E. Other Southern Studies

Computer-generated Regional Geological Maps of Southern Saskatchewan: Stonewall Formation

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A regional mapping program was initiated by the Petroleum Geology Branch in the spring of 1993 (Kreis, 1993). This project has two goals:

1) to standardize the picks of stratigraphic units stored in the Well Information System (WIS) managed by the Sedimentary Geodata Division, and

2) to produce up-to-date computer-generated structure and isopach maps at a scale of 1:2 000 000 of every major subsurface sedimentary stratigraphic unit in southern Saskatchewan from the Precambrian surface to the Upper Cretaceous Belly River Formation. Included on each map sheet will be pertinent information such as a geological overview, illustrative cross section(s), reference geophysical log(s), and a selected bibliography.

Lower Paleozoic strata have been selected for the initial stage of mapping. Research by Petroleum Geology staff and others (e.g. Paterson, 1971, 1989; Kendall, 1976; Haidl 1989, 1992; Norford *et al.*, 1994) provides detailed stratigraphic information on Lower Paleozoic rocks in the province along with accurate geophysical log picks. In addition, there are fewer well penetrations of deeper strata and the data, therefore, are more manageable. Stratigraphic picks from wells in conterminous areas of Alberta, Manitoba, Montana, and North Dakota have been added to the Petroleum Geology computer-mapping database to enhance the quality of contouring at map edges.

The following description of the Stonewall Formation has been chosen to illustrate the proposed format of the map sheets and the information to be included with it. Reduced versions of the maps and cross section are included in this report as text figures; however, full-size copies are available in the map package.

1. Stonewall Formation

a) Geological Framework

The rocks of the Stonewall Formation are part of a carbonate-evaporite sequence that was deposited in shallow warm seas which covered much of the North American craton during most of the Late Ordovician and Early Silurian (e.g. Porter and Fuller, 1959; Osadetz and Haidl, 1989; Cecile and Norford, 1993; Norford *et al.*, 1994). Present-day distribution of Stonewall strata (Figure 1) is a product of depositional thickening into the centre of the ancestral Williston Basin and of erosional truncation associated primarily with the sub-Middle Devonian unconformity.

The Stonewall Formation outcrops in east-central Saskatchewan (Figure 1) with the best exposures found along the southeastern shore of Cross Bay in Namew Lake (Haidl, 1992). In the remainder of southern Saskatchewan, these rocks are restricted to the subsurface. A total of 367 wells penetrate the Stonewall Formation in the subsurface; data from 15 drill holes in the outcrop belt are also available.

b) Stratigraphy

The Stonewall Formation is composed primarily of dolowackestone/mudstone with minor interbeds of argillaceous dolomudstone/dolomitic shale; anhydrite is also present in southeastern Saskatchewan (Porter and Fuller, 1959; Kent, 1960; Kendall, 1976). The argillaceous beds, which commonly contain quartz grains, are widespread and serve as "marker" beds for correlation of stratigraphic units and sedimentary cycles (Porter and Fuller, 1959; Kendall, 1976). These argillaceous marker beds are differentiated from the carbonates and anhydrites by a much higher gamma ray geophysical log response which makes them useful for subsurface correlations (Figure 2).

The lower boundary between the Stonewall Formation and the underlying Stony Mountain Formation is placed at the base of a marker bed which is well-defined in both core and gamma logs over most of Saskatchewan, but which becomes much more difficult to correlate in northern and western Saskatchewan owing to diminished argillaceous content (Kendall, 1976; Haidl, 1992). In southeastern Saskatchewan, this marker bed overlies an evaporite bed (the "Gunton anhydrite"); in the rest of the map area it is in contact with Stony Mountain carbonates (Figure 2).

The upper boundary of the Stonewall Formation is placed at the contact between overlying Interlake carbonates and a marker bed that is commonly less argillaceous and thicker than marker beds above and below (Figure 2). The brachiopod *Virgiana decussata* is characteristic of the fossiliferous dolowackestone/mudstone unit of the lowermost Interlake in outcrop exposures and cores in Manitoba (Baillie, 1951; Stearn, 1956). *Virgiana* sp. has been identified in cores of this unit in the Namew Lake–Cumberland Lake area in east-central Saskatchewan (Haidl, 1992), but has not been found in the two cores in southern Saskatchewan which encom-

