GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY,
MINES AND RESOURCES

PAPER 71-14

UPPER PALEOZOIC STRATIGRAPHY OF THE EAGLE PLAIN BASIN, YUKON TERRITORY

(Report, 7 figures, 2 tables and 1 chart)

H. L. Martin

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ABSTRACT

Upper Paleozoic strata in the southern part of the Eagle Plain Basin are termed the Imperial Formation of Late Devonian age, the unnamed shale unit of Devonian and Mississippian age, and the Hart River Formation of Late Mississippian (Chesteran) age. The latter is formally subdivided into the Birch, Canoe River, and Chance Sandstone Members. Both the Birch and Chance Sandstone Members are reservoir rocks where oil and gas have been discovered in commercial quantities. The hydrocarbons are present in non-argillaceous, conglomeratic sandstone whereas the intervening Canoe River Member is a siliceous shale in the southeast grading to a siliceous limestone in the central and western parts of the basin. The strata are believed to have been deposited in a deep water trough subparallel to the present-day Richardson Mountains which form the eastern border of the basin; turbidite flows are considered to be responsible for the formation of the conglomeratic sandstone.

RÉSUMÉ

Les couches du Paléozoïque supérieur de la partie sud du bassin de la plaine Eagle appartiennent à la formation Imperial de la fin du Dévonien, à une unité non dénommée de schistes du Dévonien et du Mississippien et à la formation de la rivière Hart de la fin du Mississippien (Chestérien). Cette dernière formation est nettement divisée en les niveaux de Birch, de la rivière Canoe et des grès de Chance. Les niveaux de Birch et des grès de Chance sont constitués de roches-réservoir renfermant des quantités commerciales de pétrole et de gaz naturel. Les hydrocarbures reposent dans les grès conglomératiques non-argileux tandis que le niveau intermédiaire de la rivière Canoe est constitué dans le sud-est, de schistes siliceux qui passent graduellement au calcaire siliceux dans les parties centrales et occidentales du bassin. Les couches semblent s'être déposées dans une profonde fosse marine sensiblement parallèle aux actuels monts Richardson, lesquels forment la limite est du bassin; la formation des grès conglomératiques semble résulter des courants de turbidité.

UPPER PALEOZOIC STRATIGRAPHY OF THE EAGLE PLAIN BASIN, YUKON TERRITORY

INTRODUCTION

The intermontane Eagle Plain Basin lies mainly between latitudes 65°45' and 67°15'N, and between longitudes 136° and 139°W, embracing an area of about 9,500 square miles within the northern Yukon Territory. The basin, which straddles the Arctic Circle, is bordered on the west and south by the northern and central Ogilvie Mountains respectively, its eastern limit is defined by the southern Richardson Mountains, and its northern limit by the Keele Range (Fig. 1).

Data, available as of January 1, 1971, from the fourteen wells drilled into and through the Carboniferous and Upper Devonian strata in the basin, as well as surface section studies by Bamber and Waterhouse (1971), and Norris (1968), were used in this study. The purpose of the work was to subdivide the sequence of Carboniferous-Upper Devonian rocks in the Eagle Plain subsurface into stratigraphically significant units, to describe the various rock types encountered and present their sedimentary history, to provide the paleontological evidence for age assignments, to correlate the subsurface stratigraphic units with the surrounding surface exposures, and to discuss the economic potential of the basin.

Oil and gas have been discovered in commercial quantities in strata of Carboniferous age in five wells in the southern part of the Eagle Plain. The reservoirs are composed of mud-free conglomeratic sandstone of the Chance Sandstone Member and the Birch Member (new names, this paper) of the Hart River Formation, but partial to complete cementation by silica and carbonate has reduced or destroyed the initial high porosity of these rocks. The fine-grained limestone and shale are characterized by a large silica content and very small clay-mineral content as determined by X-ray diffraction and wet chemical methods.

ACKNOWLEDGMENTS

J.B. Waterhouse of the University of Toronto identified and dated the brachiopods discussed in this report; T.P. Chamney and M.S. Barss of the Geological Survey of Canada identified and dated the microfossils and palynomorphs, respectively, from well samples submitted by the author; B. Mamet of the University of Montreal provided a tentative identification of forams present in two thin sections from well cuttings; and W.W. Nassichuk of the Geological Survey of Canada identified and dated an ammonite found in a core sample.

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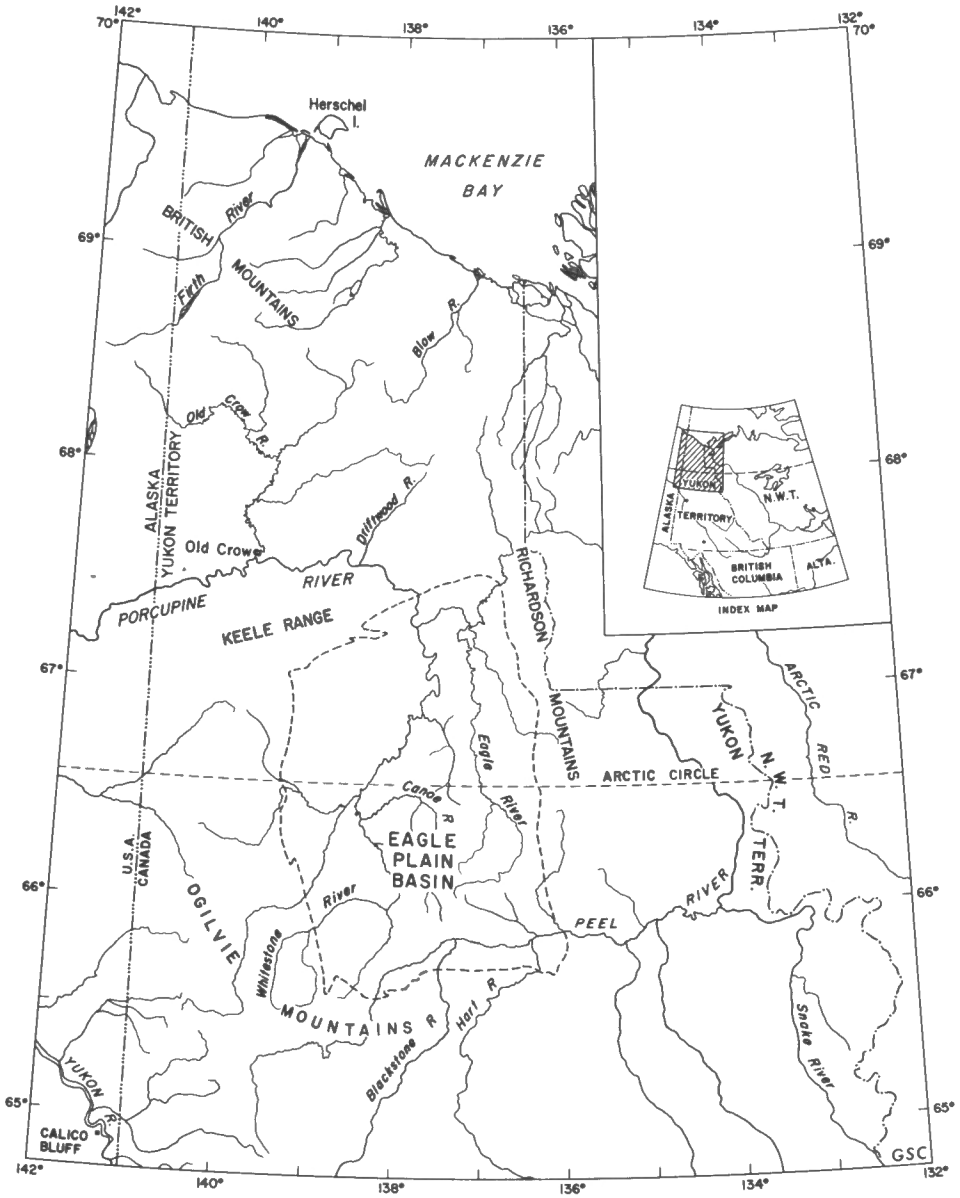

Figure 1. Index map, Eagle Plain Basin, Yukon Territory

The writer is indebted to A.E. Foscolos of the Geological Survey of Canada, Calgary, for providing the X-ray diffraction and chemical analyses of rock samples.

STRATIGRAPHY

Carboniferous rocks in the subsurface were either not deposited or were subsequently removed by pre-Cretaceous erosion from most of the Eagle Plain and are now confined to the southern part of the basin where they are exposed in the southeast along Peel River and in the southwest in the Ogilvie Mountains (Bamber and Waterhouse, 1971). Upper Devonian strata underlie Cretaceous rocks in the central and northern parts of the Eagle Plain Basin but underlie Carboniferous rocks in the southern part and outcrop in the southern Richardson and Ogilvie mountains which border the basin (Norris, 1968).

TABLE OF FORMATIONS

Period	Formation	Member	Thickness (feet)	Lithology
Cretaceous				Shale, siltstone, and sandstone
Carboniferous	Hart River	Chance Sandstone	0-1,016	Conglomeratic sandstone with siliceous and calcareous cement
		Canoe River	0-2,237	Siliceous shale and siliceous micritic limestone
		Birch	0-1,576	Conglomeratic sandstone siliceous shale and siliceous limestone
	Unnamed shale unit		0-4,400+	Siliceous shale
Devonian	Imperial		0-4,261+	Siliceous shale, siltstone and sandstone

DESCRIPTION OF FORMATIONS

Imperial Formation

The name Imperial Formation has undergone several modifications since its first use by Hume and Link, 1945 (see Tassonyi, 1969). The formation, composed of a sequence of shale, siltstone and sandstone of Late Devonian age, is confined to and outcrops along the eastern edge of the Eagle Plain Basin (see Norris et al., 1963, unit 8 of GSC map 10-63). The western limit of the Imperial Formation is at its outcrop expression (Fig. 3) where it passes laterally into a sequence of rocks known informally as the unnamed shale unit discussed below under that heading.

Socony Mobil Western Minerals South Tuttle YT N-5 well (latitude 66°24' 51.2"N, longitude 136°46'22.7"W), located on the east flank of the Eagle Plain Basin, is the only well in the area that penetrated strata of the Imperial Formation. It was spudded into the Imperial and penetrated the underlying siliceous shales of the Devonian Canol Formation at a drilling depth of 4,316 feet. The Imperial Formation, in this well, consists of two units: an upper 1,000-foot-thick shale-sandstone-siltstone sequence (which is about 25% sandstone), and a lower 3,300-foot-thick shale and siltstone sequence. The sandstone, which is composed of medium-sized, varicoloured chert grains with lesser amounts of quartz, is poorly sorted and is cemented with silica and carbonate. The shale is dark grey-brown, dolomitic in part, with some hairline fractures infilled with dolomite and lesser anhydrite. Pyrite spheres and plant imprints are present also.

Unnamed shale unit

The informal term "unnamed shale unit" was applied by Norris (1968, p. 39) to "a recessive interval comprising from place to place a variety of shales that overlie the Middle Devonian Ogilvie Formation and are overlain by relatively resistant clastic and carbonate rocks of late Mississippian age and other as yet undated beds". He found that, because the surface sections were largely covered intervals, the unit's lateral relationships were not clear, but the unit did appear to contain equivalents of the Upper Devonian Imperial Formation. Furthermore, the thickness of the unnamed shale unit appeared to vary inversely as the thickness of the underlying Ogilvie Formation, and the age of the uppermost beds of this carbonate unit varied from early Middle Devonian (Eifelian) to late Middle Devonian (Givetian) suggesting an erosional break between the shale and carbonate.

In the Eagle Plain area only one well, the Standard Oil Company of British Columbia Blackstone YT D-77 (latitude 65°46'10.77"N, 137°14'54.78"W longitude), penetrated a complete section of the unnamed shale unit. This well is considered to be a subsurface reference section and is described in the Appendix of this report (see also Fig. 2). Insufficient data as to the unit's lateral continuity and age precludes the use of a formal name for this stratigraphic interval which lies between drilling depths of 1,532 and 3,614 feet in the reference well.

In the Blackstone D-77 well, the shale is generally dark grey to black, non-calcareous, and bituminous to slightly bituminous. A few samples contain traces of white, and milky blue-white crystalline anhydrite which is thought to represent veinlet infillings. The ubiquitous pyrite in the well cuttings is present as pods, blebs, spheres, and massive whole chips, some of these resembling replaced plant fragments.

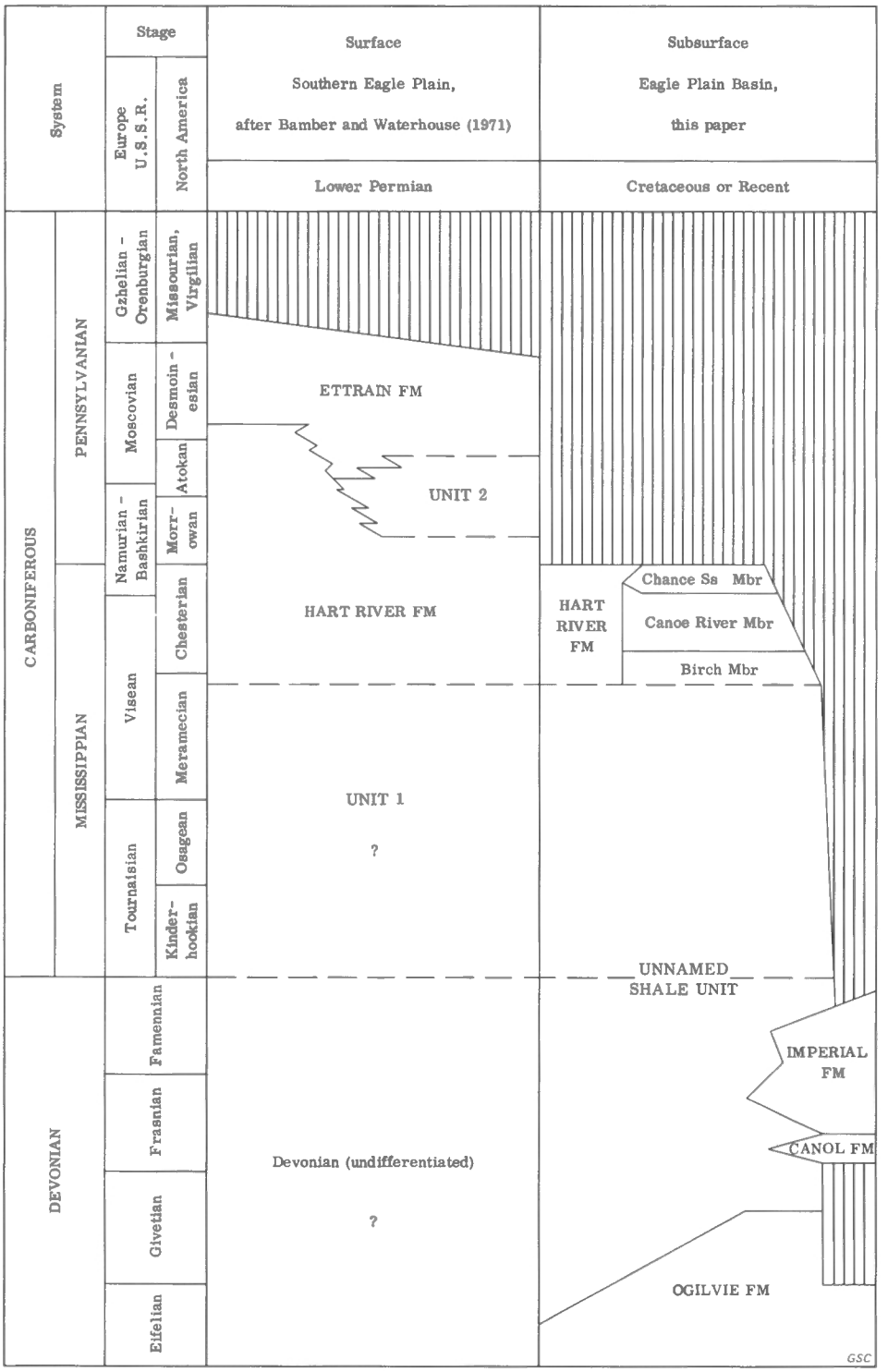

Chart 1. Late Paleozoic stratigraphic nomenclature, Eagle Plain area, Yukon Territory

