Salt Deposits of Canada

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ABSTRACT

The major salt deposits of Canada are located in Nova Scotia, New Brunswick, Ontario, Manitoba, Saskatchewan, and Alberta. Salt is also known to occur in Newfoundland, Prince Edward Island, British Columbia, and the Northwest Territories. At the present time salt is produced from three rock salt mines, one located at Pugwash, Nova Scotia, and two in Ontario at Ojibway and Goderich, and from ten brining operations, with three of these located in the Prairie Provinces, one in Nova Scotia, and the remainder in Ontario.

Salt springs and seepages were the first indications of the widespread occurrences of salt deposits in Canada. In the early history of the country the brine springs were a source of salt for Indians, explorers, traders, trappers, and settlers. Later, wells which were drilled either for water or in oil exploration penetrated and located brine-bearing strata and/or rock salt deposits.

The major known rock salt deposits of Canada which occur in three large evaporitic basins belong to three different geological ages. The deposits of the Maritime Provinces and Newfoundland occur in a Carboniferous basin, in the Windsor and Albert formations of Mississippian age. This basin is divided into three parts, the Central, the Moncton, and the Cumberland basins. The known economic salt deposits are found in the Cumberland and Moncton basins. Due to complex folding, the aggregate thicknesses of the deposits in different areas are extremely variable, ranging from a few feet to as much as 1,500 feet.

The salt deposits of Ontario are found in the Salina formation of Silurian age. The Windsor-Sarnia-Goderich deposits are located on the east flank of the Michigan basin, while the Chatham deposit is believed to lie in a westward extension of the Appalachian basin. The salt beds located in the Michigan basin have a maximum aggregate thickness of as much as 700 feet, and in the Chatham basin salt thicknesses may exceed 200 feet.

In Western Canada the salt was deposited in a northwest-southeast trending basin, known as the Elk Point Basin, which extended from northern and east-central Alberta, southeast across Saskatchewan, into southwestern Manitoba, northern North Dakota, and northeastern Montana. The deposits which are of Middle Devonian age, contain major amounts of potassium salts in that part of the basin located in Saskatchewan, Manitoba, North Dakota, and Montana. A maximum aggregate thickness of as much as 1,000 feet of salt was deposited in the Alberta basin during the Middle Devonian, while the equivalent Prairie Evaporite formation in Saskatchewan may have a maximum thickness in excess of 700 feet. In the central part of the basin in Saskatchewan there may be two additional salt beds, occurring in two formations above the Prairie Evaporite, which have an aggregate maximum thickness of 200 to 250 feet.

Because of the limited data available for the Northwest Territories, the areal extent of the salt deposits in that region is not known. However, information obtained from exploratory

drilling for oil in the Norman Wells and lower Mackenzie basin areas, has indicated the existence of salt beds, having thicknesses from 100 to 250 feet. Salt also has been encountered north of Great Slave Lake. The age of these salt occurrences range from Cambrian to Ordovician, and some may be Devonian in age. In British Columbia neither the age nor the areal extent of the salt deposit, which is believed to exist about 45 miles east of Prince Rupert, has been established.

INTRODUCTION

The subject matter of this paper covers the geology of the major salt basins and deposits in Canada (Figure 1). A brief description of the saline springs associated with the salt deposits also is given, for these were an important source of salt for the Indians, explorers, traders, trappers, and settlers during the early history of the country.

The known economic salt deposits are located in three major evaporitic basins. The deposits of the Maritimes occur in sub-basins located in a large Carboniferous basin. The Ontario deposits, which are of Silurian age, are found on the eastern flank of the Michigan basin and in a northwestern extension of the Appalachian basin which possibly joined the Michigan basin. In Western Canada the major deposits are located in the Elk Point basin which was in existence during Middle Devonian time.

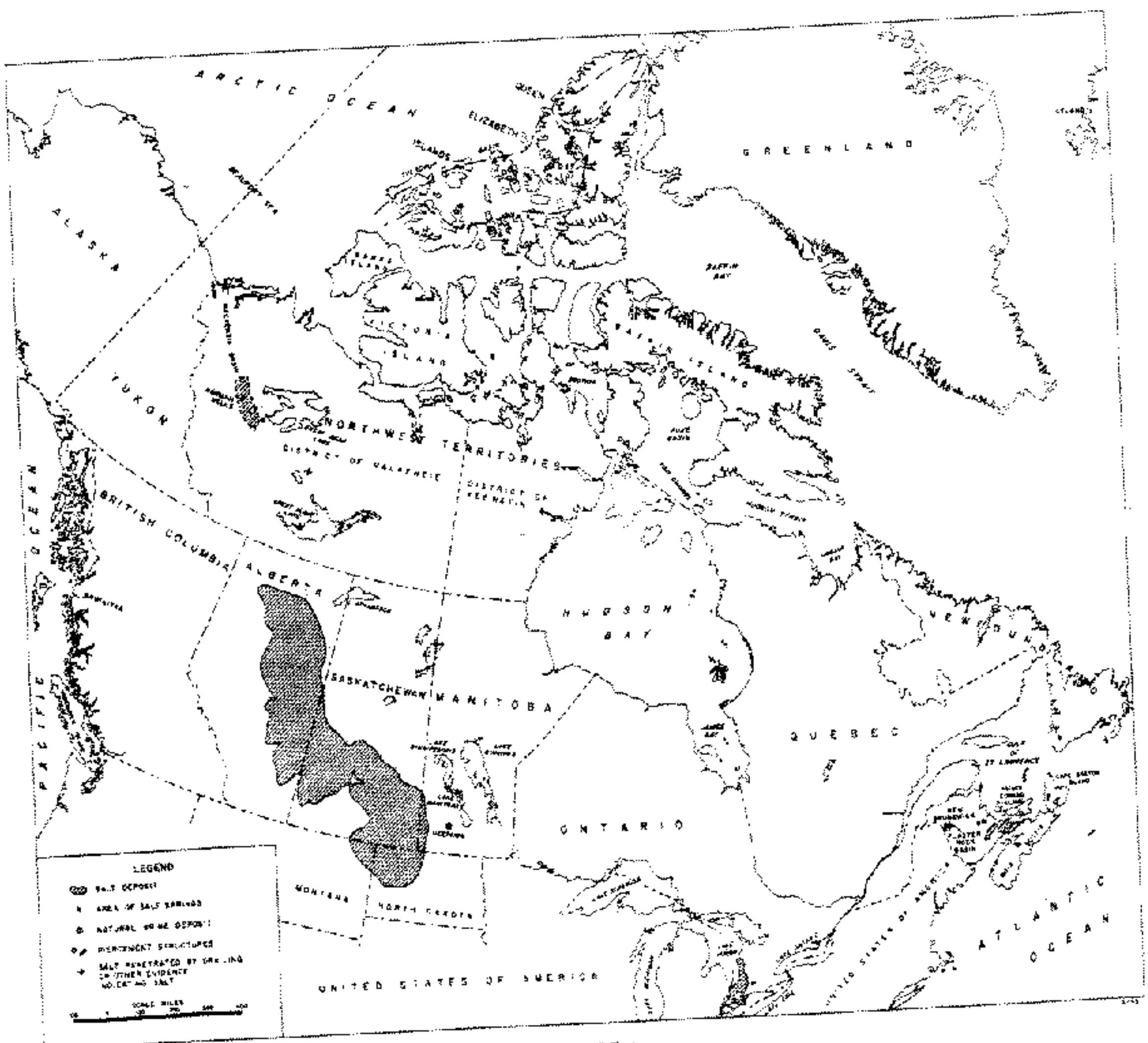

FIGURE 1
LOCATION OF SALT DEPOSITS AND OCCURRENCES IN CANADA

Salt deposits occur in the Northwest Territories in the Norman Wells and lower Mackenzie valley areas, but due to the paucity of exploratory drill holes the extent of these has not been established. In some of the Arctic Islands there are piercement structures which may be underlain by salt, but only drilling will prove or disprove this. In British Columbia a salt occurrence of unknown magnitude is located near Kwinitsa north of the Skeena River, about 45 miles east of Prince Rupert.

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SALT DEPOSITS OF THE MARITIME PROVINCES AND NEWFOUNDLAND

That salt deposits underlay widespread areas of the Maritime Provinces was first indicated by the numerous saline springs. The areas in which brine springs occur are shown in Figure 2. In Nova Scotia brine springs are located in five separate districts, as follows: (a) Cape Breton District, (b) Antigonish District, (c) Kemptown District, (d) Oxford District, and (e) Windsor District. In New Brunswick the main areas of saline springs are located northeast of Sussex and at Salina. Salt springs are also known to occur in the vicinity of Tobique River in the Plaster Rock basin located in the west part of New Brunswick. In Newfoundland saline springs are to be found in the southwestern section of the island along the eastern shore of St. Georges Bay.

In 1912 a well drilled for water in the Malagash peninsula of Nova Scotia encountered strong brines. The discovery of the brine eventually led to exploratory drilling for rock salt deposits in the area in 1917. The earliest discovery of rock salt was in Nova Scotia at a location about 7 miles northeast of Malagash station where a shaft was sunk in 1918. In New Brunswick in 1921 a thick bed of rock salt was discovered in a drill hole at Gautreau, approximately 8 miles south-southeast of Moncton. Since then a number of exploratory oil wells have encountered salt deposits in different areas, not only in New Brunswick and Nova Scotia, but also in Prince Edward Island.

GENERAL GEOLOGY

The salt deposits of the Maritime Provinces and Newfoundland occur in formations of Mississippian age. The deposition of Carboniferous sediments occurred in a large basin, occupying an area approximately 300 by 500 miles, covering parts of Quebec, Newfoundland, New Brunswick, Nova Scotia, and Prince Edward Island. The greater part of the Carboniferous basin lies under the Gulf of St. Lawrence (Figure 3).

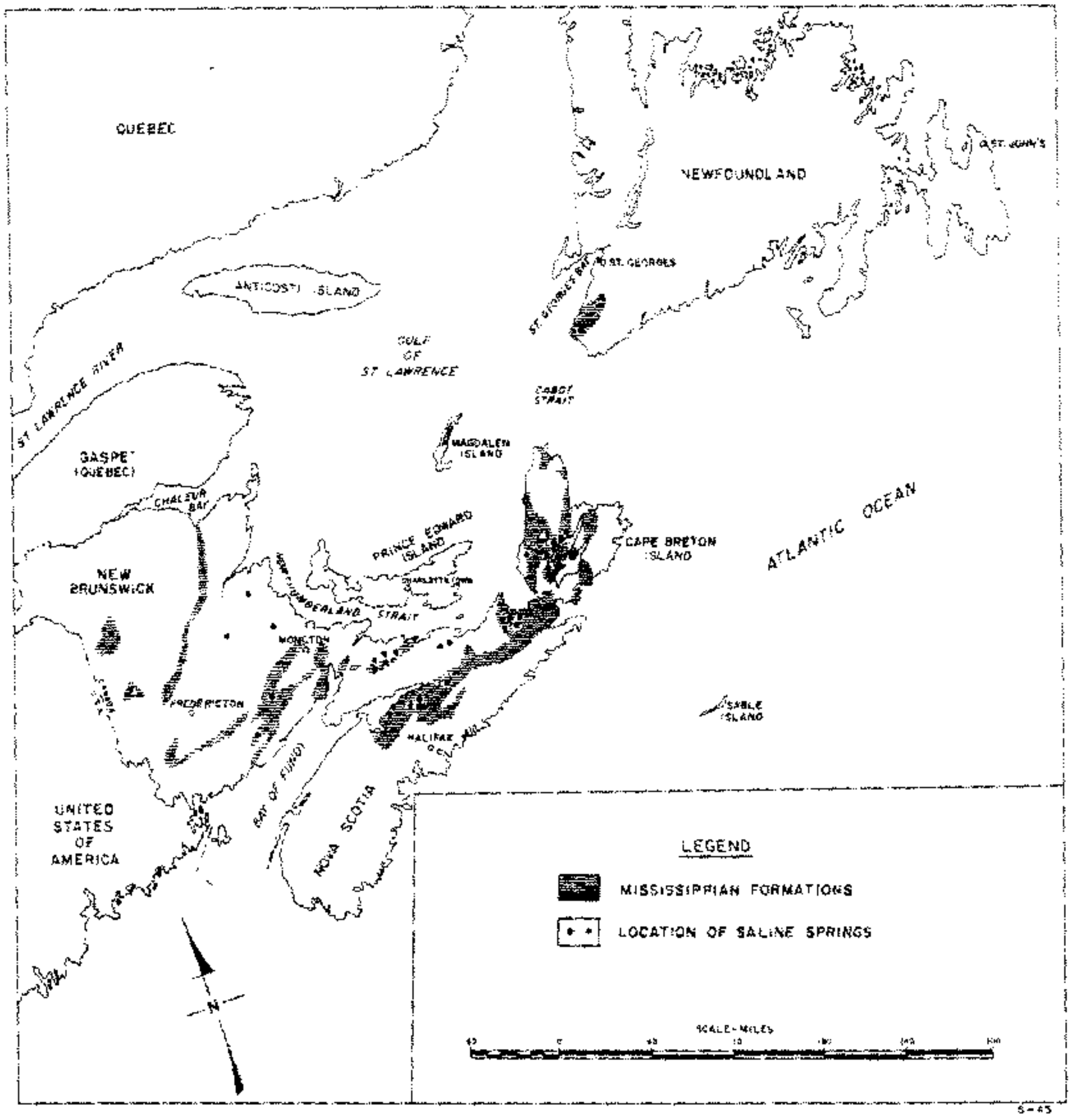

FIGURE 2

LOCATION OF SALINE SPRINGS IN THE ATLANTIC PROVINCES

STRATIGRAPHY

The sediments of the Carboniferous basin, which range from the Mississippian to the Pennsylvanian, include great thicknesses of conglomerate, sandstone, siltstone, shale, and limestone. Red beds are characteristic of both the Mississippian and the Pennsylvanian in this basin. In the Mississippian, locally there are accumulations of gypsum, anhydrite, and salt, and in the Pennsylvanian formations are composed entirely of continental sediments, while those of the Mississippian period consist of both continental and marine.

A generalized table of formations for the whole Carboniferous basin is given in Figure 4. Not all of the formations listed in the table are to be found in all localities of the basin.

As far as is known Permian formations do not occur in New Brunswick or Nova Scotia, but some of the surface beds on Prince Edward Island, which is nearer the centre of the Carboniferous basin, have been called Permian by some workers. Gussow (1953), however, believes some of these to be late Pennsylvanian.

Salt deposits occur in the Windsor group and locally in the Albert formation of the Horton Series in New Brunswick.

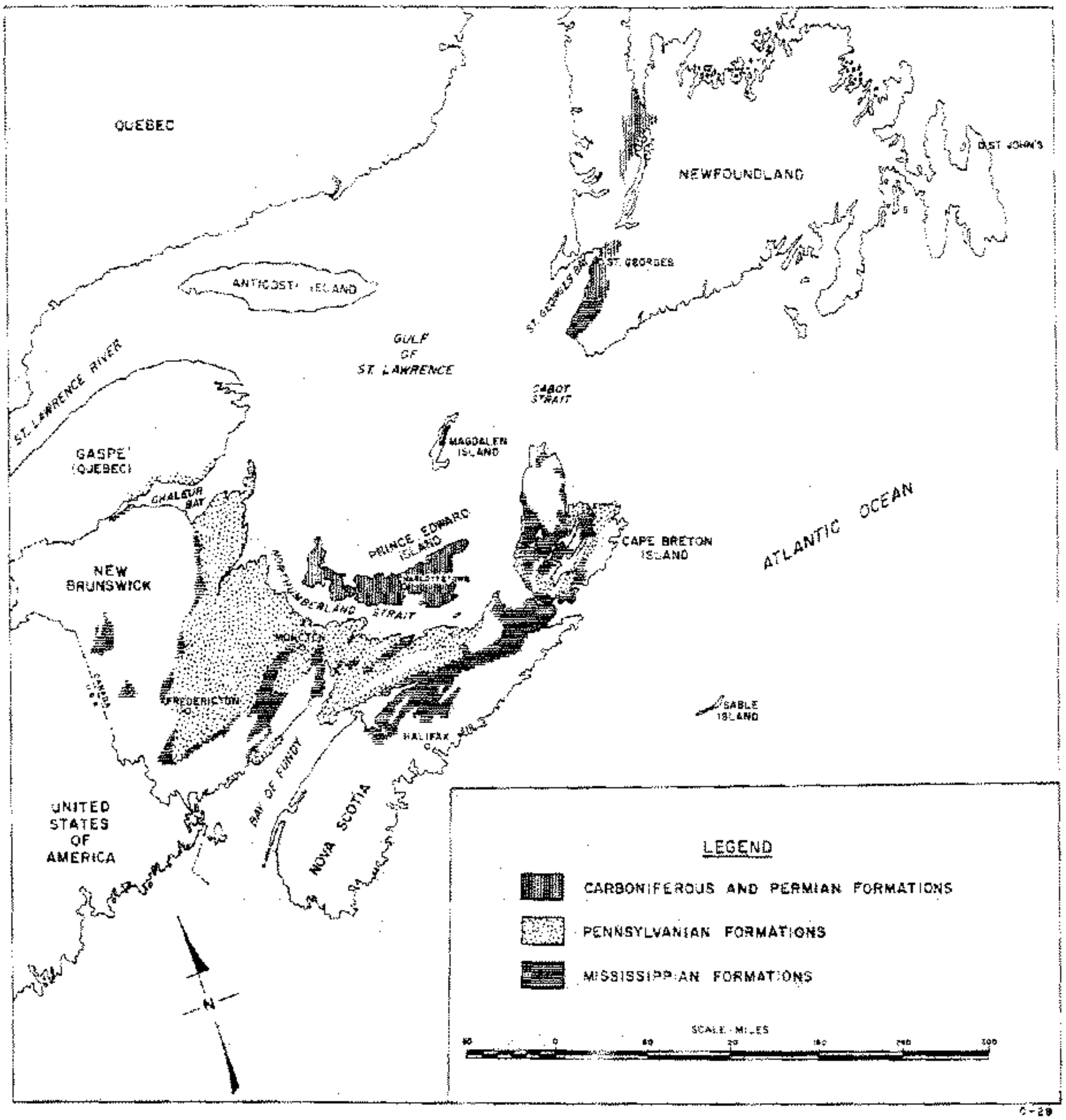

FIGURE 3

DISTRIBUTION OF CARBONIFEROUS FORMATIONS IN THE ATLANTIC PROVINCES

The Albert Formation

The Albert formation outcrops along the Kingston Uplift in the Sussex and Hillsborough areas, and along the north side of the Caledonian highlands. The location of the Albert salt basin also known as the Weldon-Gautreau basin, is shown in Figure 8.

