

# Stratigraphic and Structural Framework of Viking Sandstones in the Verendrye, North Plato, Plato, and Forgan Areas, Southwestern Saskatchewan

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## Abstract

*Regional correlation of the Upper Albian Viking sequence in southwestern Saskatchewan places the study area in the lower Viking 'regional shelf-shoreface cyclic' regressive sequence of the Western Canada Sedimentary Basin. The Viking sequence in southwestern Saskatchewan is a northeast-prograding, mudstone-encased, clastic wedge that records a complex depositional and erosional history including multiple sea-level rises and falls.*

*Log correlation and core examination reveal the Viking sequence comprises up to five, coarsening-upwards sandstone intervals distinguished on the basis of lithofacies change, erosion surfaces marked by chert-pebble intervals and, in places, by a Glossifungites trace-fossil suite. The study area was in a more proximal shoreface position than would be expected based on its hundreds-of-kilometres distance from accepted shoreface sediments at Caroline in Alberta as evidenced by the presence of large chert pebbles (up to about 7 cm in diameter) at the base of the Viking. Isopach maps of the Viking display depositional trends interpreted to relate to reactivated basement structures and underlying Mississippian topography. Deposits of the final Viking transgression are preserved in the study area and comprise cross-bedded chert-pebble conglomerates with sideritized mudstone rip-up clasts, and other pebbly mudstone deposits.*

*An isopach map of the overlying Westgate Formation mudstones reveals depositional patterns similar to previously described depositional patterns in Alberta that were interpreted to represent variable rates of sea-level rise and periods of stillstand. Viking correlations are not continuous through to the northern edge of the study area implying a more complex and unexamined stratigraphic relationship with Viking sediments deposited farther to the north at Kindersley.*

*Viking oil and gas production is from muddy, bioturbated sandstones in prograding shoreface sequences and chert pebble beds associated with multiple erosion surfaces and incised shorefaces.*

**Keywords:** Viking sandstones, southwestern Saskatchewan, Lower Cretaceous, Verendrye, Plato, Forgan, oil and gas reservoirs, prograding shoreface sandstones, transgressive deposits, incised shoreface deposits, chert-pebble conglomerates.

## 1. Introduction

The Viking Formation is a prolific oil- and gas-producing unit in Alberta and western Saskatchewan. Hydrocarbons are trapped in elongate, predominantly northwest-southeast-trending sandstone reservoirs interpreted as marine deposits formed in a diversity of environments. In Saskatchewan, although oil-recovery factors are low (5 to 15%), the Viking is recognized to have a large oil-in-place potential (Podruski *et al.*, 1987), and, therefore, interest of current operators in productivity improvement is high, making the Viking an excellent target for research.

This paper is based on work done by the author as part of a study in southwestern Saskatchewan (Tp 23 to 30, Rge 13W3 to 27W3) for the Petroleum Technology Research Centre in Regina, with funding from Saskatchewan Industry and Resources (Thomas, 2007). It describes the Viking sandstones in the Verendrye, North Plato, Plato, and Forgan areas (Figure 1) through the examination of Viking erosion surfaces, ichnofacies and lithofacies in core, and analysis of isopach and structure maps for tectonic control by older elements.

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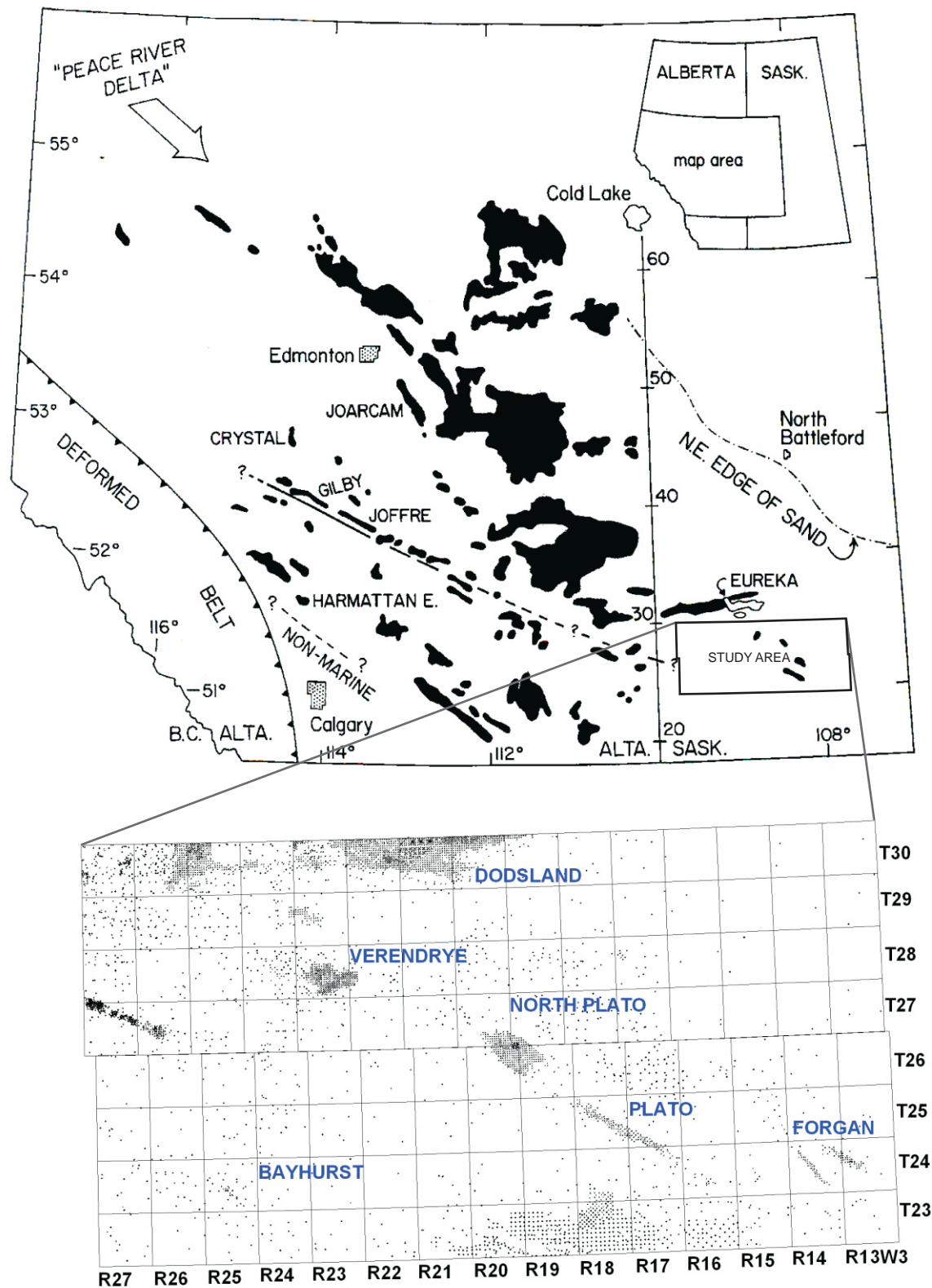


Figure 1 - Map showing study area and distribution of Viking oil and gas pools in Alberta and southwestern Saskatchewan (modified after Walz et al., 2005).

## 2. Geological Setting

Regional correlation of the Upper Albian Viking Formation in southwestern Saskatchewan places the study area in the lower Viking 'regional shelf-shoreface cyclic' regressive sequence of the Western Canada Sedimentary Basin. It is part of a northeast-prograding, mudstone-encased, clastic wedge that records a complex depositional and erosional history including multiple sea-level rises and falls. Correlation of geophysical log and core data reveals that the Viking comprises two to five sandier-upward units, each separated by erosion surfaces marked by millimetre-scale chert pebbles and overlain by marine shale and, in some areas, bentonite layers (Thomas, 2007). The Viking sequence is underlain by marine shales of the Joli Fou Formation and overlain by marine shales of the Westgate Formation (Figure 2).

The project area is located along trend with the ancestral Sweetgrass Arch, immediately overlying the 'Kindersley Block', a Mannville-age, upland region characterized by east-west and north-south drainage patterns (Figure 3). McCloud Member (Cantuar Formation, Mannville Group) isopach thicks correspond with structural lows on the sub-Mesozoic unconformity surface (Figure 4). Northwest-southeast and northeast-southwest structural features are thought to originate in the basement, propagated through the sedimentary section episodically over time (Christopher, 1999). Episodic uplift of the Sweetgrass Arch in response to increased convergence rates along the western margin of North America during the Late Albian resulted in widespread igneous intrusion and volcanism that reached southern Alberta (Arnott *et al.*, 1995). This tectonic setting helped enable relatively rapid changes in sea level to take place during the overall Viking transgression (Leckie and Reinson, 1993), and explains the presence of bentonite beds characteristic of the Viking section in this area.

Structural orientations visible on the structure maps of the tops of the uppermost Viking sandstone member (Figure 5) and the base of the Fish Scales (Figure 6) are in part a reflection of compaction and draping on the underlying Mannville paleovalley systems occupying the Mississippian structural lows, and basement-related Mississippian topographic features. Differences in detail with the sub-Mesozoic unconformity structure map are likely related to the greater number of data points available for the shallower penetration maps. Hydrocarbon production at the Bayhurst, Dodsland, and Forgan pools are clearly related to structural highs, whereas structurally lower pools have a stratigraphic component.

## 3. Previous Research

### a) Saskatchewan

Jones (1961) provided a set of isopach and structure maps for southwestern Saskatchewan and a general description of the Viking Formation. He described a sand-filled desiccation crack below the Viking Formation in the upper Joli Fou Formation suggesting very shallow to subaerial conditions existed near the end of Joli Fou deposition.

Evans (1970) described depositional trends in the Dodsland-Hoosier area, north of the study area, that were roughly perpendicular to the predominant northwesterly Viking trends. He provided evidence for erosion at the base of the Viking Formation through truncation of underlying Joli Fou markers, and informally divided the formation into four east-northeast-trending members; each separated by a chert-pebble sandstone bed, and imbricated in a southward direction. The youngest, or 'K' member, lies in Tp 29, trends more easterly than the older members, and represents non-reservoir lithofacies of bentonitic shales, shaly siltstone, and shaly silty sandstone.

Pozzobon (1987) and Pozzobon and Walker (1990) confirmed Evans's (1970) Viking correlations in the Eureka Pool, a structurally confined portion of the Dodsland trend with good core control. They interpreted Eureka sediments to be deposits of a 'transgressed and degraded shelf sand ridge', rather than eroded shoreface deposits.

