CHAPTER 7 TRIASSIC/JURASSIC FIELDS

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INTRODUCTION

The stratigraphy, geological history and morphology of the Triassic and Jurassic systems are briefly discussed in the introduction to this Atlas. Generally, Triassic strata are far more prolific hydrocarbon bearing reservoirs than are Jurassic strata. Based upon volume of oil per volume of rock the Triassic section is the richest representative of more open marine conditions on the shelf/slope of the present Montney subcrop edge. Production occurs from a relatively simple, isolated barrier bars and migrating tidal inlets. The Valhalla field produces from Halfway sandstones and the example seismic line illustrates the basement influenced syn-depositional hinge-line platform where the sediments were deformed and preserved. The Kobes field is a disturbed-belt expression of a Halfway reservoir. Here the reservoir consists of porous Halfway sandstones trending northeast-soutwest on imbricate Laramide thrust-sheets with adiabatic structural closure. The structural trapping also accounts for the Charlie Lake gas production in the same area. The second cycle of Triassic sedimentation is terminated by interbedded evaporites, red beds, sandstones, siltstones, dolomites and limestones of the Charlie Lake Fm (Carnian stage). These sediments are indicative of a prograded regime in the Peace River Arch region. The Halfway Fm predominantly produces from stratigraphic units which consist of sandstones and coquinas which exhibit a strong amplitude anomaly. In both examples, however, deeper structure, apparent on the seismic data, probably influenced deposition of the Halfway Fm.
The reservoir in the Nig Creek field is a 10m thick, widespread zone of shelly crinoidal carbonate and is situated stratigraphically 10 to 15m below the top of the Baldonnel Fm. Hydrocarbons in the Baldonnel Fm are trapped by a combination of three factors:

1) Stratigraphy - where porous Baldonnel Fm is preserved on erosional highs and sealed against the tight carbonates and shales of the Jurassic Nordegg Fm or against sandstones and shales where the pre-Cretaceous unconformity incises deeply into the Baldonnel Fm;

2) Structure - Minor Laramide structural closures trending northwest-southeast have been influenced by deep seated basement structures and control the distribution of the reservoir fluid phases; and

3) Reservoir diagenesis - Calcite infilling and replacement cause porosity reduction on a local scale and can affect reservoir fluids.

The lowest labelled horizon on the cross-section is the Charlie Lake Fm which underlies the Baldonnel Fm and is primarily composed of carbonate, siltstones and anhydrite. It has an uniform thickness of 100m in the study area. In contrast, the thickness of the Baldonnel Fm changes rapidly in the area, due to post-Triassic erosion. The amount of erosion is illustrated in the cross-section by

The reservoir in the Nig Creek field is a significant reservoir from an economic perspective, with reserves of 16.55 x 10^6 m^3 (587.8 Bcf) of gas and 22.1 x 10^6 m^3 (138 x 10^6 bbls) of oil; and

2) the structural element in the Nig Creek field is well illustrated in the example seismic line. The 'A' pool and other Baldonnel pools in the area are located close to the western edge of the Baldonnel Fm erosional limit. As a consequence of proximity to the subcrop, the Baldonnel Fm ranges from 0 to 100 m in thickness depending on the amount of post-Triassic erosion.

Although definitive dating of the Worsley/Tangent member has not been performed the dolomitized algal nature of the member compares favorably with older Charlie Lake members indicating a Triassic age. The reservoir quality of the member has been enhanced by the overlying disconformity and the member is widespread throughout the Peace River Arch area. Production occurs from the dolomitized algal mat in two separate trapping situations. The Worsley field produces from the Worsley Mbr on an upthrust horst block near the Worsley subcrop edge. Unfortunately no seismic data was available over the field itself. The Rycroft Charlie Lake "A" field produces from the Worsley/Tangent dolomite in a basement influenced erosional outlier encased in shales above (Nordegg) and below. The example seismic section once again illustrates the importance of identifying basement structure in deducing reservoir presence and structurally favorable reservoir positions.

The Nig Creek field is located in northeastern British Columbia, and was discovered in 1953. The field consists of two assigned Triassic pools, containing hydrocarbons in the Baldonnel and Halfway formations. Nig Creek field was selected as an example for the Triassic Schooler Creek Gp reservoir because:

1) the Baldonnel 'A' pool at Nig Creek is a significant reservoir from an economic perspective, with reserves of 16.55 x 10^6 m^3 (587.8 Bcf) of gas and 22.1 x 10^6 m^3 (138 x 10^6 bbls) of oil; and

2) the structural element in the Nig Creek field is well illustrated in the example seismic line.
well b-50-A/94-H. Well b-50-A is the entire Nordegg and Baldonnel formations removed, with a thick section of Cretaceous sandstone and shale infilling the erosional low. The erosional edge of the Baldonnel Fm is illustrated in Figure 7.2. The irregularity of this edge could provide numerous opportunities for stratigraphic traps as displayed by the 'A' pool.

The Nordegg Fm shale in this situation provides both a seal and source. Also evident is the Laramide low amplitude folding which strikes in a northwest - southeast direction. The reservoir facies within the Baldonnel Fm is very close to the erosional unconformity. The shelly crinoidal zone has porosities in the range of 10-12% and can be correlated over a wide area by gamma-ray logs. The shelly crinoidal zone has been interpreted as being deposited during a stillstand of the main Norian transgression.

**SEISMIC SECTION**

The example seismic line is shown in Figure 7.4. These data were recorded in 1982 using a dynamic source (single charge of 2.25 kg at 32 m depth), a 2400-m split spread, 300-m shot spacing and a 1.04-s group interval. This particular arrangement gave a coverage of 40%. Although this coverage is considered low with respect to the present industry standard, the data are fairly good in quality.

Identification of seismic reflections below one second are difficult because most wells in the Nig Creek area are quite shallow, usually bottoming in the Triassic sediments. To assist the interpretation, the well a-12-G/94-H located approximately 5.5 km to the northwest was projected into the line. The synthetic seismograms, in normal and reverse polarities, created by a 30 Hz Ricker wavelet are shown in Figure 7.5. The synthetic seismogram in Figure 7.5 shows strong amplitude reflections, which can be attributed to the sharp positive impedance contrast between shale and limestone. The time structure (30 to 40 ms anomalies) defined by these reflections is thought to be related to deeper structures, possibly associated with normal faulting and/or basement topography. It is difficult to evaluate these structures since wells penetrating beyond the Triassic are scarce in the area. However, to the southeast of the Nig Creek field normal faulting is common. The Banff event is identified at 1.25 seconds in the seismic section. The event is picked as a peak resulting from a positive impedance contrast between a unit of interlayering shale and limestone layers at the top and a clean higher velocity limestone at the base. The Banff event shows too low a reflection structure than the Kotcho event. It may suggest that the structures forming the shallow carbonate system in the area were not reactivated at a later age or the majority of the tectonic movement took place after the deposition of the Kotcho Fm.