The Albert formation consists of grey, rudaceous, lutitic sediments, and evaporites locally (Hamilton, 1961). Salt occurs in the upper part of the formation. Aggregate thicknesses of salt penetrated by bore-holes range from 235 to 1606 feet.

The Windsor Group

The Windsor group is comprised predominantly of marine sediments, consisting of red shale, fossiliferous limestone, gypsum, and salt.

TABLE OF FORMATIONS

(After Gussow, 1953)

Period	Group	Formation	Lithology	Maximum Thickness
Triassic			Continental red sandstones and conglomerates. Basalts (Nova Scotia).	700' $\pm$
			Major Unconformity	
Permian		?		
Pennsylvanian	Pictou (6700' $\pm$)	↑	Prince Edward Island (Surface formations)	5000' $\pm$
		Tormentine	Red sandstone, with siltstone, shale, and conglomerate.	500' $\pm$
		Richibucto	Predominantly buff feldspathic sandstone, green siltstone, some coal. Basal shale-pebble conglomerate.	1000' $\pm$
		- - - - - -	- - - - - - - - Disconformity - - - - - - - -	- - - - - -
		Scoudouc	Feldspathic sandstone, shale, conglomerate, buff to red.	1500' $\pm$
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		Salisbury	Red shale and siltstone, some sandstone and conglomerate. Thin coal seams.	2500' $\pm$
	Cumberland	Hiatus?	Conglomerate, sandstone, shale, coal.	9000' $\pm$
			Unconformity	
	Riversdale	Boss Point	Grey quartzose sandstone and quartz-pebble conglomerate. Fossil plants.	6200' $\pm$
		Enrage	Red sandstone, grit, shale, comglomerate.	1350' $\pm$
			Hiatus	
			Major Unconformity	
	Canso	Shepody	Grey-green and red sandstones and siltstones. Fossil plants	2320'
		Maringouin	Red Shale and siltstone (Marine to continental). (Canso in Nova Scotia shale and limestone.)	2600' $\pm$

TABLE OF FORMATIONS (Continued)				
Period	Group	Formation	Lithology	Maximum Thickness
Mississippian	Windsor ?	Hiatus	Predominantly Marine	
		Upper		
		Subzone E		
		Subzone D		
		Subzone C	Fossiliferous grey limestone and sandstone.	24'
		Lower		
		Subzone B	Fossiliferous limestone, gypsum, anhydrite, rock salt, shale and conglomerate. Finely laminated calcareous anhydrite to anhydritic argillaceous limestone.	1000' 175'
			Disconformity	
	Moncton	Hillsborough	Red sandstone, and conglomerate, shale. Basal ash bed.	2900' ±
			Unconformity	
	Horton Series / Moncton	Weldon	Red siltstone, shale, conglomerate.	5000' ±
	Horton Series	Albert	Grey-green to dark grey shale with interbedded siltstone, sandstone, limestone, conglomerate. Bituminous sandstones and oil shales. Locally rock salt near top of section. Fossil fish and plants. Marine in part.	5500' ±
		Memramcook	Red shale, sandstone, conglomerate. Fossil plants.	7000' ±
			Major Unconformity	
Pre-Carboniferous			Devonian granites, and other intrusives invading Devonian, Silurian, and Ordovician formations which comprise great thicknesses of black slate and volcanics with interbedded quartzites and limestone. Precambrian granitic gneisses, graphitic and greenstone schists.	

Figure 4. Generalized table of formations.

Bell (1929) of the Geological Survey of Canada, divided the Windsor Group in the type area into Lower Windsor, consisting of Subzones A and B, and Upper Windsor of Subzones C, D, and E, on the basis of fossil evidence. The salt deposits occur in Subzone B which is divided into four members in the following sequence:

Member 4 -- red shale, sandstone, conglomerate

Member 3 -- massive gypsum (anhydrite), salt

Member 2 -- red shale, with or without gypsum stringers, limestone nodules

Member 1 -- limestone, generally dense, though in places crystalline, bedding varies from thinly laminated to massive, grey, locally brownish or pink, fossilferous

All four members of Subzone B are not universally present in all localities, and the thick nesses are variable.

STRUCTURE AND GEOLOGICAL HISTORY

The main structural features associated with the Carboniferous basin are shown in Figure 5.

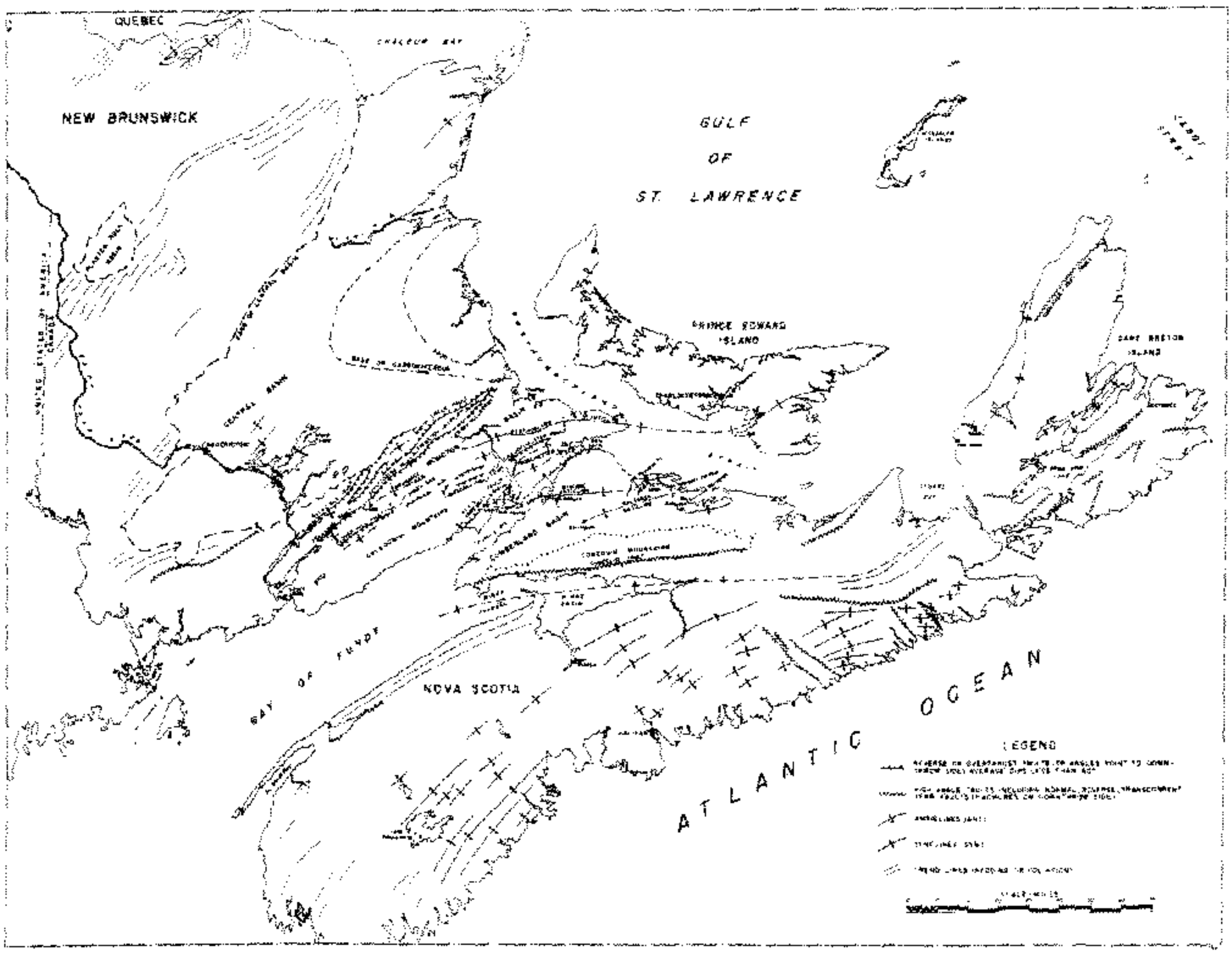

FIGURE 5
STRUCTURAL MAP OF THE MARITIME PROVINCES

At the beginning of Carboniferous time local folds of older rocks constituted mountain ridges between separate basins of Carboniferous deposition. Pre-Carboniferous rocks which formed such features as the Caledonia Mountains, the Cobequid Mountains, and other uplifts like them, were the source rocks of the Carboniferous sediments. During Mississippian time the sea transgressed and occupied parts of the area.

The major structural features of the Carboniferous basin are the Central basin, the Moncton basin, and the Cumberland basin. The Central basin occupies a triangular area bounded on the northwest by a mass of older rocks which extends from Bathurst to McAdam and on the south by the Kingston Uplift which brings Mississippian and older formations to the surface. The Moncton basin lies between the Kingston Uplift to the north and the Caledonia Mountains to the south, and the Cumberland basin is bounded on the north by the Caledonia Mountains and on the south by the Cobequid Mountains.

Movements during the deposition of the Carboniferous caused local folding and faulting, so that the basins, particularly the Moncton and Cumberland basins, are composed of a series of anticlinal and synclinal folds. Faulting has occurred both parallel to and at right angles to the folds.

The Kingston Uplift is a horst block which forms a prominent topographic feature north of Moncton. The Mississippian and older rocks, which are exposed, are considerably distorted by subsidiary folds and faults.

According to Gussow (1953) the dominant structural pattern in the Mississippian formations is controlled by four master thrust fault systems: (1) the Belleisle fault; (2) The Peekaboo-Petitcodiac-Berry Mills fault; (3) the Clover Hill, Peck Creek-Dorchester fault system along the north flank of the Caledonia Mountains; and (4) the Harvey-Hopewell fault, southeast of the Caledonia massif (Figure 5). On the northwest side of the Caledonia Mountain buttress the overthrusting is from the northwest and on the southeast side from the southeast relative to the down thrust blocks.

SALT DEPOSITS OF THE CUMBERLAND BASIN

The Cumberland basin lies between the exposed pre-Carboniferous ridge that forms the Cobequid Mountains to the south and the concealed extension of the Caledonia Mountains to the north. Mississippian rocks are brought to the surface along two major anticlines, the Malagash and the Minudie anticlines, and a few less extensive anticlines in the area between Malagash and Pugwash. The Malagash anticline also has been referred to as the Claremont anticline. Elsewhere in the basin the Mississippian is buried by a thick covering of younger formations. Along the Malagash anticline Mississippian rocks are exposed from Springhill to Malagash Point, a distance of about 42 miles, over a width of approximately one mile. The Minudie anticline extends from Nappan westwards across Cape Maringouin to Albert, New Brunswick, exposing Mississippian formations for a distance of about 12 miles in Nova Scotia.

Salt deposits in the Cumberland basin which have been exploited, or are being exploited, are located near Malagash, Pugwash, and Nappan, all in Nova Scotia.

The Malagash Deposit

The Malagash salt mine, which was in production from 1918 to 1959, is located on the north shore road of Malagash Peninsula, about 8 1/2 miles east of Wallace and 6 miles north of Tatamagouche in Colchester County.

In 1912, Peter Murray, while boring for water on his farm on the north shore of Malagash Peninsula, about 7 miles northeast of Malagash station, obtained a flow of salt water at about 80 feet. In 1917 exploration for salt was begun in the area, and twelve holes were sunk in an area of about one-tenth of a square mile. Brine was encountered in six of the wells at depths varying from 85 to 113 feet below the surface. Diamond drilling proved the presence of salt in place at depths from 94 to 173 feet below the surface. A shaft was sunk east of the diamond drill hole and encountered salt at a depth of 85 feet.

Geology and Structure

The Malagash salt deposit occurs in an upthrust fault block of Windsor evaporites on the south limb of the Malagash anticline (Figure 6). The mine lies to the east of a normal transverse fault. According to M. F. Bancroft (1957) the upthrow of the east side of this fault is estimated to be 500 feet or more. Faults apparently exist on the north and south sides of the block and to the east. The faults on the north and south sides are thrust planes, striking parallel to the anticlinal axis and dipping inward to converge at depth.

The salt beds, which generally strike east to northeast and dip to the south at 40 to 45 degrees, are crumpled locally and thickened by isoclinal folding. The layered salt deposit has a thickness of 300 feet or more. The layers range in color from pure white to very dark grey, and vary greatly in width from 2 inches and upwards. The Malagash mine operated mainly on two seams, the McKay and the Lucas. There is a third intermediate salt seam, the Chambers. These beds are conformable, never being more than 100 feet apart. Where mined, the beds range in thickness from 4 to 40 feet, being thickest on the crests of minor folds. In later years only the Lucas seam was mined. This seam is made up of three beds, the bottom consisting of pure white crystalline halite, the intermediate of interstratified salt, gypsum, and anhydrite, and the top one of crystalline white halite, with interstratified layers of dark salt. On the structural contour map of the base of the Lucas seam, the contours overlap to form a complex pattern. The folds take attitudes characteristic of salt doming, the troughs and crests widen toward the top of the deposit and narrow to recumbent folds at depth. At the mine the salt beds are truncated and overlain by 85 feet of clay. Mining commenced at 110 feet and was carried out to a depth of 1,250 feet. The seams were mined along strike for about one-half mile until the widths came down to 4 feet, when mining was discontinued.

The soluble salts from the deposits are predominantly sodium chloride, and the insoluble impurities consist chiefly of anhydrite, silica, and organic matter. Bancroft (1957) reports that thin sections of the salt display microscopic crystals of anhydrite and quartz prisms. There is evidence of recrystallization of the salt in some layers. Potassium chloride (sylvite) and magnesium potassium chloride (carnallite) are present in three well defined zones bearing persistent but small amounts of these minerals. The width of these zones ranges from a few inches to 5 feet or more. Potassium minerals also may occur in small isolated lenses.

The Pugwash Salt Deposit

When operations were suspended at the Malagash mine in 1959, the Malagash Salt Company Limited began mining salt deposits at Pugwash, which is located approximately 20 miles to the west-northwest of the Malagash mine area.

Geology and Structure

North of the Malagash anticline there are a number of folds having approximately the same trend as the Malagash anticline. Small areas of Windsor rocks are exposed in the central part of two anticlinal folds and on crests in the area west of Wallace Harbor.

In the Pugwash area the Windsor rocks form a belt approximately 3 1/2 miles long and slightly over one-half mile wide, which trends North 57° East. This exposed area of Windsor rocks is apparently a dome in the Windsor formation, lying transversely across the Pugwash anticline which trends North 85° East from Pugwash. The domal structure is located on the northern limb of the anticline. The block of Windsor beds has been upthrust from the south along a fault trending approximately North 75° East.

Drilling, carried out by the Malagash Salt Company in 1953 in the Pugwash area, indicated the existence of a slightly arched, layered deposit of salt having an extent of 175 acres. At the eastern boundary of the area the salt is almost absent but the deposit thickens rapidly toward the southwest, having a thickness of 500 feet at a distance of slightly over one-half mile from the zero isopach (Figure 7). Production is from salt beds at the 630 foot level. It is estimated that at least 80 million tons of salt are recoverable from this particular area.

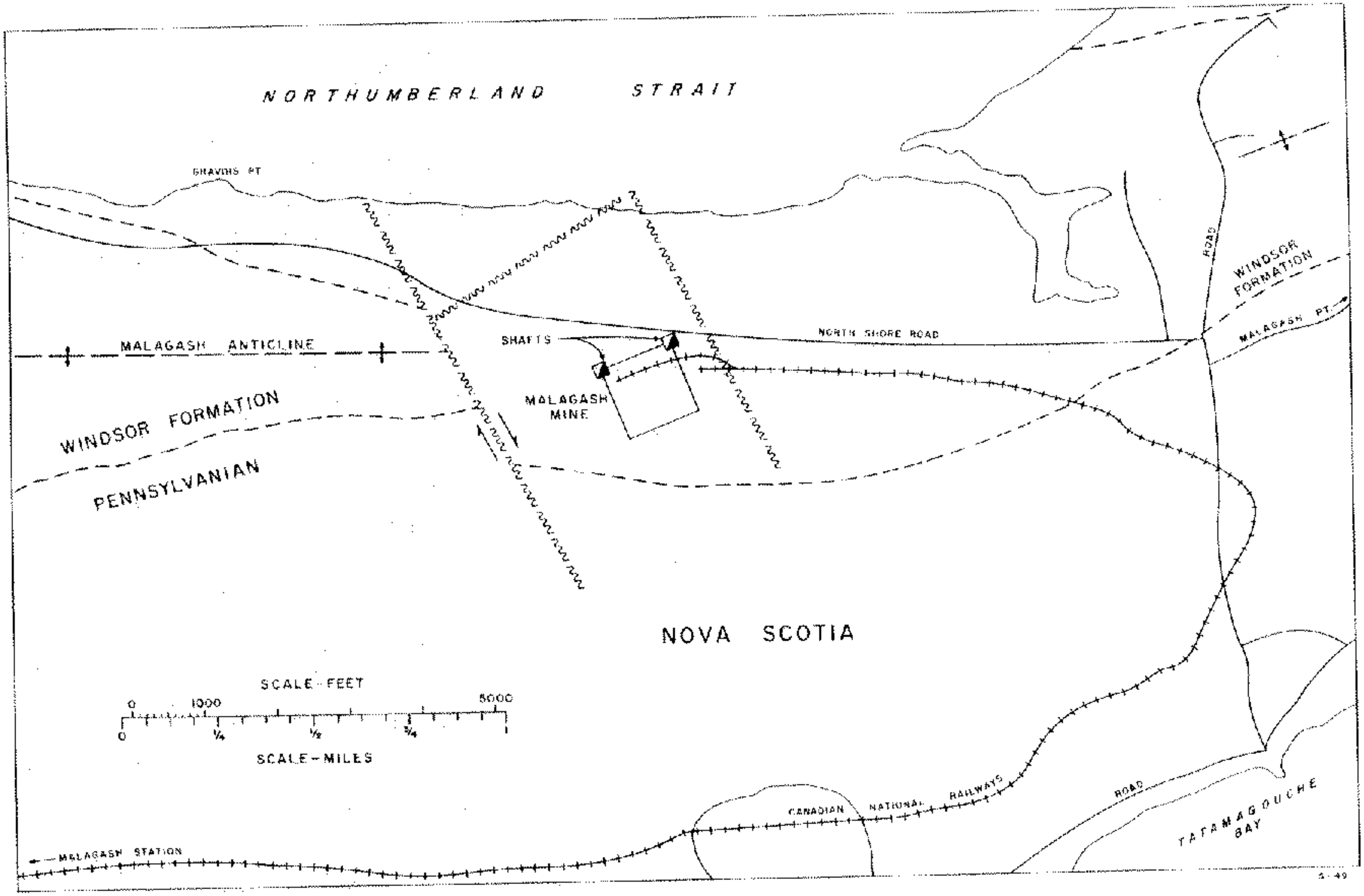

FIGURE 6

MAP OF THE MALAGASH SALT DEPOSIT AREA

(AFTER BANCROFT, 1957)