Walz *et al.* (2005) studied the Viking Formation in the vicinity of the Bayhurst Gas Pool in the southwestern corner of the study area. Bioturbated sandstones and mudstone; sandstones with organic-rich laminations and mudstones; massive sandstones with coal, plant, and shell fragments; sandstones with calcite concretions; chert-pebble conglomeratic sandstones; and fissile grey shale facies were described and interpreted as deposits of incised valley channel-fill, barrier-island, lagoon, shoreface, and offshore marine environments.

### b) Alberta

The Viking has been widely studied in Alberta. Most researchers interpret Viking sandstone bodies as having been deposited tens to hundreds of kilometres from time-equivalent shorelines through processes invoking relative sea-level rise and fall, subaerial exposure and erosion, and consequent wave or current reworking of pre-existing coarse sediments of older shoreline deposits (Beaumont, 1984; Leckie, 1986; Boreen and Walker, 1991; Davies and Walker, 1993; Leckie and Reinson, 1993; Walker and Wiseman, 1995). Boreen and Walker (1991) devised a detailed allostratigraphy for the Viking Formation in Alberta as a basis for regional interpretation of Viking

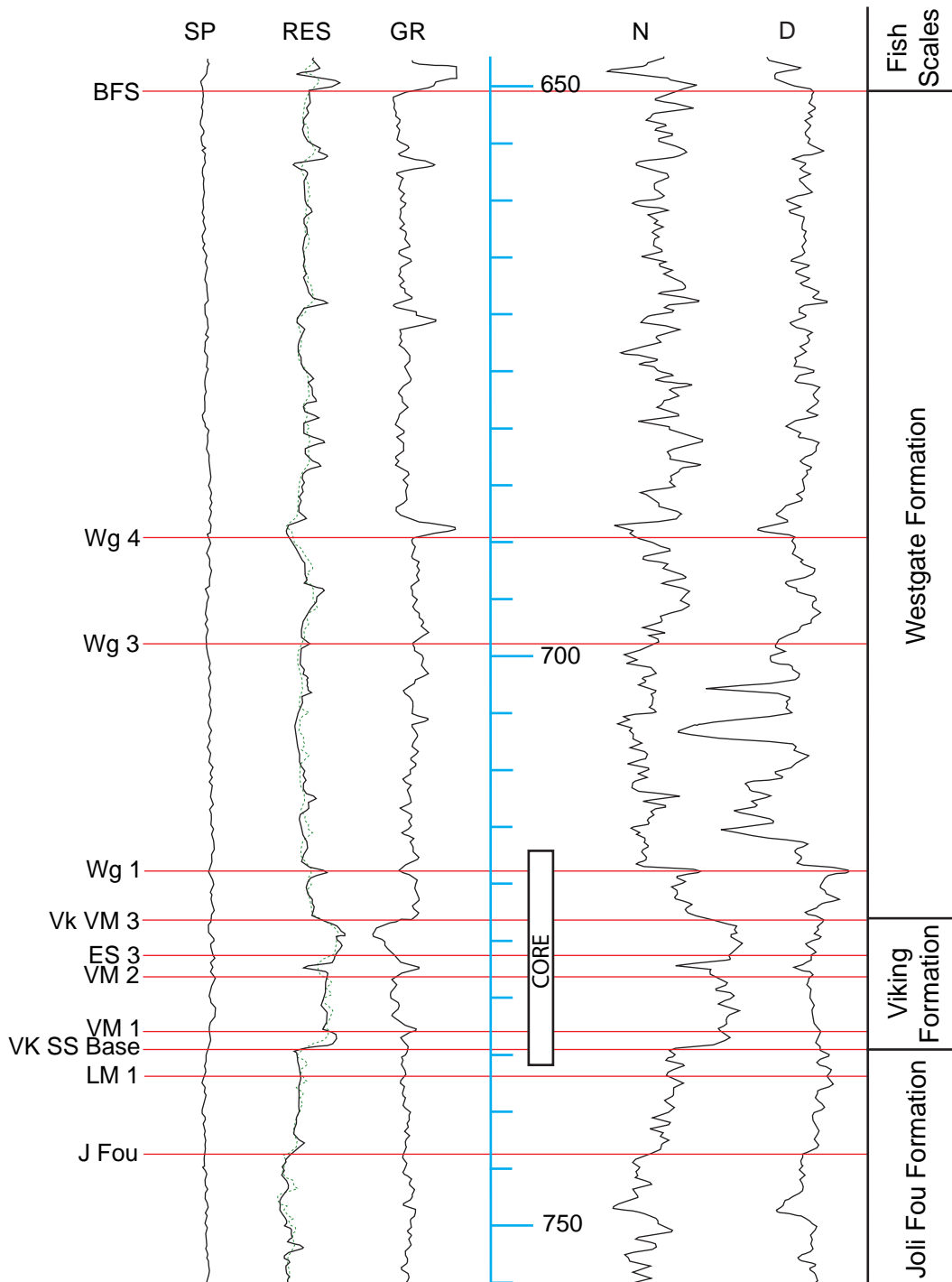
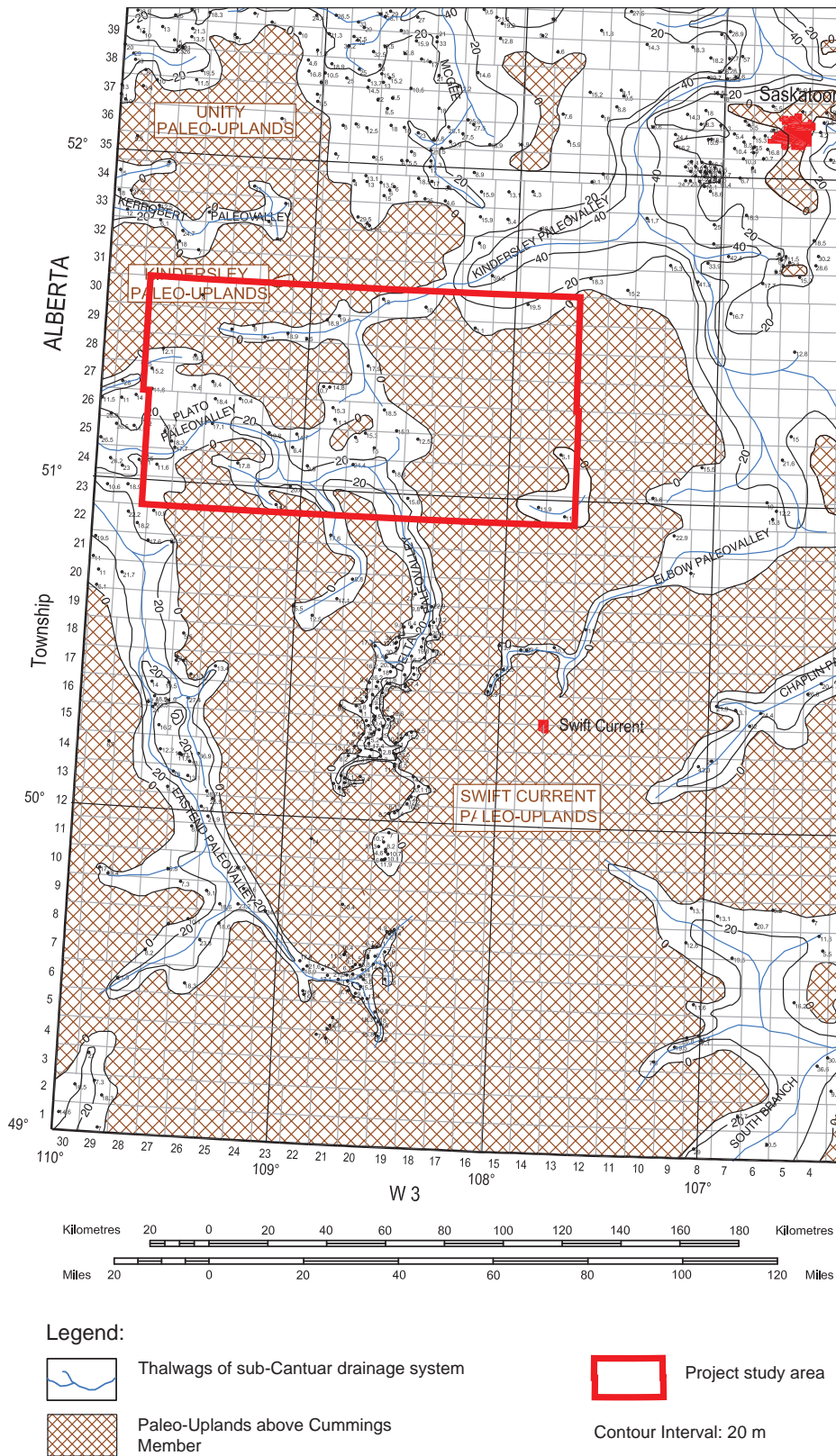
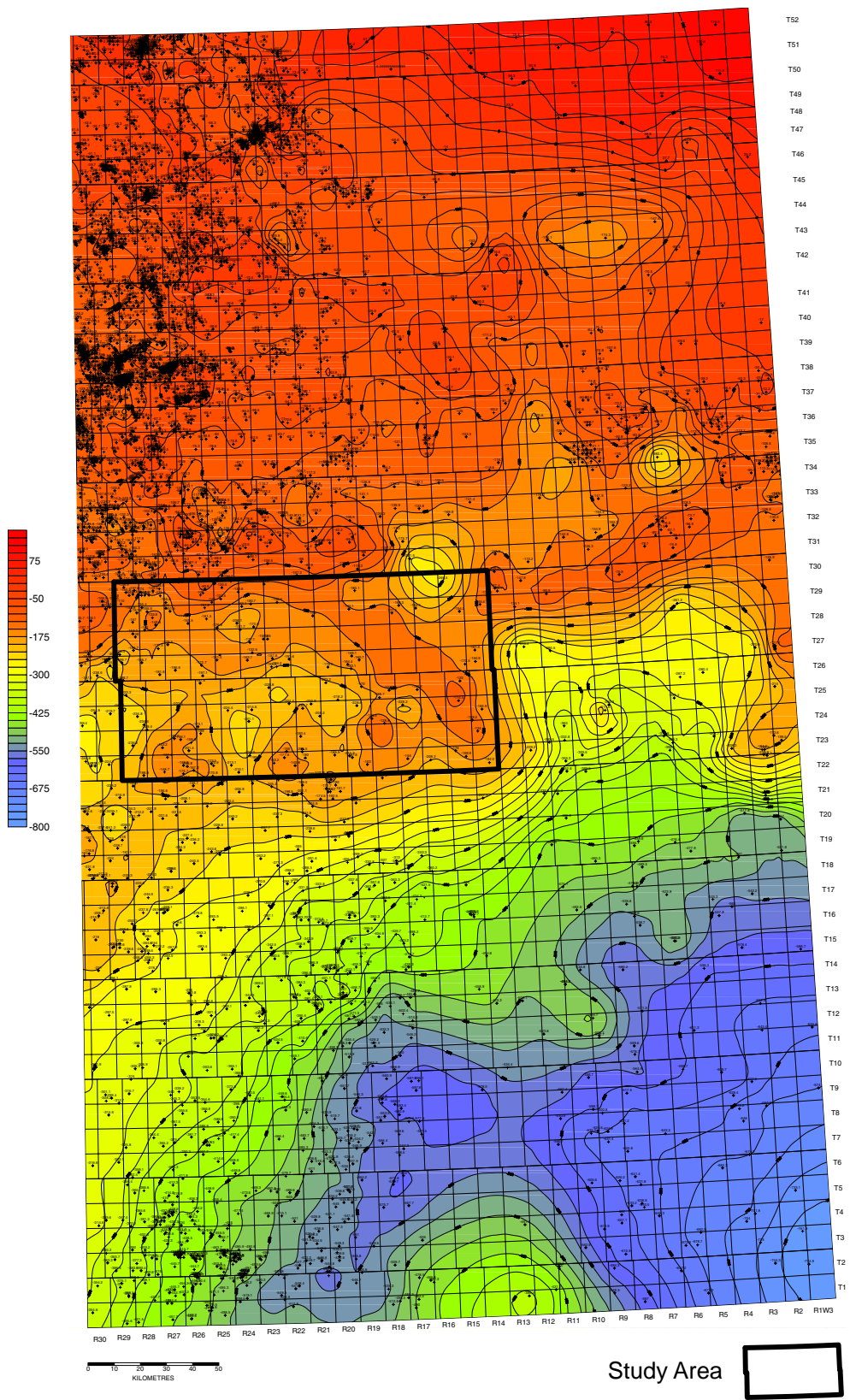


