A

LAMAR HUNT – WILLIAM CRANSTON #1
NENW Sec.8, T.163N., R.81W.
KB: 1518' (462.7m)

CHEVRON STANDARD LTD.
– CHEVRON COULTER
9–6–2–26 WPM
KB: 440m (1443.6')

MANITOBA MINERAL RESOURCES
– MMR WASKADA PROV.
11–29–1–25 WPM
KB: 1555' (474.1m)

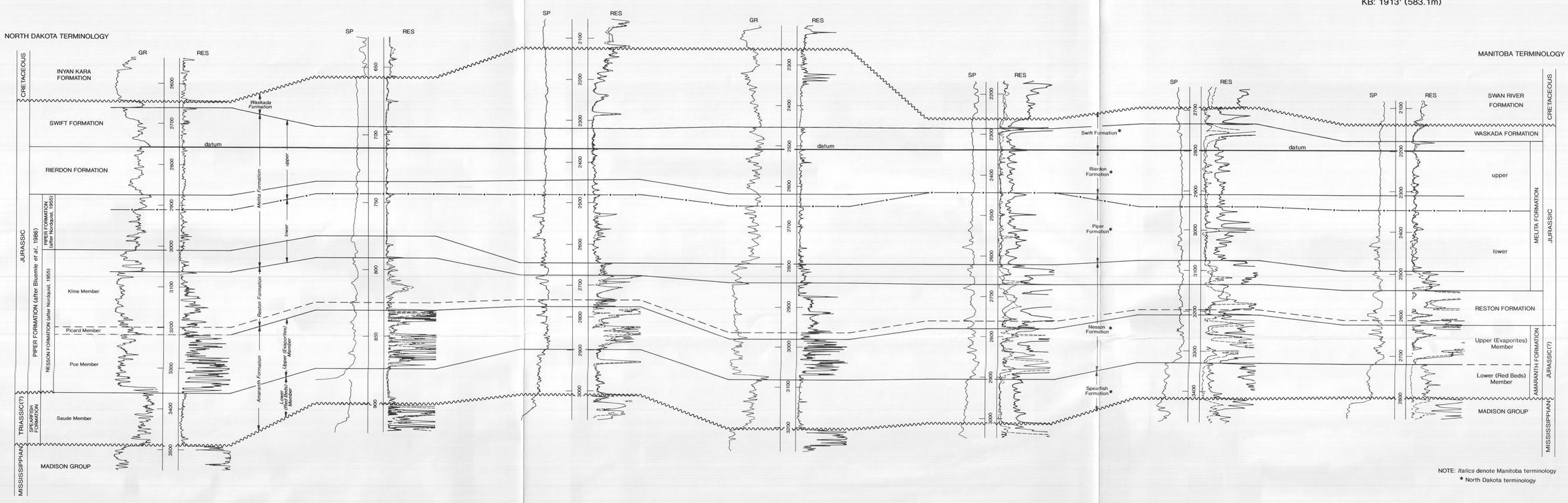
AMERADA PETROLEUM – LILLESTRAND #1
SESW Sec.31, T.162N., R.78W.
KB: 1486' (452.9m)

HUNT OIL – OLSON #1
SWNW Sec.18, T.163N., R.77W.
KB: 1520' (463.3m)

LION OIL CO. – G. A. HUSS #1
NWNW Sec.23, T.163N., R.75W.
KB: 2205' (672.1m)

JUMPING POUND PETROLEUM
– JUMPING POUND HIGH CREST
PROSPECT *et al.* HORTON #8–15
8–15–2–20 WPM
KB: 1913' (583.1m)

A′



NOTE: *Italics* denote Manitoba terminology
* North Dakota terminology

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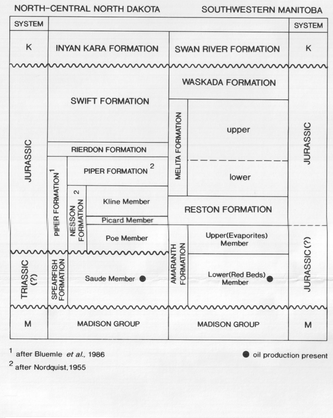
STRATIGRAPHIC NOMENCLATURE CHART