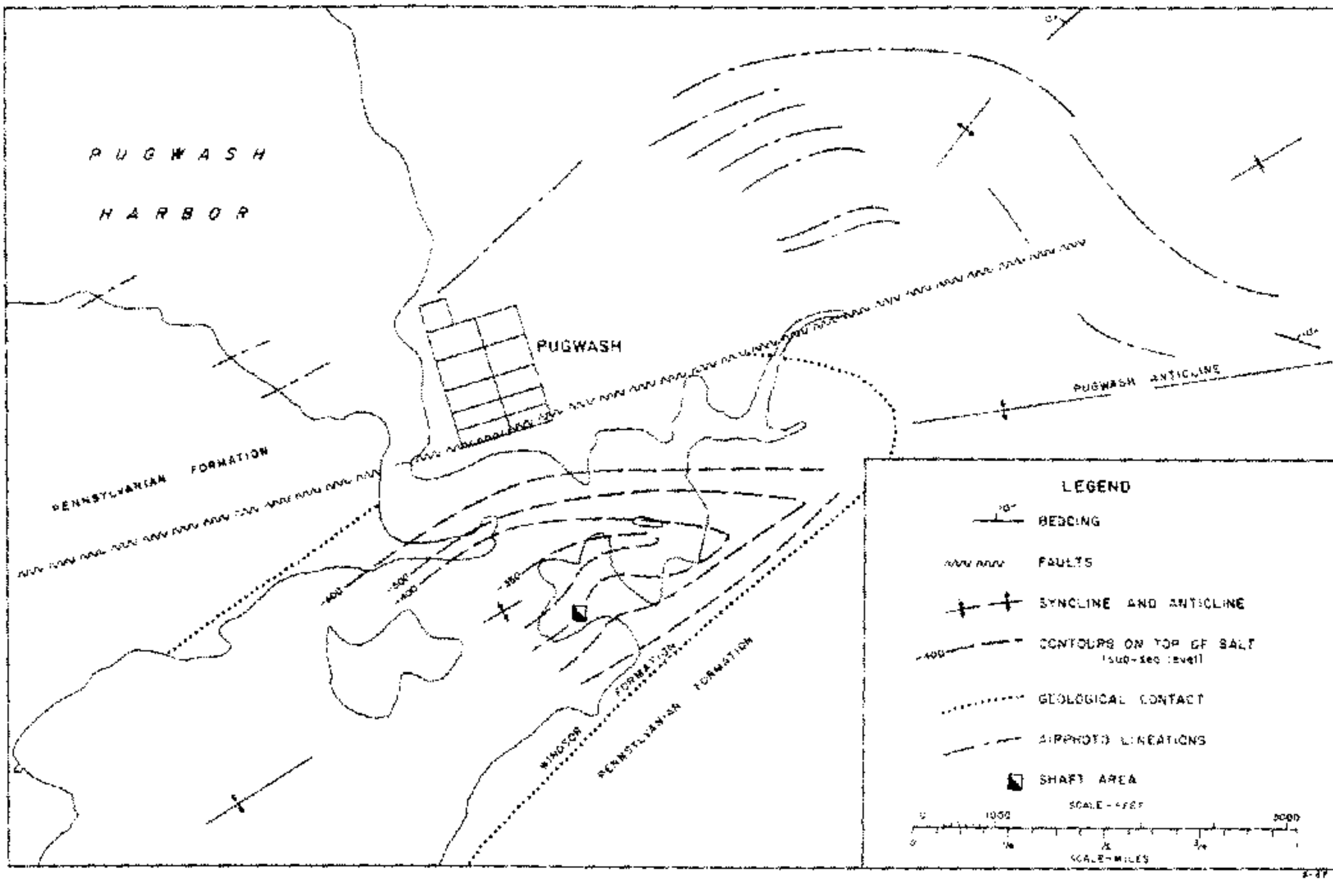

FIGURE 7
MAP OF THE PUGWASH SALT DEPOSIT AREA
IN THE PROVINCE OF NOVA SCOTIA
(AFTER BANCROFT, 1957)

Nappan Salt Deposit

The Nappan Salt deposit is located on the Minudie anticline along which Mississippian formations are exposed.

In 1931 International Petroleum Company's well Amherst No. 1, which was drilled near Nappan, encountered salt at a depth of 920 feet. This well, which went to depth of 4,132 feet, passed through 16 beds of salt, totaling 1,460 feet. From 0 to 920 feet, a series consisting chiefly of gypsum and anhydrite, associated with shale, sandstone, limestone, and grit was penetrated, and from 920 to 4,050 feet the series consisted predominantly of anhydrite and salt, interbedded with shale, sandstone, dolomite, and limestone. The thickest salt beds were encountered in the intervals from 2,550 to 2,850 feet, and from 2,990 to 3,490 feet. The great thickness of the salt strata and the large number of salt seams indicate that the structure is not a simple anticlinal structure, but a complex of folds. At Pink Rock near the centre of the Minudie anticline on the west side of Cape Maringouin, in an exposure of Mississippian strata, a gypsum bed shows well-marked flowage structures. There is further evidence of complex folding in Sun Oil Company's well, Sunoco No. 1, drilled in the Nappan area in 1945, which entered the salt zone at 1,360 feet and continued in it to a depth of 6,172 feet.

From 1942 to 1944 the Nova Scotia Department of Mines carried out a special investigation for salt and three holes were drilled at Nappan station. Here the top of the salt was encountered at depths of 772 feet and 880 feet.

In 1946 Maritimes Industries Limited (Sifto Salt Limited) drilled two holes at Nappan penetrating the top of the salt zone at 812 feet. A plant was installed and salt production began in

1947. The extraction of salt from the deposit is by brining from a thick salt bed that lies 1, 100 feet below the surface.

Salt beds are also known to occur in the Antigonish area.

SALT DEPOSIT IN CAPE BRETON ISLAND

The distribution of salt springs in Cape Breton Island indicate the general area of salt deposits (Figure 2).

Imperial Oil Limited's well, Imperial Port Hood No. 1, drilled in the Parish of Port Hood, Inverness County, encountered the salt zone at 6, 090 feet and continued in the series to 9, 660 feet. The section from 6, 090 to 6, 625 feet consists of beds of clear, translucent salt interbedded with shale, anhydritic siltstone, anhydrite, and minor beds of dolomitic and argillaceous limestone. In the interval from 6, 625 to 9, 660 feet there are at least 16 salt beds or seams.

Another well, Imperial Mabou No. 1, drilled approximately 3 miles south of Mabou station, encountered a salt-bearing zone 86 feet thick at a depth of 2, 260 feet in the Windsor formation. In this well the formation has only a total thickness of 405 feet, whereas in the Port Hood well the Windsor has a total thickness of 3, 693 feet. This difference in thickness and the lesser quantity of salt in the Mabou well probably indicates that it is located near the outer edge of this salt basin.

SALT DEPOSITS OF THE MONCTON BASIN

The Moncton basin lies between the Kingston Uplift to the north and the Caledonia Mountains to the south and extends eastward toward Northumberland Strait (Figure 5). As in the Cumberland basin the formations are folded into a number of anticlines and synclines. Major anticlines include the Smith Creek anticline, the Westmorland anticline, the Anagance axis, and the Urney anticline. In addition to these major folds there are subsidiary folds.

There is no salt production from the Moncton basin at the present time, but the occurrence of numerous brine springs; the salt beds intersected in exploratory drilling; and evidence obtained from gravity surveys, indicate the presence of extensive salt deposits.

The salt occurrences in the Moncton basin are located in three main sub-basins, namely, the Westmorland, the Sussex-Petitcodiac, and the Upham sub-basins (Hamilton, 1961).

Westmorland Sub-basin

Within the Westmorland sub-basin there are a number of sub-basins in which salt deposits occur. Deposits which more or less have been outlined by exploratory drilling include the Albert or Weldon-Gautreau and the Dorchester deposits. Other areas, in which salt deposits are indicated by gravity anomalies, are located at Baie Verte, Cookville, under Shepody Bay, and on the north side of the Tantramar fault at the east end of Cumberland Basin.

The Albert (Weldon-Gautreau) Salt Basin

The general outline of the Albert or the Weldon-Gautreau salt basin is shown in Figure 8. Salt occurs over an area of about 7 1/2 square miles in this structural basin which lies immediately north of Hillsborough. The rocks of the basin have been gently warped, forming a number of anticlines and synclines which strike in an east-northeasterly direction. The salt in the Albert basin is of Albert age.

Near Gautreau in Westmorland County, on the east side of the Petitcodiac River, about 8 miles south-southeast of Moncton, two exploratory wells encountered respectively, 489 feet and 890 feet of salt, the top of which in each case is about 1, 200 feet from the surface. The salt at Gautreau lies in a synclinal structure which plunges to the west. A well located on the west side of the Petitcodiac River and to the southwest of the Gautreau wells penetrated 898 feet of salt. The salt in this well lies in an anticlinal structure. Two other wells in the basin encountered salt zones, 1, 606 feet and 235 feet thick. The drill core at intervals shows that the beds have vertical or near vertical attitudes, which implies that the salt is locally folded. Evidence of local folding

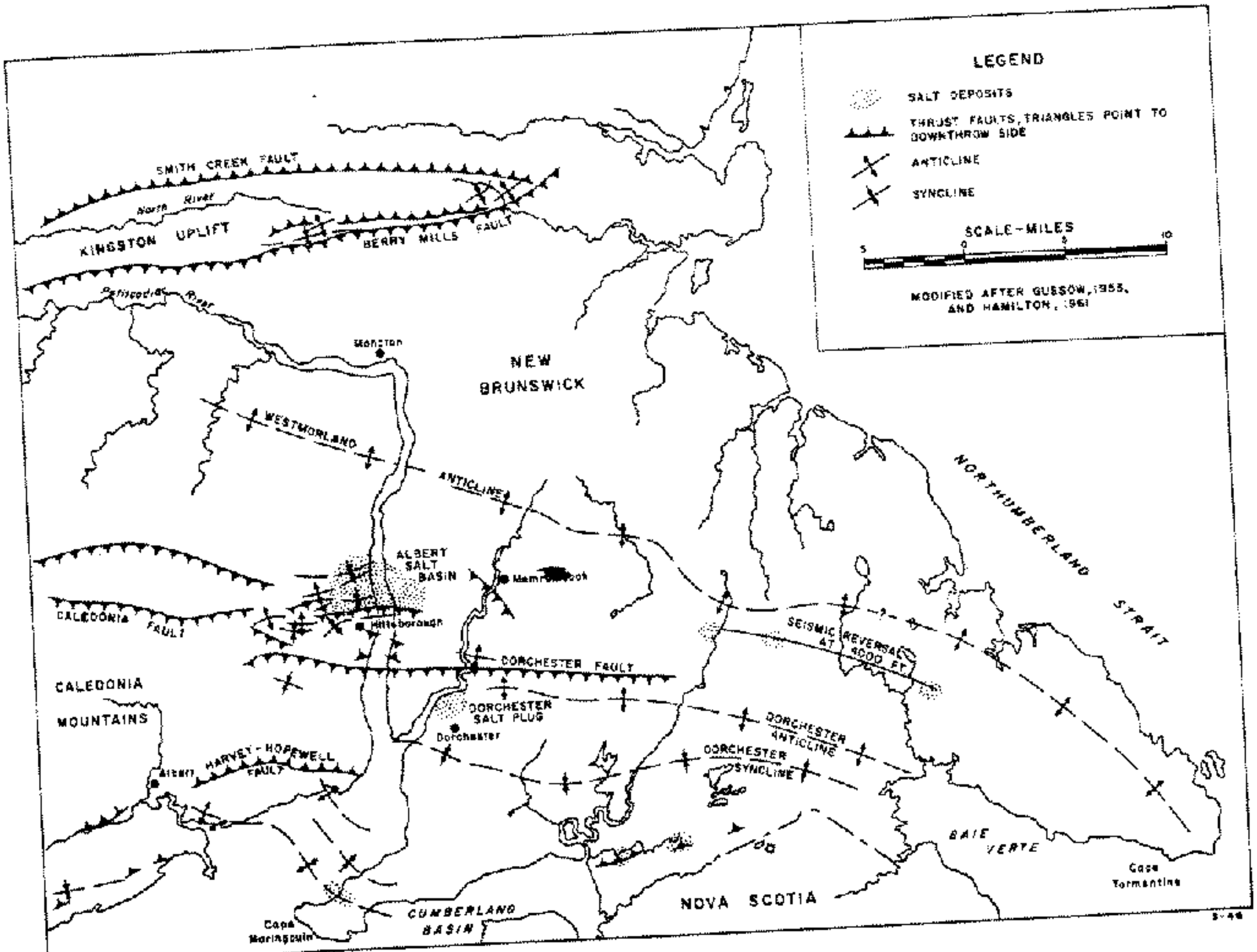

FIGURE 8

SALT DEPOSITS OF THE WESTMORLAND SUB-BASIN

is found in the gypsum at Hillsborough where locally folded and contorted zones lie between undeformed beds. It is estimated that over one billion tons of rock salt occur in the Albert basin.

The Dorchester Salt Deposit

The Dorchester Salt Deposit is located in the Westmorland sub-basin northwest of Dorchester at the western end of the Dorchester anticline along which Mississippian formations have been uplifted (Figure 8). The deposit is in the form of an elliptical plug, whose major and minor axes are respectively over 9,000 feet and approximately 6,000 feet long. The major axis of the plug strikes North 25° East. Drilling, carried out by the Shell Oil Company in 1949, intersected the plug between 395 and 4,810 feet. A total of 3,660 feet of rock salt was encountered. The salt, which is of Windsor age, has been calculated to represent a reserve of some 3 billion tons.

It has been suggested by Hamilton (1961) that the Dorchester plug is probably due to salt migration in post-Mississippian time along a fault plane which dips in a northerly direction at a steep angle.

Sussex-Petitcodiac and Upham Sub-Basins

The salt in the Sussex-Petitcodiac sub-basin is believed to be associated with the Anagance axis. Gravity data indicate that salt occurs along the axis for a distance of about 13 miles. Salt springs also occur in the general area. Hamilton (1961) believes that faulting has been the most effective factor in concentrating rock salt in the area. The Petitcodiac fault probably initiated the salt migration which continued on to form an elongated dome.

In the Upham sub-basin the most prominent salt springs are located in an area about one mile east of the Salina Post Office. The springs apparently occur along the Clover Hill fault and it is believed that the salt is carried up along the fault plane to the surface by circulating meteoric waters from a salt deposit of Windsor age, which probably lies south of the Clover Hill fault.

PLASTER ROCK BASIN SALT OCCURRENCE

Plaster rock basin is located in west central New Brunswick in Victoria County (Figure 5). It is a typical, undisturbed, structural basin covering an area of about 30 square miles. Rocks of both Pennsylvanian and Mississippian age occur in the basin. Hamilton (1961) believes that Plaster Rock basin was probably the first evaporite basin to develop during Windsor time, and that when the ancient Windsor sea withdrew to the south and east, marine waters remained in the basin to form the Windsor evaporites. There apparently was only one marine transgression of comparatively short duration in this area during the Carboniferous.

The occurrence of salt in the Plaster Rock basin is indicated by a salt spring located about one-half mile north of Plaster Rock on Salt Brook, a small tributary which enters Tobique River from the south.

PRINCE EDWARD ISLAND SALT DEPOSIT

In Prince Edward Island a rock salt deposit of undetermined size was encountered at a depth of 14, 200 feet during exploratory drilling for oil in Hillsborough Bay, on the southern side of the island. It is possible that this deposit is located along the crest of what may be an extension of the easterly plunging Dorchester anticline in New Brunswick.

SALT DEPOSITS OF ONTARIO

The salt deposits of Ontario occur in the southwestern part of the province in three main areas, namely, the Windsor, the Sarnia-Goderich, and the Chatham areas. Salt was first discovered in 1866 when a well drilled in exploration for oil at Goderich, Huron County, penetrated salt beds at a depth of 964 feet below the surface. Following this discovery further drilling was carried out in the area. In 1893 salt was discovered at Windsor. Salt is now recovered at Ojibway and Goderich by underground mining and by six brining operations located near Amherstburg and at Windsor, Sarnia, and Goderich. Estimated indicated reserves of salt in southwestern Ontario exceed 2, 000 billion tons.

GENERAL GEOLOGY

The distribution of salt in Ontario and the location of the areas of salt deposition in relation to the two main structural basins, the Michigan and Appalachian basins, in which salt deposition took place, are shown in Figures 9 and 10, respectively. These basins are separated by the northeast-trending Cincinnati arch and its northeast extension the Algonquin arch. The axis of the arch strikes northeast. In the Chatham area the axis of the arch is transversed by a minor east-trending syncline known as the Chatham sag.

The salt deposits of the Windsor, Sarnia, and Goderich areas are located on the east flank of the Michigan basin, and are a part of the Michigan basin salt deposits. The salt deposits of the Chatham area, however, as has been indicated by D. F. Hewitt (1962), possibly form the westward extension of the Ohio-New York salt deposits of the Appalachian basin. The Chatham beds probably form a link between the Michigan and Ohio salt basins.