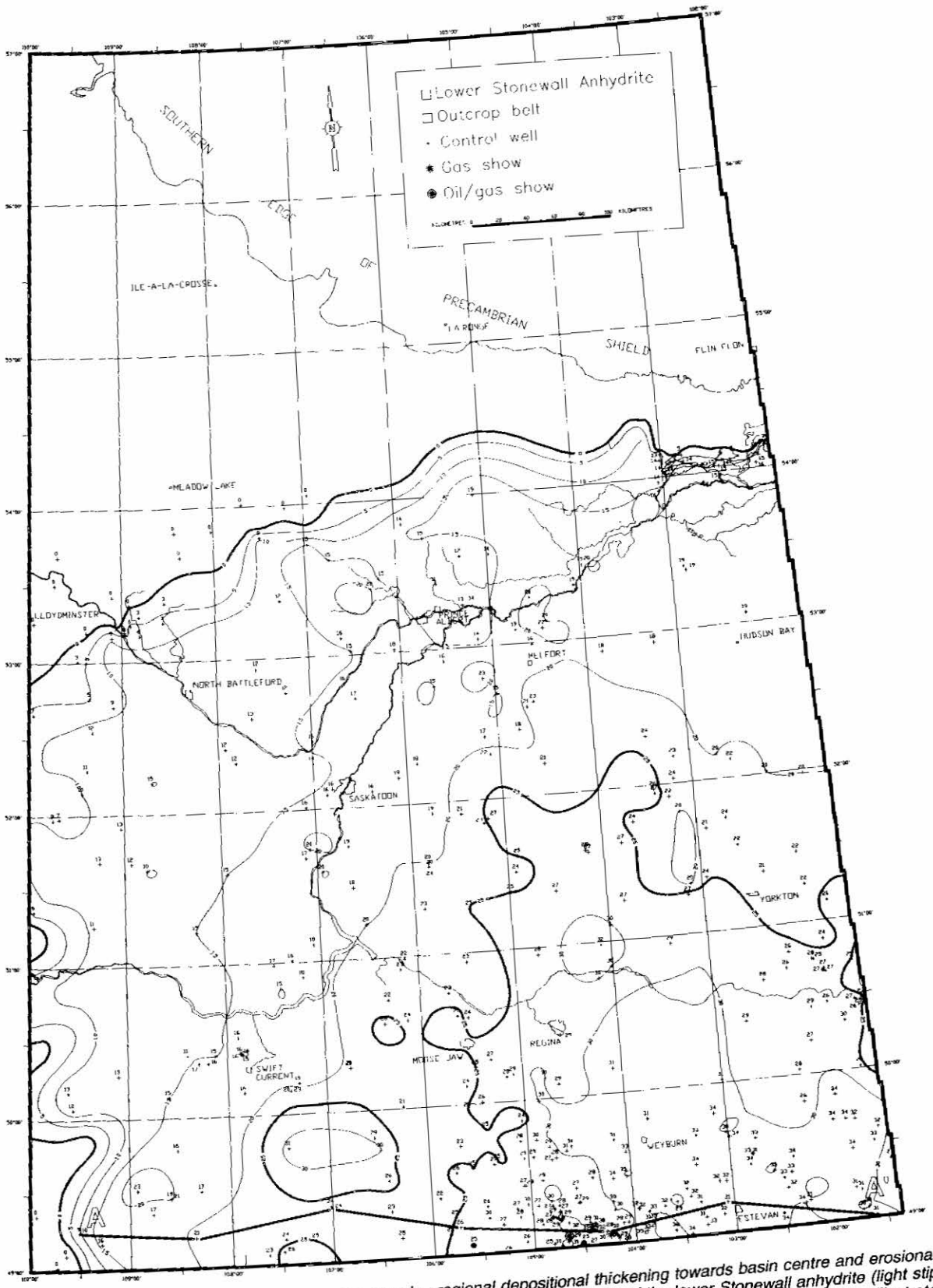

Figure 1 - Isopach map of the Stonewall Formation showing regional depositional thickening towards basin centre and erosional truncation of the unit from approximately 10 m to its zero edge. The geographic limits of the lower Stonewall anhydrite (light stipple, modified after Kent (1960) and Kendall (1976)) and the location of the W-E cross section, A-A' (Figure 2), are also illustrated. Contour interval is 5 m (Township-range grid is shown on full-scale map sheet).

