Evaporite Basin Configuration – Structural Versus Sedimentary Interpretation

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ABSTRACT

Three very extensive subsurface Devonian evaporite basins in Alberta, Canada, are discussed. The oldest, Eifelian in age, includes three major salt sequences and other strata in the Lower Elk Point Group. A younger, and the most extensive, is Givetian in age and is characterized by the Muskeg Formation of the Upper Elk Point Group. The Elk Point is also represented by the Prairie Evaporite Formation in Saskatchewan, Manitoba, Montana, and North Dakota. The youngest, and least extensive evaporite basin, Famennian in age, is represented by Stettler Formation of the Wabamum Group. Popular explanations of thickness variations of the lens or wedge shaped profiles of the basins, such as differential sedimentary tectonics, exotic reef-to-evaporite or carbonate-to-evaporite deposition, and recurrent subsurface salt-solution and collapse of overlying strata, are shown to be fictional; as these have failed to recognize and consider abundant and contradictory geological evidence. In bringing forth this evidence and in the light of Walther's Law of Correlation of Facies, the basin profiles are shown to be structural remnants of originally much vaster areas of evaporite deposition.

Each basinal cycle in Alberta generally consists of three distinctive depositional sequences, a basal red bed, a medial carbonate and an uppermost evaporite unit. The basal sequence is silty and sandy in some areas; the medial carbonate—often called "platform"—ranges from breccia-conglomerate (beach rock) to stagnant mud-flat and sabkah deposits to prolifically organic carbonate shoal sediment; the uppermost unit is of thick evaporite beds with thin beds of dolomite and shale. Regionally, the two lowermost sequences, about 150 feet thick, clearly represent basal transgressive deposits such as are recognized above known regional unconformities. It follows, therefore, that these deposits may be termed the basal diachronic facies assemblage. The recurrence of this assemblage in coarse stratigraphic cyclicity, and with stunning similarity in lithologic and sedimentary characteristics may be considered as diagnostic of a regional unconformity and may thus mark its stratigraphic position. In this paper the term "unconformity," or "regional unconformity," corresponds to a major stratigraphic hiatus and is totally analagous with the sub-Cretaceous, sub-Jurassic, sub-Permian and sub-Devonian unconformities of western Canada and the northern United States of America.

The basal assemblage is overlain by evaporites of a relatively stable sedimentary regime. The evaporites are in strict superpositional relationship with the underlying carbonates with little or no carbonate prominences having existed. The contact shows evidence of shoaled deposition and redeposition, of broken earlier carbonates infilled by later evaporite sediment which gradually and ultimately overlapped the basal assemblage as the transgression proceeded.

Within the evaporite sequences wide-ranging thin marker—horizons of shale and carbonate display the natural stratigraphic succession; the uniform thickness of each successive bed points against differential sedimentary tectonics. Th

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basal assemblage has the widest geographic distribution while successively younger evaporite beds show increasingly limited distribution. This evidence of postsedimentary structure and erosion, plus the upward change from evaporites to the next higher basal diachronic assemblage reveals an unconformable relationship and exemplifies Walther's Law of Correlation of Facies.

Walther's Law allows for evaluation of regional unconformities in other parts of the stratigraphic succession, for instance the sub-Alexo and sub-Shunda unconformities in the Devonian and Mississippian of Alberta. Such unconformities need not be confused with several or many features of shallow-water deposition and redeposition as within the basal assemblage. Regional unconformities represent regional structural movements and variable erosion of the underlying stratigraphic sequence. Thus, such a stratigraphic sequence carries imprints of its own structural movements, a widespread criterion which is vital in dealing with the real problems of sedimentation, stratigraphy, paleontological correlation and geological history as well as with the problems presented by useful hypothetical concepts.

INTRODUCTION AND GENERAL DISCUSSION

The purpose of this paper is to establish a greater degree of confidence in our present understanding of sedimentary geology in general and petroleum geology in particular. That at present our degree of confidence leaves something to be desired is shown to be so by pointing out that there are in the published literature and in our every day beliefs many discrepancies between concept and fact which are due largely to sins of omission and commission. By comparing the work of various authors and by weighing these against facts and principles which are not appreciated generally, this writer hopes to widen the limited sphere of interest and concern which prevails in the guise of practical, or commercial, geology.

The present writer may well be mistaken in some of his own concepts and conclusions as expounded herein. I hope only that others respond to the challenge to find these, improve on them and consider these as my contribution to further progress, and not just as other "equally deserving" opinions in our conventional wisdom.

While the conclusions which form the basis of this paper have served in the past for a number of presentations (and intended publication) with titles

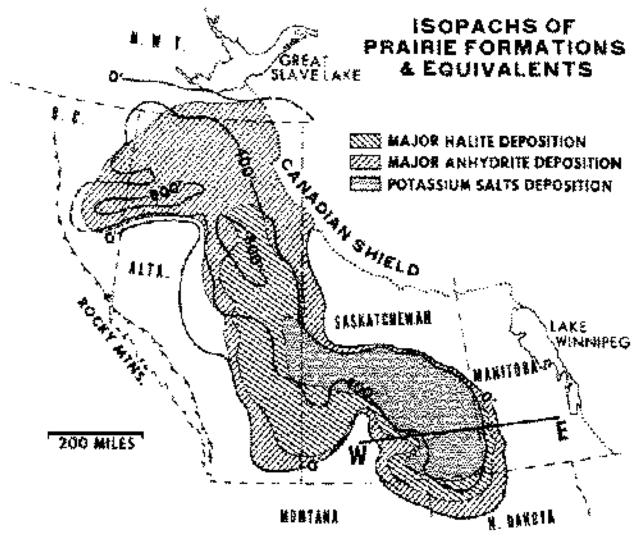

Figure 1. (after DeMille *et al.*, 1964). Middle Devonian evaporite basin of Western Canada.

encompassing a range of subjects from pure stratigraphy to petroleum exploration, they are equally useful for the purposes of the Third Symposium on Salt.

