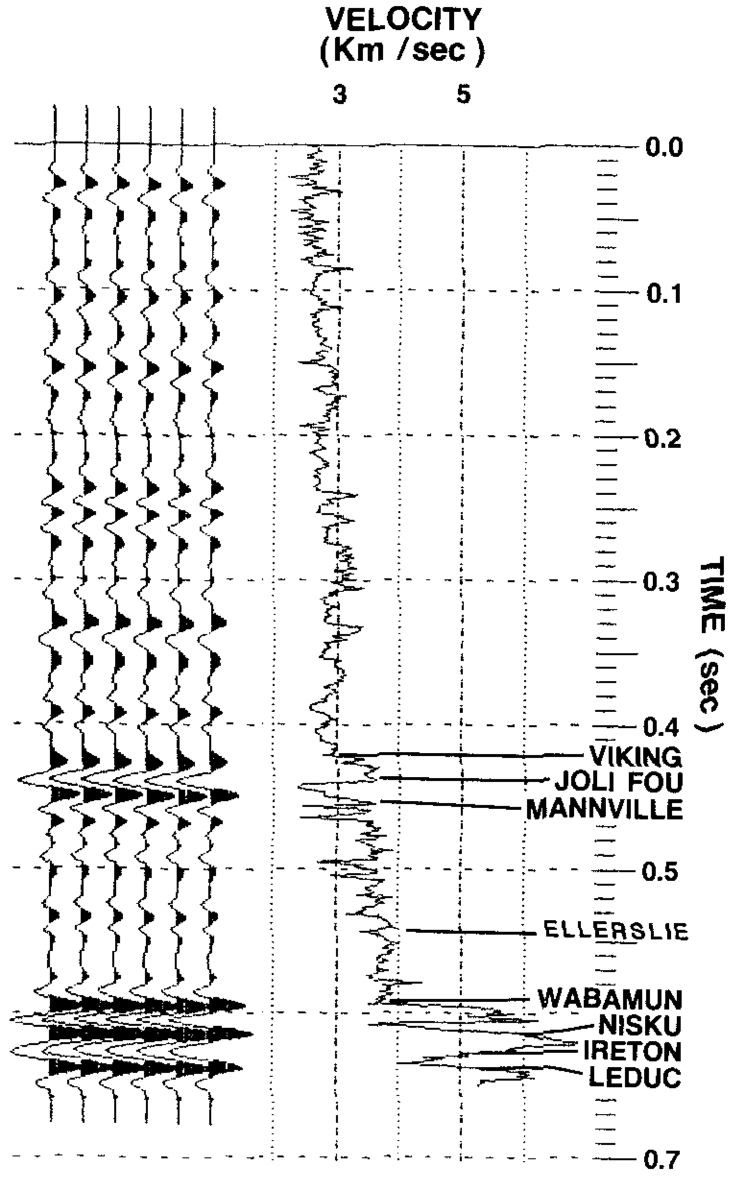

Figure 8.76. Single well synthetic trace, Peavey Blairmore pool.

CONCLUSIONS

The Peavey Blairmore pool is an Ellerslie Fm oil pool which occurs on the edge of the Morinville, Leduc Fm reef. The trapping of hydrocarbons is due to structural closure which is likely caused by the differential compaction of on-reef to off-reef strata in the Woodbend Gp. The uniformity of the Ellerslie Fm across the structure indicates that structural deformation postdates deposition of these strata. This is supported by the conclusions of Mossop (1972), Labute and Gretener (1969) and Gretener and Labute (1972).

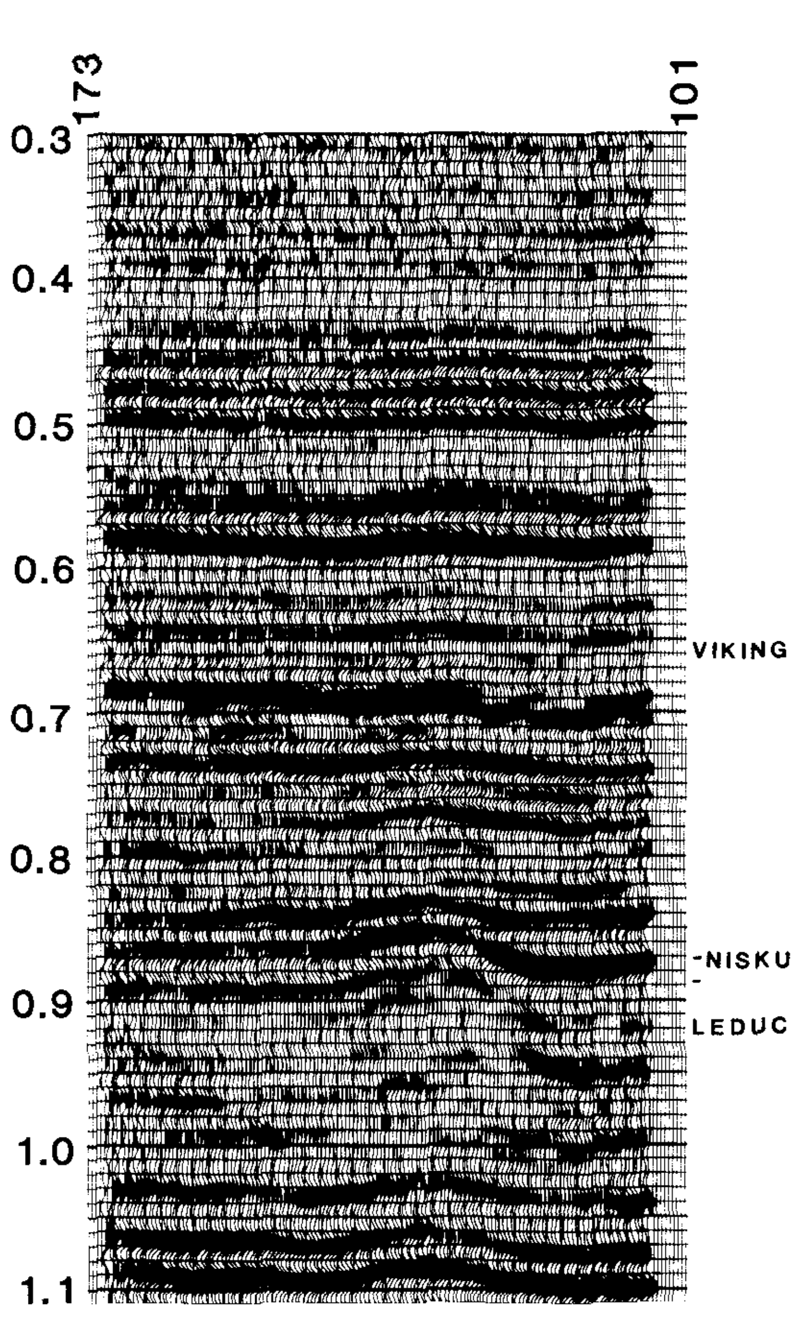

Figure 8.77. Compressed seismic section, Peavey Blairmore pool.

8–14: CRYSTAL VIKING A AND H POOLS

INTRODUCTION

The Crystal Viking A and H pools of T46-R3 W5M (Fig. 8.78) are the only Viking Fm reservoirs discussed in this chapter. The Viking Fm is a significant hydrocarbon reservoir in Alberta and Saskatchewan, however, exploitation of the Viking Fm using seismic data is difficult. Hydrocarbon traps in the Viking Fm are primarily stratigraphic and often caused by regional facies changes resulting in updip pinchout traps with downdip water, or by localized facies changes such as those associated with marine bars. Structural trapping of regionally porous Viking Fm sandstones across features such as reefs occurs, but form only a small portion of Viking Fm reserves. The difficulty in detecting these stratigraphic traps is due to the minor acoustic contrast which accompanies the lateral reservoir to non-reservoir facies changes within the Viking Fm. Furthermore the

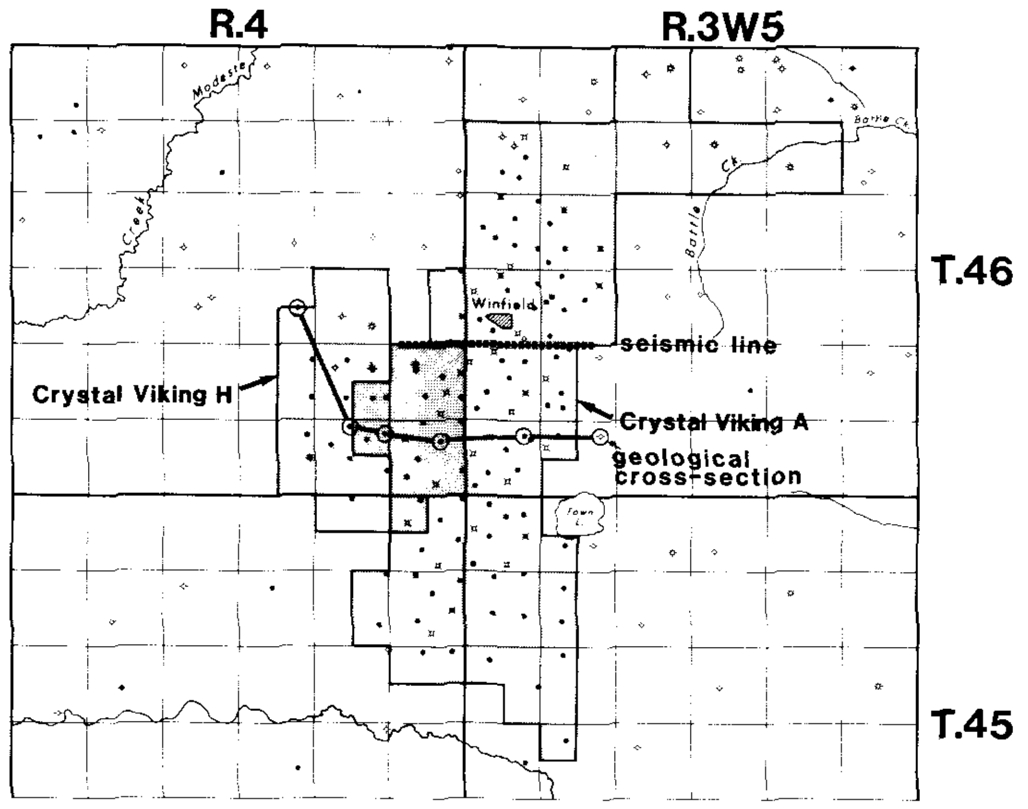

Figure 8.78. Location map, Crystal Viking A and H pools (courtesy, The Geobase Company Ltd).

stratigraphic traps of the Viking Fm are unlikely to show discernable time-structural relief.

The Crystal Viking A pool is distinct from many Viking Fm pools of Western Canada in that anomalously thick sandstones and conglomerates were deposited in an estuarine channel facies (Reinson et al., 1988). The anomalous reservoir thickness of the channel facies relative to off channel regional strata is the principal factor in determining the geophysical signature of the pool. However, this Viking Fm facies is known in only a few other areas and thus the model may have only minor application.

Reinson et al. (1988) subdivided the Viking Fm of the Crystal area into three depositional facies based on core and well-log data. These are: 1) regional facies (inner shelf - lower shoreface sediments); 2) Estuarine-bay fill (represented by the H pool); and, 3) Estuarine channel complex (with three stage subdivision).

Reinson et al. (1988) showed that regional facies consist of several funnel shaped coarsening upwards cycles indicating deposition in a regressive marine environment. It was also demonstrated that the channel facies postdates and truncates the regional facies sequence. These channel sediments, in combination with the subtidal bay fill deposits were classified as an estuarine tidal channel bay complex.

The Crystal Viking A pool as defined by the ERCB (1987) extends northward from the area to include Viking Fm gas wells which were drilled prior to the discovery of Viking oil in T46 - R3 W5M. What is presumably the updip gas cap of the A pool under existing boundary definitions includes the 11-33-46-3 W5M well, which tested gas from the Viking Fm in 1952. Discovery of the oil column and active development of the pool did not occur until 1978. Discovery of the H pool is attributed to development drilling of the A pool in 1983.

As of January 1st, 1988 the A pool has produced some 1459 x 10^3m^3 of 825 kg/m^3 oil or about 26 % of its total primary plus secondary recoverable oil reserves. Similarly the H pool has recovered some 75 x 10^3m^3 of oil.

Lithofacies of the A pool as described by Reinson et al. (1988) are conglomerates, conglomeratic sandstones through fine-grained shaly sandstones. Conglomerate thicknesses in excess of 20 m occur in localized areas. The estuarine bay fill sediments of the H pool are described as a muddy subfacies of interbedded shale and sandstone, and an upper channel-bar sandstone subfacies consisting of carbonaceous, fine- to medium-grained sandstone. Reserves and significant reservoir parameters for the Crystal Viking A and H pools are shown in Table 8.14. Productivity data for the pools are illustrated in Figure 8.79.

Table 8.14. Reserves and significant reservoir parameters, Crystal Viking A and H pools (ERCB, 1987).

	A POOL	H POOL
Initial Volume in Place	16,190 x 10^3m^3	1640 x 10^3m^3
Primary Recovery Factor	15%	15%
Additional Secondary Recovery	25%	0%
Total Initial Recoverable Reserves	5493 x 10^3m^3	246 x 10^3m^3
Production to Date	1459.3 x 10^3m^3	75.3 x10^3m^3
Remaining Established Reserves	4633.7 x 10^3m^3	170.7 x 10^3m^3
Oil Density	825 kg/m^3	807 kg/m^3
Area	4898 ha	804 ha
Average Pay	3.91	3.33
Average Porosity	9%	12%
Average Water Saturation	38%	37%
Average Depth	1752 m	1737 m
Discovery Year	1978	1983

GEOLOGICAL CROSS-SECTION

The geological cross-section of Figure 8.80 extends over the Crystal Viking A and H pools (Fig. 8.78) in a west to east direction, more or less parallel to seismic data of Figure 8.81. Development of these pools proceeded with wells which bottomed slightly below the Viking Fm and thus well log information is primarily restricted to Viking and post-Viking strata. The section is hung on the base of the Fish Scales zone in order to replicate the interpretation of Reinson (1985). The left and right justified end wells represent the regional facies and show characteristic coarsening upwards cycles. Markers denoted A, B and bentonite on these wells are laterally extensive in the area. The four central wells are representative of the channel facies. Little or no thinning of the overlying Colorado shales occurs over the Viking Fm channel facies which suggests that the channel postdates deposition of the regional facies in that these strata were relatively well compacted prior to channel incision. The four disconformable units of Reinson et al. (1988) are indicated on the geological cross-section (Fig. 8.81). The A, B and C units of the channel facies show substantial lateral accretion to the east in the progressively older B and C units, whereas the H unit is largely confined to the western side of the pool.