[1] after Bluemle *et al.*, 1986
[2] after Nordquist, 1955

● oil production present

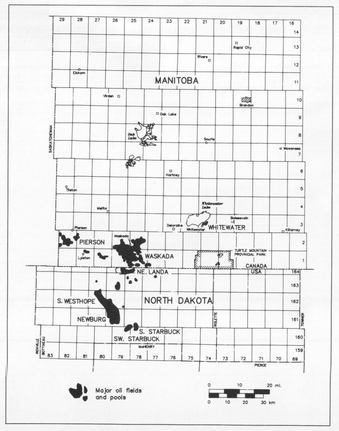


FIGURE 1: Triassic/Jurassic oil fields

STRATIGRAPHY

Spearfish Formation (North Dakota)

The Spearfish Formation (Triassic (?)) occurs in the subsurface in over half of North Dakota and attains its maximum thickness of 218 m (715 ft) in the southwestern corner of the state. The formation consists of three members that in ascending order are, the Saude, Pine Salt and Saude members.

The Saude Member conformably overlies the Minnekahta Formation and does not extend beyond the Minnekahta depositional limit (Dow, 1967). The Saude Member varies in thickness from an erosional edge to a maximum of 71 m (232 ft). It consists of fissile, grey shale interbedded with reddish-orange siltstone and mudstone. Thin beds of white and pink anhydrite are locally present. Traces of pyrite and pink dolomite have also been noted. The Saude Member is conformably overlain by either the Pine Salt or Saude members.

A maximum thickness of 66 m (215 ft) is attained by the Pine Salt Member (Dow, 1967). It consists of clear halite with thin interbeds of reddish-orange siltstone and white anhydrite, and represents a period of restricted marine conditions. The Pine Member extends beyond the underlying Belfield Member and rests in angular discordance on the pre-Spearfish unconformity.

The Saude Member conformably overlies the Pine Salt Member. Referred to as the upper red mudstone unit, it reaches a maximum thickness of 107 m (350 ft). The Saude Member consists predominantly of reddish-orange siltstones and fine-grained sandstones commonly interbedded with anhydrite (Dow, 1967). Reddish-brown and grey siltstone and shale lenses are locally present. Frosted sand grains are scattered throughout the siltstone. The Saude Member extends beyond the Pine Salt Member to rest unconformably on progressively older Paleozoic rocks.

Individual beds of the Saude Member exhibit an onlapping relationship along the unconformity surface in the north-central portion of North Dakota. This is reflected in the thickness of the member. In this area, a local, 3 to 12 m (10 to 40 ft) thick, very fine-grained sandstone with interbeds of greenish-grey siltstone and reddish-brown shale known as the "Spearfish pay" is developed (Marsh, 1972). A 6 to 8 m (20 to 25 ft) thick impermeable red shale, reddish-brown to grey siltstone, and tight, slightly cemented sandstone onlaps the pay section and forms the vertical seal.

Amaranth Formation (Manitoba)

The Amaranth Formation (Jurassic (?)) rests with marked angular unconformity on Mississippian carbonates in southwestern Manitoba and oversteps progressively older Paleozoic strata to the north and east. It is overlain with slight disconformity by limestone of the Reston Formation.

The Amaranth Formation is divided into two members. The Lower (Red Beds) Member consists of interbedded, reddish-brown, dolomitic siltstones, shales and fine-grained sandstones (Stott, 1955). The Upper (Evaporites) Member conformably overlies the Lower Member and consists of massive, finely crystalline, bluish-white anhydrite with interbeds of greenish-grey to brown shale and buff dolostone. In southwestern Manitoba, the Lower and Upper members of the Amaranth Formation reach a maximum thickness of 46 and 51.8 m (151 and 170 ft), respectively (Stott, 1955).

The age assignment generally accepted for the Upper Member of the Amaranth Formation is Middle Jurassic. However, the age assignment of the Lower Member of the Amaranth Formation is in question due to the lack of fossil evidence. A Jurassic age has been assigned to the Lower Member in southwestern Manitoba. The contact between the Upper and Lower members of the Amaranth Formation is considered to be conformable in this area (Stott, 1955; McCabe, 1956).

The Lower Member is correlative with the Spearfish Formation of North Dakota and the Lower Watrous Formation of Saskatchewan. In North Dakota and Saskatchewan, a Triassic age has been assigned to these equivalent units (see Stratigraphic Nomenclature Chart).