The regional geology of southwestern Ontario is shown in Figure 11. The region is underlain by marine sedimentary strata of Cambrian, Ordovician, Silurian, Devonian, and Mississippian ages. These rocks rest upon the uneven surface of the Precambrian basement that outcrops to the north as a part of the Precambrian Shield. The formations dip to the southwest at a rate of 30 to 35 feet per mile. The sedimentary formations have an aggregate maximum known thickness of about 5, 877 feet. A generalized summary of the stratigraphy of the geological formations of southwestern Ontario is given in Figure 12. All the salt deposits of Ontario occur in the Salina formation of Silurian age.

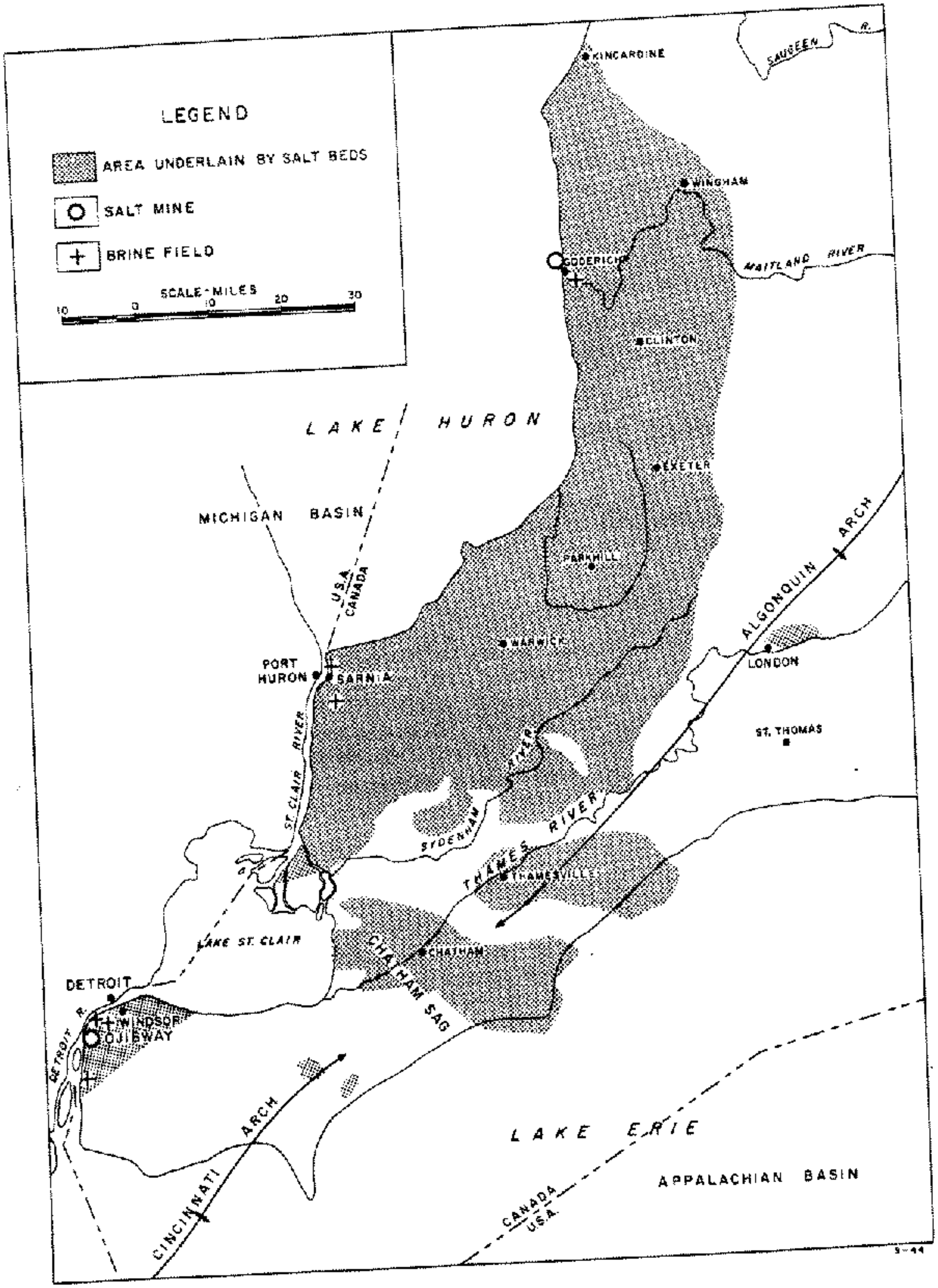

FIGURE 9

DISTRIBUTION OF SALT IN SOUTHWESTERN ONTARIO

(AFTER D.F. HEWITT, 1962)

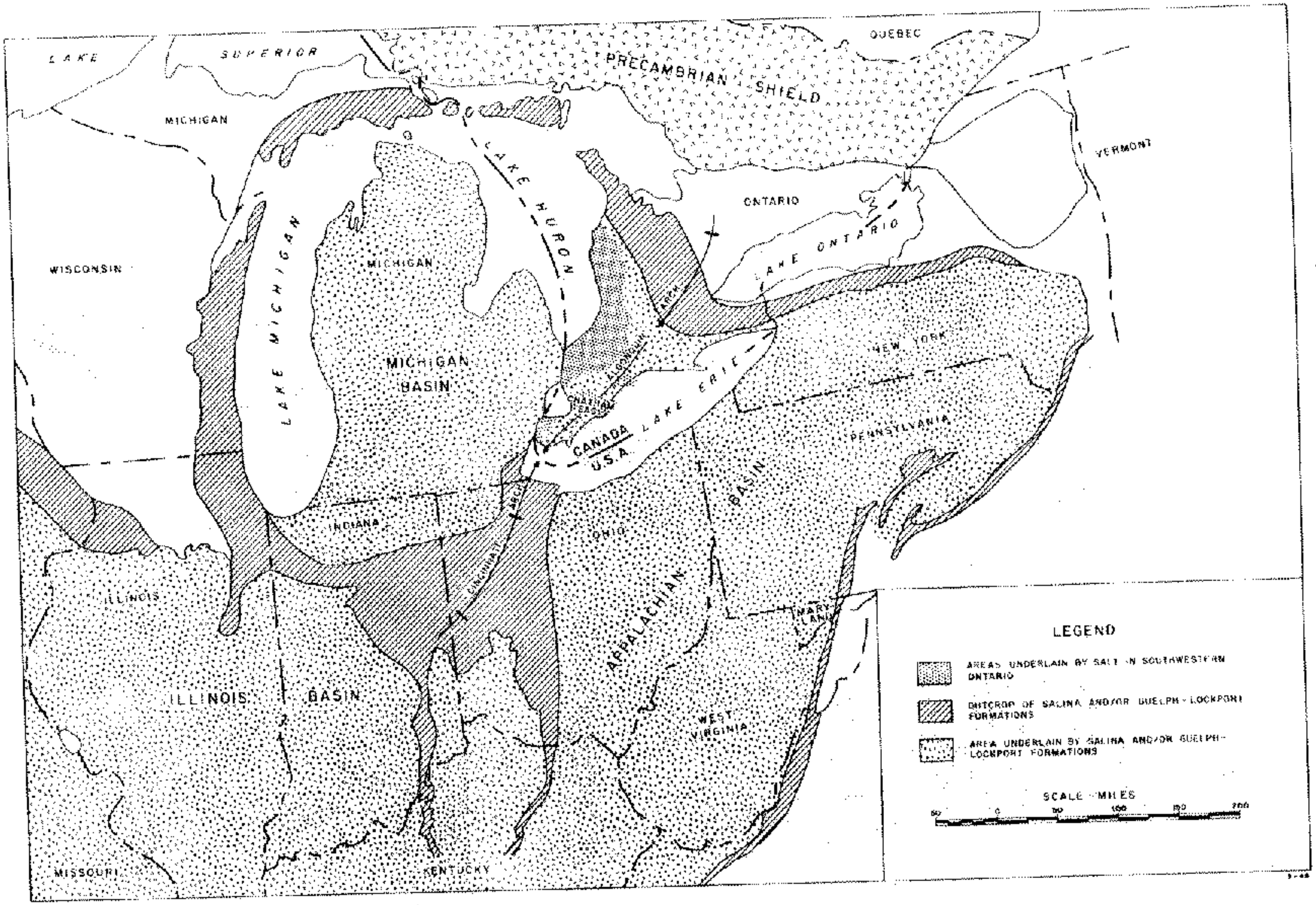

FIGURE 10

SALT DEPOSITION IN SOUTHWEST ONTARIO IN RELATION TO THE MICHIGAN AND APPALACHIAN BASINS

(MODIFIED AFTER GRIEVE, 1954)

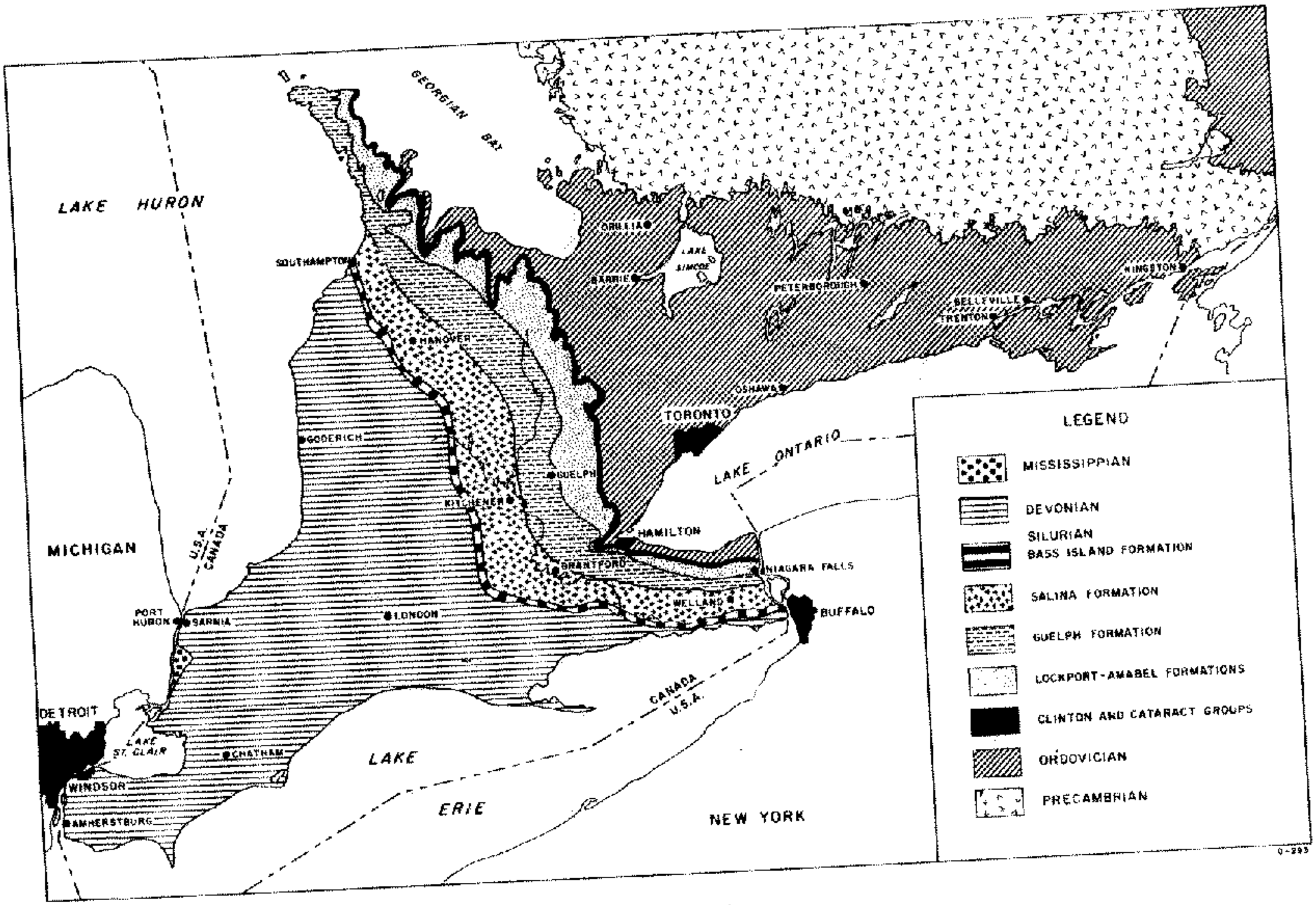

FIGURE 11

REGIONAL GEOLOGY OF SOUTHWESTERN ONTARIO

(AFTER GEOLOGICAL SURVEY OF CANADA AND ONTARIO DEPARTMENT OF MINES)

SCALE-MILES

10 0 10 20 30

TABLE OF FORMATIONS (After Geological Survey of Canada)			
Period	Formation	Lithology	Maximum Thickness
Devonian-Mississippian	Port Lambton	Grey fissile shale and dolomitic limestone overlain by black fissile shale.	200'
	Kettle Point	Black to brown bituminous fissile shale with interbeds of green shale. Characterized by small amber spore cases.	335'
Devonian	Hamilton	Grey Calcareous shale and shaly limestone.	300'
	Dundee	Lower buff, crinoidal, and arenaceous limestone with chert, succeeded by buff to brown crystalline limestone with chert and interbedded black bituminous shale.	200'
	Columbus	Calcareous sandstone, sandy limestone, dolomite.	35'
	Detroit River (group)	Succession of brown finely crystalline to granular dolomite with interbedded limestone.	300'
	Bois Blanc	Limestone, sandy limestone, dolomite, and chert.	265'
		Disconformity	
	Oriskany	Light grey, medium-grained glauconitic sandstone.	20'
Silurian	Bass Island (Bertie-Akron)	Grey to buff and brown finely crystalline dolomite-oolitic zones.	35'-395'
	Saline	Dolomite, limestone, dolomitic limestone, shaly dolomite, shale, anhydrite, gypsum, and salt.	300'-1500'
	Guelph, Lockport-Amabel	Guelph -- buff crystalline dolomite.	72'-125'
		Lockport -- grey crystalline dolomite.	170'-220'
		Amabel -- brown, bluish grey dolomite.	70'-120'

TABLE OF FORMATIONS (Continued)			
Period	Formation	Lithology	Maximum Thickness
Silurian Continued	Clinton (group) (six formations)	Grey quartz sandstone, greenish black shale, grey crystalline dolomite, dark grey to black calcareous Rochester shale, grey argillaceous dolomite or dolomitic limestone.	26'-112'
	Cataract (group)	Sandstone, brown finely crystalline dolomite, red and green shale, arenaceous shale with sandstone interbeds.	60'
Ordovician	Queenston	Red shale.	963'
	Meaford-Dundas Blue Mountain	Grey shales with occasional thin limestone beds, interbedded grey shale, silty limestone, dolomite. Shale.	580' 120'
	Gloucester (beds)	Soft, grey, and brown shale.	90'
	Collingwood (beds)	Black fissile calcareous and bituminous shale	20'-60'
	Trenton-Black River	Carbonate sequence consisting essentially of finely crystalline to sub-lithographic limestone, overlain by finely crystalline and fragmental limestone, with chert and bentonite followed by finely crystalline, fragmental limestone and shaly limestone.	865'
Cambrian	Eau Claire St. Simon Jacobsville	Arkose, grey, green, and purplish sandstone, buff dolomite.	450'
Precambrian		Metamorphosed Rocks	

Figure 12. Generalized summary of stratigraphy of the geological formations of southwestern Ontario.

THE SALINA FORMATION

In Ontario the Salina formation is exposed in a belt 5 to 16 miles wide, extending southeast from Southampton on Lake Huron, through Hanover and Kitchener, to Brantford, then eastward through Welland to Niagara River.

The Salina formation everywhere overlies the Guelph-Lockport beds and is succeeded by the Bass Island (Bertie-Akron) formation. The Guelph and Lockport formations were mapped separately in the Niagara Peninsula where the Lockport formation consists of 72 to 125 feet of grey crystalline dolomite and the Guelph of 170 to 220 feet of buff granular dolomite. In the Windsor-Sarnia area the two formations are essentially similar lithologically and are grouped in one unit.

The Bass Island formation is the youngest Silurian stratum occurring in Southwestern Ontario. In the Niagara Peninsula this formation is designated at the Bertie-Akron where it consists of about 35 feet of grey to brown, dense dolomite with some dark calcareous shale. Westward the shale is absent and the unit (Bass Island) consists of grey to buff and brown, finely crystalline dolomite. The Bass Island formation ranges in thickness from 35 to 395 feet.

According to Roliff (1944) the Salina formation consists of thin-bedded, fine-grained, grey, buff, and brown dolomites and limestones, shaly dolomites and limestones, dolomitic and calcareous shales, beds of gypsum and anhydrite, and, in many places, beds of salt. The Salina formation increases in thickness in a northwesterly direction from approximately 350 feet east of London, where no salt is present, to nearly 1,500 feet near Sarnia, where the aggregate thickness of the salt is about 700 feet (Grieve, 1955).

The Salina formation has been divided into seven lithological units. This subdivision is based on the work of K. K. Landes (1945a) on the Salina formation in Michigan, and is summarized in Figure 13.

SUBDIVISIONS OF THE SALINA FORMATION

Formation	Unit		Description
Upper Salina			Top of Salina Formation.
		G	Fine crystalline brown dolomite, shaly dolomite, some anhydrite, red shale.
	Upper Salt Beds	F	SALT, in thick beds separated by beds of shale, shaly dolomite, grey and buff and brown crystalline dolomite; anhydrite nearly always present.
		E	Thin shaly unit, argillaceous grey and buff dolomite.
		D	SALT, nearly pure; thin partings of buff dolomite.
		C	Dolomitic grey shale.
		B	SALT, thick salt beds with thin dolomite layers. (Main Upper salt).
Lower Salina		A2	Fine-to medium-grained brownish grey dolomite. Fine grey to dark grey dolomite; some dark bituminous shale; SALT, (Lower Salt) up to 140 feet thick; where salt is absent the base of A2 is marked by anhydrite.
		A1	Fine-to medium-grained, buff to brown dolomite; fine to dense, brown grey dolomite with dark grey bituminous shale; anhydrite at base.

Figure 13. Subdivisions of the Salina Formation (After D. F. Hewitt, 1962).

