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THE CLAYS AND SHALES

of

MANITOBA

by Barry B. Bannatyne

Department of Mines
and
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PROVINCE OF MANITOBA

DEPARTMENT OF MINES AND NATURAL RESOURCES

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INTRODUCTION

The sedimentary section of rocks in southwestern Manitoba contains shale beds ranging in age from the Ordovician Period to the Paleocene Epoch; the deposits are of siliceous, calcareous, kaolinitic, illitic, and bentonitic composition. The chemical and mineralogical composition and the firing properties of representative samples of each of the major shale formations are reported. The thickness, extent, and structure of the shale beds have been determined from subsurface data.

The deposits resulting from the glaciation of the Pleistocene Epoch contain much silt and clay material. These include the silty deltaic deposits, the clay matrix of boulder clay or till, and the vast areas of clay deposited in the glacial lakes that formed during deglaciation.

In the past, some of the shales have been used in the production of structural clay products and natural cement; at present, non-swelling bentonite, used mainly in the clarification of oils, and siliceous shale, used for road material, are quarried. Red River Brick and Tile, a subsidiary of Medicine Hat Brick and Tile Company Limited, is constructing a face brick plant near Lockport scheduled for production about February, 1971; Jurassic and Cretaceous shales from the Ste. Rose du Lac area, as well as other raw materials from Manitoba, will be used.

The surface clay deposits at one time supported over 40 brick plants in Manitoba, mainly for common brick production. Clay is used in the production of lightweight aggregate and as a raw material for Portland cement manufacture.

Production statistics are listed in Appendix I.

PREVIOUS WORK

Aside from reports on the general geology of Manitoba, the first reports on clays and shales of Manitoba are those of Wells (1905a, 1905b) describing the various types and their use in brick and natural cement. The Mines Branch of Ottawa surveyed the clay and shale deposits of Western Canada and three reports, by Keele (1915) and Ries and Keele (1912, 1913), were published; firing tests made on Manitoba samples were included.

A deposit of kaolinitic shale at Swan River was described by Johnston (1918) and a kaolin deposit on Punk Island, now called Deer Island, was described by Cole and McMahon (1928). A survey of brick plants in Manitoba was made by Walsh (1931), and the Deer Island deposit was investigated further.

Some reports on the glacial geology of Manitoba include data on the formation and occurrence of clay deposits. Upham's reports (1890, 1895) describe the former existence of glacial Lake Agassiz which covered much of the present area of Manitoba. Elson (1961) summarized the work of numerous investigators of the Pleistocene geology of Manitoba and his report includes an extensive bibliography. A later report by Elson (1967) contains many new interpretations of the history of Lake Agassiz.

Several investigations into possible uses for Manitoba clays and shales have been made. Matthews (1952) tested bloating characteristics for lightweight aggregate; Brady (1957, 1960, 1961) reported on the brick-making properties and the physical, chemical, and mineralogical characteristics of selected samples; Ross and Buchanan (1962) and Bannatyne (1963) reported on the bentonite in the Pembina Mountain area. In addition, the files of the Manitoba Mines Branch contain many unpublished reports.

Information on clays and shales is contained in the geological reports of Tyrrell (1892), MacLean (1915), Kirk (1930), Wickenden (1945), and Tovell (1948), in the groundwater supply papers of the Geological Survey of Canada, and in the Manitoba Soil Survey reports (see selected references).

PRESENT WORK AND ACKNOWLEDGEMENTS

This report describes the history of the clay products industry in Manitoba, the geology of the clays and shales, their physical and chemical properties, and their possible uses. The information presented is derived both from previous reports and from extensive field surveys and test work of the Manitoba Mines Branch and others.

In 1951 and 1952, F.S. Gamey, then Resident Engineer with the Manitoba Mines Branch, carried out a survey in which 300 samples were collected and tested for bloating and firing properties; student assistants were A.C. Turnock and H. Fulton. From 1962 to 1967, the writer collected an additional 400 samples; field assistants were E. Williams and R. Armstrong.

Representative samples from each shale formation and various clay samples were given preliminary firing tests in a Pereco kiln Model No. LB74-128. Detailed tests on hand-molded clay bars of more than 200 samples were made with a Robert L. Stone temperature gradient furnace Model TG-BMT (Stone, 1953), using an 8-hour firing cycle for clays with low carbon content and a 20-hour cycle for carbonaceous or bentonitic shales. Chemical analyses of selected samples were made by A. MacKay and D. Brown in the Mines Branch Laboratory. Differential thermal analyses and X-ray identifications were made by F. Wicks at the University of Manitoba (Wicks, 1963). The colour designations are from the Munsell Soil Color Charts, 1954 edition.

Mr. F. Reckseidler, Grand Marais, has kindly granted permission to publish information on a kaolinitic clay from Deer Island. Information on the present markets for clay products has been supplied by the Manitoba Department of Industry and Commerce.

During preparation of this report, a series of structure contour and isopach maps of Cretaceous and Paleocene formations was prepared and issued as part of the Manitoba Mines Branch Stratigraphic Map series; H.R. McCabe assisted in the preparation of the maps of the Jurassic and Swan River formations included in this report. A bedrock topography map of southern Manitoba is in preparation as a joint project with the Geological Survey of Canada.

The writer is also indebted to the staff of the Water Control and Conservation Branch for information supplied on the distribution of clays and shales in the province.

International Minerals and Chemicals (Canada) Limited granted the writer permission to study the core of the Cretaceous section from the I.M.C. Gerald 7-27-19-32WPM well.

The writer wishes to thank J.G. Brady, Head, Industrial Minerals Section, Mineral

Processing Division, Department of Energy, Mines and Resources, for advice in evaluating the firing properties of the various clays and shales tested; the writer accepts responsibility for the evaluations presented.

The co-operation of J.E. Wyder and the Geological Survey of Canada in obtaining sidewall samples of the Turtle Mountain and Boissevain Formations is gratefully acknowledged.

The structure contour and isopach maps were drafted by C.B. Lewis, and the temperature gradient diagrams by G. Fraser.

EVALUATION OF TEST RESULTS

For a detailed discussion of the properties of clays and shales required for various products, such as face brick, common brick, sewer pipe, pottery, and lightweight aggregate, the interested reader is referred to such standard texts as Clay Mineral Technology (Grim, 1962) and pertinent chapters in Industrial Minerals and Rocks (A.I.M.E., 1960).

In general, clays or shales of value for structural clay products should have good workability, ranging from moderately plastic for brick to highly plastic and smooth for sewer pipe; clays with smooth workability are required for pottery. The material should dry without cracking or warping and should fire very hard to steel hard for common brick and steel hard for most other higher quality clay products. The fired colour also is of importance, except for some tile products; scum is undesirable.

For common brick, absorption of up to 20% is permissible; combined air drying and firing shrinkage should generally be less than 12% to prevent problems in drying the brick, and the optimum firing temperature should be about 1800° to 2000°F (982° to 1093°C). Face brick must be steel hard, and absorption should be less than 15%. Combined shrinkage should generally be less than 10%, and maturing temperature should be in the range of 1800° to 2200°F (982° to 1204°C).

Clay used for various types of tile, such as drain tile, floor or wall tile, and chimney tile, should have an absorption ranging from 0 to 10%, and shrinkages must be less than for face brick. For sewer pipe, absorption must be even lower, generally less than 8% and preferably close to 0%.

The above comments are oversimplified, but will indicate some of the criteria used in evaluating clays and shales for the wide variety of fired clay products. Various reports of the Canadian Standards Association and the American Society for Testing and Materials outline the specifications that manufactured clay products must meet to be acceptable for marketing. It should be borne in mind that mixtures of clays are used for most manufactured products, and their fired properties are superior to those of the clays tested individually; also, the addition of various non-clay materials, such as sand, flocculating agents, and fluxing agents is a common practice to improve the molding, drying, and firing behaviour of the clays and shales.

THE CLAY INDUSTRY OF MANITOBA

The clay industry had its beginnings in the early days of settlement along Red River, when the calcareous surface clay in the Winnipeg area was used for making common brick. The first attempt at brick-making, for use in chimneys, was made in 1871 by Charley Land near Omand's Creek, but the first plant to manufacture bricks used in the erection of buildings was started by Dr. Schultz in 1872; pottery was first made in 1879 at the Sutherland and Brydon plant at Selkirk (Begg and Nursey, 1879). Three brick plants were in operation in Winnipeg by 1874, and other plants were started in the next few years at Emerson, Portage la Prairie, and Rapid City. Statistical records of brick production in Manitoba were started in 1886, at which time six brick plants were operating. This early manufacture of brick resulted from localized demands, and production was limited; between 1886 and 1900, the annual value of production averaged $20,000.

A period of rapid development in Manitoba, especially from 1908 to 1913, resulted in the establishment of many brick yards throughout the southern half of the province. Wells (1905a) listed 33 brick plants producing common brick by the soft-mud process, 2 using the stiff-mud process, and 2 (at Learys and La Riviere) using Cretaceous shales. Burning was done mostly in scove kilns, using dried wood as fuel, but a few plants had down-draft kilns using coal. The total annual output during the average 150-day season ranged from 25 million to 87 million bricks. Common brick was the major product; most of the pressed brick used for facing buildings, as well as all structural ware and sewer pipe, was imported. Some dry-press brick for building and ornamental purposes was made at Lac du Bonnet and La Riviere.

Alsip Brick, Tile & Lumber Co. Limited was incorporated in 1905 and operated a large plant in St. Boniface with a rated capacity of 12,000,000 brick; it developed into the major producer. Other large producers were located at Lac du Bonnet, Portage la Prairie, Virden, Brandon, Rapid City, Gilbert Plains, Hartney and elsewhere.

From 1902 to 1924 natural cement was produced in Manitoba from a 10- to 20-foot bed of calareous shale within the Boyne Member. The first plant was operated by the Manitoba Union Mining Company at Arnold Siding, 2 miles east of Deerwood, on the C.N.R. from 1898(?) to about 1904. The Commercial Cement Company operated a mill at Babcock in 1907, and production of natural cement continued to 1924.

In 1912, the value of production was $1,018,051, the peak year for the Manitoba clay products industry.

The brick manufacturers were dependent upon the demands of the local building trade and, following the collapse of the building boom in 1913, brick plant operations declined rapidly. By 1915, only 12 plants were in operation, and the total value of production fell below $100,000. However, the clay products industry was becoming more diversified. In 1913, the Canada Cement Company Limited opened a large plant at Fort Whyte, using glacial lake clay from adjacent pits. At Learys a bright red dry-press face brick was produced from Morden shale, but the plant closed in 1917 for a period of 30 years.

A slow but steady growth of the industry was recorded from 1915 to 1929. A small amount of fire-proofing was manufactured starting in 1915; hollow blocks, drain tile, stiff-mud face brick and soft-mud face brick were first manufactured in the early 1920s.

Five to seven brick plants were active each year including Alsip's plant in St. Boniface, Marion & Co. plant also in St. Boniface, Sidney Brick and Clay Works Limited at Sidney, A. Snyder & Co. Ltd. at Portage la Prairie, Wardrop & Sons at Whitemouth, Snyder at Gilbert Plains, and National Clay Products Limited at Edrans.

In the late 1920s a growing demand for higher quality face brick, which until then had been imported at high cost, resulted in experimentation with local clays. A plant at Sidney produced deep red to chocolate brown wire-cut tapestry brick as well as smooth-faced stiff-mud brick and hollow tile. About 1926, Alsip Brick Tile & Lumber Co. Limited began production of a stiff-mud tapestry brick in shades of red, brown, and green using a mixture of silty clay from Firdale and calcareous surface clay from St. Boniface. Later, clay from Sidney was used instead of the Firdale clay. At Edrans, where a dry-press brick of fairly deep red colour was made, a plant was installed to produce tapestry brick. Although plants were built at Carman, for sewer pipe, and in northern Winnipeg, for tapestry brick, both designed to use a mixture of Morden and Odanah shales, the ventures were short lived. Most of the face brick produced at this time was not equal in grade to the imported brick, but was able to compete with it because of its low cost. The main volume of the brick business remained in the common brick produced from surface clays by the soft-mud process in shades of white, buff, and pale red. Small amounts of hollow brick, hollow tile, and drain pipe also were produced.

The great depression of 1929 to 1933 dealt a severe blow to Manitoba's brick industry and many plants were closed and dismantled. The entire brick production of 1933 was worth only $21,000. Only four plants remained in production through the middle 1930s – the Alsip and Marion plants in St. Boniface, the Snyder plant at Portage la Prairie, and the Wardrop plant at Whitemouth. The products included common brick, face brick, hollow blocks and drain tile. In 1937, Western Clay Products attempted unsuccessfully to revive the Edrans brick plant.

Another clay industry developed during the period of 1934 to 1940. Tests were made on the bentonite of the non-swelling variety found at the base of the Pembina Member of the Vermilion River Formation, and eventually Pembina Mountain Clays Limited was formed in 1940 and has remained in continuous production. A separate Manitoba Mines Branch report (Bannatyne, 1963) describes the bentonite deposits of the province.

After some improvement in the brick industry in the late 1930s (production exceeded $100,000 in 1938), the industry declined during World War II, and in 1945 only one plant, Alsip's in St. Boniface, remained in production.

Following the end of World War II, Alsip Brick Tile & Lumber Co. Limited acquired and re-opened the brick plants at Portage la Prairie and Whitemouth, and production continued at all three Alsip plants until 1957, when the St. Boniface and Whitemouth plants were closed. The Whitemouth and Portage la Prairie plants produced common brick and the St. Boniface plant both common and face brick, using some Sidney clay.

In 1947, the Learys brick plant was re-opened and small amounts of face brick and common brick were produced annually until 1952. Also in 1947, Marion Brick, Tile & Clay Products Limited opened a new plant in Old Kildonan but, after some production of common brick, fire destroyed the plant in 1948, and it was not rebuilt. In 1948 Western Clay Products attempted to re-open the Edrans plant but only a small number of brick were produced; the last kiln load at Edrans was fired in 1949.

Following considerable investigation of the properties of a bed of kaolinitic shale within the Swan River Group, Swan River Clay Products Limited began production of a buff coloured face brick in 1953, but less than 300,000 bricks were produced before the plant closed in 1955. An attempt was made to re-open this plant in 1959, but only one kiln-load of bricks was fired.

During the period from 1951 to 1955, investigations were carried out by the Manitoba Mines Branch and by the Mines Branch at Ottawa to determine which clays and shales of the province were suitable for the production of coated lightweight aggregate. It was found that a good grade of bloated aggregate could be produced from the lower layer of glacial Lake Agassiz clay in the Winnipeg and Red River valley areas. In 1955, Atlas Light Aggregate Limited began production at its plant in St. Boniface. A new kiln added in 1960 doubled the production capacity; the plant was taken over by Kildonan Concrete Products Limited in 1965. Winnipeg Light Aggregate Limited built a plant in Transcona in 1956, but after a small amount of production, the operation ceased in 1958. Echo-Lite Aggregate Limited opened a plant in St. Boniface in 1961.

Deposits of kaolinitic clay, usually mixed with fine silica, have been reported and investigated at various times. A deposit of white clay in the weathered Precambrian surface of Deer Island has been examined by several groups, but the tonnage is reported to be small. A deposit in the Cross Lake area to the northwest of Grand Rapids was investigated in the early 1930s and again in 1960. Several small occurrences were reported in the area east of Pine River in 1947, but the tonnage is apparently small; the deposit was re-examined by Medicine Hat Brick and Tile Company Limited in 1962. Another kaolinitic deposit was discovered in the area about 12 miles north of Arborg in 1956. Extensive tests have been made on the material to determine possible economic uses; some surface stripping was done in 1961, but no production has been attained. Some of the kaolinitic clays, including that from the Swan River Group have been tested by various individuals for pottery.

In 1962, Tallclay Products Limited was formed and began an attempt to revive the Learys plant for production of face brick. New equipment was added, and extensive firing tests of the Morden shale were made. A test batch of brick was fired in the old beehive kiln on the property in the fall of 1962, but the plant now is inactive.

In 1963 and 1964, exploration by Medicine Hat Brick and Tile Company Limited outlined deposits of kaolinitic shales in the Kergwenan area, 7 miles south of Ste. Rose du Lac. The company has also staked claims on Deer Island in Lake Winnipeg, in the outcrop belt of the Winnipeg Formation, and in the area northeast of Beausejour. Construction of a face brick plant, utilizing these materials, was started in October, 1969, two miles east of Lockport; its capacity will be 20 million bricks annually. The Manitoba subsidiary is named Red River Brick and Tile, and production is scheduled for the early part of 1971 ; present market in the Manitoba area is estimated to be about 10,000,000 bricks.

Current producing companies in the clay products industry are:

Canada Cement Company, Limited, Fort Whyte: glacial lake clay used in production of Portland Cement; annual consumption: 100,000 to 150,000 tons.

Echo-Lite Aggregate Limited, 1525 Dugald Road, St. Boniface: expanded aggregate from glacial clay; capacity: 250 cubic yards per day.

Inland Cement Company Limited, Tuxedo: glacial lake clay used in production of

Portland Cement; annual consumption: 50,000 to 60,000 tons.

Kildonan Concrete Products Limited, 468 Panet Road, St. Boniface: expanded aggregate from glacial clay; capacity: 325 cubic yards per day.

Pembina Mountain Clays Limited: activation plant, 945 Logan Ave., Winnipeg; drying plant at Morden; quarries in the Miami – Thornhill area; production: 10,000 to 15,000 tons of activated and natural bentonite per year.

Possibilities for expansion of the clay industry exist in increased production of lightweight aggregate, and in the production of intermediate duty fire brick, sewer pipe, drain tile, flue lining, and various types of pottery and ceramic artware.

PRE-JURASSIC CLAYS AND SHALES

Introduction

Shales and argillaceous beds occur throughout the Ordovician to pre-Jurassic stratigraphic succession in Manitoba (see Table 1). These shaly units, as well as some argillaceous beds within the Precambrian Shield, will be discussed in order of their stratigraphic sequence.

The Precambrian Shield in Manitoba consists mainly of large areas of granitic and gneissic rocks, separating belts of metamorphosed sedimentary and volcanic rocks. Most of the argillaceous rocks have been highly metamorphosed, except for some shales exposed along Seal River, 50 to 80 miles west-northwest of Churchill. These rocks, part of the Great Island Group, consist of interbedded grey to grey-black shale and siltstone, and finely banded red shale with a slaty cleavage (see Milligan, 1955, and Davison, 1965).

During a prolonged period of exposure in late Precambrian time, the rocks of the shield were deeply weathered. Some kaolinitic and other clay deposits in this weathered zone survived erosion and were buried under deposits of Paleozoic age.

In the predominantly carbonate Paleozoic strata of southwestern Manitoba, thick kaolinitic shale beds are present in the Ordovician Winnipeg Formation; thin red shaly beds occur in strata of younger Ordovician and Middle Devonian strata. Upper Devonian and Mississippian shales are present in the subsurface.

PRECAMBRIAN WEATHERED SURFACE

Residual clays of the weathered surface of the Precambian Shield have been preserved below a cover of Paleozoic rocks along the contact between the Winnipeg Formation and the Precambrian Shield. Some clays are exposed on Deer Island and some samples have been recovered from beneath the Winnipeg Formation on Black Island. Several drill holes through a thick cover of Paleozoic rocks in the area east of The Pas have intersected from 2 to 23 feet of residual clay.

The possibility of finding kaolinitic deposits makes the Precambrian-Paleozoic contact worthy of exploration, especially in such areas as near Cranberry Portage, along the Simonhouse-Button road, on Deer and Black Islands, and south from Traverse Bay to the International Boundary.

BLACK ISLAND CLAY DEPOSIT, LAKE WINNIPEG

In 1963, Selkirk Silica Company, a division of The Winnipeg Supply and Fuel Company Limited, dredged a harbor for its silica sand quarry on the south shore of Black Island and recovered large pieces of white kaolinized schistose rock, containing some pyrite and a few dark grains of heavy minerals, from the underlying weathered Precambrian surface. A partial chemical analysis is shown in Table 2.

Table 1. GEOLOGIC FORMATIONS OF MANITOBA

ERA	PERIOD	FORMATION	MEMBER	BASIC LITHOLOGY
CENOZOIC	Recent			Soil, alluvial deposits, sand dunes, bogs.
	Pleistocene			Glacial deposits
	Eocene to Pliocene	Not reported in Manitoba		
	Paleocene	Turtle Mountain		Shale, sandstone, lignite
MESOZOIC	Cretaceous	Boissevain ?		Sand and sandstone, greenish grey; kaolinitic shale
		Riding Mountain	Odanah	Hard grey siliceous shale
			Millwood	Greenish bentonitic shale
		Vermilion River	Pembina	Non-calc. shale, bentonite beds
			Boyne	Calcareous speckled shale
			Morden	Carbonaceous shale; septarian concretions
		Favel		Calc. speckled shale, limestone bands
		Ashville (Ashville Sand)		Non-cal. silty shale; 0-90' sand
		Swan River		Sand, sandstone, shale, clay, lignite
	Jurassic	Waskada		Varicoloured shale
		Melita		Varicoloured shale, calc. shale, limestone
		Reston		Argillaceous limestone and shale
		Amaranth	Upper: evaporite	Anhydrite, gypsum; shale, dolomite
			Lower: red beds	Dolomitic shale to siltstone, anhydritic
	Triassic	Not reported in Manitoba except Permian? Lake St. Martin cryptoexplosion structure		
PALEOZOIC	Permian			
	Pennsylvanian			
	Mississippian	Charles		Dolomite and anhydrite
		Mission Canyon		Limestone, dolomite, anhydrite; oil production
		Lodgepole	Whitewater Lake Virden Scallion Routledge	Limestone argillaceous and cherty; shale; oil production
		Bakken		Black shale and siltstone
	Devonian	GROUP		
		Qu'Appelle	Lyleton	Red dolomitic shale
		Saskatchewan	Nisku	Fossiliferous limestone and dolomite
			Duperow	Shaly limestone, dolomite, anhydrite; cyclical
		Manitoba	Souris River 1st Red	Limestone, evaporite, shale; cyclical
			Dawson Bay 2nd Red	Limestone, anhydrite, basal red shale
		Elk Point	Prairie Evaporite	Halite, with potash, anhydrite, dolomite
			Winnipegosis	Dolomite, reef and inter-reef
			Elm Point	High calcium limestone
			Ashern	Dolomite and shale, brick red
	Silurian	Interlake		Dolomite
	Ordovician	Stonewall		Dolomite
		Stony Mountain	Gunton	Dolomite, upper part shaly
			Penitentiary	Argillaceous dolomite
			Gunn	Fossiliferous calc. shale; red, grey, green
		Red River	Fort Garry	Dolomite, minor limestone
			Selkirk	Dolomitic limestone, mottled
			Cat Head	Dolomite, cherty
			Dog Head	Dolomitic limestone, mottled
		Winnipeg		Quartzose sand, sandstone; shale
	Cambrian	Deadwood		Glauconitic sandstone
			Major uncomformity	

Adapted from: Geology and Mineral Resources of Manitoba, Davies et al. (1962)

Table 2	Black Island clay deposit (raw material)			
Kaolinitic schist below silica sand, south shore, Black Island; analysts, MacKay and Brown.	SiO_2	75.55%	MgO	0.39%
	Al_2O_3	17.43%	CaO	0.35%
	Fe_2O_3 / TiO_2	0.60%	LOI	3.55%
			Total	97.87%

A sample of –325 mesh material, recovered from the kaolinized rock was analyzed also (Table 3).

Table 3	Black Island clay deposit (-325 mesh)			
Kaolinitic schist below silica sand, south shore, Black Island; MacKay and Brown.	SiO_2	58.71%	Na_2O	1.20%
	Al_2O_3	27.95%	K_2O	4.11%
	MgO	0.86%	LOI	6.55%
	CaO	Tr.	Total	99.38%

A DTA analysis indicated the presence of kaolinite, quartz, and a degraded muscovite or sericite mica, possibly with some illite.

Results of a temperature gradient test of the raw material are shown in Figure 1, and of –325 mesh material in Figure 2. Because of its high silica content, the raw material has a low air-dried strength, has a tendency to crumble during molding, and is difficult to vitrify. The –325 mesh sample fires light grey (10YR 7/1) at 2100°F; it contains less quartz, and consequently the shrinkage is higher.

The presence of quartz in the –325 mesh fraction prohibits the use of this material as a source of paper clay.

Mixing the raw material with a more plastic clay should improve the molding properties, making it suitable for face brick.

DEER ISLAND CLAY DEPOSIT, LAKE WINNIPEG

Cole and McMahon (1928) reported the occurrence of a small deposit of clay on the northeast shore of Deer Island; this island, formerly called Punk Island, is 3 miles southeast of Grindstone Point. White kaolinitic clay overlies green chloritic clay; the total maximum thickness of white clay is 40 inches, and the average thickness is estimated to be 12 inches. Walsh (1931) drilled 40 holes in the area, only 10 of which intersected the white clay; he estimated the deposit contained 3,000 tons. A gradational contact exists between white and green clays and underlying Precambrian green schist from which the clays were derived by pre-Ordovician weathering.

