RESEARCH COUNCIL OF ALBERTA

GEOLOGICAL DIVISION

Preliminary Report 59-3

IRON OCCURRENCES IN THE PEACE RIVER REGION, ALBERTA

by

Donald J. Kidd

Research Council of Alberta
Edmonton, Alberta
1959

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

INTRODUCTION

Since 1955 when Premier Steel Mills, Limited started operations in Edmonton, interest in the establishment of a basic iron and steel industry in Alberta has increased. As all the raw materials for the production of iron and steel are available in Alberta the beginning of such an industry awaits only adequate markets. This report describes the deposits of one of these raw materials, the iron-rich sandstones in the Clear Hills area of northwestern Alberta. Exploration by private interests between 1953 and 1957 has outlined two deposits, each containing 500 million to 1 billion long tons with a grade of about 33 per cent iron.

The Peace River region of Alberta is shown in figure 1. Railways, highways and airlines connect the Peace River region to Edmonton and Vancouver. The chief iron occurrences are found in the Clear Hills (Fig. 1) which is approximately 50 miles northwest of the Town of Peace River, and 25 miles north of Hines Creek, a terminus of the Northern Alberta Railway. These deposits may be reached from Worsley and Eureka River, on the Hines Creek - Fort St. John gravelled road (Fig 2). A dirt road about 40 miles long leads from Eureka River Post Office to the Notikewin fire tower, 2 miles east of an iron occurrence on Swift Creek. This deposit may be reached on foot from the fire tower along an abandoned seismic trail. Other occurrences of a red-weathering ferriferous sandstone can be reached on rough roads, up to 9 miles long, which extend northward from the gravelled road, east of Worsley. In the wet weather the last 5 miles of these roads may be impassable. Most of the lesser occurrences south of the Peace River are accessible by section roads.