The next event identified on the example seismic section is the Shunda Fm. The synthetic seismogram in Figure 7.5, the Shunda is anticipated to have a poor quality reflection due to the lack of a good impedance contrast. The thin shaly-limestone beds cause destructive interference, resulting in a low amplitude reflection on the seismic section. In contrast, the erosional top of the Debolt Fm produces a reflection event which is clearly visible both in the synthetic seismogram and seismic section (near 1.1 seconds). The Debolt event is interpreted as a positive amplitude resulting from a sharp positive change in impedance, from a low-velocity shale to a clean high-velocity limestone.

Reflection changes are observed between the Debolt and Banff events. These changes in isochron may be the result of seismic activity and/or erosional effects on the Debolt surface. Located at approximately 0.95 - 0.99 seconds on the seismic section are the Halfway and Doig events. The Halfway Fm is interpreted to have been deposited as a blanket sandstone approximately 10 to 12 m thick. Porosity and permeability are generally good in the area and some gas production has been discovered at the top of the Nig Creek field. Structural closure of the Halfway Fm is considered to be the main trap type for hydrocarbons. Doig Fm channel sandstone, when present, also be prospective in the vicinity. However, the Doig Fm in the Nig Creek field generally consists of shale and siltstone.

The seismic image of the Baldonnel Fm is dominated by high amplitude (peak) events. The reflection amplitudes are caused by sharp changes in impedance (shale to dolomites) as illustrated in the synthetic seismograph in Figure 7.5. Gas may partly contribute to the high amplitude reflections. It is interesting to note that the Baldonnel event dips at well location b-50-A, where the post-Jurassic erosional channel has removed the upper dolomite and Baldonnel formations, leaving behind a thick consolidated sandstone and shale sequence. The structure on the top of the Baldonnel Fm is
Figure 7.3. Geological cross-section, Nig Creek Field.
Figure 7.4. Seismic section, Nig Creek Field.
The last two events identified on the example seismic section are the Nordegg and Bluesky formations. The Nordegg, in general, is a poor quality reflection due to the lack of impedance contrast. A clearly identifiable Bluesky event can be seen on the seismic section due to the contrast between the overlying Mannville Gp shale and the Bluesky Fm sandstone. Both the Nordegg and Bluesky events show structure on the seismic section due to drape over deep-seated structures and post-Triassic infilled topography. Also note that the Nordegg event completely dims out at location b-50-A where the entire Nordegg has been eroded and replaced by a Cretaceous age sandstone and shale unit.

**SUMMARY**

The three major factors which control the trapping of hydrocarbons in the Nig Creek field are erosional topography on the top of the Triassic surface, minor Laramide related structure, and reservoir diagenesis. Present seismic techniques can only provide images of the structural element. Occasionally, where post-Jurassic erosion has incised into the Baldonnel Fm and juxtaposed Baldonnel Fm carbonate laterally against Cretaceous age clastics, a change in seismic response may be detected. However, geological mapping remains critical to the prediction of hydrocarbon traps in the Nig Creek field.

**KOBES FIELD**

**INTRODUCTION**

The Kobes Halfway 'A' gas field is located in northeastern British Columbia approximately 76 km northwest of Fort St. John. The field was discovered in 1956 by Phillips Petroleum with the drilling of d-94-1/94-B-8 which tested 402,000 cubic feet (14,286 cubic meters) of gas per day from the Halfway Fm. The Kobes field also produces from the De bolt Fm, five zones in the Charlie Lake Fm and from the Dunlevy Fm carbonate.

**SYNTHETIC SEISMOGRAM**

*a-012-G 094-H-04 WAVEFORM-30 Hz RICKER*

**VELOCITY (m/sec) N.P. R.P.**

<table>
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<tr>
<th>BLUESKY</th>
<th>NORDEGG</th>
<th>BALDONNEL</th>
<th>CHARLIE L.</th>
<th>HALFWAY</th>
<th>DOIG</th>
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<td>0.1148</td>
<td>0.1000</td>
<td>0.0000</td>
<td>0.0000</td>
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</tbody>
</table>

**KOTCHO TETCHO**

**UTAHN (Jean Marie)**

**SYNTHETIC SEISMOGRAM**

*b-030-A 094-B-090 WAVEFORM-35Hz RICKER*

**VELOCITY (m/sec) N.P. R.P.**

<table>
<thead>
<tr>
<th>DEBOLT</th>
<th>SHUNDA</th>
<th>BANFF</th>
<th>BLAHD</th>
<th>CRUDE</th>
<th>R.P.</th>
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<tbody>
<tr>
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<td>3151m</td>
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</tr>
</tbody>
</table>

**Figure 7.9. Synthetic seismogram well b-030-A 094-B-090.**

**Figure 7.5. Synthetic seismogram for well a-012-G 094-H-04.**

**Figure 7.8. Kobes Halfway A field and position of geological cross-section and seismic section.**

**Figure 7.6. Kobes Halfway A field and position of geological cross-section and seismic section.**
The seismic method is extremely useful in identifying Triassic anidolite traps associated with the Laramide Orogene. However, since the quality of the Halfway Fm reservoir is quite variable, geological mapping is necessary in order to predict where, along the anticline, the best reservoir may be encountered.

**GEOLOGICAL CROSS-SECTION**

The location of the geological cross-section, Figure 7.7, is shown on the map of the Kobes field (Fig. 7.6). The cross-section is oriented roughly perpendicular to the trend of the field and parallel to regional dip. It interprets one key and abandoned well which was drilled to the Debolt Fm, one Triassic gas well drilled to the Doig Fm and one Cretaceous gas well drilled to the Fernie Fm. Leg traces for the above wells are not illustrated due to the highly compressed vertical scale. The geological horizons which are labelled on the cross-section correspond to correlative seismic horizons on the example seismic section.