Table I. Mineralogy and carbon content of selected unnamed shale unit samples

Location	Footage below top of unit	Rock type	Minerals[1] (semiquantitative %) Non-clays[3]							Clays[5]			Carbon[2] (weight %)		
			Q	C	D	S	P	F	A	K	I	Ch	Total	Mineral	Organic
Blackstone YT D-77	68 - 168	Sh.	61	0	0	0	8	4	0	10	11	0	3.65	0.00	3.65
	618 - 718	Sh.	65	tr	0	3	5	tr	0	13	14	0	2.32	0.46	1.86
	1018 - 1068	Sh.	74	0	0	4	3	tr	0	7	12	tr	2.32	0.24	2.08
	1228 - 1268	Sh.	83	0	0	0	5	5	0	1	6	0	5.79	0.10	5.61
	1668 - 1718	Sh.	80	1	2	3	1	3	0	3	6	1	1.12	0.43	0.69
	1798 - 1828	Ss.	82	0	3	4	1	5	0	2	3	0	1.05	0.60	0.45
Blackie YT M-59	2	Sh.	62	0	4	6	4	tr	0	4	8	0	8.53	1.29	7.24
	72	Sh.	68	0	0	0	7	3	0	6	8	0	5.02	0.12	4.90
Chance No. 1	4 - 104	Sh.	81	tr	tr	0	6	2	tr	4	7	0	---[4]	---	---
	320	Sh.	100	0	0	0	0	0	0	0	0	0	---	---	---
	1210	Ss.	95	0	0	0	5	0	0	0	0	0	---	---	---
	1222 - 1228	Sh.	93	0	0	4	0	0	0	0	0	0	---	---	---
	1814 - 1914	Sh.	76	0	0	1	4	0	5	9	5	0	---	---	---
East Porcupine River YT K-56	152 - 332	Sh.	65	tr	tr	tr	3	7	0	13	9	3	---	---	---
Peel River outcrop	200 - 400	Sh.	70	0	0	0	0	2	0	20	8	0	2.25	0.05	2.20
	600 - 700	Sh.	71	0	0	0	0	2	0	19	8	0	2.38	0.18	2.20

[1]Mineralogical analyses determined by Philips X-ray diffractometer using CuKα radiation in conjunction with LiF curved crystal monochromator. Scanning rate 1°/minute; chart speed 1 cm/minute; settings 40 kilivolts, 20 milliamperes.

[2]Carbon analyses: total carbon determined by Leco induction furnace, mineral carbon determined gasometrically, and organic carbon determined by the difference between these values.

[3]Mineral abbreviations: Q, quartz; C, calcite; D, dolomite; S, siderite; P, pyrite; F, feldspar; A, anhydrite; K, kaolinite; I, illite; Ch, chlorite. All values are semiquantitative percentages based on peak-height ratios.

[4]- - - indicates sample not analyzed.

[5]"Kaolinite", "illite", and "chlorite", as reported here, indicate well-crystallized clay minerals of the 7 Angstrom, 10 Angstrom (non-expandable), and 14 Angstrom clay mineral groups, respectively.

GSC

In the upper half of the unit, fragments of ironstone composed of medium brown, very pyritic, siliceous dolomite are present as well as persistent cuttings of sandstone and siltstone, which are thought to occur as thin beds and as thin sandstone and siltstone laminae. The sandstone is generally siliceous but is sometimes dolomitic as well, whereas the framework is composed of fine to coarse, subrounded, medium and dark grey chert grains. Two ten-foot intervals, 2,110 to 2,120 feet and 2,370 to 2,380 feet, are porous and show a light oil stain. The basal 300 feet of the section contain sandstone which, quite different from the above, is "dirty", poorly sorted, and consists of fine- to coarse-grained, subrounded, dark chert grains in an argillaceous-like matrix. This rock grades into sandy shale and shale.

Distribution and lithology

Socony Mobil Western Minerals North Cath YT B-62 well (latitude 66°11' 13.5"N, longitude 138°41'53"W) was spudded in the unnamed shale on the west flank of the Eagle Plain Basin and penetrated 2,630 feet of this unit before reaching the Ogilvie Formation. A computed continuous dipmetre log indicated that the shale generally dips about 18° to the northeast but, at and below the contact with the Ogilvie Formation, the dip declines abruptly to about 8° suggesting an angular unconformity. The shale thickness thus is exaggerated somewhat due to the structural dip and the true vertical thickness is about 2,500 feet. Two sandstone intervals, about 175 and 150 feet thick, are present in the uppermost 600 feet; the remaining 2,000 feet are almost all shale, but with some intercalated sandstone beds in the basal 600 feet.

About 17 miles west of the Cath B-62 well, Norris (ibid.) measured an outcrop section where he found 1,657.4 feet of unnamed shale of which less than 10 per cent was exposed outcrop. The shale is overlain by 125.7 feet of sandstone to which he assigned a Late Devonian or younger age. This sandstone is possibly equivalent to that found in the uppermost part of the Cath B-62 well, which is considered here to be a part of the unnamed shale unit.

At Western Minerals Chance No. 1 well (latitude 66°07'46"N, longitude 137° 31'27"W) located about 33 miles east of Cath B-62, 1,952 feet of unnamed shale were found. This well did not penetrate the underlying Middle Devonian Ogilvie Formation. The strata in this well consist of dark brown and grey, non-calcareous, pyritic shale, which is bituminous in part. The uppermost 400 feet of the section do not contain ironstone fragments although these are abundant throughout the remainder of the shale. Siltstone fragments are present throughout most of the interval; these cuttings are dark brown and pyritic, with coarse silt-size quartz and chert grains and rare, milky-white, floating chert grains up to 0.25 mm in size. A few thin, siliceous conglomeratic sandstone beds consisting of light and dark subrounded chert fragments up to 4 mm in size with lesser amounts of fine quartz grains are present also.

About 30 miles north-northwest of the Chance No. 1 well, Socony Mobil Western Minerals Ellen YT C-24 well (latitude 66°38'08.87"N, longitude 137°50'8.15"W) penetrated 2,310 feet of Upper Devonian shale, siltstone, and sandstone of the unnamed shale unit before reaching total depth in this unit. About 90 per cent of the upper 1,400 feet is composed of shale, whereas sandstone forms more than 60 per cent of the basal 900 feet. The sandstone is poorly sorted, very fine- to coarse-grained and rarely conglomeratic, with subangular to subrounded light and dark chert grains, and a siliceous and carbonate cement. Pyrite inclusions are common, and some appear to be

replaced plant fragments. The shale is dark grey with intercalated siltstone beds and shows abundant slickensides, fractures, and slump features. Plant remains and some siliceous triaxon spicules are present and pyrite is abundant again in the form of replaced wood fragments, crystals, and small spheres. Core examination indicated that the bedding dips varied from horizontal to about 45°. There is a possibility that this sequence is faulted and that the basal sandy section is actually of Cretaceous age.

Peel Plateau Eagle Plain No. 1 well (latitude 66°48'54"N, longitude 138° 08'30"W) was drilled about 20 miles north-northwest of Ellen C-24 on a structural high. The well penetrated a monotonous section of Cretaceous shale and siltstone (T.P. Chamney, pers. com.) before reaching what is considered to be Devonian shale of the unnamed shale unit at a depth of 3,514 feet. The latter is black, bituminous, very pyritic, with white and light brown calcite veinlets, and has a high gamma ray signature. The top of the Ogilvie Formation was reached at a depth of 3,592 feet, therefore only 78 feet of the unnamed shale unit is present in this well.

The unnamed shale unit is present in outcrop along the southern edge of the Eagle Plain. Towards the east and northeast it passes into rocks of the Imperial Formation (Fig. 3). On GSC Map 10-63 (Norris, et al., 1963), the unnamed shale unit was included in map-units 8 and 9 along the southern and southwestern flanks of the basin.

Bamber and Waterhouse (1971) used the term "Unit 1" for the 1,300 feet of recessive shale of Viséan age that is equivalent to the upper part of the unnamed shale unit at the Peel River outcrop section (Fig. 2).

Sixteen samples from this unit in the Eagle Plain area were selected for X-ray diffraction analysis and carbon analysis. The results, summarized in Table 1, show that 65 to 100 per cent of the rock consists of quartz with kaolinite, illite, pyrite, feldspar and siderite comprising most of the minor constituents. Analyses for organic carbon from nine of these samples gave values ranging from 0.69 to 1.24 per cent for the shales, and 0.45 per cent for the only sandstone sample analyzed. To obtain the total organic matter it is necessary to multiply the per cent of organic carbon by a variable organic factor. A mean of 1.22 was assigned to sedimentary rocks by Forsman and Hunt (1958). The total organic matter is, therefore, somewhat higher than the percentages of organic carbon shown in Table 1.

Age and correlation

Macrofossils were absent in the unnamed shale unit in subsurface. However, the following palynomorph assemblages were found and identified by Barss.
(1) Western Minerals Chance No. 1 well. Top of unnamed shale unit at 6,696 feet drilling depth.

GSC loc. 8426, core interval 7,016 to 7,022 feet.

Anapiculatisporites concinnus Playford
Anulatisporites anulatus (Loose) Potonié and Kremp
Anulatisporites cf. A. canaliculatus Playford
Convolutispora florida Hoffmeister, Staplin, and Malloy
Convolutispora cf. C. mellita Hoffmeister, Staplin, and Malloy
Densosporites bialatus (Waltz) Potonié and Kremp

Densosporites cf. D. duplicatus (Naumova) Potonié and Kremp
Densosporites rarispinosus Playford
Dictyotriletes cf. D. clatriformis (Artuz) Sullivan
Knoxisporites cf. K. hederatus (Ischenko) Playford
Knoxisporites rotatus Hoffmeister, Staplin, and Malloy
Knoxisporites seniradiatus Neves
Lycospora microgranulata Hacquebard and Barss
Lycospora cf. L. lobulata Staplin
Lycospora uber (Hoffmeister, Staplin, and Malloy) Staplin
Murospora aurita (Waltz) Playford
Murospora sublobata (Waltz) Playford
Monilospora moniliformis Hacquebard and Barss
Microreticulatisporites lunatus Knox
Perotriletes perinatus Hughes and Playford
Perotrilites magnus Hughes and Playford
Reticulatisporites cancellatus (Waltz) Playford
Reticulatisporites peltatus Playford
Reticulatisporites cf. R. rudis Staplin
Punctatisporites nahannensis Hacquebard and Barss
Spinozonotriletes balteatus Playford
Tripartites complanatus Staplin
Waltzispora albertensis Staplin

Numerous specimens were encountered that were not identifiable to the species level and were placed in the following genera:

Calamospora
Camptotriletes
Apiculatisporis
Leiotriletes
Punctatisporites
Densosporites
Lycospora
Convolutispora
Stenozonotriletes
Proprisporites
Lophotriletes
Verrucosisporites
Granulatisporites
Acanthotriletes
Triquitrites
Lophozonotriletes
Murospora
Dictyotriletes

GSC loc. 8427, core interval 7,813 to 7,818 feet.

Anapiculatisporites concinnus Playford
Anapiculatisporites serratus Playford
Anulatisporites anulatus (Loose) Potonié and Kremp
Alatisporites tessellatus Staplin
Chaetosphaerites pollenisimilis (Horst) Butterworth and Williams

Cincturasporites altilis Hacquebard and Barss
Convolutispora florida Hoffmeister, Staplin, and Malloy
Convolutispora mellita Hoffmeister, Staplin, and Malloy
Convolutispora venusta Hoffmeister, Staplin, and Malloy
Densosporites bialatus (Waltz) Potonié and Kremp
Densosporites duplicatus (Naumova) Potonié and Kremp
Densosporites spitsbergensis Playford
cf. Diatomozonotriletes rarus Playford
Dictyotriletes cf. D. clatriformis (Artuz) Sullivan
Endosporites micromanifestus Hacquebard
cf. Foveosporites insculptus Playford
Knoxisporites hederatus (Ischenko) Playford
Knoxisporites literatus (Waltz) Playford
Leiotriletes ornatus Ischenko
Lycospora microgranulata Hacquebard and Barss
Lycospora uber (Hoffmeister, Staplin, and Malloy) Staplin
Murospora aurita (Waltz) Playford
Murospora friendii Playford
Murospora intorta (Waltz) Playford
Monilospora moniliformis Hacquebard and Barss
Microreticulatisporites lunatus Knox
Perotrilites perinatus Hughes and Playford
Perotrilites magnus Hughes and Playford
Potoniespores delicatus Playford
Punctatisporites nahannensis Hacquebard and Barss
Reticulatisporites cancellatus (Waltz) Playford
Reticulatisporites peltatus Playford
Rotaspora fracta Schemel
Tripartites incisotrilobus (Naumova) Playford
Verrucosporites eximuus Playford

Numerous specimens not identifiable to species level were encountered and assigned to the following genera:

Calamospora
Apiculatisporis
Leiotriletes
Punctatisporites
Densosporites
Lycospora
Convolutispora
Lophotriletes
Granulatisporites
Acanthotriletes
Reticulatisporites
Dictyotriletes
Camptozonotriletes
Verrucosisporites

Barss stated, "The above assemblages are of Viséan age. They are typical examples of the Murospora aurita assemblage as outlined by Playford (1962-1963) in his work on the Spitsbergen Lower Carboniferous microfloras. Similar assemblages occur in western Canada, Yukon Territory, and in the Arctic Islands".

GSC loc. C-3359, well cuttings interval 8,500 to 8,600 feet.

The assemblage was not identified as to genus and species, but was considered to be of Viséan age.

(2) SOBC Blackstone YT D-77 well. Top of unnamed shale unit at 1,532 feet drilling depth, and top of Ogilvie Formation at 3,614 feet.

GSC loc. C-4249, well cuttings interval 2,760 to 2,800 feet.

Barss stated, "The spores recovered are not well preserved. Only a tentative age can be determined. The assemblage seems to be a mixed Mississippian-Devonian one, therefore a Strunian (very latest Famennian or early Tournaisian) age is suggested".

(3) Socony Mobil Western Minerals Whitestone YT N-6 well. Top of unnamed shale unit at 7,936 feet drilling depth.

GSC loc. C-7478, core sample at 7,940 feet.

Barss stated, "Some very dark poorly preserved spores. One specimen of Murospora cf. M. aurita. If this type is actually M. aurita then a Viséan to Namurian age is likely".

(4) Socony Mobil Western Minerals Blackie YT M-59 well. Top of unnamed shale unit at 6,250 feet drilling depth.

GSC loc. C-3421, core interval 6,241 to 6,250 feet.

A specimen of Densosporites, possibly Mississippian

GSC loc. C-3423, core interval 6,322.6 to 6,338 feet.

A specimen of Densosporites, possibly Mississippian.

GSC loc. C-7465, core interval 6,322.6 to 6,327 feet.

Densosporites sp., and cf. Stenozonotriletes sp. Possibly Mississippian.

GSC loc. C-7467, core sample at 6,336 feet.

Densosporites spp.
Convolutispora sp.
Lycospora sp.
Monilospora sp.
Densosporites bialatus
Anulatisporites anulatis
Murospora cf. M. aurita

Barss stated "I would consider this assemblage to be of Viséan age".

(5) Socony Mobil Western Mineral Ellen YT C-24 well. Top of unnamed unit at 4,824 feet drilling depth.

GSC loc. C-4244, core interval 4,212 - 4,221 feet. Age - Lower Cretaceous.

GSC loc. C-4245, core interval 4,854 - 4,862 feet. Age - Upper Devonian.