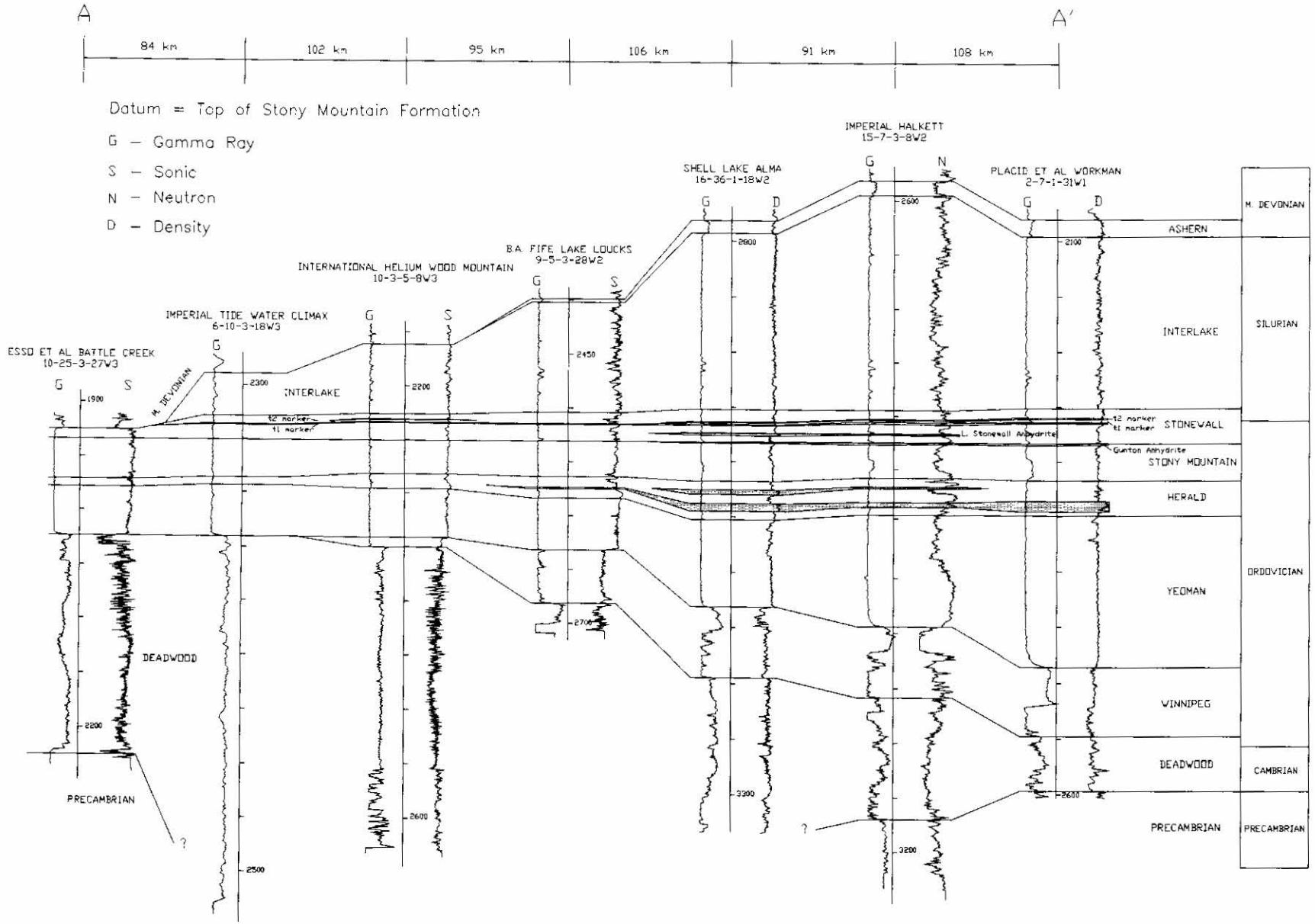

Figure 2 - West to east stratigraphic cross-section of Lower Paleozoic strata in southern Saskatchewan. Datum is top of Stony Mountain Formation. Vertical scale is in metres. Location of section is shown on isopach map (Figure 1). Geophysical logs illustrated: gamma (G), neutron (N), density (D), and sonic (S).

pass the Interlake/Stonewall boundary (Esterhazy-Rocanville area).

Strata in the Stonewall Formation (and underlying upper Stony Mountain and overlying lower Interlake) are characterized by cyclic sedimentation (Porter and Fuller, 1959; Roehl, 1967; Kendall, 1976; Johnson and Lescinsky, 1986). Kendall (1976) described four sedimentary cycles in the cored reference section of the Stonewall Formation in the Imperial Herald 1-31-1-20W2 well. The lowermost cycle comprises four units:

1) a basal argillaceous laminated dolomudstone with quartz grains,

2) bioturbated dolomudstone,

3) argillaceous laminated dolomudstone, and

4) nodular anhydrite with interbeds of laminated argillaceous dolomudstone (lower Stonewall anhydrite).