The Doig Fm is the lowest identified horizon on the cross-section. Depth control on this horizon is inferred from deeper wells outside the area and is therefore only approximate.

The next labelled event, the Debolt Fm, is 20-25 m in thickness and consists of calcareous siltstone and shale. It unconformably overlies the span Fm and is conformably overlaid by the Fernie Fm. The Doig Fm is shown to thinnest slightly to the east to correspond to the looting shing on the section. This thickening is a reflection of the angular nature of the Mississippian unconfornity.

The Doig and Halfway formations are the next labelled horizons on the cross-section. The Doig Fm is interpreted to be a trough occurring at the base of the Tertiary shale unit. The Halfway Fm is erosional and is placed at the base of the Nordegg Mbr shale. The contact between the Doig Fm and the overlying Halfway Fm is difficult to define in this area but may be correlated with the formation of an anticlinal trap in the Halfway Fm. The above zones also rely on this structure for the trapping of both oil and gas. The fault systems themselves do not seem to affect any seal since the vertical displacement of the Halfway Fm across these faults is not sufficient to juxtapose non-reservoir rock and reservoir rock.

**SEISMIC SECTION**

The example seismic section shown in Figure 7.8 is 12-fold dynamic data in February, 1981. A single 10 kg charge of dynamite at a depth of 15 m was used as the source. The shot interval was 100 m. The receiver array consisted of nine 10 Hz geophones over 50 m with a group interval of 50 m. Data were processed by a 12-bit zero phase Ricker wavelet having a dominant frequency of 35 Hz was used to generate the b-30-A synthetic.

A plan view map of the Kobes Halfway Fm is shown in Figure 7.6. The Halfway Fm is bounded above by unconformities and contact with the basal Tertiary Group. It is bounded below by unconformities and thinned from about 1,900 m in the northwest to 950 m in the southeast. Triassic sediments exhibit a general thickness increase through the Kobes area from the Halfway Fm to the top of the Charlie Lake Fm in the southeastern part of the field. The Triassic sequence in the Kobes area is bounded above by unconformities and contact with the basal Tertiary Group. It is bounded below by unconformities and thinned from about 1,900 m in the northwest to 950 m in the southeast. Triassic sediments exhibit a general thickness increase through the Kobes area from the Halfway Fm to the top of the Charlie Lake Fm in the southeastern part of the field.
Figure 7.7. Geological cross-section, Kobes field.
Figure 7.8. Seismic section, Kobes field.
SUMMARY

The Kobes Halfway "A" field produces natural gas from porous Halfway Fm nearshore marine sandstone. Net pay and porosity average 6.5 m and 5.6% respectively. Hydrocarbons are trapped structurally in an anticlinal trap which was formed by Laramide compressional forces. The presence of the structural trap is well-defined seismically, but due to the variability of reservoir quality geological mapping is necessary to identify areas along the annulus where superior reservoir rock may be encountered.

SPRIT RIVER HALFWAY FIELD

INTRODUCTION

Production in the Spirit River Halfway field is mainly from clastic carbonate coquinas of the Halfway Fm and unconformably overlying carbonate algal mats of the Charlie Lake Fm. Both the Halfway and the Charlie Lake Fm are stratigraphic traps sealed by updip Halfway Fm anhydrites and overlying Charlie Lake anhydrites and siltstones.

The Spirit River Halfway field is located in north-central Alberta (Fig. 7.10) and is one of a series of northwest-southeast trending offshore bar sequences. The porous Halfway occurs on successive progradational fringe line platforms, which in the case of the Spirit River field, is apparent on the example seismic line. The Spirit River field, however, occurs very near the depositional/erosional edge of the Halfway Fm and the SchooJer Creek Gp. It is because of this that the Halfway sequence is primarily comprised of dolomitic coquinas and stacked bar sequences which would indicate a very nearshore setting.

The geological cross-section through the Spirit River field shows the trap morphology, stratigraphy and facies relationships discussed above.

The Spirit River Halfway field is approximately 15 km long by 3.5 km wide and aligned parallel to the paleo-shoreline. The unit, near the seismic line attains a gross thickness of 20 m with maximum oil pay of 15 m. The map view (Fig. 7.11) shows both the geological cross-section and the seismic line extending from the updip Halfway Sabkha anhydrite through the intertidal algal mats and nearshore stacked bar sequence of the field into deeper water sandstones and siltstones. Production in the Spirit River/Rycroft field is primarily from the updip stacked bar.

Production in the Spirit River/Rycroft field is primarily from the updip stacked bar. Net pay and porosity average 6.5 m and 6.5% respectively. Hydrocarbons are trapped structurally in an anticlinal trap which was formed by Laramide compressional forces. The presence of the structural trap is well-defined seismically, but due to the variability of reservoir quality geological mapping is necessary to identify areas along the annulus where superior reservoir rock may be encountered.

The orientation of the example seismic section (Fig. 7.12) is shown on the schematic plan view (Fig. 7.10) and is one of a series of northwest-southeast trending offshore bar sequences. The porous Halfway occurs on successive progradational fringe line platforms, which in the case of the Spirit River field, is apparent on the example seismic line. The example seismic section (Fig. 7.12) parallels the example seismic line in a north-south configuration. The oblique orientation of the seismic line and cross-section in the northwest-southeast strike of the field helps portray field parameters over a wider area. The cross-section is hung on a structural datum which emphasizes the subtle field morphology.

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The Spirit River Halfway field is located in north-central Alberta (Fig. 7.10) and is one of a series of northwest-southeast trending offshore bar sequences. The porous Halfway occurs on successive progradational fringe line platforms, which in the case of the Spirit River field, is apparent on the example seismic line. The example seismic line was recorded in 1976 using a dynamite source (2 kg at 15 m), a 1575 m split-spread, a 134 m source interval, and a 33.5 m group interval. The field has a consistent thickness of both the stacked bar and the tidal flat are preserved as is the reservoir quality. Another more subtle flexure occurs downdip of 7-21 marking the lateral boundary between the updip Halfway Sabkha anhydrite and the platform dolomitized algal mats and dolomitic coquinas. The algal mats discontinuously overlie the stacked bar coquinas indicating a separate regressive stage. The algal mats are unconformably overlain by the Charlie Lake siltstones and anhydrites.