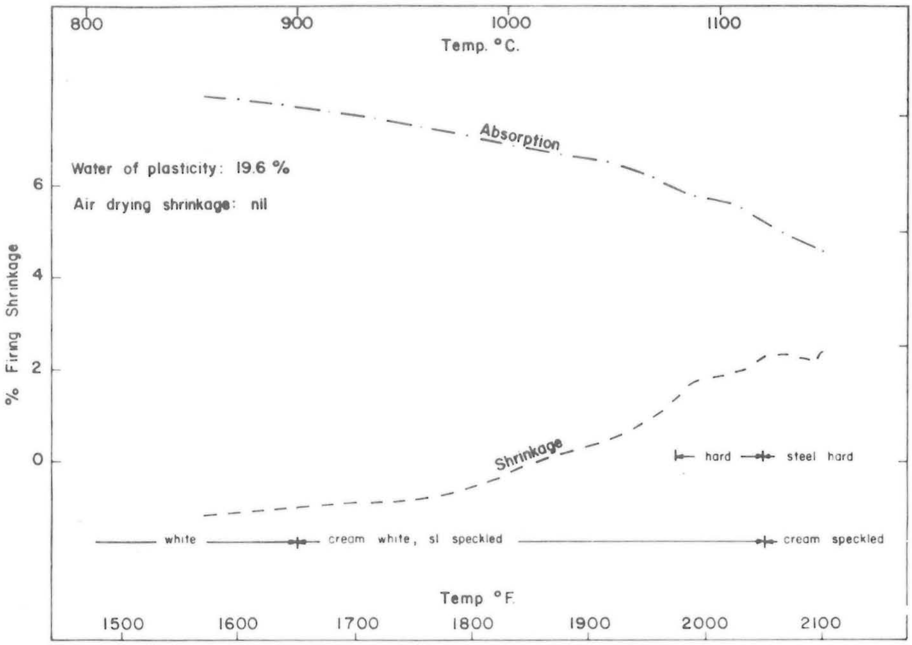


Figure 1. Temperature gradient test, kaolinitic schist, Black Island: raw material

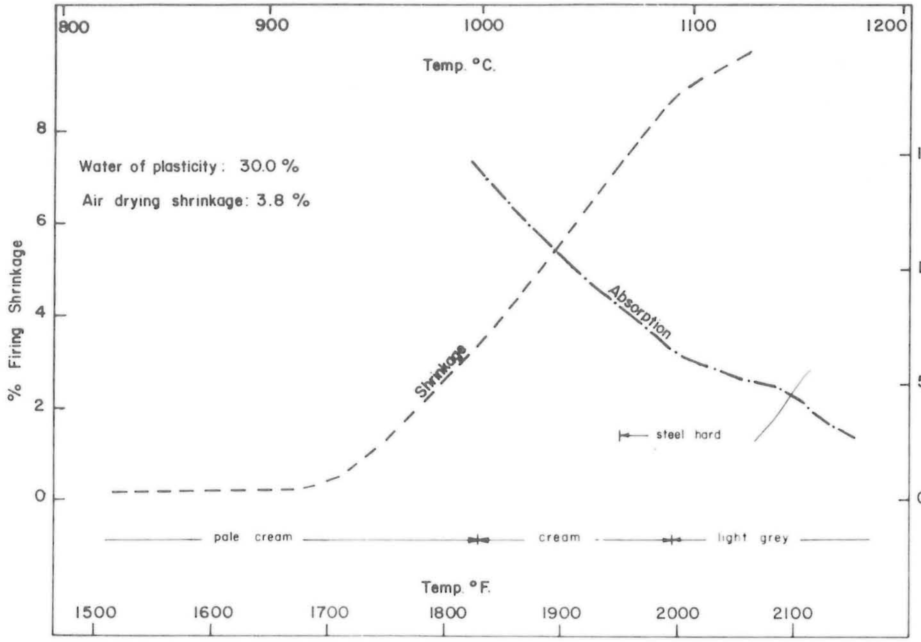


Figure 2. Temperature gradient test, kaolinitic schist, Black Island; -325 mesh material

Cole and McMahon reported detailed test results on several samples of the white and green clays. White clay from a 12-inch section occurring under 12 inches of white sand, was analyzed in both the crude and washed (−150 mesh) states (Table 4); loss on washing was 21.7% by weight.

Table 4		Deer Island clay deposit	
		Unwashed	Washed
White clay below sand, northeast shore, Deer Island; Cole and McMahon (1928).	SiO_2	63.30%	59.22%
	Fe_2O_3	1.08%	1.08%
	Al_2O_3	24.76%	27.38%
	MgO	0.89%	0.95%
	CaO	Trace	Nil
	Na_2O	0.19%	0.41%
	K_2O	1.33%	1.43%
	LOI	8.56%	9.71%
	Total	100.11%	100.18%

The chief clay mineral was thought to be kaolinite by Cole and McMahon; some pyrophyllite has been reported but not confirmed (Manitoba Mines Branch files). Also present are quartz, feldspar, and possibly some sericite.

The crude white clay has a water of plasticity of 26%, and an air drying shrinkage of 6.2%; it is very plastic and works easily. Its pyrometric cone equivalent (PCE) is cone 32 (3123^{o}F, 1717^{o}C). In the range from 2200^{o}F to 2500^{o}F, the clay burns almost white, and is hard to very hard; the firing shrinkage increases from 1.5% to 3.0%, and the absorption decreases from 15.9% to 10.7%. The washed material is generally similar, except firing shrinkage is greater and the absorption is lower. When used alone, it lacks the steel hardness necessary for face brick, because it is difficult to vitrify.

The green clay exhibited a greater range in firing properties, but, in general, requires too high a firing temperature to produce a brick with acceptable absorption. The fired colours are shades of green, brown, and reddish buff. A diagram of the occurrence is shown in Genik (1952, p.117).

A sample of white clay, submitted by F. Reckseidler, was tested by the Mineral Processing Division, Mines Branch, Ottawa (Zemgals, 1967). The raw material fires off-white above 1875^{o}F (Fig. 3); the presence of some pyrite results in the formation of brown and black specks in the fired product. The clay is difficult to vitrify, and is not steel hard at 2415^{o}F. The PCE of the clay is cone 31 (3055^{o}F, 1680^{o}C).

The pyrite is contained in the +325 mesh material. The −325 mesh material, that forms 90% by weight of the sample, is considered suitable for use in ceramic whitewares. The clay occurs in part underwater off the east shore of Deer Island, and additional exploration is required to outline the extent of the deposit.

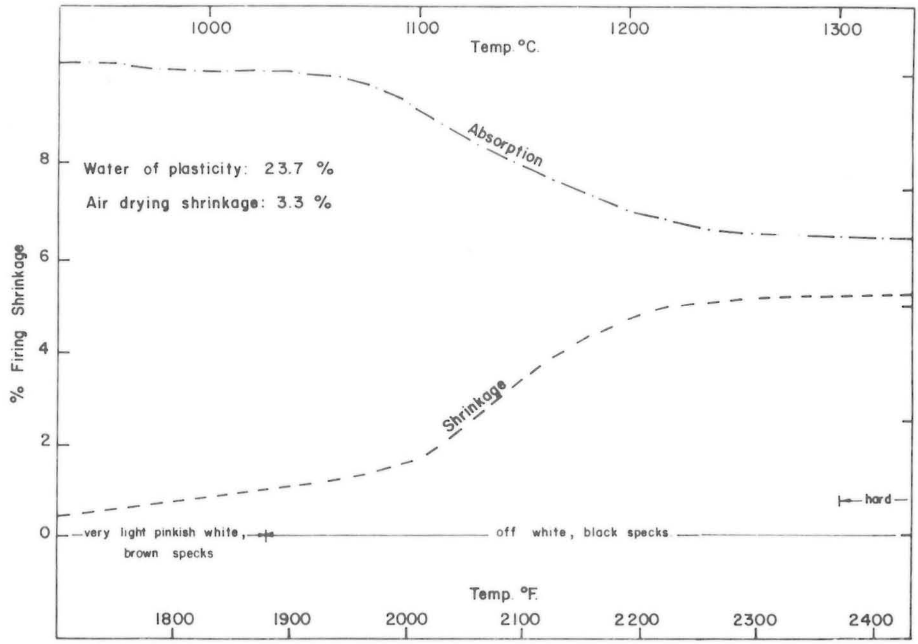


Figure 3. Temperature gradient test, kaolinitic clay, Deer Island (after L.K. Zemgals, 1967).

WINNIPEG FORMATION

The Ordovician Winnipeg Formation, the basal formation in the Paleozoic outcrop area southwest of the Precambrian Shield, contains quartzose sandstone, shale with interbedded sand, and shale beds. Also present in minor amounts are pyrite and iron oxide nodules, and phosphate pellets; iron oxide, kaolin and carbonate occur as a matrix in some sandstone beds.

The shale is green, blue-green, olive-brown or dark brown, in places pyritic and sandy, and is plastic when fairly pure. Outcrops of the shale section have been described from Deer Island, Punk Island and Grindstone Point (Baillie, 1952, pp. 42-46); it is probably present under a drift cover on parts of Black Island. The shale of the Winnipeg Formation probably was derived from weathered Precambrian rocks, and deposited in shallow to moderately deep water in a transgressive Ordovician sea that advanced from the south or southwest to the north. Reducing conditions existed at various times, as indicated by the abundance of pyrite in some parts of the section.

The outcrop belt of the Winnipeg Formation from Elk Island south to the International Boundary is covered by drift, except for a possible sandstone exposure on the west shore of Traverse Bay. Numerous water wells in this southern area have intersected the shale and sandstone beds; in the area southeast of Winnpeg, 5 to 20 feet of shale is present at the top of the Winnipeg Formation.

CHEMICAL AND MINERALOGICAL COMPOSITION

A sample of shale from the outcrop on the east side of Punk Island, 1 mile northwest of Gull Harbour, was studied in detail. The shale is greyish green, thinly bedded, smooth and non-calcareous; it contains thin quartzose sandstone lenses, isolated quartz grains, and minor iron oxide coatings along fracture planes.

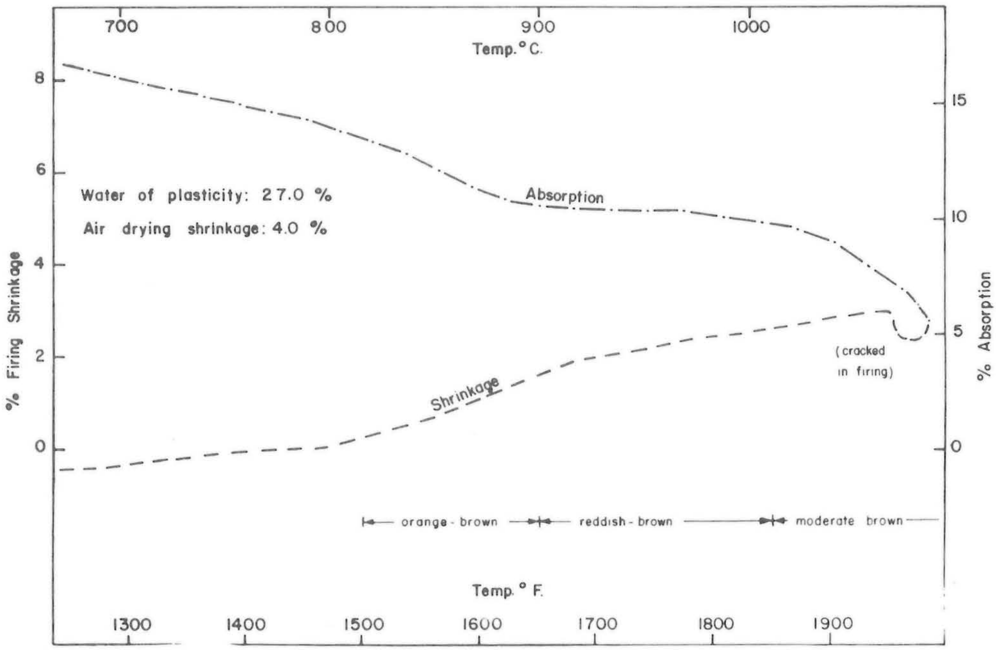


Figure 4. Temperature gradient test; shale from Winnipeg Formation, Punk Island.

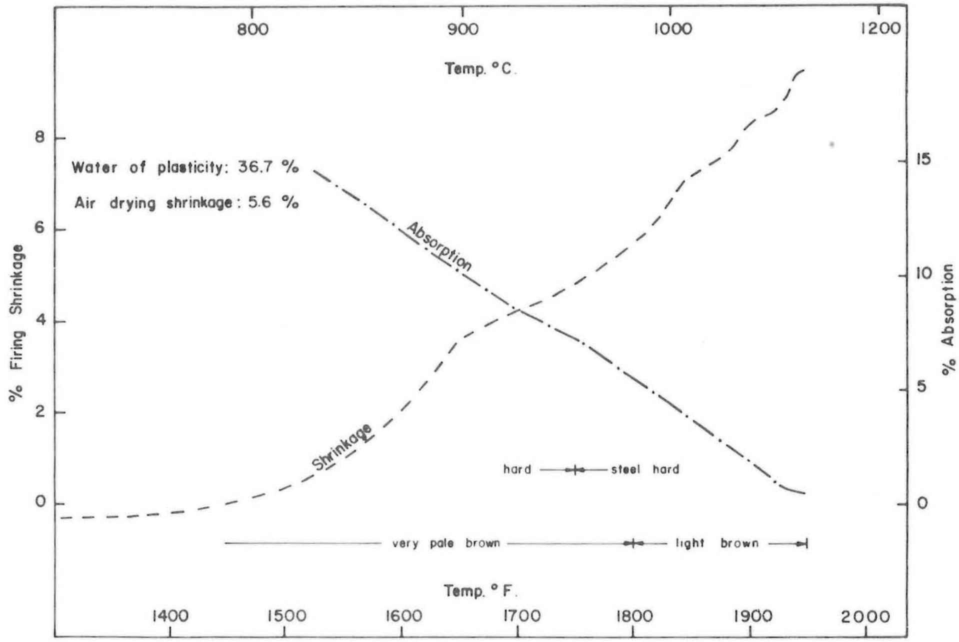


Figure 5. Temperature gradient test, Winnipeg Formation shale, Pascar No. 2 well.

Table 5	Winnipeg Formation shale			
Outcrop on east shore, Punk Island, Lake Winnipeg; MacKay and Brown, analysts.	SiO_2	60.65%	Na_2O	0.10%
	Al_2O_3	17.84%	K_2O	6.88%
	Fe_2O_3	2.71%	CO_2	nil
	FeO	0.90%	P_2O_5	0.09%
	TiO_2	0.50%	MnO	nil
	MgO	2.46%	H_2O+ / H_2O-	6.49%
	CaO	0.45%		
			Total	99.07%

An X-ray analysis of a green shale sample by Genik (1952) indicated the presence of clay minerals of the kaolin group.

FIRING TESTS

Wright (1922) collected 4 samples of shale representing 23.5 feet of section from an outcrop on the north shore of Deer Island. One sample (No. 784) from a 6– to 8–foot bed of shale had good workability, with water of plasticity of 18% and air drying shrinkage of 5%. At 1888°F, shrinkage is 0% and absorption is 9.0%; at 2000°F, shrinkage is 0.5% and absorption is 8%. The fired colour is red to dark red. Wright reported the shale produced hard dense bricks of good colour, and that it would be suitable for common or face brick.

Hutt (1932) reported:

> "On the north shore of Black Island and overlying the silica sand is a deposit of clay, fifteen hundred weight of which was tested by the Hadfield-Penfield Steel Co., Bucyrus, Ohio, who recommended the clay specially for sewer-pipe, good red face brick, smooth or rough, or good hollow tile with a deep brownish red natural glaze. A similar sample tested by the Canadian Pacific Railway Department of Development gave favorable results as far as red brick is concerned. Specimens of similar clay have been seen from Deer Island."

It is possible that the shale would not meet present-day specifications for sewer pipe, but it is suitable for face brick.

The sample collected from Punk Island was tested in the temperature gradient furnace (Fig. 4). The wet molded shale has a gritty texture because of its high sand content. It fires to reddish brown (5YR 4/5) at 1900°F; the brick is not steel hard at 1990°F. The firing properties would probably be better for a sample with lower sand content.

A sample at the top of the Winnipeg Formation shale, from a depth of 582 to 584 feet in the Pascar No. 2 well (NE 11-25-3WPM), was tested also (Fig. 5). The bluish-green massive shale has good workability; and the temperature gradient test indicated good firing properties. The colour at 1800°F is light brown (7.5YR 6.5/4). The well is 50 miles from the outcrop belt.

OTHER PALEOZOIC ARGILLACEOUS BEDS

GUNN MEMBER OF THE STONY MOUNTAIN FORMATION

The lower half of the Stony Moutain Formation, composed of purplish red fossiliferous calcareous shale and argillaceous limestone, with thin limestone interbeds, is called the Gunn Member (the Stony Mountain Shale Member of Baillie, 1952). The upper part is exposed in several quarries around the base of Stony Mountain, a 70-foot high erosional remnant 12 miles north of Winnipeg.

The high calcareous content of the member makes it unsuitable for brick. A chemical analysis of the upper 14 feet assayed 35.75% CaO and 7.1% MgO (Goudge, 1944). The lower part of the section, recovered in a cored hole at Stony Mountain is more argillaceous, but has not been reported in outcrop.

WILLIAMS MEMBER OF THE STONY MOUNTAIN FORMATION

The Williams Member, as defined by Smith (1963), is the upper 17 feet of the Stony Mountain Formation of Baillie (1952), and is composed of silty and argillaceous dolomite. In the upper half of this member, as exposed at Stonewall, the more argillaceous beds exhibit some fissility, but the varied composition and high dolomite content make the rock unsuitable for use in clay products.

No significant argillaceous beds are present in the overlying Stonewall Formation, or in the Silurian Interlake Group.

DEVONIAN ASHERN FORMATION

Samples from the outcrop area indicate the formation is composed mainly of argillaceous dolomite; the rock is not suitable for clay products. A few exposures occur in the Interlake area, near Dog Lake, northwest of Spearhill, and on P.T.H. 6 halfway between Steep Rock Junction and Fairford. A sample of brick-red very impure argillaceous dolomite from the Fairford location contained 24.65% CaO and 16.27% MgO, and approximately 11% clay. Some parts of the formation intersected in shallow drill holes near the outcrop belt have a high red shale content, but samples are not available for test work.

DEVONIAN SECOND RED BED

At the base of the Dawson Bay Formation is a 30– to 40–foot bed of mainly red with some greenish gray shale named the Second Red Bed. A few exposures have been reported on the shores and islands of Lake Winnipegosis.

A sample of red shale from Pemmican Island in Lake Winnipegosis, submitted by R. Chartrand of The Pas, was tested (Fig. 6). The clay is slightly stiff in molding, but safe in rapid drying. A hard reddish brown brick is produced when the shale is fired between 1675° and 1775°F, but the water of plasticity and combined shrinkage are high. Exploration would be required to determine the extent of this material. The shrinkage is high for the use of this shale by itself in the manufacture of face brick.

DEVONIAN FIRST RED BED

The basal unit of the Souris River Formation is another thin zone of red and green calcareous shale, called the First Red Bed; it is poorly exposed in Manitoba. A sample from the base of the high cliffs at Point Wilkins (Steeprock Point) on Lake Winnipegosis, was tested in the temperature gradient furnace; the high carbonate content makes it unsuitable for structural clay products.

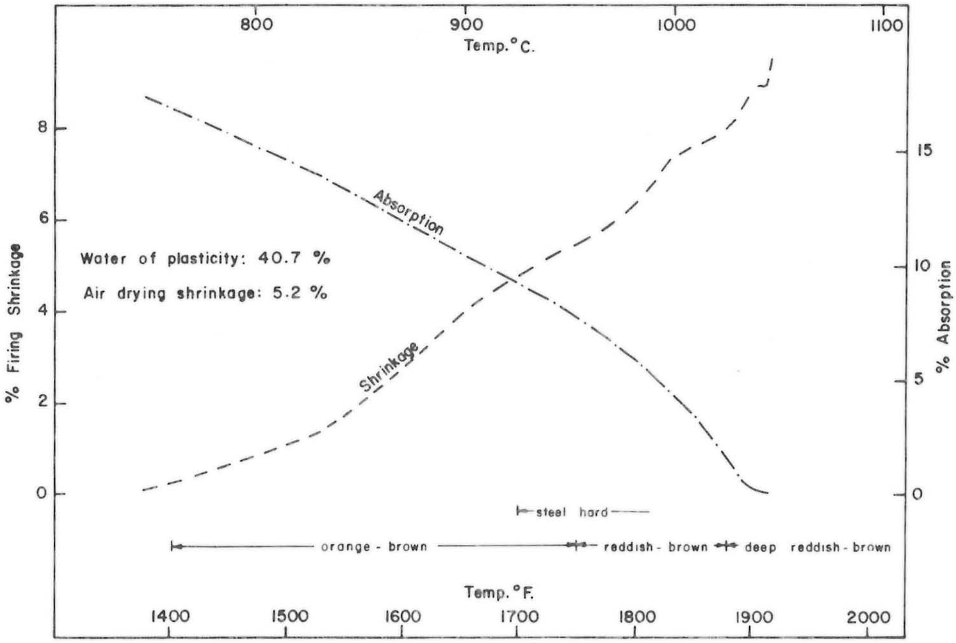


Figure 6. Temperature gradient test; Devonian red shale, Pemmican Island.

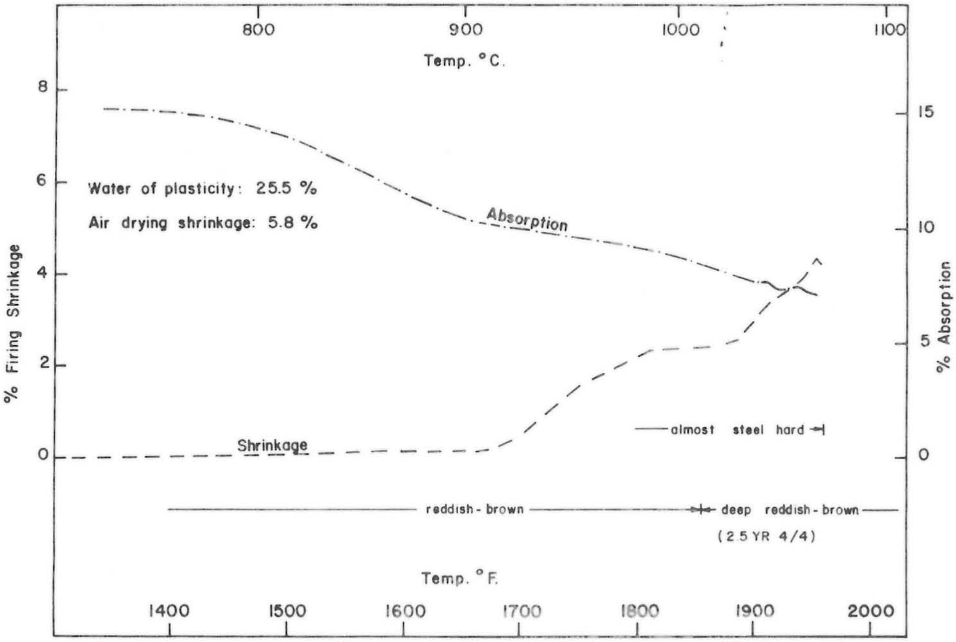


Figure 8. Temperature gradient test, brown shale, Lower Melita unit.

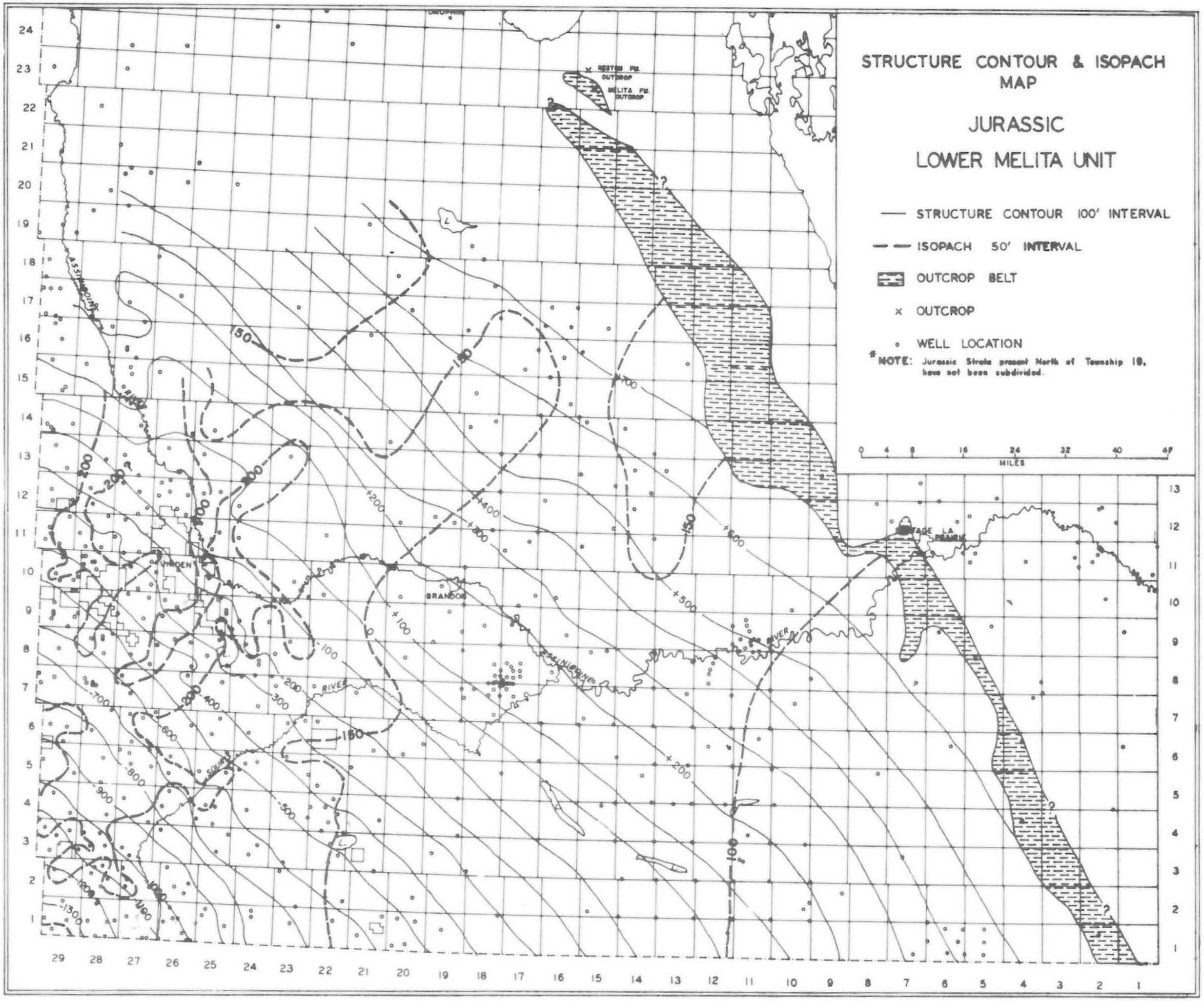

STRUCTURE CONTOUR & ISOPACH MAP
JURASSIC
LOWER MELITA UNIT
STRUCTURE CONTOUR 100' INTERVAL
ISOPACH 50' INTERVAL
OUTCROP BELT
OUTCROP
WELL LOCATION
* NOTE: Jurassic Strata present North of Township 19, have not been subdivided.
0 4 8 16 24 32 40 48
MILES
RESTON FM. OUTCROP
MELITA FM. OUTCROP
ASSINIBOINE
VIRDEN
BRANDON
RIVER
SOURIS

Figure 7.