The three subsurface Devonian evaporite basin deposits discussed herein are, in ascending stratigraphic order, in the Lower Elk Point Group, in the Upper Elk Point Group, and in the Wabamun Group of Alberta, in western Canada (Fig. 1). There is general agreement in observation that the evaporites, ranging in thickness from 0 to 1000 feet of salt or anhydrite, or both, indeed do possess basinal profiles and are associated in coarse cycles wherein the evaporite units are underlain and overlain by carbonates and other strand-line deposits (Fig. 2). However, little, if any, concrete contribution has been made toward the explanation of these empirical observations beyond perpetuating the unilateral ideas of differential sedimentary tectonics, exotic reef-to-evaporite facies relations and subsurface salt-solution with collapse and brecciation of overlying strata.

The generally accepted understanding of evaporite basin deposition is based on the hypothetical concept of differential sedimentary tectonics. This holds that varying rates of subsidence between different areas during deposition explain the simple empirical relationship of thick and thin wedges of sediment deposited in a certain period of time (Sloss *et al.*, 1949). In exploring this hypothesis for supporting factual evidence this writer has made several most pertinent discoveries.

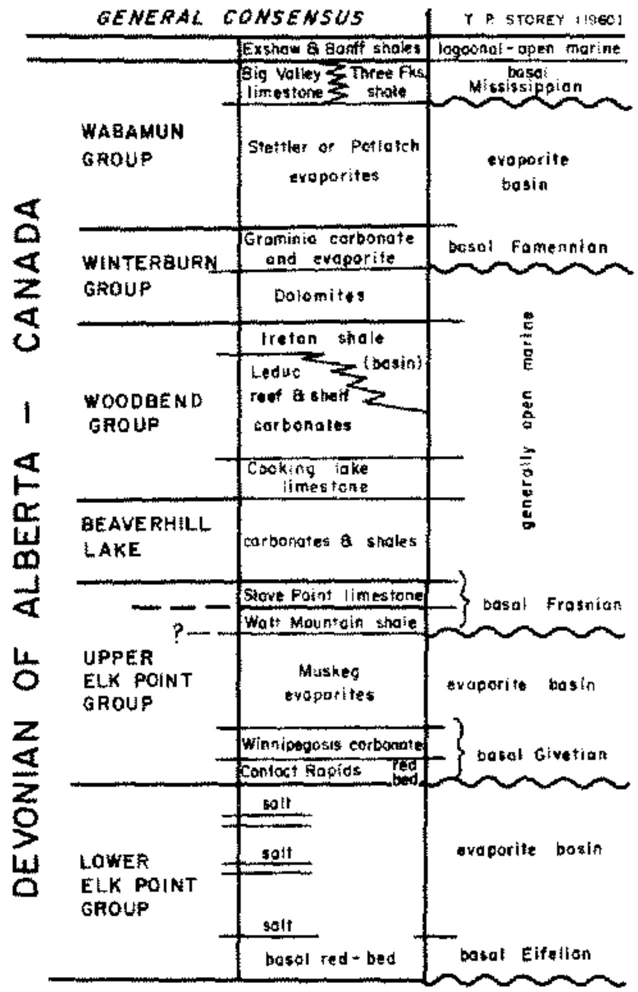

Figure 2. Generalized stratigraphic nomenclatural succession of the Devonian of Alberta, Canada.

(1) Little, if any, effort had been made by proponents of the concept to seek out and document evidence in the Devonian evaporite units for the erection of a natural geological model for these basins (Andrichuk & Wonfor, 1954, Fig. 13; Law, 1955; Belyea, 1958, Figs. 2, 3; Belyea, 1964, Fig. 6-18; DeMille *et al.*, 1964, Fig. 4). But, even where the evidence is observable and adequate for a model, as with the natural subdivision of the Lower Elk Point, the prevailing interpretation tends to distort the evidence of the natural model.

(2) The existence of abundant pertinent facts is not recognized or accepted and their significance is totally unappreciated in spite of the fact that these facts generally contradict the hypothesis. The true meaning of some of the stratigraphic and sedimentational criteria and the critical differences between them are not understood. For example, basal transgressive (diachronic facies) sediments are unwittingly represented as time-markers and, alte nately, postsedimentary structurally warped tim markers are mistaken for, and are misrepresent as, diachronic facies contacts. Consequently, t manner and form of the arrangement or presen tion of these markers carries unsuspected and u warranted builtin prejudices and conclusions; e. the use of regional unconformities or basal d chronic contacts as valid horizontal datums is u realistic and misleading (Andrichuk and Wonf 1954, Fig. 13; Harris, 1963; Parker, 1967, p. 19 1944; Grayston *et al.*, 1964, p. 55, 56, 57; Bely 1964, p. 72, 73, 74; Griffin, 1965, Figs. 4, 1 There are a few rare exceptions, however, as can appreciated from the significant work of H (1960) and Welsh (1963).