Bamber and Waterhouse (1971) reported finding goniatitic ammonoids of late middle Visean age in the Peel River outcrop section, about 300 feet below the top of the unit; in the southeastern part of the Eagle Plain early late Viséan (i.e., late Meramecian) ammonoids were found in the uppermost part of the shale. Norris (1968, p. 41) found that the unnamed shale unit appeared " . . . . to contain beds ranging in age from Middle to possibly Late Devonian or even younger". From the above data it is concluded that the unnamed shale unit ranges in age from Middle Devonian (Givetian) to late Viséan. The Viséan shale sequence is in excess of 1,950 feet, as determined from the Chance No. 1 well, and the Devonian part of the unit is in excess of 2,500 feet, as determined from the Cath B-62 well (T.P. Chamney, pers. com.). The position of the Mississippian-Devonian boundary cannot be ascertained due to lack of faunal control and the absence of a lithologic break in the succession. However, in the Blackstone D-77 well, the sample interval from 2,690 to 2,700 feet contained very abundant pyrite in the form of cubes, blebs, and massive disseminations in a black, bituminous, slightly dolomitic shale. Ironstone nodules are not present below this interval but are scattered throughout the overlying section. This suggests a break or still-stand in the sedimentary record and a possible Mississippian-Devonian contact at a depth of 2,704 feet, as picked on the gamma ray - sonic log.

The Devonian part of the unit appears to contain lateral equivalents of the Imperial Formation, and the Viséan part contains equivalents of "Unit 1" of Bamber and Waterhouse (1971). The unnamed shale unit also appears to contain equivalents of the Ford Lake Shale Formation of Late Devonian to Late Mississippian age. This latter unit composed of about 2,000 feet of predominantly siliceous shale and chert overlying the Upper Devonian Nation River Formation and underlying the Upper Mississippian Calico Bluff Formation was named by Brabb (1969). It is exposed on the banks of the Yukon River immediately west of the Yukon-Alaska Boundary and just south of the 65th parallel of latitude.

Hart River Formation

The term Hart River Formation was given by Bamber and Waterhouse (1971) to a 794-foot unit of limestone, dolomite, and shale with ironstone nodules which is exposed on Peel River about 9 miles east of its confluence with the Hart River (Fig. 2). They described the formation as consisting of 483 feet of micritic-skeletal limestone and microcrystalline dolomite, overlain by a recessive, largely covered interval, 311 feet thick, which appeared to be composed dominantly of dolomitic and calcareous shale containing nodules with skeletal fragments. The contact with their overlying Unit 2 was not seen; the contact with their underlying Unit 1 appeared to be sharp but was not studied due to high water conditions.

In the subsurface of the Eagle Plains, the Hart River Formation, where it has not been subjected to pre-Mesozoic erosion, is considerably thicker than in the surface type section. For this reason it is herein subdivided into three members which, in ascending order, are named the Birch, the Canoe River, and the Chance Sandstone. Both the Birch and the Chance Sandstone Members form hydrocarbon reservoirs in the area.

Birch Member

Definition

The Birch Member is a sequence of interbedded sandstone, shale, and limestone which conformably overlies the unnamed shale unit and underlies the Canoe River Member. Its type section (Appendix and Fig. 2) is in Socony Mobil Western Minerals Birch YT B-34 well (latitude 66°03'3.15"N, longitude 136°51'17.51"W).

At the Birch B-34 well, 1,576 feet of this member are found between drilling depths of 3,808 and 5,384 feet. The basal 1,034 feet consist of about 50 per cent sandstone, 40 per cent shale and 10 per cent limestone. The sandstone is medium to coarse grained, rarely conglomeratic, and usually tightly cemented with calcite and quartz. At the top of this interval, however, it is incompletely cemented which results in poor to fair intergranular porosity. The coarse fraction is composed of subrounded to rounded varicoloured chert grains, and the medium and fine components are mainly clear quartz. Trace amounts of coarse, calcitic crinoidal debris are present in some samples.

The shale is mainly black, bituminous, very radioactive, and slightly calcareous, with coarse, calcitic crinoid stem fragments scattered throughout. Near the base of the Birch Member, a part of the bituminous shale contains abundant white calcareous specks and some crinoidal debris.

The micritic limestone is medium to dark brown, siliceous, and contains both calcareous and siliceous monaxon spicules; it is very cherty near the base of the member.

The upper 542 feet of the Birch Member are composed dominantly of limestone with lesser amounts of dark shale and some sandstone. The limestone is similar to that described above; it is generally very siliceous and cherty, and contains abundant calcitic and siliceous spicules. The chert is dark grey and contains light grey monaxon spicules. Some detrital, very fine quartz and chert grains are present in the limestone but appear to comprise less than 10 per cent of the rock. Rare crinoid and brachiopod shell fragments are present also. Gradations occur between limestone and calcareous siltstone, but such rocks represent less than 5 per cent of the interval. The shale is generally calcareous, dark grey-brown, hard, and contains some calcitic crinoidal debris; the sandstone is similar to that of the underlying, previously described clastic sequence. A core sample from Blackie M-59 well, located about 10 1/2 miles southwest of Birch B-34, was selected for X-ray diffraction analyses of the siliceous limestone. The sample, taken from 96 feet below the top of the Birch Member, revealed that the rock consisted of 65 per cent calcite and 35 per cent quartz with a trace of pyrite. Further analysis for organic carbon yielded 7.85 for total weight per cent of carbon, of which 7.46 per cent was mineral, and 0.37 per cent was organic. Similarly, X-ray

diffraction and carbon analyses were conducted on selected well cuttings from the porous dolomitic sandstone 45 to 60 feet below the top of the Birch Member in East Chance C-18 well, about 13 1/2 miles northwest of Birch B-34. The results indicated a consistency of 68 per cent quartz, 27 per cent dolomite, and 5 per cent calcite; the total weight per cent of carbon was 4.40, of which 4.24 per cent was mineral, and 0.16 per cent was organic.

Distribution and lithology

The Birch Member can be traced from its type section throughout the subsurface of the Eagle Plain area to the type outcrop section of the Hart River Formation at the eastern edge of the basin (Fig. 2). At the western edge of the area in the Cathedral Rocks outcrop section, the largely covered recessive interval at the base of the Hart River Formation may contain a very thin Birch Member but it is more probable that the recessive interval lies wholly in the unnamed shale unit.

The thickest development of the member, 1,576 feet, is in the type well. It thins to approximately 1,100 feet at the Blackie M-59 well about 10 1/2 miles to the southwest, and is only 175 feet thick at the Chance No. 1 well about 19 miles to the west-northwest. There is a lithologic change also in that the sandstone percentage decreases with a corresponding increase in siliceous limestone and shale. Farther south at the Blackstone D-77 well about 23 miles from the Birch B-34 type well, the member is a 580-foot-thick sequence composed mainly of shale with lesser amounts of limestone and only a trace of sandstone. About 24 miles to the southeast at the type Hart River outcrop section on the Peel River, the Birch Member is 483 feet thick and consists mainly of micritic-skeletal limestone and dolomite but also contains some very sandy limestone beds; the covered intervals may represent the shale sequences. Thus, it is evident that the Birch Member, which is predominantly sandstone at its type locality, changes to mainly carbonate toward the southeast and predominantly shale near the southern and western edges of the basin. The member is absent to the north due to pre-Cretaceous erosion.

Age and correlation

At the type outcrop section of the Hart River Formation, the Birch Member equivalent contains an abundant faunal assemblage belonging to the brachiopod fauna A of Chesteran age; i.e. late Viséan to Namurian (Bamber and Waterhouse, 1971). In the subsurface, brachiopods belonging to the same fauna A assemblage were found in the Birch B-34 well 273.5 feet below the top of the member and identified by Waterhouse as follows:

GSC loc. C-4367, core sample at 4,623.5 feet drilling depth.

Quadratia cf. hirsuteformis (Walcott)
"Leiorhynchus" carboniferum Girty

Similarly, in Chance No. 1 well, a fauna from the same assemblage was found 60 to 80 feet below the top of the member as follows:

GSC loc. C-4361, core interval 6,581 to 6,591 feet drilling depth.

Orbiculoidea sp.
Quadratia cf. hirsuteformis (Walcott)
"Leiorhynchus" carboniferum Girty

From the above data it is assumed that the Birch Member in the subsurface of the Eagle Plain is Chesteran (late Viséan to Namurian) in age.

Canoe River Member

Definition

The type section of the Canoe River Member, which consists almost entirely of shale (see Appendix and Fig. 2), occurs in Socony Mobil Western Mineral Birch YT B-34 well, where 2,124 feet of this member are found between drilling depths of 1,684 and 3,808 feet. The headwaters of the Canoe River, after which this member is named, are located about 20 miles northeast of the type Birch well.

The basal 350 feet are composed of non-calcareous, dark grey shale with much calcitic crinoidal debris. It is pyritic and contains brown ironstone fragments, thin beds of calcareous siltstone and crinoidal fragments. Overlying this sequence are about 1,150 feet of calcareous, pyritic shale containing very abundant brown ironstone fragments. Skeletal content consists largely of crinoidal debris, but trace amounts of punctate and spiny brachiopod shell fragments, broken brachiopod spines, and ostracods are present also. The crinoidal debris in both types of shale consists of light brown to off-white, coarse, calcitic fragments with traces of pyrite replacement; the fragments are about the same size as the well cuttings. Present also are thin units of skeletal limestone, light brown and siliceous in part, with abundant crinoidal debris and brachiopod spines and thin interbeds of brown, calcareous siltstone with trace amounts of calcitic crinoid fragments.

Distribution and lithology

In the southeastern part of the area, the Canoe River Member can be traced from the type well to the Blackie M-59 well, where it is 2,237 feet thick; to the Blackstone D-77 well, where only about 875 feet of the member are present; and to the type outcrop section of the Hart River Formation, where the 311-foot-thick, largely covered interval at the top of the formation is thought to be the lateral equivalent of the Canoe River Member. Crinoidal debris is sparse or absent at these locations and the basal part of the member in these wells is largely bituminous black shale.

In the remainder of the area, the Canoe River Member undergoes a lateral facies change to a siliceous, cherty, spicular, micritic limestone. This change is illustrated on the stratigraphic cross-section (Fig. 2), where the carbonate and shale facies are identified. The carbonate facies reaches its maximum development in Socony Mobil Western Minerals East Porcupine River YT K-56 well (latitude 66°05'33"N,

Table II. Mineralogy and carbon content of selected Canoe River Member samples

Well Name	Footage below top of unit	Rock Type	Minerals[1] (semiquantative %) Non-Clays[3]						Clays[5]		Carbon[2] (weight per cent)		
			Q	C	D	S	P	F	K	I	Total	Mineral	Organic
Chance No. 1	388	Siliceous Limestone	66	28	6	0	0	0	0	0	---[4]	---	---
	355	Dolomitic Silty Limestone	12	71	17	0	0	0	0	0	---	---	---
	677	Silty Limestone	35	65	0	0	0	0	0	0	---	---	---
	1192 - 95	Silty Limestone	41	58	tr	0	tr	0	0	0	---	---	---
	1236	Calcareous Sandstone	82	18	0	0	0	0	0	0	---	---	---
	1439 - 44	Calcareous Shale	57	43	0	0	0	0	0	0	---	---	---
	1452	Siliceous Limestone	59	41	0	0	0	0	0	0	---	---	---
	1454	Calcareous Chert	88	9	3	0	tr	0	0	0	---	---	---
	1720 - 25	Calcareous Shale	83	16	0	0	1	0	0	0	---	---	---
	1734-39	Calcareous Shale	79	21	0	0	0	0	0	0	---	---	---
E. Chance C-18	286 - 336	Siliceous Limestone	46	51	3	0	0	0	0	0	7.46	7.02	0.44
	1166 - 1266	Siliceous Limestone	35	45	20	0	0	0	0	0	9.28	8.82	0.46
	1676 - 1746	Siliceous Limestone	32	64	4	0	0	0	0	0	9.30	8.90	0.40

Whitestone N-26	869 - 729	Siliceous Limestone	44	53	3	0	tr	0	0	0	---	---	---
	1149	Calcareous Shale	47	46	1	1	2	0	0	3	---	---	---
Blackie M-59	41	Shale	75	2	6	5	1	2	3	6	1.65	1.02	0.62
	178	Shale	76	5	4	3	3	0	3	6	1.85	1.01	0.84
Porcupine R K-56	16 - 106	Siliceous Limestone	29	63	8	0	0	0	0	0	---[4]	---	---
	106 - 156	Siliceous Limestone	32	66	tr	0	0	0	0	tr	1.2	---	---
	516 - 556	Siliceous Limestone	40	66	tr	tr	tr	tr	0	3	2.8	---	---
	1256 - 1456	Siliceous Limestone	43	51	6	0	tr	0	0	0	---	---	---
Blackstone D-77	630 - 730	Bituminous Shale	74	tr	2	0	6	tr	3	14	3.89	0.50	3.39
Parkin CK D-51	54 - 104	Siliceous Limestone	39	57	4	0	0	0	0	0	---	---	---
Birch B-34	146 - 206	Calcareous Shale	54	38	4	0	1	0	0	3	---	---	---
Peel River otc section	75	Shale	76	1	0	0	0	tr	15	8	1.14	0.19	0.95

[1] Mineralogical analyses determined by Philips X-ray diffractometer using CuKα radiation in conjunction with LiF curved crystal monochromator. Scanning rate 1°/minute; chart speed 1 cm/minute; settings 40 kilivolts, 20 milliamperes.

[2] Carbon analyses; total carbon determined by Leco induction furnace, mineral carbon determined gasometrically, and organic carbon determined by the difference between these values.

[3] Mineral abbreviations: Q, quartz; C, calcite; D, dolomite; S, Siderite, P, pyrite, F, feldspar; K, kaolinite; I, illite. All values are semi-quantitative percentages based on peak-height ratios.

[4] ---- indicates sample not analyzed.

[5] "Kaolinite", and "illite", as reported here, indicate well-crystallized clay minerals of the 7 Angstom and 10 Angstrom (non-expandable) mineral groups, respectively.

GSC

longitude 137°55'32"W) about 30 miles west of the Birch B-34 type-section well, where about 1,800 feet of the Canoe River Member are found; the section is not complete due to pre-Cretaceous erosion. Some shale beds are present in the member in the central part of the area and the shale content also increases to the west where the section is composed of about 35 per cent calcareous shale with some crinoid fragments at Socony Mobil Western Minerals Whitestone YT N-26 well (latitude 66°05'59"N, longitude 138° 20'00"W). About 1,700 feet of Hart River Formation are present (Bamber and Waterhouse, 1971) (Fig. 2) at the Cathedral Rocks anticline surface section located at the western edge of the Eagle Plain. There, the uppermost 550 feet of the Hart River Formation as well as about 500 feet in the middle are almost entirely covered and may represent dominantly shale intervals; this surface expression appears to be largely, if not entirely, equivalent to the Canoe River Member. Therefore, the member changes from shale at its type location in the east, to a limestone near the central part of the Eagle Plain, to a mixed shale and limestone sequence at its western extremity.

Table II indicates the mineralogy and carbon content of selected Canoe River Member samples as revealed by X-ray diffraction analysis and carbon analysis.

Rocks of the Canoe River Member contain abundant quartz (Table II). Silica is present as siliceous spicules, detrital silt- and clay-size quartz and chert grains, and as finely divided quartz of either replacement or chemically precipitated origin. Examination of thin sections of the siliceous carbonate rocks indicated an intimate association of lime mud and silica with varying amounts of detrital quartz and lesser chert grains, some calcitic brachiopod, crinoid, and other indeterminable skeletal fragments, and abundant calcareous and siliceous monaxon spicules. The partial to complete replacement of many siliceous spicules by calcite was probably one of the silica sources leading to the chert replacement of the carbonate; indeed, for some rock chips, the only calcareous components are the spicules.

The rocks shown as limestones on the accompanying cross-section (Fig. 2) range from non-siliceous limestone to siliceous limestone, to calcareous chert. The distinction between the latter two types is usually impossible to see by means of binocular microscope examination as a silica content of even 20 per cent (as determined by X-ray diffraction) leaves an insoluble residue that is hard, consolidated, and clay-like in appearance, and gives the impression of constituting more than 50 per cent of the rock. Indeed, most of the siliceous limestone listed in Table II appeared to be calcareous chert or calcareous siliceous shale based on the seemingly large amount of insoluble residue. The siliceous spicules are readily apparent in this residue, but the distinction between the detrital quartz and chert, and either replacement or chemically precipitated quartz is very difficult due to the fineness of the former minerals and preponderance of the latter. The dark brown colouration of the carbonate rocks is due to the inclusion of 1/2 to 1 per cent organic matter as shown in Table II. The rocks then appear to grade from limestone to chert in an irregular fashion without much visible textural change, although the carbonates appear to be much greater in abundance.