JURASSIC SHALES

INTRODUCTION

A thick section of Jurassic rocks is present in southwestern Manitoba overlying Mississippian and Devonian carbonate rocks and underlying Cretaceous shales and sandstone of the Swan River Group and, in places, the Ashville Formation. Stott (1955) divided the Jurassic section into, in ascending order, Amaranth, Reston, Melita, and Waskada Formations; shale is present in each of these units. Recent work by Medicine Hat Brick and Tile Limited has outlined deposits of shale, suitable for quality structural clay products, within the Melita Formation and the Swan River Group in the Kergwenan area between McCreary and Ste. Rose du Lac.

AMARANTH FORMATION

The basal gypsum, anhydrite, and red beds of the Jurassic section are divided into the Lower Amaranth unit, mainly red beds, and the Upper Amaranth unit, mainly evaporite. The outcrop belt, covered by glacial drift, extends from Dauphin Lake area southeastward to the International Boundary.

LOWER AMARANTH MEMBER

The Lower Amaranth unit has a maximum thickness of 125 feet and is composed of red shale, minor green and brown shale, red siltstone that grades in places to a white sandstone, and some secondary gypsum in the upper part. This member may be either Triassic or Jurassic in age.

At the Silver Plains gypsum mine, opened in 1964 by Western Gypsum Products Limited, 30 miles south of Winnipeg, Lambo (1963) reported the Lower Amaranth Member is 60 feet thick and consists of an upper reddish brown to green shaly sandstone, and a lower reddish brown sandy breccia zone.

In 1963, an outlier of the Amaranth Formation was exposed at a depth of 32 feet in an excavation at Wilkes Avenue and the Perimeter Highway, Charleswood. Eight feet of Amaranth beds were exposed, consisting mainly of red shale, grading downward to a white siltstone; small gypsum masses were present in the upper few feet.

At Amaranth, a drill hole in SW¼ sec. 25, tp. 18, rge. 10WPM intersected a complete section. It consisted of an upper 45-foot zone of reddish brown dolomitic shale grading downward into 11 feet of reddish sandstone, underlain by a 4-foot basal breccia zone.

Firing tests of several samples indicate the shaly beds are not suitable for use in clay products; the fired shales have high absorption and lack hardness, because of their high carbonate content.

UPPER AMARANTH MEMBER

The Upper Amaranth unit consists mainly of gypsum (which grades to anhydrite in the subsurface) with interbedded dolomite, argillaceous dolomite, red and green shale, and enclosed fragments of dolomite.

Shale beds within the evaporite section at Amaranth and above the evaporite at Silver Plains are too dolomitic to be used in clay products.

RESTON FORMATION

The Reston Formation, composed of argillaceous limestone, high calcium limestone and greyish green and grey shales, ranges from 15 to 150 feet in thickness. The shale parts of the section have not been reported in outcrop. A previously unreported outcrop of the limestone portion of the formation occurs along Turtle River, in SW¼ sec. 4, tp. 24, rge. 15WPM, south of Ste. Rose du Lac.

MELITA FORMATION

Overlying the Reston Formation is a thick, predominantly shale sequence, containing some sandy zones at the base, and some calcareous shale and limestone beds in the upper part. Up to 450 feet of this formation is present in the subsurface of southwestern Manitoba; it thins to the northeast, partly because of pre-Cretaceous erosion.

LOWER MELITA UNIT

The distribution of the Lower Melita unit is shown in Figure 7*. Reddish orange and brown shales are exposed in a ditch near the centre of the west boundary of sec. 22, tp. 23, rge. 15WPM.

The unit consists of a basal fine-grained sand zone, overlain by a zone of variegated shale of which orange-red and light yellowish green are the most common colours; greyish green, brownish grey, olive grey, mustard yellow, and buff-brown shales occur also. Minor sandstone and argillaceous limestone bands are present.

The basal sandstone of the Lower Melita unit was deposited in a transgressive sea. The variegated shale unit was deposited in shallow water, and fossil evidence indicates that depositional conditions fluctuated from non-marine to marine (Stott, 1955).

Medicine Hat Brick and Tile Company Limited drilled an extensive area near Kergwenan in 1963 and 1964, and outlined areas where a thin cover of glacial drift overlies Jurassic shales that are believed to be part of the Lower Melita unit and light grey to black shale of the Swan River Group.

The deposit contains a considerable range of clays and sands, some of which are suitable for ceramic use. The company plans to make use of a red-burning shale, a range of stoneware clays burning to a variety of shades from brown to buff (similar to shale from other exposures of the Swan River Group), and some impure kaolins and silica sands. Full details on the deposit have not been released by the company; a face brick and building brick plant in the Lockport area, 18 miles northeast of Winnipeg is scheduled for completion in 1971. Drain tile, flue lining, and sewer pipe may be produced in the future.

The results of a temperature gradient test on brown shale from the outcrop in sec.22, tp. 23, rge. 15WPM are shown in Figure 8. The firing properties of this shale are good, except that the fired product is not steel hard at 1955°F. A sample of reddish orange shale from the same outcrop was tested also; its firing properties are generally similar,

*The Lower Melita unit was originally defined by Stott (1955) on the basis of lithology; the intervals used in compilation of the isopach maps, Figures 7 and 12, are based on a persistent mechanical log marker, picked by H.R. McCabe, that corresponds closely but not exactly with the original contact.

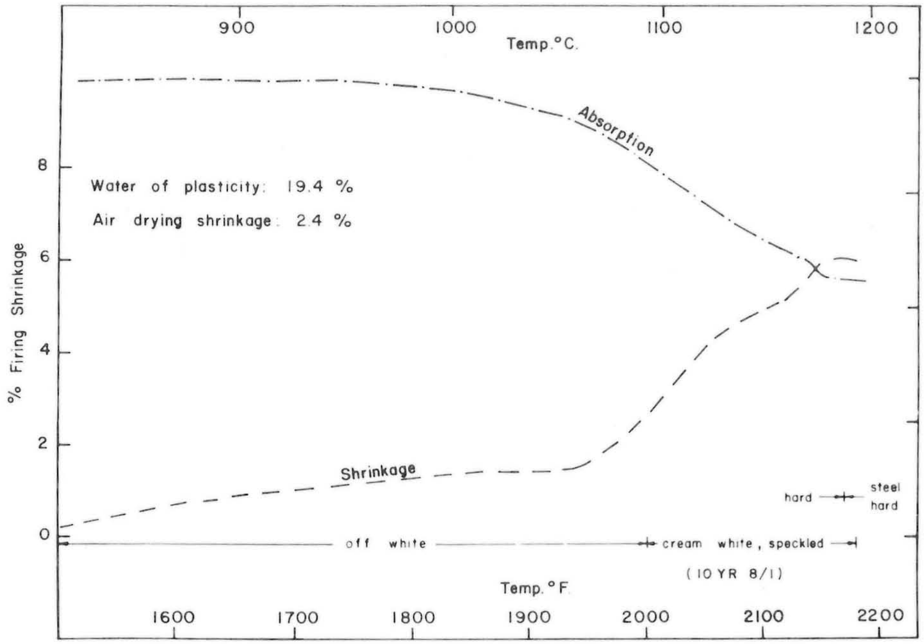


Figure 9. Temperature gradient test, light grey kaolinite shale, Kergwenan area.

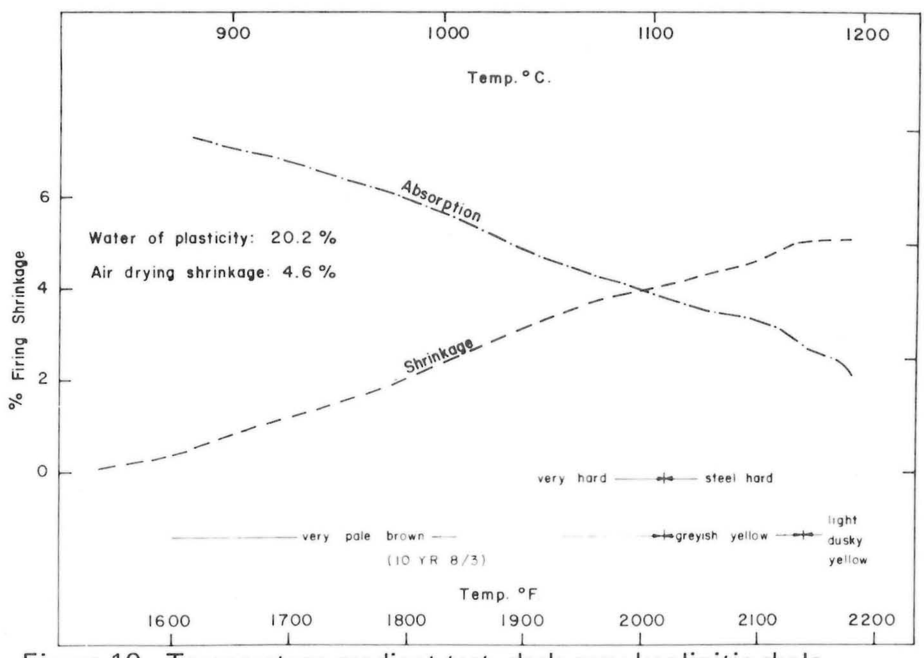


Figure 10. Temperature gradient test, dark grey kaolinitic shale, Kergwenan area.

although the firing shrinkage is higher. The results of tests of the light grey and dark grey kaolinitic shales from sec.3, tp. 22, rge. 15WPM are shown in Figures 9 and 10 respectively. These shales are equivalent in quality to the stoneware clays of the Swan River Group (see page 30), and are probably equivalent in age, being present in a channelled part of the Jurassic surface.

Green and red kaolinitic shale, probably part of the Melita Formation, occurs beneath a few feet of silica sand of the Swan River Group in sec. 7, tp. 34, rge. 20WPM, about 200 feet south of Pine River. The temperature gradient test (Fig. 11) indicates the shale has good firing properites, developing steel hardness at 1620^{o}F; it meets the requirements for face brick. Exploration is required to outline the extent of the shale in this area.

UPPER MELITA UNIT

The Upper Melita unit has a maximum thickness of 275 feet in the southwest corner of the province, and thins to the northeast (Fig. 12). Much of the unit is composed of greenish grey to brownish grey slightly carcareous shale; some brown, red, and yellow variegated shale occurs in the upper part of the unit, but only in the Morden-Boissevain area. The outcrop belt of this unit is covered in most places by a thick deposit of drift, except possibly in the McCreary-Plumas area, where few data are available on depth to bedrock.

A sample of shale cored in the Imperial Norman 4–27–13–23WPM well, was tested in the temperature gradient furnace (Fig. 13). The kaolinitic shale has good firing properties; exploration work is required to determine whether the shale is present in areas with shallow drift cover.

WASKADA FORMATION

The Waskada Formation occurs only in the subsurface, generally south of the Assiniboine River. It is best developed in the area from Virden south to the International Boundary, and has a maximum thickness of 175 feet. The lithology is variable, including green bentonitic shale, with minor beds of carbonaceous shale, red shale and calcareous sandstone (Stott, 1955). The depth of the formation precludes its use as an economic source of shale.

Note added in press:

Red River Brick and Tile began excavation of a quarry in l.s.d. 15, sec. 4, tp. 23, rge. 15WPM in August, 1970; the quarry is 470 feet long and 120 feet wide, and 6 feet of stoneware clay and kaolinitic shale had been excavated by mid-September, 1970. Twelve feet of soil and glacial drift overlie the Swan River Group strata. The company also announced it will be using clay and sand from the area northeast of Beausejour in its Lockport plant.

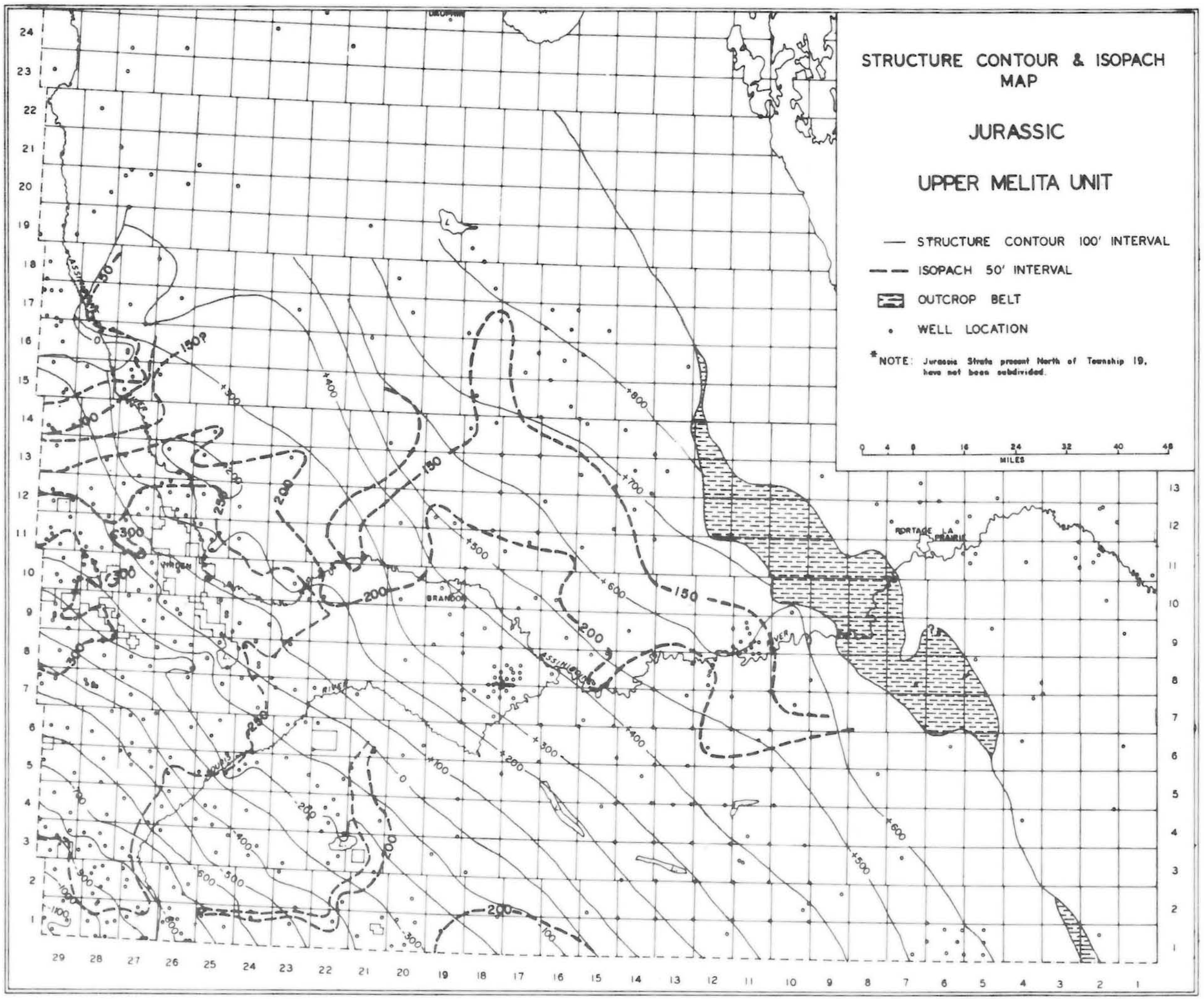

STRUCTURE CONTOUR & ISOPACH MAP
JURASSIC
UPPER MELITA UNIT
STRUCTURE CONTOUR 100' INTERVAL
ISOPACH 50' INTERVAL
OUTCROP BELT
WELL LOCATION
*NOTE: Jurassic Strata present North of Township 19, have not been subdivided.
MILES
PORTAGE LA PRAIRIE
BRANDON
VIRDEN
ASSINIBOINE
RIVER

Figure 12.

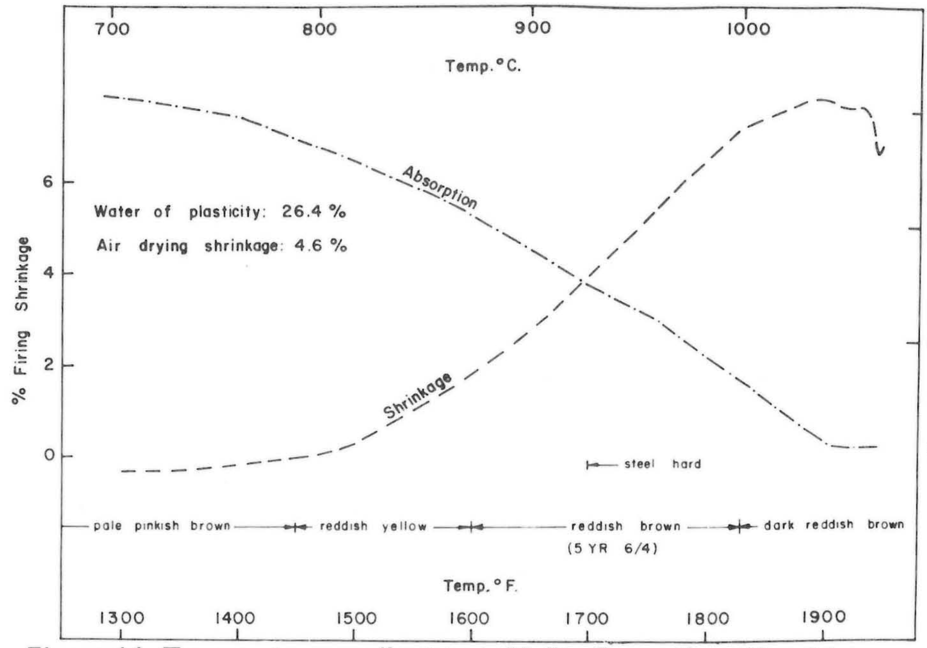


Figure 11. Temperature gradient test, Melita Formation, Pine River.

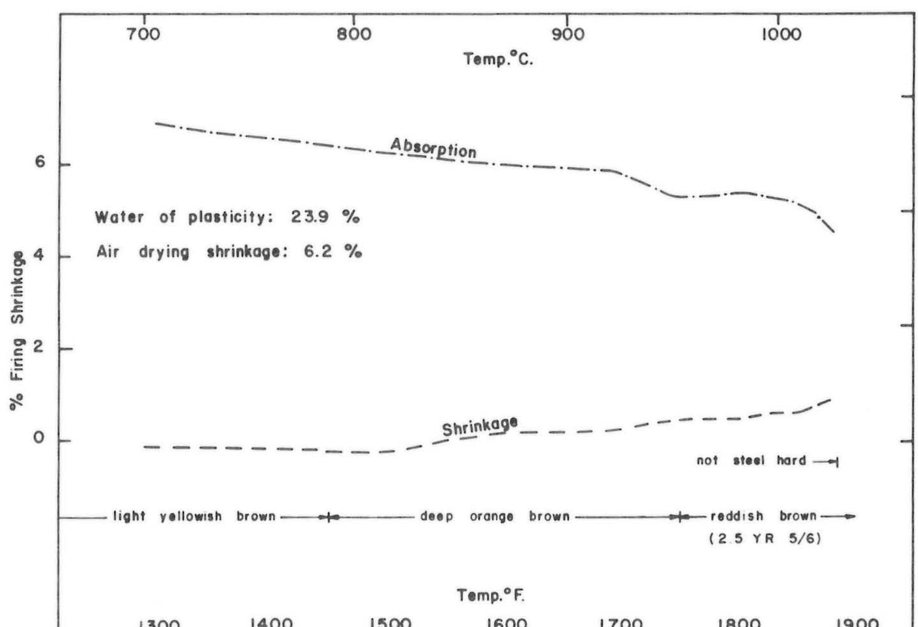


Figure 13. Temperature gradient test, Upper Melita unit.

CRETACEOUS AND TERTIARY SHALES

INTRODUCTION

The Manitoba Escarpment, the most prominent feature of Manitoba's landscape, occurs along the eastern edge of the outcrop belt of Cretaceous rocks, and its top rises 400 to 1500 feet above the first prairie level to the east. The escarpment is breached by three major rivers – the Assiniboine, the Valley, and the Swan – and the upland sections are named the Pembina, Riding, Duck, and Porcupine mountains. To the west of the escarpment is the second prairie level, underlain by shales of the Riding Mountain Formation; the thickness of the glacial drift cover ranges from zero to a reported 850 feet maximum in the central part of Duck Mountain. An exceptional feature on the second prairie level is Turtle Mountain, underlain by rock of Upper Cretaceous and Tertiary ages, and up to several hundred feet of glacial drift. Turtle Mountain is an erosional remnant of the third prairie level that extends west from the Missouri Coteau.

The Cretaceous and Tertiary section has been divided into the formations and members listed in Table 6. The shales have a varied lithology, including thick sections of bentonitic, bituminous, calcareous, carbonaceous, kaolinitic, and siliceous shales, as well as thinner zones of phosphatic fish-scale beds,nodular manganiferous beds, and some thin lignite beds. In the past, brick has been made from siliceous shale of the Odanah Member, carbonaceous shale of the Morden Member, and kaolinitic shale from the Swan River Group. Natural cement was manufactured from the calcareous shale of the upper part of the Boyne Member, and small tonnages of lignite were once mined from the Turtle Mountain Formation. A small amount of sewer pipe and tapestry brick was made at Carman from a mixture of carbonaceous Morden shale and siliceous Odanah shale. At the present time, the only economic use of the shales is the quarrying of non-swelling bentonite from the Pembina Member and the use of the hard siliceous shale of the Odanah Member as a local source of road metal. Shale from the Swan River Group will be used in the Red River Brick and Tile plant.

Two interesting results of the present study of subsurface data were:

(1) a previously unrecognized member, equivalent to the Gammon Ferruginous Member of the northern Great Plains and the lower part of the Lower Lea Park (Milk River ?) Formation of Saskatchewan, is present in the subsurface between the Boyne and Pembina Members; this unit may extend eastward to the outcrop belts on Pembina and Vermilion Rivers.

(2) the contact between the Millwood and Odanah Members, previously thought to be a facies relationship, probably approximates a time stratigraphic marker; additional evidence from the outcrop belt supports this view.

Following deposition of the Jurassic Waskada Formation, an emergent interval occurred; erosion resulted in the removal of much Jurassic rock, and the development, in places, of a deeply incised drainage pattern. Fragments of lignified wood in the Swan River Group indicate the earliest Cretaceous beds were deposited in a terrestrial environment, but the presence of glauconite in the upper part of the Swan River Group indicates marine conditions existed at that time. Continued subsidence resulted in the deposition of marine shales through most of Cretaceous time; limestone beds were deposited in the Favel Formation and in the Boyne Member. Emergent trends in western Canada, associ-

Table 6. Cretaceous and Tertiary Stratigraphic Correlation Chart

Era	Period	Epoch	North Dakota*		Western Manitoba		Southeast Saskatchewan*		
Cenozoic	Quaternary	Pleistocene		Glacial drift		Glacial drift			Glacial drift
	Tertiary	Pliocene							
		Miocene							
		Oligocene		White River					
		Eocene		Golden Valley					
		Paleocene	Fort Union	Sentinel Butte					
				Tongue River		Turtle Mountain			Ravenscrag
				Lud-low / Cannon-ball					
Mesozoic	Cretaceous	Upper		Hell Creek		?			Frenchman
			Montana Group	Colgate Member / Fox Hills		Boissevain			Whitemud
									Eastend
				Odanah	Riding Mountain	(soft) Odanah / (hard) Odanah			(soft) Bearpaw
				de Grey		Millwood			Belly River
				Gregory					
				Pembina	Vermilion River	Pembina	Lea Park		Pakowki
				Gammon		Gammon Ferruginous Equiv. ?			Milk River
			Colorado Group	Niobrara		Boyne	Colorado Group	Upper	First White Speckled Shale
				Carlile		Morden			Shale
				Greenhorn	Favel	Assiniboine			Second White Speckled Shale
						Keld			
				Belle Fourche	Upper Ashville (base of fish scale zone)			Lower	Shale
		Lower		Mowry					Fish scale zone
				Newcastle	Ashville Sand	Lower Ashville			Viking / Shale
				Skull Creek					Shale
				Dakota	Swan River				Blairmore
				Fuson					
				Lakota					

After: R. B. Hutt (1963) . East-West section of Saskatchewan. Sask. Dept. of Mineral Resources.

ated with the early stages of the formation of the Rocky Mountains, resulted in an eastward shifting of the axis of maximum deposition of marine sediments that continued throughout the time of deposition of the Riding Mountain Formation. Further emergence resulted in withdrawal of the seas from southwestern Manitoba; Upper Cretaceous and Tertiary terrestrial strata, with some possible marine interbeds, were deposited. The emergent conditions accompanied the main uplift of the Rocky Mountains, and have persisted to the present day.

SWAN RIVER GROUP

The Swan River Group lies unconformably on a weathered surface of Jurassic and Devonian rocks, and is overlain by the Ashville Formation. In the southern part of the area, the Swan River strata are probably of Lower Cretaceous age, but in the northern part of the area, some non-marine Jurassic strata may be included (Wickenden, 1945, p. 12). The Swan River Group occurs in two areas separated by a broad belt extending eastward from the Saskatchewan boundary through the Virden area to beyond Brandon in which no Swan River deposits are known to occur (Fig. 14). The Waskada Formation is included in the isopach map as the formations are difficult to distinguish on mechanical logs; similarly, the Swan River Group north of township 19 may include some sands of the Melita Formation.

Outcrops of the formation are known only from the northern part of the area, along Pine, Swan, and Roaring rivers, and south of Mafeking. There the formation is composed of fine– to coarse–grained quartzose sandstone, commonly unconsolidated, glauconitic, argillaceous, and lignitic; numerous interbeds of shale and silty shale are present.

The shale beds exposed along the Swan River to the northeast of the town of Swan River, were once used for face brick. Two types of shale are predominant – a dark grey kaolinitic shale and a light grey kaolinitic shale. Recent exploration work in the Kergwenan area has indicated the occurrence below a thin drift cover of light grey and dark grey kaolinitic shales, associated with silica sand and lignite; the strata are probably of Swan River age. Red River Brick and Tile plan to use these shales in their brick plant in the Lockport area.

Test drilling in 1969 by the Water Control and Conservation Branch in the area south of Dauphin Lake has indicated a probable thickness of 180 feet of Swan River strata deposited in a channel eroded into the Jurassic Formations. An earlier drill program, in 1966, outlined an area extending from 10 miles northeast to 5 miles east of Ethelbert, where greyish white kaolinitic shale and interbedded quartz sand of the Swan River Group are present under 30 to 40 feet of drift; from 100 to over 150 feet of Swan River strata are present. To the west, the drift cover increases to over 200 feet. Exploration in this area is required to outline deposits of kaolinitic shale and silica sand in the Swan River Group, as well as deposits of varicoloured Jurassic shale.