Nesson and Piper Formations (North Dakota)
(after Nordquist, 1955)

Nordquist (1955) examined the Jurassic strata that lie between the Spearfish and Rierdon formations and divided this strata into two formations, the Nesson and Piper. The Nesson formation is defined as the strata that overlies the Spearfish Formation and underlies the Piper Formation. These strata are present only in the subsurface of the Williston basin. Three members comprise the Nesson Formation. In ascending order, they are, the Poe, Picard, and Kline (see Stratigraphic Nomenclature Chart). The Piper Formation is the name given to describe the strata above the Nesson Formation and below the Rierdon Formation. It is divided, in ascending order, into three members, the Tampico Shale, Firemoon Limestone and Bowes.

Nesson Formation
(after Nordquist, 1955)

The Nesson Formation is a sequence of carbonates and evaporites that overlie the Spearfish Formation (Triassic (?)) and underlie the Piper Formation (Jurassic). The formation is recognizable only in the subsurface and comprises the Poe, Picard, and Kline members.

Faunal evidence for the formation is limited. Therefore, the Nesson Formation is considered to be Jurassic in age based on its stratigraphic position. A pronounced unconformity separates the Nesson Formation from the underlying Spearfish Formation. The Nesson Formation is lithologically similar and probably genetically related to the overlying Middle Jurassic Piper Formation.

The basal member of the Nesson Formation is the Poe Member. It unconformably overlies the Spearfish Formation. This contact is locally marked by a conglomeratic bed. The Poe Member consists of a sequence of evaporites thought to represent earliest Jurassic deposition. It is stratigraphically equivalent to the Upper Member of the Amaranth Formation of Manitoba.

At its type section in McKenzie County, the Poe Member consists of a 20 m (65 ft) thick bed of massive salt. The salt, referred to as the Dunham salt, is restricted to the central portion of the Williston basin (Anderson, 1964). It is overlain by 16 m (53 ft) of white to pink gypsum, anhydrite, and dark red shale with thin interbeds of grey, dense dolostone. The top of the sequence is marked by a thin bed of buff to brown, very finely crystalline to earthy limestone. The Poe Member varies lithologically across the Williston basin. To the east it consists of a massive anhydrite, and to the west, it is characterized by interbedded red shales and claystones.

The Picard is the middle member of the Nesson Formation and conformably overlies the Poe Member. At its type section in Roosevelt County, Montana, the Picard Member is 12 m (40 ft) thick and consists of dark red shale that is slightly silty in part. The lower part commonly contains masses, or thin interbeds of white earthy gypsum. The colour of the member varies locally from red to dark grey to green.

The uppermost member of the Nesson Formation is the Kline Member. This member is predominantly carbonate, consisting of a lower limestone and an upper dolostone sequence. Four units are present at its type section in Ward County, North Dakota. These include, in ascending order: a 19 m (63 ft) thick bed of light grey to buff coloured, fine to medium crystalline limestone that is gypsiferous and fossiliferous in part; a 11 m (37 ft) thick bed of light to dark brown, finely crystalline limestone that is oolitic in part and shaly toward the base; a 4 m (13 ft) thick bed of grey-green calcareous shale containing white gypsum crystals; and, a 10 m (34 ft) thick bed of light grey to white, earthy dolostone and fine-grained sandstone. The Kline Member is present only in the subsurface.

Piper Formation
(after Nordquist, 1955)

A sequence of Middle Jurassic red beds, gypsum, and normal marine beds underlying the Rierdon Formation compose the Piper Formation. The formation consists of three members, the Tampico Shale, Firemoon Limestone, and Bowes.

The lowermost member of the Piper Formation is the Tampico Shale. At its type section in Valley County, Montana, the Tampico Shale Member consists of 26 m (86 ft) of grey-green calcareous shale that is slightly silty in the middle of the section. Large amounts of interbedded red shale are present locally. Also present are a few thin beds of dense, buff to brown limestone, gypsum, and white calcareous sandstone. The member conformably overlies the Nesson Formation.

The Firemoon Limestone Member, also referred to as the "Piper Limestone," is the middle member of the Piper Formation. It consists of buff to brown, dense to earthy limestone at its type section in Valley County, Montana and is 21 m (69 ft) thick. Locally the limestone is sandy and oolitic or dolomitic and cherty. East of the Nesson anticline, the limestone becomes silty and interbedded with shale. It is conformable with the underlying Tampico Shale Member.