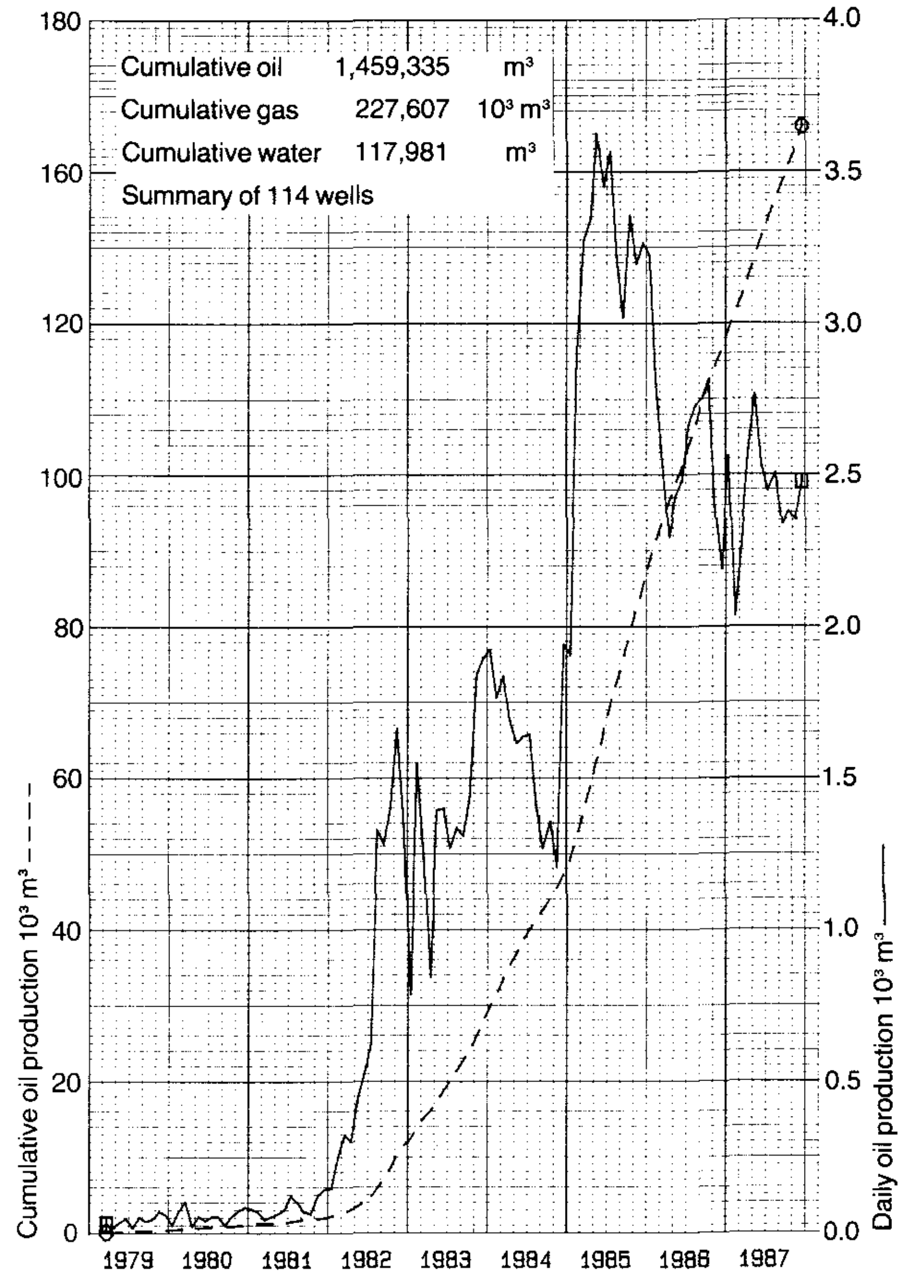

Figure 8.79. Production data, Crystal Viking A and H pools.

SEISMIC SECTION

The seismic data for the Crystal Viking pools were donated by Pulse 87 and reprocessed by Michael Broome of Exploration Seismic Services Ltd. These data which were acquired in 1983 are twelvefold, Vibroseis source, shot at 134-m source intervals with 33.5-m group intervals. The line is displayed at 7.5 inches per second in order to optimize the visual display of the pool. The lowest identified reflection is the Wabamun event (Fig. 8.82). Overlying this is the

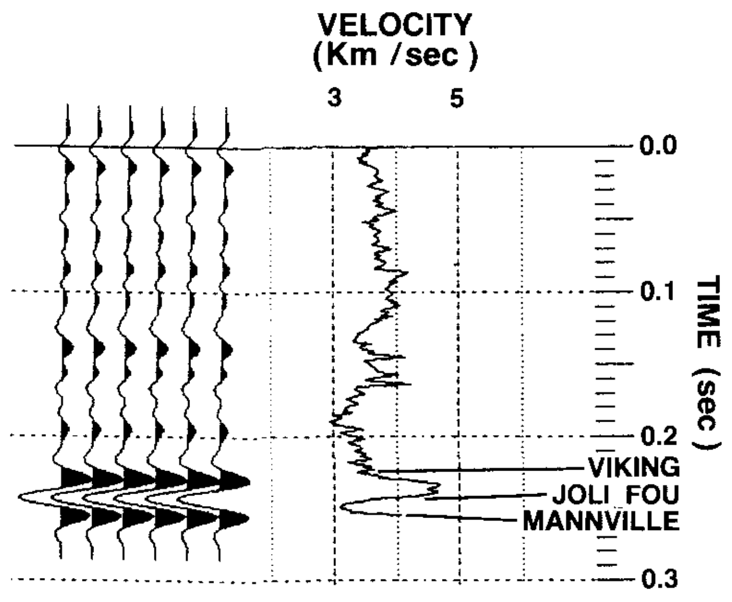

Figure 8.81. Single well synthetic trace, Crystal Viking A and H pools.

subcropping Banff Fm which shows erosional relief along the lines extent. Of note are both a local time-structural erosional low on the Banff event which occurs below the Viking A pool (traces 80-120), and a time-structural low along the lower Mannville event. Identification of the seismic events are shown on the synthetic seismic trace of Figure 8.83. Compaction of a lower Mannville thick is thought to be a mechanism for focusing the channeling facies of the Crystal Viking sediments. This compaction of the lower Mannville is thought to postdate the deposition of the regional Viking Fm strata but as mentioned predates the channel cut. This sequence is schematically shown in Figure 8.84. The Mannville event and Viking event are noted on Figure 8.82 at 1110 and 1130 ms respectively. The interval between these two events thickens by approximately 6 to 8 ms from traces 70 to 170 with a maximum time thickness observed near trace 110. This signature coincides with the thick channel facies of Figure 8.81 and is interpreted as Viking Fm thickening. This thickening is confirmed by the data of Figure 8.85 which shows a thickening of the base of Fish Scales to Mannville interval across the pool. Note also that the Mannville event and to some extent the Viking event appear to be time-structurally low across the anomalous area (traces 70 to 170). These data suggest that the Mannville Gp, Joli Fou Fm and the regional Viking strata were all structurally low prior to channel incision and that the low was due to the differential compaction of lower Mannville strata between areas of variable lower Mannville thickness.

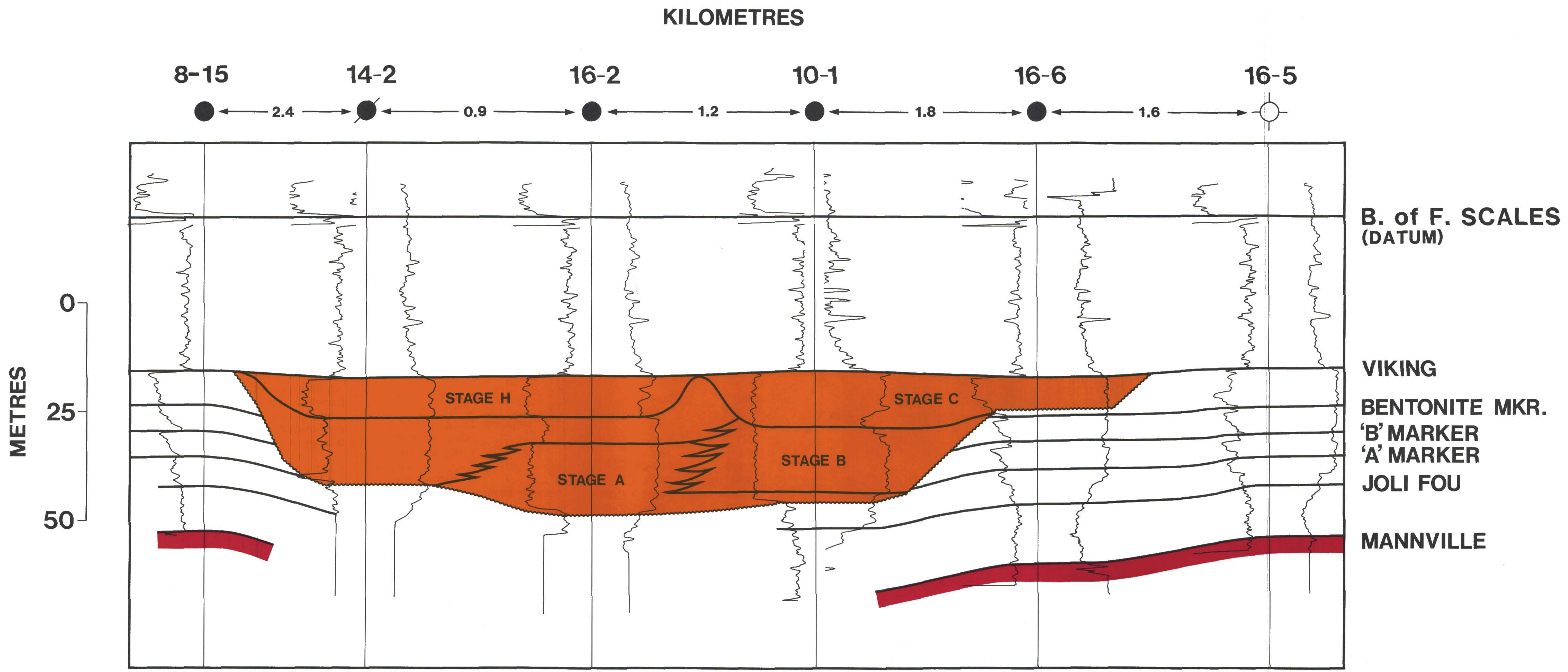

Figure 8.80. Geological cross-section, Crystal Viking A and H pools.

DRAFTING: K. GRIMSON | LOG PLOTS: | AUTHOR: D. CEDERWALL (ADAPTED FROM REINSON 1985)

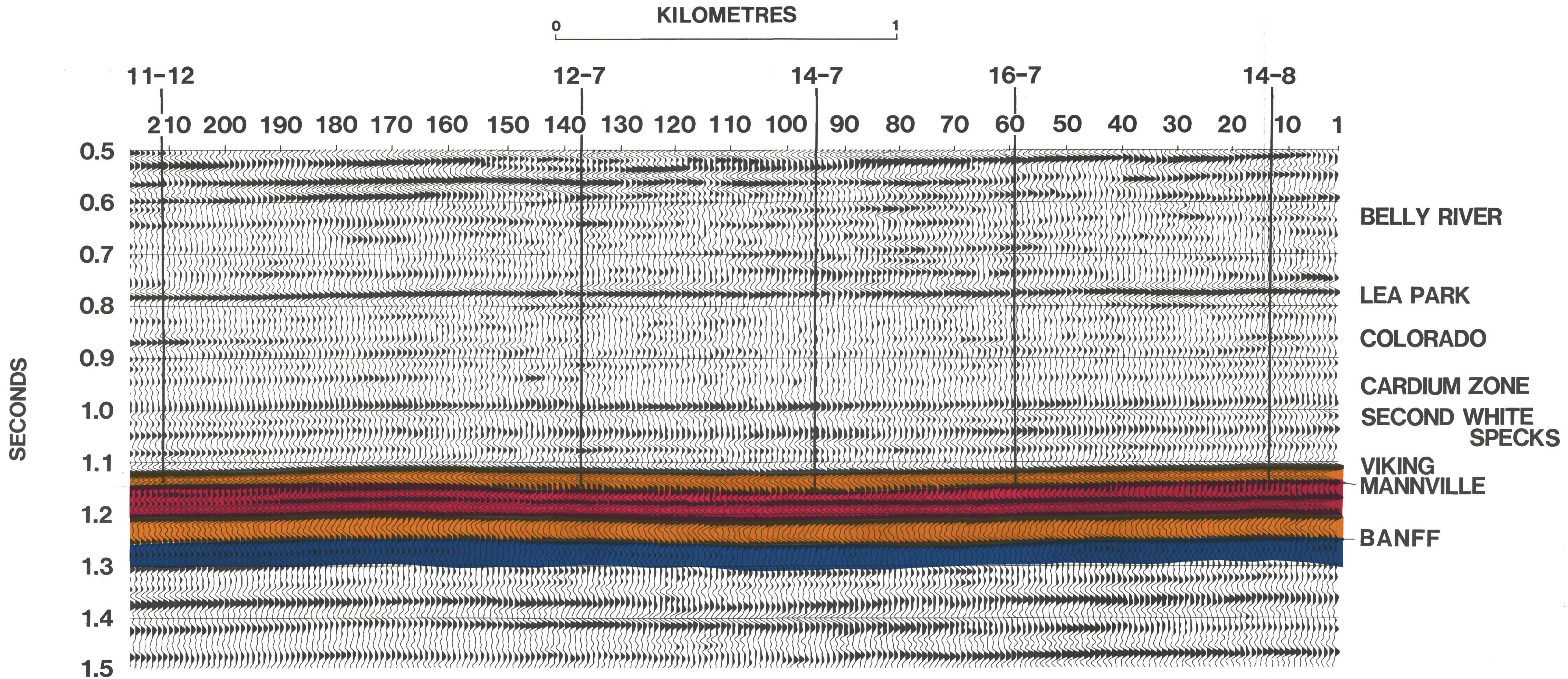

Figure 8.82. Seismic section, Crystal Viking A and H pools.