Figure 2 - Reference well (K-Town Plato N 12-34-26-20W3) for the Viking sequence and adjacent strata in the study area. Spontaneous potential, resistivity, gamma-ray, and density and neutron porosity geophysical log curves are illustrated, together with the stratigraphic nomenclature utilized in this paper (left margin) and the conventional lithostratigraphic subdivisions (right margin).



**Figure 3 - Regional isopach map of the McCloud Member of the Cantuar Formation showing elements of the Mannville paleotopography (modified from Christopher, 2003, Figure 27).**



**Figure 4 - Regional structure contours (contour interval = 25 m) on the sub-Mesozoic unconformity (modified from Marsh and Heinemann, 2005).**

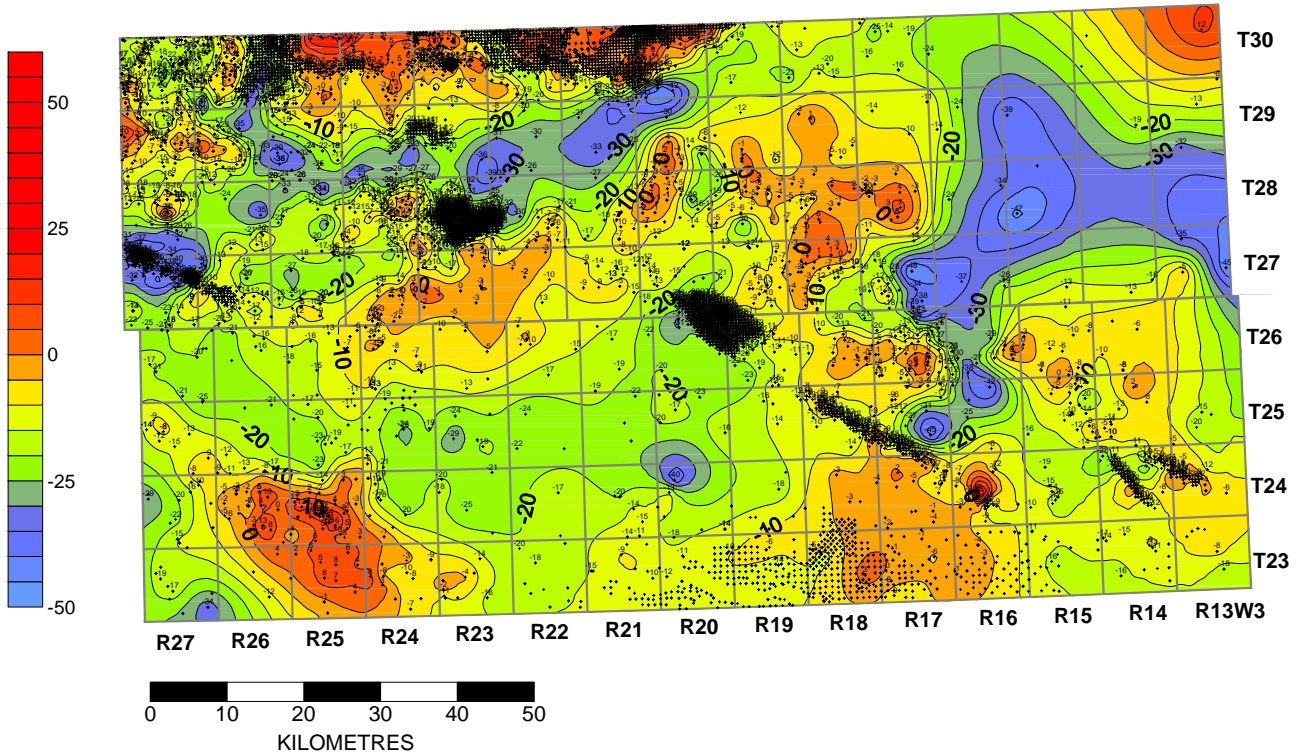


Figure 5 - Structure (contour interval = 5 m) on the top of uppermost Viking sandstone member.

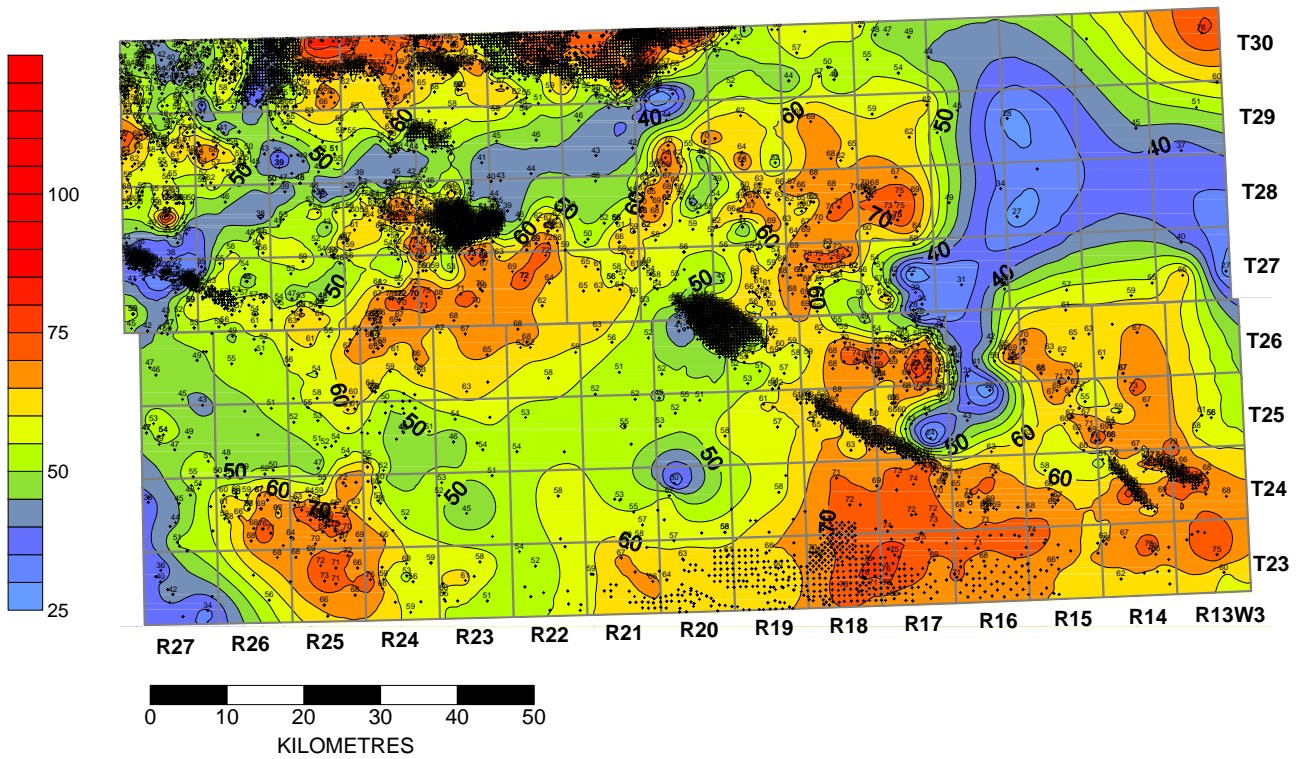


Figure 6 - Structure (contour interval = 5 m) on the base of the Fish Scales (BFS).



Allomember E is also recognized, consisting of a thin veneer of coarse-grained to granular sandstone conglomerate truncating the 'regional shelf-shoreface cyclic' sequence. This ravinement deposit is thought to record the final transgression of the Lower Colorado Sea (Leckie and Reinson, 1993; Walker, 1995). Allomember C refers to interpreted incised valley and shoreface sequences identified at Crystal, Joffre, and Joarcam in Alberta (Boreen and Walker, 1991); Allomember C has not been formally identified in Saskatchewan. Allomember D does not extend as far east as Saskatchewan.