The Bowes Member, the uppermost member of the Piper Formation, comprises red to varicoloured shales in the Williston basin. It grades westward into a sandstone and sandy oolitic limestone. At its type section in Blaine County, Montana, the Bowes Member is 17 m (57 ft) thick. In ascending order, it consists of four units: a light grey, sandy and oolitic limestone that grades upward into a light brown, fine-grained calcareous sandstone; a light grey, oolitic to sandy limestone with thin beds of light grey calcareous sandstone; a light grey, fine- to coarse-grained, very calcareous sandstone with rounded limestone and quartz grains; and, a light brown, finely crystalline to fragmental limestone that is very sandy to argillaceous in part. The member is conformable with the underlying Firemoon Limestone.

Piper Formation (North Dakota)
(after Bluemle, et al., 1986)

Following the work of Nordquist (1955), Bluemle *et al.* (1986) redefined the sequence of strata above the Spearfish formation and below the Rierdon Formation in North Dakota as the Piper Formation (see Stratigraphic Nomenclature Chart).

The Piper Formation (Jurassic) as defined by Bluemle *et al.* (1986) in North Dakota represents a sequence of white to buff, brown or grey, dense, finely crystalline limestones, red, grey-green, and purple, slightly silty shales, gypsum, and anhydrites. The limestones can be oolitic, dolomitic, and fossiliferous. Bluemle *et al.* (1986) includes seven members within the Piper Formation; these are, in ascending order, the Dunham Salt, Poe, Picard, Kline, Tampico Shale, Firemoon Limestone, and Bowes members. The sequence reaches a maximum thickness of 191 m (625 ft) and is equivalent to the Upper Member of the Amaranth Formation, the Reston Formation, and the lower unit of the Melita Formation of Manitoba.

Reston Formation (Manitoba)

The Reston Formation consists of an interbedded sequence of dark grey to greenish-grey, locally reddish- to yellowish-brown shales and light buff to white, slightly dolomitic, argillaceous, partly sandy limestones. The limestone beds are more common towards the top of the unit, which is marked by an oolitic, sandy zone. Anhydrite and gypsum are present locally.

The Reston Formation conformably overlies the evaporites of the Amaranth Formation throughout most of southwestern Manitoba, except north of the Virden area (approximately Township 12), where it rests unconformably on the carbonates of the Lodgepole Formation (Mississippian). The Reston is overlain with slight disconformity by sandstones and shales of the Melita Formation. The thickness of the Reston Formation ranges approximately from zero to 46 m (151 ft) in southwestern Manitoba (Stott, 1955).

Melita Formation (Manitoba)

The Melita Formation is underlain with slight disconformity by the oolitic and argillaceous limestones of the Reston Formation. North of Township 20, the Melita Formation oversteps the Reston Formation to rest unconformably on Mississippian and Upper Devonian strata. The Melita Formation is conformably overlain by the Waskada Formation, south of Township 12. North of Township 12, the Melita is overlain unconformably by either the Swan River Formation or the Ashville Formation, both Cretaceous in age (Canadian Society of Petroleum Geologists, 1990).

The Melita Formation is subdivided into two units. The lower unit comprises a basal fine-grained sandstone, overlain by beds of varicoloured shales and thin interbeds of sandstone. The upper unit consists of greenish-grey to brownish-grey, slightly calcareous, silty shales. Interbeds of light grey, dense, variably fossiliferous limestones occur in the upper part of the unit (Bannatyne, 1970; Stott, 1955). The maximum thickness of the Melita Formation in southwestern Manitoba is approximately 143 m (469 ft) (Canadian Society of Petroleum Geologists, 1990).

Rierdon Formation (North Dakota)

The Rierdon Formation is a 30 m (100 ft) sequence of varicoloured shales that conformably overlie the Piper Formation. It is conformably overlain by the Swift Formation in the central portion of the Williston basin, but this contact is unconformable along the flanks of the basin (Francis, 1957). The Rierdon Formation has a notable wireline log characteristic in comparison to the Swift Formation. This log characteristic is referred to as the "Rierdon shoulder."

Lithologically, the Rierdon Formation consists of grey to green to red, calcareous shales with thin beds of limestone (Francis, 1957; Peterson, 1957; Bluemle *et al.*, 1986). The formation grades eastward in North Dakota into sandstone and becomes difficult to distinguish from the overlying Swift Formation. The shales also become less calcareous to the east.

Swift Formation (North Dakota)

The Swift Formation in the Williston basin consists of three informal members, a lower shale, a middle sandstone, and an upper shale (Francis, 1957). The formation attains a maximum thickness in North Dakota of 152 m (500 ft) (Bluemle *et al.*, 1986). The Inyan Kara Formation (Cretaceous) of the Dakota Group unconformably overlies the Swift Formation.