The platform depocentre extends from 8-9 to 16-23 where consistent thickness of both the stacked bar and the tidal flat are preserved as is the reservoir quality. Another more subtle flexure occurs updip of 8-33 where the Halfway has graded into siltstones and very fine-grained sandstones indicative of deeper water deposition. The general structural configuration of the field at the time of discovery had been preserved in a relative sense and is apparent on both the cross-section and the example seismic line.

SEISMIC SECTION

The orientation of the example seismic section (Fig. 7.12) is shown on the schematic plan view (Fig. 7.10). The example seismic section was recorded in 1976 using a dynamic source (2 kg at 15 m), a 1575 m split-spread, a 134 m source interval, and a 33.5 m group interval.
The seismic section was produced using conventional processing and is presented as a normal polarity section.

Deep well control is limited in the area with the example synthetic from 6-24-77-6W6M (Fig. 7.13) being 5 km off the line to the east. The synthetic seismogram illustrates the horizons of interest which can be directly correlated to the seismic line. The synthetic was generated using a zero phase Ricker wavelet with a central frequency of 35 Hz. The Wabamun event is the lowest labelled event on the seismic section. This event corresponds to the peak resulting from the sharp positive impedance contrast between the Wabamun carbonate and underlying shales. The Charlie Lake 'A' pool is a stratigraphic trap sealed by disconformably overlying shales of the Jurassic Nordegg Fm. The Nordegg Fm is a likely source due to its very high organic material content. Shales of the Charlie Lake Fm also underlie the Charlie Lake 'A' which itself grades into a burrowed intertidal channel shale surrounding the productive outliers. Exsag of the Charlie Lake 'A' has not been conducted but it very distinctly identifies other productive algal member of the Charlie Lake, such as the Boundary Lake Member, and is most likely of Triassic age.

The Charlie Lake 'A' is the last depositional event of the Triassic and the area deposited is a transgressive regime in the Peace River Arch area. The algal mat of the Charlie Lake Fm ranges from 0.5 to 5 m thick where present and lies conformably upon a burrowed intertidal channel shale. The Charlie Lake 'A' outlier was preserved on a basement rooted paleo-high. Dip oriented cross-section suggests that the Charlie Lake 'A' outlier was deposited in a shallow flat complex and baring sea level increase and associated high energy conditions, would be preserved on a structurally high position. The example seismic line (Fig. 7.16) further supports this interpretation.

**SYNTHETIC SEISMOMGRAM 16-24-077-06W6M WAVEFORM 35 Hz RICKER**

**VELOCITY(m/s) N.P. R.P.**

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<thead>
<tr>
<th>Velocity (m/s)</th>
<th>N.P.</th>
<th>R.P.</th>
</tr>
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<tbody>
<tr>
<td>1715</td>
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**Figure 7.13. Synthetic seismogram well 16-24-077-06 W6M.**

**REPRODUCTION OF CHARLIE LAKE 'A' FIELD**

**INTRODUCTION**

Production in the Rycroft Charlie Lake 'A' field (Fig. 7.14) emanates from a syncline of dolomitized algal mat. This member of the Charlie Lake Fm is known by various names within industry: Charlie Lake 'A', the Nordegg Fm, and the Wabamun. The Charlie Lake 'A' pool is a stratigraphic trap sealed by disconformably overlying shales of the Jurassic Nordegg Fm. The Nordegg Fm is a likely source due to its very high organic material content. Shales of the Charlie Lake Fm also underlie the Charlie Lake 'A' which itself grades into a burrowed intertidal channel shale surrounding the productive outliers. Exsag of the Charlie Lake 'A' has not been conducted but it very distinctly identifies other productive algal members of the Charlie Lake, such as the Boundary Lake Member, and is most likely of Triassic age.

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**SEISMIC SECTION**

The orientation of the example seismic section (Fig. 7.16) parallels the cross-section in its dip orientation and is illustrated on the schematic plan view. The example line was recorded in 1980 using a dynamite source (2.2 kg at 20 m), a 134-m source interval, and a 2.2-km shot interval. The example synthetic was generated using a zero phase Ricker wavelet with a central frequency of 35 Hz. Front plane wave is displayed with 295 x 10^6 m^3 (16.7 MMSTB) oil in place, with 295 x 10^6 m^3 (15.7 MMSTB) as the last depositional event of the Triassic.

**GEOLOGICAL CROSS-SECTION**

The geological cross-section (Fig. 7.15) parallels the example seismic line (7.16) in a southwest - northeast orientation normal to the orientation of the pool. Rycroft Charlie Lake 'A' field is unconformably overlies the Charlie Lake Fm and is in turn overlain by the Triassic/Jurassic boundary disconformity which separates the Charlie Lake 'A' from the Nordegg shale.

The algal mat of the Charlie Lake Fm ranges from 0.5 to 5 m thick where present and lies conformably upon a burrowed intertidal channel shale. The example line shows the erosional edge of the outlier with erosion most likely taking place during, or immediately following deposition. The erosional edge of the outlier would mark the shoreline/sabkha edge in there is an indication of Charities 'A' dolomite or shale deposition in the 7-22 well.

Basement faulting was subsiding during Charlie Lake deposition and directly influenced deposition and preservation of the Charlie Lake 'A'. The dip oriented cross-section suggests that the Charlie Lake 'A' outlier was preserved on a basement rooted paleo-high. Dip oriented cross-section suggests that the Charlie Lake 'A' outlier was deposited in a shallow flat complex and baring sea level increase and associated high energy conditions, would be preserved on a structurally high position. The example seismic line (Fig. 7.16) further supports this interpretation.

**SUMMARY**

The Spirit River field produces from Charlie Lake dolomitized algal mat and Wabamun coquinoid sandstones. Thickness ranges from 5-30 m with maximum oil pay of about 15 m. A technically influenced basement hinge-line provided for Halfway platform coquina deposition and is preserved across the area. The seismic section shows the relationship between basement structure and Halfway Fm facies and structure. Halfway Fm deposition was commensurate with basement faulting making identification a key interpretive parameter.