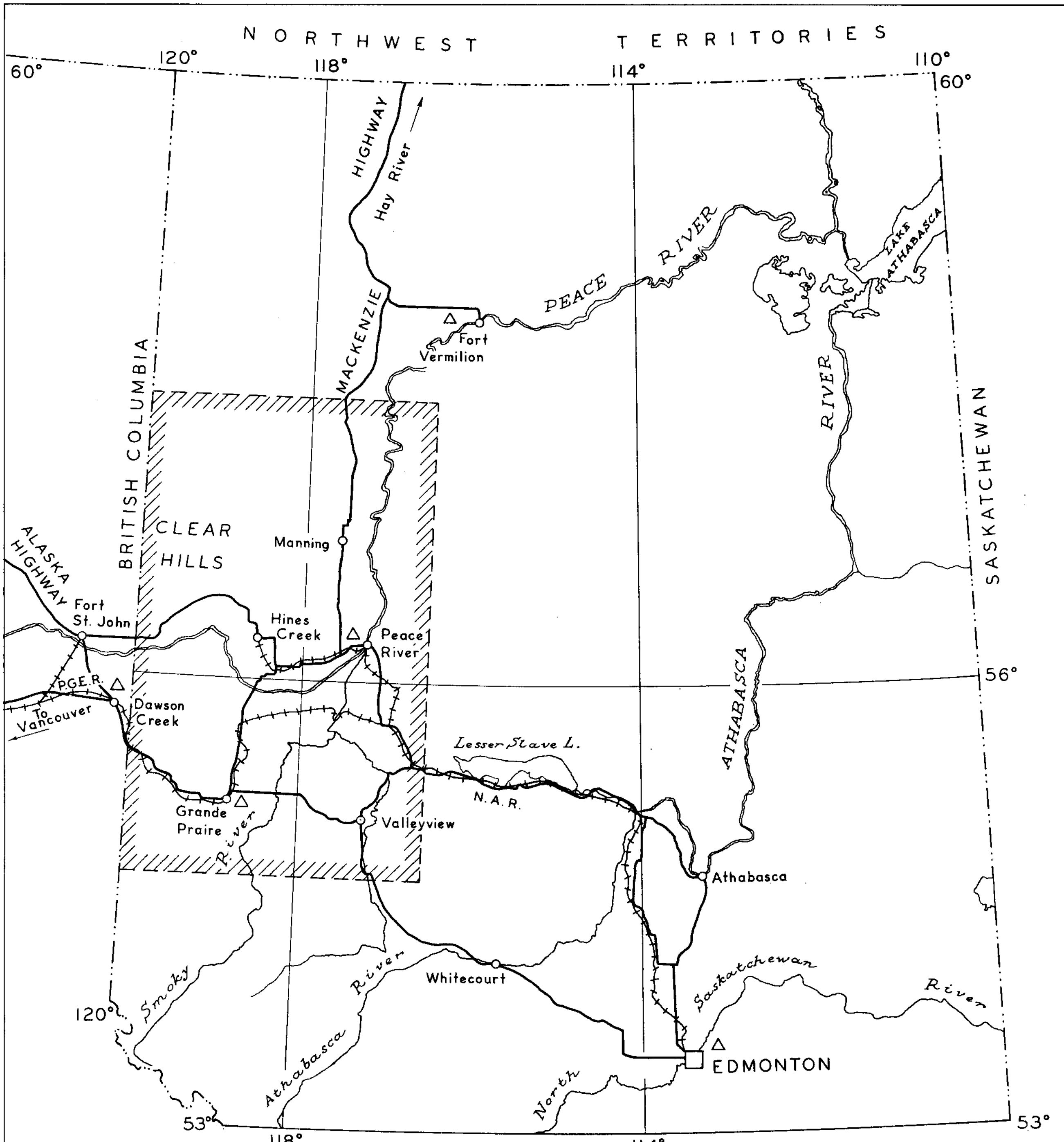


Figure 1

LOCATION OF PEACE RIVER REGION

ALBERTA

SCALE IN MILES

35 0 35 70 105

LEGEND

Peace River Region	▨
Main Highways	—
Railways	++++
Main Airfields	△

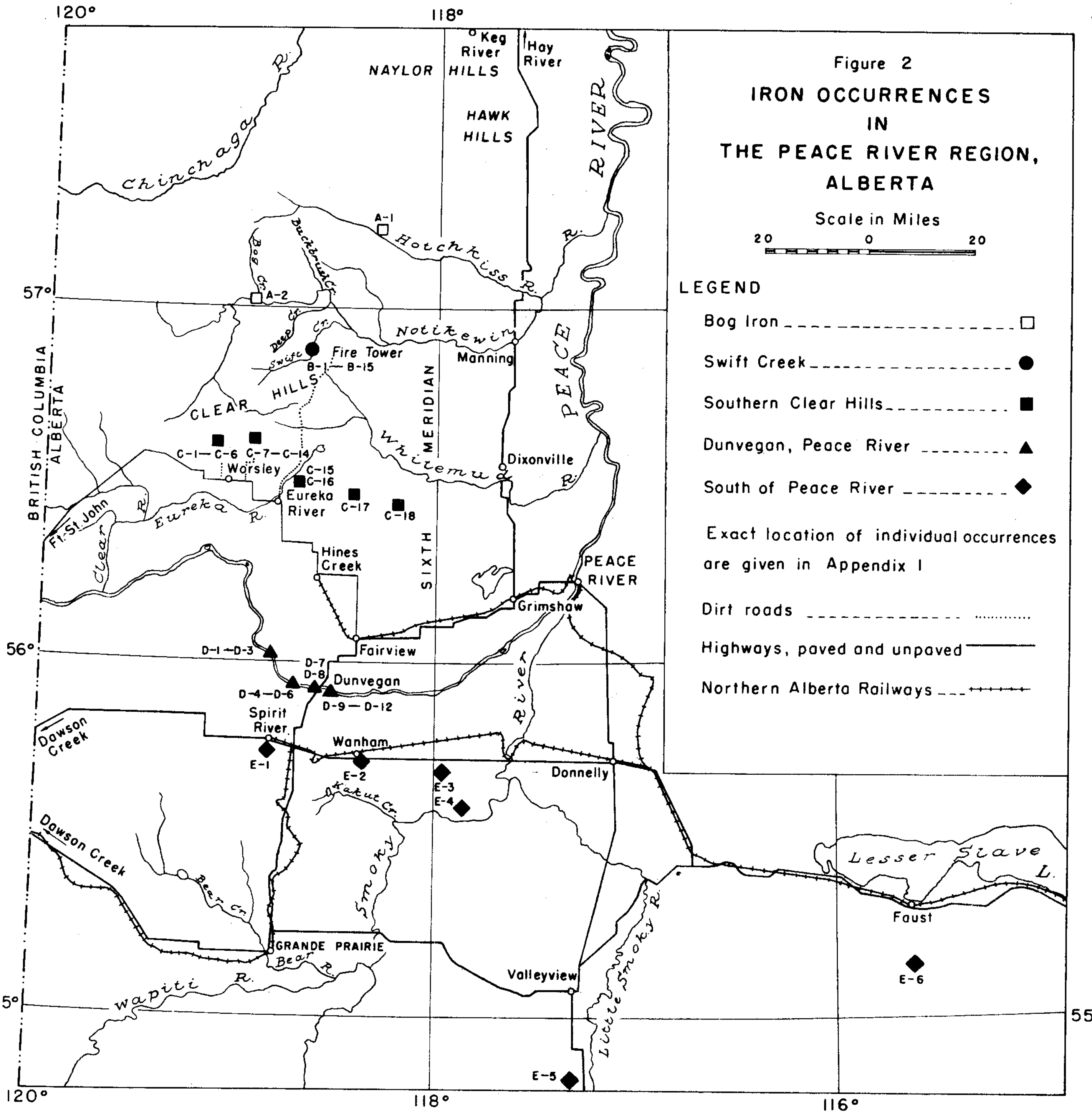


Figure 2

IRON OCCURRENCES IN THE PEACE RIVER REGION, ALBERTA

The Clear Hills vary in elevation from less than 3,000 feet around Swift Creek in the east, to 3,600 feet in the southwest near the British Columbia boundary. Adjacent to Swift Creek the average elevation of the hills is about 2,700 feet and the local relief is about 400 feet. The Clear Hills resemble a trefoil in shape with the northern lobe bent to the east in Tp. 96, Rs. 5 and 6, W. 6th Mer. The terrain is rolling and thickly wooded with spruce on the uplands, poplar on the slopes, and willow along the rivers; muskeg covers only small areas of the upland. The streams, which cut into bedrock only on the flanks of the Clear Hills, flow into the Peace River. Because of the generally thick drift cover, rock outcrops are scarce in the Clear Hills.

History of Exploration

The recent interest in iron in the Clear Hills started with the discovery of oolitic "hematite" in the Phillips Petroleum Company Phil C No. 1 well (Lsd. 8, Sec. 23, Tp. 90, R. 5, W. 6th Mer., Fig. 5) drilled in 1953 (Petroleum and Natural Gas Conservation Board, 1955, p. 202). Similar ferruginous material was recorded in two other nearby wells (McDougall, 1954).

842-4

Core drilling carried out near Swift Creek showed the presence of an iron deposit approximately 13 miles long by 3 miles wide with an average thickness of 10 feet. Reserves were estimated at nearly 1 billion tons, grading approximately 34 per cent iron and 20 per cent silica (McDougall, 1954). Metallurgical testing of the iron-bearing material from outcrops showed that fluxing costs would be prohibitive in view of the low lime and high silica contents. 842-7
2

A few holes, each approximately 50 feet deep, were drilled near an iron showing north of Worsley (Lsd. 2, Sec. 5, Tp. 88, R. 6, W. 6th Mer.). Some overburden was stripped off with a bulldozer. Fifty tons of the ferruginous sandstone were tested metallurgically. Reserves of between 500 million and 1 billion tons, grading 33 per cent iron, have been estimated (MacGregor, 1958, p. 54).

G. L. Colborne (1958) of Cleveland Cliffs Iron Company, examined the Swift Creek occurrence in 1957. He reported a grade of 30 per cent iron.

Field Work

8 [illegible]

The Swift Creek deposit was examined during the summers of 1956 and 1958. Iron-bearing sandstone outcrops in the southern Clear Hills and similar red-weathering ferruginous sandstones at Wanham and Spirit River were investigated in 1958. A brief examination of the eastern flanks of the Hawk and Naylor Hills and of the summit of Watt Mountain (Fig. 4) disclosed no ferruginous outcrops, but angular oolitic iron sandstone float was noted near the Naylor Hills fire tower (Lsd. 3, Sec. 9, Tp. 100, R. 23, W. 5th Mer.) at an altitude of about 2,500 feet.

Acknowledgments

Field assistance was given by B. E. Henson in 1956 and by R. H. Cooper in 1958. Numerous courtesies were rendered by Messrs. Melvin Anderson and George Running of Worsley, Messrs. Martin and James Satre and Ben Basnett of Eureka River, and Department of Lands and Forests officials in the area. Permission to quote from D. B. McDougall's reports of 1954 and 1956 and from the Mines Branch Report of Investigation No. MD 3042, is gratefully acknowledged. Polished sections of the Swift Creek iron specimens were prepared by the Mines Branch, Department of Mines and Technical Surveys, Ottawa.