The upper three cycles in this well differ from the lower cycle in that Unit 2 is more fossiliferous in these cycles and the anhydrite of Unit 4 is absent. The number, thickness and completeness of cycles varies but, in general, a similar pattern of sedimentation characterizes Stonewall deposition throughout Saskatchewan. An anhydrite bed is present in the uppermost cycle in some areas (e.g. Tp. 2, 3, Rge. 14, 15W2; Tp. 2, Rge. 18W2; Tp. 17, Rge. 19W2; Tp. 21, Rge. 16W2). In both the upper and lower cycles, the anhydrite beds are less than 5 m thick and are restricted to the centre of the depositional basin. These factors support an interpretation that these and other Williston Basin Ordovician/Silurian carbonate-evaporite deposits are products of shallow basin, shallow water, "brining upward" cycles, although the cycles may be more complex than originally interpreted (Kendall, 1976, 1985, 1988, 1992).

c) Thickness and Structure

Thickness of the Stonewall Formation ranges from 35.7 m in southeastern Saskatchewan to zero at the erosional edge (Figure 1). Depositional thickening occurs towards the centre of the Williston Basin. Preserved minimum depositional thickness (i.e. rocks overlain by Interlake strata) is approximately 11 m; thus strata less than 11 m thick reflect erosional truncation of Stonewall strata.

In general, structure contours on top of the Stonewall Formation reflect the structure of the Precambrian surface. In the north, structure contours show a gentle southwesterly-dipping surface (Figure 3). In the south, contours define the northern flank of the asymmetrical Williston Basin. The present-day geometry of this basin, and that of three local structures in southwestern Saskatchewan (Swift Current High, Eastend (Ponteix) Syncline, and Val Marie Arch; Figure 3), can be attributed to Laramide deformational events (Christopher *et al.*, 1971). However, the area of maximum thickness of the Stonewall Formation coincides with the area of maximum depression in the structural Williston Basin (cf. Figures 1 and 3) indicating that the geometry of the ancestral Williston Basin, during Stonewall deposition, was similar to that of the present-day structural basin. Similarly, many small local structures (e.g. Hummingbird-Minton area: Tp. 1 to 3, Rge. 19 to 21W2; southeast of Moose Jaw: Tp. 14, Rge. 23, 24W2) can be attributed to reactivation of Precambrian structures (Christopher *et al.*, 1971; Potter and St. Onge, 1991).

Correlation of marker beds in the Interlake, Stonewall, and Stony Mountain formations is difficult in the northern and western parts of the map area and in those wells for which there are no gamma ray logs. Therefore, minor local variations on the structure and isopach maps may be caused by inconsistent picking of stratigraphic boundaries.

d) Ordovician-Silurian Boundary

The Ordovician-Silurian boundary (438 million years BP) is found in the vicinity of the *t* marker bed(s) (Figure 2) in the upper half of the Stonewall Formation (Brindle, 1960; McCabe, 1988; Bezys, 1991; Haidl, 1991). Brindle (1960) identified Upper Ordovician fossils *Halysites (Catenipora) gracilis* Hall and ?*Opikina stonewallensis* Stearn below the lower t_1 marker and Silurian fossils *Favosites* cf. *favosus* Goldfuss and *Syringopora* sp. in the fossiliferous dolowackestone unit between the lower t_1 and upper t_2 markers in the Imperial Herald 1-31-1-20W2 well. Preliminary paleontological data from the IMC K-1 Esterhazy 3SWD 16-26-20-33W1 well, provided by the Geological Survey of Canada, suggest that the Ordovician-Silurian boundary coincides with the t_2 marker (Haidl, 1991; Nowlan and Aldridge, pers. comm.; Norford, pers. comm). Ordovician conodonts were identified above the t_1 marker and Silurian conodonts above the t_2 marker (Nowlan and Aldridge, pers. comm.).

e) Economic Considerations

At present there is no hydrocarbon production from the Stonewall Formation in Saskatchewan. However, there have been three hydrocarbon shows out of a total of only ten drillstem tests within this unit in Saskatchewan (Figures 1 and 3), and the Stonewall has produced oil in North Dakota. All three hydrocarbon shows occur in the vicinity of the Hummingbird Trough, an area characterized by widespread multi-stage dissolution of the Middle Devonian Prairie Evaporite. Salt dissolution in this area is presumed to be related to structural features originating in the Precambrian basement (Kent, 1960; Kendall, 1976). The reservoir characteristics of the Stonewall Formation are also demonstrated as potash companies in the Esterhazy-Rocanville area use it for salt water disposal.