CHEMICAL COMPOSITION

Shales from the outcrop in the SW¼ sec. 10, tp. 37, rge. 26WPM and from the stockpile at the former brick plant of Swan River Clay Products Limited were analyzed by MacKay and Brown (Table 7). The outcrop is shown in Plate 1A.

Table 7	Kaolinitic shales of the Swan River Group			
		(1)	(2)	(3)
1) 5-foot section of dark grey (slightly carbonaceous) shale	SiO_2	66.05%	79.38%	69.99%
	Al_2O_3	22.96%	13.32%	14.56%
	Fe_2O_3	1.70%	1.02%	1.35%
	TiO_2	1.56%	1.54%	1.02%
2) 7.5-foot section of light grey shale	MgO	0.34%	0.55%	1.03%
	CaO	0.26%	0.40%	0.84%
	Na_2O	0.19%	0.22%	4.42% (Na_2O + K_2O)
3) Shale from pit, sampled at brick plant stockpile	K_2O	1.52%	1.12%	
	H_2O-	1.00%	0.53%	n.d.
	LOI	–	–	5.64%
Analysts: MacKay and Brown	Total	95.58%	98.08%	98.85%

MINERALOGICAL COMPOSITION

The dark grey and light grey samples of kaolinitic shale, were examined by DTA and X-ray powder photograph methods (Wicks, 1963).

The dark grey shale has kaolinite, with a well-ordered crystal lattice, as the main clay mineral; illite is present. Quartz forms 5% to 10% of the sample, and a "considerable quantity" of organic matter and a few percent of pyrite are present also. Some siderite may be present.

The light grey shale has kaolinite, with a well-ordered crystal lattice, as the main clay mineral, but the DTA curve indicates it contains much less illite than the above sample. Quartz is more abundant, forming 20% to 25% or more of the sample; organic matter and pyrite are not present.

TEMPERATURE GRADIENT TESTS

The dark grey carbonaceous shale from SW¼ sec. 10, tp. 37, rge. 26WPM requires slow firing to prevent bloating; although it meets most specifications for face brick, it has poor drying qualities (Fig. 15). The shale fires light brown, 7.5YR 6/4, at 1950°F.

The light grey kaolinitic shale has excellent working and firing properties, and is classified as a stoneware clay (Fig. 16). It works easily, is safe in rapid drying; and fires to a speckled pale yellow, 2.5Y 8/4 at 2150°F. The shale has a PCE of cone 18 (2780°F, 1528°C); it is thus not refractory enough to be classified as a fire clay.

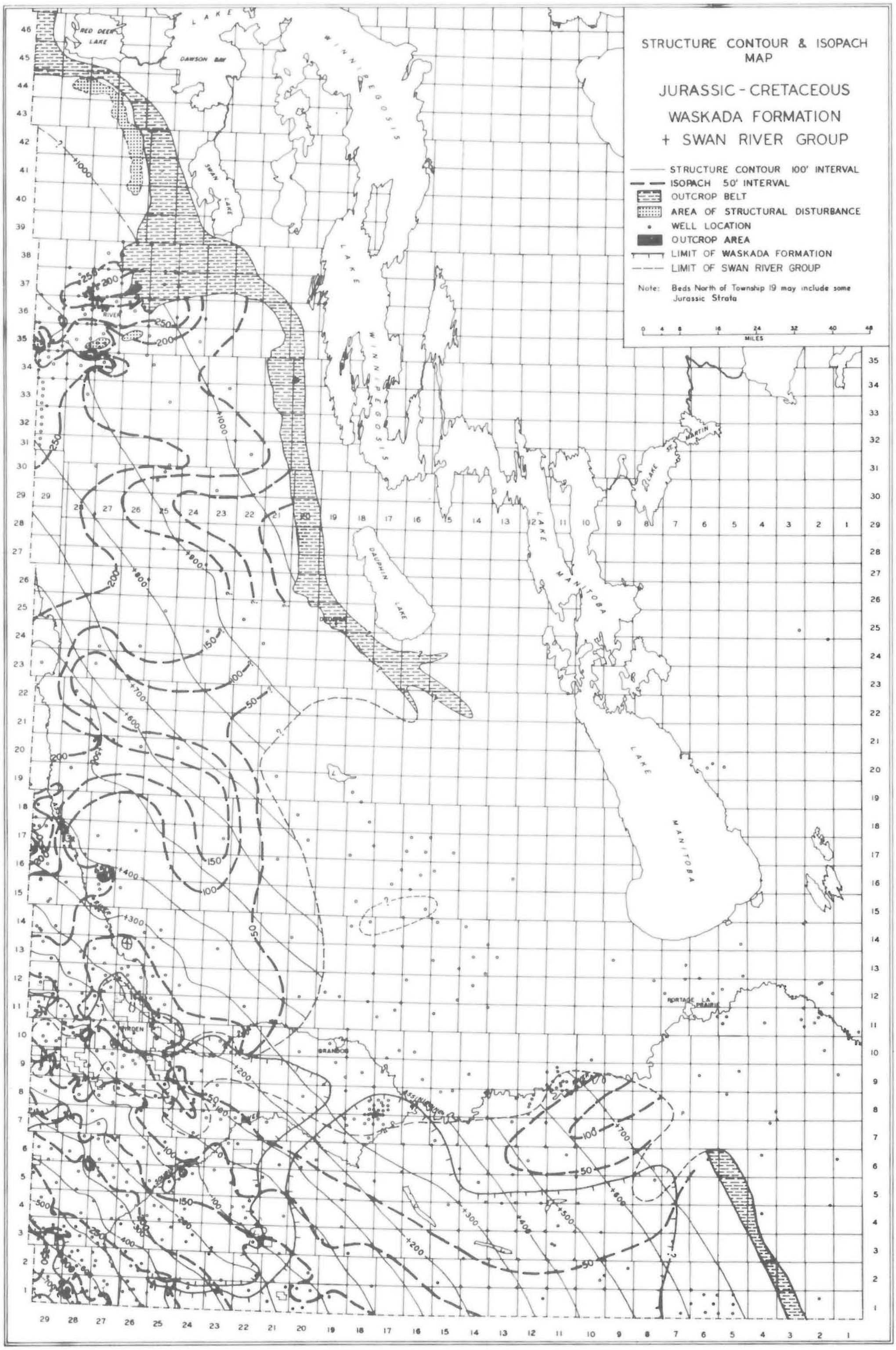

STRUCTURE CONTOUR & ISOPACH MAP
JURASSIC - CRETACEOUS
WASKADA FORMATION
+ SWAN RIVER GROUP
STRUCTURE CONTOUR 100' INTERVAL
ISOPACH 50' INTERVAL
OUTCROP BELT
AREA OF STRUCTURAL DISTURBANCE
WELL LOCATION
OUTCROP AREA
LIMIT OF WASKADA FORMATION
LIMIT OF SWAN RIVER GROUP
Note: Beds North of Township 19 may include some Jurassic Strata
MILES
LAKE WINNIPEGOSIS
LAKE MANITOBA
DAUPHIN LAKE
SWAN LAKE
RED DEER LAKE
DAWSON BAY
LAKE ST. MARTIN
PORTAGE LA PRAIRIE
BRANDON
VIRDEN

Figure 14.

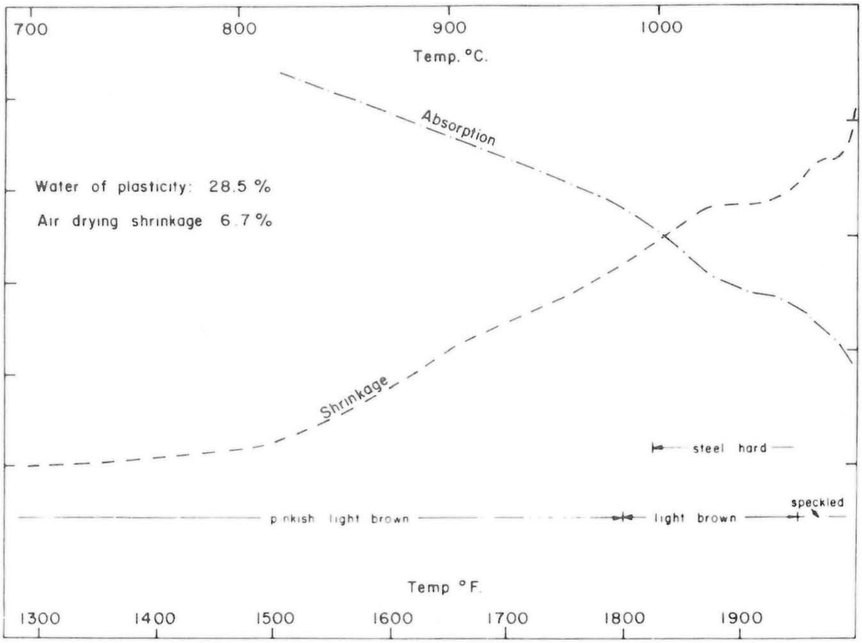


Figure 15. Temperature gradient test, dark grey kaolinitic shale, Swan River Group.

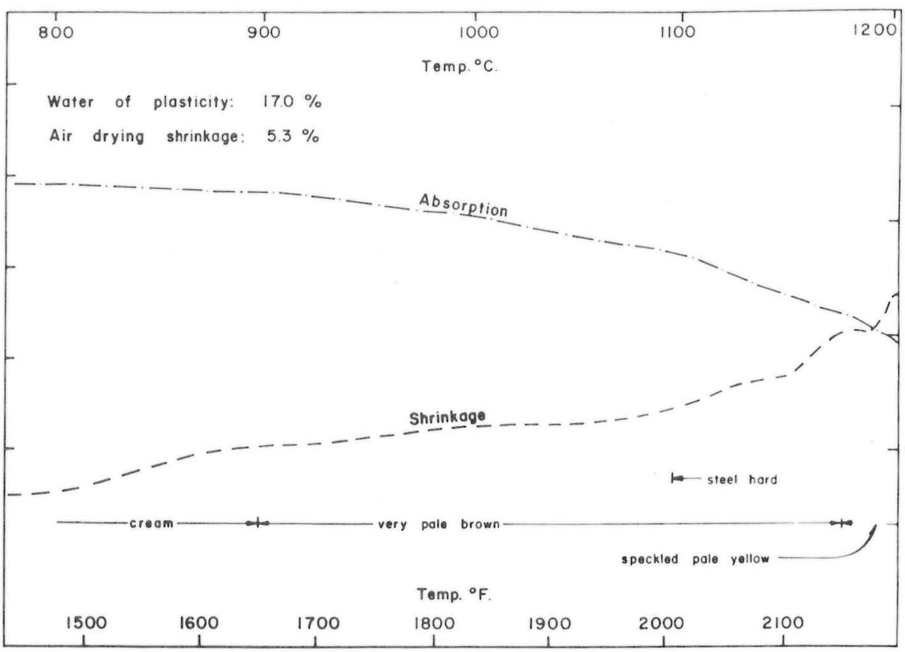


Figure 16. Temperature gradient test, light grey kaolinitic shale, Swan River Group.

Brady (1960) tested a sample of Swan River shale, which from its composition and firing properties, would appear to consist mainly of the grey kaolinitic shale, mixed with some quartz sand and some of the dark grey carbonaceous kaolinitic shale. Brady found the sample to have good workability, good plasticity, and to extrude very well with de-airing. Water of plasticity is 19%, and the air-drying shrinkage ranged from 6.5% from a plastic state to only 1% from a dry-pressed state. The shale has a tendency to crack with rapid drying. It has a long firing range where the shrinkage and absorption change slowly in the region where the material is hard to very hard. Brady classed it as a grey, non-calcareous stoneware-type clay that fires to a speckled buff colour, and concluded: "Provided the material will dry satisfactorily and the volume expansion (caused by the presence of 40% quartz) can be dealt with, this clay is considered to be suitable for: drain tile, building tile, extruded and pressed buff face brick, sewer pipe, flue liners, stoneware products, and art pottery. The high quartz content would likely be beneficial in a salt glazing process for sewer pipe, flue liners, and stoneware products. Full-scale commercial tests should be carried out to determine the quality of the ware."

The difference in composition between the dark grey and light grey shales is well shown by the temperature gradient curves (Figs. 15 and 16). The firing properties of the light grey shale are superior to those of the sample, containing some organic material, that was tested by Brady. Exploration in this area is required to determine if economically recoverable amounts of clay are present; little information on the bedrock distribution is available for the area northeast of Swan River.

The samples of light grey and dark grey kaolinitic shale from the Kergwenan area (Figs. 9 and 10) have properties similar to the above Swan River shales, and are believed to be equivalent in age. As the detailed stratigraphy of this area has not yet been reported, the temperature gradient tests have been included with those of the Melita shales; these materials will be used together in the manufacture of face brick.

PRODUCTION HISTORY

Swan River Clay Products Limited began production of dry press face brick in 1953 in a plant at Swan River; shale of the Swan River Group was quarried in a pit 25 feet by 150 feet in SW¼ sec. 10, tp. 37, rge. 26 WPM. The bricks were fired in three up-draft kilns, using wood for fuel. Production from the plant, that closed in 1955, is reported as 14,400 face brick in 1953, 115,000 in 1954, and 90,000 in 1955. More bricks were fired at the plant in 1959, but it is idle at present. Red River Brick and Tile are scheduled to begin quarrying the shales in the Kergwenan area in the summer of 1970.

KAOLINITIC DEPOSITS OF POSSIBLE CRETACEOUS? (SWAN RIVER) AGE

Clay deposits containing pockets of kaolinite mixed with silica sand and, in places, other materials, have been reported from north of Arborg, east of Pine River, and in the Cross, Cedar, and Moose lakes area. The Arborg deposit has been dated as lower Cretaceous; the age of the other deposits has not been determined.

KAOLINITIC CLAY DEPOSIT NORTH OF ARBORG

Kaolin and Minerals Exploration Ltd. explored from 1956 to 1958 a large deposit of kaolinitic clay extending across the central part of township 24, range 1EPM. The discovery hole, in l.s.d. 10, sec. 14, tp. 24, rge. 1EPM, was drilled to investigate an occurrence of lignitic material. Considerable exploration by rotary drilling and an electromagnetic survey has outlined the deposit over a distance of five miles. Subsequently, three test pits were excavated. More exploration involving recovery of cored samples, is necessary before meaningful tonnage estimates can be made.

The kaolinitic clay, which occurs interbedded with fine grained silica and other clays, occupies a deep, sinuous, steep-walled gorge eroded into flat-bedded Ordovician dolomite; the channel, buried under an average of less than 20 feet of glacial drift (range: 6 to 49 feet), is of the order of 300 feet in width and over 100 feet in depth. Dyer and Crozier (1933, p. 63) reported: "W.A. Bell of the Geological Survey, says that a plant fragment of the species *Pityophyllum graminaefolium* was found in carbonaceous sandy sediments" of "Lower Cietaceous" age in this deposit.

The deposit consists of a variety of clays, sand, and lignitic materials in separate beds, pockets, or lenses; in places, the beds are drag-folded and squeezed into lenses of various dips. In large parts of the deposit, the essential material is a mixture either of massive white to off-white kaolinite containing variable amounts of clastic quartz. Other clays present are variegated clay of stoneware grade, chololate brown brick clay, and black to deep-brown clay and silica sand coloured by lignitic material. Silica, ranging from sand- to clay-size particles, occurs in varying amounts in all the clays (Dawson, 1958).

Temperature gradient tests using a mixture of 65% Arborg kaolinite and 35% surface clay from 4 different areas near Winnipeg indicate a product with steel hardness, low firing shrinkage, and low absorption can be produced; the product is smooth-faced and ranges from orange to pale greenish buff and olive shades. Appropriate mixtures would be suitable for face brick and probably sewer pipe production.

In addition to possible ceramic uses, the samples were tested to determine the suitability of the kaolin for use as paper clay. The main problem in producing a high quality product has been the elimination of quartz which persists, in trace amounts, down to the 0.9 micron range; also, the colour is off-white.

An analysis of a -20 +150 mesh fraction of silica sand, from the high silica material, showed 98.5% SiO_2 and 0.55% Fe_2O_3 (Dawson, 1958); this corresponds to fourth quality glass sand as defined by the American Ceramic Society and the United States Bureau of Standards. Silica sand, similar in appearance to the sand in the Arborg deposits, has been reported from a water well at Fisher Branch and from the Bralorne Fisher Branch 1-24-24-3WPM well; in the latter well, 100 feet of sandy material was intersected beneath 20 feet of glacial drift. These occurrences may represent a westward extension of the channel north of Arborg, and kaolinitic clays could possibly be associated with the sand.

CHEMICAL AND MINERALOGICAL COMPOSITION

Differential thermal analysis indicates the white to off-white material consists mainly of kaolinite and quartz. A chemical analysis, reported by Dawson (1958), or a -200 mesh fraction, is shown in Table 8.

Table 8	Kaolinite-quartz material, -200 mesh, north of Arborg			
Sample from test pit in sec. 14, tp. 24, rge. 1EPM	SiO_2	67.68%	CaO	nil
	Al_2O_3	21.60%	Na_2O } K_2O	0.83%
	Fe_2O_3	1.11%		
	TiO_2	1.00%	LOI	7.78%
	MgO	trace	Total	100.00%

The mineral composition, calculated from the above analysis, is estimated as: kaolinite, 52.38%; quartz, 40.41%; feldspar, 4.91%; limonite, 1.30%; and rutile, 1.00%.

CERAMIC PROPERTIES AND TEMPERATURE GRADIENT TEST

The clay has good workability and is safe in rapid drying. The firing properties to 2160°F of a naturally occurring sample of the kaolinite-silica material are shown in Figure 17. Additional tests show the material fires white to off-white up to 2440°F, at which temperature the firing shrinkage is 6%. The PCE's for 3 samples were cone 26 (2950°F, 1621°C), cone 28 (2995°F, 1646°C), and cone 29 (3018°F, 1659°C).

KAOLINITIC CLAY EAST OF PINE RIVER

A small deposit containing white kaolinitic clay mixed with fine grained silica sand occurs in l.s.d. 3, sec. 2, tp. 33, rge. 20 WPM, 14 miles east of the town of Pine River. Tests on selected samples of the clay indicate it is of stoneware quality. The clay was discovered in 1943, and several claims were staked. Between 1943 and 1947, several pits and auger holes were put down in the area, immediately north of the Pine River-Winnipegosis road. Some creamy white marl, which resembles the kaolinitic clay superficially, is associated with the kaolinitic clay.

The deposit was investigated by drilling in 1962 by Medicine Hat Brick and Tile Company, Limited. The drill hole results indicated the deposit is probably the remnant of a channel eroded in weathered Devonian carbonate rocks and filled with Swan River Group (?) black carbonaceous clay, kaolinitic sand, and, in the upper part, some kaolin; detailed drilling indicates the kaolin is confined to the area of the pits, and most of it has probably been removed. The channel is about 75 feet wide, has a depth of at least 63 feet, and has been traced over a length of about 200 feet, trending east-west.

A sample of the Pine River kaolinitic clay was analysed by MacKay and Brown (Table 9).

Table 9	Pine River kaolinitic clay			
Sample from pit in l.s.d. 3, sec. 2, tp. 33, rge. 20WPM; analysts: MacKay and Brown	SiO_2	65.50%	Na_2O	4.26%
	Al_2O_3	19.02%	K_2O	0.65%
	Fe_2O_3	0.69%	MnO	nil
	TiO_2	1.76%	P_2O_5	0.15%
	MgO	0.35%	CO_2	nil
	CaO	0.19%	H_2O	7.80%
			Total	100.34%

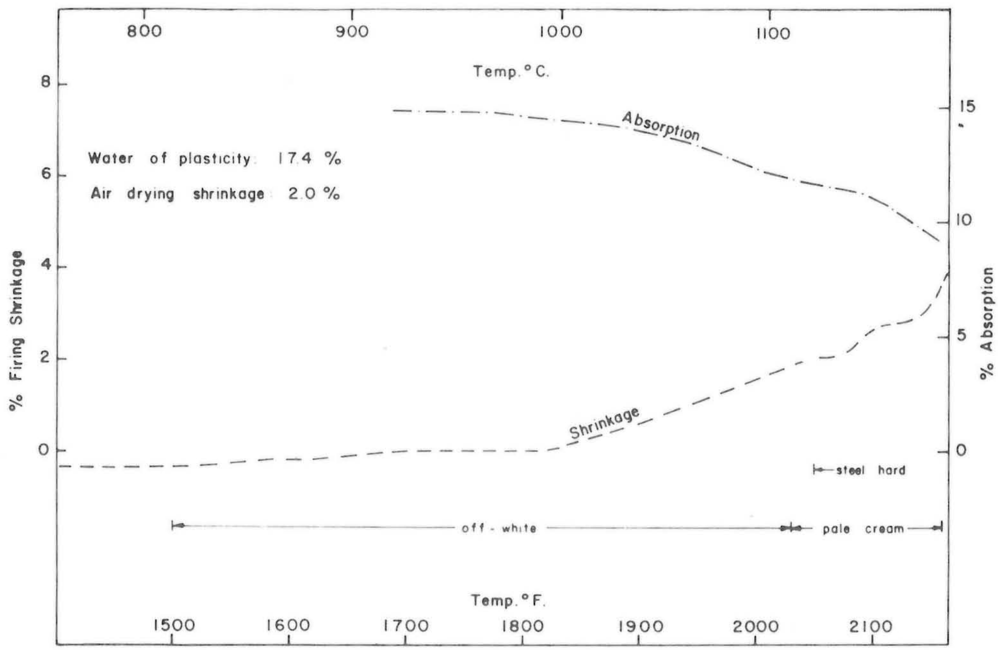


Figure 17. Temperature gradient test, kaolinitic material north of Arborg.

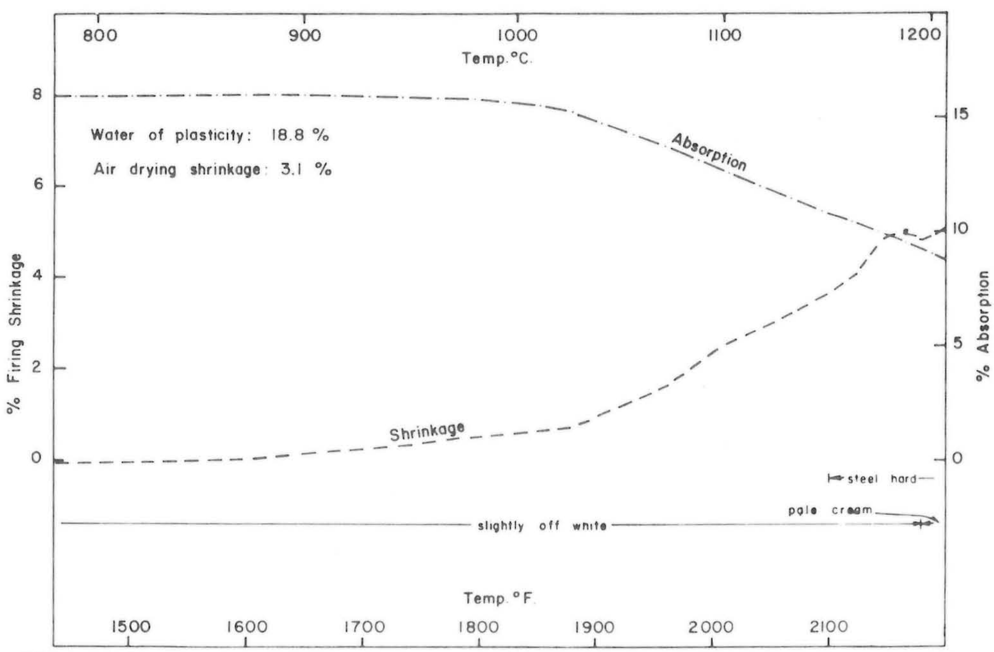


Figure 18. Temperature gradient test, Pine River kaolin.

The sample was examined also by DTA and X-ray (Wicks, 1963). The DTA curve indicates the sample is a mixture of kaolinite and quartz. The kaolinite is a normal well-crystallized kaolinite with no structural disorders along the b-axis. The X-ray powder photograph indicated a small amount of illite is present.

The results of a temperature gradient test of the sample are shown in Figure 18. The clay is safe in rapid drying. The PCE's of two samples tested by the Mines Branch, Ottawa, were cone 23 (2921°F, 1605°C) and cone 26+ (2962°F, 1628°C).

The clay is a high quality clay, but is similar to other kaolinitic materials in Manitoba in having a high content of clastic quartz. Unless additional tonnage can be outlined, more detailed testing is not warranted. The deposit could be suitable for ceramic art ware uses.

CEDAR, CROSS, AND MOOSE LAKES AREA

White clay has been reported from several places in the area around Cross, Cedar, and Moose Lakes, northwest of Grand Rapids. The white clay, probably an impure kaolin, occurs in small pockets associated with red clay, marl, and black lignitic clay, but no extensive deposit has been found. A considerable amount of quartz sand occurs mixed with the white clay. Some work was carried out by the Chartrand Syndicate of The Pas in 1929 and 1930 on claims staked 1 mile northwest of the northwest bay of Cross Lake, in the northeast part of township 50, range 15 WPM.

Selected samples of white clay from a deposit on the north shore of Moose Lake 16 miles northeast of the former Moose Lake settlement and from the deposit near Cross Lake were tested by the Mines Branch at Ottawa. The clays appear to be a kaolinitic, stoneware type.

The sample from Moose Lake is a white, soft clay with a water of plasticity of 26% and an air drying shrinkage of 4.6%. It is plastic, works very well, and has satisfactory drying behavior. The clay fires white, and very hard between 2100°F and 2300°F, in which range firing shrinkage increases from 6.8% to 9.8%, and the absorption decreases from 10.7% to 5.8%. The clay has a PCE of cone 30(3029°F, 1665°C). The fired colour is slightly tinged and not a pure white.

A sample of white clay from the Cross Lake area has a water of plasticity of 19.7%, and an air drying shrinkage of 5.2%. At 2100°F, it fires off-white, with no firing shrinkage, 15% absorption, and is almost steel hard. At 2300°F, it is slightly cream coloured, has 1.3% firing shrinkage, 11% absorption, and is steel hard.