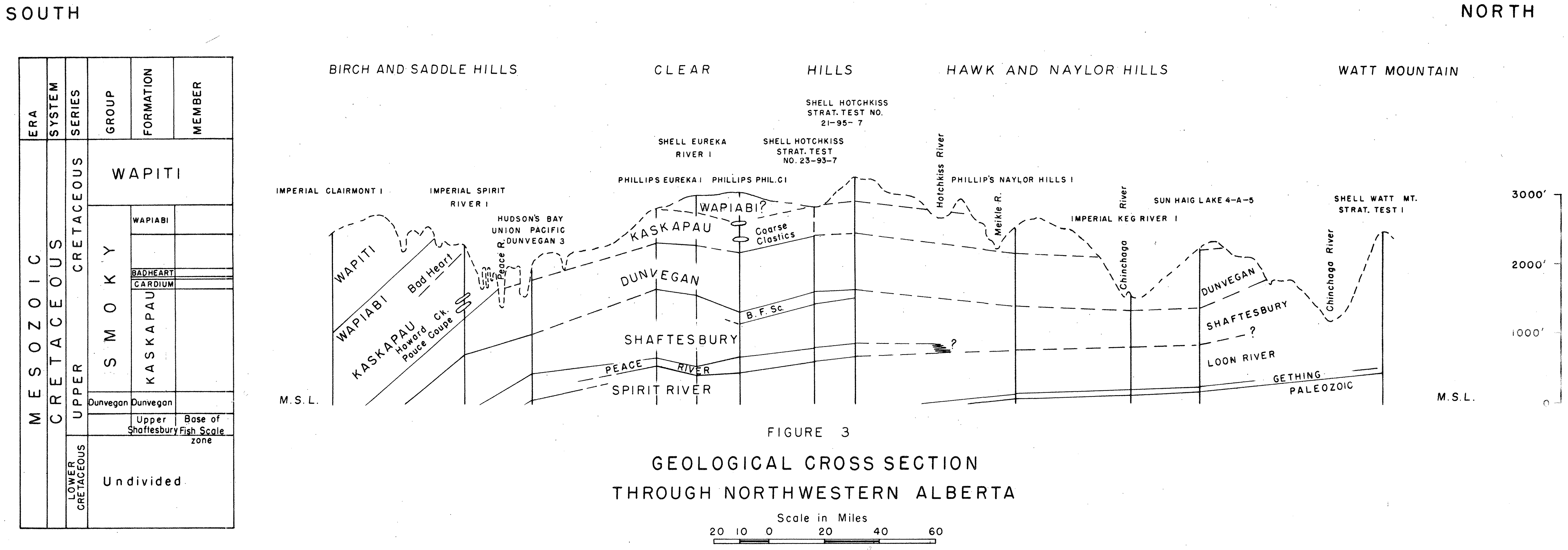


FIGURE 3

GEOLOGICAL CROSS SECTION
THROUGH NORTHWESTERN ALBERTA

Scale in Miles
20 10 0 20 40 60

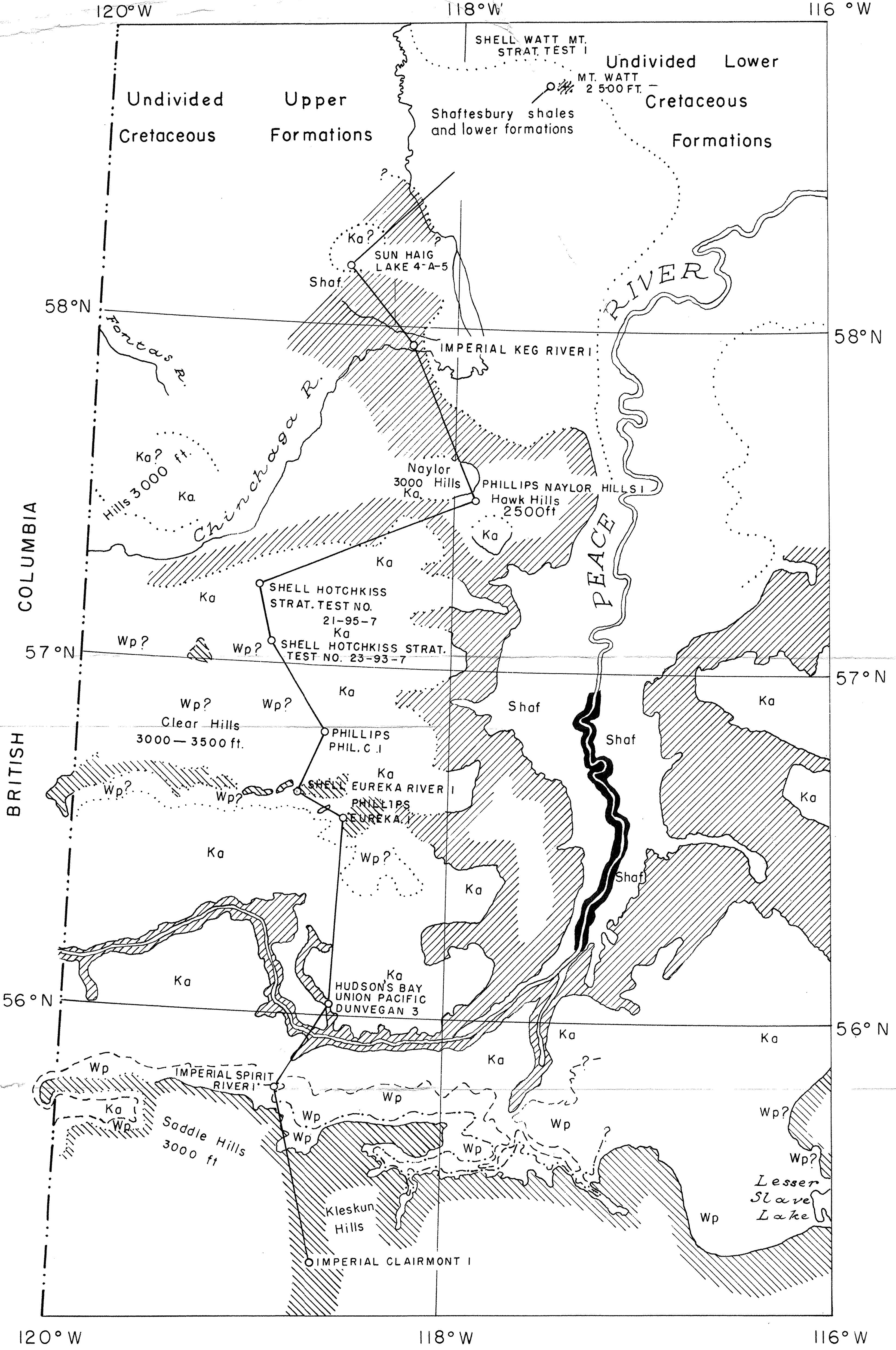


FIGURE 4

GEOLOGICAL MAP OF NORTHWESTERN ALBERTA

Scale in Miles

20 10 0 20 40

LEGEND

UPPER CRETACEOUS

Wapiti formation	▨
Wapiabi formation	Wp
Bad Heart member	—·—·—
Cardium formation	— — —
Kaskapau formation	Ka
Dunvegan formation *	▨
Shaftesbury (Upper) formation	Shaf.

LOWER CRETACEOUS

Shaftesbury (Lower) formation	Shaf.
Peace River formation	■
Undivided	☐
Geological boundary, observed	～
Geological boundary, assumed	⋯
Oil or gas well.	○

Sources of information.

Crickmay, C.H. (1944); Geol. Surv. Can. Map No. 1000A (McLearn and Kindle, 1950); Geol. Surv. Can. No. 1002 A (1951); Gleddie, J. (1949; revised 1954); Law. J (1955); Harding, S.R.L. (1955) Geological Cross Section of Northwestern Alberta, Fig. 3

* Dunvegan formation west of 118° W Longitude includes Upper Shaftesbury formation along the Peace River.

Compiled by D. J. Kidd, 1958.

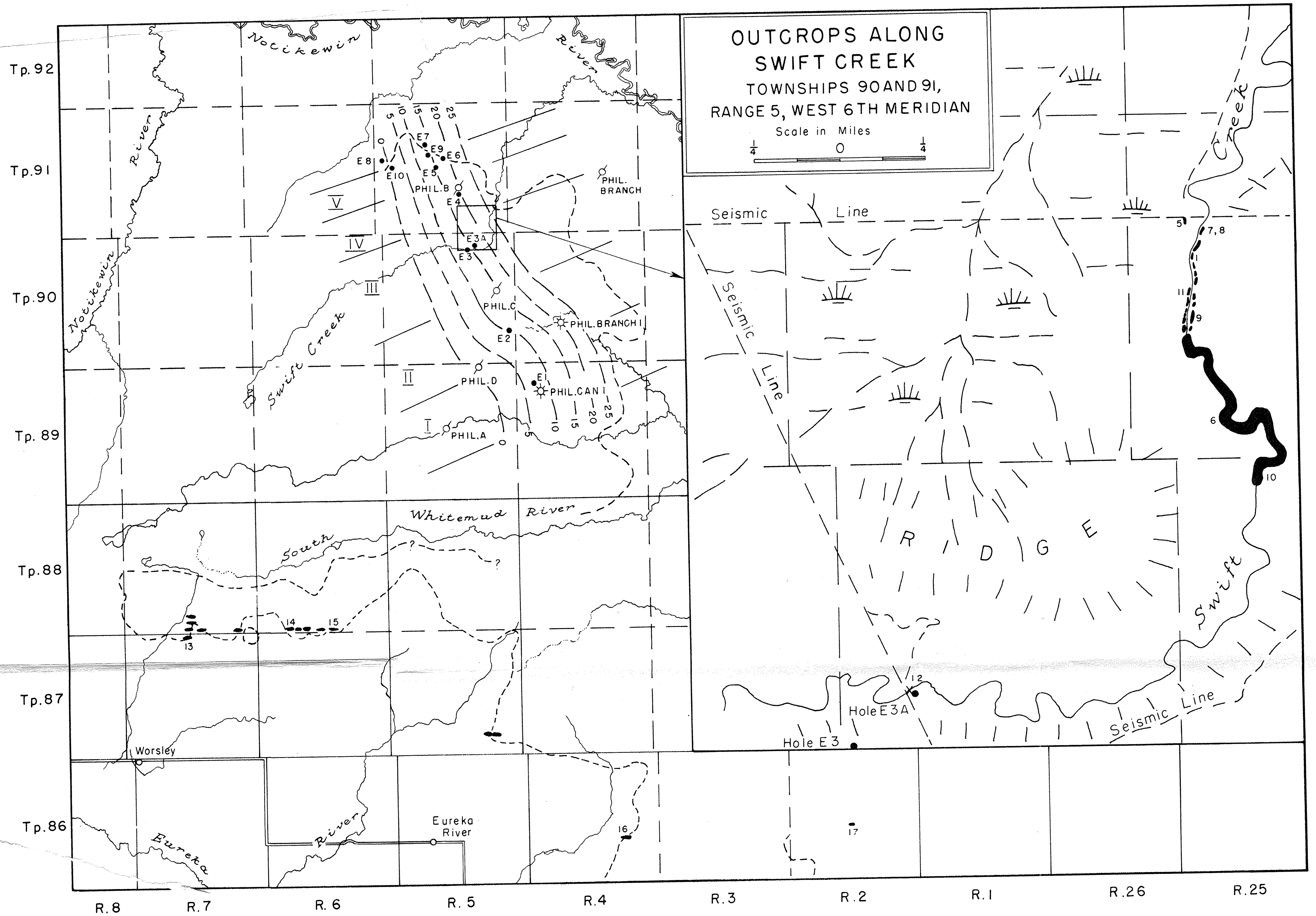


FIGURE 5

IRON DEPOSITS IN THE CLEAR HILLS

NORTHWESTERN ALBERTA

Scale in Miles

4 2 0 4 8 12

LEGEND

Ferruginous sandstone outcrop	▬
Shale outcrop	X
Core hole	E4 ●
Abandoned well	⌀
Potential gas well	☼
Block, for calculation of reserves	IV
Location of sample	15
Assumed outcrop limit of ferruginous sandstone	- - - -
Isopach of ferriferous sandstone	10 —— ——

GENERAL GEOLOGY

Stratigraphy

The Clear Hills are directly underlain by Upper Cretaceous sandstones and shales (Figs. 3 and 4). The following sequence of Upper Cretaceous strata of the Peace River region is summarized from Stelck and Wall (1954, p. 6) and Stelck, Wall, and Wetter (1958, p. 17).

Formation	Member
Wapiti	(Wapiti sandstones
	(Basal Wapiti sand
Wapiabi	(-shale
	(Chinook sandstone
	(-shale including "first" white-speckled shale marker-bed
	(Bad Heart sandstone
	(-shale
Cardium	(Baytree conglomerate
	(Cardium sand
Kaskapau	(- shale including "second" white-speckled shale marker-bed
	(Howard Creek sand
	(- shale
	(Pouce Coupe sand
	(- shale
	(Doe Creek sand
	(- shale
Dunvegan	(upper plant-bearing deltaic sequence
	(middle conglomeratic arkosic member
	(brackish lower member
	(basal sand member
Upper Shaftesbury	(- shale
	(Fish-scale sand (basal Upper Cretaceous)

Considerable variation in depositional environment is shown by the above sequence. The upper Shaftesbury is marine. The beds of the Dunvegan formation reveal a complex depositional history. Brackish-water and fluvial sediments are dominant in the lower part whereas a deltaic origin is indicated for the upper portion of the formation. Intertonguing of the deltaic sand of the upper Dunvegan with the brackish to marine shale of the lower Kaskapau has resulted in the development of such sands as the Doe Creek, Pouce Coupe and Howard Creek members. The shale and sand members of the upper Kaskapau, Cardium and Wapiabi formations represent a marine sequence. The onset of fresh-water and continental conditions is revealed in the sandy deposits of the Wapiti formation.