The deepest event discernable is the Wabamun at 1.23 s at trace 560. Normal faulting is evident at the Wabamun level and was active up to the Halfway time. Each event in the Halfway Fm grades into deeper water siltstones and sandstones. Halfway Fm is interpreted to be the peak resulting from positive impedance contrast between the Debolt carbonate and the underlying Montney shale. The synthetic was generated using a zero phase Ricker wavelet with a central frequency of 35 Hz. The Wabamun event is the lowest labelled event on the synthetic seismogram well 16-24-077-06 W6M. The example synthetic is presented as a normal polarity section.
Figure 7.11. Geological cross-section of the Spirit River Halfway field.
Figure 7.12. Seismic section of the Spirit River Halfway field.
Figure 7.15. Geological cross-section, Rycroft Charlie Lake A field.
Figure 7.16. Seismic section, Rycroft Charlie Lake A field.
The seismic section shows the relationship between basement structure and presence of Charlie Lake algal mat. Charlie Lake deposition was concurrent with basement faulting making structural interpretation of deep events an essential parameter in Triassic interpretation. Normal faulting is evident at the Wabamun level, producing a broad horst. Fault offset is apparent at the Wabamun event with flexure evident at both the Debolt and Triassic reflectors at traces 105; 151.

The Wabamun event is the lowest labelled event on the seismic section. This event corresponds to the peak resulting from the sharp positive impedance contrast between the Wabamun Gp carbonate and overlying Banff Fm shale. The next event identified on the example seismic section is the Debolt Fm. It is interpreted to be the peak resulting from positive impedance contrast between the Debolt Fm carbonate and the conformably overlying Golata Fm shale. The next event identified on the example seismic section is the Charlie Lake. It is interpreted to be the peak resulting from the positive impedance contrast between the Charlie Lake Fm clastic/carbonate and the disconformably overlying Nordegg Fm shale.

**SYNTHETIC SEISMOGRAM**

"WAVEFORM-35 Hz RICKER"

**VELOCITY(m/sec) N.P. R.P.**

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<tr>
<th></th>
<th>1500</th>
<th>1000</th>
<th>500</th>
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**RYCROFT CHARLIE LAKE • A POOLS**

2,500,000 m³ (15.7MMSTB) OIP

295,000 m³ (1.8MMSTB) PRIMARY RECOVERY

718,000 m³ (4.5MMSTB) SECONDARY RECOVERY

**INTRODUCTION**

The Rycroft Charlie Lake A pool produces from a dolomitized laminated algal mat ranging in thickness from 0.5 to 5 m. The stratigraphic trap was formed by algal mat deposition and preservation, directly over a paleohigh, with subsequent marine shale deposition forming the overlying and lateral seal.

**SUMMARY**

The Wabamun event is the lowest labelled event on the seismic section. This event corresponds to the peak resulting from the sharp positive impedance contrast between the Wabamun Gp carbonate and overlying Banff Fm shale. The next event identified on the example seismic section is the Debolt Fm. It is interpreted to be the peak resulting from positive impedance contrast between the Debolt Fm carbonate and the conformably overlying Golata Fm shale. The next event identified on the example seismic section is the Charlie Lake. It is interpreted to be the peak resulting from the positive impedance contrast between the Charlie Lake Fm clastic/carbonate and the disconformably overlying Nordegg Fm shale.

The seismic section shows the relationship between basement structure and presence of Charlie Lake A algal mat. Charlie Lake A deposition was concurrent with basement faulting making structural interpretation of deep events an essential parameter in Triassic interpretation. Normal faulting is evident at the Wabamun level, producing a broad horst. Fault offset is apparent at the Wabamun event with flexure evident at both the Debolt and Triassic reflectors at traces 105 and 151.

Charlie Lake A algal mat relates directly to the horst outlined by the normal faults identified at the reflector. The updip edge of the Charlie Lake A, which most likely represents the algal mat/shoreline transition, coincides with the normal fault southwest of the 7-22 well. The downdip edge of the outlier, which represents the erosional extent of the paleotide, coincides with the normal fault at trace 151. Triassic Charlie Lake A algal mat has been preserved on a basement paleohigh.

**VALHALLA FIELD**

**INTRODUCTION**

The Valhalla Halfway "C" pool is located in west-central Alberta approximately 40 km northwest of Grande Prairie. It was discovered in 1980 by Petro-Canada Exploration Inc. with the drilling of 8-5-
Figure 7.19. Impedance logs for gas filled Halfway sand model.

Figure 7.20. Synthetic seismogram of gas filled Halfway sand model.
Figure 7.21. Geological cross-section, Valhalla Halfway 'C' field.
Figure 7.22. Seismic section, Valhalla Halfway 'C' field.
The Halfway Fm unconformably overlies the Doig Fm and is conformably overlain by the Charlie Lake Fm. The Doig Fm is a regressive shale to sandstone unit in the Valhalla area. The top of the Doig Fm is marked by an erosional surface. This erosional event produced numerous channels which in some areas to the south and north of the Valhalla area are present. These tight facies act as the updip seal for this stratigraphic trap. A thin transgressive lag at the base of the Halfway Fm is also shown. Note that a free water leg is not present in the early Halfway transgressive shoreline and is interpreted to be a barrier bar, from its elongate shape and characteristic subsea, and the orientation of the field with respect to depositional environments.

The Halfway Fm consists of fine-grained, well-sorted, subrounded and crossbedded sandstones. The paleoenvironment during the Middle Triassic was arid and warm with low rates of sediment influx from the east (Campbell and Horne, 1986). This, combined with the low topographic relief, resulted in the deposition of contemporaneous Charlie Lake Fm sabkha facies in the supratidal area to the east of the shoreline. The sedimentary facies of the Charlie Lake Fm interfinger with and eventually conformably overlies the Halfway Fm due to the generally continuous regression of the Halfway sea. A plan view map of the Valhalla field is shown in Figure 7.8. This map has been simplified by plotting only those wells which penetrated the Halfway Fm and by having the seismic reflector of the Halfway Fm status only. Net pay is contoured at two metre intervals on the map of the Valhalla field. It is oriented roughly perpendicular to the strike of the field. Three non-productive wells, one well in the near-shore and off-shore positions it is comprised of barrier bar sandstones and associated open marine siltstones and shales. The paleoenvironment during the Middle Triassic was arid and warm with low rates of sediment influx from the east (Campbell and Horne, 1986). This, combined with the low topographic relief, resulted in the deposition of contemporaneous Charlie Lake Fm sabkha facies in the supratidal area to the east of the shoreline. The location of the geological cross-section (Fig. 7.19), is shown on the map of the Valhalla field. It is oriented roughly perpendicular to the strike of the field. Three non-productive wells, one well in the near-shore and off-shore positions it is comprised of barrier bar sandstones and associated open marine siltstones and shales. The paleoenvironment during the Middle Triassic was arid and warm with low rates of sediment influx from the east (Campbell and Horne, 1986). This, combined with the low topographic relief, resulted in the deposition of contemporaneous Charlie Lake Fm sabkha facies in the supratidal area to the east of the shoreline. The seismic section over the Valhalla field clearly shows direct evidence of the Halfway Fm reservoir by the presence of a "bright spot".