DONOR: PULSE '87	PROCESSOR: EXPLORATION SEISMIC SERVICES LTD.	AUTHOR: D.CEDERWALL , M. MANSELL

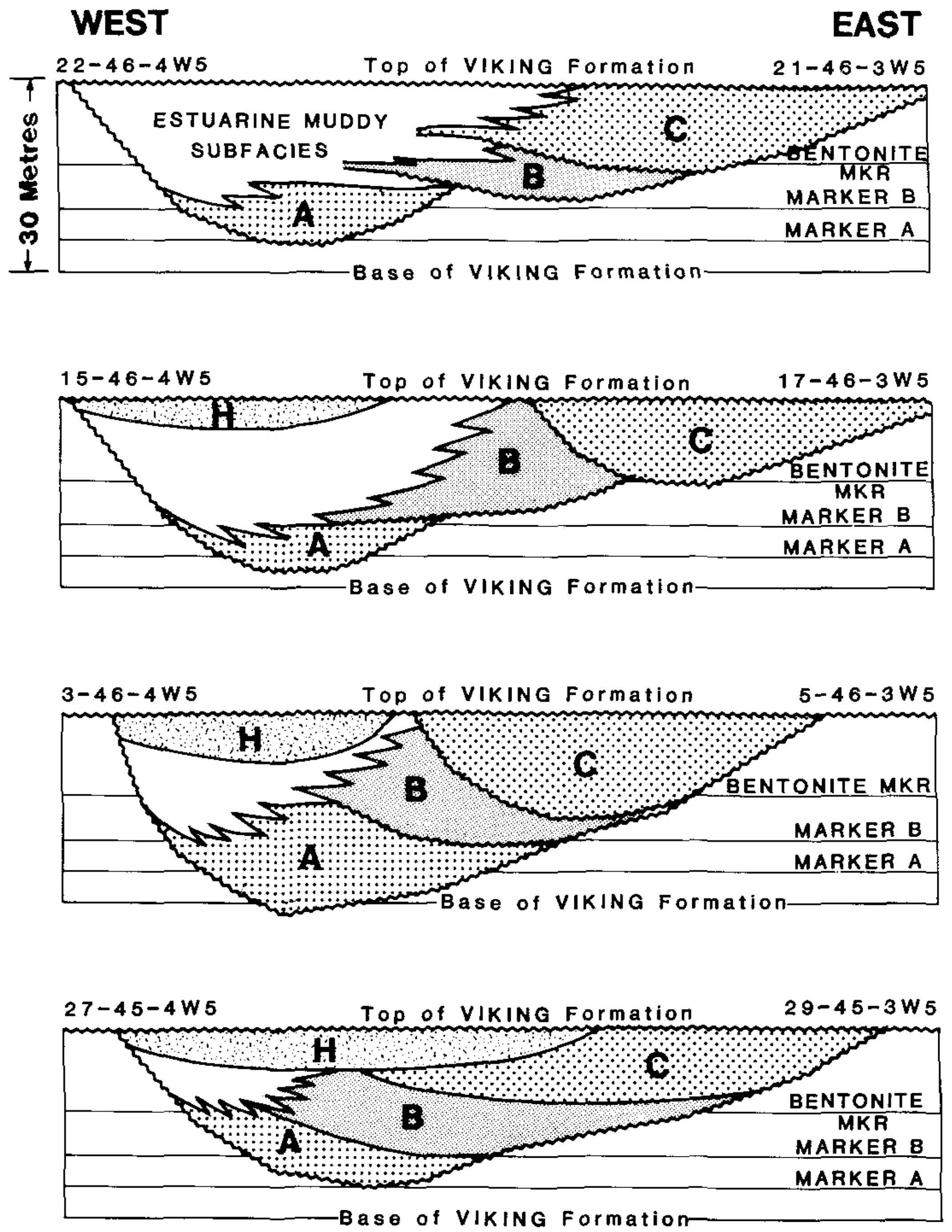

Figure 8.83. Schematic geological cross-section, Crystal Viking A and H pools, (adapted from Reinson, G.E., Clark, J.E. and Foscolos, A.E. 1988, Reprinted by permission of American Association of Petroleum Geologists).

After examination of the seismic data across other channel deposited reservoirs and noting the strong draping characteristics associated with these strata, a marked absence of drape across the channel facies is observed for the comparative analogous Viking Fm pool. This absence of drape is attributed to the differences in the depositional sequence where: 1) the channel facies sandstones of subsections 8-10 and 8-12 were deposited concurrently with the regional facies strata and thus the dewatering of these sediments provided drape from differential compaction; and 2) the regional facies Viking Fm strata were relatively well compacted prior to channeling and redeposition of channel facies sediments thus negating the possibility of differential compaction.

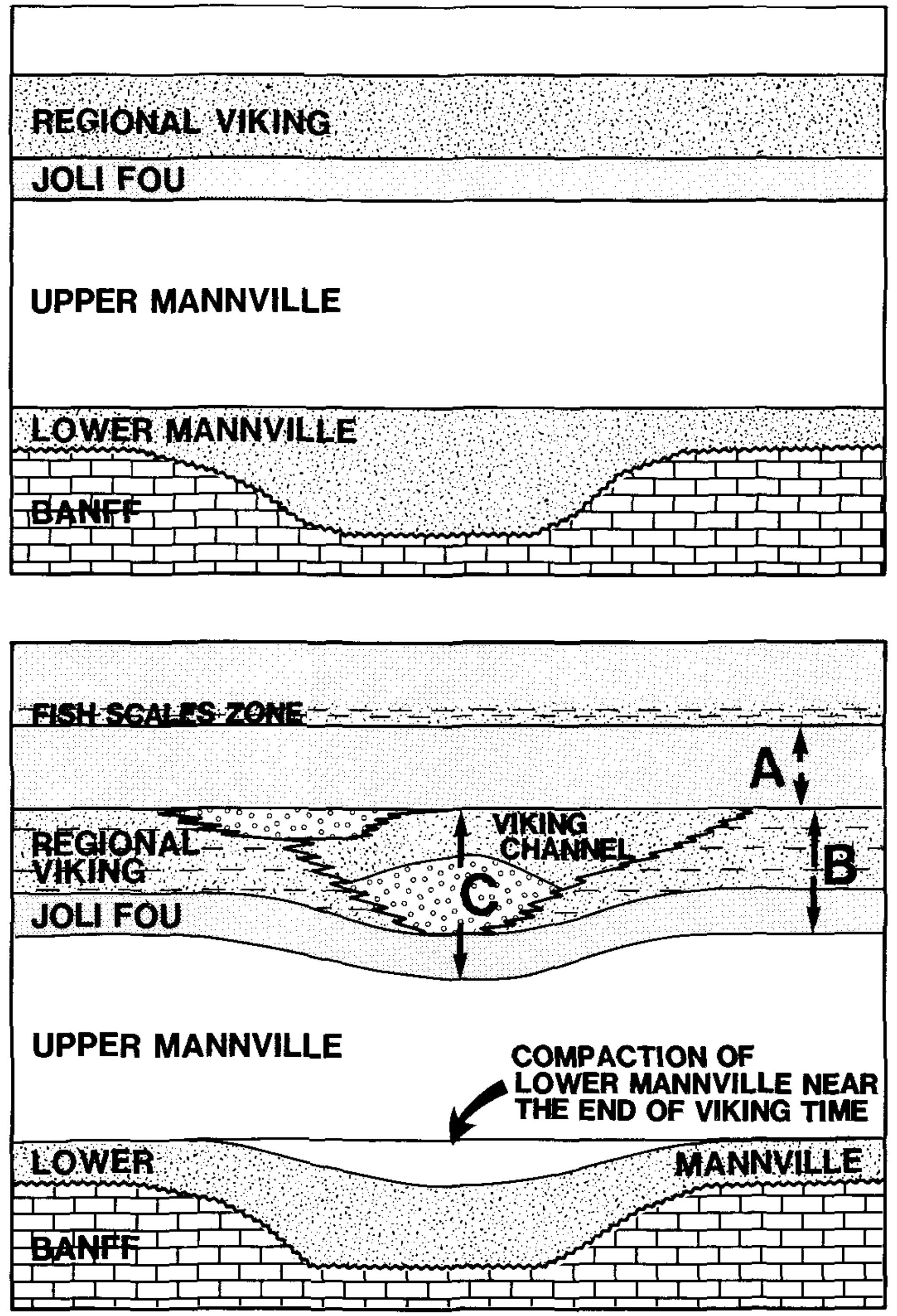

Figure 8.86. Schematic geological cross-section of facies development, Crystal Viking A and H pools.

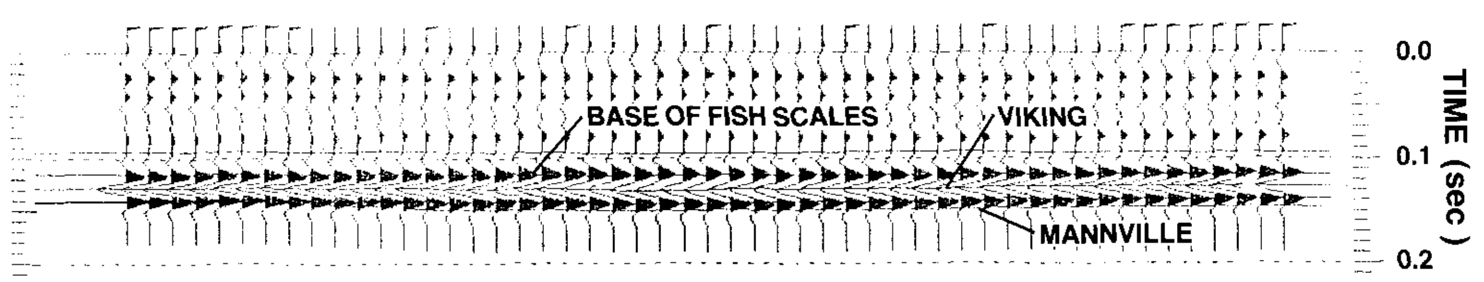

Figure 8.84. Mutiwell synthetic seismic model, Crystal Viking A and H pools.

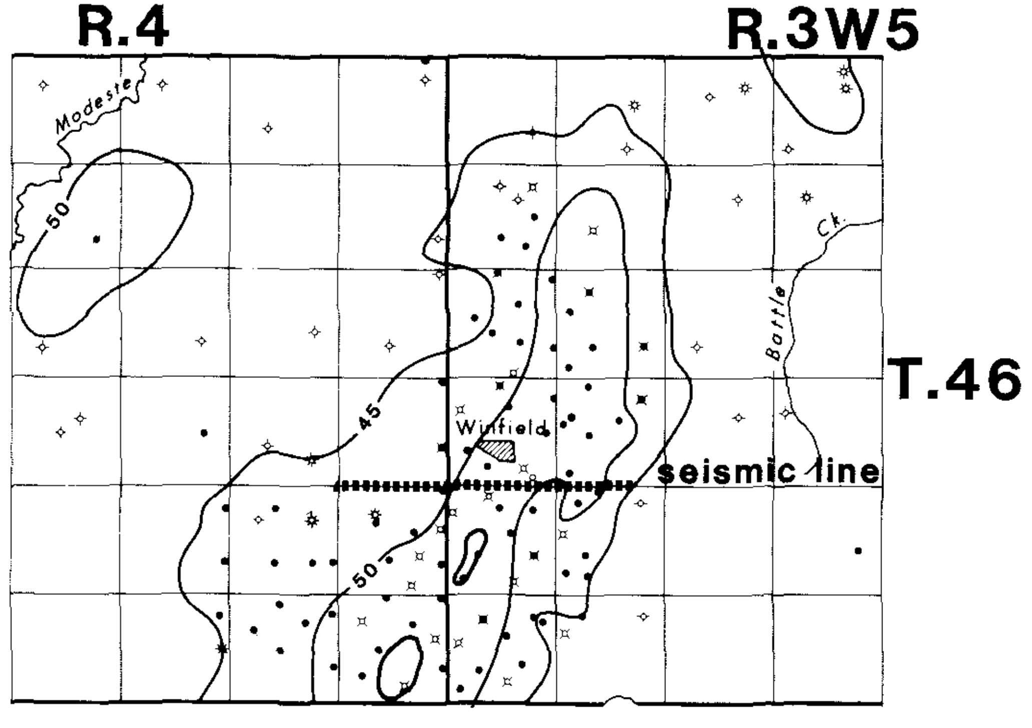

Figure 8.85. Isopach of the base of Fish Scales to top of Mannville Gp for the Crystal Viking A and H pools showing the pre-Viking structural low.

A model of the seismic response of the Crystal Viking pool is shown in Figure 8.86. Note however, that these data were modified to include a uniform thickness in the Joli Fou to Mannville interval. This modification was deemed necessary as few of the available well logs penetrated the Mannville Gp. Note also that the well locations annotated above the seismic data of Figure 8.82 are those used in the model rather than those of the geological cross-section.

CONCLUSIONS

The Crystal Viking A pool is an estuarine channel fill, whereas the smaller H pool is set in a subsidiary facies of this complex. The channel is unconformable and eroded into regional Viking Fm strata. The seismic signature of this channel is characterized by an increase in Viking to Mannville interval time and a time-structural low on the Mannville event. An absence of detectable drape along the Viking Fm event suggest that compaction of the regional Viking facies predates the deposition of the channel facies.