Age of the Clear Hills Iron Deposits

Age assignment of the iron-bearing sands is difficult because of the character of the sands and the limited amount of sampling and other data available. The thicknesses of the potentially ferriferous sand members in the Kaskapau and Wapiabi formations at their type localities range from less than 10 feet to a maximum of about 30 feet. The problem of recognition is enhanced by the deltaic origin of the sands in the lower Kaskapau and inherent tendencies of these sands to lense out locally. Notwithstanding these difficulties, some attempts have been made to date the Swift Creek iron deposit.

From a study of the microfauna in McDougall's core samples, Lenz (1956) equated the shales below the oolitic sandstone bed with the lower part of the *Gaudryina irenensis* microfaunal zone of Stelck and Wall (1954). This correlation indicates the age of the iron deposit to be about equivalent to that of the Doe Creek sand member. A few pelecypods were collected in the oolitic sandstone bed but because of the unsatisfactory condition of the material, precise identification is not possible. C. R. Stelck (pers. comm. Sept. 1958) reported that these pelecypods appear to be of Pouce Coupe age. One shale sample collected from an outcrop (12, Fig. 5), 70 feet above the iron deposit, was submitted to J. H. Wall for microfaunal examination. He reported obtaining an arenaceous foraminiferal assemblage which, although not entirely diagnostic, is suggestive of Wapiabi age. If the interpretations of Lenz and Wall are correct, then an unconformity is indicated at the level of the iron deposit on Swift Creek.

Some additional subsurface data regarding the stratigraphic position of the oolitic sandstone beds in the Clear Hills is contained in the Oil and Gas Conservation Board schedules of wells. The presence of iron-bearing sand in the area was discovered in the samples from the Phillips Petroleum Company Phil C No. 1 well (Lsd. 8, Sec. 23, Tp. 90, R. 5, W. 6th Mer.). In this well, the ferriferous sandstone band is at a depth of 494 feet, that is, about 370 feet above the Dunvegan formation (Petroleum and Natural Gas Conservation Board, 1955, p. 202) (Fig. 6). Similar ferruginous material was recorded in two other wells in the area: Phil B. No. 1 (Lsd. 2, Sec. 15, Tp. 91, R. 5, W. 6th Mer.), and Phil Branch No. 1 (Lsd. 13, Sec. 9, Tp. 90, R. 4, W. 6th Mer.) (McDougall, 1954).

The individual sands in the Kaskapau and Wapiabi formations are difficult to recognize in the subsurface by means of well electrologs. In summary then, with the limited amount of information available it is difficult to correlate the iron-bearing sandstone beds of the Clear Hills with the sand members in the Dunvegan, Spirit River, and Pouce Coupe areas.

Structure

The strata from the Peace River to the Northwest Territories form a homoclinal structure with southwest dips of 20 to 25 feet to the mile (Law, 1955). Local folding is known in the region but it is of minor importance. The regional dip in the eastern part of the Clear Hills is only about 8 feet to the mile (McDougall, 1954).

The iron-bearing sandstone layers in the Clear Hills are nearly horizontal and these layers might be found in the uplands as erosional remnants northward to the Chinchaga River. Thus one of the more favorable locations to prospect for iron is on the northern and northeastern flanks of the uplands overlooking the upper Chinchaga River Valley and on the Naylor Hills.

DESCRIPTIONS OF DEPOSITS

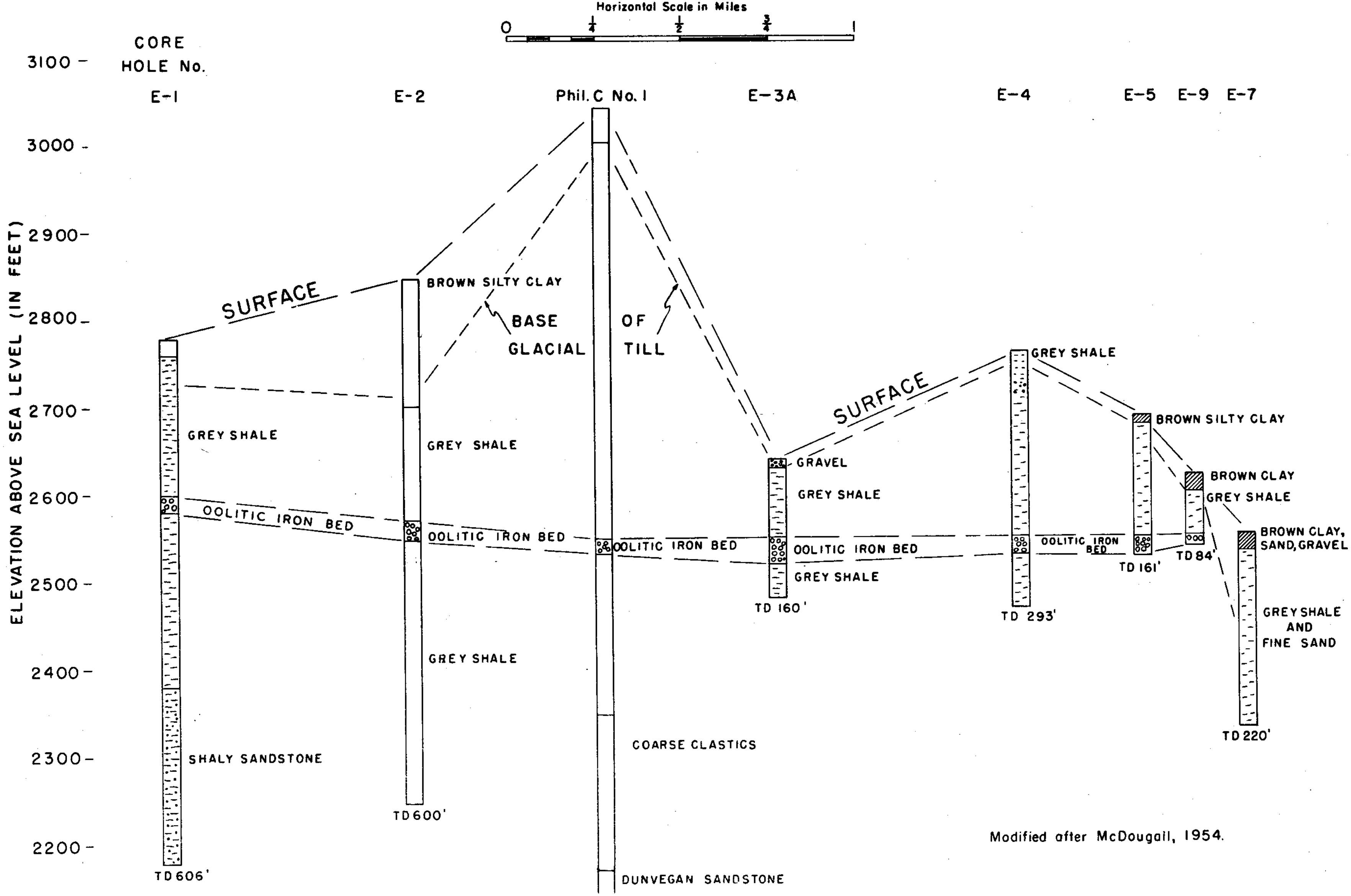
Swift Creek Deposit

Oolitic iron sandstone outcrops as a weathered seam along both sides of Swift Creek for nearly three-quarters of a mile and at an elevation of about 2,560 feet (inset map, Fig. 5). Up to 28 feet of the bed are exposed; the base is obscured and may lie below creek level. An isolated outcrop of the same iron sandstone was found three-quarters of a mile north of the most northerly outcrop in Swift Creek. The northern limit of the seam is 6 miles south of the Notikewin River (McDougall, 1954) and is erosional. The deposit trends south towards the south Whitemud River (Fig. 5). The eastern limit of the ferruginous sandstone bed has not been found but may be on the east flanks of the hill in Tp. 91, R. 4; estimated limits are shown on figure 5.

FIGURE 6

CORRELATION OF McDOUGALL'S CORE HOLES AND PHILLIPS' C NO.1 WELL

SWIFT CREEK AREA, CLEAR HILLS, ALBERTA



Modified after McDougall, 1954.