In the initial efforts of this writer to understa these popular concepts and to verify them on f tual bases, several different observations in f pointed to quite different explanations of the sinal profiles. These are:

(1) The basal carbonate and other lithofacies less-restricted environments include abundant se mentary breccia-conglomerates, perhaps analag with modern beach rock and other strandline posits. These sediments exhibit lithological gra tion laterally and vertically with each other by deposition *generally* with the superjacent ev orites; i.e., by overlap of one lithofacies by anot (Fig. 6). This evidence strongly suggests a c temporaneous sedimentary relationship betw such an assemblage of lithofacies where ma marine transgressions are recognized upon regic unconformities (Fig. 3). For instance, identical dence may be seen also in the sedimentary relati ship between the Devonian Slave Point Limest

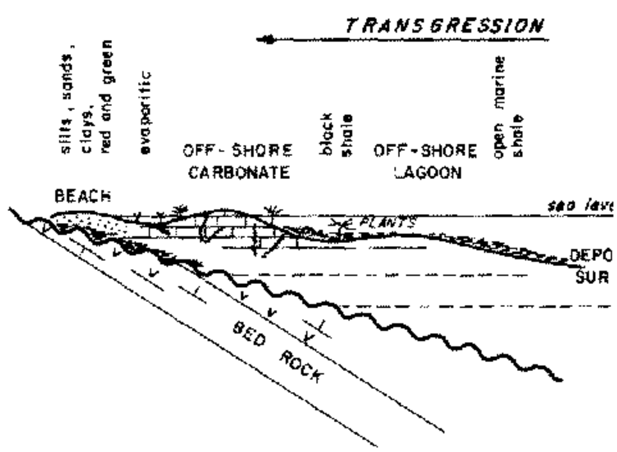

Figure 3. Generalized concept of basal transgressive litho assemblage showing penecontemporaneous and on-lap and ov relationships.

and other facies sediments (Koch, 1959) on the sub-Upper Devonian unconformity as well as between the Big Valley Limestone and related black and green shales above a regional unconformity (Harris, 1963; Wilson, 1955). Although in the latter two instances the dating and sedimentary relationships of other authors is questioned, the vertical and lateral gradation is between strandline facies and the superjacent open-marine facies of carbonates and shales. Thus, the basal transgressive breccia-conglomerate carbonates, which occur only in relatively thin beds and recur with only coarse cyclicity within the overall succession, may be viewed as a fundamental sedimentary structure diagnostic of regional unconformities and its stratigraphic position (Fig. 2). Congruently, above these unconformities there are to be found lithologically gradational (diachronic) facies which are stratigraphically (bed-by-bed) conformable with the overlying sediments. This observation is simply a corroboration of Walther's Law of Correlation of Facies (Storey & Patterson, 1959, Fig. 5). All in all the cyclic recurrence of these basal deposits and the stunning similarity in lithologic character and sedimentary structure at different stratigraphic levels must be seen to be believed (Figs. 7, 8).

(2) Below these unconformities structural discordance can be observed within the carbonate-evaporite succession, as well as in other successions which are open-marine (Fig. 5). However, this evidence can be observed only through painstaking detailed stratigraphic subdivision of the thick evaporite succession (Fig. 4) in conjunction with an appreciation of the significance of Walther's Law. The stratigraphic subdivision of the Lower Elk Point is not a problem (except in the marginal areas) because the succession is already established clearly in a natural vertical arrangement as recognized by Crickmay, 1954; Law, 1955; van Hees, 1956; Sherwin, 1958; and Grayston *et al.*, 1964. However, these same authors have not subdivided the Muskeg Formation of the Upper Elk Point.

DIFFERENTIAL SEDIMENTARY TECTONICS

Notwithstanding that the *concept* of differential sedimentary tectonics may well be validly supported in certain instances (if any attempt were made to do so), there are basically two lines of fundamental evidence which contradict the idea as a valid universal generalization:

A. Self-contradictory evidence.

B. Incompatibility with facts and principles.

Self-contradictory evidence.

(1) According to the concept of differential subsidence, thicker, more-open marine sedimentary deposits reflect areas of greater subsidence, while less subsidence is reflected in thinner, shallow-water to near-shore deposits of a more restricted environment. In the Upper Elk Point, however, the Muskeg Formation shows almost no variation in lithologic character from "thicks" to "thins" except on the Peace River high where, in fact, the rocks are of a less restricted near-shore environment. Thus the observed facts tend to contradict the concept (Fig. 5). By and large, this same contradiction prevails in the Midcontinent region where so-called geosynclinal areas (in nonevaporite provinces) are interpreted to have existed *during* deposition, despite the acknowledgement that the facies here generally are identical to those in the cratonic areas (Ham and Wilson, 1967).

(2) While normal clastic-sediment basin-infill accompanied by basal transgressive clastics and conglomerates is universally accepted as a basic criterion marking the start of a new sedimentary sequence or regime, analagous criteria with respect to evaporite or carbonate and shale basins are not at all equally accepted, primarily because these have been mistaken for other criteria. The basal transgressive deposits of the Eifelian Lower Elk Point, the Givetian Upper Elk Point, the basal Frasnian Ghost River Formation (Storey, 1955, 1959), the Famennian Stettler or Potlatch evaporites (Figs. 9, 10), the basal Mississippian-Big Valley Limestone, and the Mississippian Shunda Formation, in western Canada are characterized particularly by almost ubiquitous near-shore sedimentary breccia-conglomerate carbonates, few evaporite beds, red and green clays and, locally, by finely to poorly sorted quartz-clastics. However, this clearly valid analogy between the two types of sedimentary regimes is made non-existent by the acceptance as unquestionably valid of two *a priori* conclusions:

(A) Differential sedimentary tectonics is the exclusive explanation for variations in thickness of stratigraphic units. This can be seen in the work of Parker (1967, p. 1930, 1940, 1941), whereas even on the basis of his own evidence which he obviously does not understand or carry to logical conclusions, it is obvious that regional unconformities and transgression may explain most of the variations in thickness. Parker, at least, should