The spiculite cherts are medium grey to creamy white megascopically. Thin section examination of these cherts indicated that the spicules comprise as much as 80 per cent of the rock mass in a matrix of cryptocrystalline silica which appears to be slightly coarser than that comprising the spicules. A very small amount, i.e. less than 5 per cent, of detrital quartz and chert fragments is present also. Thin sections of the dark cherts were not prepared; they appeared to be largely featureless but binocular examination of cuttings submerged under water showed occasional chips with irregular laminations and possible spore material suggesting a significant content of organic matter.

All shales of the Canoe River Member are siliceous. Clay minerals are absent or rare and the illite in Table II is mainly a measurement of green glauconite. The sample from the Peel River outcrop section had a kaolinite content five times higher than the highest reading from those from the subsurface, but the total clay mineral content was still under 25 per cent. Bituminous shale, as typified by the sample from the Blackstone D-77 well, and non-bituminous shale are present; the organic content of the former is about four times higher than the latter, as shown in Table II. Thin section examination of calcareous shale samples indicated an abundance of finely divided detrital quartz and lesser chert grains in a matrix of lime mud and cryptocrystalline quartz. Organic matter commonly imparts a dark brown colouration to the rock thereby obscuring the details of the thin section. Finely comminuted calcitic skeletal debris as well as coarser fragments, such as spicules, brachiopod shells, and crinoids, are present in some places.

Age and correlation

At the Birch B-34 type section, brachiopods belonging to brachiopod fauna A of Chesteran age were found in the upper half of the Canoe River Member and were identified by Waterhouse as follows:

GSC loc. C-4357, core sample at 2,167 feet drilling depth.

"Leiorhynchus" carboniferum Girty

GSC loc. C-4358, core sample at 2,328 feet drilling depth.

Orbiculoidea sp.

Palynomorph identifications by Barss yielded age assignments for this member as follows:

GSC loc. C-4239, core interval, 2,161 to 2,171 feet drilling depths.

Barss stated, "Similar assemblage to C-4238. (see age discussion on Chance Sandstone Member at that location below). Most probably Permian although late Stephanian cannot be ruled out".

GSC loc. C-7436, core interval 2,322 to 2,325 feet drilling depth.

Florinites visendus
Potonieisporites elegans
Florinites sp.
Punctatisporites spp.
Densosporites spp.
Reticulatisporites cancellatus

Barss stated, "The presence of Florinites and Potonieisporites would indicate a Pennsylvanian or possibly younger age. However the other spores that are present appear to be the same colour and preservation and together with the Florinites etc., compare with the assemblage reported by Felix and Burbridge from the Springer of Southern Oklahoma. I would think that the age is probably middle Namurian".

GSC loc. C-7437, core interval 2,325 to 2,330 feet drilling depth.

Florinites guttatus
Potonieisporites elegans
Florinites visendus
Perotrilites perinatus
Guthorlisporites sp.
Rugospora sp.
Schopfipollinites sp.
Proprisporites sp.
Densosporites rarispinosus
Murospora cf. M. aurita
Potoniespores delicatus
and others

Barss stated, "I would consider this assemblage similar to the one above and of probable middle Namurian age".

GSC loc. C-4241, core interval 3,594 to 3,604 feet drilling depth.

Similar assemblage to C-4240.

A single ammonoid, Nomismoceras sp., was found in a completely pyritized form in the Birch B-34 well in a core sample at 3,595.4 feet (GSC loc. C-8201), and indicated a late Viséan age (W.W. Nassichuk, pers. com.).

Foraminifers present in a thin section prepared from a sample of drill cuttings between drilling depths of 3,610 and 3,620 feet (i.e., 686 to 696 feet below the top of the Canoe River Member) in the Blackie M-59 well were identified by B. Mamet (pers. com.) as Eolasiodiscus sp. and Earlandia sp. (GSC loc. C-8203), and indicate an age range from late Chesteran to Morrowan or possibly Atokan.

Also in the Blackie M-59 well, palynomorph assemblages were identified by Barss as follows:

GSC loc. C-7450, core sample at 2,963 feet drilling depth.

Vittatina spp.
Potonieisporites sp.
Limitisporites sp.
Vestigisporites sp. are present

GSC loc. C-7451, core sample at 2,970 feet drilling depth.

Vittatina sp.
Striatopodocarpites sp.
Striomonosaccites sp.
cf. Lueckisporites sp.
and an unidentifiable bisaccate type

GSC loc. C-7453, core interval 3,900 to 3,903 feet drilling depth.

Vittatina spp.
Protohaploxypinus sp.
Limitisporites sp. are present

GSC loc. C-7454, core interval 3,905 to 3,910 feet drilling depth.

Vittatina spp.
Florinites sp.
Vestigisporites sp. are present

Barss stated, "There are not many spores in the above samples and they are in various states of preservation. The immediate impression is that they belong to the same assemblage. This assemblage has been reported from the Tatonduk River in Paper 68-18 by Bamber and Barss, and is considered to be of Permian age. Some of the forms have their beginning in latest Pennsylvanian but the abundance of the striate bisaccate and striate types without any evidence of typical late Pennsylvanian types present, would favour the Permian age. There are reworked Mississippian spores in nearly every sample".

Subsequent studies suggest that the assemblage is a reflection of the environment and is possibly as old as Middle Pennsylvanian (Barss, pers. com.). It must be pointed out that the exact upper age limit of fauna A has not been determined. Although the lower limit was defined by the presence of early late Viséan (late Meramecian) goniatitic ammonoids in the unnamed shale in the southeastern part of the Eagle Plain, the Hart River Formation may even contain upper Meramecian rocks. This cannot be verified at the present time. Furthermore, the presence of palynomorphs, identified as Middle Pennsylvanian to Permian, in the same core interval that yielded Late Mississippian to Early Pennsylvanian brachiopods and a Late Mississippian ammonite indicates a problem beyond the scope of this paper. However, the detailed brachiopod zonations supported by foraminiferal studies in Bamber and Waterhouse (ibid.) suggest that the Chesteran age determinations based on the presence of macrofossils are preferable to the age assignments based on palynomorph assemblages.

In Socony Mobil Western Minerals Parkin YT D-51 well (latitude 66°10' 08.5"N, longitude 137°26'04.5"W), a core interval 404 to 413.5 feet contained the following assemblages identified by Waterhouse as belonging to brachiopod fauna A:

GSC loc. C-4365, 4,141 feet drilling depth.

Quadratia cf. hirsuteformis (Walcott)
"Leiorhynchus" carboniferum Girty

GSC loc. C-4366, 4,122 feet drilling depth.

"Leiorhynchus" carboniferum Girty

GSC loc. C-4368, 4,124 feet drilling depth.

"Leiorhynchus" carboniferum Girty
Aviculopecten sp.

GSC loc. C-4369, 4,126 feet drilling depth.

Quadratia hirsuteformis (Walcott)

GSC loc. C-4370, 4,128 feet drilling depth.

Quadratia hirsuteformis (Walcott)

GSC loc. C-4371, 4,129 feet drilling depth.

Quadratia hirsuteformis (Walcott)
dielasmatid

The largely covered shale sequence at the type Hart River outcrop section on Peel River, here considered to be correlative with the Canoe River Member, contained a fauna A assemblage 75 feet above its base; no other fossils were found in the shale sequence (Bamber and Waterhouse, ibid.). At the Cathedral Rocks anticline section, these authors found fauna A assemblages in the uppermost Hart River Formation which correlate with the Canoe River carbonate facies in the subsurface.

The Canoe River Member carbonate and shale facies are thus considered to be Chesteran, i.e. late Visean to Namurian, in age.

Chance Sandstone Member

Definition

The Chance Sandstone Member is a conglomeratic sandstone unit that conformably overlies the Canoe River Member. It underlies unnamed uppermost Hart River Formation carbonates in the south-central part of the basin, and subcrops at the sub-Mesozoic unconformity in the southeastern part of the Eagle Plain.

In the Western Minerals Chance No. 1 well (latitude 66°07'46"N, longitude 137°31'27"W), the designated type-section well for the member, 598 feet of Chance Sandstone were encountered between drilling depths of 4,258 and 4,856 feet. The type member is described in the Appendix of this report. Chance No. 1 well was completed in 1960 as the first potential hydrocarbon producer in the Yukon Territory, with the Chance Sandstone forming the reservoir rock.

At its type section, the sandstone is conglomeratic in the uppermost 250 feet, and mainly medium to coarse grained with intervals of calcareous shale in the remainder of the unit. Except for the uppermost 100 feet, the sandstone is cemented with calcite. The coarsest fraction is composed of subrounded to rounded chert grains which are milky white, medium and dark grey, light brown, and rarely green in colour; a few quartzite grains are present also. The finer fraction is composed largely of anhedral to subhedral quartz, and comprises less than 25 per cent of the siliceous fraction. The reservoir part is confined to the uppermost 100 feet which are porous and permeable. X-ray diffraction analyses and thin section examinations of seven core samples indicated that the reservoir rock is composed entirely of chert and quartz grains but, unlike the carbonate-cemented portion, the quartz grains comprise about 50 per cent of the rock mass and are predominantly subhedral.

Distribution and lithology

In the Eagle Plain area, much of the Chance Sandstone Member has been removed by pre-Cretaceous erosion and is thought to be present now only in the subsurface (Figs. 2, 3). It is present in the Chance No. 1 discovery well, and two step-out wells, Canoe River Chance YT J-19 (latitude 66°08'31.20"N, longitude 137°32'28.022"W), and Socony Mobil Western Minerals Chance YT G-8 (latitude 66°07'18.1"N, longitude 137°30'50.8"W), located about 1 mile north and one-half mile south, respectively. The member is present also at the Birch B-34 and Blackie M-59 wells. At the latter two wells, 736 feet and 1,016 feet, respectively, of Chance Sandstone Member overlie the Canoe River shale facies. The uppermost 190 feet of the member at Blackie M-59 is a glauconitic, calcareous siltstone containing abundant chonetid and linoproductid brachiopod remains. X-ray diffraction analyses of a core sample at 1,962 feet indicated a composition of 50 per cent quartz, 30 per cent calcite, 16 per cent dolomite, 2 per cent kaolinite, and 2 per cent glauconite.

The Chance Sandstone Member is not present in the Whitestone YT N-26 and the East Porcupine River K-56 wells, which lie about 11 1/2 miles and 22 1/2 miles respectively, west of the Chance No. 1 well, but its absence could be due to erosion because the Canoe River carbonate facies immediately underlies the sub-Mesozoic unconformity in these two wells.

Age and correlation

No diagnostic fossils were found in the Chance Sandstone Member in the subsurface. However, at the Chance No. 1 and Chance G-8 wells, a siliceous limestone sequence, which overlies the Chance Sandstone and is considered to be uppermost Hart River Formation, contained a fauna belonging to brachiopod fauna A of Chesteran age according to J.B. Waterhouse.

Chance No. 1 well contained the following:

GSC loc. C-4363, core sample at 4,153 feet (107 feet above top of Chance Sandstone).

Quadratia hirsuteformis (Walcott)
"*Leiorhynchus*" *carboniferum* Girty
?*Crurithyris* sp.

GSC loc. C-4364, core sample at 4,067 feet (193 feet above top of Chance Sandstone).

?*Flexaria* sp.

At the Chance C-8 well, *Neospirifer* sp. was present at 3,943 and 3,954 feet (295 and 306 feet above top of Chance Sandstone, GSC locations C-4359 and C-4362, respectively).

At the Birch B-34 well, a core from near the centre of the Chance Sandstone Member contained the following palynomorph assemblages identified by Barss:

GSC loc. C-7432, core sample at 1,298 feet drilling depth.

Vittatina
Limitisporites
Pityosporites
Protohaploxypinus
Potonieisporites
several other very poorly preserved bisaccate forms
Mississippian spores are also present
Age is Permian

GSC loc. C-7433, 1,300 feet drilling depth.

Vittatina are quite numerous.
Age is most probably Permian

GSC loc. C-4238, core interval 1,298 to 1,303 feet drilling depth.

Barss stated, "Most probably Permian. Forms present are very similar to Tatonduk River assemblage of Bamber and Barss (1969). Reworked Mississippian spores present".

In the Blackie M-59 well, palynomorphs from the upper half of the sandstone unit belong to the same assemblages as those found in the underlying Canoe River Member, and were identified by Barss as follows:

GSC loc. C-7445, core interval 1,960 to 1,964.6 feet drilling depth.

Spores are broken and very poorly preserved.
There are specimens of Vittatina, Striatoabietites, and a specimen of Laevigatosporites present.

GSC loc. C-7446, core interval 1,974.3 to 1,978.6 feet drilling depth.

Vittatina spp.

GSC loc. C-7448, core interval 2,127 to 2,130 feet drilling depth.

?Potonieisporites sp.

GSC loc. C-7449, core interval 2,173 to 2,176 feet drilling depth.

Numerous Vittatina
Striomonosaccites sp.
Limitisporites sp.
Sacs are broken very badly

The same comments listed in the discussion of the Canoe River Member for GSC locations C-7450 to C-7454 apply; i.e. the assemblage is considered to be of Permian age by Barss.

For core intervals 2,154 to 2,194 feet (GSC loc. C-3417) in the Chance Sandstone Member, and 2,962 to 2,972 and 3,900 to 3,910 (GSC locations C-3418 and C-3419, respectively) in the Canoe River Member, Barss stated, "The above three samples contain numerous striate bisaccate, monolete bisaccate, monolete monosaccate, striate monosaccate and forms assignable to the genus Vittatina. This assemblage of palynomorphs is indicative of an Early Permian age, although some of the forms appear first in the Middle Pennsylvanian. In all three samples there are numerous reworked spores of Mississippian age".

A thin section prepared from a well cutting sample from about the middle of the Chance Sandstone in this well (2,310 to 2,320 feet, GSC loc. C-8202) contained Foraminifera identified as Trepeilopsis sp. and apterrinellids (B. Mamet, pers. com.). These forams have an age range from middle Chesteran to Pennsylvanian.

The above palynomorph assemblages are the same as those found in the underlying Canoe River Member and, therefore, the same comments apply regarding the conflict of age assignments as determined from palynomorphs and from invertebrate faunal assemblages. The Chance Sandstone Member in the Birch B-34 and Blackie M-59 wells is considered to be the same age as in the type member, i.e. Chesteran (late Viséan to Namurian). There is a possibility that the sandstone units in the Chance well area and those in the Blackie-Birch area were deposited as discrete sandstone bodies of somewhat different ages, but at the present time they are considered to be contiguous.

At the outcrop section on Peel River, 209 feet of calcareous and dolomitic conglomeratic sandstone overlie the type Hart River Formation (Fig. 2). This clastic unit, which is largely covered, was called "Unit 2" by Bamber and Waterhouse (1971). The lower part is unfossiliferous, but the upper 60 feet contain a fauna that they identified as Moscovian (Middle Pennsylvanian) in age. The contact with the underlying 311-foot shale unit (Canoe River Member of this report) was covered and there is the possibility of an unconformity, of even a fault, separating these two units, but this cannot be documented either way at the present time. The relationship between the Chance Sandstone Member and "Unit 2" is not clear, but if future work proves their continuity, then the type Hart River Formation will have to be redefined to include "Unit 2".

Similarly, at the Cathedral Rocks anticline near the western edge of the Eagle Plain (Fig. 2), "Unit 2" is younger in age than the Chance Sandstone of the subsurface. There, Bamber and Waterhouse (ibid.) found a late Bashkirian to early Moscovian fauna in a largely covered skeletal limestone and sandstone unit overlying carbonates of the Hart River Formation. These carbonates are poorly exposed also and the contact with "Unit 2" is not seen. "Unit 2" may be laterally continuous but is slightly younger in age than the Chance Sandstone.