Southeast of Swift Creek the oolitic iron sandstone is approximately 20 feet thick as determined from the most easterly holes drilled by McDougall. Towards the southwest the thickness decreases to 12 feet at core hole 3A (Figs. 5, 6) and oolitic material is absent 9 miles to the south-southwest in Phil A No. 1 well. From the core-hole data, McDougall (1954) calculated that the deposit underlay an area of 42.9 square miles, and in the vicinity of Swift Creek the beds dip south-southwest at 10 feet to the mile.

The oolitic sandstone bed is olive-green to greyish-green at the base, brown to reddish-brown with white-weathering patches in the middle, and reddish-brown in the upper 10 to 15 feet. The middle beds contain horizontal lenticles of greyish-green oolitic sandstone more than 8 feet long and up to 10 inches thick. Along some steep-dipping joints the sandstone is purplish-red to dark-blue in color. Horizontal cracks and indentations, and vertical and near-vertical joints striking in a westerly direction are common in the outcrops. A peculiar rectangular network of lines on the faces of the more weathered upper parts of the ferruginous seam was observed in the northern outcrops (1, 7, 8, Fig. 5). The sides of these rectangles or boxes are 2 to 6 inches in length. The surface of the sandstone in one outcrop is armored with limonite.

Petrography

The iron-bearing sandstone in the outcrops along Swift Creek is a friable aggregate of chocolate-brown oolites about 0.5 mm. across. They form up to 60 per cent of the rock in the upper part of the seam and decrease irregularly from this amount toward the bottom. They consist of goethite and quartz which alternate in concentric shells of variable width; they commonly contain nuclei of quartz fragments, but a small proportion carry nuclei of a green chamosite-like mineral, feldspar, or a fragment of another oolite. More than 15 per cent are rolled grains of oxidized ironstone without enclosing concentric bands. These have been called false oolites by Cayeux (1922) who described them in some of the French iron deposits. The oolites are closely packed but mostly do not touch one another. They lie in a matrix of quartz, brown goethite, up to 8 per cent grey siderite, up to 20 per cent of a green chamosite-like mineral, smaller percentages of yellow apatite or collophane, and minute fragments of a fine-grained white to dark-grey sericitic mineral. The presence of goethite in the oolites and groundmass was confirmed by X-ray diffraction powder patterns. Small amounts of both magnetite and pyrite were found near the base of the sandstone, and less than one per cent of magnetite at the top of one outcrop. The lower part of the sandstone contains up to one per cent of minute pale-brown to reddish-brown amorphous or structureless globules in the matrix. A few of these rounded particles show a faint radial structure; several others exhibit a vague polyhedral packing. Lenz (1956, p. 6) thought that these might be chamosite, or chamosite and siderite, but the writer considers that they are probably microspherulitic siderite.

TABLE I

Chemical Analyses of a Clay Ironstone Nodule and a Sideritic Mudstone

	1	2
SiO_2	9.74	8.51
TiO_2	0.21	0.36
Al_2O_3	4.14	6.12
Fe_2O_3	20.69	1.77
FeO	28.79	36.91
MnO	-	0.42
MgO	2.08	3.75
CaO	2.22	5.54
Na_2O	0.18	0.05
K_2O	0.54	0.03
H_2O+		4.05
H_2O-	26.47	10.00
CO_2		20.70
P_2O_5	1.01	1.30
S	-	0.05
C	-	0.27
	96.07	99.83

1. Clay ironstone nodules from the lower part of an outcrop along Swift Creek. Analyst: H. Wagenbauer, Research Council of Alberta.

2. Sideritic chamosite mudstone, Cleveland ironstone, Great Britain. Analyst: J. E. Stead (in Pettijohn, 1957, p. 451).

TABLE II

Grade and Thickness of Swift Creek Deposit

Hole No.	Total iron weighted average (per cent)	Thickness sampled (feet)	Horizontal interval represented by weighted average (miles)	Thickness sampled X horizontal interval	Weighted average X thickness sampled X horizontal interval
	1	2	3	4	5
E1	34.07	8.0	2.8	22.4	763.2
E2	34.14	10.0	3.5	35.0	1194.9
E3	29.16	17.0	3.5	59.5	1735.0
E4	30.72	20.2	2.1	53.1	1631.2
E5	33.39	19.0	1.4	26.6	888.2
Total	--	74.2	13.3	196.6	6212.5
Overall Weighted Average	31.55	14.8	--	--	--

$$\text{Overall weighted average total iron} = \frac{\text{total of column 5}}{\text{total of column 4}}$$

$$\text{Overall weighted average thickness} = \frac{\text{total of column 4}}{\text{total of column 3}}$$

TABLE III

Some Chemical Analyses of Iron-rich Samples from the Swift Creek Deposit

Weight per cent

	3*	4	5	6
Total Fe	30.15	34.26	37.17	32.98
SiO_2	25.36	23.88	20.43	29.26
Al_2O_3	6.24	5.94	5.72	5.47
MgO	--	1.17	0.78	1.60
L.O.I.	--	12.00	9.69	11.91
P	0.58	0.62	0.45	0.45
S	0 to 0.70	tr	--	--

	7	8	9	10	11
Total Fe	11.0	26.3	30.9	36.3	26.1

3. Cuttings from Phil Can. No. 1 Well. Colborne (1958, p. 37).
   Total iron includes 0.15% Mn.

4. Composite sample from McDougall's cores: Janes (1957, p. 81).

5. Channel sample cut across an outcrop 12.5 feet thick along Swift Creek. (Location on Fig. 5)
   Analyst: Lerch Brothers, Incorporated, Hibbing, Minnesota.
   Total iron includes 0.18% Mn; L.O.I. includes 8.70% combined water and 0.99% carbon; CaO 2.13%; Na_2O 0.07%; K_2O 0.14%.

6 to 11. Grab samples from outcrops (see Fig. 5 inset map for locations).
   Analyst: H. Wagenbauer, Research Council of Alberta.
   In number 6: CaO 1.57%; Na_2O 0.13%; K_2O 0.48%; TiO_2 0.21%.

---

* Analyses are numbered consecutively throughout this report.

Sandstone in the cores differs from that at the surface only in its larger content of siderite which forms up to 40 per cent of the matrix in the lower parts of the outcrops and decreases in amount towards the top. Most of these characteristics of the iron-rich sandstone have been noted previously by Lenz (1956) and Janes (1957).

In the bottom 3 feet of two outcrops clay ironstone nodules constitute more than 75 per cent of the rock; they are surrounded by oolites. These nodules are composed of fine-grained siderite and a greenish chamosite-like mineral. A chemical analysis of these nodules is compared with an analysis of sideritic mudstone in table I.

Grade and Reserves

A grade of 31.55 per cent iron for the Swift Creek deposit has been calculated from analyses of cores from McDougall's drill holes (see Fig. 5 for locations of holes and Appendix II for analyses). A weighted average for each hole has been determined (Table II); an overall average grade has been obtained by weighting the analyses for each hole for the distances between the holes, and an average thickness of 14.8 feet in a similar manner. Analyses of other samples from the deposit are given in table III.

The iron content in all samples ranges from 37.17 per cent to 11.0 per cent, the lower assays coming from samples near the base of the bed. Hence, grades closer to those shown by the composite core sample and the channel sample (Table III) may be expected rather than the overall average grade of 31.55 per cent.

The sulfur content ranges from zero to about 0.03 per cent in all the samples from McDougall's cores (oral comm. G. R. Heffernan, March 1959).

The sample containing 0.70 per cent sulfur given by Colborne (see Table III) may have included some pyritic sandstone from below the iron seam.

The iron beds in the area shown on the isopach map have been divided arbitrarily into five blocks with the eastern boundary along the 25-foot isopach and the western boundary along the 7-foot isopach (Fig. 5). The average thickness of the deposit is taken as 14.8 feet (Table II). The volume of each block has been calculated by multiplying the average area of the ends of each block by the width (Table IV). The reserves are estimated at 1,511,000,000 tons.

TABLE IV

Reserves of the Swift Creek Deposit

Block No.	Area of ends of block (ft.-miles)	Width of block (miles)	Volume of block (millions of cu.ft.)	Millions of tons in block
	14.8 x 3			
I		3.25	4,023	366
	14.8 x 3			
II		3.25	4,191	381
	14.8 x 3.25			
III		4	4,951	450
	14.8 x 2.75			
IV		2	2,166	197
	14.8 x 2.5			
V		1.25	1,289	117
	14.8 x 2.5			
Total	--	--	--	1,511

840

3,784

Southern Clear Hills Deposits

Friable red-weathering ferriferous sandstones were traced in more than 15 outcrops along the southern slopes of the Clear Hills for approximately 37 miles (Figs. 2 and 5) at elevations between about 2,610 feet and 2,720 feet. These sandstones had been exposed during the construction of seismic and lumbering roads and originally lay under 1 to 4 feet of overburden along the edges of small scarps. Most of the sandstone exposures are less than 100 feet long. Hence the continuity of the sandstone between outcrops is uncertain. There may be several lenses, or even erosional gaps between the outcrops. Exposures of oolitic sandstones reach thicknesses of 30 feet, and average more than 7 feet. A southerly dip of about 40 feet to the mile was measured in the middle of the south side of Tp. 88, R. 7, W. 6th Mer.