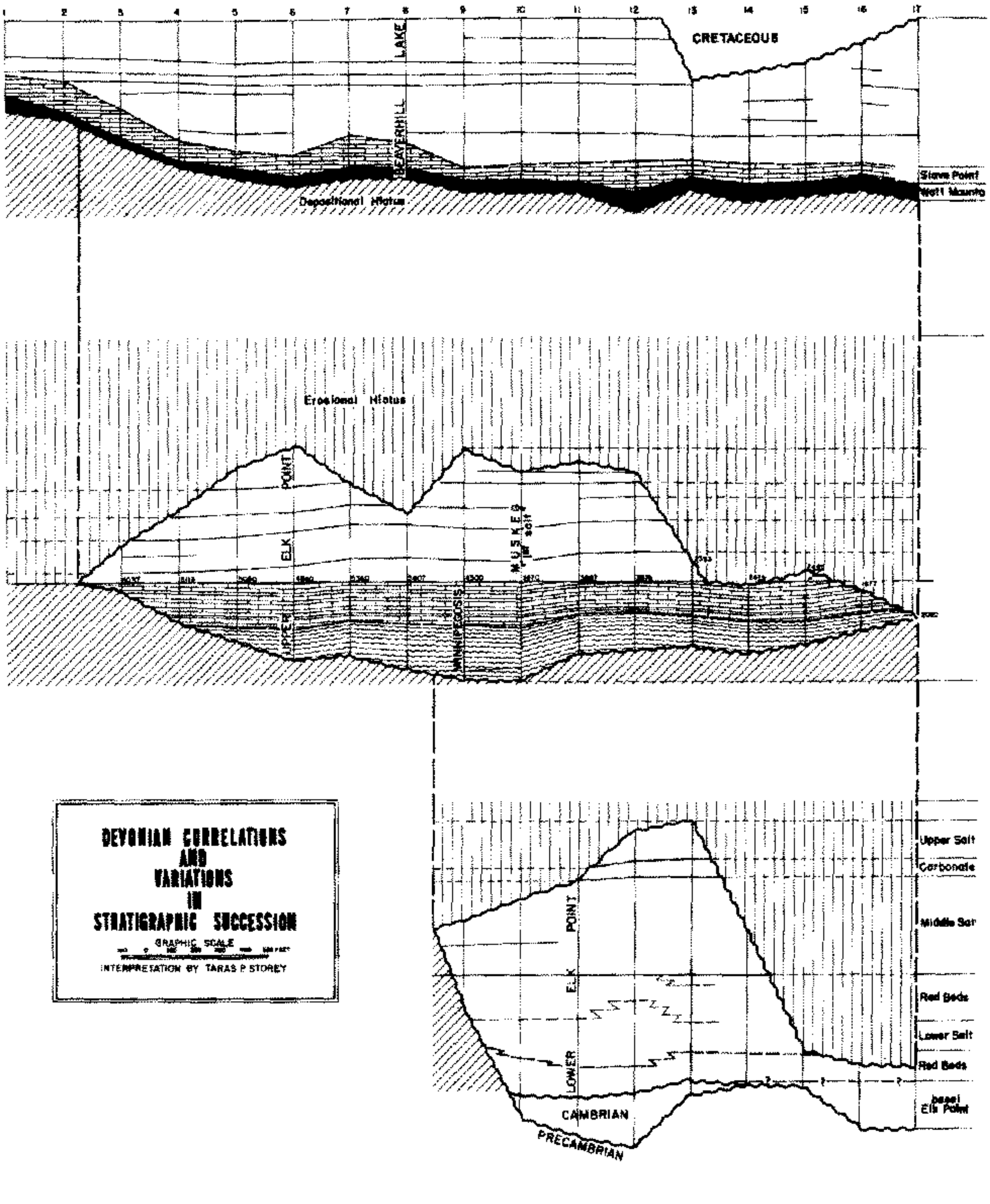

Figure 4. Stratigraphic subdivision of evaporitic and open-marine stratigraphic sequences to discriminate between diachronic, u formable and time-marker (planes of contemporaneity) horizons. See Figure 5 for line of cross-section.