Hart River Sandstone Analysis

Grain size analyses on six core samples selected at random from the Chance Sandstone Member plus two samples from the Birch Member were performed primarily to gain a better understanding of the materials comprising the sandstones. Four of the samples were porous, siliceous types, i.e. composed entirely of chert and quartz, whereas the other four were cemented with calcite. Thin section examinations of the samples were made also.

The rocks were disaggregated by crushing and pounding with a rubber mallet, acidized if carbonate-cemented, treated with ASTM Standard Hexametaphosphate solution, and scrubbed by an ultrasonic probe. They were then filtered, dried, and sieved using a half- ϕ set (from -2 to 4.5 ϕ). After sieving, each size fraction was weighed, and then examined under a binocular microscope.

Histograms and grain percentages, i.e. percentages of light and dark coloured chert fragments and quartz grains, are shown on figures 4 to 7. The results of the grain size analyses were plotted on probability paper, and the graphic mean, inclusive graphic standard deviation, inclusive graphic skewness, and graphic kurtosis were calculated as proposed by Folk (1968); these statistical parameters are summarized also in figures 4 to 7. Owing to the nature of the probability curve, all of the graphic parameters could not be obtained for the sandy conglomerates. The geological significance of such statistical data is not known fully for ancient rocks, and they are presented here mainly as descriptive terms to aid in rock classification.

From the figures it can be seen that dark coloured chert dominates the coarse sand- to gravel-size range, whereas quartz grains comprise most of the medium sand-size and finer fractions. The chert grains are varicoloured: black, medium grey, and off-white predominating, and light green, tan, yellow, and light orange present in lesser amounts. Rare spiculite grains and grains of quartzite were seen also. Most of the chert grains are subrounded and near-spherical. A few of the coarser off-white grains are pitted from pressure contact with adjoining grains. Pyrite cubes commonly were found still attached to the chert grains. Thin section examination showed that most of the chert grains are composed of microcrystalline quartz but some radiating fibres of chalcedony are present also. The grains are commonly fractured and these fractures filled with quartz vein fillings. Rounded and near-spherical quartzite grains, although rare, were present in most of the thin sections examined.

Quartz grains are clear, and are subhedral to rarely euhedral, and anhedral. Thin section examination indicated that the crystal faces are a diagenetic phenomena in that they are overgrowths in optical continuity with the quartz nucleus and formed by unimpeded growth into the rock pores. The weight percentages of quartz grains shown in figures 4 to 7 are, therefore, somewhat higher than initially deposited. Although most of the quartz crystals showed no visible demarcation line between overgrowth and nucleus, some grains were seen with dust lines separating subangular nuclei from overgrowths. The overgrowths are assumed to be the result of direct precipitation since they do not contain inclusions. The primary porosity of the sandstones has been somewhat diminished by the quartz grain growth; indeed, in some thin sections the quartz formed interlocking grains completely destroying the porosity. However, most of the non-porous sandstone is predominantly calcite cemented, and it is apparent that the spar was deposited after some quartz growth had occurred. Where calcite and quartz cementation is sparse to absent porosity values in excess of 20 per cent can be expected.

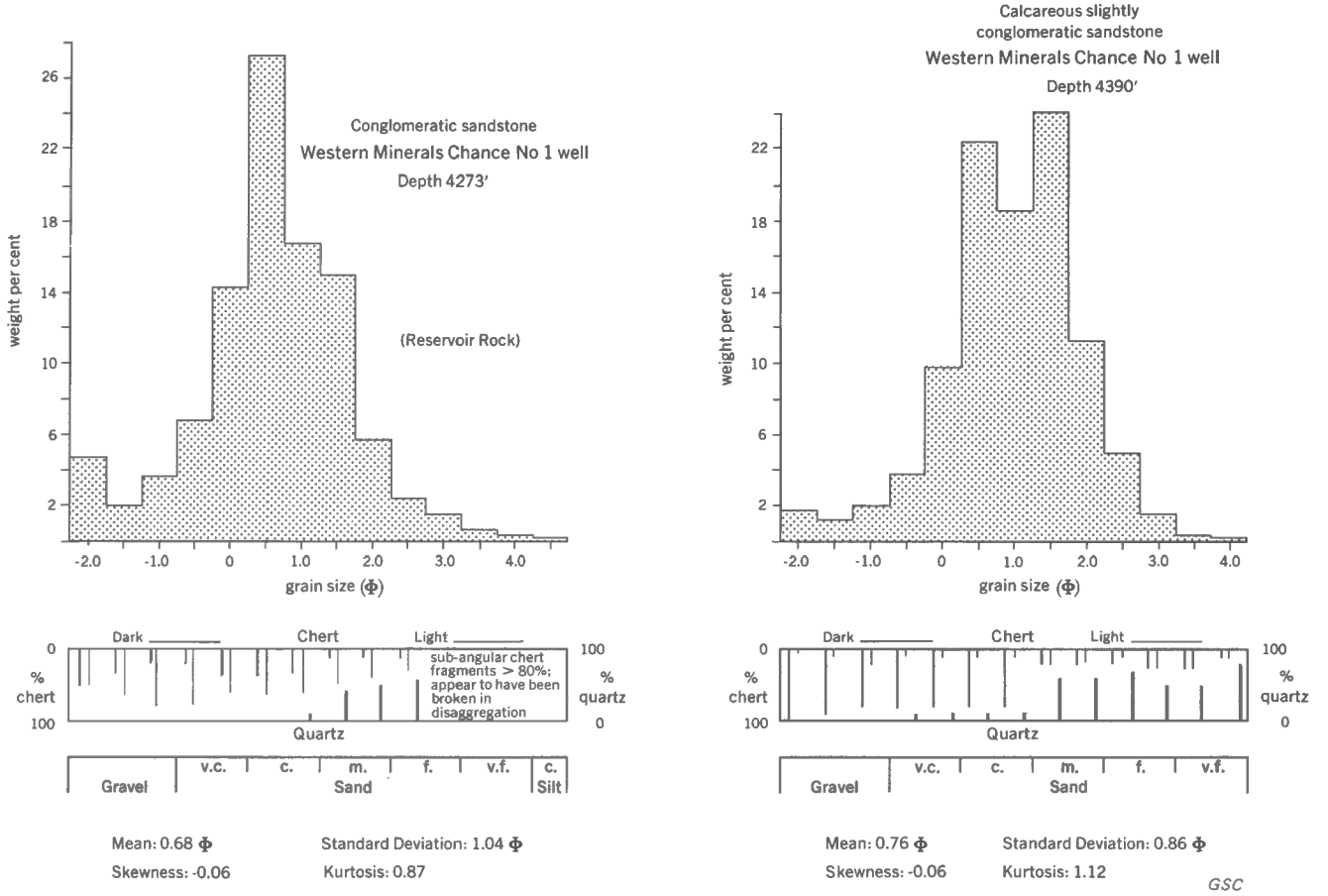

Figure 4. Histograms and grain percentages, Chance Sandstone Member, Western Minerals Chance No. 1 well

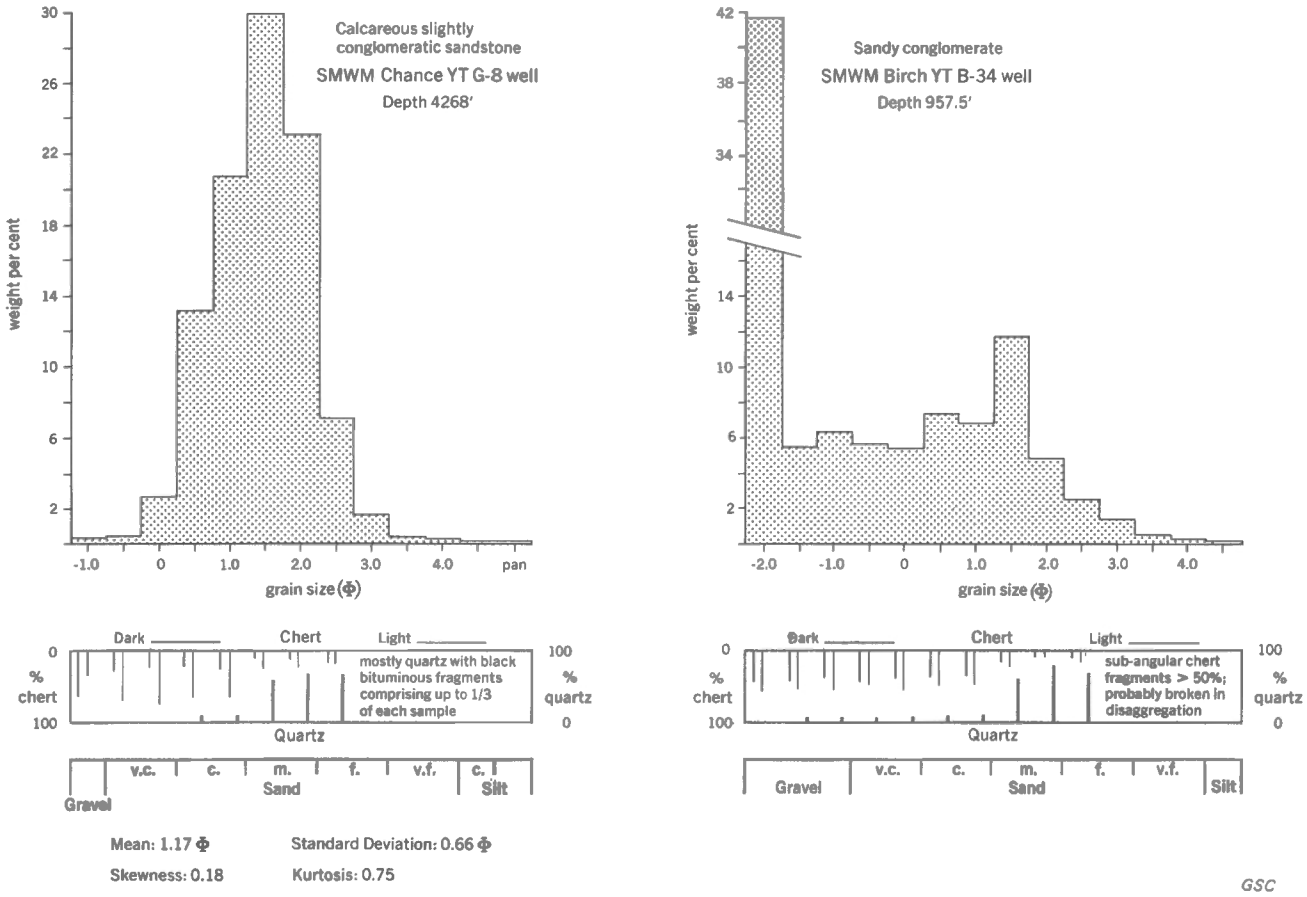

Figure 5. Histograms and grain percentages, Chance Sandstone Member, Socony Mobil Western Minerals Chance YT G-8 and Socony Mobil Western Minerals Birch YT B-34 wells

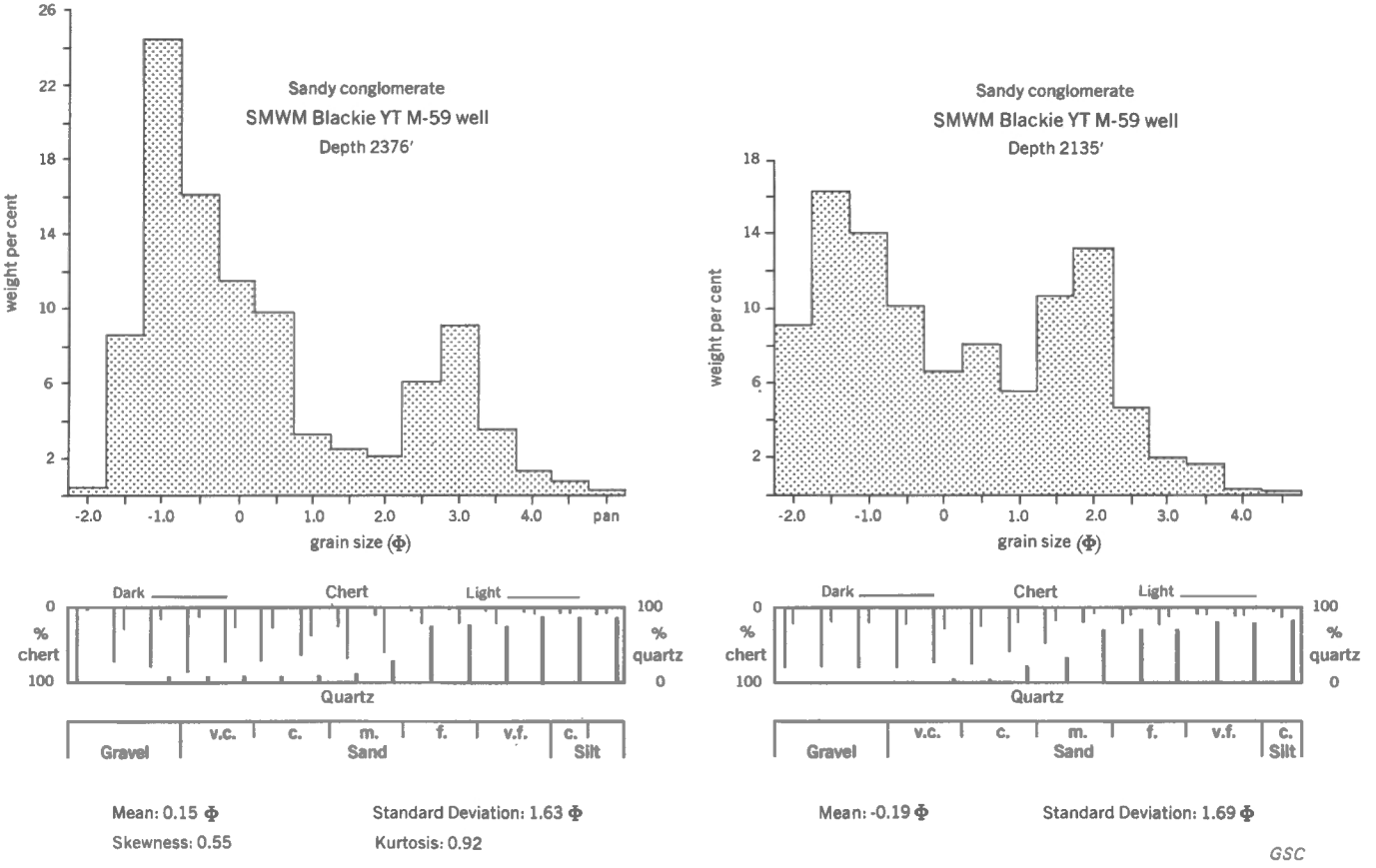

Figure 6. Histograms and grain percentages, Chance Sandstone Member, Socony Mobil Western Minerals Blackie YTM-59 well