ASHVILLE FORMATION

The Ashville Formation overlies the Swan River Group and underlies the Favel Formation. It is made up mainly of dark grey to black carbonaceous shale. Wickenden (1945) notes that the upper part of the formation is a greasy black rock that weathers brownish and breaks into numerous flat chips. The lower shale is dark grey, has a more clayey texture, and breaks into chunky fragments. In general, the firing properties of the two shales are similar. Outcrops of the formation occur along the northeast and north slopes of Riding Mountain, along the Wilson River eastward from Ashville, and on the lower slopes of Duck and Porcupine mountains. The formation contains minor calcareous bands as well as numerous thin layers of bentonite. The distribution of the formation is shown in Figures 19 and 20. The base of the "Fish Scale" marker zone is picked as the contact between the Lower Ashville (Lower Cretaceous age) and Upper Ashville (Upper Cretaceous age).

CHEMICAL COMPOSITION

Samples (1) from near the middle of the Ashville Formation, from an outcrop along the Wilson River in SW¼ sec. 24, tp. 25, rge. 21WPM, and (2) from the lower part of the formation, from an outcrop in NE¼ sec. 31, tp. 25, rge. 20 WPM were analyzed (Table 10).

Table 10 — Shale from the Ashville Formation

		(1)	(2)		(1)	(2)
1) From outcrop on Wilson River, SW¼ sec. 24, tp. 25, rge. 21WPM; 5-foot section sampled; MacKay and Brown.	SiO_2	55.32%	57.44%	K_2O	2.33%	2.65%
2) From NE¼ sec. 31, tp. 25, rge. 20WPM; 1.5 foot section exposed in ditch; MacKay and Brown.	Al_2O_3	19.21%	15.76%	MnO	nil	nil
	Fe_2O_3	3.51% (Fe_2O_3 + FeO)	6.73%	P_2O_5	0.15	- -
	FeO		0.52%	CO_2	nil	nil
	TiO_2	0.49%	0.77%	H_2O+	13.06% (H_2O+ + H_2O-)	8.25% (H_2O+ + H_2O-)
	MgO	1.06%	1.08%	H_2O-		
	CaO	0.45%	nil	Carbon	3.0%	5.07%
	Na_2O	0.23%	1.30%	Total	99.81%	99.57%

MINERALOGICAL COMPOSITION

Sample (1) was examined also by DTA and X-ray powder photograph. The major constituent is illite, with calcium and magnesium as exchangeable ions; some kaolinite is present. The shale contains minor amounts of gypsum, quartz, and pyrite, and the organic content is moderate.

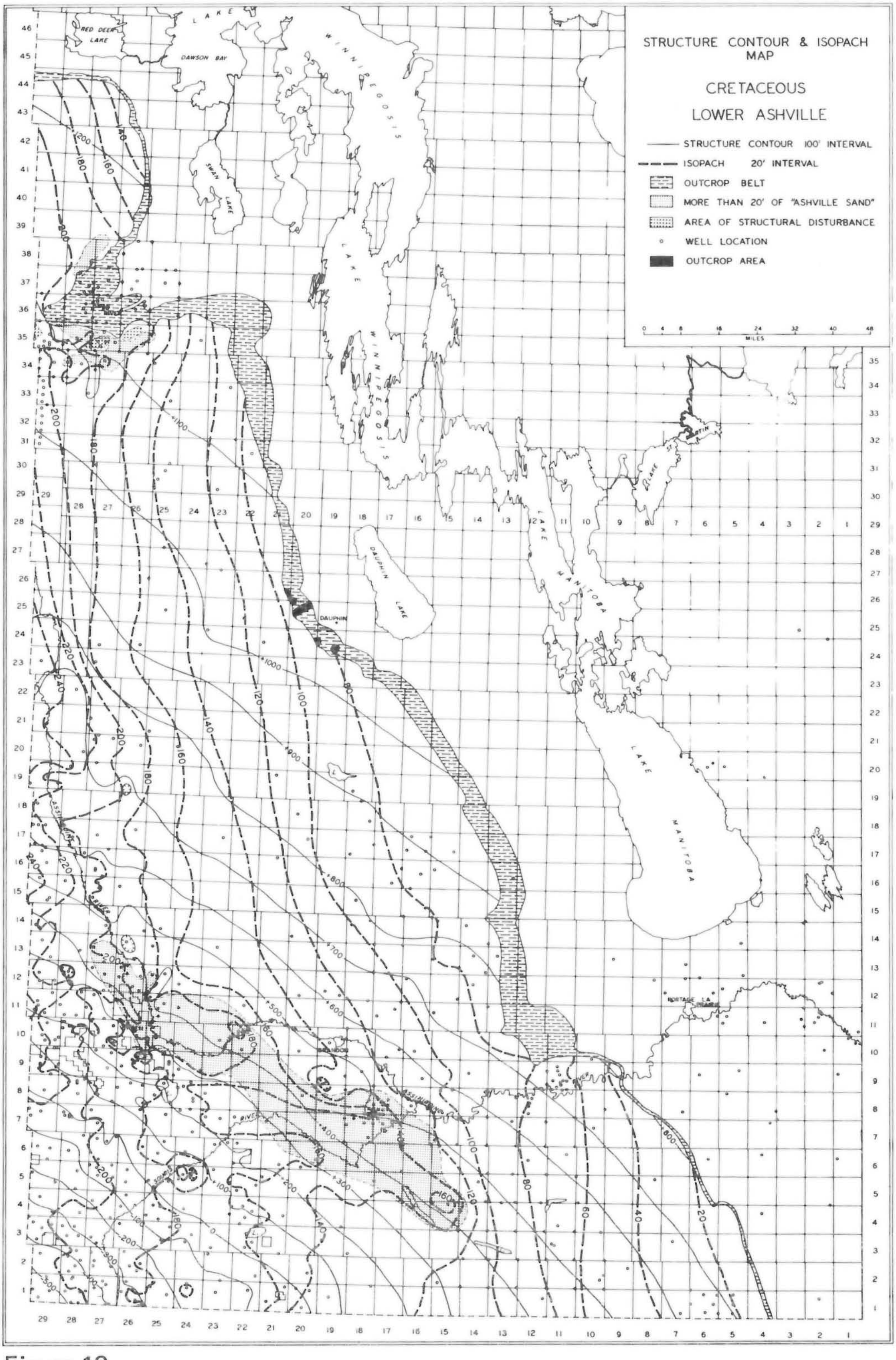

STRUCTURE CONTOUR & ISOPACH MAP
CRETACEOUS
LOWER ASHVILLE
STRUCTURE CONTOUR 100' INTERVAL
ISOPACH 20' INTERVAL
OUTCROP BELT
MORE THAN 20' OF "ASHVILLE SAND"
AREA OF STRUCTURAL DISTURBANCE
WELL LOCATION
OUTCROP AREA
MILES
RED DEER LAKE
DAWSON BAY
SWAN LAKE
LAKE WINNIPEGOSIS
DAUPHIN LAKE
DAUPHIN
LAKE MANITOBA
PORTAGE LA PRAIRIE
BRANDON

Figure 19

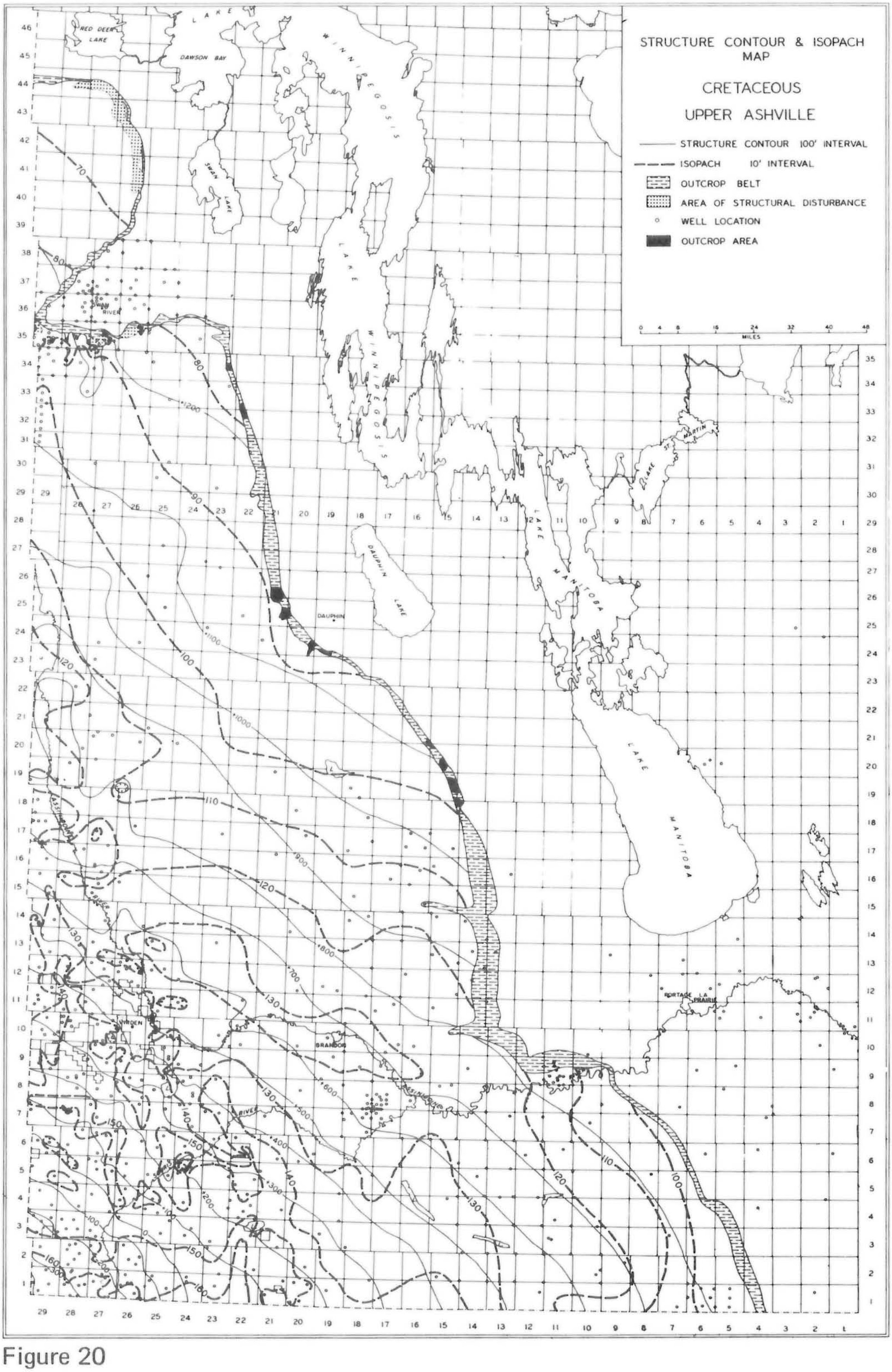

STRUCTURE CONTOUR & ISOPACH MAP
CRETACEOUS
UPPER ASHVILLE
STRUCTURE CONTOUR 100' INTERVAL
ISOPACH 10' INTERVAL
OUTCROP BELT
AREA OF STRUCTURAL DISTURBANCE
WELL LOCATION
OUTCROP AREA
MILES
RED DEER LAKE
DAWSON BAY
LAKE WINNIPEGOSIS
SWAN LAKE
SWAN RIVER
DAUPHIN
DAUPHIN LAKE
LAKE MANITOBA
LAKE ST. MARTIN
VIRDEN
BRANDON
ASSINIBOINE RIVER
PORTAGE LA PRAIRIE

Figure 20

A sample from near the top of the formation, collected from SW¼ sec. 13, tp. 24, rge. 20WPM, was examined by DTA. The major constituent is illite, with calcium as the exchangeable ion. The organic content is very high, much greater than in the above sample. Minor constituents include pyrite, siderite, gypsum, a small amount of quartz, and a trace of dolomite.

TEMPERATURE GRADIENT TESTS

The temperature gradient curves for samples (1) and (2) are shown in Figures 21 and 22 respectively. The samples are similar in their high absorption, short firing range, and high firing shrinkage. The sample from the lower part of the formation has a higher iron and carbon content; it fires the deepest red (10R 4/8) of any of the clay and shale samples tested in this study. However, its high shrinkage makes it unsuitable, by itself, for brick.

Another sample from the upper, calcareous part of the formation produced a soft brick with very high absorpiton, unsuitable for structural clay products. One of the samples obtained from subsurface core (at a depth of 1211 to 1219 feet from a well in 4-27-13-23WPM) showed better firing properties than the above samples, having lower absorpiton, and a longer firing range (Fig. 23). This sample is from near the Ashville-Swan River contact and may indicate a higher kaolinite content in this zone; this part of the section was not observed in outcrop, but is probably present near surface in the area east of the town of Ashville.

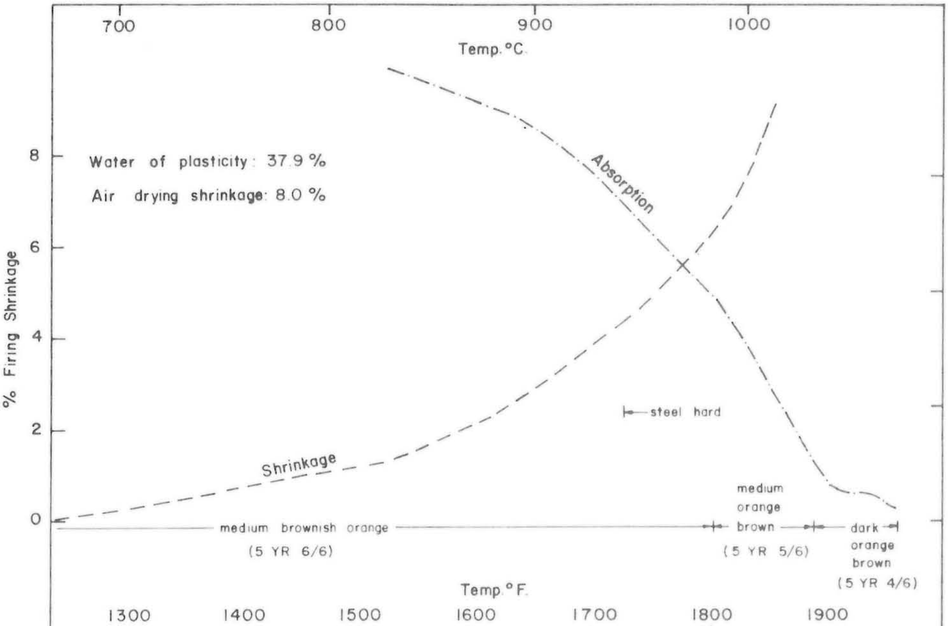


Figure 21. Temperature gradient test, Upper Ashville Formation.

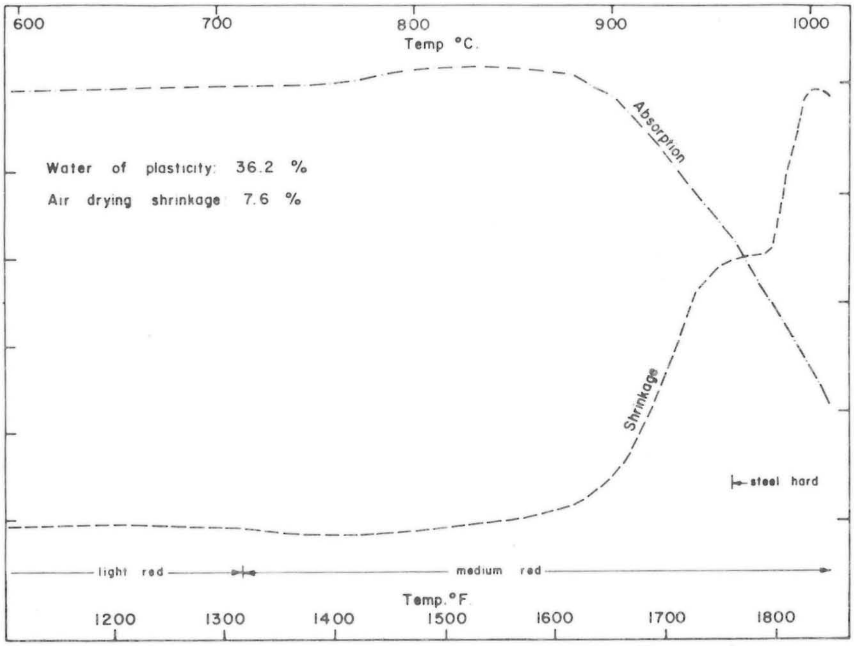


Figure 22. Temperature gradient test, Lower Ashville Formation.

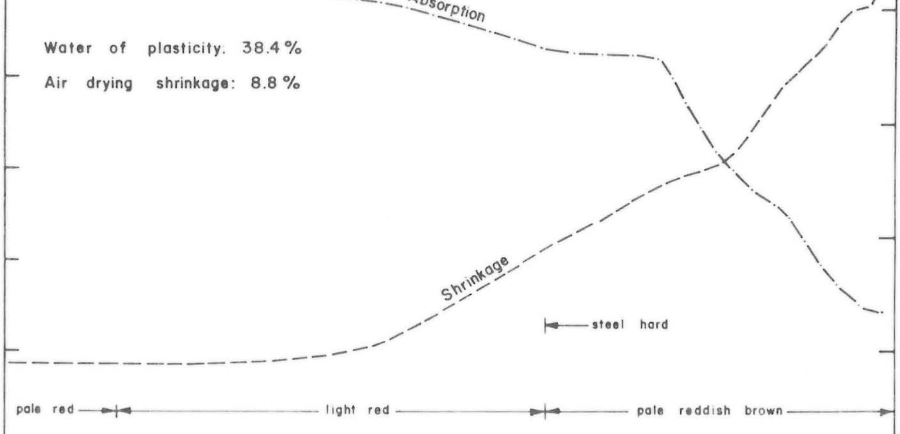


Figure 23. Temperature gradient test, Ashville Formation, Imperial Norman. 4-27-13-23WPM well.

FAVEL FORMATION

The Favel Formation overlies the Ashville Formation and underlies the Morden Member of the Vermilion River Formation. The formation is best exposed in the northern areas, especially along the east and west branches of the Favel River, and along the Vermilion River. The middle part of the formation is exposed along the banks of the Assiniboine River north of Holland.

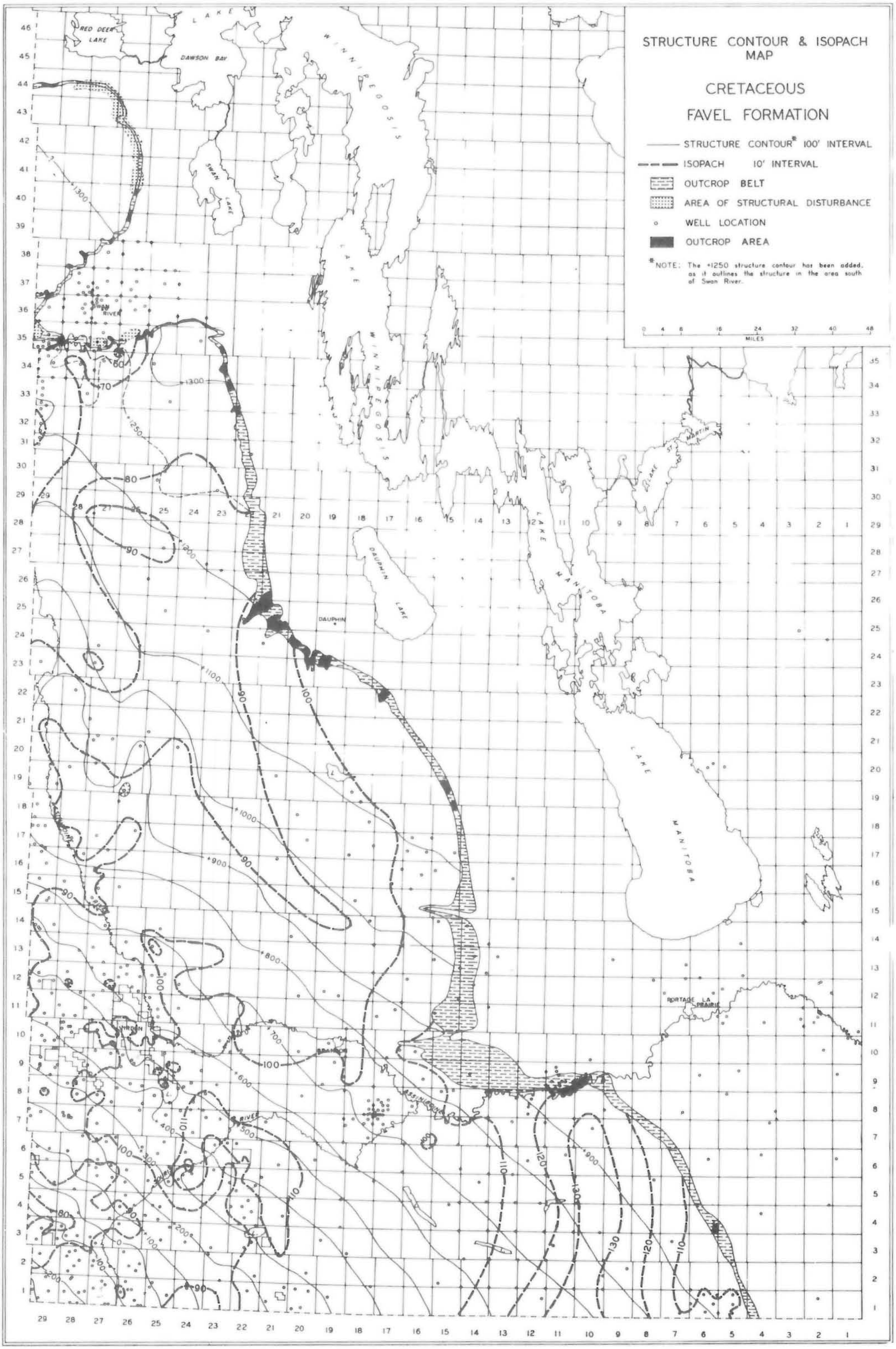
The formation, consisting mainly of grey shale with specks of white calcareous material, contains many limestone beds, as well as beds of impure limestone, and some thin bentonite layers. The formation ranges in thickness from 60 to 80 feet in the northern part of the area, from 90 to 110 feet in Riding Mountain area, and from 100 to 130 feet in Pembina Mountain area. The formation was divided by Kirk (1930) into the upper Assiniboine beds and the lower Keld beds.

A complete section of the Favel Formation is exposed along Vermilion River: the Assiniboine beds in l.s.d. 5, sec. 35, tp. 23, rge. 20WPM, and the Keld beds in l.s.d. 8, sec. 8, tp. 24, rge. 20WPM. (See Wickenden, 1945, pp. 24-25); a generalized description is given below.

Morden Member	Thickness in feet
Dark grey, non-calcareous shale	–
Favel Formation	
1)Assiniboine beds	
Shale, speckled and non-speckled, thin limestone beds; fossils	18.0
Limestone, grey, weathers brown; fossils	4.0
Shale, dark grey, speckled, calcareous; minor bentonite	32.5
2) Keld beds	
Limestone, impure, medium grey, weaters buff, fossils	0.8
Shale, medium to dark grey, speckled, calcareous; two 0.5-foot limestone beds near top; minor bentonite	22.7
Shale, dark grey, speckled, slightly calcareous, minor bentonite	31.5
Ashville Formation	
Shale, dark grey, non-calcareous	–
Total Favel	109.5 feet

CHEMICAL COMPOSITION

A chemical analysis of a sample from near the base of the Favel Formation, in SW¼ sec. 13, tp. 24, rge. 20WPM is shown in Table 11.



STRUCTURE CONTOUR & ISOPACH MAP
CRETACEOUS
FAVEL FORMATION
STRUCTURE CONTOUR* 100' INTERVAL
ISOPACH 10' INTERVAL
OUTCROP BELT
AREA OF STRUCTURAL DISTURBANCE
WELL LOCATION
OUTCROP AREA
*NOTE: The +1250 structure contour has been added, as it outlines the structure in the area south of Swan River.
MILES
RED DEER LAKE
DAWSON BAY
LAKE WINNIPEGOSIS
SWAN LAKE
DAUPHIN LAKE
DAUPHIN
LAKE MANITOBA
LAKE ST. MARTIN
PORTAGE LA PRAIRIE
ASSINIBOINE
RIVER

Figure 24.

Table 11	Shale from Favel Formation			
Sample near base of formation, in SW¼, sec. 13, tp. 24, rge. 20WPM. Analysts: MacKay and Brown	SiO_2	17.20%	K_2O	0.89%
	Al_2O_3	6.24%	MnO	nil
	Fe_2O_3	3.25%	P_2O_5	0.44%
	TiO_2	0.24%	CO_2	26.4%
	MgO	0.74%	H_2O+ } H_2O-	7.17%
	CaO	35.18%		
	Na_2O	0.27%	Carbon	1.0%
			Total	99.02%

This chemical analysis is very close to that of the natural cement rock from the Boyne Member at Babcock (analysis 1, page 51).

MINERALOGICAL COMPOSITION

A sample from the upper part of the Favel Formation, collected from an outcrop in NE¼ sec. 26, tp. 8, rge. 11 WPM on the Assiniboine River, was examined by DTA. The sample is composed mainly of illite, with approximately 30% dolomite, and a high organic content. Minor constituents include gypsum, pyrite, and small amounts of limonite, siderite, and quartz.

The sample that was analyzed chemically, was examined also by DTA and X-ray analysis. The major constituent is calcite, forming approximately 60% of the sample; illite is the main clay mineral, and some kaolinite or chlorite is possibly present. The shale has a high content of organic matter, and small amounts of gypsum, pyrite, quartz and siderite.

TEMPERATURE GRADIENT TESTS

As shown by temperature gradient tests, shales of the Favel Formation have a wide range of firing behaviour, caused mainly by variations in the organic and calcareous content of the shales.

Two samples of the highly carbonaceous shales of the upper part of the Favel Formation, from an outcrop in NE¼ sec. 26, tp. 8, rge. 11 WPM, were tested. In general, they fire reddish brown, with moderate to high absorption and high firing shrinkage, and lack steel hardness below 1950°F. The shale must be fired slowly to prevent black coring; a white efflorescence formed on the dried brick after the absorption test, indicating the presence of excess soluble salts. It is not a suitable material for face brick.

The highly calcareous shales of the lower part of the Favel Formation, as exposed along Vermilion River, fire to light shades of cream or buff, with high to extreme absorption, and produce a very soft brick. They are unsuitable for brick, but their chemical composition suggests they may be suitable as a natural cement rock. However, variations in the firing results probably reflect variations in chemical composition, and it may be difficult to obtain a uniform source material.