## 5. Isopach and Lithofacies Trends

Lithological breaks and distinct scour surfaces are often difficult to recognize in the characteristically intensely bioturbated, muddy Viking sandstone sequence as much of the core is broken and rubbly. Surfaces are, therefore, often interpreted as erosional where underlying, fine-grained facies were not the source of overlying, coarser-grained chert pebble sandstone layers. Chert-pebble beds overlain by interbedded mudstone-sandstone strata are generally interpreted as transgressive lags formed during marine transgression. Sandier sediments which overlie the deposits associated with transgression are usually interpreted as prograding shoreline deposits.

The offlap relationship is noted in that, from southwest to northeast, Viking members successively become thinner and finer grained in a northeasterly direction. Each member is 5 to 8 m thick in the southwestern corner of the project area, thinning to 1 to 2 m to the northeast. The vertical succession coarsens upwards from VM1 to VM3, a consequence of continued progradation of shoreface sediments.

A complication arises in the uppermost Viking member, VM3, where a transgressive lag of variable thickness, generally less than 1 m, is interpreted to onlap the older, scoured Viking section during the final transgression by the Lower Colorado sea. In the absence of sufficient preserved core and adequate log data to distinguish the facies, the transgressive sequence has been incorporated into VM3 for discussion purposes.

The isopach maps are assumed to represent sediments that were deposited during progradation, affected by erosion during sea-level fall, and subsequently reworked during the consequent transgression. Structural control of these three processes may be evident in the series of Viking isopach maps presented, but, given that the northwesterly depositional strike is along the dominant structural strike, some controls may be masked. Interpretation of the isopach maps of individual Viking sandstone members provides the supportive evidence for structural control during sedimentation.

### a) Isopach of Total Viking Sandstone Interval (VS)

Viking sandstones thin northeastward, from 35 to 20 m thick where VM1 through VM5 are present in the southwest. Then, where only VM1, VM2, and VM3 are preserved, the Viking sandstones steadily thin along a shallower gradient to 10 m in the central map area, and to 5 m in the northeast (Figure 8). A departure from this general trend is an east-west thickening (through Tp 29 and 30, Rge 23 to 27) to the north, coincidentally in the vicinity of Evans (1970) 'K' member and a previously described Mannville paleovalley (Figure 3).

The predominant northwesterly isopach trend accommodates the general theory that the Viking shoreline prograded northeastward, perpendicular to strike, on a relatively flat sea floor, at least as far as the North Plato and Plato pools. Isopach thins in the vicinity of the Verendrye Pool suggest Mannville-age, east-west features controlled sedimentation and that either the area was a topographic high or that sedimentation did not keep pace with shoreface progradation taking place to the southeast. Whether this was due to less accommodation space, or to the preservation of less sediment following erosion during a subsequent marine transgression is not known.

### b) Erosion Surface at the Base of Viking Sandstone Interval

An isopach map of strata from the base of the Viking sandstone interval (BVS) to the top of the Lower Marker 1 (LM1) (Figure 9) provides a possible image of the eroded floor of the Viking sea after a basin-wide drop in sea level allowed progradation of shoreface sediments into the distal basin. However, whether the BVS is in fact the base of the initial Viking progradation and/or a later event in this area is uncertain. The question arises primarily because of the presence of large chert pebbles, the largest 7 cm across and others commonly 2 to 5 cm in diameter, observed in core (Figure 10) at the base of the Viking sandstone interval at the Verendrye, North Plato, Plato, and Forgan pools. These pebble beds display a sharp erosional contact rather than the gradational contact described as typical for the base of the Viking Formation, and the pebble size indicates a more proximal source than expected for an apparently distal basin area. Walker (1995) described a size segregation of Viking chert pebbles based on proximal-distal relationships on the floodplain for the Viking in Alberta.

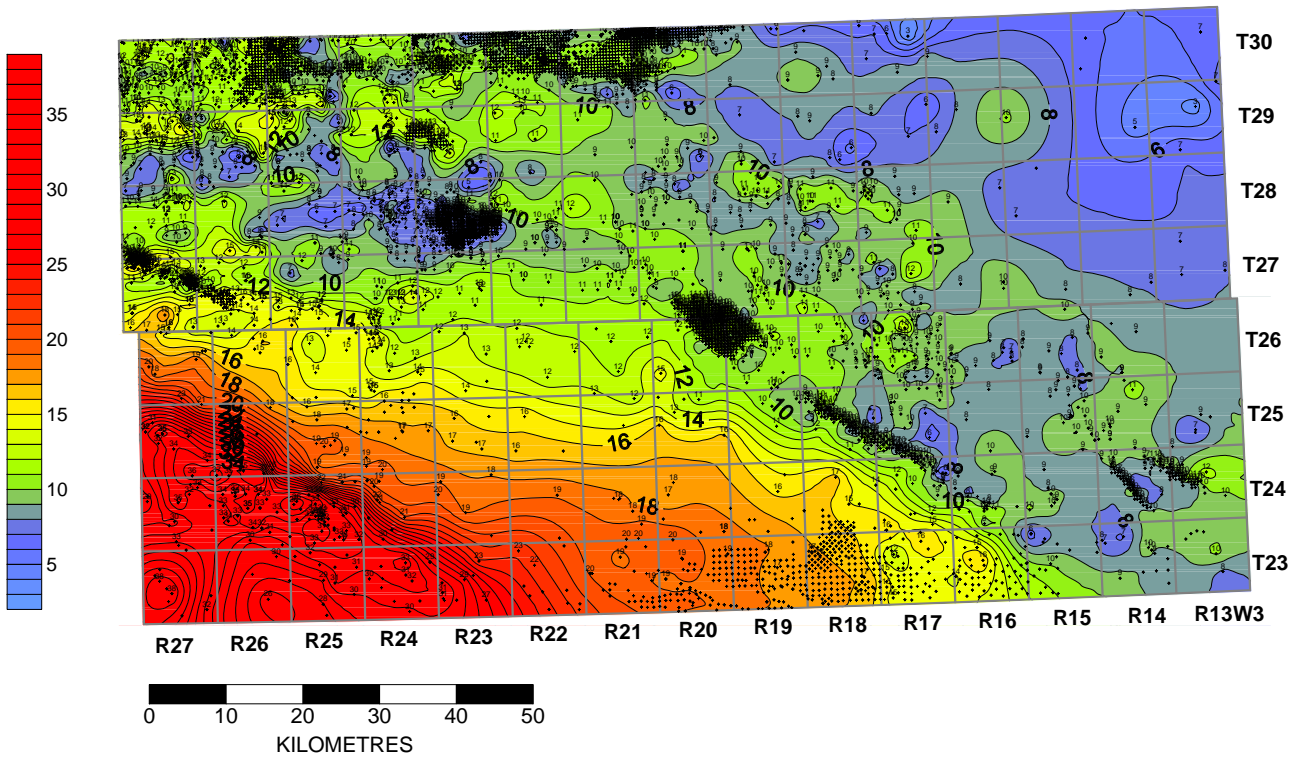


Figure 8 - Isopach map (contour interval = 1 m) of the Viking sandstone interval.

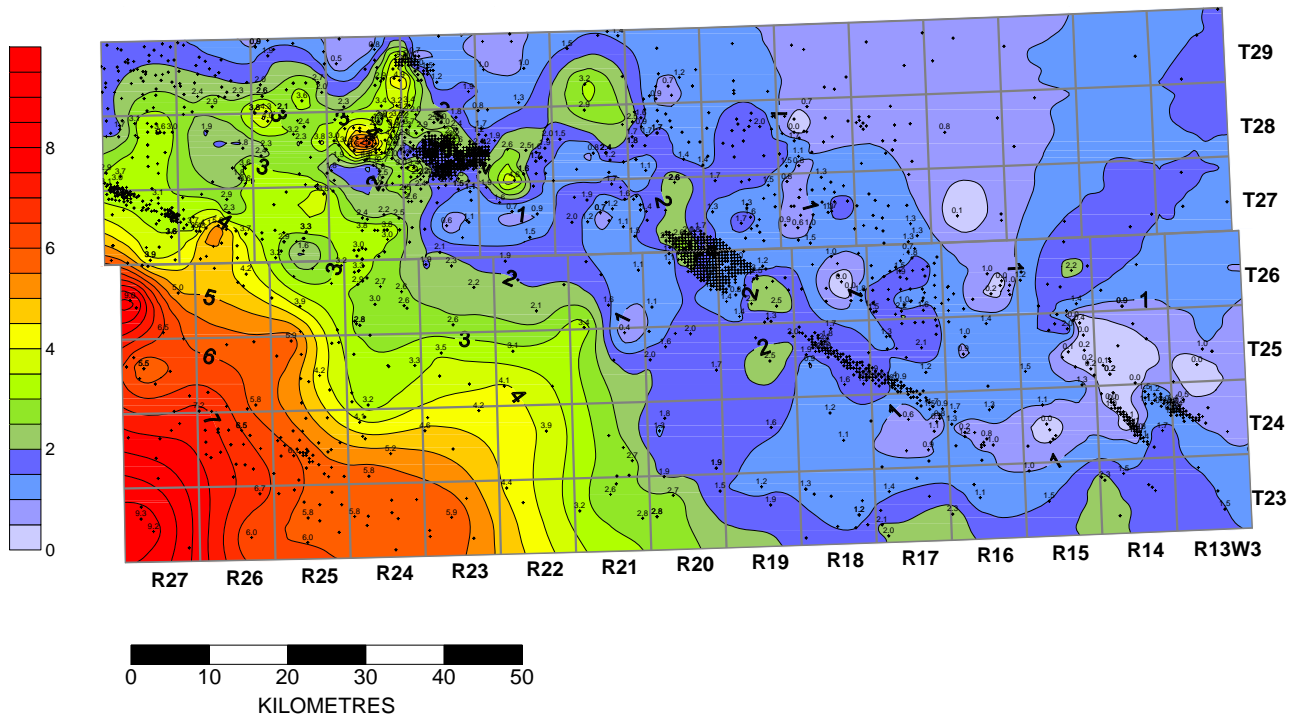
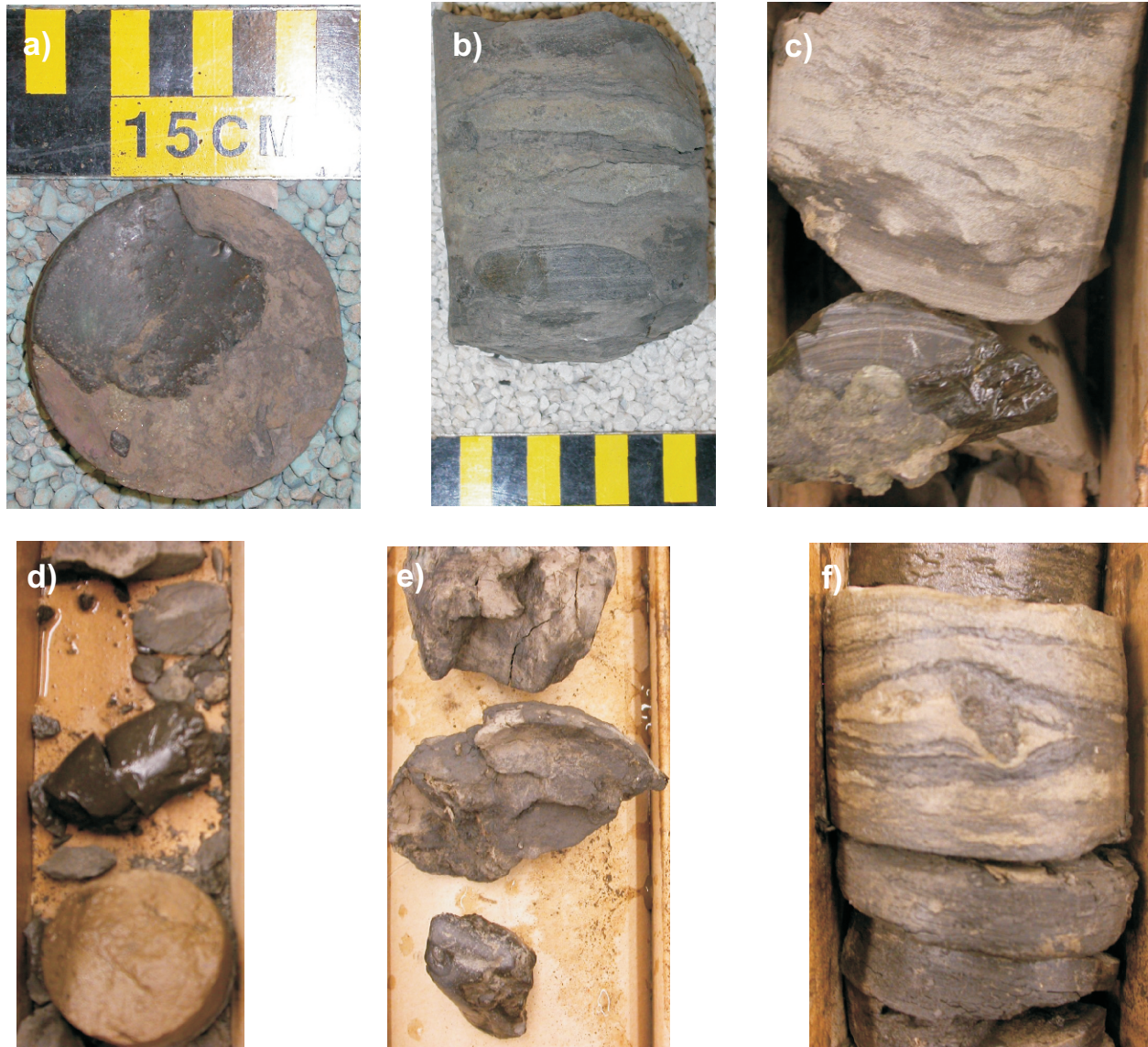