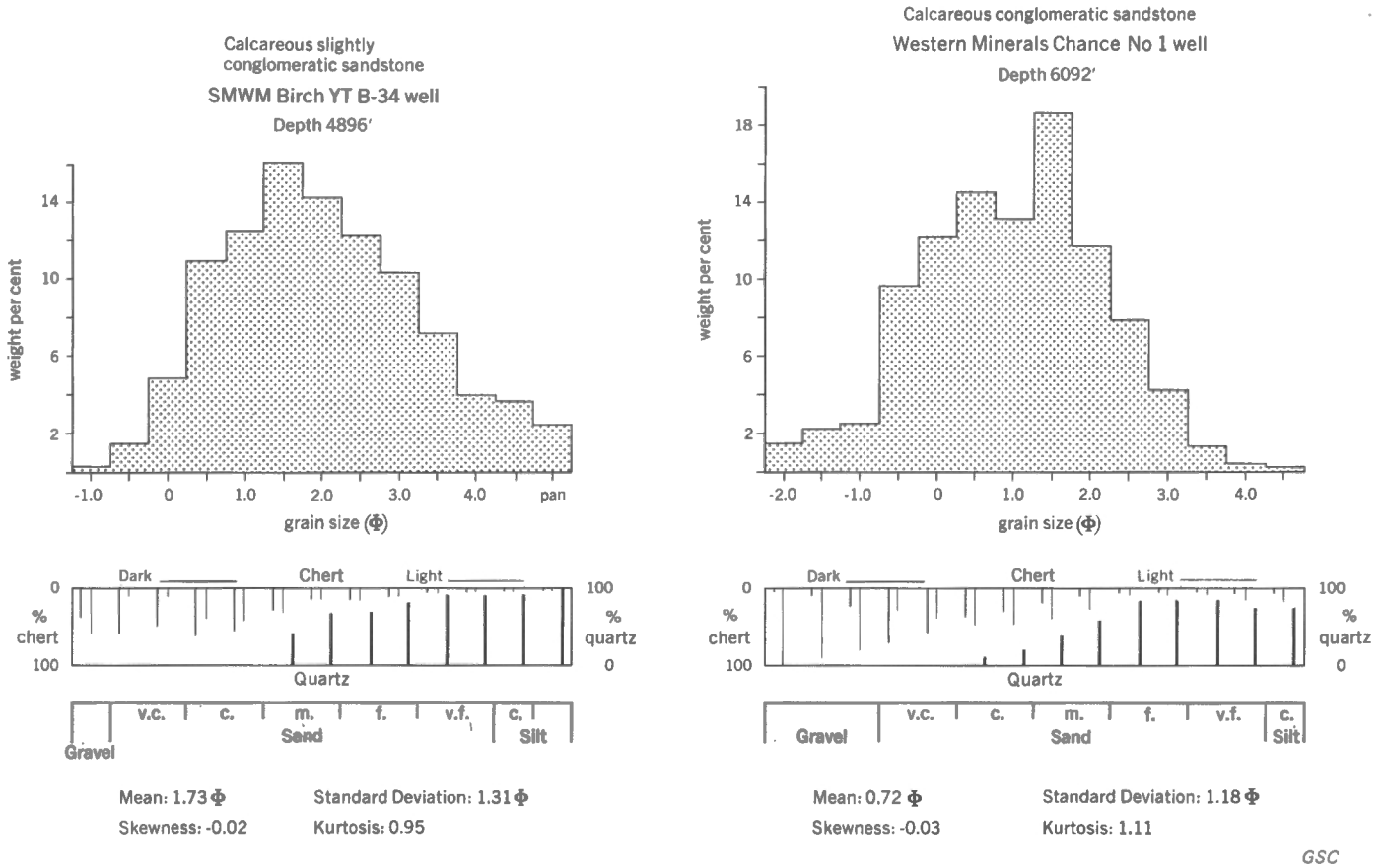

Figure 7. Histograms and grain percentages Birch and Canoe River Members, Socony Mobil Western Minerals Birch YTB-34 and Western Minerals Chance No. 1 wells

The coarse, rounded fraction consisting largely of varicoloured chert grains is thought to have come from older reworked sandstones, whereas the more angular and finer quartz grains are probably primary, suggesting a multiple source for these sandstones. The sandstones from the Birch and Chance Sandstone Members appear to be much the same in composition, texture, and diagenetic history, suggesting that they were deposited under the same sedimentary conditions.

The pictorial histograms shown in figures 4 to 7 are inaccurate with respect to the finer fractions which are in excess due to splitting of the coarser grains in disaggregation; the coarser fractions contain aggregates composed of both fine, and fine and coarse grains, but the percentage of aggregate was less than 20 per cent in each size range and these were subtracted from the individual sample weights. Some of the finest size ranges contain green glauconite grains and black pyrobitumen which has some affect on the sample weight. Finally, the quartz overgrowths, being a diagenetic feature, have masked the original size of the deposited quartz. In view of the type of sandstones encountered, i.e. from slightly conglomeratic sandstone to sandy conglomerate, it is not suprising that the statistical parameters should show wide fluctuations. The graphic mean, being a measurement of overall size, ranges from -0.19 to 1.73 ϕ, which is very coarse to medium sand-size; the standard deviation, a measurement of sorting, ranges from 0.66 to 1.69 ϕ, which indicates moderately well sorted to poorly sorted. The skewness measures the degree of asymmetry and whether a curve has an asymmetrical tail on the left or right and ranges from -0.06 to 0.55 ϕ, which is near-symmetrical to strongly fine-skewed. The Kurtosis, a measurement of the ratio between the sorting in the tails of the curve and the sorting in the central portion, ranges from 0.75 to 1.12 ϕ, i.e. from tails better sorted than the central portion to tails about equally sorted. The bimodal nature of some of the curves and histograms reflects the quartz and chert relationships as shown on the grain percentages chart for each size range.

SEDIMENTARY HISTORY

The extremely siliceous nature of the lime mud and shale, and the conglomeratic and mud-free nature of the sandstone pose problems in reconstructing the depositional environments. However, a comparison of the sequence with actual and proposed models by Wilson (1969), Thomson and Thomasson (1969), Tyrrell (1969), and Laporte (1969), suggests an intermediate to deep water depositional environment for the Imperial - unnamed shale - Hart River sequence in the Eagle Plain Basin.

All of the above authors agree that "deeper water" carbonates include such features as:

(1) dominance of lime mud
(2) dark colour due to preservation of organic material
(3) profusion of sponge spicules
(4) very siliceous, with variable mixtures of lime mud and microcrystalline quartz
(5) common occurrence of chert beds and nodules
(6) either very specialized benthonic fauna, or more commonly, pelagic fauna only

The widespread Imperial Formation has been called a thick sequence of turbidites by Glennie (1963), and the Famennian rocks of the Richardson Mountains were considered to have been deposited from southerly flowing turbidity currents by Bassett and Stout (1967). The few cores cut in this rock unit in the Eagle Plain area show features which support this concept, such as crude gradational bedding, highly variable bedding dips, the extremely siliceous nature of the shales, the abundant pyritized plant fragments, and the extremely variable shale-siltstone-sandstone sequences.

If this origin and depositional environment is correct, then the deep water origin of the remainder of the sedimentary succession discussed in this paper can be argued as follows: the Devonian-Mississippian boundary in the Eagle Plain area is conformable but the Tournaisian is greatly condensed owing to the deep water, starved basin type of environment (Adams, et al., 1951) which is thought to have been present at this time; the entire sedimentary record of the Tournaisian period may be represented by only a few feet of siliceous shale. The pyritic zone in the Blackstone D-77 well discussed above is thought to represent at least part of such a starved basin deposit.

The development of the shallow to deep water facies of the Lower Pennsylvanian Dimple Limestone in Texas was discussed by Thomson and Thomasson (1969). The Hart River Formation shows a great deal of similarity to the Dimple Limestone which is a sequence of siliceous limestone, conglomerate, shale and chert, gradationally overlying Mississippian and underlying Pennsylvanian terrigenous flysch facies, respectively. In the deeper water facies, chert pebble conglomerates with practically no matrices are common in the lowest part of the formation. Shales are spicular and composed of lime and terrigenous mud, and the black chert beds associated with the shales are in most places almost entirely composed of siliceous spicules. The authors recognized three facies: shelf, slope, and basin. The slope facies are referred to as "proximal" turbidites following the usage of Walker (1967) and the basin deposits are "distal" turbidites. The rock sequence comprising the Hart River Formation has characteristics of both the proximal and distal turbidite facies of the Dimple Limestone. In the Hart River, graded bedding is very pronounced in cores of the conglomeratic sandstones; in limestone thin section, fine-grained chert and quartz also showed some crude gradational aspects.

Wilson (1969) in his discussion of "deeper water" limestone cited three types of microfacies which he considered to be deposited below wave base. These also are found in the Hart River carbonate facies and consist of dark, laminated lime mudstone, calcisiltite with spicules and associated quartz grains, and a much less common facies of lithoclastic grainstone or micro-breccia. The latter rock type was found only in the uppermost part of the Hart River carbonates, whereas the spicular calcisiltite was most common, and the sparsely laminated lime mudstones were less abundant. The laminae are caused by concentrations of organic matter. Wilson (ibid.) observed many minor sequences where the finest grained material capping the strata was siliceous, and replacement chert nodules and thin chert bands occurred as diagenetic products in these levels; such siliceous rocks are very common in the Hart River Formation. In his discussion on organic constituents, Wilson (ibid.) stated that certain characteristic brachiopods occurred in the deeper water carbonates and shale and pointed out that the leiorhynchids were especially characteristic of this environment in Devonian and Mississippian sediments; "Leiorhynchus" carboniferum is abundant in the Hart River Formation. He also stated that dark shales are found basinward of the lime mudstone-calcisiltite facies, again a feature found in the Hart River. Furthermore, in his examples of sediments in cratonic basins which are of probable deeper water origin,

Wilson (ibid.) pointed out that in all these sequences, the beds in question occurred in the lower part of an upward-shallowing lithogenetic series and represented transgressive deposits. The Hart River comprises the youngest recognized Paleozoic strata in the Eagle Plains subsurface, but it is overlain by the shallow-water Ettrain Formation in the surrounding surface sections (Bamber and Waterhouse, 1971).

In the Eagle Plain area, the sedimentary record is envisaged as a continuous sequence with no erosional breaks from the Upper Devonian Imperial Formation, through the unnamed shale unit, the Hart River Formation, and into the Ettrain Formation. Uplift and erosion of the Middle Devonian Ogilvie Formation was followed by subsidence and the formation of a basinal trough sub-paralleling the Richardson Mountains. Slow deposition of siliceous shale with periodic influxes of turbidite deposits from the east and northeast formed the rocks of the Imperial Formation. An increase in subsidence rate relative to sea level coupled with a lowered rate of sedimentary infill initiated bottom starvation in Tournaisian time in the south-central part of the basin, but it is thought that sedimentary infill continued during this time in the southeastern part of the Eagle Plain. A return to conditions similar to those prevailing during deposition of the sediments comprising the Imperial Formation occurred, and the dark siliceous shales of the unnamed shale unit were deposited with periodic turbidite flows again bringing in sand.

Development of carbonate shelves to the northwest and southeast provided a source of limestone mud which resulted in the mixed carbonate-terrigenous sediments of the Birch Member. An increase in the rate of lime mud deposition led to the development of the Canoe River carbonate facies which graded into the basinal dark shales of the Canoe River shale facies. At the Canoe River East Chance C-18 well, the Canoe River Member is a mixed carbonate-shale facies and is thought to be close to the break between the slope and basin facies. However, the Birch B-34 and Blackie M-59 wells were drilled in the basin facies. These shaly sediments were probably deposited as prograding fronts, accounting for the greatly thickened succession at the latter two wells relative to the Peel River outcrop section.

Rejuvenated uplift in the east brought in the graded, mud-free conglomeratic sandstones of the Chance Sandstone Member; the abrupt lateral and vertical facies changes between the sandstones and limestones are thought to be due to multiple source areas from the east and north.

Outcrops of the type Ettrain Formation show it to be a skeletal, sparry limestone (Bamber and Waterhouse, 1971). The writer thinks that this lithology represents the shallow-water shelf facies and that the lateral equivalents of the Ettrain in the central parts of the Eagle Plain Basin, now eroded, were micritic limestones of the deeper water facies and thus were indistinguishable from the Hart River carbonate. The carbonate overlying the Chance Sandstone Member at Chance No. 1 and at Chance G-8 may be remnants of this Ettrain equivalent; elsewhere in the subsurface it has been removed by post-Paleozoic erosion.

In summary, the Devonian Imperial Formation and unnamed shale unit are thought to have been deposited in a deep water trough where turbidite material was intermixed with dark siliceous shale. A starved basin was present during Tournaisian time, but a resumption of shale and turbidite infill occurred in the Viséan. Conglomeratic sandstones and siliceous limestones of the Birch Member and Canoe River carbonate facies are thought to represent slope and shallower basin deposits, whereas the Canoe River shale facies represents the deeper water basin infill. The Chance Sandstone Member represents a return to slope conditions caused by uplift to the east which initiated turbidite flows of this conglomeratic deposit.

ECONOMIC GEOLOGY

In the Eagle Plain area, the economic objectives in the Upper Devonian-Carboniferous sedimentary sequence are the conglomeratic, non-argillaceous sandstones of the Birch and Chance Sandstone Members of the Hart River Formation. Their possible turbidite origin accounts for their erratic thicknesses; the Chance Sandstone is thought to be essentially continuous in the southeastern and south-central parts of the area where it has not been subjected to complete erosion, whereas the sandstones of the Birch Member thin rapidly westward and form possible hydrocarbon reservoirs only in the easternmost parts of the Eagle Plain basin.

The shales of the basinal facies are bituminous in part or contain significant organic matter, and the limestones of the slope facies also contain abundant organic matter. These are considered as the probable source beds for the hydrocarbons entrapped in the sandstone facies.

PRESENT DISCOVERIES

SMWM Birch B-34

A thick, porous section of the Chance Sandstone is present at Birch B-34 at the eastern edge of the Eagle Plain Basin, but drillstem tests conducted in this interval recovered only small quantities of drilling fluid. This porous sandstone immediately underlies Cretaceous glauconitic shale. However, in the Birch Member, a drillstem test between 4,430 and 4,501 feet recovered 5,525 mmcf/d of gas, and 300 feet of gas-cut water which was considered to be mud filtrate. Analysis of the gas indicated 86.69 per cent by volume of methane, 6.91 per cent ethane, 2.35 per cent propane, 1.91 per cent carbon dioxide, with minor amounts of nitrogen, butane, pentane, hexanes, and heptanes plus. The interval was not cored and the intergranular porosity is estimated as poor due to partial cementation by quartz and carbonate. A drillstem test at the base of the Birch Member, between 5,195 and 5,412 feet, recovered 7.34 mmcf/d of gas, and 330 feet of gas-cut drilling fluid. Analysis of the gas indicated 90.63 per cent by volume of methane, 5.21 per cent ethane, 1.65 per cent propane, 1.13 per cent carbon dioxide, and minor amounts of nitrogen, butane, pentane, heptanes plus, and hexanes. Again the interval was not cored, and the well cuttings of sandstone show poor porosity due to partial cementation by quartz and calcite. The present status of the well is a Birch Member gas well protectively plugged and fitted with a wellhead. The net gas pay is 12 feet.

SMWM Blackie YT M-59

At Blackie M-59, 50 feet of net pay is present in the Chance Sandstone between drilling depths of 2,116 and 2,170 feet. From core analysis, the average porosity is about 15 per cent, and weighted average horizontal and vertical permeabilities are about 90 md. and 28 md. respectively. Maximum gas recovery on three drillstem tests was 2.8 mmcf/d, with no condensate, oil or water recoveries. Analysis of the gas indicated 98.47 per cent by volume methane, with minor amounts of nitrogen, carbon dioxide, ethane, propane, and isobutane. A 128-foot net porous zone between 2,354 and 2,579 feet was found to be fresh water wet on drillstem testing; water analyses of this zone were not considered representative as the samples appeared to be filtrate contaminated. A small unmeasured gas blow and 1,850 feet of gas-cut mud were recorded in a drillstem test of the Birch Member between 6,218 and 6,338 feet; porosity is very poor since the sandstone is almost completely cemented by quartz and calcite. The well status is a suspended Chance Sandstone gas well.

Canoe River East Chance C-18

At the Chance C-18 well, the Chance Sandstone is eroded, but 155 feet of Birch Member sandstone was penetrated before the well reached total depth. No cores were cut, but two drillstem tests were conducted in the Birch Member. The uppermost test, from 4,910 to 4,980 feet, recovered 533 mcf/d of gas and 420 feet of black, watery mud, and the lowermost test, from 5,000 feet to total depth at 5,055 feet, had a recovery of 5.7 mmcf/d of gas, and 120 feet of salt water (28,600 ppm). Analysis of the gas from the uppermost test indicated the following volumes: methane 31.25 per cent, ethane 25.13 per cent, carbon dioxide 18.14 per cent, nitrogen 10.92 per cent, propane 9.46 per cent, butanes 3.32 per cent, pentanes 1.21 per cent, and minor amounts of hexanes, heptanes plus, and helium. Gas from the lowermost test consisted of 70.84 per cent methane, 14.92 per cent nitrogen, 5.95 per cent ethane, 4.78 per cent carbon dioxide, 2.14 per cent propane, and minor amounts of butanes, pentanes, heptanes plus, and hexanes. The sandstone has fair porosity and is partly cemented by dolomite. The well was abandoned.