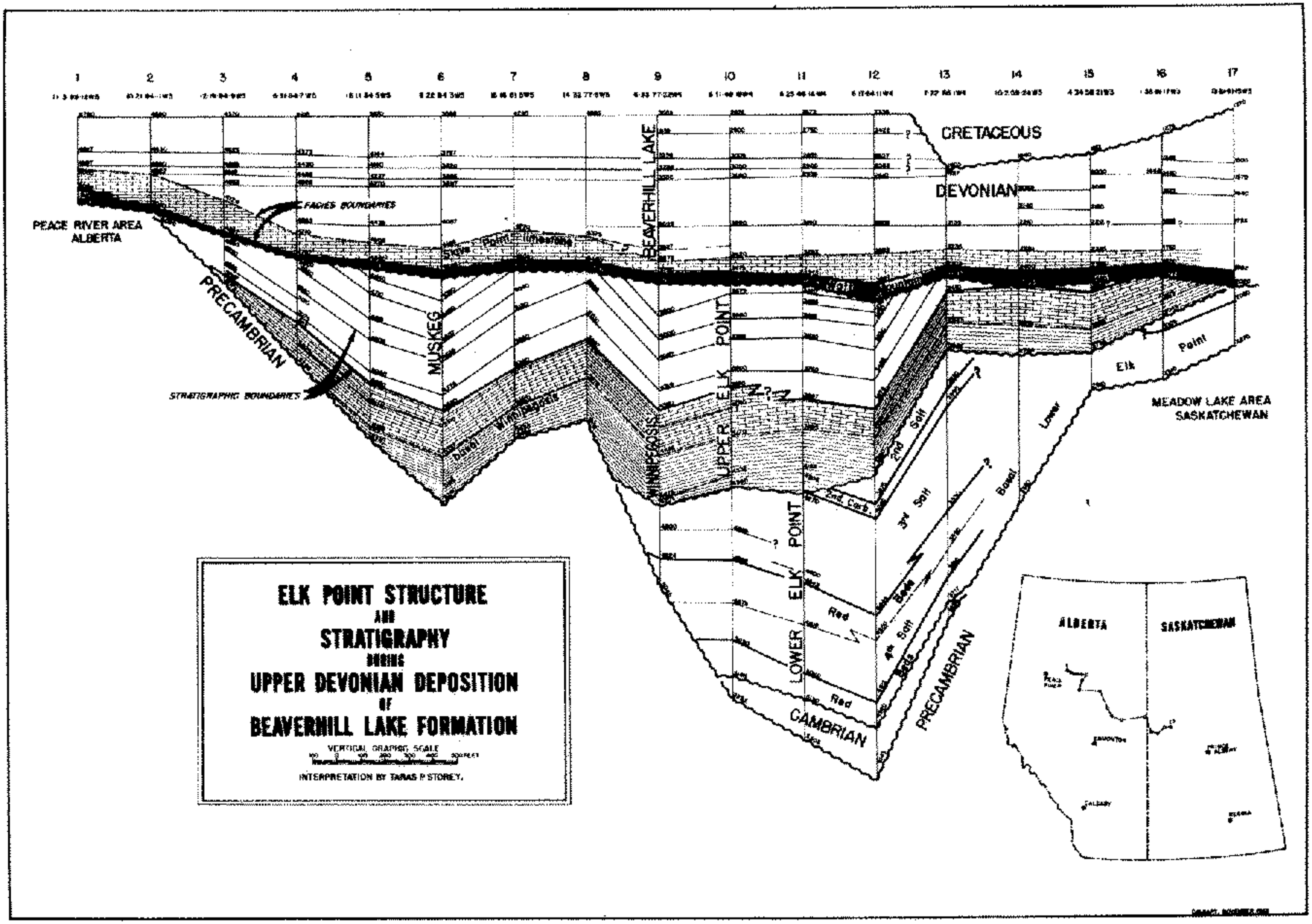

Figure 5. Note 1: The two generations of paleotectonic structure below sub-Watt Mountain unconformity and erosion of progressively older strata. Note 2: Different stratal relationships at this unconformity do not require descriptive terms other than "regional unconformity." Note 3: The sub-Upper Elk Point unconformity is eroded and overlapped by the sub-Watt Mountain unconformity just as are the progressively older Upper Elk Point strata.

Figure 6. Basal transgressive breccia-conglomerate carbonate, reworked and infilled by "penecontemporaneous" anhydrite deposition. Dolomite fragments obviously are derived from carbonates which predate evaporite deposition. (Well location: Lsd. 12, Section 17, Township 39, Range 20 west of Fourth Meridian). Interval commonly called "Nisku Reef."

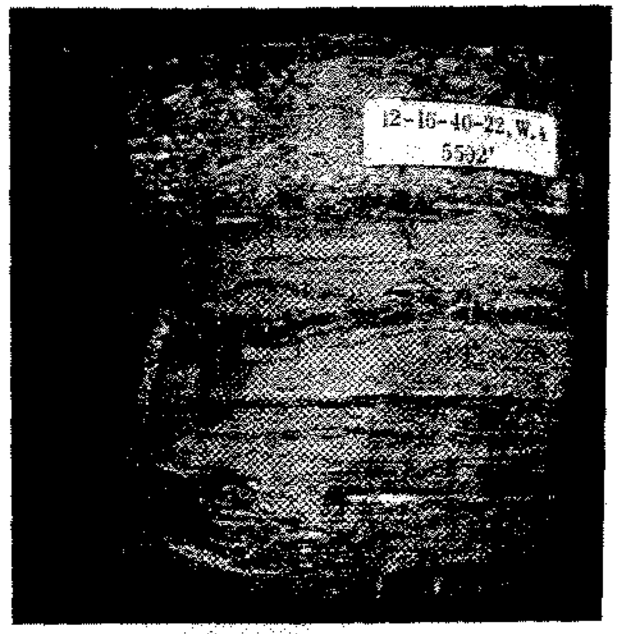

Figure 7. Finely laminated dolomite with interbedded evapoı (anhydrite) of basal Famennian in subsurface of central Albeı Interval commonly called "Nisku Reef."

Figure 8. Finely laminated and breccia-conglomerate dolomite with interbedded evaporite (anhydrite) of basal Frasnian in subsurface of west-central Saskatchewan (Well location: Lsd. 8, Section 11, Township 62, Range 22, west of the Third Meridian; depth of core: 2223 feet). Interval commonly called "Winnipegosis Reef."

Figure 9. Basal transgressive carbonate conglomerate of I Famennian in sub-surface of central Alberta. Light, earthy, d dolomite fragments on left and at bottom are typical of Ste Formation; dark, granular dolomite, top right, is Nisku fragm (Well location: Lsd. 14, Section 2, Township 39, Range 22, we Fourth Meridian; Core No. 4). Interval from gas-producing sec called "Nisku Reef."

Figure 10. Basal transgressive carbonate conglomerate of basal Famennian in sub-surface of central Alberta; light, dense fragments are of reworked Stettler Formation carbonate; dark, porous dolomite, Nisku and Leduc fragments. (Well location: Lsd. 7, Section 9, Township 39, Range 22, west of Fourth Meridian). Interval from gas-producing section called "Nisku Reef."

feel obliged to entertain and attempt to use such basic evidence. This is in contrast with the abundant evidence for regional unconformities unearthed by Ham and Wilson (1967) in their search through prior publications. As specific examples, one needs only to consider the sub-Devonian, the sub-Jurassic, and the sub-Cretaceous unconformities in western Canada as completely valid analogues for differential structure development and differential erosion to explain variations in thickness of the stratigraphic succession.