Figure 9 - Isopach map (contour interval = 0.5 m) of strata from the base of the Viking sandstone interval (BVS) to the top of the resistivity marker bed in the lower Viking (LM1) (note that LM1 is not correlated into Tp 30).



**Figure 10 - Photographs of large chert pebbles associated with an erosion surface at the base of the Viking sandstone interval: a) Ish Verendrye 01/14-16-28-23W3, plan view of single, 5 cm x 5 cm x 1 cm chert pebble in very fine-grained silty mudstone, 714 m; b) Ish Verendrye 01/14-9-28-23W3, cross-sectional view of 5 cm x 1.5 cm chert pebble in pyritized, sandy mudstone, 710.5 m; c) Wascana Plato 01/9-10-23-13W3, 7 cm chert pebble in pyritized, muddy sandstone, 772.75 m; d) Tidewater Plato Crown 01/11-11-25-17W3, 4 cm chert pebble in bioturbated, muddy sandstone, 2536 ft (772.97 m); e) Tri Link Plato 01/12-7-25-17W3, 5 cm chert pebble associated with sandy mudstones, 2135 ft (650.75 m); f) Helmsman Plato 21/11-29-25-17W3, 3 cm chert pebble 'floating' in bioturbated, muddy sandstone, 679 m (core diameters are in the range 7 to 8.5 cm).**

The isopach map (Figure 9) of the bed lying between the base of the Viking sandstone and the top of the resistivity marker bed (LM1) indicates that geometric and spatial relationships exist between the base of the Viking sandstone interval and both the underlying east-west-trending Mannville paleovalleys and the northwesterly trending basement-related features. The east-west isopach thins in the northern part of the map is in the same area as Evans (1970) Viking 'K' member. Isopach thins are interpreted to represent sites of deep erosion.

The isopach map also reveals the area of the Verendrye Pool as restricted to the southeast flank of a deep scour, whereas the North Plato, Plato, and Forgan pools appear to be situated distally, in toe-of-slope positions.

### c) Viking Member 1 (VM1)

Identification of the oldest Viking member, VM1, is clear in the western part of the study area where it is 6 m thick (Figure 11), becoming less distinguishable from VM2 where the member thins to less than 1 to 2 m in the northeast. VM1 overlies a sharp, pebble-strewn erosion surface (BVS) and comprises bioturbated, fine-grained, muddy siltstones, variably overlain by a thin chert pebble-bearing erosion surface and in places a centimetre-thick bentonite layer, and then interbedded shale and very fine sandstone. Typically, the trace fossil *Helminthopsis* can be identified.

Interpretation of the VM1 isopach map suggests that structural features may have played a role during the deposition-erosion cycle. For example, the member prograded northeastward along a Mississippian structural low (Figure 4) and was limited by, or subsequently eroded along, a northwest-trending linear. The 2 m isopach thickening in the far eastern area suggests there may have been shoaling related to Mississippian topography, *i.e.*, a high farther out on the distal shelf.

### d) Viking Member 2 (VM2)

Identification of VM2 is typically assisted by its containing layers of bentonite and chert pebbles. A *Glossifungites* trace fossil suite characterized by *Thalassinoides* and *Skolithos* may be recognized at the top of the member. VM2 is typified by intensely bioturbated, muddy sandstones interspersed with centimetre-thick, sandy storm beds overlying sandy mudstones in an environment interpreted to be lower shoreface. Trace fossils *Teichichus*, *Planolites*, *Thalassinoides*, *Terebellina*, *Zoophycos*, and *Rosselia* are common. VM2 is the main producing reservoir at Verendrye. In the eastern part of the area, VM2 thins and is difficult to pick reliably, but it appears to thicken in a 'shoal' area to the east.

An isopach map of the top of VM2 to BVS interval (Figure 12) further indicates that rectilinear northwest- and lesser northeast-trending basement features, and east-west Mannville paleovalleys were controlling factors during the deposition and/or erosion of these Viking strata. The Verendrye Pool is positioned at the confluence of several of these 'older' features. In contrast, North Plato and Plato are on a broad shelf, separated from a shoal to the northeast. Forgan may be on a thin outer shoal. Comparison between the distribution patterns shown on the isopach map of the top of VM2 to BVS (Figure 12) and on the isopach map of the top of VM1 to BVS (Figure 11) suggests progradation of VM2 over VM1.

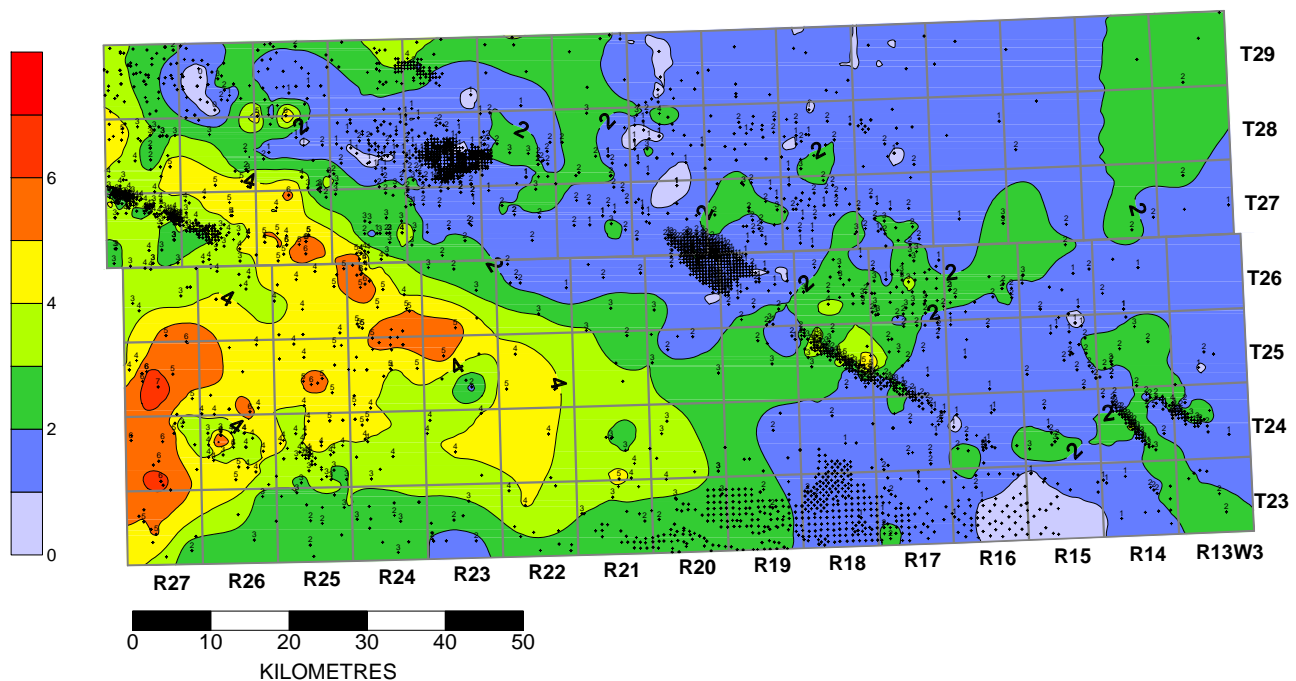


Figure 11 - Isopach map (contour interval = 1 m) of strata from top of Viking member 1 (VM1) to base of Viking sandstone interval (BVS) (note that VM1 is not correlated into Tp 30).