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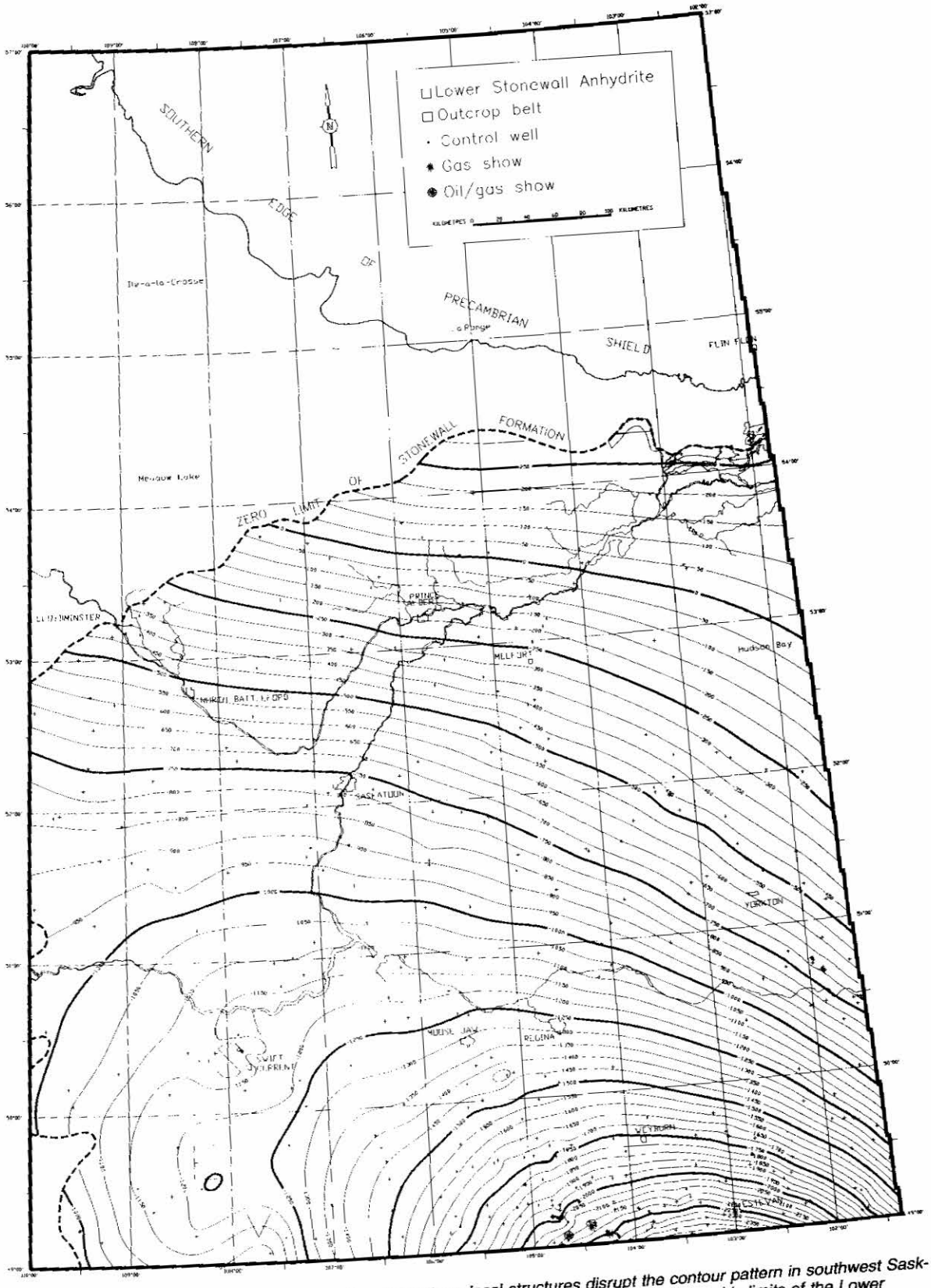

Figure 3 - Structure map of the Stonewall Formation. Note: three local structures disrupt the contour pattern in southwest Saskatchewan: Swift Current High (S), Eastend (Pontelx) Syncline (E), and Val Marie Arch (V). Geographic limits of the Lower Stonewall anhydrite (modified after Kent (1960) and Kendall (1976)) are also shown. Contour interval is 50 m (township-range grid shown on full-scale map sheet).

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