THE SALINA SALT DEPOSITS

All the salt deposits in southwestern Ontario that have been examined in drill cores and in the rock salt mines are characteristically layered and bedded. Salt layers, as much as 10 inches thick and ranging in color from white to dark grey to yellowish brown, alternate with layers composed of paper-thin laminae of anhydrite and dolomite.

Dellwig (1955) in his description of the salt of the Michigan basin has pointed out that there are some differences between salt deposits of the deeper parts of the basin and the marginal deposits such as at Detroit, although both are layered deposits. Dellwig states that the layered salt is composed of three distinct units: carbonate and sulphate laminae; clear salt; and cloudy salt. Apparently the clear salt and the cloudy salt differ in the manner of crystal growth. The cloudy salt contains numerous liquid inclusions while the clear salt does not. In core from the deeper part of the Michigan basin the two types of salt are separated into distinct layers but this relationship is less pronounced in the marginal deposits and in many instances the entire salt mass shows a uniform degree of translucency. There appears to be no regular sequence or ratio of thickness between the two types of salt and the anhydrite. In the deeper deposits the anhydritic layers are separated by layers of salt less than one-half inch to 3 inches thick, while in the marginal deposits the separation may vary from 3 to 12 inches. The thickness of individual anhydrite laminae rarely exceeds 0.5 millimeter. The laminae are composed primarily of anhydrite and also contain dolomite, pyrite, quartz, celestite, polyhalite, and carbonaceous material. A low percentage of insolubles is present in the salt layers.

Dellwig (1954) and Hewitt (1962) consider that, for deposition of layered salt, the mass of the brine must be concentrated to, or near the saturation point so that only halite is precipitated, and that the anhydrite-dolomite laminae are the result of intermittent influx of water or brine into the basin carrying $CaCO_3$ and $CaSO_4$. Thick salt beds represent periods of influx of brine, which was almost depleted in $CaSO_4$ and $CaCO_3$, into a uniformly subsiding basin.

Isopach maps showing the distribution and thicknesses of the lower and upper salt units in southwestern Ontario, based on the work of D.F. Hewitt (1962), are shown in Figures 14 and 15. The lower salt bed, in the A2 unit, is found only in the Sarnia-Goderich salt area (Figure 14). The A2 salt which has a maximum thickness of 140 feet in the Sarnia area, extends as far south as Wallaceburg, and to the east almost as far as Strathroy. The lower salt thins or is absent over a number of the Guelph reefs, which stood up in relief as hills on the sea floor at the time of early Salina deposition.

Units B, D, and F contain the salt beds designated as the upper salt. Units B and D are almost entirely salt, while unit F may consist of a number of beds separated by beds of shale, shaly dolomite, crystalline dolomite, and anhydrite. The total thickness of the upper salt is shown in Figure 15.

The Windsor Area

Salt beds of the B, D, and F units underlie an area of about 105 square miles in the Windsor area and have a maximum aggregate thickness of approximately 300 feet along the Detroit River south of Windsor. The beds thin to the southeast and pinch out about 12 miles south and east of Windsor. The Canadian Rock Salt Company Limited's Ojibway mine is in the F unit, and a number of brine wells have been operated in the B, D, and F salt units in the area.

Geology of the Ojibway Salt Deposit

The salt bed being mined lies at an elevation of 945 to 975 feet below the mine shaft collar. The bed, which averages 27 feet in thickness, is flat lying. A thickness of 18 to 21 feet of salt is mined, leaving 6 feet or more of salt in the roof.

The salt section exposed in the mine consists of medium-to coarse-grained salt, 2 to 5 millimeters in grain size. The salt bed is well layered and in certain zones has a varved character. The bedding is made evident by dark grey to yellowish brown layers, generally 3 to 8 inches apart in the white salt. These dark layers in the salt contain paper-thin lamellae of anhydrite, that stand out on surfaces that have been exposed for some time. The thin individual layers or beds are remarkably persistent throughout the mine, indicating a period of uniform deposition broken

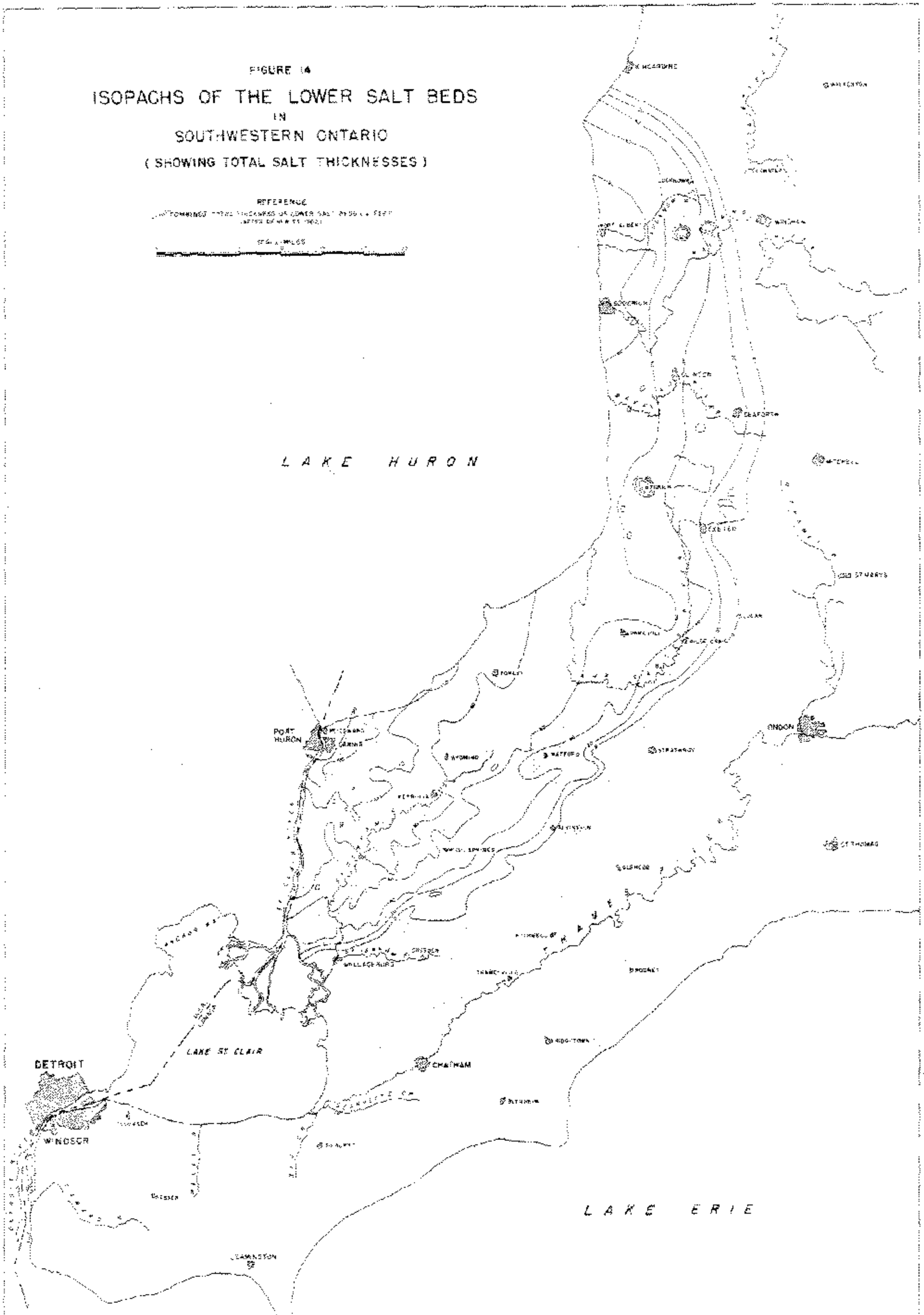

FIGURE 14

ISOPACHS OF THE LOWER SALT BEDS IN SOUTHWESTERN ONTARIO

(SHOWING TOTAL SALT THICKNESSES)

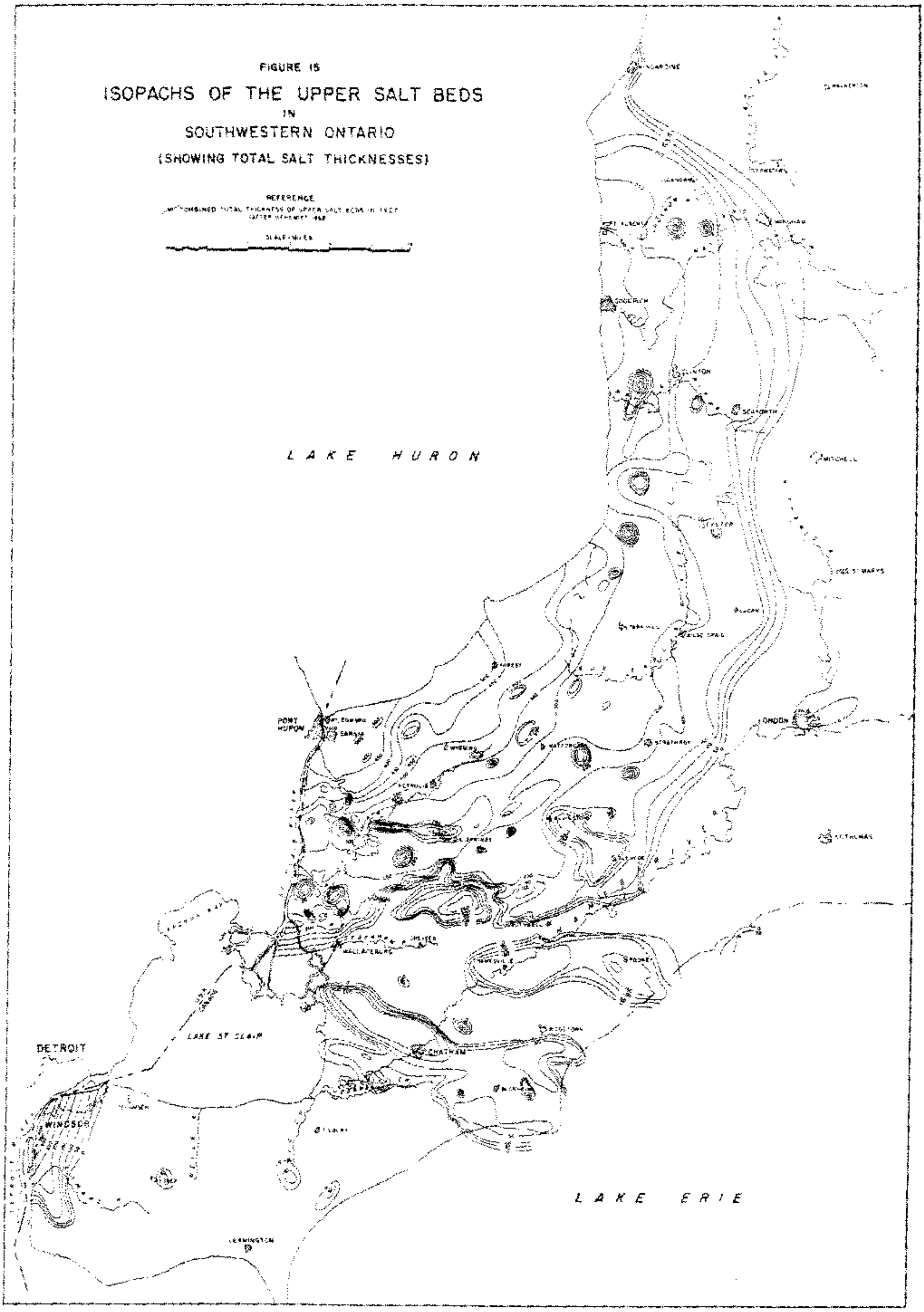

FIGURE 15
ISOPACHS OF THE UPPER SALT BEDS
IN
SOUTHWESTERN ONTARIO
(SHOWING TOTAL SALT THICKNESSES)

only by changes in salinity, probably due to influx of less saturated brine into the basin and precipitation of anhydrite for short periods. Shaly layers are absent.

D. F. Hewitt (1962) states, that, in many places there are large patches of very coarse-grained, clear, crystalline salt replacing the bedded deposit. These patches of secondarily crystallized salt are completely surrounded by bedded salt with no disturbance of bedding in the surrounding area. It is believed that the salt in these patches recrystallized in solution.

The salt in the deposit is very pure, containing less than 2 per cent impurities. Unlike the salt deposits of the Maritime Provinces and Western Canada there are no potash salts present, indicating that the precipitation sequence was never completed. The balance of evaporation and influx of brine must have been such that there never was complete evaporation of the brine.

The Chatham Area

The Chatham salt deposits are separated from those of the Sarnia-Goderich area by a salt-free area as shown in Figure 9. Evans (1950) suggests that this salt-free area existed as a ridge over which no salt was deposited.

Salt beds of the Chatham region underlie a land area of over 300 square miles and extend under Lake Erie for an undetermined distance. The Chatham salt area is divided into two easterly-trending minor basins separated by a salt-free area. One basin extends through Chatham and the other through Thamesville and Rodney. Salt of the B unit only occurs in the Chatham basin. In some localities the salt thickness exceeds 200 feet.

The Sarnia-Goderich Area

The salt deposits in the Sarnia-Goderich area are the most extensive in Ontario. The deposits, which underlie a land area of more than 3, 000 square miles, occur in the A2, B, D, and F units of the Salina formation.

In the Sarnia area the upper salt, which occurs in the B, D, and F units of the Salina formation, has a total thickness of more than 500 feet, while the lower salt of unit A2 has a thickness in excess of 140 feet, giving a total thickness of about 700 feet. In both the Sarnia and Goderich areas the salt beds thin eastwards, and in both areas the salt of the B unit persists farthest to the east. Grieve (1954) and Hewitt (1962) indicate that, in addition to the regional changes in thickness of the salt beds due to their location in the basin, there are minor local variations in thickness of the salt due to local thinning or non-deposition over buried Guelph hills or reefs, or to removal of salt beds by leaching and solution.

SALT DEPOSITS OF WESTERN CANADA AND THE NORTHWEST TERRITORIES

In Western Canada as in the Maritime Provinces, the presence of salt deposits was first indicated by saline springs and by exploratory wells drilled for oil. Saline springs are known in all four western provinces and in the Northwest Territories (Figure 16).

In Manitoba, from about 1800, Indians, trappers, and freed men from the Hudson's Bay Company collected and evaporated brines from springs along the west shore of Lake Winnipegosis to produce salt. At Monkman's Springs on the Red Deer peninsula in the southern part of Lake Winnipegosis, commercial production of salt began in 1820 and continued until about 1876. The salt springs in Manitoba occur in a narrow belt extending from the Carrot River in the north to the Red River in the south and bordering Lakes Winnipegosis and Manitoba. The largest springs flow from formations of Devonian age.

Salt springs in Saskatchewan occur along the Carrot River, and at Senlac Lake, a small lake located in sections 19 and 30, township 39, range 25, west of the 3rd Meridian. This lake is fed by saline springs in various parts of the lake bottom and along the shore. When the brine was analyzed in 1924 the NaCl and $MgCl_2$ contents were respectively, 50, 058 and 15, 932 parts per million. Salt was produced from the brine of this lake for a short period, ending in 1921.

In Alberta saline springs occur in the McMurray district and along the Salt River which flows into Slave River about half way between Lake Athabasca and Great Slave Lake. Salt

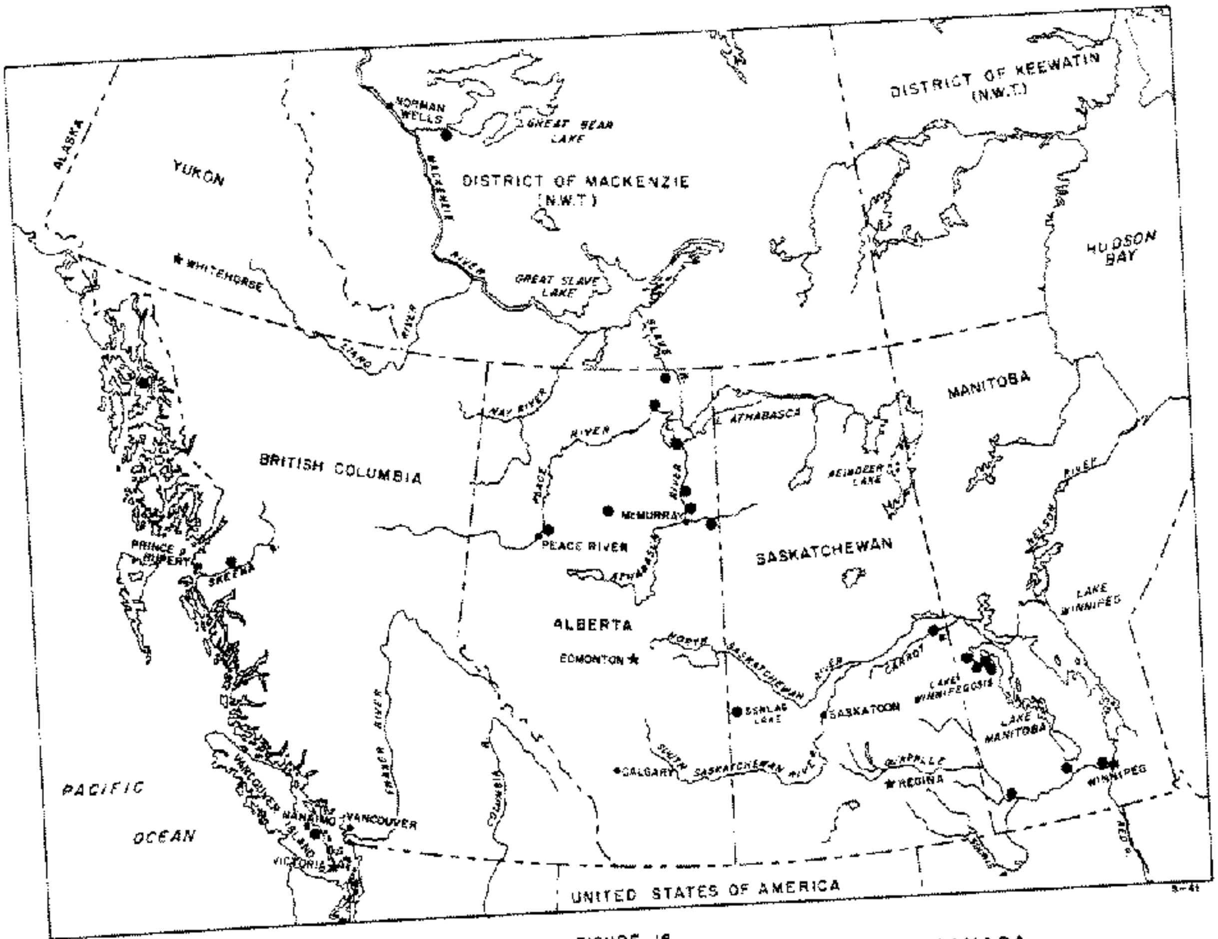

FIGURE 16
LOCATION OF AREAS OF SALINE SPRINGS IN WESTERN CANADA
● SALINE SPRINGS
SCALE - MILES
100 0 100 200 300 400

deposited by these springs was utilized in the early years of the nineteenth century. Numerous saline springs occur near La Saline, about 26 miles north of McMurray. Other areas of saline springs are shown in Figure 16.