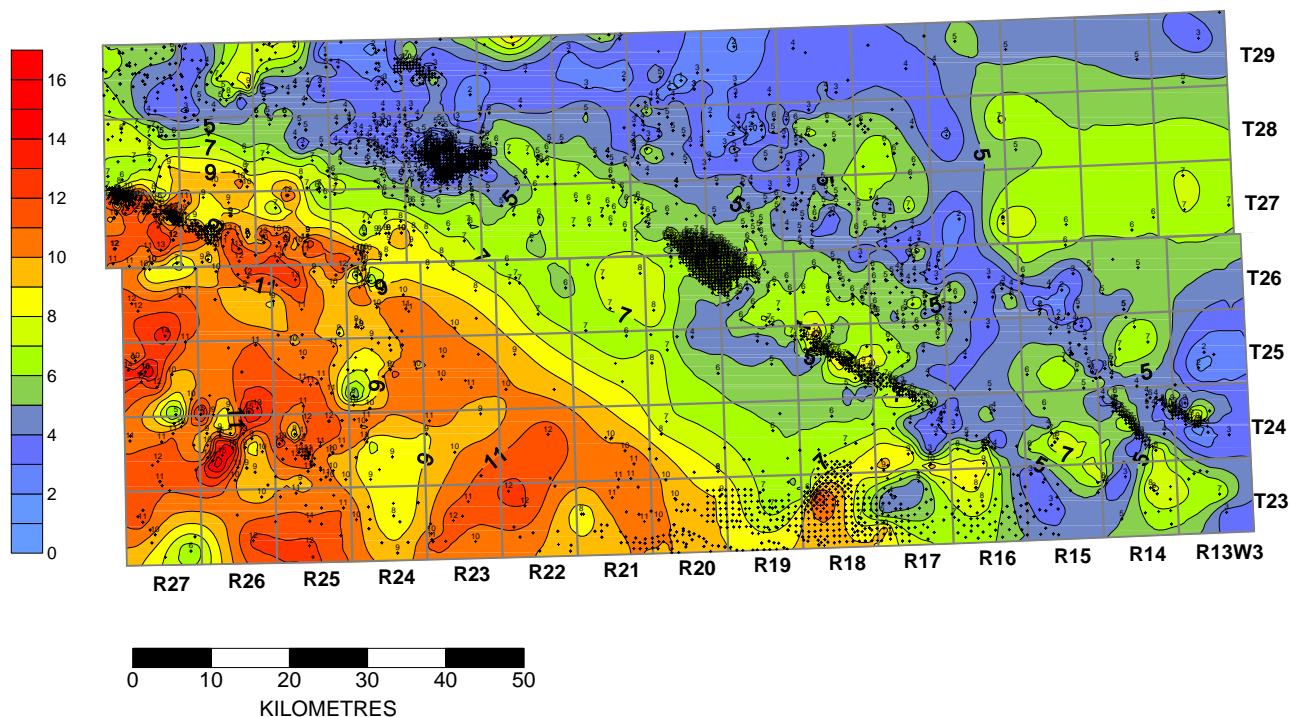


Figure 12 - Isopach map (contour interval = 1 m) of strata from the top of the Viking member 2 (VM2) to the base of the Viking sandstone interval (BVS) (note that VM2 is not correlated into Tp 30).

### e) Viking Member 3 (VM3)

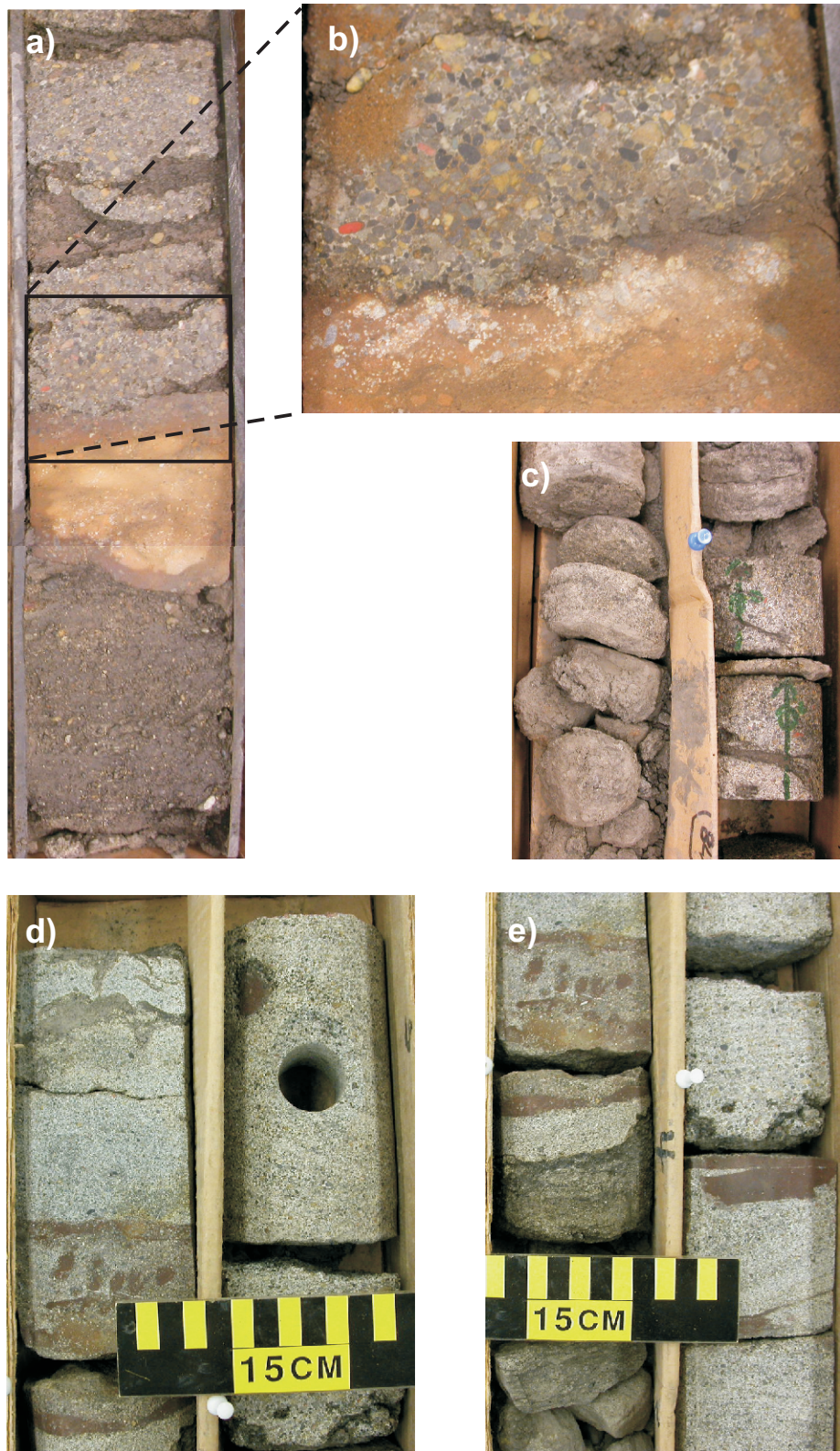
In the western part of the study area, minimal core penetrations into only the upper few metres of VM3 suggests it is coarser grained than VM1 and VM2. Viking member 3 comprises chert pebble-bearing, fine- to medium-grained sandstones interbedded with intensely bioturbated muddy sandstones, and clean sandstone storm beds interpreted to have been deposited in an upper lower-shoreface environment. *Glossifungites* trace fossils, *Skolithos*, and *Thalassinoides* filled with the coarser sediment fraction can be observed where sharp bases of the individual chert pebble layers overlie mudstone or sandstone beds (Figure 13; *Glossifungites* trace fossils suggest a period of sea-level fall, scouring, and non-deposition allowing the development of a firmground (see Downing and Walker, 1988). Farther east, in the North Plato area, this member, or its stratigraphic equivalent, forms the main reservoir and comprises individual layers of pebbly or gritty sandstone, in places, interbedded with mudstones and siltstones overlying bentonitic mudstones and, in other places, more gradationally admixed with muddy, pebbly sandstone.

Closely associated with, but in uncertain relationship to, VM3 is the coarsest fraction of the Viking sandstone interval. It includes: cross-bedded, multi-coloured chert-pebble conglomerates (Figure 14); grey-patina chert-pebble sandstones and mudstones in discrete or thoroughly bioturbated beds; sideritized mudstone rip-up clasts; bioturbated muddy sandstones; and mudstone interbeds. The top of the coarse fraction is taken as the top of the uppermost Viking sandstone member. The base of the coarse fraction in VM3 is commonly not readily definable. This member is interpreted to represent lag deposits (Figure 15) of the final Viking transgression. Following a final drop in sea level and movement of coarse sediments to more distal areas, the subsequent scour and reworking of sediments by wave and current action caused cross-bedding to develop in shoal areas, with subsequent burial by marine mudstones (Walker, 1995).

Viking member 3 is not as broadly distributed as VM2, possibly implying either a shorter progradational period or a longer period of erosion during the final transgression (Figure 16). Northwest-southeast-trending basement-control features dominate the isopach map of strata from the top of the Viking sandstone interval to the top of VM2, with a subordinate northeast-southwest-trending feature appearing to control an isopach set-back between Verendrye and North Plato. Verendrye lies at the confluence of the basement trends and an east-west Mannville feature. Development of a *Glossifungites* trace-fossil assemblage in between successive pebble and mudstone layers at North Plato, Plato, and Forgan confirms a period of transgression followed by sea-level drop, a period of in-faunal colonization, and subsequent scour and infilling with younger sediments.