The seismic section over the Valhalla field clearly shows direct evidence of the Halfway Fm reservoir by the presence of a "bright spot". Where sufficient thickness and porosity is present this direct hydrocarbon indicator may be used as an exploration tool. Subtle structural variations on underlying strata are also evident and may be used in conjunction with geological mapping to define favorable areas for Halfway Fm barrier bar development.

The Wabamun event is the lowest labelled event on the seismic section (Fig. 7.20). As shown on the map in Figure 7.18 the seismic section runs east-west, approximately perpendicular to the trend of the Valhalla field and at 45° to regional dip, which is to the southwest at approximately the same dip. Wabamun Fm is conformable over which phosphates of the basal Nordegg Fm, the uppermost identified horizon on the geological cross-section, were deposited.

The Halfway Fm is comprised of alternating anhydrite and dolomite units with minor amounts of siltstone and sandstone, deposited in a sabkha environment. Several correlatable units exist within the Charlie Lake Fm one of which is a fining-upward sequence marked on the geological cross-section. The inrush from this facies upward unit in the top of the underlying Halfway Fm is fairly uniform across the geological cross-section with only minor thinning evidenced near the shoreline. The seismic section was correlated with the geological cross-section using the Wabamun event as a seismic marker.

The Halfway Fm contains only gas, and one in which both oil and gas are present are incorporated into the cross-section. The log traces represented are the gamma-ray and bulk density curves. The lowest identified horizon on the geological cross-section is the Doig Fm. As stated earlier, the Doig Fm is a regressive siltsand shale sequence, the top of which has been eroded.

The next horizon identified on the geological cross-section is the Halfway Fm unconformably overlies the Doig Fm and is conformably overlain by the Charlie Lake Fm. The Doig Fm is a regressive shale to sandstone unit in the Valhalla area. The top of the Doig Fm is marked by an erosional surface. This erosional event produced numerous channels which in some areas to the south and north of the Valhalla area are present. These tight facies act as the updip seal for this stratigraphic trap. A thin transgressive lag at the base of the Halfway Fm is also shown. Note that a free water leg is not present in the early Halfway transgressive shoreline and is interpreted to be a barrier bar, from its elongate shape and characteristic subsea, and the orientation of the field with respect to depositional environments.

The seismic section over the Valhalla field clearly shows direct evidence of the Halfway Fm reservoir by the presence of a "bright spot". Where sufficient thickness and porosity is present this direct hydrocarbon indicator may be used as an exploration tool. Subtle structural variations on underlying strata are also evident and may be used in conjunction with geological mapping to define favorable areas for Halfway Fm barrier bar development.
The next event identified on the seismic section is the Belloy event. This is expected over the oil-filled portion of the Valhalla field, since the impedance contrast between the clean sandstone at the top of the Belloy Fm and an underlying shale, consistently results in a strong reflector that is unambiguously mapped.

The Belloy is the next labelled event and is picked to be the trough originating from the negative impedance contrast between the clean sandstones at the top of the Belloy Fm and an underlying shale. This anomaly amplitude is related to the presence of gas-saturated Belloy Fm sandstone.

The synthetic seismic response from a theoretically thinning gas-saturated Belloy Fm sandstone is shown in Figure 7.22. Figure 7.21 is the model from which this response was derived. It shows the impedance tracings from a gas-saturated Belloy Fm sandstone thin from a maximum of nine metres to zero by one metre increments, based on the sonic and density logs from 6-31-5-8 W6M. The units above and below the porous interval were held at constant bulk density and Poisson's ratio. The top of the Doig Fm is marked by an erosional surface. The Halfway Fm unconformably overlies the Doig Fm and is conformably overlain by the Charlie Lake Fm. The Doig Fm has a crossbedded fossiliferous marine sandstone which is predominantly of Recent age. It consists of dolomite, anhydrite, and minor amounts of siltstone, the reservoir consists of sandstones and coquinas which were deposited in a shallow marine environment and gas-saturated and tight back barrier sand to the northeast where it interfingers with the clean sandstones and siltstones with the overlying Charlie Lake Fm. The Halfway Fm in the Wembley area has been interpreted to result from the presence of a deeper hingeline which appears to have influenced the location of the barrier bar.

**SUMMARY**

The Halfway Fm in the Wembley area has been interpreted to have been deposited in a warm arid environment at a latitude of approximately 30° north of the paleoequator (Campbell and Horne, 1986). It is a predominantly regressive shoreline complex of prograding barrier islands and tidal channels deposited on a gently sloping surface. The Halfway Fm thins and becomes a tight back barrier sand to the northeast where it interfingers with the time equivalent evaporites of the Charlie Lake Fm. The thinnest part of the Halfway Fm to the northeast has been interpreted to have been caused by post-Doig deposition of evaporites which resulted in its erosion by the Halfway Fm against the resulting ramp (Cant, 1986).

The Charlie Lake Fm is a predominantly evaporitic unit, deposited in a shallow marine environment and gas-saturated and tight. It consists of dolomite, anhydrite, and minor amounts of siltstone and sandstone. Oil reserves are also recognized in the Charlie Lake Fm and the Doig Fm but due to thin pay zones and poor recovery factors these reserves account for only a 7% addition in the recoverable oil reserves from the Triassic in the Wembley field.

Oil reserves are also recognized in the Charlie Lake Fm and the Doig Fm but due to thin pay zones and poor recovery factors these reserves account for only a 7% addition in the recoverable oil reserves from the Triassic in the Wembley field.
Figure 7.25. Geological cross-section, Wembley Halfway 'B' field.
Figure 7.26. Seismic section, Wembley Halfway 'B' field.
The next identified horizon in Figure 7.25 is the Halfway Fm. It can be seen to thin from 30 m (6-15) to 10 m (10-18). As illustrated by the log traces, the Halfway Fm has a complex lithology in the Wembley and Hythe areas. The two wells, 6-15 and 6-13, which are located in the Hythe field, display the characteristic log response of infilled tidal channels. The lower 10 m of the Halfway Fm in the 6-15 well is a coarsening-upwards sequence truncated by the tidal channel. From the gamma-ray response the tidal channel infill is interpreted to be primarily sandstone. In the 6-13 well the lower 10 m of tidal channel infill is shell-hash conglomerate, the upper 7 m is sandfilled. A permeability barrier is present between the Hythe and Wembley fields which may be provided by a facies change or by cementation of Halfway Fm porosity. The remaining wells on the cross-section are in the Wembley field. The log traces represented are the gamma-ray and bulk density curves.