Salt springs occur in the Northwest Territories in the Norman area along a small stream which flows from the south into the Great Bear River near its mouth.

In British Columbia a strong saline spring is located about 45 miles east of Prince Rupert on the banks of the Skeena River at Kwinitsa. Other saline springs have been reported near Nanaimo on Vancouver Island, and on Admiralty Island.

The first discovery of rock salt in Alberta was in 1907 in the McMurray district and about 1928 rock salt was penetrated in a well drilled for oil near Unity, Saskatchewan. Since then the extensive drilling in exploration for oil has indicated the vast extent of the salt deposits of Western Canada. The major, known salt deposits are of Middle Devonian age.

GENERAL GEOLOGY

The major salt deposits of Western Canada were deposited in a northwest-trending structural basin, known as the Elk Point basin, which extended from north central to east central Alberta, southeast across Saskatchewan, into southwestern Manitoba, northern part of North Dakota, and northeastern Montana (Figure 17). The shape and location differed from that of the present Williston basin.

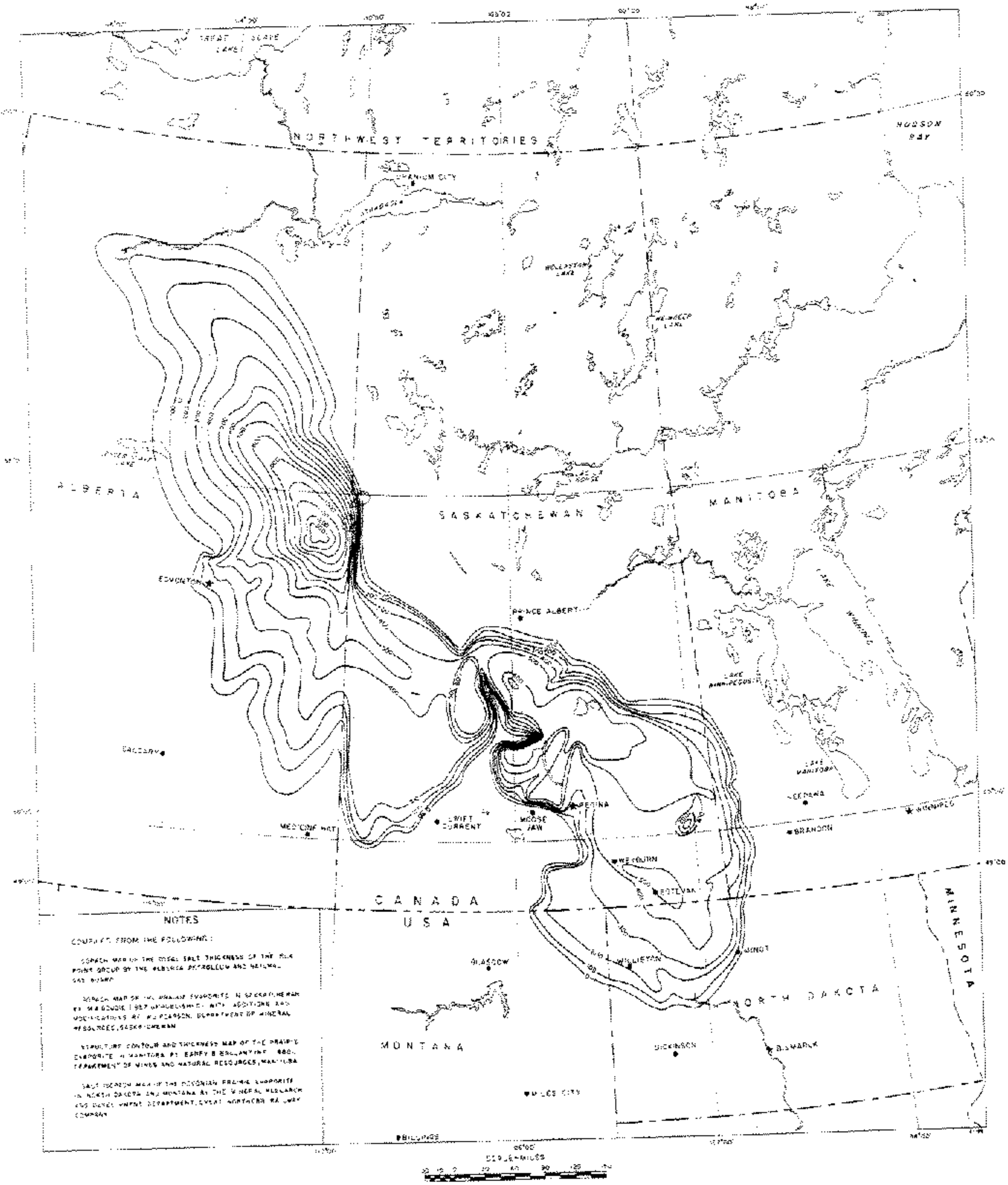

FIGURE 17

ISOPACH MAP SHOWING THE TOTAL THICKNESS OF THE SALT IN THE ELK POINT GROUP

A generalized summary of the stratigraphy of the Middle Devonian and of the underlying and overlying formations is given in Figure 18. Formation names given are those used in the Saskatchewan part of the basin. In Saskatchewan, Manitoba, North Dakota, and Montana the lower limit of the Elk Point group is placed at the base of the Ashern formation and the upper limit at the top of the Prairie Evaporite formation. The Elk Point group in Alberta, however, includes the strata between the base of the Meadow Lake formation which lies below the Ashern formation in the Meadow Lake area of Saskatchewan and the top of the Dawson Bay equivalent.

Three major evaporitic cycles are evident in the Saskatchewan portion of the basin, occurring in the Prairie Evaporite, Dawson Bay, and Souris River formations. These three cycles are shown in the columnar section of the Socony Sohio well, located in Lsd 14-11-28-22-W2 (Figure 19). The Elk Point group in the central part of the Alberta basin contains three major salt units.

DEVONIAN SALT DEPOSITS

In that part of the basin located in Saskatchewan, Manitoba, North Dakota, and Montana, the salt deposits of greatest areal extent, and of the greatest economic importance, are those of the Prairie Evaporite formation. In Alberta the Elk Point group contains one to three economic salt units depending on the location in the basin. Other salt deposits of Middle Devonian age occur at the top of the Dawson Bay formation and in the Davidson number of the Souris River formation in the central part of the salt area in Saskatchewan. These salt units have been named the Hubbard (Lane, 1959) and the Davidson (Baillie, 1953) evaporites, respectively. In Alberta salt of Upper Devonian age occurs locally in the Stettler formation which is correlated with the Potlach facies of other areas.

Salt Deposits in the Elk Point Basin in Alberta

The Elk Point group in Alberta contains three major salt beds, while in Saskatchewan the group contains only one major salt unit. Another dissimilarity is that the evaporite in Alberta does not contain the vast deposits of potassium minerals similar to those occurring in the basin to the east. These differences in the lithology between the eastern and western parts of the Elk Point basin are indicative of differences in degree of restriction to influx of sea water or brine. The potash deposits indicate that the evaporitic cycle was completed before influx of more brine, whereas in the Alberta basin the evaporitic cycle was never entirely completed before influx of additional brine. It is believed that a restricted channel in the Elk Point basin existed in the area of the Saskatchewan-Alberta border at about latitude 52°40'.

Exploratory wells which have been drilled in the central part of the Alberta sub-basin have penetrated three major salt units, having an aggregate thickness ranging from over 600 feet to nearly 1,000 feet. The isopach map of the total salt thicknesses of the Elk Point basin shows that the aggregate thickness in the central part of the Alberta basin may be as high as 1,300 feet (Figure 17). In three of the wells which penetrated all three salt units, the thickness of the uppermost salt varies from 405 to 451 feet, while that of the middle unit ranges from 118 to 128 feet, and that of the lowest from 227 to 433 feet. A cross section including parts of both the Alberta and Saskatchewan sub-basins illustrates the relationship of the upper salt bed of the Elk Point group in Alberta to that of the Prairie Evaporite salt in Saskatchewan (Figure 22).

Allan (1943) in his report on the salt deposit at Waterways, Alberta, describes the bedded nature of the salt. In two of the exploratory wells in the area which penetrated 199 and 211 feet of rock salt respectively, a bed of massive, hard, almost translucent anhydrite occurs above the salt. The uppermost 6 feet of the salt deposit consists of transparent, colorless rock salt and the remainder mainly of white to translucent, fine- to coarse-grained, crystalline, bedded salt. An eight-foot core sample from Industrial Minerals No. 1 well contains 142 distinct beds, some separated by thin anhydrite layers which are seldom over one millimeter thick or by scattered clusters of anhydrite in sub-parallel planes. In the lowest part of the deposit, however, the anhydrite layers may increase in thickness from one to three or five millimeters. In one well, a 201 foot interval of the salt contains 480 layers of anhydrite. Anhydrite is the only impurity in the Waterways deposit.

TABLE OF FORMATIONS			
Epoch	Group	Formation	Lithology
Upper Devonian	Qu'Appelle	Three Forks (Potlach)	
	Saskatchewan	Nisku	Dolomitic Limestone, crystalline.
		Duperow (Beaverhill Lake)	Limestone dominant. Buff chalky, sucrosic or argillaceous. Intermittent dolomitic layers. Frequently marly or argillaceous.
Middle Devonian	Manitoba	Souris River	Hatfield Member Shale, marlstone, lightcolored cryptocrystalline limestone, minor localized halite, basal red and green dolomitic shale. Harris Member Light colored, cryptocrystalline limestone, alternate sequence of shales, carbonates, anhydrites, minor halite, basal red and green dolomitic shale. Davidson Member Davidson Evaporite -- mainly halite (0-200'). Carbonate Unit -- brown bituminous stromatoporoidal dolomites (biostromal); light colored carbonates (sheet reef) cryptocrystalline, light colored limestone. First Red Beds -- red and green dolomitic shales.
		Dawson Bay	Hubbard Evaporite -- Mainly halite (0-60'). Carbonate Unit -- black bituminous limestone, pelletoidal limestone, dolomitic anhydrites; brown fragmental limestones; grey and buff fragmental to cryptocrystalline limestones; buff microgranular limestones. Second Red Beds -- red and green dolomitic shales.
	Elk Point	Prairie Evaporite	Potash salts, halite, anhydrite, minor dolomite (0-700'+).
		Winnipegosis	Tan saccharoidal dolomite, minor limestone, sporadic inclusions of halite near top (25-300'+) (reefoid in part).
		Ashern	Shale, red and green, dolomitic.
Silurian		Interlake	Dolomite

Figure 18. Generalized summary of the Stratigraphy of the Middle Devonian in Saskatchewan.

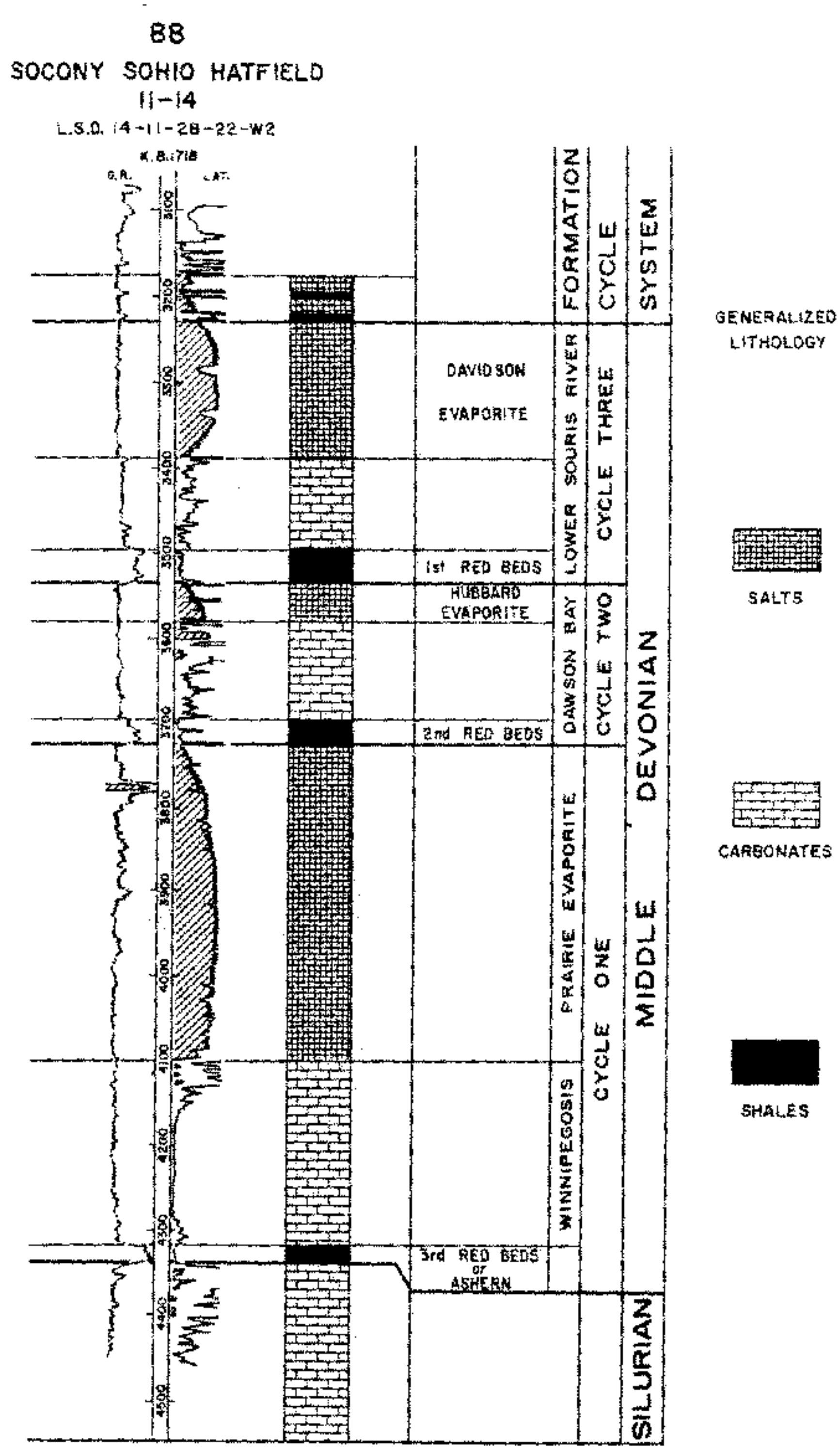

FIGURE 19
COLUMNAR SECTION
SHOWING
MIDDLE DEVONIAN EVAPORITE CYCLES
(AFTER O.M. LANE, 1959)

The Stettler formation of Upper Devonian age contains a maximum concentration of evaporites in an area east of Drumheller, and decreases in thickness from this area to the west, north, and east. Salt beds from 35 to 90 feet thick have been recorded in this formation. In Lsd 7-19-36-19-W4, between Stettler and Big Valley, 100 feet of salt have been penetrated.

Salt Deposits in the Elk Point Basin East of Alberta

The Prairie Evaporite formation, which contains the major salt deposits, is underlain by the Winnipegosis formation. The Winnipegosis, which has a variable thickness ranging from less than 30 feet to more than 300 feet, consists chiefly of tan dolomites. Reefs of the bioherm type are well developed in this formation.

The Prairie Evaporite is overlain by the Second Red Beds of the Dawson Bay formation. This unit, which forms a distinctive horizon marker, has a thickness varying from 8 to 40 feet and consists chiefly of red and green dolomitic shales. The Second Red Beds represent a period of uplift, during which subareal erosion took place to form this unit, before subsidence and transgression of the sea recurred.

The Prairie Evaporite formation, which forms the upper most unit of the Elk Point group in Saskatchewan, Manitoba, North Dakota, and Montana, occupies a large part of the Elk Point basin area. The formation ranges in thickness from less than 50 feet near the edges to over 700 feet in the deeper parts of the basin. The stratigraphy of the Prairie Evaporite formation is variable depending on the location in the major basin. In the central part of the basin the formation consists chiefly of halite with major amounts of potassium minerals in the upper portion, and some clay and anhydrite interbedded throughout. The clay occurs as thin layers, partings, and irregular inclusions, and the anhydrite as laminae and thin beds, which become thicker and more abundant towards the base of the salt. Drill cores from some wells indicate that the bottom salt in some areas is underlain by a thick bed of anhydrite, which may in turn be interlayered with thin beds of dolomite near the base. In the northeastern part of the basin, anhydrite and dolomite are interlayered with the salt in the middle of the salt section. At the basin edge anhydrite occurs above the salt. The variation in lithology in different parts of the basin is indicative of the existence of sub-basins which at times were separated, so that some may have received an influx of fresh brine, while others received little or none. In sections of the formation where the chief mineral is essentially halite, bedding is indicated by interlayering of salt beds ranging in color from brown, tan, and white to translucent. The salts of the Prairie Evaporite formation vary in texture from fine to coarse grained.

In the central part of the basin in Saskatchewan salt also occurs in the Hubbard and the Davidson evaporites in the Dawson Bay and Souris River formations, respectively. These evaporites are essentially composed of halite with only minor anhydrite. The maximum thickness of the Hubbard evaporite is about 60 feet while that of the Davidson is in excess of 200 feet (Figures 20 and 21).