(B) The panacea of subsurface removal of salt by recurrent solution with accompanying collapse of overlying strata into breccia zones (DeMille *et al.*, 1964, Pl. 1, Figs. 1, 2) is also very questionable. On close examination it is clear that many of the fragments in Figure 1 are water-worn, rounded pebbles of conglomerate and that the sedimentary clay matrix has not been crushed as it should be if this part of the succession had collapsed. Yet, there are literally innumerable examples of sedimentary breccia-conglomerate carbonates where no underlying salt beds can be postulated as ever having existed! For examples, such conglomerates are found in the basal Upper Devonian Ghost River Formation lying on eroded Cambrian strata in the mountains closest to Calgary and in the basal Alexo beds in mountain sections where there has been mapped over 500 feet of erosion of the underlying normal marine Fairholme Group. On the other hand, the evidence depicted in Figure 2 is not unique for the stratigraphic level concerned, as such normal sedimentary breccias can be seen over very wide areas 500-600 feet higher at levels commonly called the first, second and third fragmental (carbonate) zones. These are here considered to be normal because they recur in a cyclicity which appears to be related to repeated regressive effects at the shoreline, far to the west during the transgression of the Ghost River Formation.

Incompatibility with facts and principles.

(1) In 1956 my first attempt was made at detailed stratigraphic subdivision of the Middle Devonian evaporite successions of the Upper and Lower Elk Point groups in central and northern Alberta. In 1960 the same approach was applied to the Upper Devonian Stettler or Potlatch Evaporite Formation in southern Alberta and Montana. This subdivision was based on the correlation of thin-bed markers on mechanical well logs and examination of core and rock cuttings of these markers (Fig. 4). Two important interdependent observations evolved which startled my beliefs at that time:

(A) There are within the successions of the evaporite basins (as also in open-marine shale/carbonate basins) numerous local and fewer regional markers, the latter being traceable in both of the Middle Devonian evaporite sequences for distances of over 150 miles. These markers, consisting of clayey and calcareous material, show a striking parallelism and consequently a striking uniformity of thickness in units between them over very wide areas.

(B) In Alberta the Muskeg marker beds and intervals between them are conformable with and in superpositional relationship to the basal Winnipegosis carbonate of the Upper Elk Point (Fig. 4), while the Stettler markers show the same relationship to the basal Stettler sediments. This evidence is a contradiction of the generally accepted belief that these basal carbonates are reefoid (albeit they are fossiliferous) and that they had a penecontemporaneous restricting influence on the sedimentation of what in fact are superjacent evaporites (DeMille *et al.*, 1964, Fig. 4). This had been my belief in 1955 when I offered such views in an oral presentation at that time. Restoration of the thin-bed markers of the evaporite-carbonate successions to the near-horizontal position as they were at the time of their deposition shows that the rate of subsidence during deposition of individual beds was rather uniform over exceedingly wide areas regardless of the gross thickness of the evaporite succession. Extrapolation of the bed-thicknesses beyond their present limits suggests that their areal extent must have been considerably greater originally, as Porter (1955) shows for the Mississippian succession in Saskatchewan and Manitoba. Such restoration and extrapolation of each succession shows clearly that the higher or younger beds and markers now have a more limited areal distribution than the older or lower beds (Fig. 4). This suggests without question an erosional and subcrop pattern and relationship between the Middle Devonian Muskeg evaporite-carbonate succession and the younger and higher basal Upper Devonian succession of Watt Mountain Shale Gilwood Sand and Slave Point Carbonate (Fig. 5). It follows, too, that such an erosional pattern must have been preceded by structural movements of the beds prior to or during (?) their erosion. This applies also in the relationship of the Lower Elk Point evaporite succession to the basal Upper Elk Point and in the relationship of the Stettler to the overlying Big Valley Limestone and the Three Forks Shale. The superpositional relationship of each of the three Devonian evaporite successions to the overlying basal assemblage illustrates and supports Walther's Law of Correlation of Facies, dictating that such contacts, between evaporites and overlying strandline facies[2] must be considered as probably unconformable. This, however, is not the basis of the prevailing understanding of such contacts, nor of the dating or relative age determination of the related parts of the stratigraphic succession. For instance, while Wilson (1955), Storey (1956), and Harris (1963), have indicated evidence for the sub-Big Valley and Three Forks unconformity over wide areas, such evidence has not been fully accepted (Billings Geol. Soc. Guide Book, 1962, p. 2-3) and instead an unsubstantiated unco formity is implied above these formatior Also, while it has been acknowledged ge erally that there is a "major" unconformi below the Watt Mountain of Alberta, Grifl (1965) believes one to be higher in the s tion above the Slave Point Limestone a seems to be unappreciative of its sub-W Mountain position. Further, while an unc formity has long been recognized below t Second Red Bed in the Saskatoon and sou western areas of Saskatchewan and Montana, its significance has been miss completely between these areas. The reas for the persistence of such geological pr lems is largely because so many geologi seem to prefer the "evidence" of correlati charts which often are encumbered uns pectingly by *a priori* conclusions based incomplete and at times contradictory dence.