**Figure 13 - Photographs of Glossifungites trace fossil assemblage: a) Storm Plato N 01/3-25-26-20W3, chert-pebble-filled Thalassinoides burrow in mudstone, 715.25 m; b) PCI Flaxcombe 01/11-12-28-26W3, mud-lined Skolithos and Thalassinoides burrows, 745 m; c) Imperial Glidden 01/13-22-26-19W3, Thalassinoides burrows in pebbly sandstone, 2250 ft (685.80 m); d) Imperial Glidden 01/7-33-26-23W3M, Diplocraterion burrow in pebbly sandstone, 2250 ft (685.80 m); e) NCO CN Plato N 01/13-22-26-19W3, chert-pebble-filled Thalassinoides burrows, 696.25 m; f) Racing et al Forgan W 04/15-24-14W3, Thalassinoides burrow truncated by ravinement surface, 653 m (core diameters are in the range 7 to 8.5 cm).**



**Figure 14 - Photographs of cross-bedded, chert-pebble conglomerate: a) Wascana Pinkham 21/6-32-28-25W3, cross-bedded conglomerate with mudstone rip-ups, truncating sideritized mudstone layer which overlies chert-pebble mudstones, 735 to 735.2 m; b) enlargement of Wascana Pinkham 21/6-32-28-25W3, calcite-cemented, grain-supported, chert pebbles up to 3 mm and rarely 12 mm in size at ca. 735.1 m; c) Ish Kindersley 01/6-35-28-24W3, multi-coloured chert-pebble conglomerate with sideritized mudstone rip-up clasts, 708.7 m; d) Canus Amoco Ulster Teo 01/6-2-29-24W3, cross-bedded, multi-coloured conglomerate with sideritized mudstone rip-up clasts, 2327 ft (709.27 m); e) Canus Amoco Ulster Teo 01/6-2-29-24W3, 2335 ft (711.7 m) (core diameters are in the range 7 to 8.5 cm).**



**Figure 15 - Photographs of Viking transgressive lag: a) Gulf Totnes 31/11-17-28-18W3, pyritized chert-pebble conglomerate with scour surface into sideritized mudstone, 718 to 718.1 m; b) Ish Kindersley 01/6-35-28-24W3, bioturbated muddy sandstone truncated and overlain by pebbly mudstones, 710.5 m; c) NCO Plato N 01/10-15-27-19W3, bioturbated, multi-coloured chert pebble mudstone, 696.5 m; d) Murphy et al Kindersley 01/7-19-28-21W3, sideritized chert-pebble mudstone rip-up clasts, 743.5 m; e) Canus et al N Verendrye, 01/12-32-28-23W3, chert-pebble sandstone interbedded with sideritized mudstone, 2300 ft (701.04 m) (core diameters are in the range 7 to 8.5 cm).**

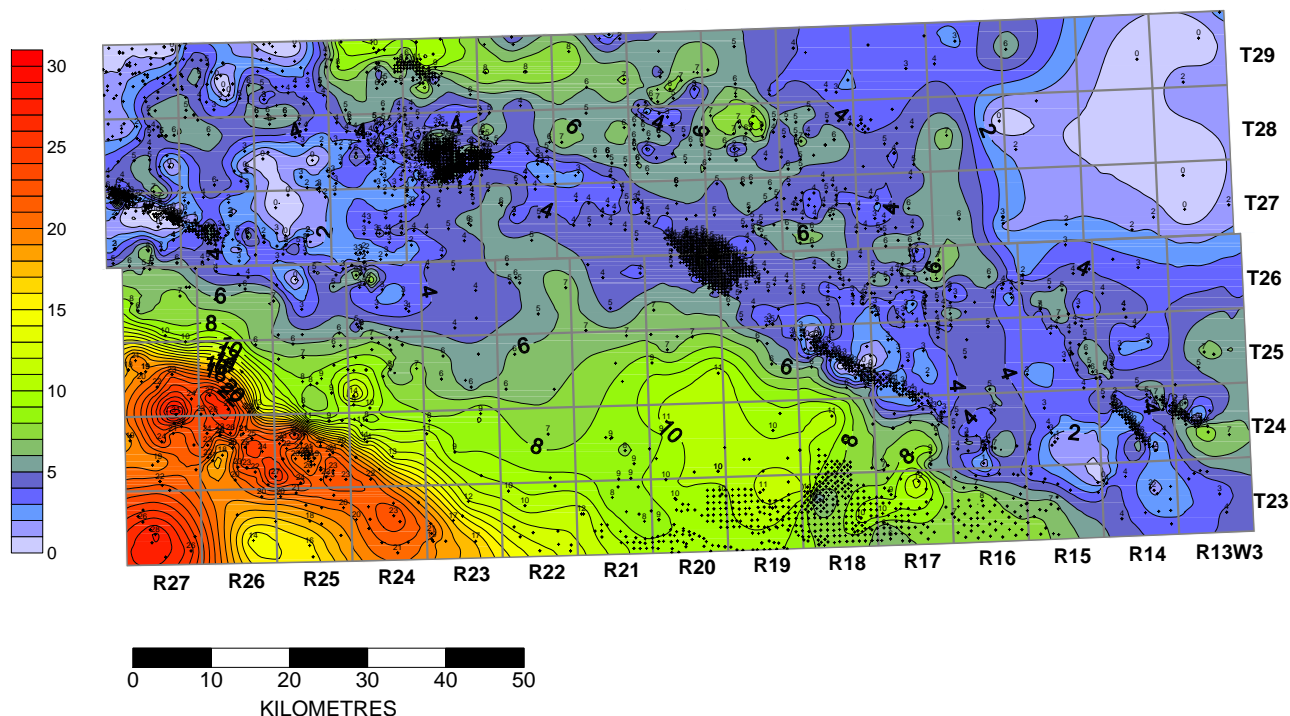


Figure 16 - Isopach map (contour interval = 1 m) of strata from top of Viking sandstone interval (TVS) to top of VM2 sandstone member (note that VM2 is not correlated into Tp 30).

#### f) Viking Members 4 and 5 (VM4 and VM5)

Viking member 4 and VM5 are restricted to the southwestern corner of the map area. The sharp, northwest-southeast break-in-slope in contours in the Bayhurst area is a major erosional feature and indicates the position of an interpreted barrier bar complex. A smaller scale, northeast-southwest-trending break in the isopach contours in Tp 24, Rge 26W3, outlines the position of an interpreted incised channel fill (Walz *et al.*, 2005).

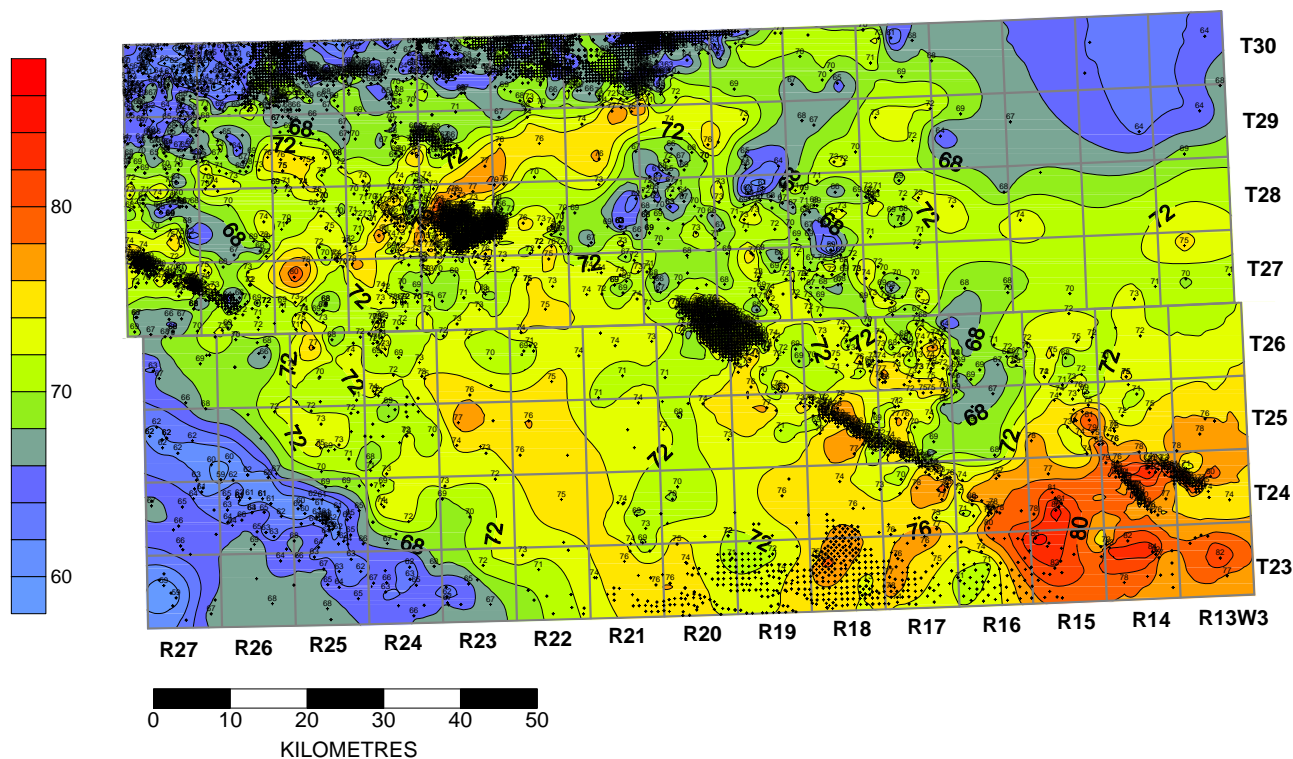
#### g) Westgate Formation Isopach

In central Alberta, where the BFS is a flat-lying to gently dipping horizon, the isopach map of the Westgate Formation has been interpreted as expressing, in part, the wave-modified, erosional, topographic relief on the final Viking transgressive surface of erosion prior to burial by the Lower Colorado Sea (Walker, 1995). In this project, individual Viking member isopach maps may reveal evidence of syn-sedimentary structural control on sedimentation and erosion processes, but supporting evidence that the same is true for the BFS is absent. In this report, the presumption is made, therefore, that the current structure on the BFS is a reflection of post-sedimentary tectonics and that the BFS is flat lying in southwestern Saskatchewan.

Two features are prominent in the isopach map of the Westgate Formation (Figure 17): a sharp, asymmetric, 'step'-like feature in the Bayhurst area and a flat, rectilinear 'block' basinward in the central map area similar to features recognized in the Viking/Westgate of Alberta in the Caroline (Davies and Walker, 1993) and Joffre/Gilby (Walker, 1995) areas in Alberta (Figure 18). The 'steps' have been related to changing rates of sea-level rise and the flat area basinward to periods of stillstand in the overall transgression. Approximately 20 m of erosional relief are apparent from the thinnest isopach areas and corresponding Viking isopach thick, to the thickest isopach areas and Viking isopach thin. A regional map of the Westgate Formation in western Saskatchewan is provided for comparison of scale (Figure 19).