Western Mineral Chance No. 1

The "discovery" well of the Eagle Plains area was completed in 1960 as a suspended Chance Sandstone gas or oil well with 54 feet of net gas pay and 4 feet of net oil pay. Between 4,262 and 4,365 feet, core analysis indicated continuous porosity values from 12 to 23 per cent; below this interval the sandstone is largely cemented with calcite. Weighted average porosity of the sandstone in this pay interval is 14.8 per cent, and weighted average horizontal permeability was 258 md. Maximum gas flow obtained from drillstem tests was between 7 and 10 mmcf/d in the interval 4,314 to 4,354 feet, and an oil recovery of 2,000 feet from the interval 4,353 to 4,387 feet. Water recoveries were obtained from the Chance Sandstone in tested intervals below 4,415 feet. In the underlying Canoe River limestone sequence oil and water recoveries were obtained from a number of drillstem tests between 5,054 and 5,190 feet. No porosity was seen in the well cuttings and it is thought that the fluid recovery was from a fractured zone. The Birch Member was found to be very thin with only about 40 feet of non-porous sandstone present in the shale-limestone-sandstone sequence.

SMWM Chance YT G-8

About one-half mile south of the Chance No. 1 discovery well, the exploratory outpost well Chance G-8 was completed as a Chance Sandstone oil well (suspended) with 17 feet of net oil pay. Perforated intervals opened to oil production are 4,393 to 4,404 feet, and 4,422 to 4,456 feet; the average oil gravity is 33° API at 60°F, and the total sulphur about 1.7 weight per cent. The conglomeratic sandstone is partly cemented with calcite, and contains some black pyrobitumen infilling. Therefore, the porosity is erratic in the reservoir and not as high as in the Chance No. 1 well. Porosity values obtained from eight core samples in the reservoir zone ranged from 2.0 to 13.2 per cent permeability from 0.2 to 27 md., and calcite cement (weight per cent soluble in acid) from 11.46 to 25.72; the total porosity plus calcite cement was between 25 and 28 per cent in all cases. Analysis of the gas obtained from a drillstem test in the reservoir indicated 83.97 per cent methane, 7.12 per cent ethane, 3.99 per cent carbon dioxide, 2.93 per cent propane, and minor amounts of butane, nitrogen, pentanes, hexanes, and heptanes plus.

Canoe River Chance YT J-19

Another exploratory outpost well, Chance J-19, was completed about 1 mile north of Chance No. 1 as a suspended Chance Sandstone gas and oil well with a net pay of 187 feet, of which the lower 42 feet is oil-filled and the remaining 145 feet gas-filled. Core analysis of part of the gas-bearing sandstone interval indicated a weighted average porosity of 12.26 per cent, and weighted horizontal permeability of 82.05 md., whereas core analysis of part of the oil-bearing reservoir indicated a weighted average porosity of 10.79 per cent, and a weighted average horizontal permeability of 32.23 md. Gas analysis showed 76.01 per cent methane, 6.82 per cent ethane, 5.33 per cent carbon dioxide, 4.66 per cent propane, 3.60 per cent nitrogen, 1.90 per cent butanes, and minor amounts of pentanes, hexanes, and heptanes plus. Oil analysis showed an API gravity of 31.8° at 60°F, and a sulphur weight per cent of 1.11.

The erratic pattern of quartz grain growth followed by carbonate cementation has largely destroyed or reduced most of the porosity in the conglomeratic sandstones. In the five wells that have Chance Sandstone present, all have zones of good porosity, but the Birch Member sandstones are much more erratic in development and usually are completely cemented. Because the Chance Sandstone is thought to be laterally continuous south of its erosional edge (Fig. 3), the prospects of additional discoveries are excellent in and near the members subcrop. However, the porous Birch sandstone development is thought to be restricted north of a line joining the Birch B-34 and East Chance C-18 wells. Fractured zones in the Canoe River carbonates show some promise but these are at best marginal prospecting zones.

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APPENDIX

Sample logs of:

(1) SOBC Blackstone YT D-77 well (subsurface reference section of unnamed shale unit).

(2) SMWM Birch YT B-34 well [type Canoe River Member (shale facies) and type Birch Member of the Hart River Formation].

(3) Western Minerals Chance No. 1 well [type Chance Sandstone Member and Canoe River Member (carbonate facies) of the Hart River Formation].

Standard Oil Company of British Columbia Blackstone YT D-77

Location: Lat. 65°46'10.77"N; Long. 137°14'54.78"W
Elevation: 2,116 feet K.B.
Total depth: 13,217 feet
Completed: January 8, 1963
Status: Dry and abandoned

Log by H.L. Martin from samples stored at the Institute of Sedimentary and Petroleum Geology, Calgary, Alberta.

Sample depth (feet)	Lithology	Thickness (feet)
	Sample description begins at 1,500 feet drilling depth in Hart River Formation (Birch Member).	
1,500-1,530	Shale: black, bituminous, calcareous in part; traces of limestone, dark grey-brown, micritic, siliceous with calcitic spicules and floating clear quartz grains; some black chert cuttings with vague spicular texture	30
	Unnamed shale unit (subsurface reference section) picked at 1,532 feet from logs	
1,530-1,710	Shale: black, very bituminous in upper 40 feet, slightly bituminous below, dark brown streak, fissile; abundant pyrite inclusions, from 1,620 to 1,640 feet very abundant granular pyrite inclusions impart a coarse silty appearance to the shale; trace siltstone; rare trace sandstone, light brown, grey, and medium grey-brown, siliceous and about 5% dolomitic	
	X-ray diffraction analysis, 1,600 to 1,700 feet: Quartz 67%, Pyrite 8%, Feldspar 4%, Kaolinite 10%, Illite 11%. Organic carbon content 3.65%	
	Palynology, 1,600 to 1,700 feet. A few spores were recovered but no age determination was possible	180
1,710-1,790	Shale: as above, with traces of white crystalline anhydrite which probably occurs as fracture infillings. From 1,760 to 1,770 interbedded sandstone, light brown-grey, medium-grained chert and quartz framework, with siliceous and dolomitic cement	80

Sample depth (feet)	Lithology	Thickness (feet)
1,790-1,800	Shale: as above; no anhydrite	10
1,800-1,820	Sandstone: slightly conglomeratic, chert and quartz grains in siliceous and dolomitic cement, dark chert grains subrounded to well rounded	20
1,820-1,940	Shale: black and dark grey, very pyritic, fissile, ironstone fragments abundant, medium brown, pyritic, slightly dolomitic, traces black coaly plant? material in some ironstone fragments. Sandstone, as above, very pyritic in part, with lesser siltstone, occurs in trace amounts and is probably present as thin lenses; a few chips were seen with thin sandstone and siltstone laminae	120
1,940-2,000	Shale: dark grey, slightly bituminous, very pyritic, with soft, argillaceous brown siltstone and light brown sandstone in trace amounts	60
2,000-2,110	Shale: black, bituminous, soft, fissile, with abundant pyrite as pods, disseminated, and as complete well cuttings. Trace amounts of siltstone and sandstone, much as above. Rare traces of milky white anhydrite	110
2,110-2,120	Sandstone: light brown, fine-grained, well-sorted, poor intergranular porosity with light oil stain, dolomitic and siliceous cement	10
2,120-2,260	Shale: dark grey to black, as above. Stringers of dirty, argillaceous sandstone, shale with patches of argillaceous sandstone or floating quartz grains, medium grey siliceous sandstone, and medium brown siltstone. Sandstone fragments 2,150 to 2,170 feet, very pyritic. Rare traces white anhydrite. Trace plant? imprints X-ray diffraction analysis 2,150 to 2,250 feet: Quartz 65%, Calcite trace, siderite 3%, Pyrite 5%, Feldspar trace, Kaolinite 13%, Illite 14%. Organic carbon content 1.86%	140
2,620-2,280	Sandstone: light brown and grey, fine-grained, dolomitic and siliceous	20

Sample depth (feet)	Lithology	Thickness (feet)
2,280-2,400	Shale: dark grey to black, bituminous, pyritic, traces anhydrite veinlets; trace ironstone fragments; sandstone interbeds, medium- to coarse-grained, light to medium brown, trace porosity, siliceous and dolomitic	120
2,400-2,690	Shale: dark grey to black, slightly to nil bituminous; sandstone and siltstone stringers, as above; abundant pyrite; traces shale breccia; traces black carbonaceous plant? fragments; about 10% dark brown shale with black carbonaceous imprints; rare traces ironstone fragments	
	X-ray diffraction analysis 2,550 to 2,600 feet: Quartz 74%, Siderite 4%, Pyrite 3%, Feldspar trace, Kaolinite 7%, Illite 12%, Chlorite trace. Organic carbon content 2.08%	
	Palynology, 2,500 to 2,600 feet. No spores recovered under normal palynological extraction techniques	290
2,690-2,700	Shale: black, bituminous; very abundant pyrite as cubes, blebs, massive, and whole cuttings, slightly dolomitic	10
2,700-2,740	Shale: black, bituminous, trace pyrite	40
2,740-2,750	Shale: black, dolomitic, resinous, contains coarse dolomite crystals	10
2,750-2,760	Shale: black, bituminous, dolomitic, slightly pyritic	10
2,760-2,840	Shale: black, very bituminous, pyritic, brown streak, smooth, high lustre, with traces of slickensides. Rare trace white anhydrite	
	X-ray diffraction analysis 2,760 to 2,800 feet: Quartz 83%, Siderite 5%, Feldspar 5%, Kaolinite 1%, Illite 6%. Organic carbon content 5.61%	
	Palynology, 2,760 to 2,800 feet. Spores not well preserved. Only tentative age can be determined Seems to be a mixed Mississippian-Devonian one, therefore a Strunian age (very latest Famennian or early Tournasian) is suggested (M.S. Barss)	80
2,840-3,000	Shale: black, not as bituminous as above, much harder but still has brown streak, abundant pyrite, blocky, traces calcite, dolomite, and anhydrite fracture infillings	160

Sample depth (feet)	Lithology	Thickness (feet)
3,000-3,180	Shale: dark grey-brown to black, slightly bituminous, softer than above, pyritic; high lustre. Traces plant? fragments, siltstone; rare trace white dolomite and anhydrite fracture infillings	180
3,180-3,320	Shale: dark grey, non-bituminous, silty "granular" appearance in part, rare pyrite inclusions and spheres, traces siltstone and anhydrite X-ray diffraction analysis 3,200 to 3,250: Quartz 80%, Calcite 1%, Dolomite 2%, Siderite 3%, Pyrite 1%, Feldspar 3%, Kaolinite 3%, Illite 6%, Chlorite 1%. Organic carbon content 0.69%	140
3,320-3,500	Shale, siltstone, and sandstone - Shale: dark grey as above. Siltstone: dark grey-brown. Sandstone: dark grey-brown, "dirty" appearance, fine to medium subrounded dark and medium grey chert and quartz grains. The sandstone appears to grade to shale or sandy shale. Some plant? fragments and rare beds of bituminous shale X-ray diffraction analysis 3,330 to 3,360 feet (sandstone): Quartz 82%, Dolomite 3%, Siderite 4%, Pyrite 1%, Feldspar 5%, Kaolinite 2%, Illite 3%. Organic carbon content 0.45%	230
3,500-3,610	Shale: dark grey-brown to black, bituminous with brown streak, abundant pyrite as cubes, massive, and spheres. Trace anhydrite and quartz veinlets	110
	Ogilvie Formation picked at 3,616 feet from logs	
3,610-3,660	Limestone: micritic-skeletal, dark grey to brown-grey broken fragments of brachiopods, crinoids, and other indeterminate skeletal debris, and whole ostracods in lime mud matrix	50
	end of sample description	

Socony Mobil Western Minerals Birch YT B-34

Location: Lat. 66°03'3.14"N; Long. 136°51'17.51"W
Elevation: 2,190 feet K.B.
Total depth: 5,413 feet
Completed: June 8, 1965
Status: Birch Member Gas Well (Capped).

Log by H.L. Martin from samples stored at the Institute of Sedimentary and Petroleum Geology, Calgary, Alberta.

Sample depth (feet)	Lithology	Thickness (feet)
	Sample description begins at 1,650 feet drilling depth in Hart River Formation (Chance Sandstone Member).	
1,650-1,680	Sandstone: salt and pepper, medium- to coarse-grained, dark rounded and subrounded chert grains and lesser quartz with abundant brachiopod fragments and brachiopod spines, glauconitic, calcite cemented with trace porosity and light oil stain. Grades into sandy skeletal limestone with partial siliceous replacement of skeletal debris	30
	Type Canoe River Member	
	picked at 1,684 feet from logs	
1,680-1,710	Shale: dark grey-brown, calcareous, glauconitic, pyritic, trace calcitic broken brachiopod fragments	30
1,710-1,760	Limestone: medium grey-brown, glauconitic, abundant brachiopod fragments and spines, siliceous, grading into chert; interbedded with shale, dark grey-brown, siliceous	50
1,760-2,090	Shale and mudstone: dark grey-brown, highly siliceous, calcareous, glauconitic, grading into limestone, micritic-skeletal, glauconitic, siliceous. Abundant calcite brachiopod spines, siliceous and calcitic brachiopod spines, siliceous and calcitic brachiopod shell fragments, lesser coarse crinoidal debris; pyrite mostly as blebs with rare nodules. Scattered very fine carbonaceous fragments	

Sample depth (feet)	Lithology	Thickness (feet)
	Thin section prepared from well cuttings collected between 1,760 and 1,810 feet. Most rock chips are dominantly quartz of which about 10% is coarse silt-size to very fine sand-size subrounded terrigenous floating grains. Remainder is micro-crystalline quartz, some of which appears to be of replacement origin. A few chips were seen with greater than 50% calcite where broken skeletal debris, including siliceous and calcareous spicules, are in a matrix of intimately associated lime mud and microcrystalline quartz	
	X-ray diffraction analysis, 1,830 to 1,890 feet: Quartz 54%, Calcite 38%, Dolomite 4%, Glauconite 3%, Pyrite 1%	330
2,090-2,100	Shale: dark grey-brown, abundant glauconite, very silty, trace pyrite	10
2,100-2,310	Shale: dark grey-brown, very slightly calcareous, pyritic, brown streaks, slightly bituminous, scattered broken fragments of calcite brachiopod spines and shells and spicules. Siltstone, calcareous, medium brown, calcitic spicules, trace glauconite; siltstone is present in minor amounts and probably occurs as thin interbeds. Rare traces of brown ironstone fragments	
	Palynology, 2,167 to 2,171 feet. Similar assemblage to that of 1,298 to 1,303 feet (see text). Most probably Permian although late Stephanian (Late Pennsylvanian) cannot be ruled out (M.S. Barss)	210
2,310-2,320	Sandstone: salt and pepper, colourless to white, light and lesser dark chert, coarse, subrounded, with fine- and medium-size quartz grains, siliceous cemented in part, good intergranular porosity	10
2,320-2,640	Shale: dark grey-brown to dark grey, slightly to non-calcareous in uppermost 150 feet, calcareous below, pyrite in part; trace to abundant ironstone fragments, medium brown, pyritic; siltstone, trace to minor amounts; scattered coarse-size calcitic skeletal debris, such as echinoderms, punctuate brachiopods, brachiopod spines, spiny brachiopods, ostracods	
	Palynology, 2,323 to 2,330 feet. Namurian (Early Pennsylvanian), probably middle or late because of presence of Florinites sp. (M.S. Barss)	320