Structure of the Salt Deposits

The salt beds of the Elk Point basin generally dip to the southwest at a rate of 10 to 40 feet per mile, but exploratory drilling has indicated local warping. The salt occurs at 600 to 800 feet below the surface near McMurray in Alberta and to the southeast in Saskatchewan the subcrop of the northern edge of the Prairie Evaporite lies at depths from over 2, 400 to 2, 800 feet below the surface. The northern edge of the salt in some localities is depositional while in others it is considered to be erosional where the salt section thins abruptly. Near Edmonton, Alberta, the salt beds lie 5, 000 to 6, 000 feet below the surface, and in the Moose Jaw-Regina area in excess of 5, 000 feet. In northeastern Montana and in North Dakota, near the southern edge of the salt basin, the salt lies at depths ranging from 8, 000 to over 12, 000 feet.

In that part of the basin which occupies south central Saskatchewan there is an area in which salt is absent. It is considered that this salt-free area is due to removal of the salt by solution and transportation. The occurrences of salt springs is evidence that salt is being removed by solution at the present time. The solution of the salt is attributed to the movement of subsurface waters in a northwesterly direction across the salt basin (Milner, 1957). Walker (1957) has shown that salt isopachs can be connected across the saltless area, indicating that the salt at one time

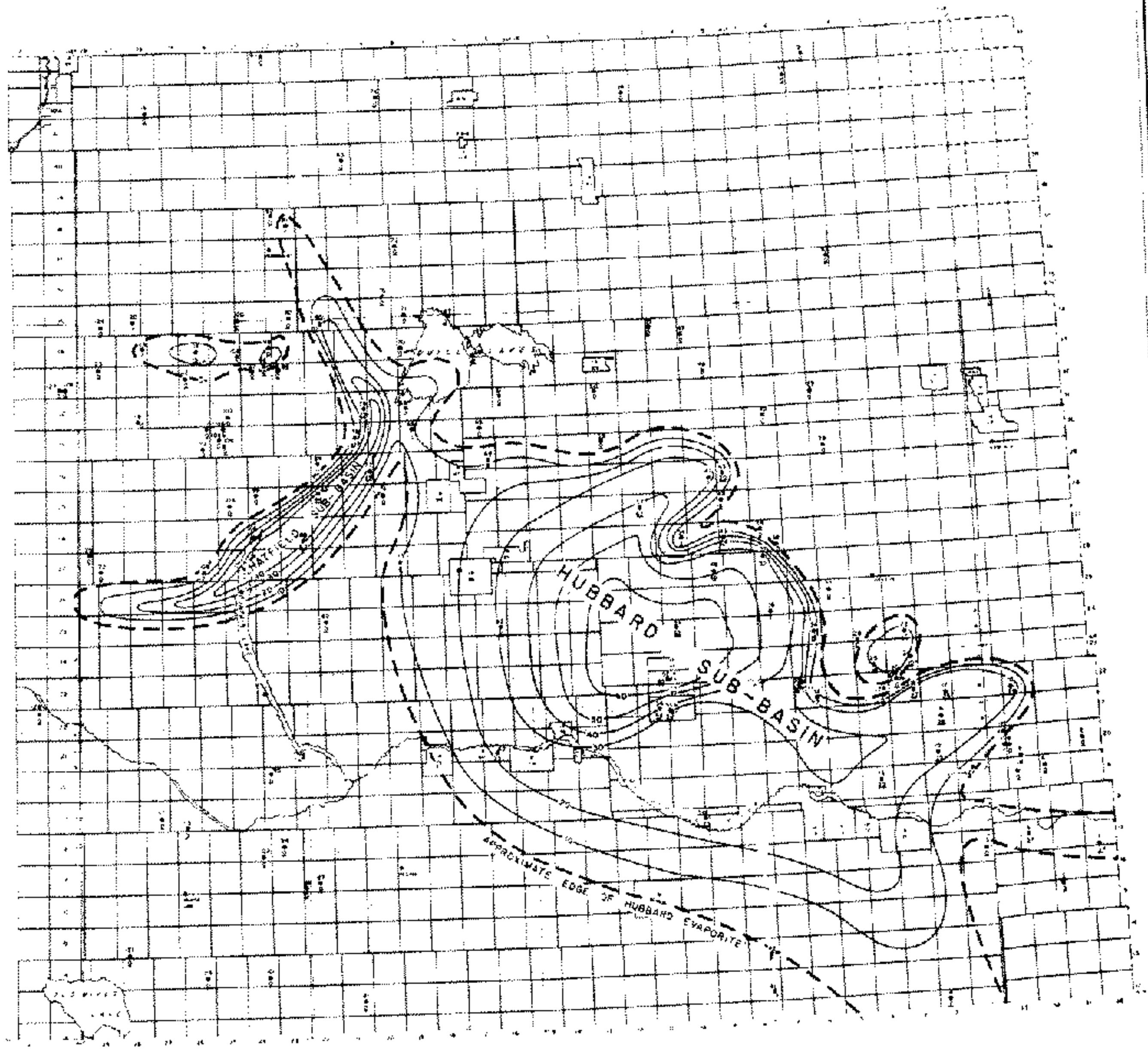

FIGURE 20

ISOPACH MAP

OF THE

HUBBARD EVAPORITE

CONTOUR INTERVAL 10'

SCALE - MILES

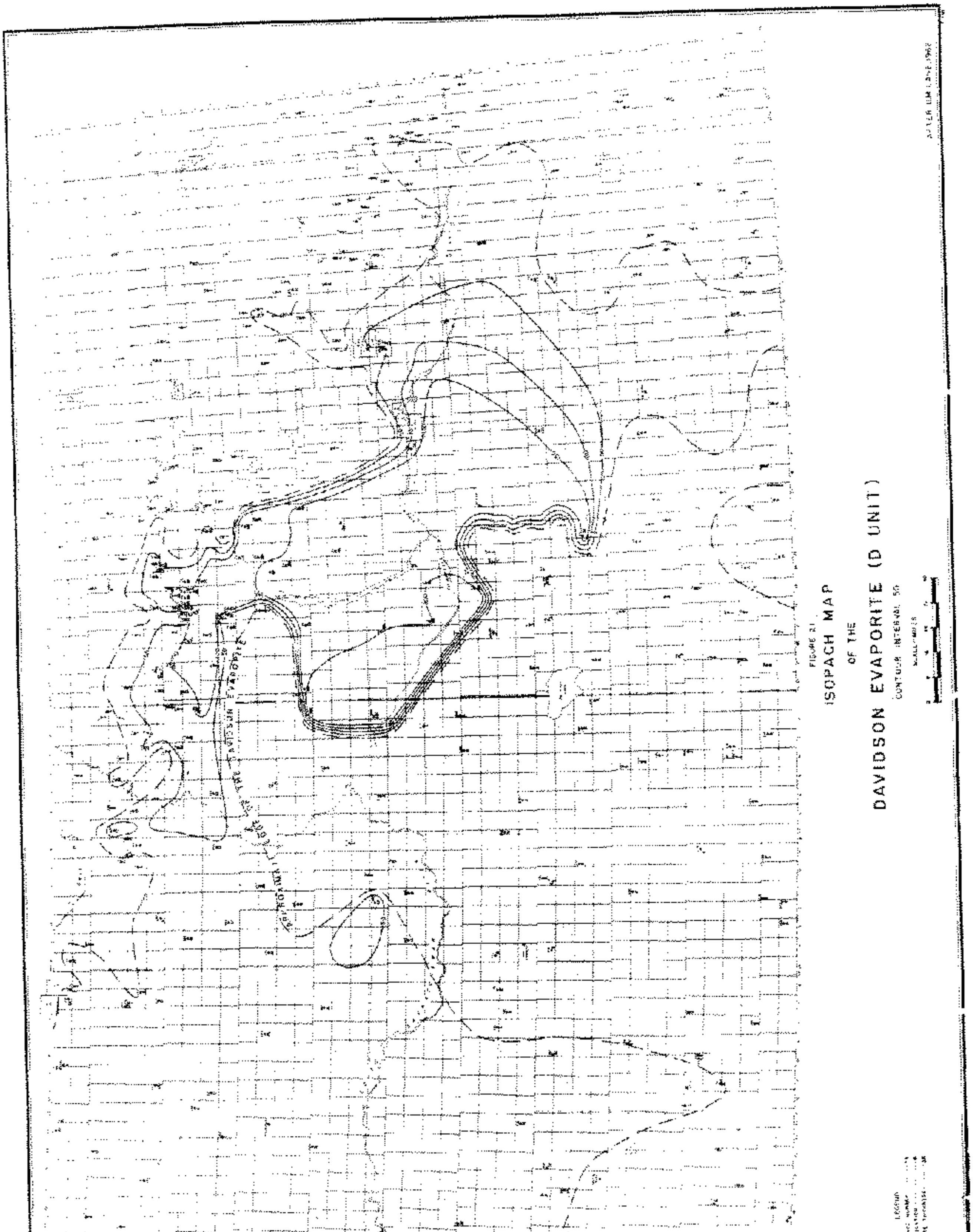

FIGURE 21
ISOPACH MAP
OF THE
DAVIDSON EVAPORITE (D UNIT)
CONTOUR INTERVAL 50
SCALE-MILES

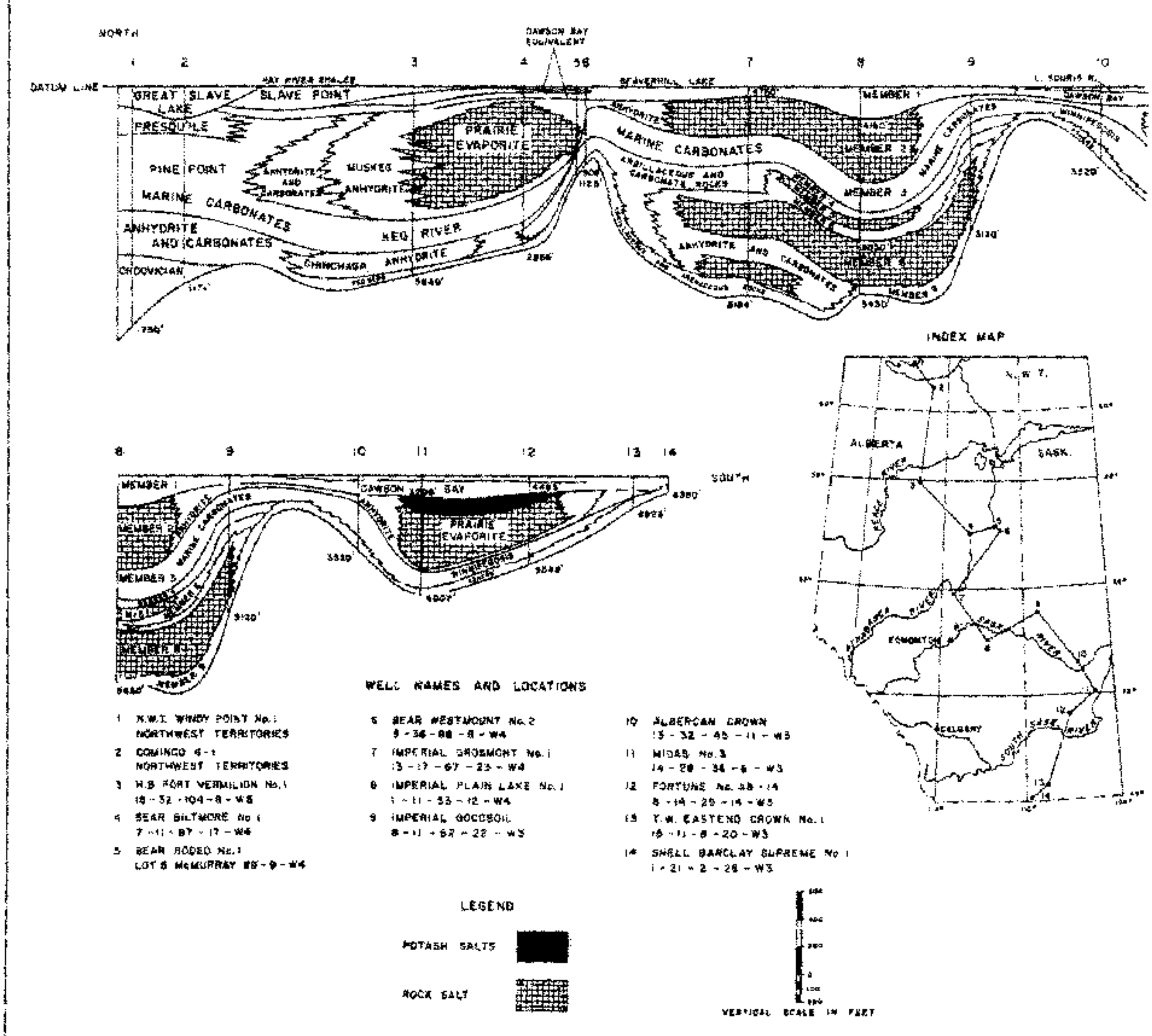

FIGURE 22

FACIES AND STRUCTURAL CROSS – SECTIONS OF MIDDLE DEVONIAN FORMATIONS IN THE ELK POINT BASIN IN ALBERTA AND WESTERN SASKATCHEWAN

(AFTER GOVETT, 1961, MODIFIED)

was a continuous sheet. Geophysical evidence indicates that channeling in the salt has taken place in various parts of the salt basin.

Seismic data based on reflections from the Paleozoic surface provide valuable information in indicating areas from which salt has been removed. Seismic highs are considered to represent areas of greatest thicknesses of Devonian salt and the lows and depressions in the seismic pattern are indicative of lesser amounts or complete absence of salt.

THE POTASH DEPOSITS OF THE PRAIRIE EVAPORITE FORMATION

The Prairie Evaporite formation is of economic importance because, in addition to the immense quantities of halite, it contains vast deposits of high-grade potash ore. The major potash deposits are located in Saskatchewan, but extend into Manitoba and North Dakota, where the potash-bearing zones or beds are thinner. There are no known economic potash deposits in the Alberta sub-basin.

The potash mineralization is concentrated within the upper 150 to 200 feet of the Prairie Evaporite formation. The potassium minerals occur in distinct beds and zones, interlayered with beds of halite which contain only minor amounts of or no potassium minerals. Clay is also associated with the deposits, occurring as thin layers and lenses, and interstitially in some potash beds. A very minor amount of anhydrite may also be present. In parts of the potash basin there are three major potash-bearing zones with possibly a minor fourth or even a fifth bed in places. In some localities, particularly in the extreme eastern part of the basin, the upper zones are poorly developed and only the third or lowest zone contains potash of ore grade in mineable thicknesses. The potash zones or beds are separated by more or less barren halite beds.

Commonly the uppermost potash zone is separated from the second by a halite bed which may range in thickness from 10 to 30 feet and the second from the third by a halite interval of 30 to 80 feet, depending on the location of the sub-basin of potash deposition. If a lower fourth and/or a fifth zone exist they are usually thin and are of no economic importance. The uppermost potash zone may be overlain by a halite bed ranging in thickness from less than one foot to 40 feet or more. Throughout the potash basin the uppermost salt is overlain by the Second Red Beds which ranges in thickness from 8 to 40 feet. Near the northern edge of the basin the Red Beds may rest directly upon the potash beds, and at the outer edge of the basin in places much or all of the potash-bearing beds has been eroded away, so that if any potash is present, it represents only the lower part of the earliest potash deposition.

Three predominant minerals occur in the potash-bearing formation; halite ($NaCl$), sylvite (KCl), and carnallite ($KCl.MgCl_2.6H_2O$). Halite and sylvite occur together as the mechanical mixture known as sylvinite. Polyhalite ($K_2SO_4.2CaSO_4.2H_2O$) and leonite ($MgSO_4.K_2SO_4.4H_2O$), in very minor amounts, have been reported from a few potash wells. The main potash minerals, sylvite and carnallite, may occur separately or in close association. The sequence of occurrences may not always be the same in all localities. A diagram based on a Gamma Ray-Neutron log illustrating the lithology and mineralogy, and the relationship of the various potash zones which may be encountered in a potash deposit in central Saskatchewan, is shown in Figure 23.

GEOLOGICAL HISTORY OF THE ELK POINT BASIN

The development of the Elk Point basin on the eastern part of the Alberta shelf was influenced by several tectonic elements during Silurian-Middle Devonian time (Figure 24). The term "Alberta shelf" has been applied to the vast area, which, since late Precambrian time, has constituted the western extension of the central North American craton, of which the Canadian Shield is the core. It occupied that region lying between the Canadian Shield and the Cordilleran geosyncline (Figure 24). The Alberta shelf region was emergent following Upper Ordovician time and sedimentation was not resumed until late Lower Silurian. According to Webb (1954) the Silurian seaways were restricted and a broad uplift occurred prior to Devonian time. It is believed that the uplift of the Peace River ridge in northwestern Alberta caused this rise. The growth of the great intracratonic basin began during Silurian time and the Elk Point-Broadview syncline was the major locus of subsidence between the positive tectonic elements shown in Figure 24.