## 6. Conclusions

Regional correlations place the study area in the lower Viking 'regional shelf-shoreface cyclic' regressive sequence of the Western Canada Sedimentary Basin (Leckie and Reinson, 1993), characterized by allostratigraphic members A and B (Boreen and Walker, 1991).



**Figure 17 - Isopach map (contour interval = 2 m) of the Westgate Formation in the study area.**

The Viking sandstone interval in the study area records a complex depositional and erosional history, including multiple sea-level rises and falls. Regressive surfaces of erosion are subsequently reworked during transgression forming transgressive surfaces of erosion in this relatively distal area of the basin.

Chert pebbles ranging in size from 5 to 7 cm are present at the base of the Viking sandstone interval in the project area of southwestern Saskatchewan; they suggest an unsuspected proximity to nearshore sediments in this interval's history of deposition and erosion.

Isopach maps reveal that:

- 1) Viking sedimentation and erosion in this area took place over a Mannville-age upland basin situated on trend with the Sweetgrass Arch, and were likely controlled by both Mississippian topographic and basement tectonic features; isopachs of the prograding Viking shoreface are limited by northwesterly structural trends as well as minor northeasterly ones.
- 2) The Westgate isopach map, as a reflection of the Viking topography during the final marine transgression, shows both a 'step' and a basinward flat area that are similar to features described in Alberta and interpreted to represent variable rates of sea-level rise and periods of stillstand.
- 3) Coarser clastic sediments were apparently not deposited in, or were entirely removed from, a major east-west topographic depression that was evident in Mannville times as a paleovalley and is interpreted as having persisted through the period of Viking deposition; this low area seems to have been filled from a younger, northerly-derived source of very fine-grained sediment, adding another complexity to Viking stratigraphy in Saskatchewan.

Viking oil production is from muddy sandstones in prograding shoreface sequences at Verendrye and from chert-pebble beds associated with multiple erosion surfaces and incised shorefaces developed under fluctuating sea-level conditions at North Plato and Plato. Production at Forgan and east of Verendrye may be related to a topographically controlled outer shoal development spatially associated with Mississippian topography.

## 7. References

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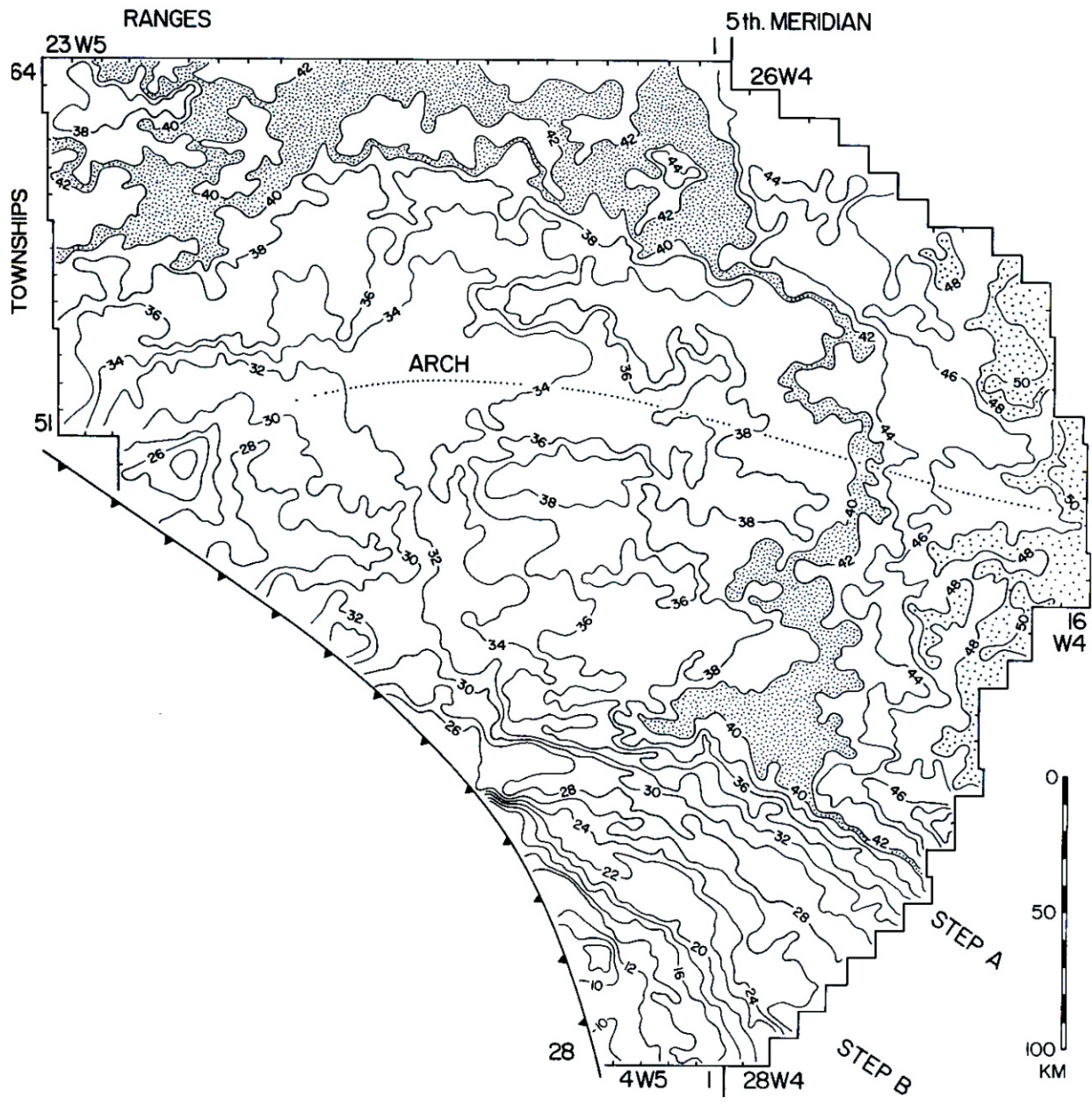


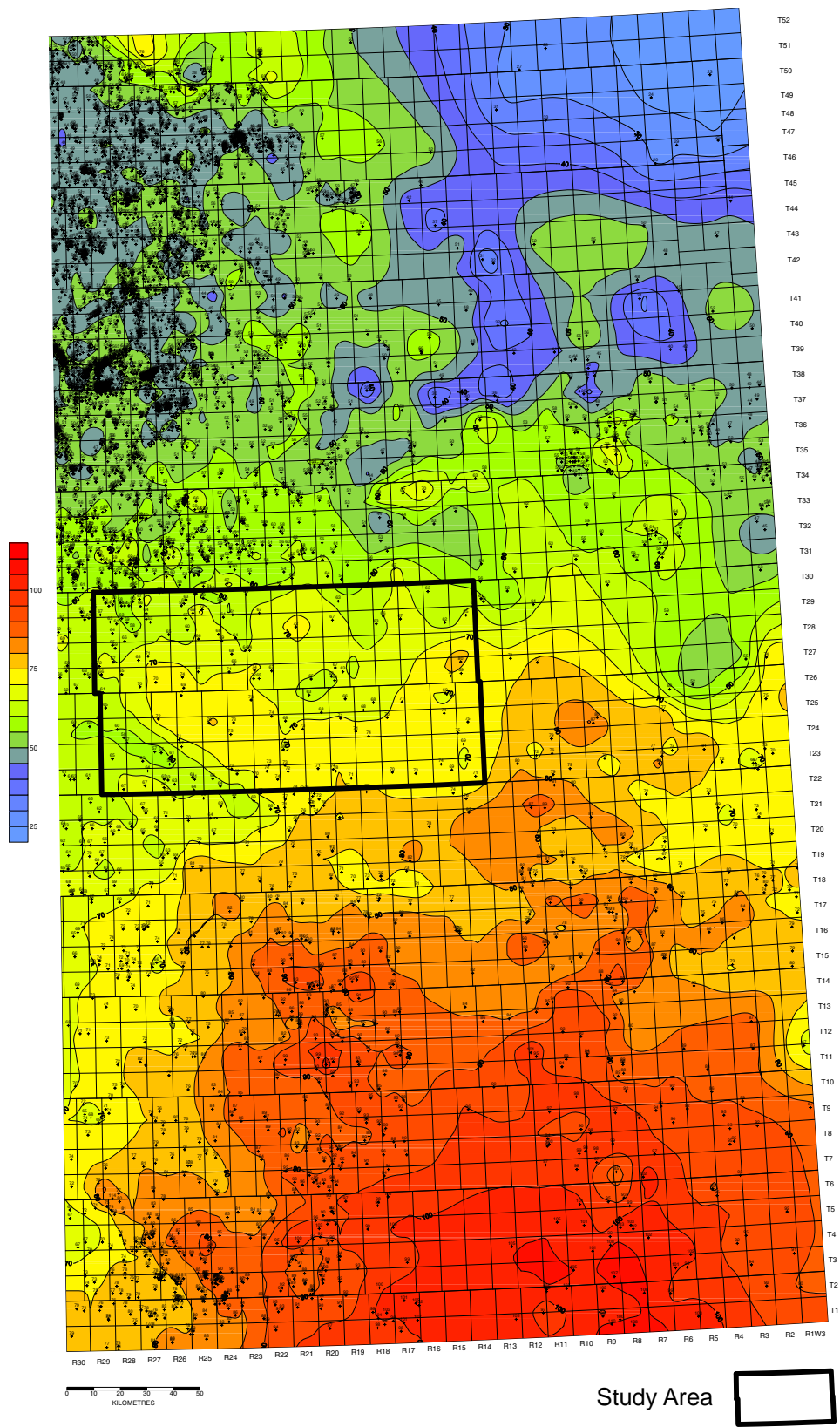
Figure 18 - Isopach map of strata from the base of the Fish Scales (top of Westgate) to VE4 (top of the Viking sandstones) in Alberta (Walker, 1995).

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**Figure 19 - Regional isopach map (contour interval = 5 m) of the Westgate Formation in Saskatchewan (Marsh and Heinemann, 2005).**

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