The Doig Fm is the lowest identified horizon on the geological cross-section. The top of the Doig Fm is an erosional surface and is picked at the base of a transgressive lag which marks the start of Halfway Fm deposition. The position of a Doig erosional channel which incised into preceding Doig regressive marine clastics and was then backfilled with clean crossbedded marine sandstones is illustrated. This channel can be in excess of 40 m deep in the Wembley area. It is interpreted to be an estuarine channel (Cant, 1986) from sedimentary structures, the presence of marine fossils and linear areal expression.

Figure 7.24. Wembley Halfway 'B' field and location of geological cross-section and seismic section.

Figure 7.25. Synthetic seismogram 16-08-073-08W6M.

angle to both the trend of the field and regional dip. The cross-section incorporates three oil and three gas wells which produce from the Wembley Halfway B pool and one oil and one gas well which produce from the Hythe field. The log traces represented are the gamma-ray and bulk density curves.

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The updip seal (not illustrated) for the Wembley field is provided by dolostone units, with minor amounts of siltstone and sandstone, deposited in a sabkha environment. As previously stated, the Charlton Lake section is highly conformable and is the probable source for the sabkha cement which overlies porosity in the upper few metres of the Halfway Fm.

SEISMIC SECTION

The example seismic section (Fig. 7.20) is ultrasonic data acquired in January, 1978. The data were recorded utilizing a 512-1277 instrument, split-spread receiver configuration (near offset 302 m, far offset 1458 m), a 50 m group interval and a 100 m source interval (200 kHz CMP data). A seven second sweep length was used with a 36 Hz to 14 Hz down-sweep with 16 sweeps over 100 m. The receiver array consisted of 10 geophones over 11 m. Data were sampled at four milliseconds on a 12 second record with an out/64 Hz, notch out, and 30% overlap.

As shown in Figure 7.24 the seismic section runs east-west, approximately perpendicular to the Halfway Fm and at approximately 45° to regional dip, which is one degree to the southeast. The seismic section begins in the Hyble field to the west and crosses the Wembley field where it ends near the zero poy contour. It crosses the glacial transition zone of both fields and a Dog eastward channel in the Wembley Fm, it is displayed as a normal polarity section; an increase in impedance at an interface is displayed as a reflection of a deep seated hinge line which influenced the development of the Halfway shoreline. The Bluesky to Nordegg isochron contour. It crosses the gas/oil transition zone of both fields and a normal polarity section; an increase in impedance at an interface is displayed as a reflection of a deep seated hinge line which influenced the development of the Halfway shoreline. The Bluesky to Nordegg isochron

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Events in the waveform changes may be more apparent on higher resolution sections and would require corroboration by additional seismic coverage over the area.

SUMMARY

Hydrocarbons of the Wembley Halfway "B" field are stratigraphically trapped in a reservoir which consists of sandstones and coquinas deposited in a near-shore marine environment. Reservoir parameters are quite varied due to the complex nature of the Halfway Fm in the area. The seismic method does not provide direct evidence of the Wembley field. The presence of a pre-existing structure, as illustrated by the seismic section, may be used indirectly to identify areas of potential shoreline development. Changes in the seismic response at the Halfway level may have limited usefulness in facies and porosity prediction.

STURGEON LAKE SOUTH TRIASSIC "A" POOL

The Sturgeon Lake South Triassic "A" pool was discovered in 1955 in the Sturgeon Lake area (Fig. 7.28) on the northeast edge of the Sturgeon Lake South Leduc oil pool which was discovered during development drilling of the Leduc pool. A second Triassic pool, "B," was discovered in 1957 on the south edge of the Leduc pool. The "A" pool had initial in-place oil reserves of 4.77 x 10^12 m^3 (30 x 10^9 bbls). With a primary recovery factor of 11%, remaining oil reserves totalled 0.94 x 10^12 m^3 (6.9 x 10^9 bbls). Cumulative production to the end of 1987 was 411.8 x 10^6 m^3 (2.6 x 10^9 bbls) of light oil (844 kg/m^3 - 30° API) from a mean depth of 1500 m. Oil is produced from a maximum 8.4 m (28 ft) of sandstone, and has been interpreted as a delta front facies. These sandstones are interbedded with siltstones and shales which make up the base and top of the reservoir.

The Sturgeon Lake South Triassic "A" reservoir consists primarily of sandstone, and has been interpreted as a delta front facies. These sandstones represent lobes of river-dominated delta which prograded westward from a shoreline located a few miles east of the present subcrop edge (Mill, 1976). The four porous members shown on the seismic cross-section are interpreted as a large, complex tidal flat. Dip of the Monastery Fm reservoir facies over the underlying Leduc reef probably forms the trapping mechanism, while lateral seals are provided by the Monastery Fm shales and Nordegg Fm shales. Likely source rocks are the Nordegg Fm and Monastery Fm shales, but deeper sources cannot be ruled out. Other shows from the porous Triassic member which produces at Sturgeon Lake South are the Tangent gas show from a dolomite lens, and a gas zone at Whitehorse (Mill, 1976).

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The seismic method is of limited use in defining the Triassic oil accumulations. Due to the nature of the reservoir, conventional seismic methods do not clearly indicate the presence or absence of reservoir. On the other hand, seismic clearly shows the presence of the Leduc reef and illustrates structural drapes in the overlying strata. If geological mapping indicates the presence of reservoir quality rock, seismic may be used to indicate structurally favorable drilling positions.