The upper parts of the sandstone contain up to 75 per cent oolites in a matrix of calcite and siderite. The oolites are 0.4 mm. to 0.6 mm. across and consist of quartz and reddish-brown goethite, with greenish tinges here and there. They decrease in amount toward the bottom where the sandstone contains up to 85 per cent angular detrital quartz grains, about 0.2 mm. across, and less than 1 per cent feldspar grains in a matrix of calcite and siderite. The sandstone also contains up to 15 per cent of green chamosite-like grains, 20 per cent microspherulitic carbonate, and 8 per cent siderite grains. The groundmass comprises 5 to 65 per cent of the rock.

The weathered character of the outcrops and their size and number did not permit systematic sampling of the deposits in the southern Clear Hills.

Analyses of five grab samples are listed in table V (see Fig. 5 for locations). These analyses show that the highest iron contents in the ferruginous sandstones are found north of Worsley (Fig. 5). There the average iron content is about 35 per cent. Generally those samples with the highest proportion of oolites contain the most iron. The top 9 feet comprise the highest-grade part of the sandstone, which extends for 7 miles along the southern edge of the Clear Hills. If this sandstone is assumed to extend 4,500 feet back into the Clear Hills before the overburden becomes too thick for strip-mining, and 11 cubic feet of it weigh 1 ton, then reserves can be tentatively estimated to be:

$$\frac{(5280)\ (7)\ (4500)\ (9)}{11} = 136,100,000 \text{ tons}.$$

TABLE V

Chemical Analyses of Ferruginous Sandstone, Southern Clear Hills

	Weight per cent				
	13	14	15	16	17
Total Fe	27.33	41.47	38.10	20.90	18.49
Mn	0.25	0.29	0.29	0.18	0.16
SiO_2	41.74	18.84	25.32	39.46	55.68
Al_2O_3	5.94	6.63	6.02	3.97	5.10
CaO	0.63	0.52	0.95	9.19	3.40
MgO	0.83	0.82	0.48	1.05	0.90
TiO_2	0.24	0.34	0.23	0.17	0.27
P	0.377	0.353	0.536	0.278	0.120
S	0.007	0.012	0.008	0.032	0.015
C	0.65	0.66	0.58	2.55	1.10
Combined water	6.84	8.79	7.60	5.37	3.27

Analyses by Lerch Brothers, Incorporated, Hibbing, Minn.

Dunvegan Deposits

83 N-2
83 M-2

Oolitic iron sandstones (D-1 to D-12, Fig. 2) were observed by M. B. B. Crockford along the Peace River at an elevation of about 1,700 feet above sea level (Appendix I) for a distance of about 15 miles above Dunvegan Ferry (McDougall, 1956, p. 14, and pers. comm. M. B. B. Crockford, December 17, 1956). These strata weather a distinctive reddish-brown color and are used as markers in geological mapping. These sandstones are either near the top of the Dunvegan formation or above it, perhaps in the Howard Creek sandstone member in the lower Kaskapau formation. Thicknesses vary from 1 to 9 feet.

Other Deposits

83 M-9, 8

Ferruginous beds are present in members of the Wapiabi formation south of the Peace River (Fig. 2, Appendix I). The Bad Heart member forms an escarpment which extends eastward from the vicinity of Spirit River Town to the Smoky River. The thickness increases from 15 feet at Spirit River to 25 feet on the Smoky (Rutherford, 1930). The ridge-forming sandstone is medium- to coarse-grained, porous and characteristically dark-red weathering (Rutherford, 1930). Gleddie (1954, p. 498) states:

> "The Bad Heart contains ironstone concretions, glauconite and some interbedded sandy shale, and a few bands of chert pebbles. Along the Smoky River the Bad Heart is capped by a hard limy ironstone ledge at least one foot thick".

This ironstone is apparently that which was recorded by Dawson (1881) from the Smoky River. His specimens assayed 30.98 per cent iron (Dawson, 1881, p. 16M).

The Bad Heart sandstone at Spirit River is similar petrographically to the lower part of the ferruginous sandstone in the southern Clear Hills. It contains up to 85 per cent detrital quartz grains, 0.3 mm. or less across, and locally up to 10 per cent oolites, probably of goethite. The groundmass is calcite and siderite. In well samples the sandstone contains pyrite and glauconite (Harding, 1955).

In the Wapiabi formation there are at least three ironstone beds lying 40 to 75 feet below the Bad Heart sandstone at Spirit River Town. These bands are siliceous, commonly oolitic, orange-red weathering and locally form minor scarps (Gleddie, 1954).

Oolitic iron has been reported by M. Fuglem (Oil and Gas Conservation Board written comm.) in or near the Bad Heart sandstone in two wells. In Gulf Little Smoky No. 12 well (Lsd. 12, Sec. 27, Tp. 67, R. 22, W. 5th Mer.) (E-5, 83K-1 Fig. 2) ironstone concretions were recorded at 2,420 feet, 50 feet below the top of the Bad Heart sandstone, or 580 feet above the top of the Dunvegan sandstone. In Sun Faust No. 1 well (Lsd. 9, Sec. 4, Tp. 71, R. 11, W. 5th Mer.) (E-6, 83O-1 Fig. 2) oolitic ironstone was recorded 20 feet below the top of a sandstone logged as Bad Heart, at a depth of 1,420 feet.

ECONOMIC CONSIDERATIONS

Technological advances have been made by the North American steel industry in the past 15 years as a consequence of the depletion of the rich Lake Superior iron deposits, and of steel makers' recent preference for iron concentrates assaying more than 60 per cent iron beneficiated from either low-grade magnetite deposits or soft and porous limonite deposits. A variety of direct reduction processes recently brought to the attention of Canadian steel interests, or under development, makes it possible to mine hitherto uneconomic iron deposits (Rogers, 1958). These factors have placed the huge Clear Hills low-grade deposits in a favorable technological position.

These two Clear Hills deposits are soft, porous, easy to drill, and amenable to strip-mining methods. They are near oil and gas fields and are about 30 miles from the railway at Hines Creek. Potentially competitive deposits elsewhere in Western Canada include the following:

(1) Titaniferous magnetite sandstone lenses east of the Crowsnest Pass in southern Alberta,

(2) Magnetite deposits which are found in the Precambrian rocks of Saskatchewan. One of these underlies 2,000 feet of soft sedimentary rock and is located east of Prince Albert.

Before iron can be produced from the Clear Hills deposit, several factors must be considered. The oolitic iron sandstones are of low grade, containing between 25 and 35 per cent iron. The occurrence, mineralogy, composition and reserves of other North American and Western European deposits are compared with those of the Clear Hills in table VI. In many places the silica content is over twice that generally accepted by North American blast-furnace operators. A silica content of 10 to 11 per cent approaches the maximum permissible (Roe, 1957). The lime content is very low, especially in the Swift Creek deposits, and large amounts of flux would be required. The phosphorous content is too high for the long-established North American smelting methods but perhaps not too high for the more versatile European steel-making techniques. The percentages of other constituents, such as sulfur, are within metallurgically acceptable limits (Roe, 1957). Certain of these problems, in particular the high silica content, may be overcome by standard beneficiation techniques.

Similar "minette" and Salzgitter ores of France and Germany (Table VI) are benficiated by the Krupp-Renn process, a direct reduction method which was developed expressly for the oolitic iron ore (Roe, 1957, p. 200). Roe described the upgrading of Czechoslovakian iron ores containing 26 to 30 per cent to a "luppen" (small agglomerated pellets of metallic iron and slag) containing 92 to 93 per cent iron, despite a lime to silica ratio of only 0.09 approximately. Premier Steel Mills, Limited found that it could make a concentrate from the Clear Hills deposits suitable for blast furnace operation and that it is feasible to concentrate this ore by means of the Krupp-Renn process; MacGregor (1958, p. 54) stated,

> "The economics of this process are not as favorable, however, as those of blast furnace operation. At the present time it appears that a blast furnace operation would be economical once markets become sufficient to use the output of such a blast furnace".

Further exploration for petroleum and intensive prospecting in the Clear Hills and other uplands in northwestern Alberta (Figs. 3 and 4) may disclose in Cretaceous sandstones other large iron occurrences close enough to the surface to be cheaply quarried, and more amenable to beneficiation.