The lower shale member consists of a greenish-grey, splintery, slightly silty, slightly calcareous to noncalcareous shales (Francis, 1957). The shales become interbedded with siltstones to the east. Brown to yellowish shales also occur at the base of the member. The middle member is a fine-grained, calcareous sandstone. It consists primarily of clear quartz grains that are fairly well sorted and angular to subrounded. Glauconite is common, but is not present everywhere. Minor beds of greenish-grey calcareous to noncalcareous shale are common. The upper member consists of greenish-grey and light grey, generally calcareous shale.

Waskada Formation (Manitoba)

The Waskada Formation is conformably underlain by the Melita Formation. It is unconformably overlain by the Swan River Formation (Cretaceous), except along the northern edge where strata of the Swan River pinch out and the Waskada beds are overlain by the Cretaceous Ashville Formation (Canadian Society of Petroleum Geologists, 1990).

The Waskada Formation consists predominantly of varicoloured shale. Green, bentonitic shales and thin beds of white, very fine- to fine-grained, calcareous, pyritic and glauconitic sandstones are common throughout the formation. Minor beds of grey to black, slightly carbonaceous shales and trace red shales and ironstones are also present within the unit (Bannatyne, 1970; Stott, 1955).

The Waskada Formation occurs as an erosional wedge, extending as far north as the Virden area (Township 12). It attains a maximum thickness in southwestern Manitoba of approximately 53 m (174 ft) (Canadian Society of Petroleum Geologists, 1990).

PETROLEUM POTENTIAL

The Spearfish Formation is productive in several fields in north-central North Dakota (Fig. 1). Newburg and South Westhope fields are the most prominent. Production from these fields is from a combined structural/stratigraphic trap. In the Newburg/South Westhope area, a basal sandstone bed of the Spearfish Formation onlaps productive Mississippian Madison Group strata. The sandstone bed is, in turn, onlapped by impermeable red shales, green siltstones and cemented sandstones that form vertical and lateral seals. This sequence is located on the updip flank of a syncline formed by the dissolution of the Devonian Prairie Formation salt section.

The Spearfish Formation also produces east of the Newburg/South Westhope area. Production is from beds that are stratigraphically higher than those productive in Newburg/South Westhope. These beds are part of an interbedded sequence of sandstones and shales that progressively overstep the underlying Paleozoic erosional surface to rest unconformably on productive Mississippian strata. Production from the sanastone beds is believed to be Mississippian sourced.

The Amaranth Formation is the only productive zone within the Jurassic sequence of southwestern Manitoba. Production is obtained from a lower sandy interval of the Lower Member of the Amaranth Formation. The most prospective areas occur where this sandy interval overlies productive portions of Mississippian strata that have been truncated at the Paleozoic erosion surface. It is believed that the oil produced from the Lower Member of the Amaranth Formation is sourced by the Mississippian (Barchyn, 1982).

The majority of production from the Amaranth Formation in southwestern Manitoba is obtained from the Waskada Field, a field which also produces oil from Mississippian strata. Production in the Pierson and Coulter fields (Fig. 1) is also obtained from the Amaranth Formation.

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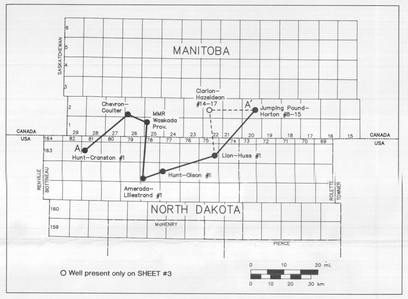

○ Well present only on SHEET #3

LINE OF CROSS–SECTION

METRIC CONVERSION TABLE

1 metre (m)	= 3.28 feet (ft)
1 cubic metre (m³)	= 6.29 barrels (bbls) (oil) = 220 imperial gallons = 35.49 cubic feet (gas)
1 hectare (ha)	= 2.47 acres
1 kilometre (km)	= 0.62 miles (mi)

SHEET # 2 : TRIASSIC/JURASSIC

CORRELATION CROSS–SECTIONS ALONG THE UNITED STATES–CANADA INTERNATIONAL BORDER (NORTH DAKOTA–MANITOBA)

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NORTH DAKOTA GEOLOGICAL SURVEY
REPORT OF INVESTIGATION 92

MANITOBA ENERGY AND MINES
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