It is the Watt Mountain-Muskeg contact central and north-central Alberta that r resents the Upper-Middle Devon unconformity (Storey, 1955, 1959) whicl continent-wide. This unconformity in t represents continent-wide epeirogen structural movements *after* the Middle De nian sediments had been deposited and t it is postulated, led to the complete wi drawal of the shallow seas from continental area. The unconformity and structural discordance cannot be recogni without detailed stratigraphic subdivision the successions wherein time-markers diachronic horizons may be differentia one from the other and the significance each evaluated (Fig. 5). Utilizing the dence of the basal transgressive brec conglomerate carbonates in conjunct with reliably documented faunal horiz the unconformity can be traced from Arctic regions to the New York ar

2. It is important to note here that open-marine successions su the Frasnian Fairholme Group and the basal Mississippian I Formation of Alberta also are overlain unconformably by the diachronic assemblages known respectively as the basal Alexc Shunda formation.

3. From below the Beavertail Limestone along the lower Mack River, to below the Slave Point Limestone (and shale) at Great Lake, to below the Watt Mountain (and much lower in the sec of Alberta, to below the basal Souris River (First Red Bed) a Saskatchewan and into the northern United States, to the ba the Callaway Limestone of the Mississippi Valley region as trated by Branson (1944, p. 176-177), to the base of the Tully Limestone as recorded and documented by Heckel (196

Whether we examine the subunconformity structures (faults or regional or local folds in the Upper or Middle Devonian evaporite provinces of western Canada, in the non-evaporite or open-marine provinces of the Northwest Territories, or in the Mississippi Valley (as well as in other parts of the stratigraphic succession), we can discern similar basin patterns which are primarily due to post-depositional movement and erosion and only to a minor degree to depositional variables such as variations in topography during the Upper and Middle Devonian transgressions.

The same procedure has been used here, in conjunction with well documented paleontological data by Crickmay (1952), to prove that the Big Valley and Three Forks formations above a regional unconformity (Wilson, 1955, Harris, 1963) must be considered Mississippian in age and not Devonian. It is interesting to note that this conclusion cannot be arrived at logically on the basis of either paleontologic or lithofacies evidence alone; i.e., without the stratigraphic evidence, because of the *a priori* concept that the Big Valley and Three Forks *are* Devonian in age!

Thus it can be seen that the Upper and Lower Elk Point and Stettler or Potlatch evaporite basins of Alberta and adjacent areas all show clear evidence of uniformity of bed-thicknesses which indicate uniform rates of subsidence during deposition in spite of the variations in the gross thicknesses of the evaporite successions. The greatest variations in thicknesses, based on detailed work, are from the tops of the evaporite successions downwards where they are superposed unconformably by strandline and open marine sediments. Thus it can be seen that there is abundant and adequate evidence to solve the problems of evaporite-basin configuration and sedimentation without having to cling to hypothetical concepts stripped of factual support.

SUMMARY AND CONCLUSIONS

It is concluded on the basis of the foregoing discussed basic principles and abundant evidence found in both different geographic areas and at different stratigraphic levels that regional unconformities constitute the backbone of stratigraphical geology. Yet, in my opinion, failure to recognize this is the weakest link in general geological thinking. While these remarks may shock most sedimentologists and stratigraphers, they probably would be regarded as no great revelation by hard-rock geologists. Such a statement will undoubtedly be viewed as being typical of a catastrophist—this is what I have experienced many times over. But, the irony of the situation lies in the fact that if *catastrophism* is involved it occurs primarily with the reactionary response of most sedimentary geologists, but in particular cannot be applied to the almost unbelievable mildness of the epeirogenetic paleostructural movements and their vast geographic extent during a particular time (period). This is the reason why it is so difficult to recognize and appreciate regional unconformities! As these unconformities generally have not been recognized readily, it is most important that some of the criteria for their recognition are better appreciated. Those discussed herein are:—

(1) "Radical" changes in the vertical lithologic succession suggest that "drastic" alteration must have occurred in the depositional continuity of the succession. This relates to Walther's Law of Correlation of Facies and implies that uplift interrupted the deposition of the earlier sediments and erosional unconformity developed before and during deposition of the later sediments.

(2) In view of the fact that unconformity-bound successions each carry imprints of their own structural history, the identification of the differences between two successions in superposition is basic in recognizing the presence and the stratigraphic position of a regional unconformity.

(3) Unconformities of regional extent reflect variable topographic elevation, thus synonymizing transgression characterized by a number of different diachronic facies whose geographic distribution is generally as extensive regionally as is the transgression. Therefore, such assemblages of diachronic facies might be considered as valid evidence for considering the presence of regional unconformities and their stratigraphic position.

(4) Regional transgressions in environments conducive to carbonate deposition developed breccia-conglomerate carbonates which contain reworked endogenous and some exogenous materials and fragments. Generally, the section carrying the assemblage of diachronic facies averages 150 feet in thickness and is overlapped by restricted or normal marine sediments which may range up to 3000 feet in thickness before another such assemblage recurs. Thus the breccia-conglomerate carbonate has

unique sedimentary structure features which assume strong diagnostic indications of regional unconformities and their stratigraphic position.

(5) Regional unconformities, therefore, are extremely important in checking regional correlations of strata and determining their geographic limits due to resultant stratigraphic hiatuses. In terms of reference to concepts of Sloss *et al.*, (1949) and the American Stratigraphic Commission generally, the procedure herein is based on the use of objective time-stratigraphic units and markers which are discriminated from their objective but undiscriminated criteria.