The consumption of steel in Western Canada is:

	1956	1957
Prairie Provinces	390,000 tons	427,000 tons
British Columbia	389,000 tons	364,000 tons

Production in Alberta comes from Premier Steel Mills, Limited, in Edmonton, which has an ingot capacity of 100,000 tons per year. In Saskatchewan production will come from the Interprovincial Steel Corporation mill (capacity 100,000 tons) which is being built in Regina. Both mills use or are planning to use scrap steel. However, should pig iron be available at competitive prices it might have some technological advantages over scrap. The Consolidated Mining and Smelting Company recently announced that it will build a plant to produce 100,000 tons of pig iron and various steel products annually from the tailings of its plant at Kimberley, British Columbia. For the consumption of steel in Western Canada, approximately 400,000 tons per year might be produced by steel mills in Alberta and Saskatchewan. For such a production approximately 200,000 tons of pig iron might be obtained from Alberta iron ore. Economic operation of a blast furnace to produce this pig iron would require a market for about 350,000 tons per year (Heffernan, 1959). Hence under present economic conditions additional markets for pig iron are required before a blast furnace can be operated. The iron deposits at Swift Creek could supply indefinitely the 1 million tons of ore required annually for such an operation. The deposit at Worsley could supply the same operation for several decades.

Table VI

Typical Direct-Shipping and Concentrating Iron Ores

Type of Deposit and Location	Ore Minerals	Age	Associated Rocks	Chemical Composition per cent								Annual Production (Long Tons)	Reserves (Long Tons)
				Fe	Mn	P	S	SiO_2	Al_2O_3	CaO	Moisture		
Sedimentary													
Oolitic													
Clear Hills, Alberta (1) Swift Creek	goethite siderite chamosite	Late Cretaceous	sandstone shale	31.55	0.18	0.45	0 - 0.7	25	6	1.5	10 - 12	nil	1.5 billion
(2) Worsley	goethite siderite chamosite	Late Cretaceous	sandstone shale	30	0.22	0.3	0.013	35	6	3	4 - 8	nil	100 million
Birmingham, Alabama	hematite	Silurian	limestone shale	32 - 45	0.25	0.25 - 1.5	0.05	2 - 25	2 - 5	5 - 20	0.5 - 3.0	5 to 6 million	several billion
Wabana, Newfoundland	hematite siderite chamosite	Ordovician	sandstone shale	51	0.13	0.88	0.04	12	5	3	1.5	2 to 3 million	4 to 10 million
Central England	siderite chamosite	Jurassic	shale	28	2.24	0.07 - 1.2	0.04 - 0.74	2.10 - 32.7	2.82 - 16.8	1.9 - 33.85	15	12 to 20 million	3 billion
Lorraine "Minette" France, Luxembourg and West Germany	goethite hematite siderite	Jurassic	shale sandstone limestone	30	0.3	0.5 - 1.8	0.2	7 - 20	5	5 - 12	13 - 19	32 to 50 million	5 billion
Salzgitter, West Germany	siderite	Early Cretaceous	sandstone shale	25 - 33	0.2	0.4	-	21 - 30	7 - 8	4 - 7	-	3 million	1 billion
Siderite													
Algoma, Ontario	siderite pyrite	Precambrian	banded chert and pyrite volcanic rocks	35	3	0.022	2 - 6	3 - 12	1.82	3 - 4	0.74	1 to 1.5 million	300 million
Taconite													
Lake Superior region	magnetite	Precambrian	taconite	27.7 - 36.7	0.03 - 0.9	0.013 - 0.056	-	35 - 56	0.10 - 1.42	0.01 - 1.07	0.13 - 11.0	2 to 4 million	many billion
Other													
Choteau, Montana	titaniferous magnetite	Cretaceous	sandstone	44	0.5	0.02	0.05	17	5.2	1.6	-	nil	2 to 10 million
Residual													
Lake Superior region	hematite goethite magnetite	Late Precambrian	banded chert	50 - 62	5	0.03 - 0.25	low	7 - 12	2	0.5	11	25 to 50 million	almost exhausted
Labrador and Ungava, Quebec	hematite goethite	Late Precambrian	banded chert dolomite	50 - 61	0.08 - 8.0	0.057 - 0.13	0.01 - 0.03	3 - 8	0.22 1.5		10.0	12 million	over 600 million
Steep Rock, Ontario	hematite goethite	Late Precambrian	dolomite iron formation volcanic rocks	53	0.18	0.28	0.3 - 0.4	6.5 - 8.1	1.4	-	9.4 - 9.7	2 to 3 million	over 300 million
Cuba	hematite limonite magnetite		serpentine laterite	54	0.5 - 0.9	0.01	0.4	5.7	10 - 12	-	25	variable 0.2 million (1953)	several hundred million
Replacement													
Adirondacks, New York	magnetite	Early Paleozoic?	granite gneiss	22 - 53	-	0.01 - 0.2	0.03 - 0.9	1 - 37	0.5 - 7	1.4 - 5.8	-	4 to 5 million	possibly 1.5 billion
Cornwall, Pennsylvania	magnetite	Post-Cambrian	limestone skarn quartz diabase	29 - 43	-	0.016	2.00	16	5	4	-	1 million	not known
Texada Island, British Columbia	magnetite	Jurassic	limestone skarn	41	-	0.05	1.44	4 - 8	2	1 - 4	-	0.2 to 0.5 million	not known
Vancouver Island, British Columbia	magnetite	Jurassic	limestone skarn	50 - 65	-	0.004 - 0.121	0 - 3	3 - 12	-	-	-	0.4 to 1.3 million	not known
Marmora, Ontario	magnetite hematite	Precambrian	gneisses marble	35 - 47	-	0.13	0.04 - 0.05	21 - 4	-	-	-	one million	20 million

Compiled from many sources.

Unlike any of the iron and steel works in Eastern Canada a primary steel industry erected in Alberta can obtain all its raw materials from within the province. Fluxing limestone and coking coal for blast furnaces are present for hundreds of miles in the foothills of Alberta and British Columbia. The below-average cost of electric power in central Alberta would encourage the use of electrical smelting or direct reduction methods. Alberta's extensive strip-mineable coal reserves can supply an abundance of steam-generated electric power. Supplies of low-cost gas and oil fuels in the prairies are sufficient to last at least a generation. Other requirements such as fireclays for refractories should present no serious problems (Goodwin, 1951).

Transportation is the most important factor in determining the location of producing plants in relation to source of raw materials and consumer markets. As finished iron and steel have a very high freight rate, Convey and Gertsman (1952) stressed the importance of locating a blast furnace close to the market and close to the source of fuel rather than close to the iron ore deposit.

In conclusion the only major problem standing in the way of a basic iron and steel industry in Alberta at the present is one of markets.

REFERENCES CITED

Colborne, G. L. (1958): Sedimentary iron in the Cretaceous of the Clear Hills area, Alberta; unpublished M.Sc. thesis, Univ. of Alberta, 101 pages.

Cayeux, L. (1922): Les minerais de fer oolitique de France; Minerais de fer secondaire, Fasc. 2.

Convey, J., and S. L. Gertsman (1952): The past, present and future of the Canadian steel industry; Can. Mines Branch, Mimeographed Circular, 25 pages.

Crickmay, C. H. (1944): Preliminary map, Pouce Coupe-Peace River, Alberta and British Columbia; Geol. Surv. Can. Paper 44-31.

Dawson, G. M. (1881): Report on an exploration from Port Simpson on the Pacific coast to Edmonton, on the Saskatchewan, embracing a portion of the northern part of British Columbia and the Peace River country; Geol. Nat. Hist. Surv. Can., Rept. Prog. 1879-1880, pt. B, p. 1 - 177.

Gleddie, J. (1954): Upper Cretaceous in western Peace River plains, Alberta; Ralph Leslie Rutherford Memorial Volume, "Western Canada Sedimentary Basin", Am. Assoc. Petroleum Geol., appendix, p. 486-509.

Goodwin, W. M. (1951): Basic industry for Alberta, a study of factors affecting the future of an iron and steel industry in the Prairie regions; Mineral Resources Division, Can. Mines Br., 9 pages.

Harding, S. R. L. (1955): Regional discussion of the Cardium formation; Bull. Can. Inst. Min. Met., Vol. 48, No. 513, p. 19 - 24.

Heffernan, G. R. (1959): Western natural resources - iron ore and steel; The Alberta Professional Engineer, Vol. 13, No. 1, p. 2-3.

Janes, T. H. (1957): A survey of the iron ore industry in Canada during 1956; Can. Dept. Mines & Techn. Surv., Mineral Resources Div. Information Circular MR 22, 83 pages.

Law, J. (1955): Geology of northwestern Alberta and adjacent areas; Bull. Am. Assoc. Petroleum Geol., Vol. 39, p. 1927 - 1978.

Lenz, A. C. (1956): Oolitic iron ore, Clear Hills, Alberta; unpublished manuscript, Univ. of Alberta, 38 pages.

McDougall, D. B. (1954): Preliminary report on Peace River iron ore; unpublished report, 18 pages (available at Research Council of Alberta).