8–15: PEMBINA OSTRACOD E POOL

INTRODUCTION

The Pembina Ostracod E pool is located in T50-R4 W5M (Fig. 8.87), 80 km southwest of Edmonton, Alberta, and illustrates significant lateral facies variation within the Ostracod member which is coincident with localized structure on the pre-Cretaceous unconformity. Furthermore, the example is of interest in that the underlying Banff Fm which forms a structure beneath the Ostracod

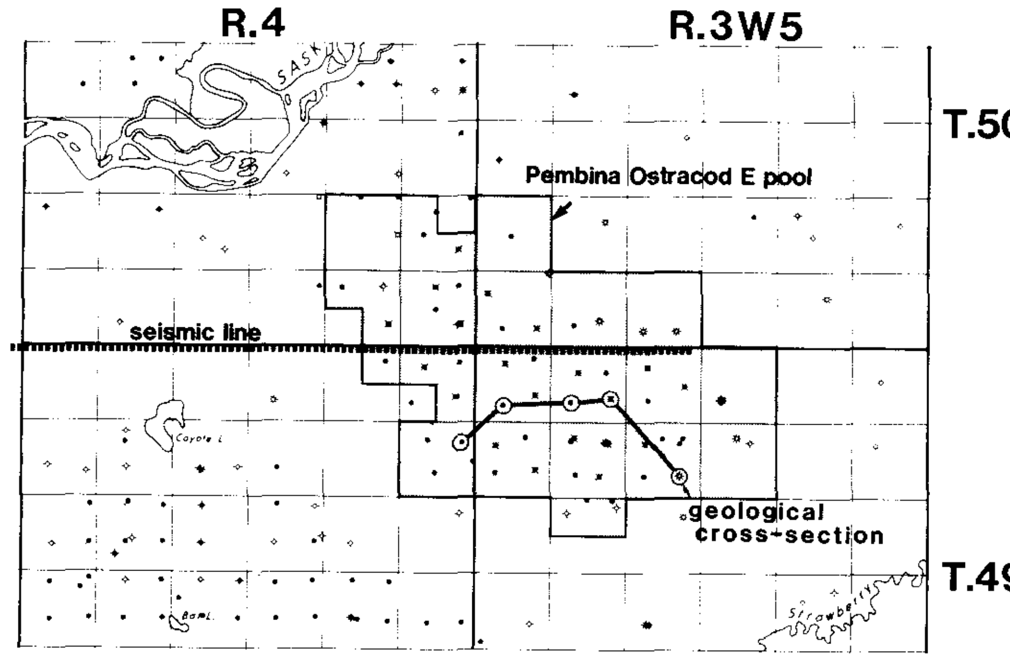

Figure 8.87. Location map, Pembina Ostracod E pool (courtesy, The Geobase Company Ltd).

member pool can also be an important hydrocarbon trap. Porous carbonates of the Clarke's Mbr (Banff Fm) are known to occur at the unconformity and form oil reservoirs such as the Glenevis, Alexis, Cherhill, and Highvale pools.

Development of the Ostracod member to a reservoir facies at this location is due to shoaling of sandstones across the erosionally high Clarke's Mbr, which results in a less shaly more porous sandstone. Mapping of the Glauconitic Sandstone member to pre-Cretaceous unconformity interval across the Clarke's Mbr highs shows thinning of these lower Mannville sediments. This thinning effect is only partially representative of the relief on the Clarke's Mbr in that sediments of the thicks are compacted. The absence of lower Mannville strata is an indication that the highs were subaerially exposed through much of lower Mannville time and later at Ostracod member time formed a high on which the reservoir sandstones developed.

The subcropping Banff Fm in this area is conformable on the Exshaw Fm. The Banff Fm consists of a lower micritic unit, a middle tight clean carbonate which normally forms the subcrop and occasionally the upper porous Clarke's Mbr. The Banff Fm, whose subcrop edge is roughly 40 km east of the pool location, dips to the southwest at approximately 5 m/km. Immediately west of the pool the Banff is overlain by the Nordegg Fm. Clarke's Mbr highs appear to have an inner micritic facies which is typically a dolomite with vuggy porosity and a flanking facies of a cleaner crinoidal limestone with intercrystaline porosity.

The reservoir unit of this example is the Ostracod member of Glaister (1959). He used the top of this member as the division

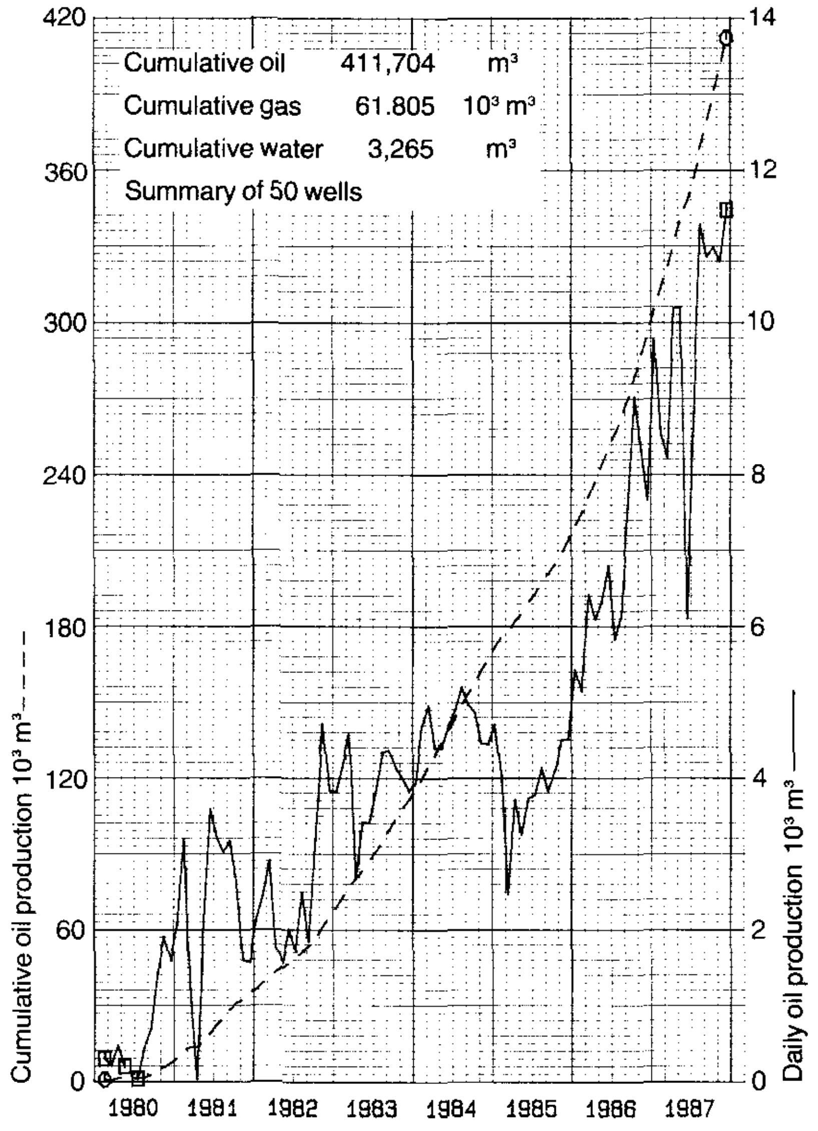

Figure 8.88. Production data, Pembina Ostracod E pool.

between his informal upper and lower Mannville subdivisions. The Ostracod member generally occurs as a tight, non-reservoir facies immediately below a laterally extensive marine sheet sandstone of the Glauconitic Sandstone member in this area. Within localized areas such as the Pembina Ostracod E pool the unit thickens and attains porosity which in this example averages 16%. The enhancement of the Ostracod member as a reservoir unit is likely due to wave action where it was structurally high due to both the relief on the underlying Banff Fm and differential compaction of the infilling lower Mannville.

The Pembina Ostracod E pool covers approximately 3185 ha and contains some 3500 x 10^3m^3 of oil in place, of which 1180 x 10^3m^3 are estimated to be recoverable. An average pay thickness for the pool of 1.27 m is indicative of the thinness of the reservoir. Reserves and other significant reservoir parameters for the pool are shown in Table 8.15. Productivity data for the pool are illustrated in Figure 8.88.

Table 8.15: Reserves and significant reservoir parameters, Pembina Ostracod E pool (ERCB, 1987).

Initial Oil in Place	3557 x 10^3m^3
Primary Recovery Factor	12%
Secondary Recovery Factor	23%
Total Established Recoverable Reserves	1197 x 10^3m^3
Cumulative Production to Date	411.7 x 10^3m^3
Remaining Established Reserves	785.3 x 10^3m^3
Area	3249 ha
Average Pay Thickness	1.27 m
Average Porosity	16%
Average Water Saturation	25%
Oil Density	840 kg/m^3
Average Depth	1579 m
Discovery Year	1980

GEOLOGICAL CROSS-SECTION

The Pembina Ostracod E pool geological cross-section (Fig. 8.89) shows strata from the Banff to Viking formations. The Ostracod member is situated between the upper Mannville Glauconitic Sandstone member and the Banff Fm. Two notable features associated with the pools occurrence are the thinning of the lower Mannville and structural relief on the pre-Cretaceous unconformity. Unconformity relief is erosional in nature and the location of these highs is largely due to the local resistance of the Clarke's Mbr to erosion. Total Clarke's Mbr relief is not demonstrated in Figure 8.89 due to the absence of an off-structure well. The 3-31 well does represent an area where it is partially eroded, however this particular well is located in an erosional low within the high, rather than off-structure.

The interval at approximately 820 m subsea and labeled as the Ostracod member (Fig. 8.89) is the reservoir facies. This unit thickens and has enhanced reservoir characteristics coincident with the underlying pre-Cretaceous structure. Immediately above this at 800 m subsea is the coarsening upwards Glauconitic Sandstone member which locally has been termed the Pembina Barrier by Smith and Meekel (1983). The 7-28 well represents the southern limit of the Pembina Barrier.

SEISMIC SECTION

The seismic data for the Pembina Ostracod E pool were donated by Chevron Canada Resources Ltd. and reprocessed by Exploration Seismic Services Ltd. The line (Fig. 8.90) is approximately 20 km long and is part of a regional twelvefold dynamite survey with 200-m shotpoint intervals and 50-m group intervals. The line shows the flank of the pre-Cretaceous Clarke's Mbr high and the corresponding lower Mannville and Mannville Gp thinning on the western portion of the pool.

A time window of 200 to 800 ms was selected in order to optimize the display of this pool. Shallow reflectors, particularly those above the Viking event at approximately 980 ms, show poor response presumably due to both the use of a heavy charge as an energy source and the wide spread lengths. The data, however, show excellent response over the Lower Cretaceous interval from 980 to 1100 ms.

The eastern end of the line which is in the productive area of the pool shows the Lower Cretaceous unit to be some 120 ms in time-thickness. A peak-trough sequence (980-1010 ms) is the Viking to Joli Fou interval. The Mannville event is identified as the next lower peak on the data with the upper Mannville consisting of an additional full cycle trough peak trough. The lower Mannville interval is represented by the following peak to trough (1070-1100 ms) and is bounded by the Banff event (peak at 1100 ms).

West of trace 300 the following observations can be made: 1) lower time-structural relief on the Lower Cretaceous; 2) thickening of the lower Mannville; and 3) a thinning of the Banff to Wabamun

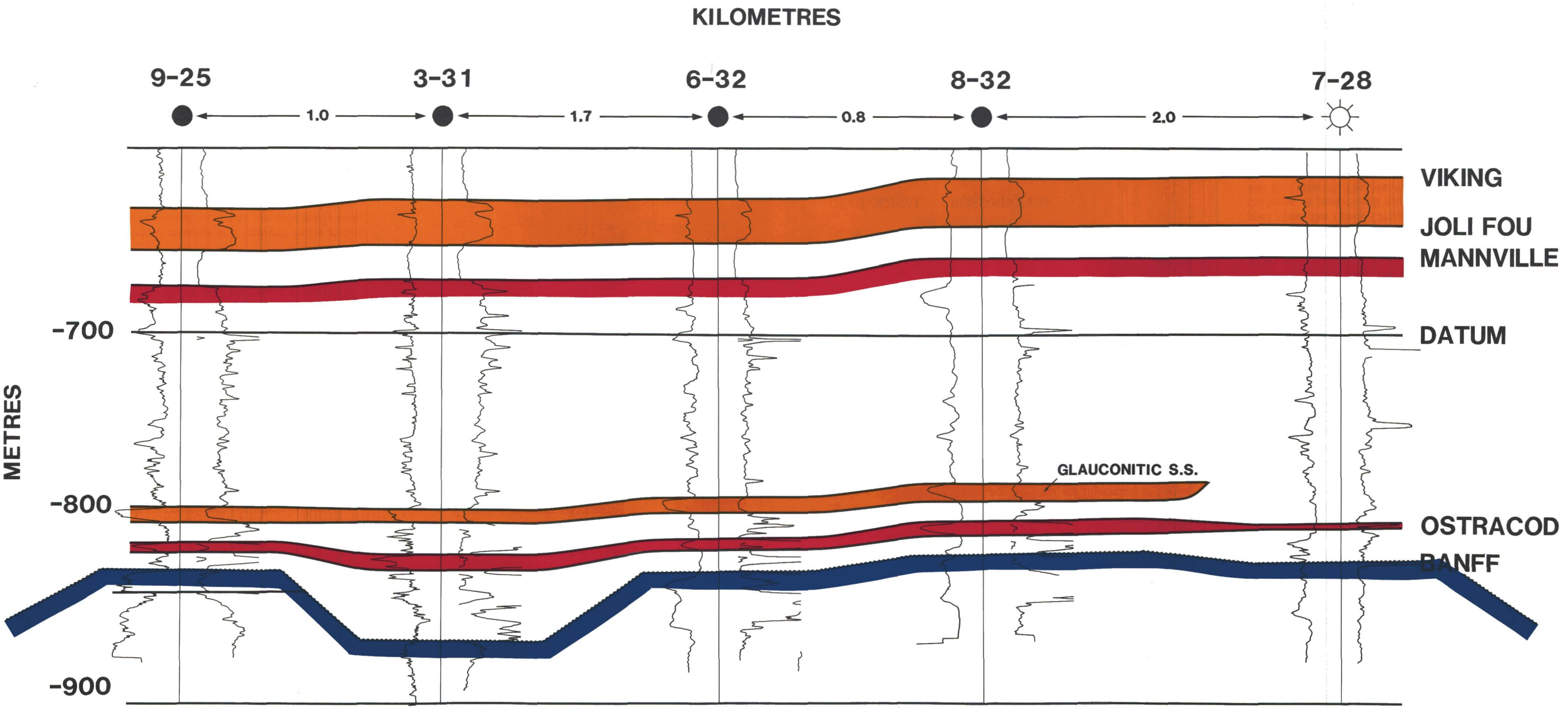

Figure 8.89. Geological cross-section, Pembina Ostracod E pool.