GEOLOGICAL CROSS-SECTION

Figure 7.28 indicates the location of the cross-section shown in Figure 7.29. It also illustrates structural relief on the top of the Triassic unconformity surface. The contours indicate a reduction in the southeast trending regional dip at the edge of the Leduc pool, suggesting a "draping" of Triassic sediments over the Leduc reef. The Triassic "A" wells are on the map with triangles. The remaining oil wells belong in the Leduc and Triassic "B" pool.
Figure 7.29. Geological cross-section, Sturgeon Lake South Triassic "A" pool.
Figure 7.30. Seismic section, Sturgeon Lake South Triassic "A" pool.
Drilling density north of the Triassic "A" pool is insufficient to establish structural closure, but this is the generally accepted trapping mechanism (Podruski et al., 1987). Also, it is possible that the presence of the underlying reef influenced facies distributions within the Montney Fm, resulting in an accumulation of porous sands flanking the ancestral high (Mull, 1976).

The cross-section runs southwest-northeast through the southeast portion of the Triassic "A" pool and is comprised of three Leduc oil wells (3-5L, 02/10-5, 1-9), an abandoned Triassic oil well (13-4) and three abandoned wells (13-4, 16-1, 9-14). (Stains symbols represent the Triassic level). The log pairs illustrated on the cross-section are gamma ray and sonic transit time in each example excepting that of 15-4, where the bulk density log is depicted instead of sonic transit time.

The Mississippian unconformity exposed Debolt Fm sediments in this locale, and has been interpreted as draping over the edge of the underlying Leduc reef. Overlying the Debolt Fm are Belloy strata which are unconformably overlain by the Montney Fm. The "flattening" of the Triassic unconformity surface mentioned earlier is clearly demonstrated on the cross-section. Also, the subcrop of Montney Fm sediments is demonstrated by the correlation of three internal marker horizons "A", "B", "C". The producing zone at 13-4 has as its lower boundary the silt zone correlated as Marker "C", and is sealed above by the Nordegg Fm phosphatic shales. The trapping mechanism is believed to be structural drapes over the Leduc reef.

**SEISMIC SECTION**

The location of the seismic line illustrated in Figure 7.30 is shown in Figure 7.28. The geological cross-section of Figure 7.29 was chosen to approximately parallel the location of the seismic line. The seismic data were acquired in February 1979 using a single 2.27 kg charge of dynamite in a depth of 12.2 m and a source interval of 134 m. A 48 channel DFS-V instrument was used in conjunction with a symmetric split-spread receiver configuration having a zero offset of 134 m and a far offset of 1676 m. Receiver arrays were comprised of nine L-15 10 Hz geophones over 33.5 m at a group interval of 67 m. This configuration of source and receiver produced 1200% CMP coverage. Data were sampled at 2 ms on a 3 sec record with a 12-128 Hz field filter. The seismic section was produced using conventional processing and is presented as a normal polarity section. (i.e. An increase in acoustic impedance at an interface produces a positive

![Figure 7.28. Sturgeon Lake South Triassic "A" pool showing structural relief on the Triassic surface.](image)

![Figure 7.31. Synthetic seismogram well 01-09-069-21 W6M.](image)
The seismic data were correlated with the aid of several synthetic seismograms, one of which is illustrated in Figure 7.31. This synthetic seismogram was generated with a zero phase Ricker wavelet having a central frequency of 30 Hz. The sonic log was simplified using a blocking algorithm resulting in a 0.4 m sampling. The original sonic log was sampled at 0.2 m increments.

The horizons correlated on the section are as follows:

- Manning - a continuous peak due to the transition from Harvard Fm shale to Mannville Op sandstone.
- Gething - a fairly continuous peak due to the transition from Blanezy Fm sandstone to Gething interbedded silty sandstones and shales. The velocity of the shales is such that the Gething Fm has a higher average velocity than the overlying porous Blanezy Fm sandstone.
- Montney - a very weak discontinuous peak associated with the transition from Nordegg Fm shale to Triassic interbedded sandstone, siltstone and limestone. This weak peak is overshadowed by the large amplitude peak above it due to a sharp increase in velocity within the Fernie Fm shale.
- Debolt - a fairly strong peak resulting from the sharp transition from Triassic and Belloy Fm sandstone and shale to Debolt Fm dolomite.
- Pekisko - an intermittent peak due to the slight velocity increase from Shunda Fm argillaceous limestone to clean Pekisko Fm limestone.
- Beaufort - a strong continuous trough associated with the distinct velocity decrease from the Pekisko Fm limestone to Belloy Fm shale.
- Wabamun - a strong continuous peak resulting from the transition from Shunda Fm argillaceous limestone to clean Pekisko Fm limestone.
- Z Marker - a continuous peak due to the sharp transition from shale to marlstone within the Irenon Fm.
- Muskeg - a weak peak due to the contrast between Muskeg Fm anhydrite and overlying Watt Mountain Fm shale.
- Montney - a strong continuous peak resulting from the transition from Irenon Fm marlstone to Beaverlill Lake Op dolomite.
- Muskeg - a weak peak due to the contrast between Muskeg Fm anhydrite and overlying Watt Mountain Fm shale.

The seismic data is contaminated to some degree by noise, particularly toward the southwest end of the seismic line. This noise, combined with the very small acoustic impedance contrast due to the Triassic anhydriticity and Montney Fm sandstone-siltstone-shale sequences, precludes detailed analysis of waveform signatures associated with the particular porous member of the Montney Fm which produces at Sturgeon Lake South. Acquiring data having a broader bandwidth, particularly in the higher frequency range, may reveal a Triassic seismic anomaly which is not apparent on the seismic section (Fig. 7.30).

The seismic section clearly shows Leduc reef development on the Beaverlill Lake platform at the southwest end of the line. The Leduc event correlates to the peak at 1,465 seconds at the 02/105 location. Drape of the overlying events is also illustrated on the seismic data. A general thinning in the Montney-Debott onchoor toward the northeast end of the line is indicative of the Triassic subcapping in this area. Aside from these general observations, very little information regarding the producing zone of the Triassic “A” pool can be obtained from conventional seismic data.

SUMMARY

The reservoir of the Sturgeon Lake South Triassic “A” pool is a porous sandstone having approximately four metres of net pay. The trapping mechanism appears to be structural depocentre over the underlying Sturgeon Lake South Leduc reef. The pay is poorly defined seismically in that there is no discernible response due to the presence or absence of reservoir. On the other hand, the display characteristic is clearly denotative of seismic pattern. It appears that an exploration strategy for similar pools would entail geological mapping to determine the presence/absence of reservoir quality rocks, followed by seismic exploration to find a structurally favorable location.

REFERENCES