OIL SHALE INVESTIGATIONS

The Favel Formation was investigated by three oil companies in 1965 and 1966 as a possible source of oil shale. An earlier report by Ells (1921) had indicated oil contents of up to 7.5 Imperial gallons per ton in the Favel shale in the Riding Mountain and Porcupine Mountain areas. The recent work reported a maximum content of 12 Imperial gallons per ton in the Favel Formation in the Pembina Mountain area (sample from a depth of 345 feet in a core hole at l.s.d. 16, sec. 11, tp. 8, rge. 11WPM). However, average content of the tested section was 3.6 Imperial gallons per ton over a 159-foot interval. Samples from the Boyne Member, Morden Member, and Ashville Formation were included in the analyses; the results showed maximum contents of 13.0, 4.8, and 11.9 gals./ton respectively. The oil shale reservations were dropped because of the consistently low values encountered.

VERMILION RIVER FORMATION

The Vermilion River Formation, on the basis of outcrop studies, is divided into the Morden, Boyne, and Pembina Members, in ascending order. A study of the mechanical logs from several hundred oil wells in southwestern Manitoba has indicated the presence of an additional member between the Pembina and Boyne Members; it is stratigraphically equivalent to the Gammon Ferruginous Member in the northern plains of the United States. The member may extend as far as the outcrop belt along Pembina River and along Vermilion River.

MORDEN MEMBER

The Morden Member consists predominantly of a dark grey to black carbonaceous non-calcareous shale, and shows little variation in lithology throughout its extent either vertically or regionally. A decrease in the thickness of the formation from north to south is shown in the isopach map (Fig. 25). Only a few thin bentonite beds and partings are known to occur within the Morden shale, and are much less common than in the other upper Cretaceous strata.

The shale beds contain calcareous concretions, some septarian, and some of large size up to 6 feet in diameter. Pyrite is present as concretions, in irregular masses, or as a layer of fine crystals between the shale layers. A considerable amount of selenite (gypsum) as flakes and crystals is associated with the pyrite. A coating of yellow material possibly jarosite ($KFe_3(SO_4)_2(OH)_6$), is present in most exposures of the shale.

Shale from the Morden Member has been used periodically in the production of common and face brick at a plant at Learys, but no extensive continuous production has been achieved.

CHEMICAL ANALYSES

A representative sample of Morden shale from the pit at Learys brick plant was analyzed (Table 12).

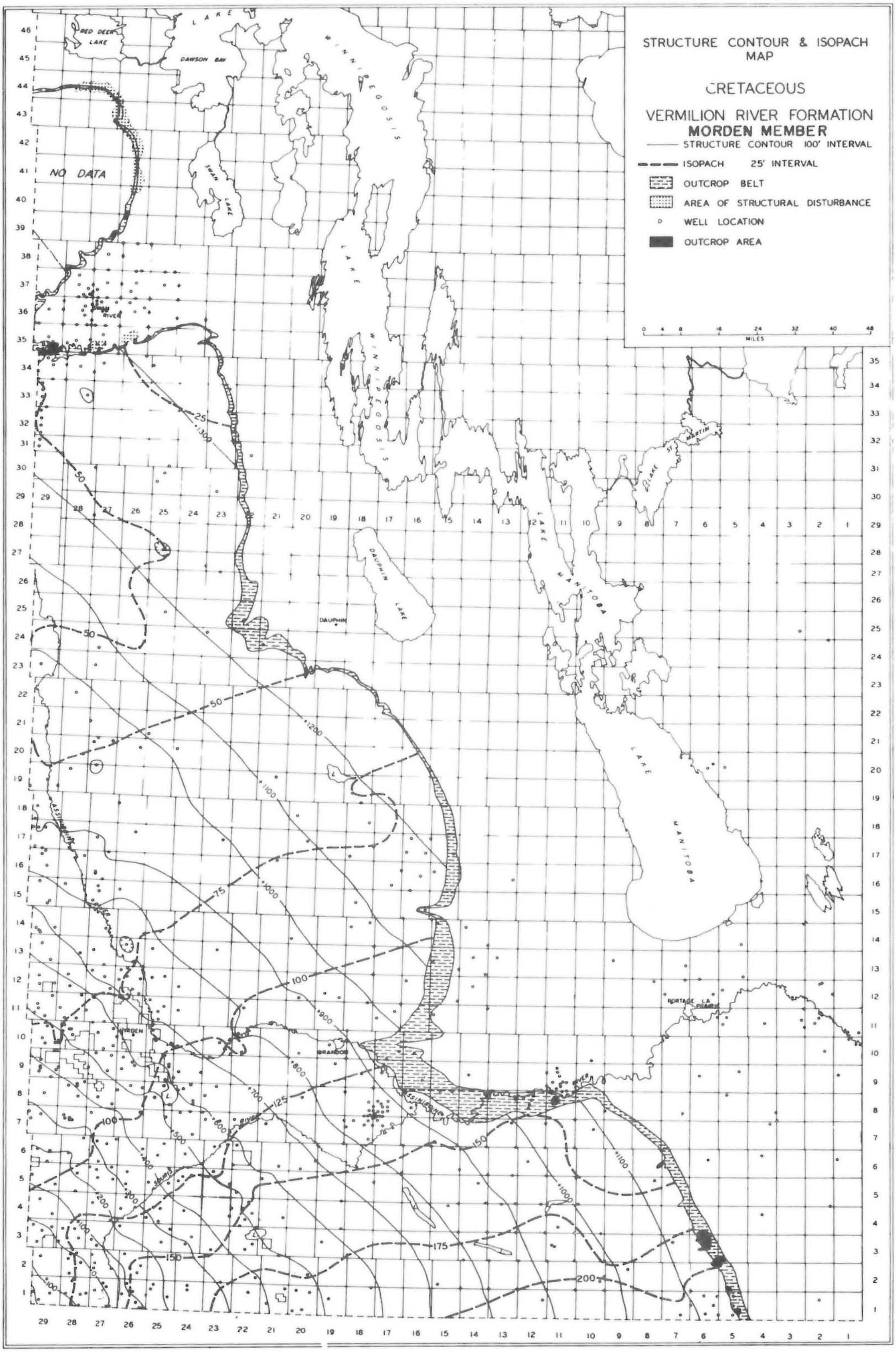

STRUCTURE CONTOUR & ISOPACH MAP
CRETACEOUS
VERMILION RIVER FORMATION
MORDEN MEMBER
STRUCTURE CONTOUR 100' INTERVAL
ISOPACH 25' INTERVAL
OUTCROP BELT
AREA OF STRUCTURAL DISTURBANCE
WELL LOCATION
OUTCROP AREA
NO DATA
LAKE MANITOBA
DAUPHIN
BRANDON
PORTAGE LA PRAIRIE

Figure 25.

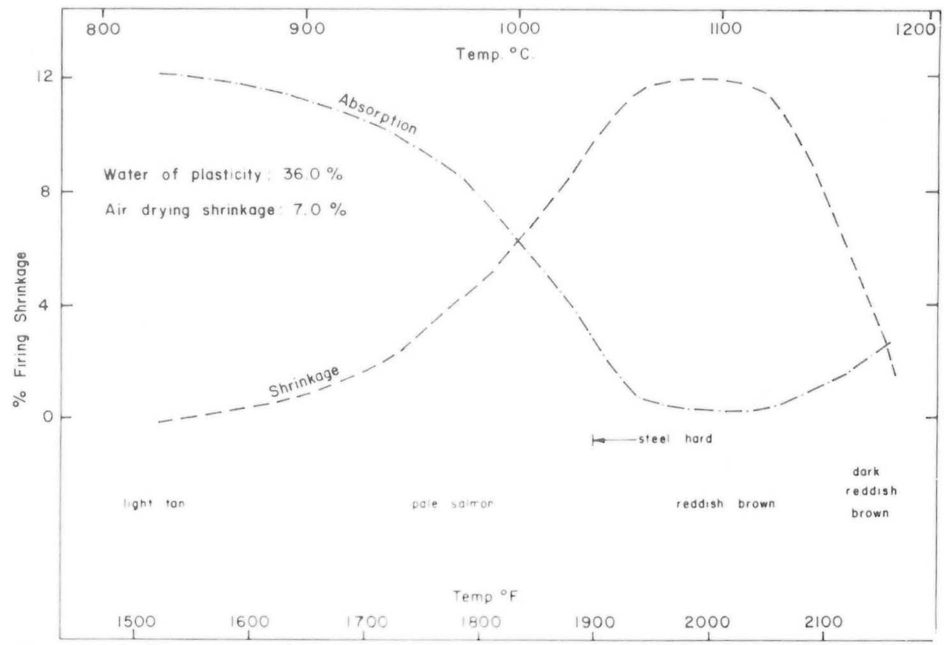


Figure 26. Temperature gradient test, Morden shale, Learys (after Bell and Zemgals, 1963).

Table 12	Carbonaceous Shale of the Morden Member			
From 30-foot face exposed in pit at former Learys brick plant, SW¼ sec. 13, tp. 6, rge. 8WPM; analysts: MacKay and Brown.	SiO_2	62.43%	K_2O	3.00%
	Al_2O_3	17.33%	MnO	0.01%
	Fe_2O_3 } FeO	2.49%	P_2O_5	0.12%
			CO_2	nil
	TiO_2	0.84%	H_2O+ } H_2O-	9.60%
	MgO	0.80%		
	CaO	0.38%	Carbon	2.1%
	Na_2O	0.41%	Total	99.51%

MINERALOGICAL COMPOSITION

Three samples of the Morden shale were examined by DTA. Of the two samples from Pembina Mountain, one was near the top of the formation at Learys, and the other was from the middle of the formation at Lake Minnewasta. The third sample was from the northern area, along Vermilion River (see Plate 2A).

The samples from Learys and Lake Minnewasta are composed of illite, with a small amount of quartz and possible traces of pyrite. The organic content of the Learys sample is moderate to low. The Lake Minnewasta sample has a low organic content, and also a small trace of gypsum.

The Vermilion River sample also is composed mainly of illite; the exchange ions are magnesium and possibly sodium, instead of calcium, as in the Learys sample. Less than 5 per cent siderite, less than 1 per cent gypsum, and about 1 or 2 per cent pyrite are present. The organic content is high.

TEMPERATURE GRADIENT TESTS

A temperature gradient test by Bell and Zemgals (1963) of a composite sample over a 20-foot section from the Learys deposit indicated the Morden shale is a common reddish brown firing carbonaceous shale with a short firing range (Fig. 26). The shale is dark grey, non-calcareous, and has good plasticity and workability. PCE of the shale is cone 12 (2439°F, 1337°C). Bell and Zemgals concluded that the Morden shale has too short a firing range to be used for face brick. The Learys shale fires reddish yellow 5YR 6/6 at 1900°F. The combined drying and firing shrinkage makes this shale difficult to use in clay products.

Temperature gradient tests on samples of Morden shale from Learys (NW¼ sec. 13, tp. 6, rge. 8WPM), from Lake Minnewasta (SE¼ l.s.d. 8, sec. 5, tp. 2, rge. 5WPM), and from south of Morden (NW¼ l.s.d. 13, tp. 1, rge. 5WPM) gave closely similar firing results. A sample of the highly carbonaceous Morden shale exposed in a 14-foot section along Vermilion River in SW¼ l.s.d. 15, sec. 23, tp. 23, rge. 20WPM was tested, and showed an even shorter firing range; the fired product has a higher absorption than that from Learys.

PRODUCTION HISTORY LEARY'S BRICK PLANT

The plant and its adjoining pit of Morden shale are located in the Boyne River valley in SW¼ sec. 13, tp. 6, rge. 8 WPM, 77 miles southwest of Winnipeg on the Canadian National Railway. The brick plant commenced operations in 1900 as the Boyne Valley Brick Company; it was taken over by C.E. Leary in 1914, and production continued to 1917. After lying idle for 30 years, the plant was repaired by W.A. Leary and production on a very limited scale was recorded from 1947 to 1952, only one or two kiln-loads being fired each year. (See plate 2B).

A 30-foot bank of Morden shale is exposed on the south bank of the Boyne River, 200 feet south of the brick plant. The shale is suitable for small scale production of dry-press face brick, providing care is exercised in mining the shale and during firing in the kiln. Glacial overburden and possibly a slumped block of Boyne shale occur above the shale. Calcareous septarian concretions, some several feet in diameter, occur within the shale.

The bricks were fired in a beehive down-draft kiln, with a capacity of 80,000 bricks; wood was used for fuel. Burning of one load required 2 or 3 weeks, as a long oxidation period was found necessary to prevent black cores and bloating.

Annual production for the period from 1947 to 1952 ranged from 30,000 to 97,000 dry-press face brick and from 3,800 to 94,000 common brick.

Tallclay Products Limited attempted to bring the plant into production in 1962, but only one kiln-load of brick was fired; these bricks showed white lime specks and were cracked, possibly the result of contamination of limestone gravel from the overburden.

BOYNE MEMBER

The Boyne Member is 140 to 150 feet thick in the Pembina Mountain area. The upper part consists of buff and grey speckled calcareous shale, and has been used in the production of natural cement. The lower part consists of dark grey carbonaceous and calcareous shale, containing abundant small white specks that are small fossils, mainly foraminifera. Most of the Boyne shales are somewhat petroliferous. In the area along the east side of Riding Mountain the upper highly calcareous shale of the Boyne Member is not present, either through erosion prior to deposition of the Pembina Member, or possibly because of a facies change; there the member consists of a dark grey to black carbonaceous shale, in places showing some white specks. Numerous thin bands and partings of bentonite occur throughout the section. The Boyne Member is correlated with "The First White Speckled Shale" horizon of Saskatchewan and Alberta, and with the Niobrara Formation of North Dakota. A structure contour and isopach map of the upper part of the Vermilion River Formation, from the top of the Pembina to the base of the Boyne Members, is shown in Figure 27. The Pembina, Boyne, and intervening Gammon Ferruginous Members have been combined in this map because it was thought that the correlations of the top and base of the Gammon Ferruginous Member were too uncertain in some areas to warrant publication as separate maps.

TYPES OF SHALE, CHEMICAL AND MINERALOGICAL COMPOSITION, AND FIRING TESTS

a) Buff-weathering, highly calcareous shale

In the Pembina Mountain area, the upper 25 feet of the Boyne Member consists of a highly calcareous shale that is bluish-grey when fresh but weathers to a yellowish buff and tends to outcrop in cliffs (Plate 1B).

Wells (1905) reported a chemical analysis of these beds (Table 13), which he described as "cream-coloured, soft, dry chalk . . . with an average thickness of 12 feet".

Table 13	Calcareous shale, Boyne Member			
From a 12-foot section in Pembina River valley, tp. 1, rge. 6WPM; from Wells (1905)	Insoluble	13.10%	SO_3	0.15%
	Fe_2O_3 + Al_2O_3	10.09%	Moisture	1.04%
	MgO	0.63%	CO_2 + Carbon	33.50%
	CaO	41.49%	Total	100.00%

A DTA analysis of a sample collected from NW¼ sec. 11, tp. 6, rge. 8WPM, on the north slope of the Boyne River valley, indicated that calcite is the main constituent, forming approximately 55% of the sample. The clay mineral present is illite. Minor constituents include a trace of gypsum, a small quantity of limonite, probably some quartz, and a very small amount of organic matter.

Temperature gradient tests show the fired brick has a very high absorption, increasing from 45% at 1450°F to 56% at 1950°F, and decreasing to 24% at 2060°F. The fired product is soft, and is not suitable for brick.

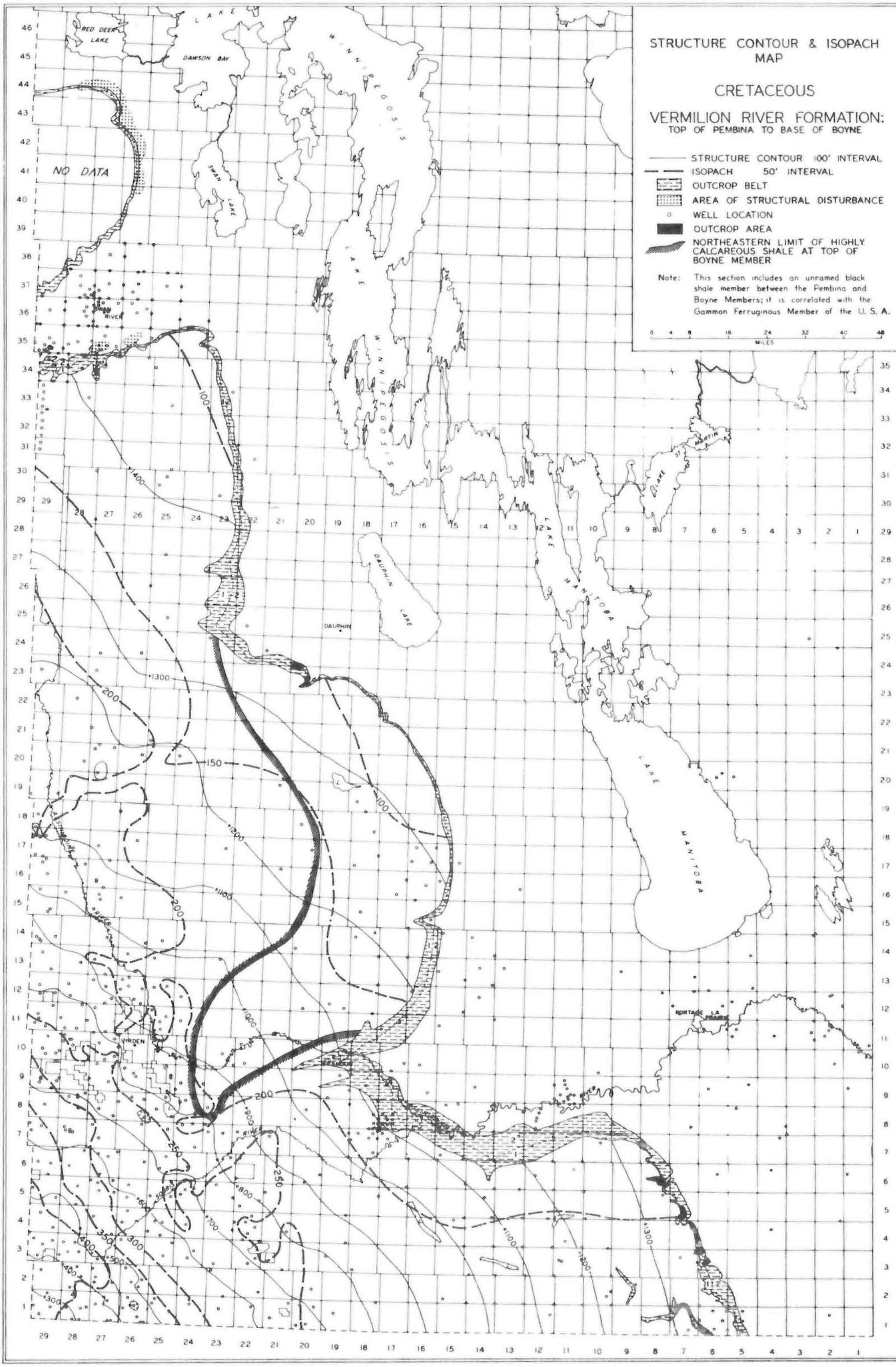

STRUCTURE CONTOUR & ISOPACH MAP
CRETACEOUS
VERMILION RIVER FORMATION:
TOP OF PEMBINA TO BASE OF BOYNE
STRUCTURE CONTOUR 100' INTERVAL
ISOPACH 50' INTERVAL
OUTCROP BELT
AREA OF STRUCTURAL DISTURBANCE
WELL LOCATION
OUTCROP AREA
NORTHEASTERN LIMIT OF HIGHLY CALCAREOUS SHALE AT TOP OF BOYNE MEMBER
Note: This section includes an unnamed black shale member between the Pembina and Boyne Members; it is correlated with the Gammon Ferruginous Member of the U. S. A.
MILES
RED DEER LAKE
DAWSON BAY
LAKE WINNIPEGOSIS
SWAN LAKE
NO DATA
DAUPHIN LAKE
DAUPHIN
LAKE MANITOBA
LAKE ST. MARTIN
PORTAGE LA PRAIRIE
VIRDEN

Figure 27.

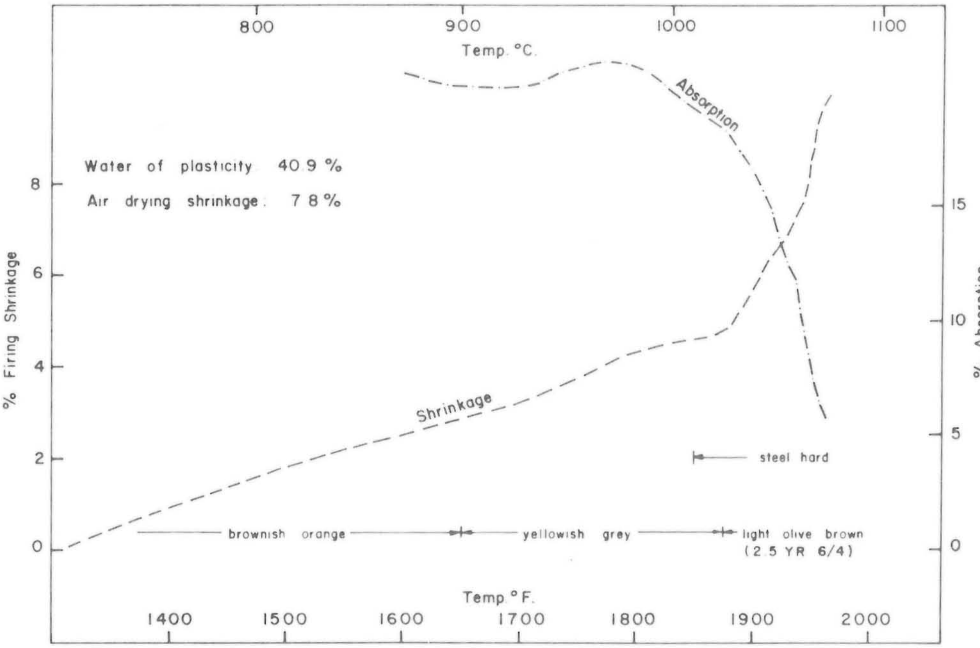


Figure 28. Temperature gradient test, Boyne Member, near base, Pembina River.

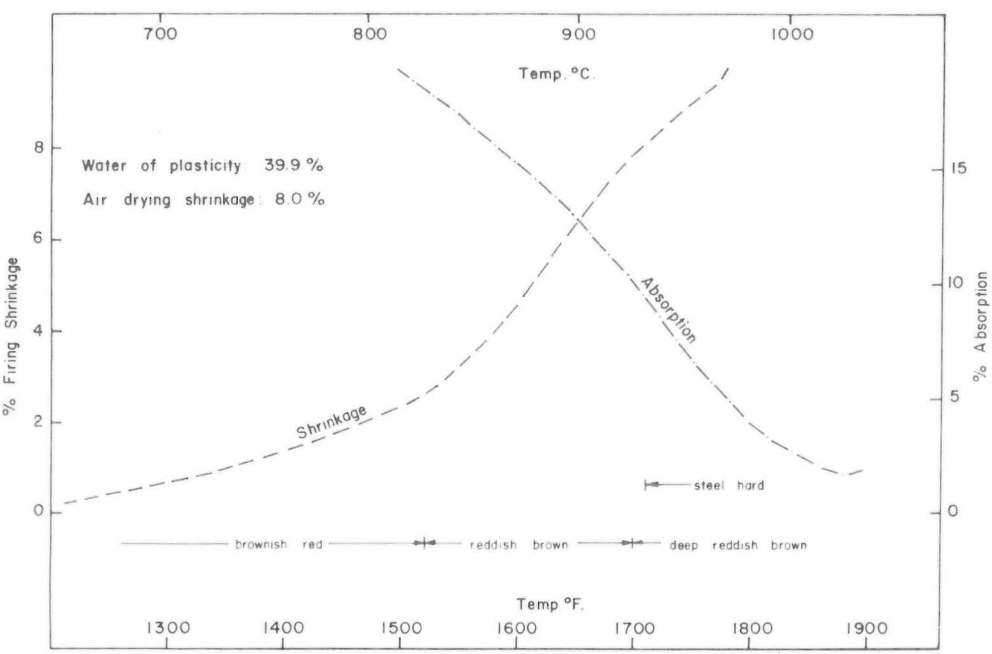


Figure 29. Temperature gradient test, Boyne Member, Vermilion River.

b) Grey calcareous shale

The buff-weathering section is underlain by 25 to 30 feet of mainly light grey-weathering calcareous shale. Included in this section is a 7-foot bed of shale which was once used in the production of natural cement at Babcock and Arnold.

A sample of grey shale from NW¼ sec. 11, tp. 6, rge. 8WPM, not as calcareous as the natural cement rock, was tested. A DTA analysis showed that illite is the main constituent and that calcite is an intermediate constituent forming approximately 20% of the sample. The sample contains also a moderate amount of organic matter, a trace of siderite and pyrite, some gypsum, and a small amount of quartz.

A temperature gradient test indicates the shale fires to a pale yellow (5Y 8/3) between 1600° and 2000°F, has an absorption of 18% to 20%, and a firing shrinkage increasing from 5% to 11%. The shale fires hard, but not steel hard. Although the firing characteristics are much better than the highly calcareous shales, this grey shale is not suitable for face brick.

The natural cement rock has a very low magnesium content. Goudge (1944) reported chemical analyses of each foot of the 7-foot layer mined at Babcock; a typical analysis of a 1-foot section and the range within the 7-foot bed are given in Table 14; the former workings are no longer accessible.

Table 14	Natural cement rock, Boyne Member		
From sec. 15, tp. 6, rge. 8WPM. Sample (1): from south chamber; 1-foot bed 5 feet below top. Sample (2): range for south chamber and east tunnel. From Goudge (1944)		(1)	(2)
	SiO_2	17.51%	13.50–20.08%
	Al_2O_3	6.40%	5.44– 7.60%
	Fe_2O_3	3.20%	2.56– 3.84%
	MgO	0.14%	0.11– 1.52%
	CaO	37.53%	35.42–39.96%
	SO_3	4.62%	3.94– 5.57%
	LOI	30.10%	28.40–31.40%
	Total	99.50%	

c) Dark grey carbonaceous calcareous shale, southern area

In the Pembina Mountain area, the lower part of the Boyne Member contains a dark grey shale, samples of which were collected from a 40-foot exposure in l.s.d. 5, sec. 8, tp. 1, rge. 6WPM, on the north slope of the Pembina River valley.