DRAFTING: LOG PLOTS: AUTHOR: D. CEDERWALL

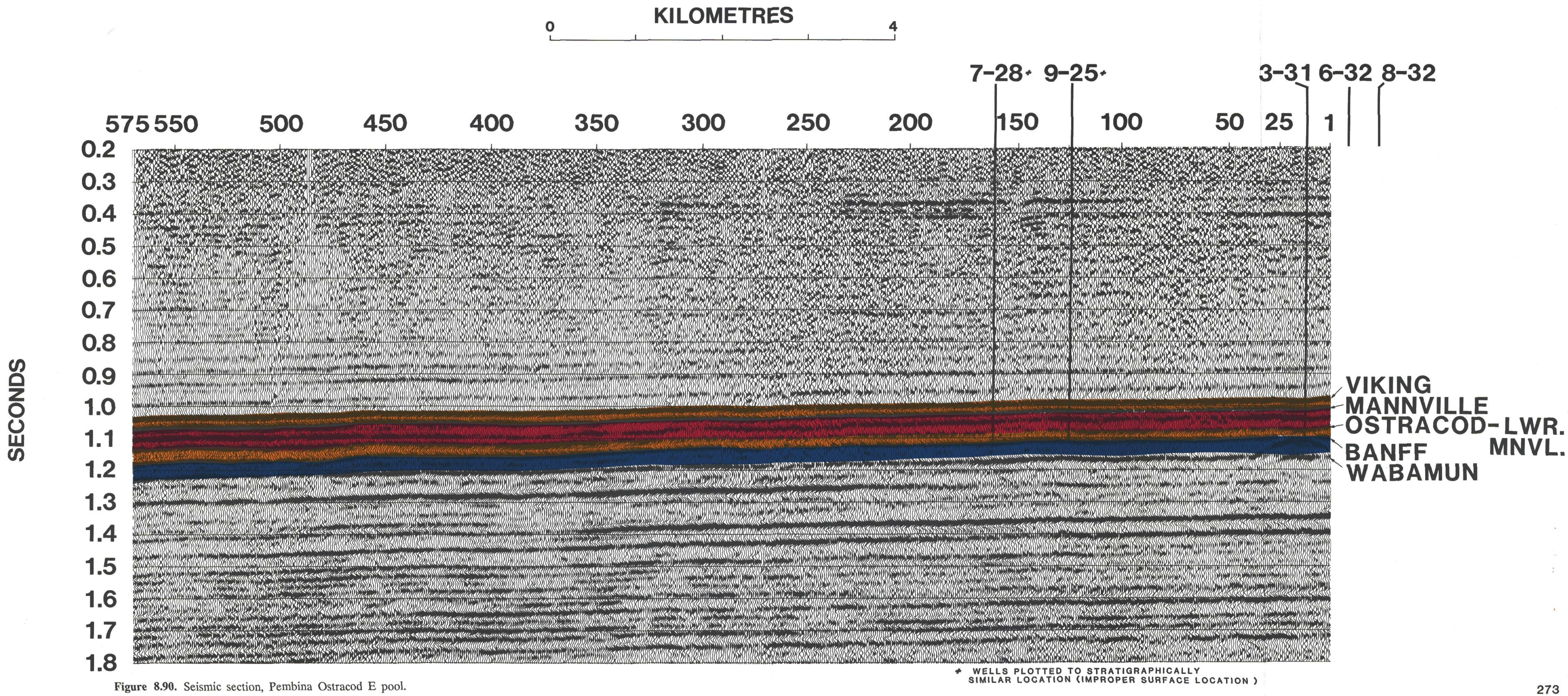

Figure 8.90. Seismic section, Pembina Ostracod E pool.

DONOR: CHEVRON CANADA RESOURCES LTD. | PROCESSOR: EXPLORATION SEISMIC SERVICES LTD., M. BROOME | AUTHOR: D. CEDERWALL

Gp time interval. These features are due to the absence of the Clarke's Mbr to the west and the proportionate increase in lower Mannville thickness away from the pre-Cretaceous erosional high. Diffractions are present near trace 25 on the Banff event level. This

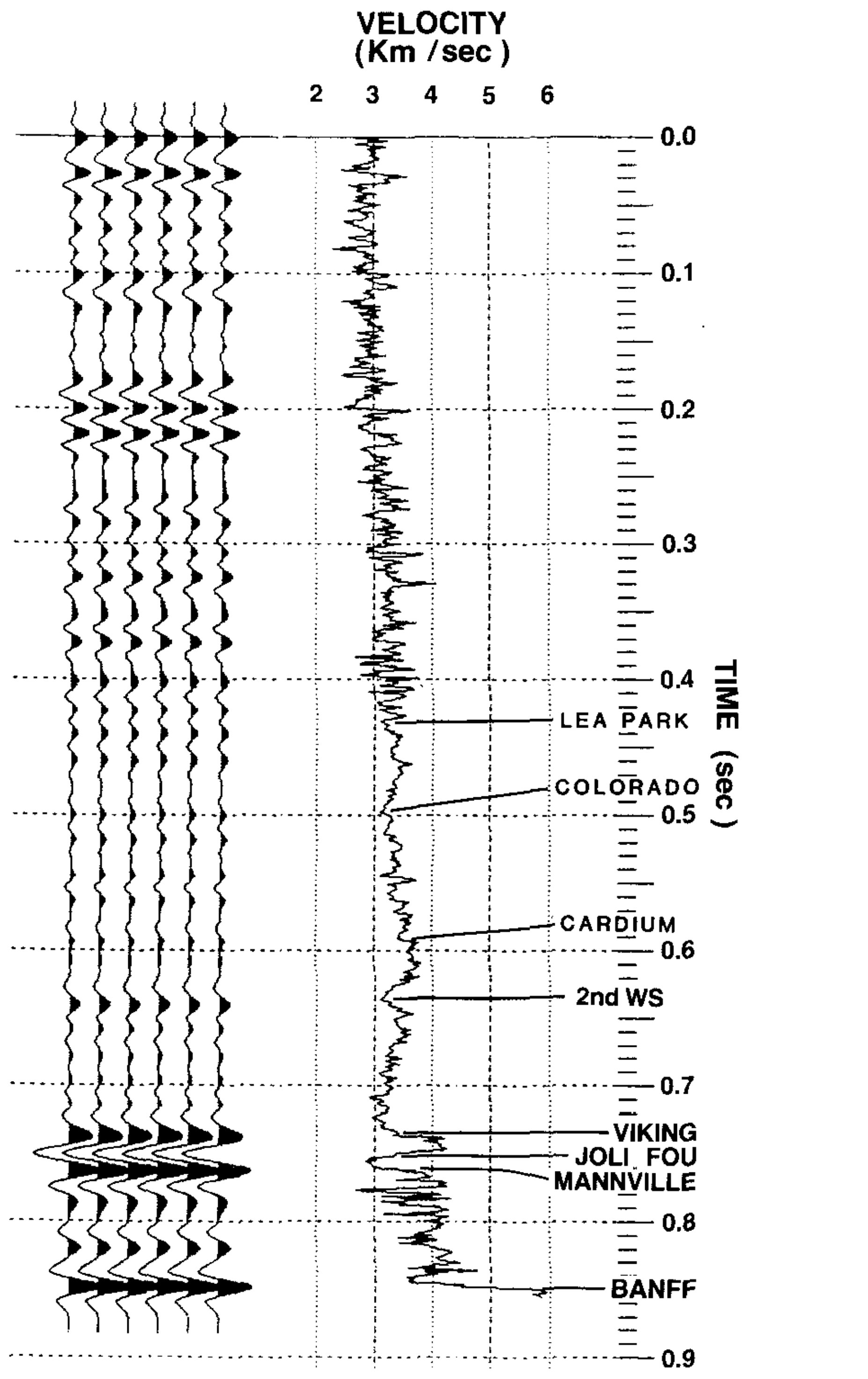

Figure 8.91. Single well synthetic seismic trace, Pembina Ostracod E pool.

feature corresponds to the localized erosional low which occurs in the 3-31 well (Fig. 8.89).

The observed lower Mannville thinning and time-structural relief on the data form a close approximation to the limits of the field, however note that this relationship is indirect as the Ostracod zone has no directly observable seismic response (Fig. 8.91).

The seismic data fails to show a direct response to the Clarke's Mbr porosity (which sometimes causes the pre-Cretaceous event to change from a single peak to a doublet peak across the porous highs). Presumably the thickness of Clarke's Mbr porosity is insufficient and/or the frequency content of this data is too low to respond to the two positive reflection coefficients which occur at the: 1) lower Mannville to Clarke's Mbr interface; and 2) Clarke's Mbr to tight Banff Fm interface.

CONCLUSIONS

The Pembina Ostracod E pool is a Lower Cretaceous pool which is not directly detectable with seismic data. However, development of a reservoir facies in the Ostracod member is coincident with pre-Cretaceous structure which is mappable with seismic data. Features which are diagnostic of this pool are: 1) lower Mannville and Mannville Gp thinning; 2) pre-Cretaceous unconformity to Wabamun Gp thickening; and 3) time-structural relief of the Mississippian and Lower Cretaceous.

A lateral character change along the unconformity reflector can be diagnostic of Clark's Mbr porosity within this area, but is not demonstrable with this specific data. The dimensions of a sharp erosion feature atop the Banff Fm high are shown via well control and the observed diffraction pattern on the seismic data. The occurence of this pool and several other central Alberta pools are schematically depicted in Figure 8.92.

8–16: PEMBINA-LOBSTICK GLAUCONITE E POOL

INTRODUCTION

The Pembina-Lobstick Glauconite E pool (Fig. 8.93), is located in T49-R6 W5M approximately 125 km southwest of Edmonton, Alberta. The example shows significant gas reserves trapped in the

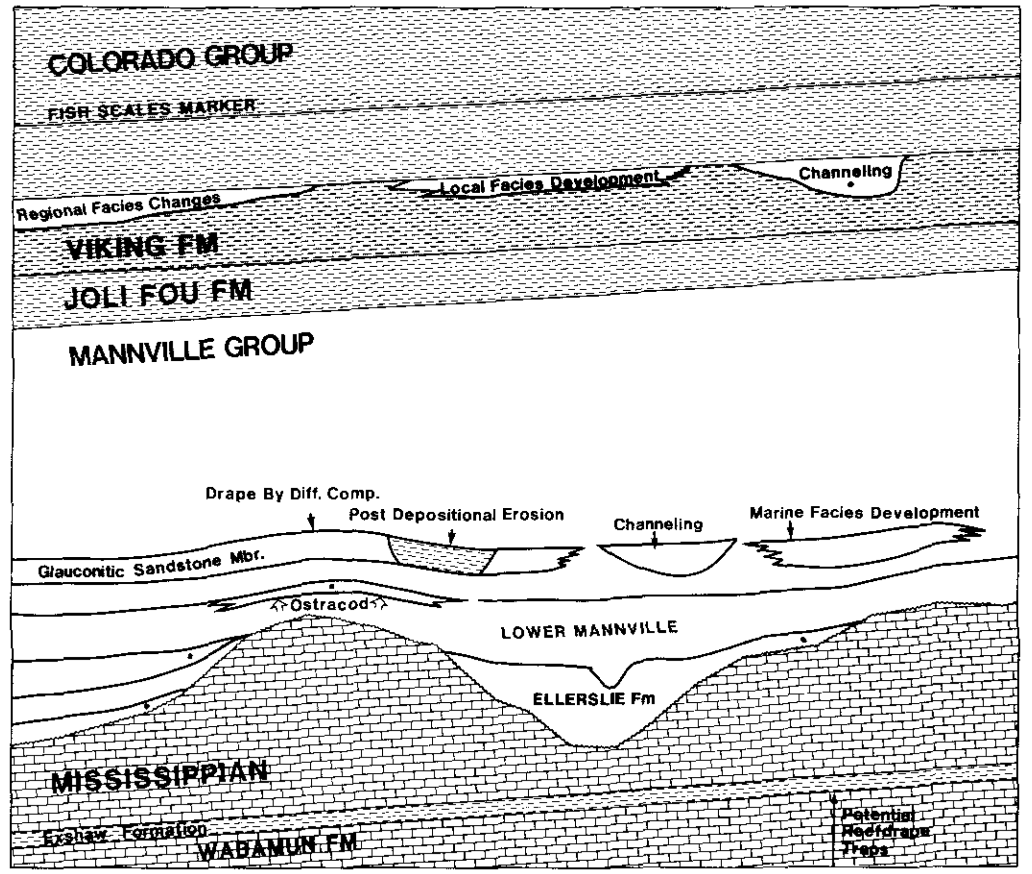

Figure 8.92. Schematic geological cross-section of pool trap types in central Alberta.

marine upper Mannville Glauconitic Sandstone member. Post-depositional erosion of an existing marine sandstone unit and shale infill is postulated as a trapping mechanism for the pool.