(6) Another observation which seems most pertinent to our understanding of transgressions representing shale/carbonate/evaporite environments of deposition is the almost inevitable occurrence of the basal carbonate "platform." The apparent universality of this phenomenon may be readily appreciated by referring to correlation charts representing stratigraphic-environmental successions in other countries similar to those successions discussed herein. My personal explanation of this phenomenon is that shallow-water marine transgressions, especially under tropical or subtropical climatic conditions and particularly onto carbonate terrains, will almost invariably develop beach and near-shore carbonates and other strandline sediments similar to some of the modern sediments I have seen in the Persian Gulf area. Failure to recognize regional unconformities represents failure to utilize and understand all the various pertinent criteria. This is an age-old problem with geologists which, in the past, has led to some of the most violent disagreements among some of the most famous geologists. Basically, the problem is: Is this contact a diachronic facies horizon, thus supporting the interpretation of contemporaneity, or is it an unconformity, thus suggesting superposition? We must, therefore, take full cognizance of this problem and, if or when the occasion arises, be prepared to simultaneously entertain both sides of the argument before drawing final conclusions.

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REFERENCES

Andrichuk, J.M. and Wonfor, J.S., 1954, Late D vonian geologic history in Stettler area, Albert Canada: Am. Assoc. Petroleum Geologists Bul v. 38, p. 2500-2536.

Belyea, H.R., 1964, Upper Devonian—Part II, Geological history of western Canada: Albe Soc. Petroleum Geologists, p. 66-88.

———, 1955, Cross-sections through the Devoni System of the Alberta Plains: Canada Geol. S vey Paper 55-3, p. 29.

———, 1958, Devonian sediments in southe Alberta and correlations with northweste Montana, *in* Beartooth uplift and sunlight bas Billings Geol. Soc. Guidebook, 9th Ann. Fi Conf., Aug. 1958, p. 49-56.

Branson, E.W., 1944, Devonian of northeast Missouri, *in* Symposium of Devonian Str graphy: Illinois Geol. Survey Bull. 68-A, 174-181.

Crickmay, C.H., 1952, Discrimination of l Upper Devonian: Jour. Paleontology, v. 26, 585-609.

———, 1954, Paleontological correlation of Point and equivalents, *in* western Canada s mentary basin—a symposium: Am. Assoc. Pe leum Geologists, p. 143-158.

DeMille, G., Shouldice, J.R., and Nelson, H. 1964, Collapse structures related to evapor of the Prairie Formation, Saskatchewan: G Soc. America Bull., v. 75, p. 307-316.

Grayston, L.D., Sherwin, D.F., and Allan, J 1964, Middle Devonian, *in* Geological histor western Canada: Alberta Soc. Petroleum G ogists, p. 49-59.

Griffin, D.L., 1965, The Slave Point, Beave Lake and Muskwa formations of northeas British Columbia and adjacent areas: Bri Columbia Dept. Mines Petroleum Res. Bull. p. 90.

Ham, W.E., and Wilson, J.L., 1967, Paleo epeirogeny and orogeny in the central Un States: Am. Jour. Sci., v. 265, p. 332-407.

Harris, C., 1963, Relationship of the Exshaw Formation in Alberta: Univ. Washington, unpub. M.S. thesis.

Heckel, P., 1965, Apparent structural control of Tully Limestone deposition in the Devonian Catskill delta complex of New York State (abs.), *in* Abstracts for 1965: Geol. Soc. America Spec. Paper 87, p. 76.

Hite, R.J., 1960, Stratigraphy of the saline facies of the Paradox Member of the Hermosa Formation of southeastern Utah and southwestern Colorado, *in* Geology of the Paradox Basin fold and fault belt: Four. Corners Geol. Soc., 3d Field Conference, 1960, p. 86-89.

Koch, N.G., 1959, Correlation of the Devonian Swan Hills Member, Alberta: Univ. Alberta, unpub. M.S. thesis.

Law, J., 1955, Geology of northwestern Alberta and adjacent areas: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 1927-75.

Parker, J.M., 1967, Salt solution and subsidence structures, Am. Assoc. Petroleum Geologists Bull., v. 51, p. 1929-1947.

Porter, J.W., 1955, Madison complex of southeastern Saskatchewan and southwestern Manitoba: Alberta Soc. Petroleum Geologists Jour., v. 3, p. 126-130.

Sherwin, D.F., 1962, Lower Elk Point section in east-central Alberta: Alberta Soc. Petroleum Geologists Jour., v. 10, p. 185-191.

Sloss, L.L., Krumbein, W.C., and Dapples, E.C., 1949, Integrated facies analysis, *in* Sedimentary facies in geologic history: Geol. Soc. America Memoir 39, p. 91-123.

Storey, T.P., 1955, Age of the Ghost River Formation: Alberta Soc. Petroleum Geologists Jour., v. 3, p. 157-158.

———, 1956, Evidence for pre-Mississippian erosion of Devonian in Manitoba: Alberta Soc. Petroleum Geologists Jour., v. 4, p. 186-187.

———, 1959, Basal Upper Devonian strata between Drumheller and Rocky Mountains, Alberta (abs.), *in* Alberta Soc. Petroleum Geologists, 9th Ann. Field Conf., Sept. 1959, p. 91.

———, and Patterson, J.R., 1959, Stratigraphy—traditional and modern concepts: Am. Jour. Sci., v. 257, p. 707-721.

van Hees, H., 1956, The Elk Point Group, a discussion: Alberta Soc. Petroleum Geol. Jour., v. 4, p. 29-39.

Welsh, J.E., 1963, Paradox basin salt disconformities (and their relationship to oil production), *in* Oil and gas possibilities of Utah, reevaluated: Utah Geol. and Mineralog., Survey Bull. 54, p. 487-494.

Wilson, J.L., 1955 Devonian correlations in northwestern Montana, *in* Sweetgrass arch—disturbed belt, Montana: Billings Geol. Soc. Guidebook, 6th Ann. Field Conf., Sept. 1955, p. 70-77,