A DTA analysis of a composite sample from this section indicates the shale is composed of illite, with possibly some kaolinite and chlorite, and with a few per cent each of siderite, dolomite, and calcite; the organic content is high. Minor constituents include quartz, pyrite, and a trace of gypsum.

A temperature gradient test (Fig. 28) of the composite sample showed that the shale has too short a firing range to be suitable for face brick.

d) Dark grey carbonaceous calcareous shale, northern area.

North of the Assiniboine River, the Boyne Member is considerably thinner than at Pembina Mountain. Wickenden (1945) estimated the thickness to be 80 feet at Riding

Mountain and only 40 feet at Porcupine Mountain. The shale appears to be less calcareous and more carbonaceous than that of Pembina Mountain. Samples were collected at SW l.s.d. 15, sec. 23, tp. 23, rge. 20WPM, from one of the excellent exposures of the Boyne Member along the Vermilion River.

A DTA analysis showed illite to be the main constituent, with some kaolinite present; carbonate minerals present are siderite, possibly forming over 10% of the sample, and calcite, approximately 15%. The organic content is high. Minor minerals are quartz, pyrite, and gypsum.

A temperature gradient test of this same sample showed the shale fires a deep reddish brown colour (2.5YR 4/4), free of scum, and is steel hard about 1710°F (Fig. 29).

Although the firing range is limited, the relatively low temperature at which steel hardness is reached is an advantage; however, the combined air drying and firing shrinkage is excessive, and the shale is not suitable for face brick.

PRODUCTION HISTORY: NATURAL CEMENT

The Manitoba Union Mining Company erected the first natural cement mill in Manitoba at Arnold, 2 miles east of Deerwood, and production lasted for a few years between 1898 (?) and 1904; no production figures are available. The major producer was the Commercial Cement Company, which operated at Babcock from 1907 to 1924; the natural cement bed occurs about 15 feet above the railway track on the south side of the valley. Adits were driven into the side of the valley and rooms were cut out. Six continuous upright kilns were set up at the mine, and the rock was burned about 12 hours at temperatures up to 1800°F. The clinker produced was then crushed and sacked; capacity was 250 barrels daily.

The Manitoba product was a rapid hardening type of use as a mortar. Also, large quantities were used in equal proportion with Portland cement in concrete work, such as street or sidewalk construction. Annual production statistics are available only for the period from 1908 to 1912; production ranged from 8,600 tons to 21,350 tons, and the value from $8,600 to $28,289. Later production figures are combined with those of Portland cement in available statistics.

As the natural cement was made by burning masses of calcareous shale which varied in chemical composition, it was of less uniformity than the Portland cement made from carefully prepared mixtures, and was superseded by it. The natural cement operations have been described by Wells (1905) and Goudge (1944).

GAMMON FERRUGINOUS MEMBER, OR LOWER LEA PARK EQUIVALENT

A study of the Cretaceous interval in several hundred mechanical logs from oil wells showed that a previously unrecognized black shale member is present in the subsurface of southwestern Manitoba between the calcareous speckled shale at the top of the Boyne Member and the bentonite beds at the base of the Pembina Member. The member has a maximum thickness of 180 feet in the southwest corner of Manitoba, and thins eastward (see cross-section on Manitoba Mines Branch stratigraphic map series KVR-2).

Two previous publications have also recognized this member. Williams and Burk (1965, section B-B', p.173) show the lower part of the Lea Park Formation (possibly equivalent to the Milk River Formation of Alberta) extending to the Manitoba border. Gill and Cobban (1961) mention that the lower foot or so of the Pembina Member exposed in the Pembina Valley, North Dakota (in SW¼ sec. 30, tp.163N., rge. 57W.), 6 miles south of the International Boundary, may represent the thin east edge of the

Gammon Ferruginous Member, which reaches a thickness of 800 to 1000 feet in extreme western North Dakota.

The recognition of this member in Manitoba may be important in the interpretation of the stratigraphy on the Riding Mountain and Duck Mountain areas. An examination of the core from the pilot hole of the K-2 shaft of International Minerals and Chemicals Limited at Esterhazy showed the member to be 47.9 feet thick. Wickenden (1945) describes the lack of well-developed speckled shale of the Boyne Member in the Vermilion River area. It is possible that some of the upper part of the section in SW¼ sec. 23, tp. 23, rge. 20WPM described by Sternberg (in Wickenden, 1945, p. 39) and assigned to the Boyne Member may be correlated with the Gammon Ferruginous Member.

As more detailed studies are necessary to determine whether or not the member is present in outcrop, firing tests cannot be reported as yet; it is probable that the high organic content would make the shale unsuitable for brick.

PEMBINA MEMBER

The Pembina Member overlies the Gammon Ferruginous and Boyne Members. At the upper contact of the Pembina Member, the chocolate brown, waxy carbonaceous Pembina shales grade upward into the bentonite beds of the Millwood Member. The lower part of the Pembina Member consists of interbedded yellow non-swelling bentonite and black highly carbonaceous shale. The deposits of non-swelling bentonite are described in detail in Manitoba Mines Branch Publication 62-5 (Bannatyne, 1963), in which analyses and tests by Ross and Buchanan (1962) and others are reported.

Table 15 — Carbonaceous shale, Pembina Member

1) Brown shale, SE¼ sec. 26, tp. 4, rge. 7WPM; from Ross and Buchanan (1962).

2) Carbonaceous shale, l.s.d. 5, sec. 21, tp. 2, rge. 6WPM; MacKay and Brown.

3) Black shale interbedded with non-swelling bentonite; (Keele, 1917).

	(1)	(2)	(3)
SiO_2	68.08%	58.17%	47.88%
Al_2O_3	12.96%	15.21%	16.10%
Fe_2O_3	5.13% (Fe_2O_3 + FeO)	3.13% (Fe_2O_3 + FeO)	2.62%
FeO			1.35%
TiO_2	0.65%	0.69%	0.59%
MgO	2.57%	1.54%	1.84%
CaO	0.88%	0.53%	1.38%
Na_2O	1.18%	0.38%	1.96%
K_2O	3.35%	3.31%	2.77%
MnO	n.d.	n.d.	n.d.
P_2O_5	n.d.	0.30%	n.d.
SO_3	0.31%	n.d.	n.d.
Carbon	n.d.	3.60%	n.d.
H_2O+	3.60%	14.12% (H_2O+ and H_2O-)	n.d.
H_2O-	4.33%		n.d.
LOI	0.93%	–	22.72%
Total	100.06%	100.98%	99.21%

CHEMICAL AND MINERALOGICAL COMPOSITION

Two shale samples from the upper part of the member and one sample of the black shale interbedded with the non-swelling bentonite were tested.

Brown shale (sample F, Bannatyne, 1963) collected from the section above the non-swelling bentonite beds in the Miami pit of Pembina Mountain Clays Limited (SE¼ sec. 26, tp. 4, rge. 7WPM) was analyzed (sample 1, Table 15).

X-ray diffraction of sample F (Ross and Buchanan, 1962) showed the major mineral constituent is montmorillonite essentially free of collapsed (illitic) layers. Other minerals include quartz, and the analysis showed weak reflections indicative of minerals in the kaolin and/or chlorite groups; the presence of a mica mineral is also suggested. Microscopic examination of the +200 mesh fraction showed a few microfossils, some waxy green montmorillonite, and small grains of dolomite, goethite, quartz, mica, apatite, and a zeolite mineral. The differential thermal analysis curve is somewhat similar to curves for standard samples of mixed-layer montmorillonite-illite.

A sample from immediately above the non-swelling bentonite zone, Dead Horse Creek valley, l.s.d. 5, sec. 21, tp. 2, rge. 6WPM, in a ditch on the east side of road, was analyzed (sample 2, Table 15). A differential thermal analysis (Wicks, 1963) of this sample indicated it is composed mainly of a mixed layer illite-montmorillonite with traces of quartz and pyrite. The exchangeable ion may be sodium. The organic content of the sample is very high. An X-ray powder photograph verified the presence of illite and a lesser amount of montmorillonite, and suggested that kaolinite might be present. Quartz and plagioclase also were identified.

Black carbonaceous shale, interbedded with non-swelling bentonite, was analyzed by Keele (1917) (sample 3, Table 15). Keele described the shale as very plastic, but stiff and hard to work; it requires slow drying to prevent cracking. The carbon content is so high that firing without bloating or carbon coring would be difficult. It fires light red, yields a rather punky and weak body, and is not recommended for use in fired clay products. The material is reported to be a poor bloater (Matthews, 1952).

POTENTIAL USES, AND PRODUCTION: SHALE AND BENTONITE

Attempts to dry bars for temperature gradient tests, using samples of the above shales, were unsuccessful; the bars cracked badly and showed high air drying shrinkage. The shales are not suitable for brick. Sample F, from the upper part of the Pembina Member, is a good bloater and would probably be suitable for lightweight aggregate.

The non-swelling bentonite deposits of the Pembina Member of the Vermilion River Formation have been described in previous reports (Bannatyne, 1963; Ross, 1964). In 1966 and 1967, Pembina Mountain Clays Limited have quarried the bentonite in SE¼ sec. 24, tp. 4, rge. 7WPM; another pit in SE¼ sec. 26, tp. 4, rge. 7WPM has been worked in recent years. The clay is dried at Morden, and some of the dried milled bentonite is sold directly for use as a bleaching agent for mineral lubricating oils, used lubricating oils, and animal fats and tallows; as a carrier for insecticides and pesticides; as a binder in foundry sands under the trade name of Pembond, and as cleansing powder for chincillas.

The remainder of the clay is shipped to the company's Winnipeg plant at 945 Logan Avenue where it is activated with sulphuric acid, washed, dried, and ground; it is sold as a bleaching agent in two grades. Mineral oil grades are used for decolourizing linseed oil, soybean oil, rapeseed oil, and others, and also for decolourizing animal fats and tallows. Some of the bentonite is calcined, and sold as an animal bedding.

RIDING MOUNTAIN FORMATION

The Riding Mountain Formation forms the bedrock for most of the second prairie level in Manitoba, west of the escarpment. In most places it is covered by glacial and Recent deposits, ranging from a few feet to over 800 feet in thickness; in the Turtle Mountain area it is overlain by younger rocks of the Boissevain and Turtle Mountain Formations.

In general, the formation is composed of two main rock types, an upper layer of hard, grey, siliceous Odanah shale, and a lower layer of soft, greenish brown, bentonitic Millwood shale. A problem has existed as to whether the Odanah and Millwood beds are separate stratigraphic units or are in part laterally gradational.

Since the previous reports on Manitoba by Wickenden (1945) and Tovell (1948), considerable subsurface information has become available. On the basis of these data, and on studies of outcrops showing the contact between the Odanah and Millwood shales, the writer believes that the base of the Odanah is a definite stratigraphic marker horizon; it is associated with a 7- to 12-inch bed of green to olive waxy bentonite that has been traced for a distance of 180 miles in surface outcrops. The contact has also been correlated with an electric log marker and a change in gamma ray-neutron response shown on mechanical logs from deep wells across all of southwestern Manitoba. On this basis, it is proposed that the Riding Mountain Formation be divided into the Odanah Member and the Millwood Member.* These names are proposed for Manitoba only, although Gill and Cobban (1963) have extended the Odanah into North Dakota. The reason for restricting the geographic extent of these members is the occurrence of facies variations whereby the Odanah Member loses its distinctive hard siliceous lithology to the west near the Saskatchewan boundary, and the calcareous content in the lower part of the Millwood Member increases southward from the Pembina River area.

MILLWOOD MEMBER

The Millwood Member consists of bentonitic shale composed largely of partly swelling montmorillonite. It increases in thickness from 80 feet in the Pembina Mountain area to over 500 feet in the St. Lazare-Roblin area (Fig. 30). (See Plate 3A).

The Millwood shale outcrops in places along the Manitoba Escarpment and along the Souris, Pembina and Assiniboine River valleys, usually under a cover of hard Odanah shale; buttes of Millwood shale are common in the outcrop belt. Outcrops show a distinctive "popcorn" or "cauliflower" weathered surface with little or no vegetation. Brown and reddish brown ironstone and yellowish calcite concretions occur in layers within the Millwood Member. Near the contact with the overlying Odanah Member, olive-green waxy bentonite with good swelling properties occurs in thin bands, one of which is 7 to 10 inches thick; one bentonite bed over 24 inches thick is present directly under glacial till in the Beulah area, north of Miniota, but this may not be its original thickness.

CHEMICAL AND MINERALOGICAL COMPOSITION

Analyses of the Millwood Member and detailed outcrop sections are given in Bannatyne (1963). A chemical analysis (sample D, Twin Sisters Butte, sec. 26, tp. 4, rge. 7WPM) is given in Table 16.

*Tyrrell (1890) divided the Riding Mountain Formation into a lower Millwood Series and an upper Odanah Series.

Table 16	Bentonitic shale, Millwood Member			
Twin Sisters Butte, sec. 26, tp. 4, rge. 7WPM; from Ross and Buchanan (1962).	SiO_2	66.20%	K_2O	2.28%
	Al_2O_3	14.02%	MnO	0.86%
	Fe_2O_3	4.49%	SO_3	0.60%
	TiO_2	0.51%	H_2O+	3.88%
	MgO	3.02%	H_2O-	4.51%
	CaO	1.22%	LOI	1.61%
	Na_2O	1.36%	Total	100.09%

X-ray diffraction methods indicated the major constituent is montmorillonite essentially free of collapsed (illitic) layers. However, differential thermal analysis gave curves similar to standard samples of mixed-layer montmorillonite-illite. The X-ray methods indicated quartz and cristobalite are intermediate mineral constituents. Constituents identified by microscopic examination, and present in minor amounts, are white opaline microfossils, goethite, carbonate minerals, mica, zeolite, and gypsum (Ross and Buchanan, 1962).

ECONOMIC POTENTIAL

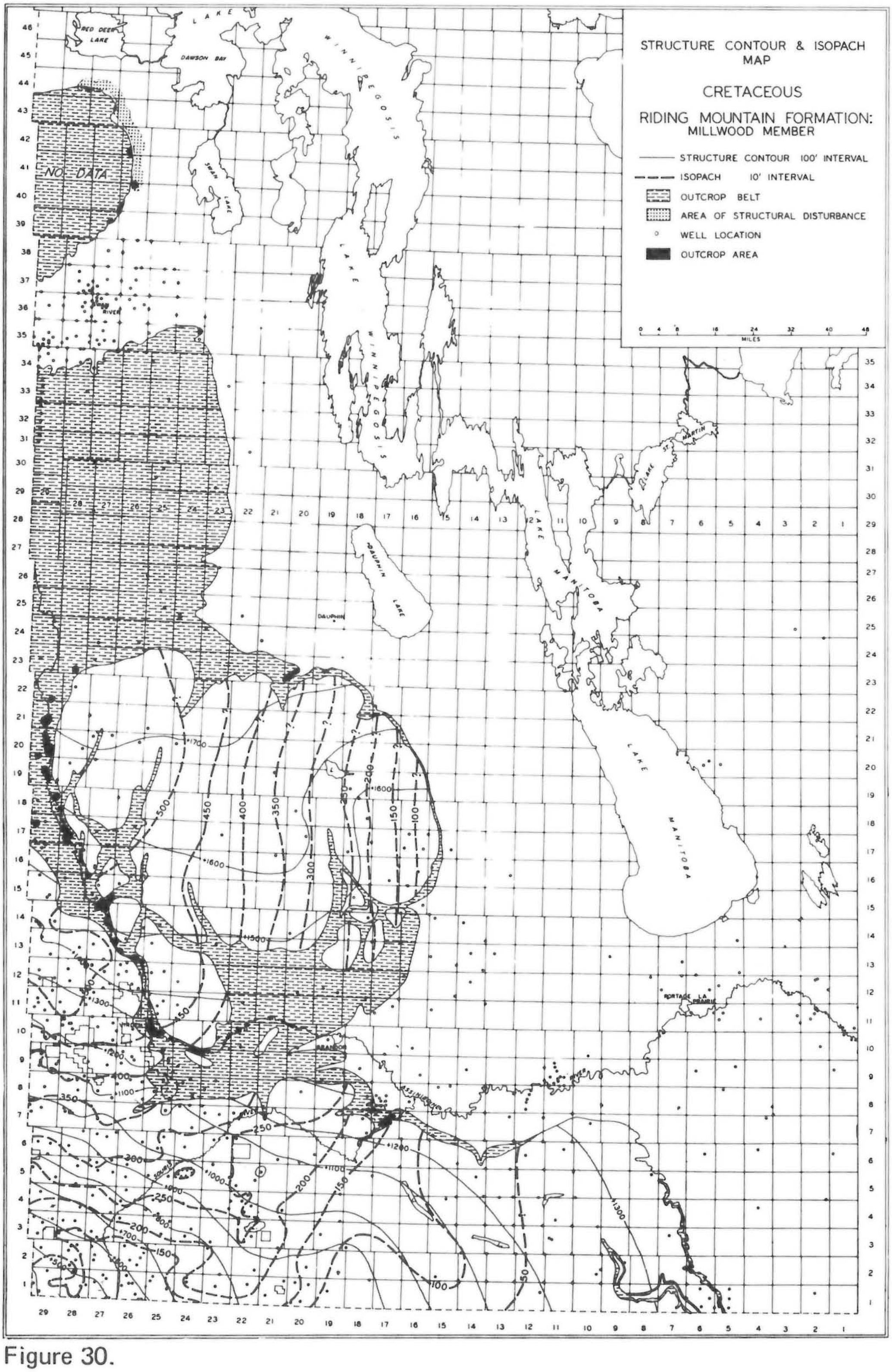
Tests have shown that the partly swelling bentonitic Millwood shale is suitable for the production of lightweight aggregate, and of value for use in slurries sprayed from aircraft to control forest fires. The gel-forming properties are too low to permit use of the shale in drilling mud, and, though it may be of use in iron foundry sands, the fact that the binding properties decrease with re-use seriously limits its value. The high montmorillonite content precludes the use of the material, by itself, in the production of fired clay products.

The Millwood beds exposed in the Millwood-Harrowby area do not have as high a swelling potential as those from Pembina Mountain; the beds in this northern area have a higher content of quartz silt.

Samples of partly-swelling Millwood shale from the Pembina Mountain area have been tested for use as a binder in iron ore pelletization, but the pellets produced have a low green strength; otherwise, the binding properties are good. The bed of olive-green waxy bentonite in the upper part of the member in the Beulah area, NE¼ sec. 7, tp. 15, rge. 26WPM, was tested. The bentonite has a high swelling index; in tests in which 2 gms. of finely ground bentonite were mixed with 100 ml of water, from 28 to 35 ml of gel were formed. The colloidal content of the bentonite ranged from 65% to 78%. The yield and gel strength of the sample are anomalously low for a bentonite with the above properties. A limited amount of test hole drilling by hand-auger indicated the bentonite occurred in lenses up to 26 inches thick with erratic distribution. Additional exploration is required to determine the extent of this material; the occurrence of the bentonite directly below glacial till may account for its erratic distribution and properties.

ODANAH MEMBER

The typical lithologic type of the Odanah Member is light, hard siliceous shale that is steel grey or slightly greenish grey when dry and dark greenish grey when moist. The shale occurs both as thin fissile beds, and as thick massive beds that are brittle and break with a



STRUCTURE CONTOUR & ISOPACH MAP
CRETACEOUS
RIDING MOUNTAIN FORMATION: MILLWOOD MEMBER
STRUCTURE CONTOUR 100' INTERVAL
ISOPACH 10' INTERVAL
OUTCROP BELT
AREA OF STRUCTURAL DISTURBANCE
WELL LOCATION
OUTCROP AREA
MILES
NO DATA
LAKE WINNIPEGOSIS
DAWSON BAY
SWAN LAKE
DAUPHIN LAKE
DAUPHIN
LAKE MANITOBA
LAKE ST. MARTIN
PORTAGE LA PRAIRIE

Figure 30.

subconchoidal fracture. The joints and bedding planes within the shale are usually stained reddish to purplish brown or brown from iron and manganese weathering products. Ironstone nodules of concretionary or septarian structure occur throughout the whole of the Odanah, but are more common in the upper part; Kirk (1920) reported that compact, ellipsoidal, grey limestone concretions are found in some exposures. Thin interbeds of bentonite and bentonitic shale are present; most commonly within the lower 100 feet of the member.

Outcrops of the Odanah shale are abundant in southwest Manitoba wherever the glacial drift cover is generally thin. The best exposures are seen along the escarpment and in river valleys (Fig. 31). Typical hard grey siliceous shale comprises the Odanah Member along the east side of Riding Mountain and Pembina Mountain.

Chemical and DTA analyses indicate that an increase in the generally low montmorillonite or mixed-layer illite-montmorillonite content occurs in different parts of the section. This increase is noticeable at the base of the member in some thin beds exposed at Wawanesa, at Oak Lake, at Beulah, and at St. Lazare. A higher illite-montmorillonite content may be present in the lower part of the member in the eastern Riding Mountain area, where precise determination of the Millwood-Odanah contact is difficult. In an outcrop northeast of Oak Lake, three "softer beds" of shale are interbedded in the basal part of the Odanah shale, and range in thickness from 1½ to 3 inches; the central ½ inch or so of each of these beds is a band of bentonite.

An increased montmorillonite content is also present at a higher elevation within the member near Onanole. The result of this increase is a softer shale, somewhat resembling part of the Millwood in appearance when wet, but differing in chemical and firing properties.

The softer shale in the upper part of the member is present also in southwest Manitoba, as shown by exposures at Ninga and Coulter. In particular, the cuttings from wells in the Turtle Mountain area indicate a 150- to 200-foot interval of soft shale at the top of the Odanah Member.

These increases in clay content of the Odanah Member may explain several topographic features of the area west of the Manitoba escarpment, as the resistance of the shale to erosion, either pre-glacially or during glaciation, would be considerably affected. These features include the lack of outcrop in the area around Turtle Mountain; the thick drift in the southwestern corner of Manitoba along the probable courses of pre-glacial valleys; the paucity of Odanah-type outcrops in southeast Saskatchewan, and the absence of known Odanah outcrops from Duck and Porcupine Mountains.

CHEMICAL COMPOSITION

Analyses of three samples of Odanah shale are listed in Table 17.

*The Odanah was named by Tyrrell after a small village on the Minnedosa (then the Little Saskatchewan) River, but it is no longer shown on present day maps. It was located in the centre of sec. 10, tp. 15, rge. 18WPM, about 2 miles northwest of Minnedosa, as shown on a "Map of Part of the Province of Manitoba" in Macoun (1882).

Table 17 — Siliceous shale, Odanah Member

(1) Bluish grey shale from Souris River, near Souris City; from Wells (1905).

(2) Light grey fissile shale, Big Creek, NW¼ sec. 8, tp. 17, rge. 15WPM; from Wells (1905).

(3) Hard grey shale, NE l.s.d. 13, sec. 12, tp. 5, rge. 8WPM; analysts: MacKay and Brown

<table>
<tr><th></th><th>(1)</th><th>(2)</th><th>(3)</th></tr>
<tr><td>SiO_2</td><td>79.55%</td><td>81.94%</td><td>76.07%</td></tr>
<tr><td>Al_2O_3</td><td>8.35%</td><td>6.52%</td><td>8.59%</td></tr>
<tr><td>Fe_2O_3</td><td rowspan="2">1.90%</td><td rowspan="2">2.40%</td><td>1.73%</td></tr>
<tr><td>FeO</td><td>0.58%</td></tr>
<tr><td>TiO_2</td><td>n.d.</td><td>n.d.</td><td>0.38%</td></tr>
<tr><td>MgO</td><td>1.02%</td><td>0.93%</td><td>0.96%</td></tr>
<tr><td>CaO</td><td>1.50%</td><td>0.80%</td><td>0.60%</td></tr>
<tr><td>Na_2O</td><td rowspan="2">1.17%</td><td rowspan="2">1.30%</td><td>0.29%</td></tr>
<tr><td>K_2O</td><td>1.48%</td></tr>
<tr><td>P_2O_5</td><td>n.d.</td><td>n.d.</td><td>0.01%</td></tr>
<tr><td>CO_2</td><td>n.d.</td><td>trace</td><td>nil</td></tr>
<tr><td>SO_3</td><td>n.d.</td><td>0.16%</td><td>n.d.</td></tr>
<tr><td>H_2O</td><td>6.06%</td><td>6.78%</td><td>7.92%</td></tr>
<tr><td>Carbon</td><td>n.d.</td><td>trace</td><td>0.25%</td></tr>
<tr><td>Total</td><td>99.55%</td><td>100.83%</td><td>98.86%</td></tr>
</table>

MINERALOGICAL COMPOSITION

Three samples of Odanah shale, selected from different areas and horizons within the member, were analyzed by Wicks (1963).

A sample of hard grey shale from the northeast corner of l.s.d. 13, sec. 12, tp. 5, rge. 8WPM, taken from a 30-foot section exposed in a ravine along the south side of P.T.H. 23, was selected as being representative of the Odanah shale exposed in the Pembina Mountain area. Illite, probably with some interlayered montmorillonite, is the clay mineral present, but it is an intermediate, not a major constituent. Calcium is the main exchangeable ion, but some magnesium is suggested. The organic content is very low. Only the slightest suggestion of quartz is indicated. An X-ray powder photograph showed no identifiable clay minerals, indicating a low content of clay; quartz and cristobalite are present in small amounts. Chemical analysis (Table 17, sample 3) confirmed the low clay content, and indicated the unidentified major constituent is composed of silica; the silica, probably amorphous, may be of biochemical or volcanic origin.

Another sample of typical, hard Odanah shale, collected from 5 exposures along P.T.H. 3 east of La Riviere, in E¼ sec. 30, tp. 3, rge. 9WPM, is representative of a 150-foot section. The DTA analysis is similar to the above sample, except that no quartz is indicated on the DTA curve.

A third sample of Odanah shale, collected from a road cut south of Miniota, in SW¼ sec. 19, tp. 13, rge. 26WPM, is similar to the first sample except that no quartz is indicated on the DTA curve, and there is no suggestion of magnesium exchangeable ions.

Bell and Zemgals (1963) investigated a sample of Odanah shale from NE¼ sec. 17, tp.