The Lobstick Glauconitic Sandstone member pools are located just south of an extensive east to west trending zero edge of the member. A uniformly thick, coarsening upwards sandstone that is laterally pervasive over several hundred square kilometres termed the Pembina Barrier by Smith and Meekel (1983) occurs north of the zero edge. In this area the Glauconitic Sandstone member is commonly water bearing with rare gas entrapment where it is draped over pre-Cretaceous highs such as those formed by the Clarke's Mbr at the Glenevis and Alexis pools. South of this edge, and north of the Hoadley Barrier complex, (Chiang, 1985) the Glauconitic Sandstone member is mainly comprised of non-reservoir clastics. However, at Lobstick it is gas bearing and very similar in log signature to the northern lying wet Glauconitic Sandstone member. Neither stratigraphic nor structural position explain the trapping mechanisms of gas in this pool, however an examination of wells

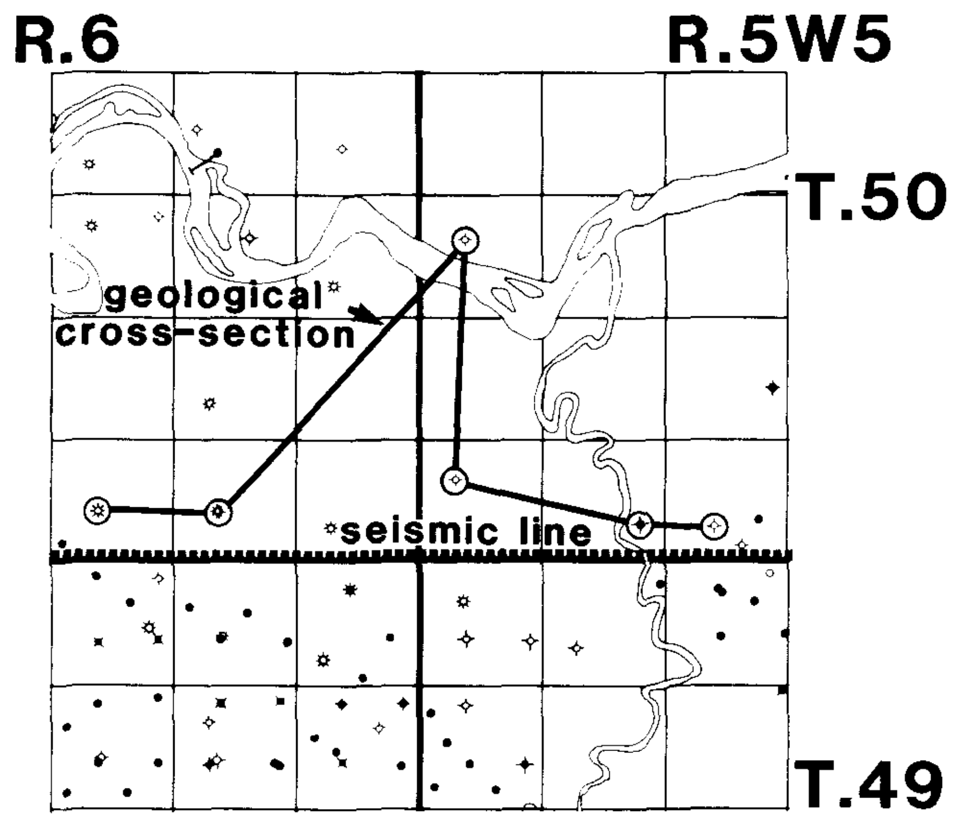

Figure 8.93. Location map, Pembina-Lobstick Glauconite E pool (courtesy, The Geobase Company Ltd).

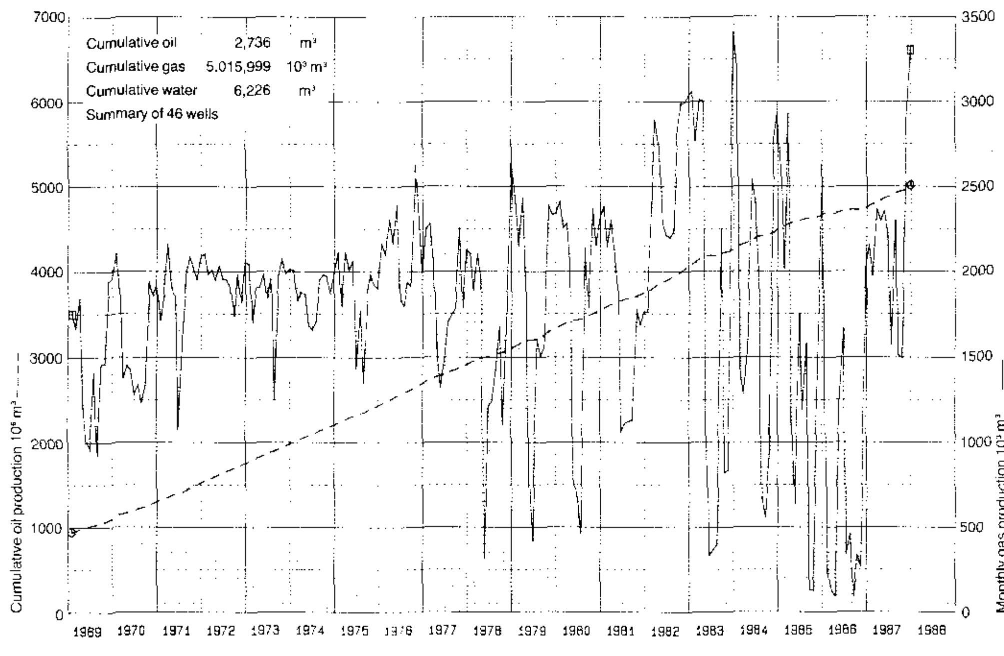

Figure 8.94. Production data, Pembina-Lobstick Glauconite E pool.

such as the location 6-2-50-6W5M suggests that there was post-depositional erosion of the reservoir sandstone and a replacement of the interval with a shale. Separation of the Lobstick pools (from a once continuous marine sheet sandstone) by post-depositional erosion is suggested as the trapping mechanism for the Pembina-Lobstick A, E, G, I and D pools. Reserves and significant reservoir parameters for the two larger pools (E and G) are given in Table 8.16. Production data for this subsection are illustrated in Figure 8.94.

Table 8.16: Reserves and significant reservoir parameters, Pembina - Lobstick Glauconite E and G pools (ERCB, 1987)

	E POOL	G POOL	COMBINED
Initial Volume in Place			5000 x 10^6m^3
Pool Recovery Factor	80%	80%	
Surface Logs	5%	5%	
*Initial Est. Reserves			3800 x 10^3m^3
Net Cumulative Production			1573 x 10^6m^3
Remaining Est.			2227 x 10^6m^3
Area	3660 ha	1758 ha	
Average Pay Thickness	7.91 m	4.78 m	
Average Porosity	14.8%	14.0%	
Gas Saturation	55%	60%	
Mean Depth	1700 m	1693 m	
Discovery Year	1959	1960	

*Initial Established Reserves for the Pembina Lobstick Glauconite A, G, I, D and E pools are 9484 x 10^6m^3 (334 BCF) gas.

GEOLOGICAL CROSS-SECTION

Figure 8.95 is a geological cross-section which displays the three areas of the Glauconitic Sandstone member deposition referred to in the introduction. The 3-5 and 6-4 locations show the Pembina Glauconitic Sandstone Barrier of Smith and Meekel (1983), which is a laterally uniform coarsening upwards sandstone that is wet in the study area. To the south and east the two Glauconitic Sandstone member gas wells (6-3 and 6-2) show a similar coarsening upwards signature. Separation between the two previously mentioned areas is detected at the 11-18 well which lacks the sandstone facies and is interpreted as the shale fill of an erosional channel. This feature could also be interpreted as an area of nondeposition of the Glauconitic Sandstone member reservoir, however an erosional model hypothesis is favored in view of the narrow width of this feature, and the observed seismic response of Figure 8.96.

SEISMIC SECTION

Seismic data for the Pembina-Lobstick Glauconite E pool were donated by Chevron Canada Ltd. and reprocessed by Exploration Seismic Services Ltd. These data are part of a regional east west line whose location is shown on Figure 8.93. Annotated on Figure 8.96 are the Wabamun, Banff, lower Mannville, Glauconitic Sandstone, Mannville and Viking events. To the west of trace 180 some Nordegg Fm and possibly some Pekisko Fm may occur but are not distinguished within what is labelled as the Banff interval. Identification of the seismic events are shown on the synthetic seismic trace of Figure 8.97.

Noteworthy on the data is a local change in the signature of the Mannville interval (traces 180-340 from 1.140 - 1.180 secs), which coincides with the shaled out Glauconitic Sandstone member interval shown in the 11-18 and 11-16 locations of Figure 8.95. To the east of wells 8-5 and 6-4, Figure 8.96, the data shows the signature of the regionally uniform and wet Glauconitic Sandstone or "Pembina Barrier". To the west of trace 340 the Mannville signature is similar to that of the "Pembina Barrier" area. This area is represented on the cross-section by the 6-3 and 6-2 wells which have produced 13 and 18 BCF of gas respectively. The seismic data of Figure 8.96 and the data of the geological cross-section (Fig. 8.95) suggest that these reserves are trapped against the updip feature shown from traces 180 to 340. Notable features of this interval are lateral weakening of the lower Mannville event and the discontinuity of events with the Glauconitic Sandstone to pre-Cretaceous interval. A local pre-Cretaceous high of approximately 10 ms and weakening of the unconformity event is also noted over this area. Negative drape due to compaction of the shaled out Glauconitic member interval is suggested by the structural lows along the Mannville event at 1050 ms, (traces 190-280). The time-structural low shown on both of these reflections is coincident with the previously described pre-Cretaceous high.

CONCLUSIONS

Reservoir sandstones of the Pembina Lobstick Glauconite E pool have geological and geophysical characteristics which are very similar to those of the Pembina Barrier. The trapping mechanism of this pool has a geophysical and geological signature which contrasts with the Pembina Barrier. Furthermore, these data allow the conjecture that this trap is a shale filled channel comparable to that of the Provost Basal Quartz C pool and to those described by Vigrass (1977).

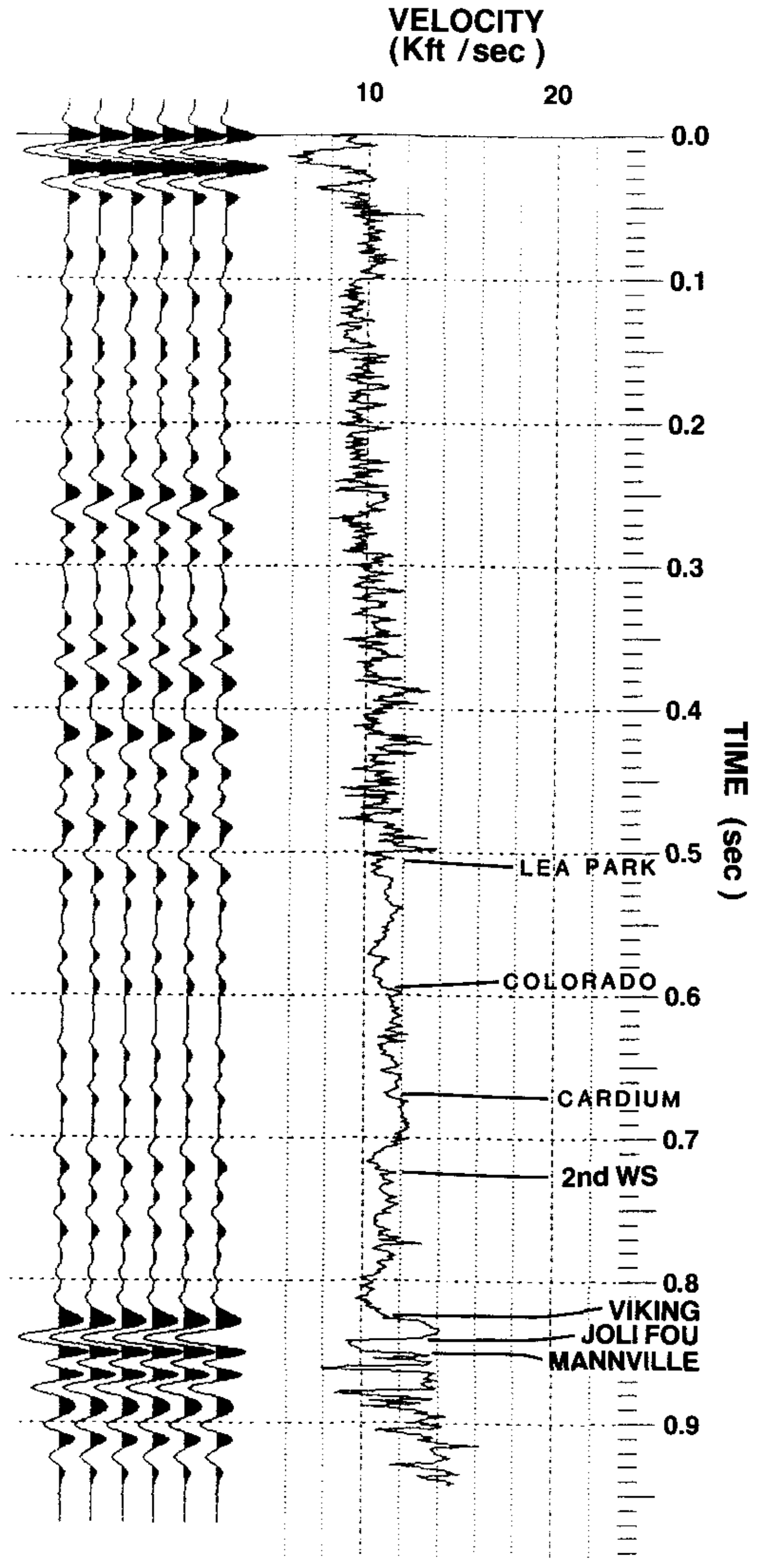

Figure 8.97. Single well synthetic seismic trace, Pembina-Lobstick Glauconite E pool.

8–17: MARTEN HILLS WABISKAW A AND WABAMUN A POOLS

INTRODUCTION

The Marten Hills field (Fig. 8.98) lies within T74 through T76, R23 W4M through R2 W5M, approximately 250 km north of Edmonton, Alberta, and contains significant gas reserves (920 BCF recoverable) in the Lower Cretaceous Wabiskaw Mbr and Devonian Wabamun Gp (Table 8.17).