McDougall, D. B. (1956): Summary report on Clear Hills iron; unpublished report for Premier Steel Mills, Limited, 16 pages.

MacGregor, J., chairman (1958): Report of the Royal Commission on the development of northern Alberta; private report, 115 pages.

McLearn, F. H., and E. D. Kindle (1950): Geology of northeastern British Columbia; Geol. Surv. Can., Mem. 259, 236 pages.

Pettijohn, F. J. (1957): Sedimentary rocks; 2nd edition, Harper and Brothers, New York, 718 pages.

Petroleum and Natural Gas Conservation Board (1955): Schedule of wells drilled for oil and gas in 1954; Calgary, Alberta, 271 pages.

Petroleum and Natural Gas Conservation Board (1956): Schedule of wells drilled for oil and gas in 1955; Calgary, Alberta, 301 pages.

Roe, L. A. (1958): Iron ore beneficiation; Edwards Brothers, Ann Arbor, Michigan, 305 pages.

Rogers, R. R. (1958): New processes promise much for iron ore; The Northern Miner, Annual Review Number, Nov. 27, p. 69, 74.

Russell, L. S. (1943): Sexsmith-Bison area; Geol. Surv. Can. (Map only).

Rutherford, R. L. (1930): Geology and water resources in parts of the Peace River and Grande Prairie districts, Alberta; Res. Coun. Alberta, Rept. 21, 68 pages.

Stelck, C. R., and J. H. Wall (1954): Kaskapau foraminifera from Peace River area of Western Canada; Res. Coun. Alberta, Rept. 68, 38 pages.

Stelck, C. R., Wall, J. H., and R. E. Wetter (1958): Lower Cenomanian foraminifera from Peace River area, Western Canada; Res. Coun. Alberta, Geol. Div. Bull. 2, Pt. 1, 35 pages.

Appendix I

Location of iron occurrences in the Peace River region

Note: The Clear Hills occurrences are in unsurveyed or partially surveyed territory, thus locations are only approximate.

Recent bog iron

South bank, Hotchkiss River	Near boundary of Tps. 94 and 95, R. 3, W. 6th Mer.
North bank, Notikewin River	Sec. 35, Tp. 92, R. 5, W. 6th Mer.

Upper Cretaceous sandstone deposits

Swift Creek area	B-1	Lsd. 12, Sec. 1, Tp. 91, R. 5, W. 6th Mer.
	B-2	
	B-3	
	B-4	
	B-5	
	B-6	
	B-7	
	B-8	Lsd. 5, Sec. 1, Tp. 91, R. 5, W. 6th Mer.
	B-9	
	B-10	Lsd. 13, Sec. 36, Tp. 90, R. 5, W. 6th Mer. and Lsd. 3, 4, and 5, Sec. 1, Tp. 91, R. 5, W. 6th Mer.
	B-11	Lsd. 5, Sec. 1, Tp. 91, R. 5, W. 6th Mer.
	B-12	
	B-13	
	B-14	
	B-15	Lsd. 5, Sec. 12, Tp. 91, R. 5, W. 6th Mer.

Southern Clear Hills	C-1	Lsd. 12, Sec. 6, Tp. 88, R. 7, W. 6th Mer.
	C-2	Lsd. 16, Sec. 33, Tp. 87, R. 7, W. 6th Mer.
	C-3	North side of Lsd. 16, Sec. 33, Tp. 87, R. 7, W. 6th Mer.
	C-4	Lsd. 8, Sec. 4, Tp. 88, R. 7, W. 6th Mer.
	C-5	Lsd. 9, Sec. 4, Tp. 88, R. 7, W. 6th Mer.
	C-6	Lsd. 2, Sec. 3, Tp. 88, R. 7, W. 6th Mer.
	C-7	Lsd. 4, Sec. 1, Tp. 88, R. 7, W. 6th Mer.
	C-8	Lsd. 2, Sec. 1, Tp. 88, R. 7, W. 6th Mer.
	C-9	Lsd. 9, Sec. 1, Tp. 88, R. 7, W. 6th Mer.
	C-10	Lsd. 2, Sec. 5, Tp. 88, R. 6, W. 6th Mer.
	C-11	
	C-12	Lsd. 1, Sec. 5, Tp. 88, R. 6, W. 6th Mer.
	C-13	Lsd. 4, Sec. 4, Tp. 88, R. 6, W. 6th Mer.
	C-14	Lsd. 2, Sec. 4, Tp. 88, R. 6, W. 6th Mer.
	C-15	Lsd. 13, Sec. 2, Tp. 87, R. 5, W. 6th Mer.
	C-16	
	C-17	Lsd. 15 and 16, Sec. 14, Tp. 86, R. 4, W. 6th Mer.
	C-18	Lsd. 8, Sec. 16, Tp. 86, R. 2, W. 6th Mer.
Peace River, Dunvegan	D-1	Lsd. 5, Sec. 22, Tp. 81, R. 6, W. 6th Mer.
	D-2	Lsd. 4, Sec. 23, Tp. 81, R. 6, W. 6th Mer.
	D-3	Lsd. 8, Sec. 11, Tp. 81, R. 6, W. 6th Mer.
	D-4	Lsd. 1, Sec. 20, Tp. 80, R. 5, W. 6th Mer.
	D-5	Lsd. 14, Sec. 16, Tp. 80, R. 5, W. 6th Mer.

Peace River, Dunvegan, cont'd	D-6	Lsd. 8, Sec. 15, Tp. 80, R. 5, W. 6th Mer.
	D-7	Lsd. 8, Sec. 14, Tp. 80, R. 5, W. 6th Mer.
	D-8	Lsd. 9, Sec. 12, Tp. 80, R. 5, W. 6th Mer.
	D-9	Lsd. 13, Sec. 11, Tp. 80, R. 5, W. 6th Mer.
	D-10	Lsd. 16, Sec. 7, Tp. 80, R. 4, W. 6th Mer.
	D-11	Lsd. 4, Sec. 17, Tp. 80, R. 4, W. 6th Mer.
	D-12	Lsd. 7, Sec. 16, Tp. 80, R. 4, W. 6th Mer.
South of Peace River	E-1	Sec. 20, 21 and 22, Tp. 78, R. 6, W. 6th Mer.
	E-2	Sec. 3 and 4, Tp. 78, R. 3, W. 6th Mer.
	E-3	Sec. 27 and 28, Tp. 77, R. 26, W. 5th Mer.
	E-4	Along Smoky River between Kakut Creek and Little Smoky River
	E-5	Sec. 14, Tp. 71, R. 11, W. 5th Mer.
	E-6	Sec. 27, Tp. 67, R. 22, W. 5th Mer.

Appendix II

Chemical analyses of Core Samples, Swift Creek deposit
Weight per cent

Sample No.	Total Iron	Fe_2O_3	SiO_2	Al_2O_3	MgO	Loss on Ignition	Total	Sampled interval in feet
E1A [1]	35.02	50.10	27.49	6.11	2.62	13.64	99.96	180 to 185
E1B	32.49	46.48	23.18	7.25	4.68 [2]	16.32	97.91	185 to 188
E2A	30.64	43.84	31.68	7.40	2.53 [2]	12.80	98.25	278 to 282.5
E2B	37.01	52.94	19.93	6.55	2.87 [2]	16.37	98.66	282.5 to 288
E3A	36.34	51.98	21.52	6.30	1.31 [2]	15.35	96.46	93 to 98
E3B	35.36	50.58	27.34	5.95	2.34 [3]	12.57	98.97	98 to 103
E3C	19.59	28.02	48.46	6.00	2.68	12.52	97.68	103 to 110
E4A	36.67	52.46	23.80	5.80	1.60 [2]	14.56	98.22	220 to 225.5
E4B	34.58	49.47	27.34	6.50	2.06 [2]	13.75	99.12	225 to 232
E4C	29.04	41.55	34.05	6.55	2.63	12.98	97.76	232 to 238
E4D	24.80	35.47	37.89	7.70	3.30	12.63	96.99	238 to 240.5
E5A	34.16	48.88	26.14	7.40	2.64 [2]	12.93	97.99	135 to 141
E5B	34.16	48.88	25.57	6.50	1.66 [2]	16.37	98.98	141 to 145.5
E5C	32.63	46.67	24.70	8.05	3.32 [2]	15.24	97.98	146 to 151
E5D	32.14	45.98	27.36	7.45	2.95 [2]	13.76	97.50	151 to 154.5

Analyses from McDougall (1954, p. 10). Each sample is composed of chips taken at 3-inch intervals and represents approximately 5 feet of core. Numeral in sample number denotes No. of hole. Samples were dried at 110°C.before analysis; iron was calculated on ignited material; analyst: Prof. W. E. Harris, University of Alberta.

1. Total includes: P 0.55%, S 0.032%, as determined for Premier Steel Mills, Limited.
2. Combined MgO + CaO, calculated as MgO.
3. Includes 0.19% CaO.