Sample depth (feet)	Lithology	Thickness (feet)
2,640-2,670	Limestone: light brown, crinoidal, with some silica replacement, well-cemented with spar, trace pyrite, abundant brachiopod spines, white rounded chert inclusions appear to be of replacement origin	30
2,670-3,200	Shale: dark grey and brown-grey, moderately calcareous, pyrite inclusions, very abundant coarse crinoid stem fragments, lesser brachiopod spines and rare brachiopod shell fragments. Trace to moderate amounts of siltstone, brown, calcareous, with rare crinoid fragments. Ironstone fragments common, slightly dolomitic, pyritic. Limestone, as above, well cuttings noted at 2,690 to 2,710 feet and 2,910 to 2,920 feet	530
3,200-3,310	Shale: medium grey, calcareous content slight, shale flocculates in acid. Crinoid stem fragments present but in trace amounts. Ironstone fragments darker than above, orange-brown and very abundant	110
3,310-3,360	Shale: medium grey as above with laminated or interbedded dark grey shale. Rare crinoid fragments	50
3,360-3,390	Shale: dark grey, non-calcareous, hard (does not flocculate as above). Rare crinoid stems	30
3,390-3,460	Shale: medium and dark grey; latter predominates, appears to be interbedded as rare chips seen with medium and dark laminae. Medium grey shale as above, i.e. flocculates in acid. Crinoid fragments rare, but some present in every sample	70
3,460-3,710	Shale: dark grey, non-calcareous to very slightly calcareous, crinoidal fragments more abundant than above. Traces dark grey-brown siltstone, slightly calcareous, with crinoidal fragments Palynology, 3,594 to 3,604 feet. Similar assemblage to 2,323 to 2,330 feet, i.e., Namurian (M.S. Barss) Macropaleontology, 3,595.4 feet. Single ammonoid, Monismoceras sp., indicates a late Viséan age (W.W. Nassichuk)	150
3,710-3,730	Shale: as above, with 20 to 30% dark brown bituminous shale	20

Sample depth (feet)	Lithology	Thickness (feet)
3,730-3,750	Shale: medium and dark grey, abundant pyrite, no crinoidal debris. About 10% siltstone	20
3,750-3,810	Shale: medium grey, abundant pyrite, crinoidal fragments, trace siltstone. Trace ironstone 3,790 to 3,800 feet. From 3,800 to 3,810 feet, about 35% dark grey non-calcareous shale	60
	Note: Crinoid fragments found between 2,320 and 3,810 feet consist of separate light brown to off-white calcitic coarse fragments with traces of pyrite replacement in the centre. These fragments are the same size as the well cuttings	
	Type Birch Member	
	picked at 3,808 feet from logs	
3,810-3,830	Limestone: medium to dark grey-brown, siliceous and chertified, up to 10% detrital quartz, micritic, spicular. Greater than 50% dark grey spicular chert in cuttings	20
3,830-3,840	Sandstone: calcareous, cherty, coarse-grained	10
3,840-3,850	Limestone and chert: as above	10
3,850-3,870	Shale: dark grey, very hard, siliceous, calcareous, with white calcite filled fractures	20
3,870-3,980	Limestone and chert: as above, calcite and siliceous spicules; interbeds of siltstone and siliceous, calcareous shale	110
3,980-4,000	Sandstone: salt and pepper, coarse, poorly sorted, subrounded, dark chert grains with lesser quartz, calcareous cement, tight	20
4,000-4,220	Limestone: medium to dark brown, micritic, trace dolomitic, siliceous, siliceous and calcareous spicules common, rare trace crinoidal debris, dark chert inclusions near base, some rare chips contain up to 15% floating quartz grains, abundant calcite infilled fractures. Interbeds (about 25%) of shale, calcareous and non-calcareous, dark grey, very silty. From 4,130 to 4,170 feet, black bituminous shale	220

Sample depth (feet)	Lithology	Thickness (feet)
4,220-4,230	Sandstone: salt and pepper, coarse dark and light chert grains, subrounded with lesser fine clear quartz grains, siliceous and calcareous cement, tight	10
4,230-4,380	Limestone and shale: as above, cherty in part, sandy in part, traces brachiopod and crinoid fragments. Calcareous siltstone, dark brown grey, 20%	150
4,380-4,620	Sandstone: light brown and grey, coarse subrounded varicoloured chert grains with lesser quartz grains, calcareous and siliceous generally, but some dolomitic cement also, scattered poor to fair intergranular porosity, interbeds of calcareous siltstone 10%, dark shale, 10%, and siliceous spicular limestone, 5%	240
4,620-4,700	Limestone: dark brown, siliceous, micritic, spicular, with shale, black, slightly bituminous, in basal 30 feet	
	Palynology, 4,622 to 4,631 feet. No spores present in samples prepared for palynological analysis	
	Macropaleontology, 4,623.5 feet. Quadratia cf. hirsuteformis (Walcott) "Leiorhynchus" carboniferum Girty. The age of the assemblage is Chesteran (J.B. Waterhouse)	80
4,700-4,800	Shale: black, bituminous, brown streak, waxy in part, dolomitic in part. Traces of dark grey calcareous siltstone	100
4,800-4,840	Shale: dark grey, non-bituminous, dolomitic in part, with trace calcareous and pyritic siltstone, rare trace calcareous sandstone	40
4,840-4,870	Shale: black, bituminous, brown streak, calcareous in part	30
4,870-4,930	Sandstone: light brown, salt and pepper, conglomeratic, with light and dark subrounded and rounded chert grains and lesser and finer quartz. Calcareous, with trace dolomite rhombs. Tight except for 4,910 to 4,920 feet when poor intergranular porosity is present	
	Grain size analysis from sample at 4,896 feet (see text)	60
4,930-4,940	Shale: dark grey, pyritic, with brown ironstone fragments	10

Sample depth (feet)	Lithology	Thickness (feet)
4,940-5,000	Shale: black, bituminous, brown streak, traces of coarse crinoid fragments. From 4,980 to 5,000 feet, about 25% calcareous shale with abundant white specks. Traces calcareous siltstone	60
5,000-5,060	Sandstone: light grey and brown, mostly light coloured coarse subrounded chert grains, with lesser quartz and trace dark chert grains, calcareous cement, poor intergranular porosity 5,000 to 5,010 feet. Interbeds of non-calcareous dark grey shale in basal 30 feet	
	Palynology, 5,047 to 5,052 feet. No spores recovered under normal palynological extraction techniques	60
5,060-5,090	Shale: black, bituminous, with about 25% calcareous white speckled shale, traces of coarse crinoidal debris	30
5,090-5,260	Sandstone: medium grey and brown, coarse to conglomeratic, varicoloured chert subrounded and rounded grains; crinoid fragments, both siliceous and calcitic, and brachiopod fragments are also part of framework but the latter are rare. Traces intergranular porosity but most of the sandstone has calcareous cement. Interbedded with about 25% shale, bituminous and also white speckled calcareous shale, with rare brachiopod fragments, crinoids, and trace ostracods. Some crinoid stems are silicified and pyritic	150
5,260-5,370	Shale: black, bituminous, and white speckled in lesser amount. Traces crinoidal fragments. Trace brown dolomitic ironstone fragments 5,320 to 5,330 feet. Interbedded (about 10%) with limestone, dark grey-brown, siliceous, cherty, spicular, micritic	110
	<u>Unnamed shale unit</u>	
	picked at 5,385 feet on logs	
5,370-5,400	Shale: black, bituminous, brown streak, non-calcareous pyrite nodules common	30

Western Minerals Chance No. 1

Location: Lat. 66°07'46"N; Long. 137°31'27"W
Elevation: 1,769 feet K.B.
Total depth: 8,648 feet
Completed: May 25, 1960
Status: Suspended Chance Sandstone gas or oil well

Log by H.L. Martin from samples stored at the Institute of Sedimentary and Petroleum Geology, Calgary, Alberta.

Sample depth (feet)	Lithology	Thickness (feet)
	Sample examination begins at 3,950 feet in Lower Cretaceous strata.	
3,950-4,030	Shale: dark grey, micromicaceous, pyritic, glauconitic in part, with lesser siltstone, brown grey	
	X-ray diffraction analysis of shale cuttings from 3,950 to 4,030 feet: Quartz 65%, Kaolinite 10%, Illite (glauconite) 8%, Feldspar 5%, Pyrite 6%, Dolomite 4%, Siderite 2%	
	Chemical analysis: carbonates 8%, organics 3.9%, residue 88.1%	
	Micropaleontology: 3,000 to 4,034 feet, Gaudryina tappanae Chamney, Gaudryina cf. G. subcretacea Cushman, Ammobaculites cf. A. fragmentarius Cushman, Gavelinella sp., Bathysiphon scintillata Chamney, Ammodiscus sp. (minute). Age: This is a Lower Cretaceous microfauna, with predominantly Early Lower Cretaceous (Neocomian) taxa. From report no. Mes. 3 TPC 1968, by T.P. Chamney	80
	Hart River Formation	
	picked at 4,036 feet on logs	
4,030-4,050	Chert: light brown, blue-grey, with crinoidal texture preserved, 50%. Limestone, dark brown, siliceous and calcareous crinoids fragments and spicules in micritic dark brown siliceous matrix	20

Sample depth (feet)	Lithology	Thickness (feet)
4,050-4,200	Limestone: medium brown, as above, with 20% shale, calcareous, dark brown, siliceous, with crinoidal fragments	
	X-ray diffraction analysis, 4,063 to 4,067 feet, Calcite 70%, Quartz 30%	
	Macropaleontology: GSC Location C-4364, depth 4,067 feet, ?Flexaria sp., GSC Location C-4363, depth 4,153 feet, Quadratia hirsuteformis (Walcott), "Leiorhynchus" carboniferum Girty, ?Crurithyris sp.	
	This assemblage belongs to the brachiopod fauna A zone assemblage as identified by J.B. Waterhouse, and indicates a Chesteran age	150
4,200-4,230	Limestone: medium brown, micritic with rare crinoidal remains, silty, trace dolomite	30
4,230-4,240	Sandstone: coarse- to fine-grained subrounded chert and quartz grains, calcite cemented 50%. Limestone, medium brown, silty and sandy, micritic	10
4,240-4,260	Shale: dark grey-brown, calcareous, slightly bituminous brown streak, trace crinoid fragments	
	X-ray diffraction analysis at 4,255 feet: Quartz 80%, Calcite 20%	20
	Type Chance Sandstone Member	
	picked at 4,258 feet from logs	
4,260-4,360	Sandstone: salt and pepper, conglomeratic, rare chert pebbles up to 9 mm in size, most commonly 1.5 to 2 mm, varicoloured chert grains, subrounded to rounded; quartz grains less than 40% of rock and less than 0.80 mm in size, subhedral to euhedral common due to grain growth; very friable; porosity very good, up to 25%	
	X-ray diffraction analyses at 4,268, 4,273, 4,280, 4,282, 4,310, and 4,322 feet indicated 100% quartz, whereas at 4,348 feet 99% quartz and 1% calcite was indicated	
	Grain size analysis at 4,273 feet (see text)	100

Sample depth (feet)	Lithology	Thickness (feet)
4,360-4,510	Sandstone: much as above but cemented by calcite, tight	
	Grain size analysis at 4,390 feet (see text)	150
4,510-4,530	Sandstone: light brown, fine- to medium-grained clear and frosted quartz with lesser milky white chert grains and trace dark chert grains, well-sorted, calcite-cemented; tight	20
4,530-4,550	Shale: dark grey-brown, calcareous, 90%. Sandstone, very fine sized quartz and (10%) chert grains in calcareous and dolomitic cement; dolomite rhombs, replace calcite and encircle quartz grains, tight	
	X-ray diffraction analysis, 4,545 feet (sandstone): Quartz 50%, Calcite 42%, Dolomite 8%	20
4,550-4,620	Sandstone: salt and pepper, medium to coarse subrounded to rounded chert grains and lesser quartz, calcite cemented, tight	
	X-ray diffraction analysis, 4,580 feet: Quartz 60%, Calcite 40%	70
4,620-4,630	Limestone: dark brown; micritic, trace crinoid fragments	10
4,630-4,720	Sandstone: salt and pepper much as above, tightly cemented with calcite, fine- to medium-grained with some coarse grains	90
4,720-4,750	Shale: dark brown, calcareous, some crinoidal debris and rare brachiopod fragments; floating coarse silt and very fine-grained quartz. Grades to sandy limestone, very fine sized quartz grains floating in micrite, trace calcitic spicules, stylolites, 10%	
	X-ray diffraction analysis, 4,744 feet: Quartz 99%, traces of pyrite and dolomite	
	X-ray diffraction analysis, 4,751 feet (sandy limestone): Calcite 65%, Quartz 35%, dolomite trace	30

Sample depth (feet)	Lithology	Thickness (feet)
4,750-4,780	Sandstone: light brown, salt and pepper, coarse and rare conglomeratic light and dark chert subrounded and rounded grains with sub-equal, medium-grained quartz, calcite cemented	30
4,780-4,790	Sandstone: brown, much as above but abundant dolomite replacement of calcite cement; dolomite rhombs less than 0.06 mm	10
4,790-4,850	Sandstone: light brown, salt and pepper, much as above with 10 to 15% dolomite replacement, pyrite	60
	Top Canoe River Member (carbonate facies)	
	picked at 4,856 feet on logs	
4,850-5,240	Limestone: light to medium brown, dolomitic, slightly silty, siliceous in part, calcite spicules, micritic; cherty, abundant light brown chert fragments with trace spicular content; monotonous sequence of well cuttings	
	X-ray diffraction analysis at 5,194 feet: Quartz 66%, Calcite 28%, Dolomite 6%	
	X-ray diffraction analysis at 5,211 feet: Calcite 71%, Dolomite 17%, Quartz 12%	390
5,240-5,800	Limestone: dark brown, siliceous, micritic, dolomitic cherty. Siliceous content varies from slight to abundant, and samples generally contain more than 10% brown chert fragments with vague skeletal texture (spicular? or radiolarian?), and dark brown to black dense chert. Dolomitic, rhombs less than 0.06 mm in size and appear to be present throughout section but form less than 20% of the rock. Some traces of siliceous monaxon spicules in the highly siliceous limestone chips. Abundant fracture-filled calcite veinlets. Rare crinoidal fragments. Traces of black flecks scattered throughout interval. No pyrite	560
5,800-6,020	Limestone: medium to dark brown, very cherty, siliceous in part, micritic, less than 10% dolomite rhombs. Chert fragments are spicular, light brown, and dense, dark brown. Some samples left a hard siliceous residue with faint laminations on acidizing, others left only about 5% quartz silt residue	220

Sample depth (feet)	Lithology	Thickness (feet)
6,020-6,070	Shale: black, brown streak, rare crinoidal debris, grading in part to siliceous limestone	
	X-ray diffraction analysis 6,048 to 6,051 feet: Calcite 58%, Quartz 41%, Dolomite trace, pyrite trace	50
6,070-6,100	Sandstone: light brown, salt and pepper, conglomeratic, milky white through dark chert rounded and subrounded pebbles greater than 2.0 mm, with quartz and varicoloured chert grains about 0.5 mm in calcite cement. Poor intergranular porosity	
	X-ray diffraction analysis 6,092 feet: Quartz 82%, Calcite 18%, Pyrite trace	30
6,100-6,320	Limestone: medium brown, cherty, siliceous in part, micritic, scattered monaxon siliceous spicules, less than 10% quartz silt and rare quartz grains up to 0.2 mm in size. Chert is grey, spicular, and dense, dark brown	220
6,320-6,520	Limestone, shale, and chert, interbedded - Limestone: dark brown, micritic, siliceous, grading to calcareous chert; calcite-filled veinlets common, 40%	
	Shale: dark brown-grey, slightly calcareous, 25%. Chert, mostly dark brown, lesser grey and medium grey-brown 35%	
	X-ray diffraction analysis 6,408 feet: Quartz 59%, Calcite 41%	
	X-ray diffraction analysis 6,410 feet: Quartz 88%, Calcite 9%, Dolomite 3%, Pyrite trace	200
	Top Birch Member	
	picked at 6,521 feet on logs	
6,520-6,570	Sandstone: light to medium brown and salt and pepper, coarse-grained light and dark chert and quartz in calcite cement; tight. Lesser interbeds of calcareous dark brown shale	50
	end of sample description	