Gas entrapment in the Wabiskaw Mbr is primarily structural and is attributed to the differential compaction of the lower Mannville strata across pre-Cretaceous Devonian highs. In the area the Wabis-

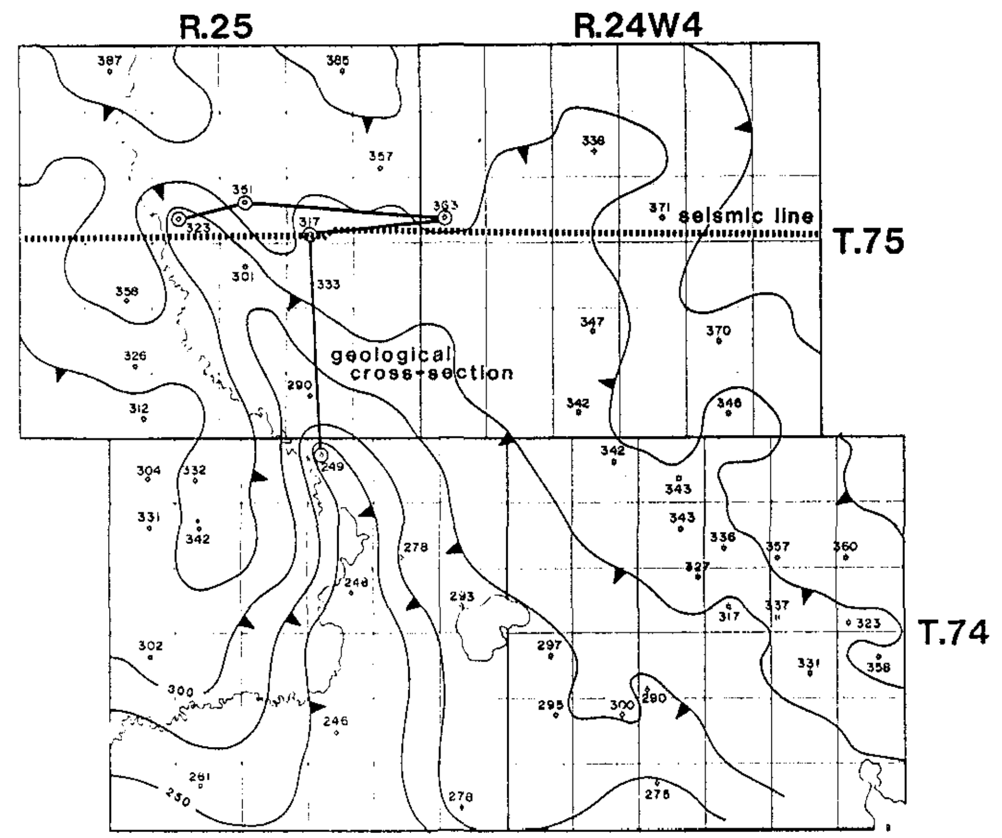

Figure 8.98. Location map, Marten Hills Wabamun A and Wabiskaw A pools (courtesy, The Geobase Company Ltd).

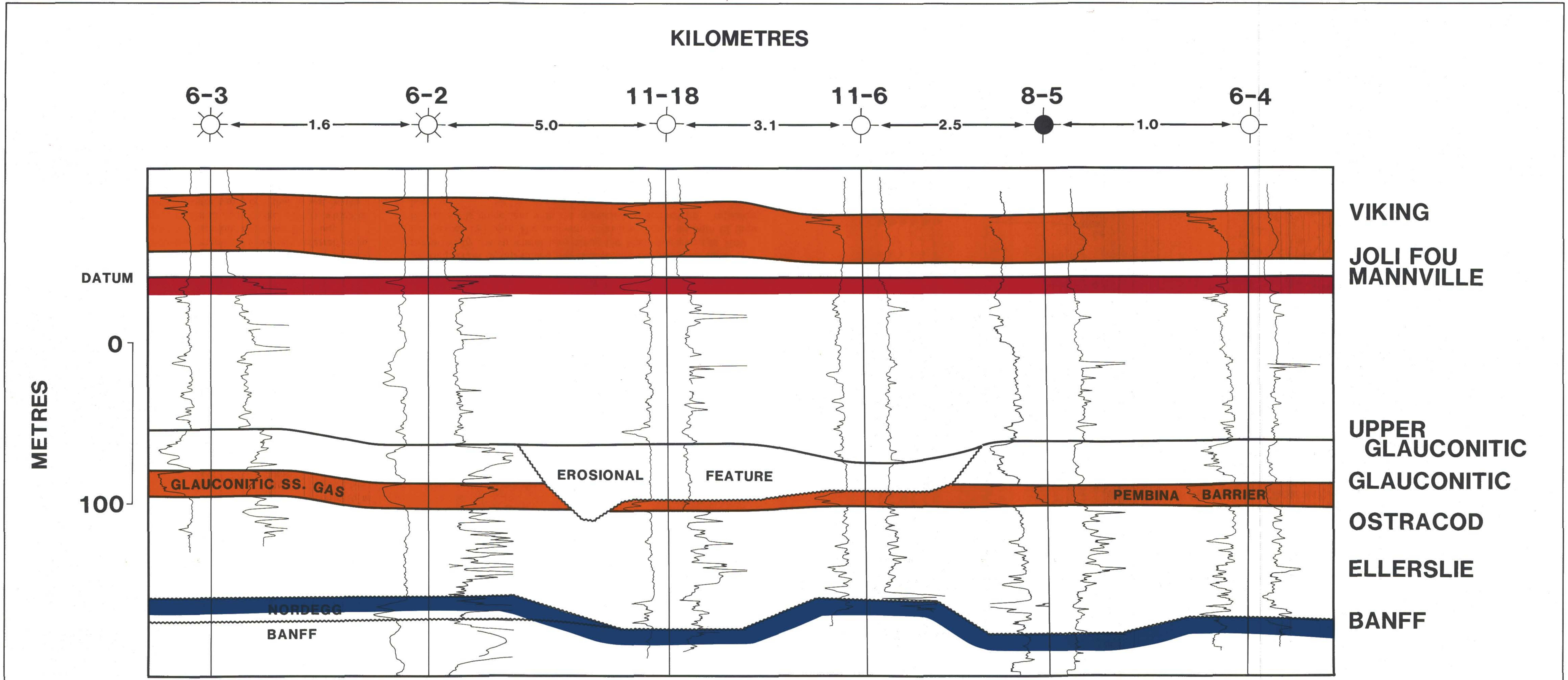

Figure 8.95. Geological cross-section, Pembina-Lobstick Glauconite E pool.

DRAFTING: K.GRIMSON | LOG PLOTS: | AUTHOR: D. CEDERWALL

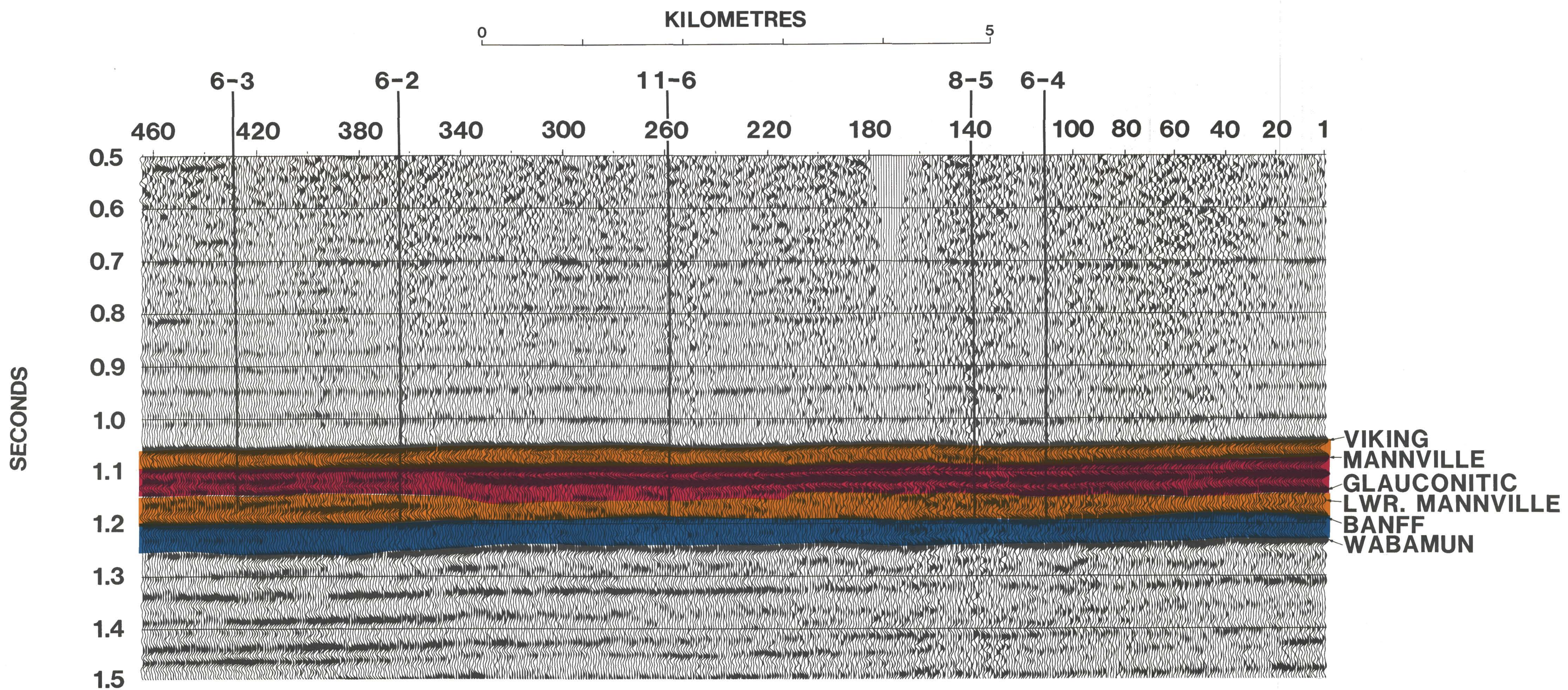

Figure 8.96. Seismic section, Pembina- Lobstick Glauconite E pool.

DONOR: CHEVRON CANADA RESOURCES LTD. | PROCESSOR: EXPLORATION SEISMIC SERVICES LTD., M. BROOME | AUTHOR: D. CEDERWALL

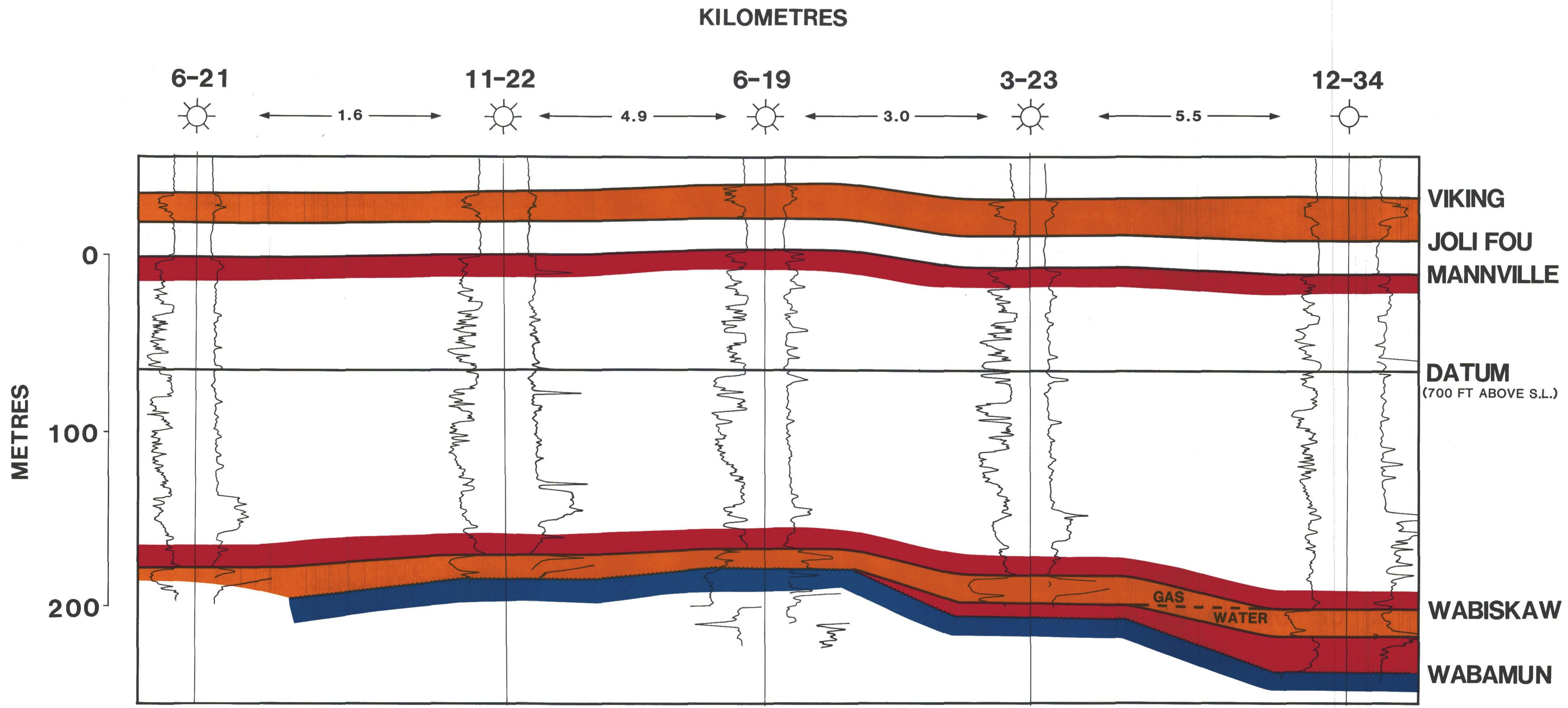

Figure 8.100. Geological cross-section, Marten Hills Wabamun A and Wabiskaw A pools.