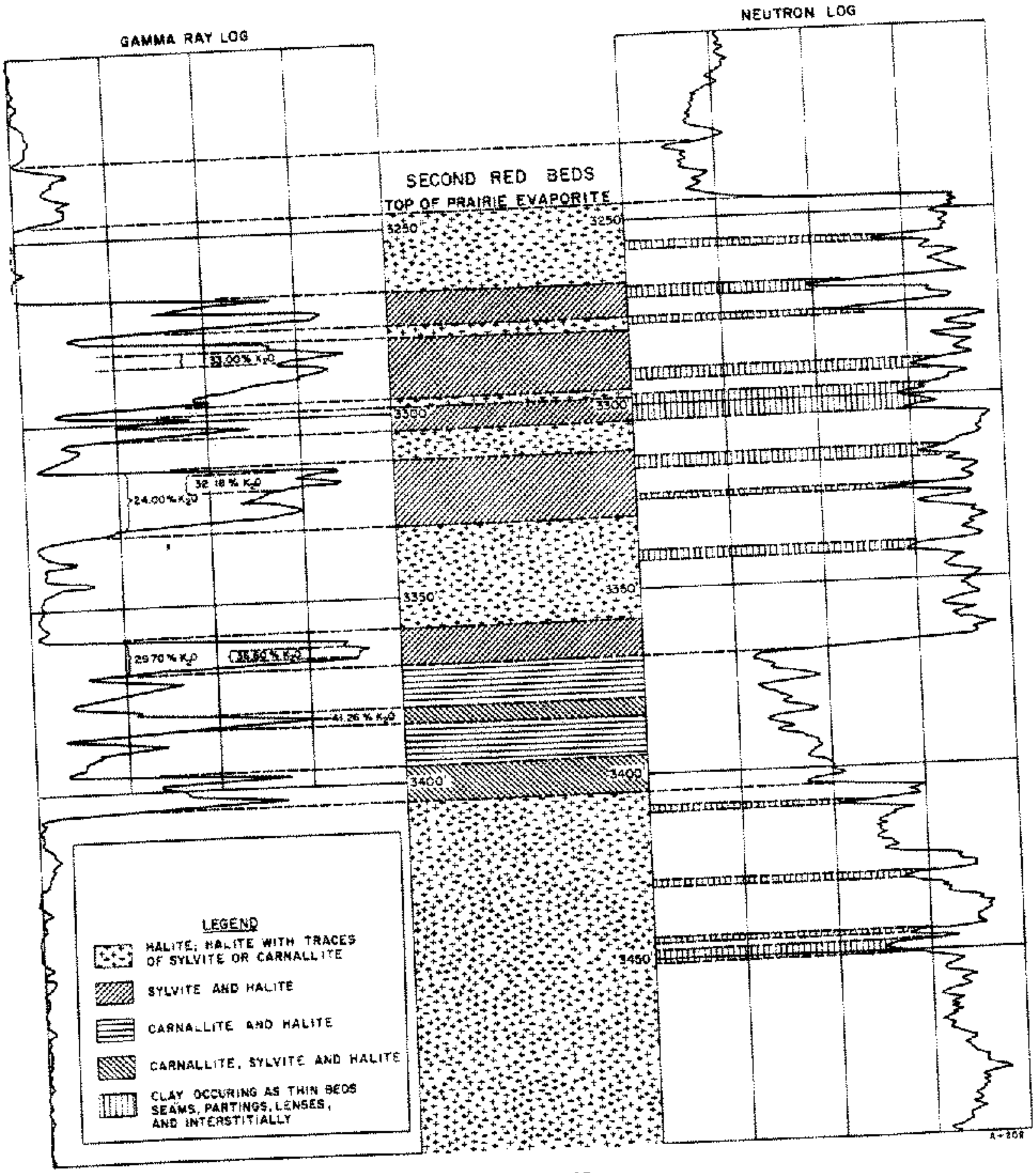

FIGURE 23

CORRELATION OF GAMMA RAY AND NEUTRON LOGS WITH THE MINERALOGY AND LITHOLOGY OF THE UPPER PART OF THE PRAIRIE EVAPORITE AND OVERLYING SECOND RED BEDS

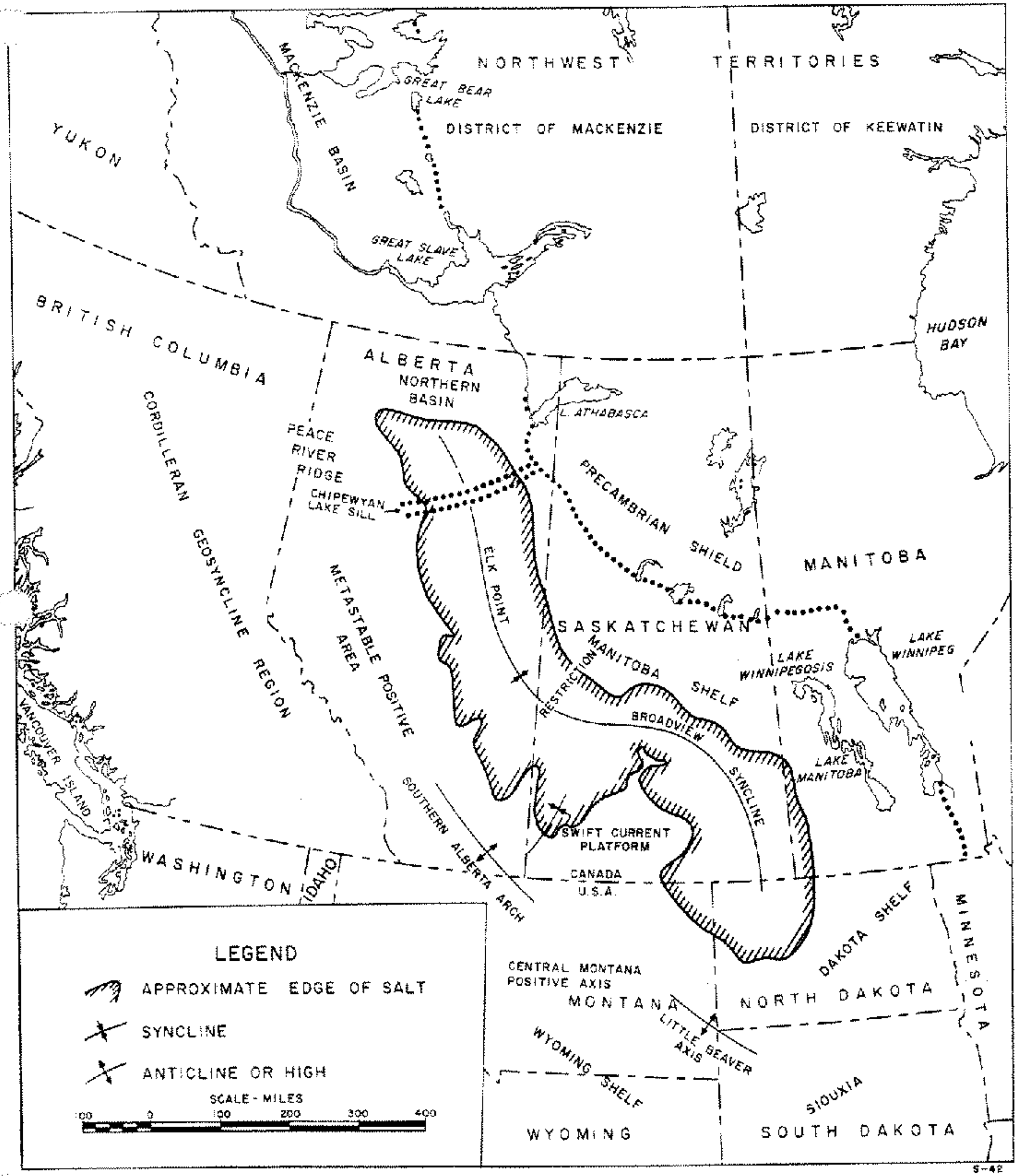

FIGURE 24

THE ELK POINT SALT BASIN AND RELATED TECTONIC ELEMENTS

1. The South Alberta arch, probably an extension of the Montana axis, was established in Precambrian or Cambrian time and continued to exist till late Devonian.
2. The Peace River high or ridge, which probably had been established by Cambrian time, existed well into the Upper Devonian, but had lost its effective expression by the end of the Devonian.
3. A metastable positive belt, located parallel to the present foothills in Alberta, and believed to have been emergent during the Ordovician continued to be an area of uplift during Silurian and Middle Devonian times. This belt was probably an effective land barrier between the Cordilleran seaway to the west and the evaporite basin on the Alberta shelf.
4. The Manitoba shelf, which extended from southwestern Manitoba, through central Saskatchewan into Alberta, was tectonically stable throughout the Middle Devonian. Normal marine conditions were in existence on the 150 mile wide shelf area.
5. The Dakota shelf which includes east-central and southern North Dakota, northern South Dakota, and parts of eastern Montana, and the Little Beaver axis which lies on the margin of the Dakota shelf, were emergent during the deposition of the Elk Point group.
6. The Swift Current platform which protruded into the basin from the south in southern Saskatchewan was a stable shelf on which depositional conditions were similar to those on the Manitoba shelf.

The early Middle Devonian sea advanced from the northwest of Alberta, becoming more saline in a southeasterly direction. In the northwest the major restrictions were caused by the Peace River ridge on the west and the Precambrian Shield on the east. The exact position of the shoreline north of McMurray is not known but Govett (1961) believes that an embayment extended some distance to the east along Lake Athabasca. There were possibly two sub-basins in the Northwest Territory-Alberta region (Figure 22), one in the north and one, designated here as the central Alberta sub-basin, in the south. The quantity of salt in the northern basin is believed to be small, but increases towards Fort Vermilion. Govett (1961) suggests that waters flowed southwards from the northern basin through a narrow channel over the Chipewyan Lakes sill into the central Alberta basin which extended a short distance into Saskatchewan. Restriction was almost complete except for the channel over the Chipewyan Lakes sill, which resulted in the deposition of two major salt beds and one more restricted bed in the Alberta basin, prior to the deposition of salt in the eastern part of the Elk Point basin.

The marine advance that deposited the carbonates at the base of the uppermost major salt unit in Alberta transgressed over a wide area. At this time the Peace River ridge ceased to be an effective restrictive barrier, except possibly in the extreme west. During this marine incursion the sea made its first major advance into Saskatchewan through a restricted channel centered at about latitude 52°40' in the area of the Saskatchewan-Alberta border (Govett, 1961). This marine advance is represented by member 3 (Belyea, 1959) in Alberta, and by the Winnipegosis formation in Saskatchewan (Figure 22). In the Great Slave Lake area, the Pine Point limestones and the Presqu'ile dolomite were deposited during the marine advance. The Presqu'ile has been interpreted as a barrier reef which migrated northwards (Law, 1955). Reefs also were formed on the Manitoba shelf in southwestern Manitoba and central Saskatchewan, probably constituting an effective barrier which restricted the spread of the evaporite on the east and northeast. With the restriction of circulation, marine conditions gave way to a widespread evaporitic environment in the extensive basinal area south of the Presqu'ile barrier reef. This evaporitic basin extended from northern and east central Alberta, southeastward across Saskatchewan, into southwestern Manitoba, northern North Dakota, and northeastern Montana. The greatest thicknesses within the basin are localized, indicating considerable areal variation in negative movements and intensity of restriction. The great thicknesses of salt also indicate uniform subsidence contemporaneous with precipitation.

The salinity of the seawater increased southeastwards. That the central Alberta basin contains three major salt units is evidence of considerable subsidence in this part of the Elk Point basin. The upper major salt unit of central Alberta, which is referred to as the first salt unit, continues through the restricted channel to the east as the Prairie Evaporite of Saskatchewan. In the central part of the basin east of the Saskatchewan-Alberta border, the concentration of the seawater became high enough to permit deposition of potassium salts in the upper part of the Prairie Evaporite formation. It is evident that the restriction between the sub-basin of central Alberta and that to the east was great enough to permit complete evaporation of the brine in the eastern part of the basin, whereas the restriction over the Chipewyan Lakes sill was not great enough to prevent some influx of brine into the Alberta basin from the northern basin.

Following the termination of the Prairie Evaporite deposition renewed subsidence and invasion of seawater occurred in the central part of the basin before the end of Middle Devonian time. The evidence for this is to be found in the evaporite sequence of the Dawson Bay and Souris River formations. During these cycles the brine was never sufficiently concentrated to permit deposition of potassium salts. The Middle Devonian period ended with a brief, but broad emergence, during which there was eastward truncation by erosion, before the transgression of the Upper Devonian sea.

SALT DEPOSITS OF THE NORTHWEST TERRITORIES

There are no known salt deposits in the Northwest Territories-Alberta border region. In the Norman Wells area and the lower MacKenzie valley or vicinity, wells have penetrated from 100 to 250 feet of salt in beds of Devonian or Ordovician age, at depths ranging from 2, 100 to 3, 000 feet. The age of the formation has not been determined because of lack of fossils in the evaporitic beds. At Imperial Vermilion Ridge, east of Norman Wells, salt was reported in the Cambrian at depths of 3, 370 to 5, 460 feet.

On the northern slopes of the Richardson Mountains gypsum piercement structures are emplaced in Cretaceous rocks, and it has been suggested that this gypsum might be of Cambrian age. This formation in the Norman Wells area contains thick salt beds. Only drilling will prove whether or not salt underlies these structures.

At Windy Point on the north shore of Great Slave Lake a well drilled by Imperial Oil Limited penetrated salt in an evaporite formation which is presumed to be of Ordovician age. About 72 miles northwest of the north arm of Great Slave Lake and 5 miles west of Mazenod Lake an indication of salt is found in outcrop where salt casts are found in beds of Ordovician age.

In the Canadian Arctic Islands gypsum tectonics are found on a number of the islands located in the Sverdrup basin (Figure 25). There are two different types of piercement structures. One type forms circular domes, which according to Kranck (1961), probably formed slowly, more or less contemporaneously with sedimentation, and are probably the result of load pressure. The other type is the elongated anticlinal diapir, which is produced essentially by tangential compression. The parts of these piercement structures which have been observed are principally composed of gypsum; however, anhydrite has been found in some. The gypsum is probably associated with salt, although up to the present time no salt has been found.

SALT IN BRITISH COLUMBIA

In 1913 drilling operations were carried out in an endeavour to locate rock salt in an area about 45 miles east of Prince Rupert, where in 1911 a strong salt spring had been discovered on the banks of the Skeena River at Kwinitsa. Salt was encountered in five holes in the form of salt mud. According to Forbes (1931) the deepest hole encountered salt mud at 110 feet after passing through 10 feet of surface soil and gravel and 100 feet of clay. The last 30 feet of the 250 foot hole contained salt crystals mixed with mud. It is probable that a salt deposit exists in this basin, but its thickness and areal extent has not been determined. There was only very minor production of salt from this occurrence in 1913 by the British Columbia Salt Works Limited.

This salt occurrence is located in a northerly-trending basin, which extends about 3 miles north from the Skeena River, varying in width at the north from one-half mile or less to about 2 1/2 miles on the north side of the Skeena River. The basin is bounded on the west side by a granite mass and on the east by steeply dipping basic schists.

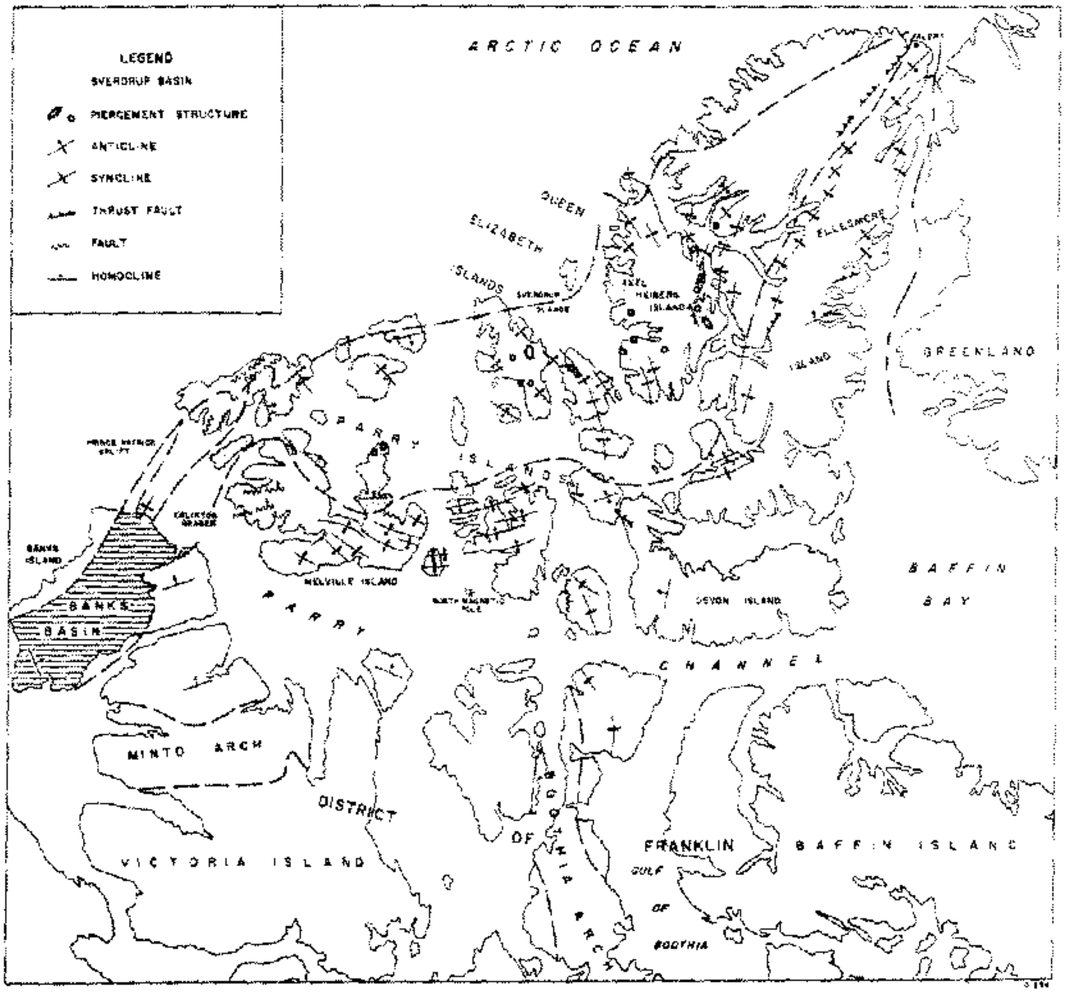

FIGURE 25

PIERCEMENT STRUCTURE IN THE SVERDRUP BASIN OF THE CANADIAN ARCTIC ARCHIPELAGO

(AFTER THORSTEINSSON AND TOZER, 1960)

SALT PRODUCTION IN CANADA

Commercial salt production in Canada is from three rock salt mines and from ten brining operations. The salt mines are located at Pugwash, Nova Scotia, and at Ojibway and Goderich in Ontario.

The brining operations are carried on in Alberta at Lindbergh; in Saskatchewan near Unity; in Manitoba at Neepawa; in Nova Scotia at Nappan near Amherst; and in Ontario at Sandwich, Goderich, Sarnia, Watford, and Windsor. In all of these operations, except at Neepawa, Manitoba, production is from artificial brine wells by solution mining. Wells are drilled into the salt bed, water is injected to dissolve the salt, and the brine is pumped out. At Neepawa the brine occurs in porous sedimentary rocks at depth, from whence it is brought to the surface by pumping.

The total salt production in Canada for 1960 was 3, 206, 164 tons. Of this Ontario produced 90. 01 per cent, Nova Scotia 5. 28 per cent, Alberta 2. 26 per cent, Saskatchewan 1. 56 per cent and Manitoba the remainder.

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