DRAFTING: K. GRIMSON | LOG PLOTS: | AUTHOR: D. CEDERWALL

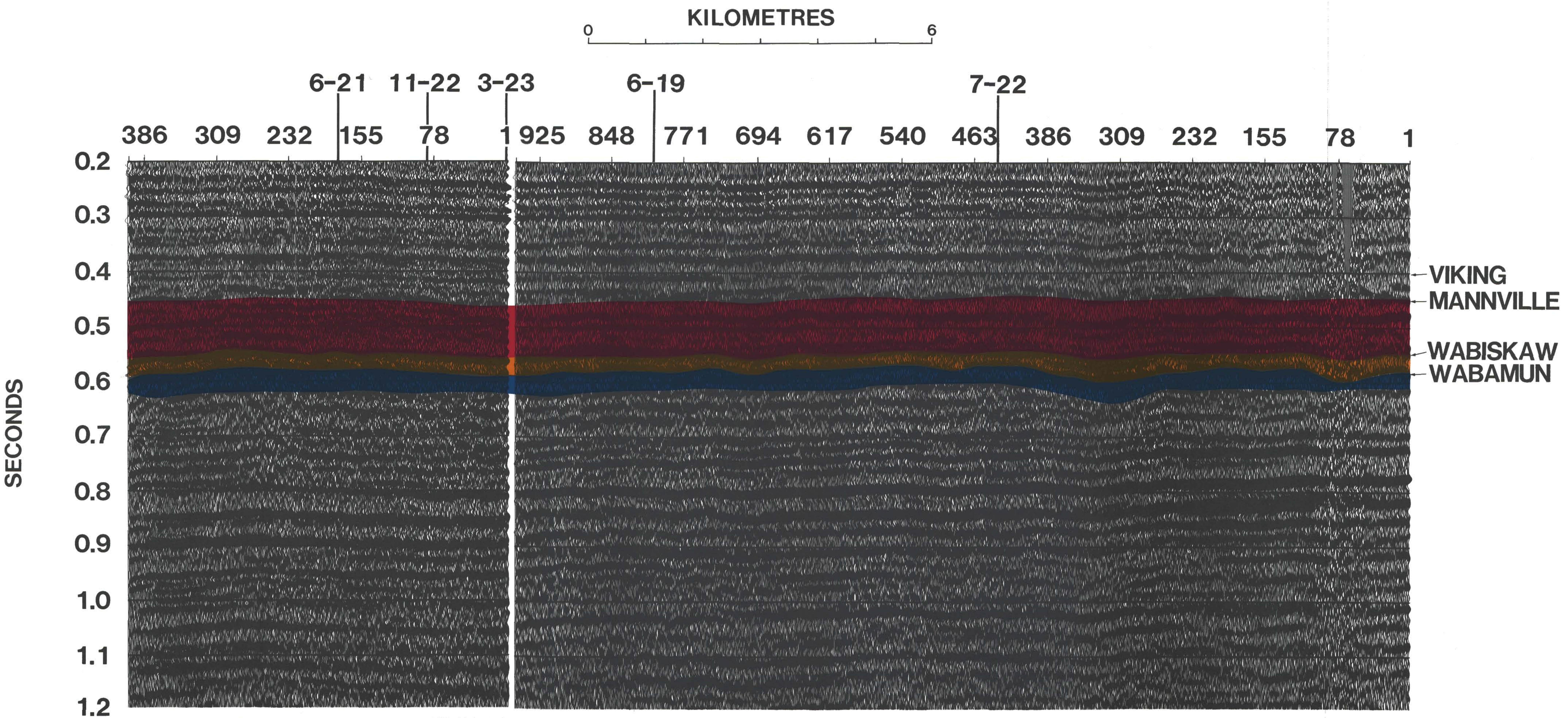

Figure 8.101. Seismic section, Marten Hills A and Wabiskaw A pools.

DONOR: CANADIAN OCCIDENTAL PETROLEUM LTD. | PROCESSOR: EXPLORATION SEISMIC SERVICES LTD., M.BROOME | AUTHOR: D.CEDERWALL kaw Mbr is a widespread 12 to 18 m thick, coarsening upwards, marine sheet sandstone and is mapped in an extensive southwest to northeast trending belt some 50 km wide. Wabiskaw Mbr deposition probably occurred in a stable environment with little primary structure, as the unit shows a uniform regional thickness. Thinning of the sandstone is observed in only the highest paleotopographic locations, where the lower Mannville is absent due to emergence in pre-Wabiskaw time. Updip of the field, the Wabiskaw Mbr sandstone contains heavy oil, whereas downdip both isolated gas bearing closures and an extensive water leg occur. Structure values on the top of the sandstone indicate monoclinal regional dip to the southwest of 2.5 m/km which is locally interrupted by bullseye closures that mirror structure on the pre-Cretaceous erosional surface. The Paleozoic strata at the subcrop were differentially eroded prior to deposition of the Lower Cretaceous, leaving remnant Wabamun Gp cuestas which are now gas bearing. Compaction of the laterally adjacent lower Mannville strata has caused gas to be structurally trapped in the Wabiskaw Mbr. Occasionally gas is trapped in other draping Lower Cretaceous sandstones.

Of interest is the fact that the Marten Hills discovery well was drilled on an interpreted Leduc Fm anomaly (Benson and James, 1974). This anomaly was later determined to be a Wabamun Gp thick which gave apparent velocity pull-up of the deeper events. Time-structural pull-up in this area is due to the velocity contrast between Mannville Gp clastics and the Wabamun Gp carbonates. This effect is of similar magnitude and character to velocity pull-up generated by Devonian Leduc Fm reefs of central Alberta (Chapter 4, this volume).

The Marten Hills field is a major gas field containing some 920 BCF of initial recoverable gas in the Wabiskaw Mbr, Wabamun Gp and associated formations. Shallow depth of burial (685 m) and an attendant low reservoir pressure are offset by the excellent porosity and permeability of the reservoir. The sheet like geometry and significant structural closure on the sandstone lead to large lateral distances from well bore to gas-water contacts, thus creating optimum production characteristics.

By contrast the Wabamun Gp gas reserves are in direct communication with the aquifer and thus have poorer production characteristics. However, gas reserves of the Wabamun Gp are thought to charge the Wabiskaw Mbr reservoir in structurally high areas where the two formations are in contact.

Reserves and significant reservoir parameters are shown in Table 8.17. Productivity data for this subsection are illustrated in Figure 8.99.

Table 8.17: Reserves and significant reservoir parameters, Marten Hills Wabiskaw and Wabamun pools (ERCB, 1987).

	WABISKAW A	WABAMUN A	TOTAL
Initial Volume in Place	$23{,}553 \times 10^6 m^3$	$1069 \times 10^6 m^3$	$32{,}622 \times 10^6 m^3$
Pool Recovery Factor	80%	65%	
Surface Loss	5%	5%	
*Initial Est. Reserves	$17{,}900 \times 10^6 m^3$	$5600 \times 10^6 m^3$	$23{,}500 \times 10^6 m^3$
Net Cumulative Production			$15{,}366 \times 10^6 m^3$
Remaining Est. Reserves			$8134 \times 10^6 m^3$
Area	82,374	32,374	
Average Pay Thickness	5.23 m	11.39 m	
Porosity	27.8%	13.8%	
Gas Saturation	65%	55%	
Mean Formation Depth	685.8	712.8	
Discovery Year	1961	1961	

*Other Reserves also occur in the Marten Hills Wabiskaw C, Wabamun C and miscellaneous category for a total of 26 109 x $10^6 m^3$ (920 BCF) of initial established reserves.

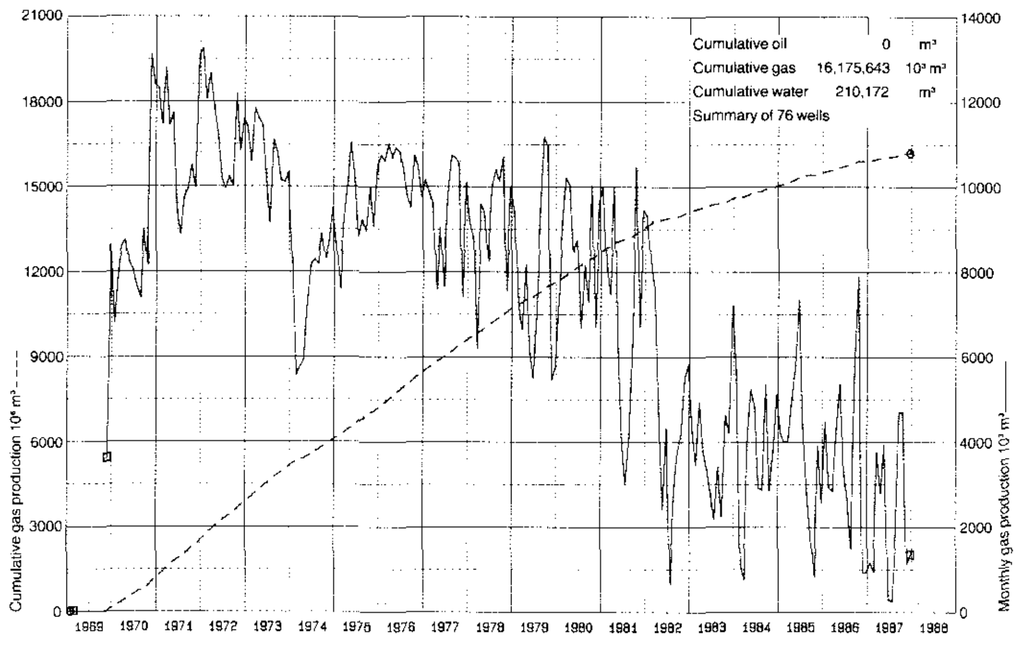

Figure 8.99. Production data, Marten Hills Wabamun A and Wabiskaw A pools.

GEOLOGICAL CROSS-SECTION

The cross-section of Figure 8.100 is oriented east to west and shows strata from the Wabamun Gp to the Viking Fm. Note however that the 12-34 location is well removed from the seismic line and is included to show a structurally low position of the reservoir. Also the 3-23 location is presented in an improper lateral position in order to simplify Figure 8.100. A proper perspective of the location of this well is shown on the seismic data of Figure 8.101. The units are labelled in ascending order as the Wabamun Gp, lower Mannville, Wabiskaw Mbr, Mannville Gp, Joli Fou Fm and Viking Fm.

The Wabiskaw Mbr, as shown in Figure 100, is a relatively uniform widespread coarsening upwards unit that has a striking resemblance to the Glauconitic Sandstone members of the Pembina-Lobstick Glauconite pool. Notable features of this section are the thickening of the Wabiskaw to Wabamun interval in structurally low and wet wells (ie. 12-34) and the thinning of this interval in structurally high, productive wells, (ie. 3-23 and 6-19). Some depositional control of the Wabiskaw Fm is suggested in the structurally highest wells, (ie. 8-16) where it is in direct contact with the subcrop.

SEISMIC SECTION

The seismic data (Fig. 8.101) for the Marten Hills example were donated by Canadian Occidental Petroleum Ltd. and reprocessed by Exploration Seismic Services Ltd. The data was acquired in 1977 and is a sixfold dynamite source line using 134-m shot point intervals and 33-m station intervals. The data is compressed to 77 traces per inch, in order to display the lateral extent of the Wabamun Gp highs and the corresponding lower Mannville thinning. A single well synthetic seismic trace showing the identification of the events is shown in Figure 8.102.

The Wabiskaw event of Figure 8.101 shows little or no discernable character change along the lines lateral extent similar to the uniform depositional characteristics suggested by the log traces of the cross-section (Fig. 8.100). The data does, however show substantial changes in the Wabiskaw to pre-Cretaceous unconformity interval which are directly related to the magnitude of the pre- Cretaceous highs. Coincident with these interval thins and the pre-Cretaceous highs are the apparent time-structural pull-up of the deeper events. This is due to the lateral contrast of the high-velocity Wabamun Gp carbonates to the lower-velocity lower Mannville strata which occur

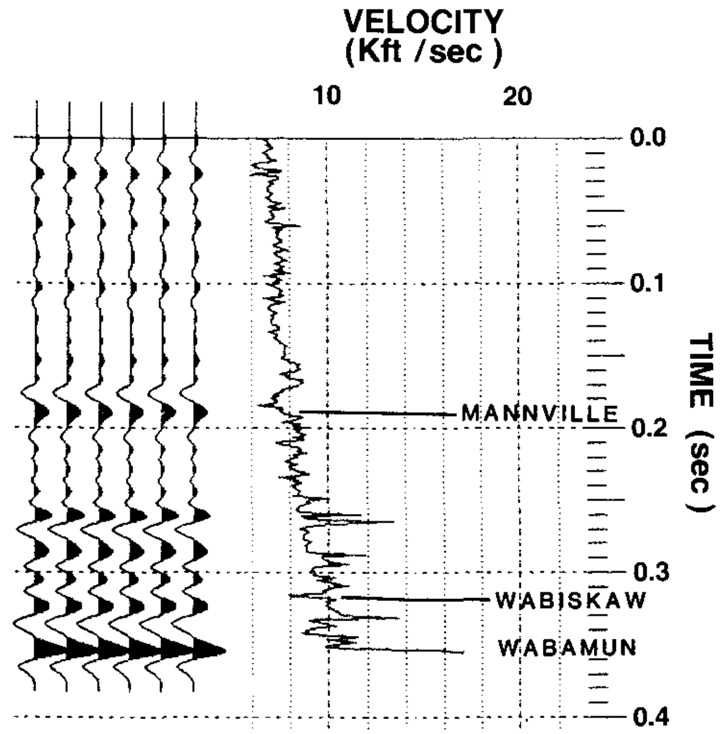

Figure 8.102. Single well synthetic seismic trace, Marten Hills Wabamun A and Wabiskaw B pools.

offsetting these highs. Time-structural relief on the order of 10 to 15 ms occurs between the highs and lows of the uncomformity event and is coincident with Wabiskaw to Wabamun interval changes of 5 to 8 ms.

CONCLUSIONS

Substantial gas reserves are trapped in the Wabiskaw Mbr and Wabamun Gp of the Marten Hills field. Little or no primary structural closure existed on the marine Wabiskaw Mbr sandstone, but rather a model of differential compaction between areas of lower Mannville thicks and thins is suggested as a mechanism for creating structural closure. These changes in the lower Mannville thickness are in direct response to erosional relief of the subcropping Wabamun Gp, which is also gas bearing. Direct detection of Wabiskaw Mbr gas is not demonstrated here, but the extent of the pool is discernable through time-structural and interval mapping of the Wabiskaw and Wabamun events.

SUMMARY

Lower Cretaceous reservoirs of the Western Canadian sedimentary basin occur in a wide variety of depositional environments and therefore show a wide variation in their geometry, making geophysical exploration largely dependent on an understanding of the local geology. However, the detection of: 1) drape due to differential compaction; 2) onlap; and 3) specific lateral character variations, are the main elements of the seismic expression of many of this chapters examples.

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