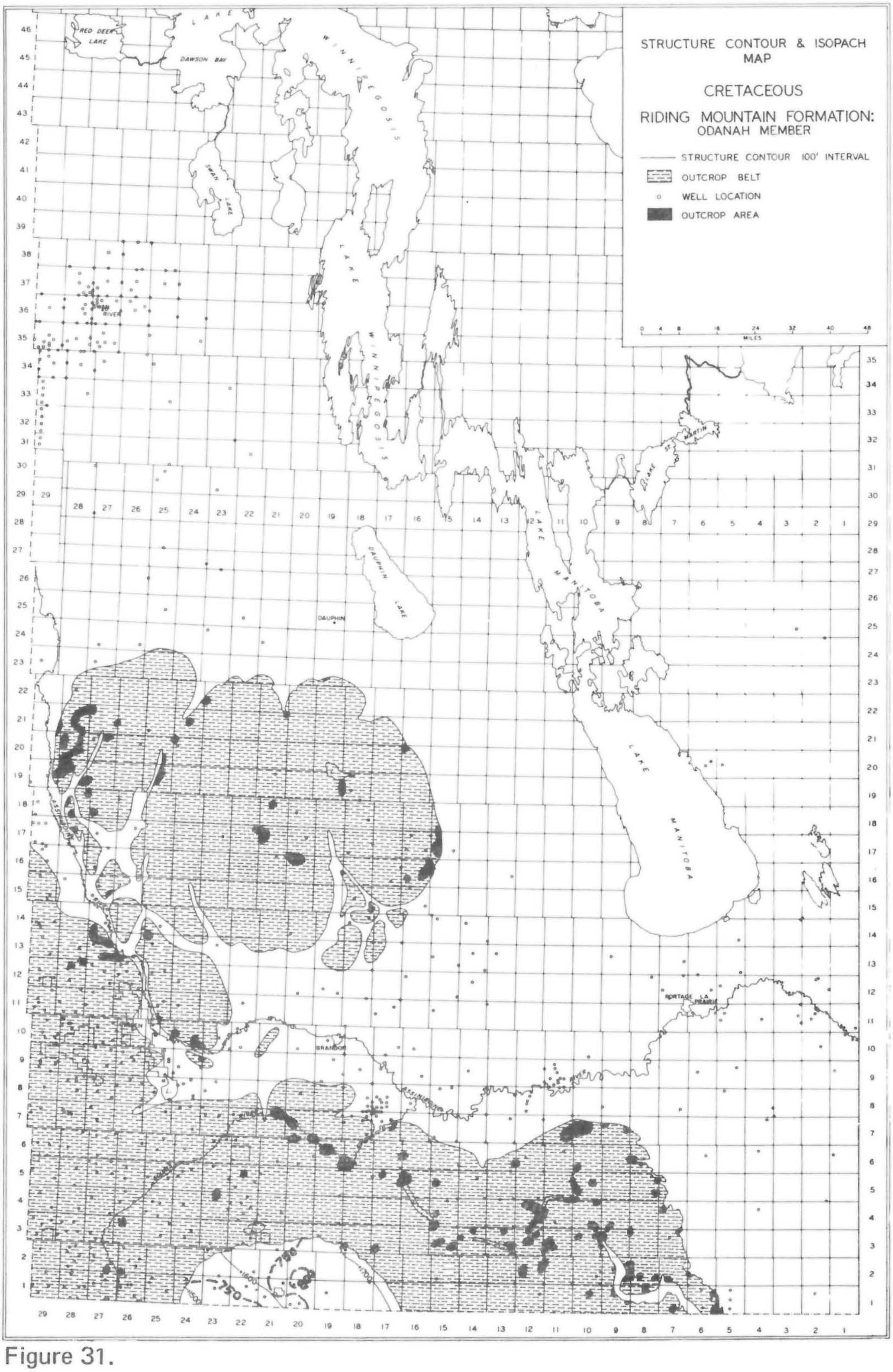

STRUCTURE CONTOUR & ISOPACH MAP
CRETACEOUS
RIDING MOUNTAIN FORMATION: ODANAH MEMBER
STRUCTURE CONTOUR 100' INTERVAL
OUTCROP BELT
WELL LOCATION
OUTCROP AREA
MILES
RED DEER LAKE
DAWSON BAY
LAKE WINNIPEGOSIS
SWAN LAKE
LAKE MANITOBA
DAUPHIN LAKE
DAUPHIN
LAKE ST. MARTIN
BRANDON
PORTAGE LA PRAIRIE
ASSINIBOINE

Figure 31.

6, rge. 8WPM, in the Boyne River valley. DTA analysis indicated the sample probably contains an illitic clay mineral and a small amount of oxidizable material, probably carbonaceous.

TEMPERATURE GRADIENT TESTS

a) Typical Odanah shale

In general, Odanah shale fires to an orange-buff to orange-red (7.5YR 8/6 to 2.5YR 6/6) body with high absorption and moderate shrinkage, without steel hardness; many samples have dark specks in the 2000° to 2200°F range. The shale has a high fusion point, of the order of 2400° to 2600°F, caused by its high silica, low flux content.

The sample from NE¼ sec. 17, tp. 6, rge. 8WPM, tested by Bell and Zemgals (1963), is representative of the shale tested from numerous other outcrops, such as at La Riviere, Swan Lake, Mariapolis, Altamont, Notre Dame des Lourdes, Belmont, Dand, and the harder shales from Beulah and St. Lazare. The tested sample is a grey, non-calcareous shale, fairly plastic, with good workability; although slightly gritty, it would probably extrude satisfactorily when finely ground. The brick cracks with rapid drying at 85°C. The firing characteristics are shown in the temperature gradient graph (Fig. 32).

Bell and Zemgals (1963) concluded the shale, by itself, was not suitable for vitrified clay sewer pipe, as its absorption is too high, and that excessive fuel costs would be required to produce face brick from this material as it would have to be fired to 2250°F, 200° to 400°F higher than usual for face brick. In addition, the fired product is not steel hard.

b) Variations within the Odanah Member

Temperature gradient and bloating tests on numerous samples of the Odanah shale indicate some variations in the properties of this shale, probably caused by differences in amount of illite or illite-montmorillonite present, the presence of bentonite (montmorillonite) bands and partings, the local occurrence of silt-and sand-rich shale, and variations in organic content.

Two samples of Odanah shale fire steel hard at the comparatively low temperature of 2000°F. One sample, collected from a road cut in a valley 1¼ miles west of Beulah, in SE¼ sec. 12, tp. 15, rge. 27WPM, was tested (Fig. 33). The combined air drying and firing shrinkage of the shale is too high to be acceptable for face brick. The stratigraphic position of this sample is close to the Odanah-Millwood contact.

The second sample was collected from a road cut in the upper part of the Odanah Member south of the south entrance to Riding Mountain National Park, in NW¼ l.s.d. 13, sec. 18, tp. 19, rge. 18WPM. The shale has the flaky, hard, grey, iron-stained appearance of the typical Odanah shale, but its firing properties (Fig. 34) indicate a higher clay content. As in the above sample, the shale has too high a combined air drying and firing shrinkage to be used in face brick. The shale has excellent workability.

Three samples of Odanah shale differ from the typical Odanah in having a high absorption of 18% to 22% at temperatures over 2200°F. These samples were collected from road cuts south of Miniota, in NE¼ sec. 12, tp. 13, rge. 27WPM; northwest of Birnie in S½ sec. 5, tp. 18, rge. 15WPM; and southwest of Treherne in sec. 27, tp. 7, rge. 10WPM. These shales when fired produce a somewhat porous brick of a pale rosy buff colour. Their firing shrinkage is 4% to 5% at 2100°F; air drying shrinkage ranges from 4% to 8%. In general, these shales are difficult to work as they have an open, weak body when wet-moulded; they do not fire to steel hardness below 2200°F and are unsuitable, with-

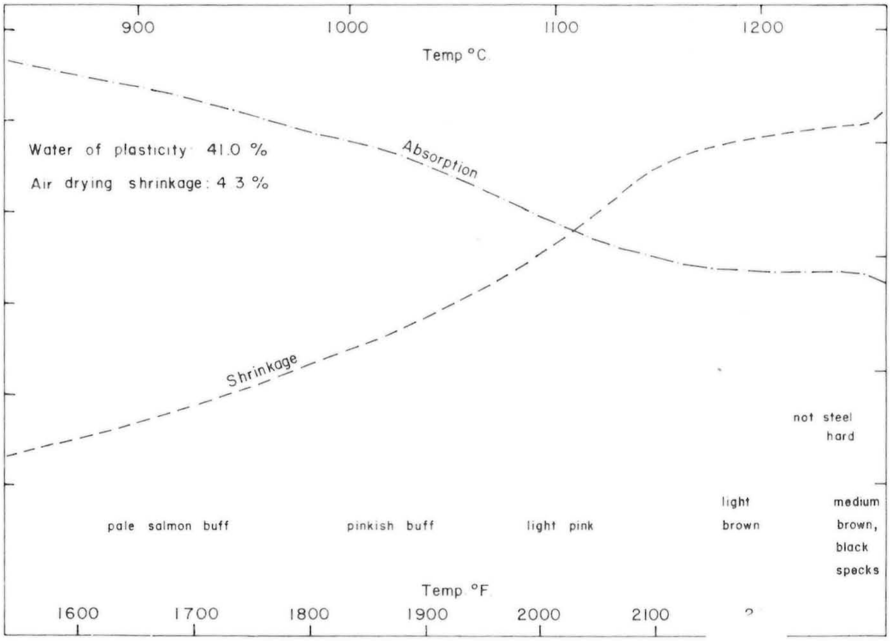


Figure 32. Temperature gradient test, Odanah shale, near Altamont (after Bell and Zemgals, 1963).

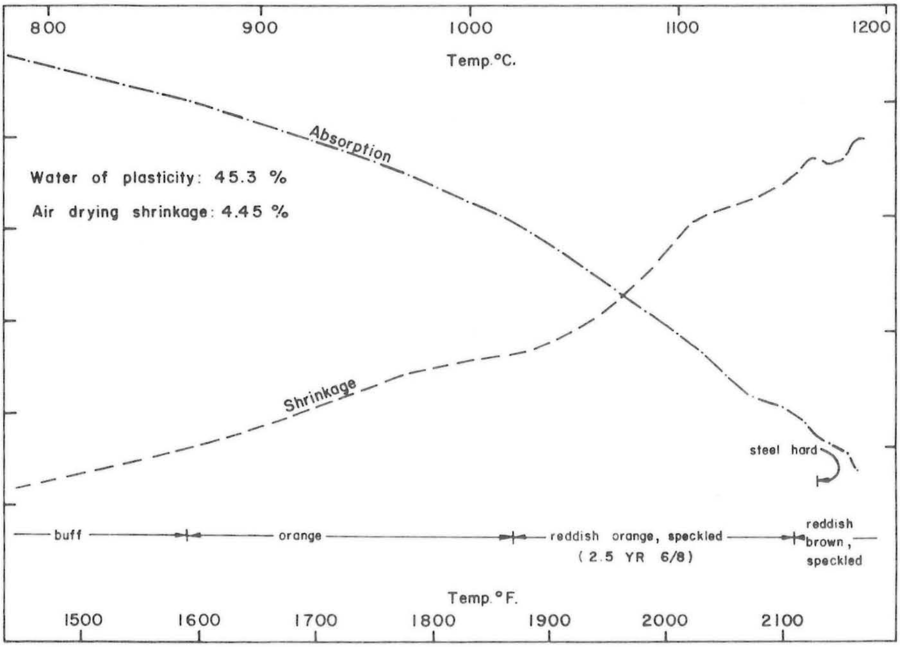


Figure 33. Temperature gradient test, Odanah shale, Beulah.

out admixtures, for face brick.

c) Shale intermediate between Millwood and Odanah

A zone of thin beds of shale in the lower part of the Odanah member has firing properties distinct from those of either the typical siliceous shale of the Odanah or the bentonitic shale of the Millwood. In natural exposures, the shale when moist is dark olive and occurs in soft thin tabular flakes resembling the Millwood, but on drying the shale turns a steel grey colour and hardens considerably, thus resembling the Odanah shale. This intermediate type of shale has been sampled near theOdanah-Millwoodcontact near Millwood (NW¼ sec. 11, tp. 20, rge. 29WPM), east of St. Lazare (W½ sec. 22, tp. 17, rge. 28WPM), northeast of Oak Lake (SE¼ sec. 1, tp. 10, rge. 23WPM), and on the Souris River southwest of Wawanesa (sec. 16, tp. 7, rge. 17WPM). Temperature gradient tests of these samples show they attain steel hardness at a comparatively low temperature.

A sample from a road cut southeast of St. Lazare has the best firing properties (Fig. 35). The shale has good workability. The fired colour is orange-brown (5YR 5/6). The shale has some good firing properties, but the high shrinkage would cause drying problems and it may be difficult to outline a large area of suitable or uniform material as the outcrop occurs on the slope of the Assiniboine River valley.

PRODUCTION HISTORY

The Odanah shale was once used at La Riviere in production of dark reddish brown and yellow buff dry pressed brick. The plant was located at SW¼ sec. 30, tp. 3, rge. 9WPM, on the west bank of Mary Jane Creek. A 70-foot high face of Odanah shale is exposed on the east bank of the creek; Walsh (1931) reported the upper 30 feet of shale was used in brick production. The plant closed about 1912.

A plant designed to produce sewer pipe and brick from a mixture of the carbonaceous Morden shale and siliceous Odanah shale was erected at Carman by the Canada Brick Tile and Fireproofing Co. and operated about 1916. The plant was located on the NE¼ sec. 25, tp. 6, rge. 6WPM. Shale was obtained from the Morden and La Riviere areas.

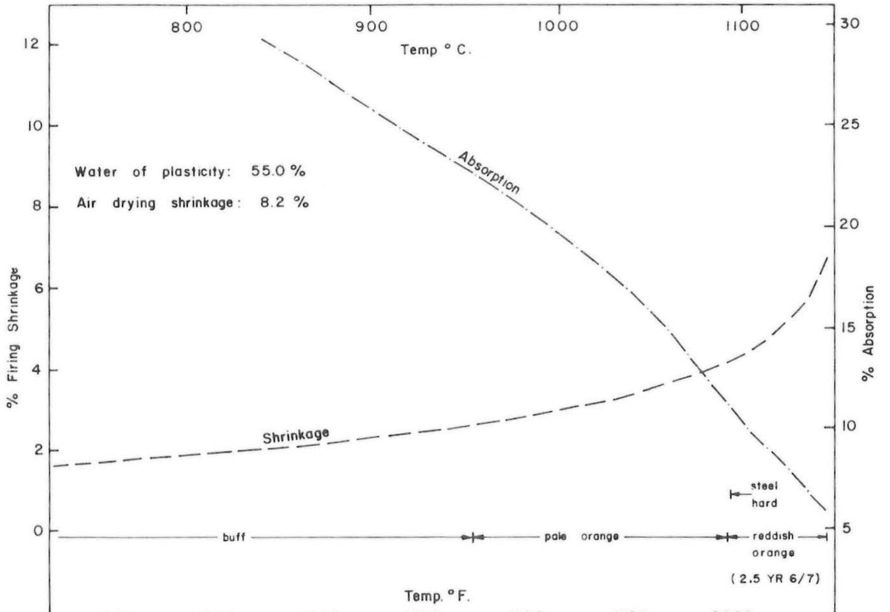


Figure 34. Temperature gradient test, Odanah shale, Onanole.

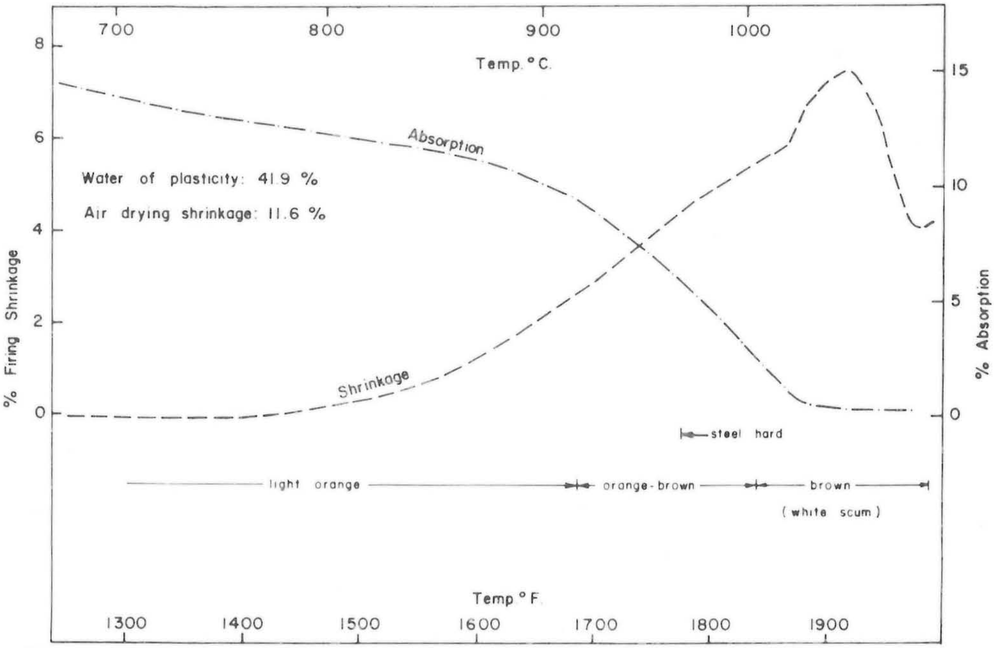


Figure 35. Temperature gradient test, Odanah shale, St. Lazare.

TURTLE MOUNTAIN AND BOISSEVAIN FORMATIONS

INTRODUCTION

In the Turtle Mountain area of southwestern Manitoba, the Cretaceous marine beds of the Riding Mountain Formation are overlain by non-marine (and possibly local marine) strata of Upper Cretaceous and Tertiary age. These beds, the youngest of the bedrock formations in Manitoba, are composed of sandstone, shale, and lignite; they dip slightly to the west.

The beds have been divided into the Boissevain Formation of sandstone and shale, up to 140 feet thick, and the overlying Turtle Mountain Formation, consisting of at least 480 feet of sandstone, shale, and thin lignite beds. Exposures of the formations consist of several scattered outcrops in ravines on the lower slopes of Turtle Mountain and in road cuts. The formations have been intersected in more than 20 oil wells, and 2 stratigraphic test holes from which sidewall samples were obtained. Data from these wells were used for preliminary isopach maps of the formations (Fig. 36). However, correlation of these formations with equivalent strata exposed along the Missouri Coteau of Saskatchewan and North Dakota is difficult, and not yet definitely established.

Turtle Mountain is a topographic rise extending 40 miles along the International Boundary from range 18WPM to range 24WPM, and extending northward as far as the central part of Township 3. It rises to a height of 2500 feet, about 800 feet above the general second prairie level elevation. From both a geological and topographical viewpoint, Turtle Mountain may be considered an outlier of the third prairie level which extends westward from the Missouri Coteau. The broad depression, at least 40 miles wide, that separates Turtle Mountain from the Missouri plateau was an extensive river basin previous to the glacial epoch. Lemke (1960) has suggested this may be an area of slight tectonic depression.

Most of the bedrock under Turtle Mountain is deeply buried by glacial material deposited as an end moraine and as ground moraine; the drift is over 400 feet thick in some parts of the area. The surface is very irregular, being dotted with lakes and swampy depressions.

Outcrops in the Turtle Mountain area occur in ravines that have cut through the overlying glacial deposits, and in several road cuts. Some sections have been recorded from lignite mines that once operated in the area. However, these exposures are generally of small extent, and most of the Boissevain and Turtle Mountain Formations is not exposed.

In 1968, arrangements were made with a Geological Survey of Canada party under J.E. Wyder, investigating Pleistocene deposits in the area, to drill two holes through the bedrock of Turtle Mountain; sidewall samples were collected where possible at 3-foot intervals or less. The following descriptions provide the first available data on the lithology of the entire section of the Boissevain and Turtle Mountain Formations.

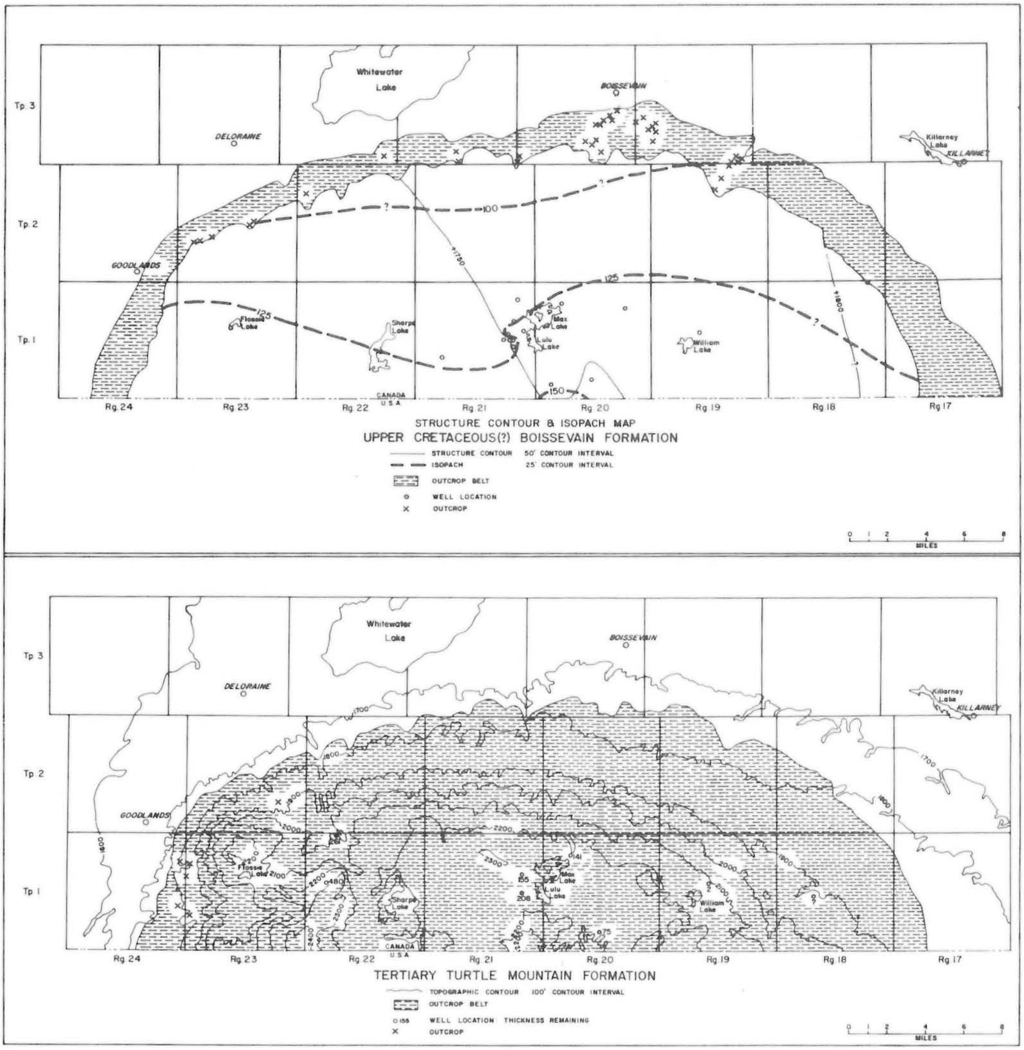


Figure 36. Structure contour and isopach map.

Hole MNR No. 2: NW5–20–1–22WPM Elev. 2310 feet

Depth (in feet)	Lithology of sidewall samples
	SURFICIAL DEPOSITS
0–45	Sand and gravel, brown to grey clay; lignite fragments.
45–106	Clay till, grey, calcareous; minor gravel.
108	Sand, yellowish brown, silty and clayey, calcareous.
110–124	Till, as above, pebbles more abundant.
	TURTLE MOUNTAIN FORMATION
125–141	Sandstone, very find grained quartzose, impure (upper part feldspathic), micaceous, non-calcareous; minor shale.
141–150	Shale, silty, dark grey; sandstone, very fine grained, grey.
151–157	Sandstone, very fine grained; some pyrite; lignite fragments.
158–180	Shale, silty, light to dark grey; interbedded siltstone, light grey.
188–188.5	Sandstone, fine to medium grained, feldspathic; some kaolinized feldspar grains.
189	Shale, carbonaceous; interbedded sandstone.
190–196	Sandstone, fine to medium grained, impure; interbedded shale, grey and dark grey.
197–220	Sandstone, hard layer(s) reported at 198 (no samples between 197 and 220 feet); E-log indicates sandstone.
221	Shale, silty, kaolinitic, light grey.
231–241	Sandstone, fine to medium grained, light grey, impure, in part calcareous, micaceous; lignite fragments.
265	Shale, silty, light grey-brown.
275–285	Sandstone, silty, light grey.
291–298	Shale, silty grey; interbedded shale, calcareous, light brownish grey.
306	Shale, kaolinitic, light grey.
312	Sandstone, impure, grey and brownish grey.
315	Shale, carbonaceous, black; sandstone, very fine grained, grey.
321–345	Sandstone, very fine to medium grained; minor white clay pockets at 321.
354	Shale, silty, grey; thin lignite bands.

The elevation of the last sample in hole MNR No. 2 is 1956 feet; hole MNR No. 1, approximately 2.5 miles to the north, and slightly up-dip from hole MNR No. 2, is believed to provide an overlap of 10 feet or more in the section.

Hole MNR No. 1: NW15–32–1–22WPM Elev. 1970 feet

Depth (in feet)	Lithology of sidewall samples
	SURFICIAL DEPOSITS
3–4	Sandstone, silty, very fine grained; marl, grey to white.

TURTLE MOUNTAIN FORMATION

5–20	Sandstone, very fine to medium grained, impure, micaceous; thin band of kaolinized sand at 9 feet; minor lignite fragments at 10 feet.
21–23	Shale, silty, dark to light grey.
24–75	Sandstone, mainly fine grained, impure, non-calcareous; lignite fragments at 39 and 66 feet.
78–90	Shale, silty, micaceous, grey; interbedded siltstone, micaceous, light grey.
98–102	Shale, silty, grey.
105–111	Siltstone, shaly, grey; lignite fragments at 111.
113–115	Shale, silty, grey to light grey; bentonitic at 114.
117–141	Siltstone, sandy and shaly, light grey; lignite fragments at 141
144–180	Sandstone, very fine to fine grained, impure, upper part calcareous; lignite fragments at 170 and 177.
180–188	Interbedded siltstone, shaly, grey, and shale, silty, light grey.
188–204	Interbedded, siltstone, shaly, light grey; sandstone, very fine grained, grey to dark grey; and shale, silty; lignite fragments at 189, 195 to 198, and 201.
207–231	Shale, silty, light grey, non-calcareous; dark grey, carbonaceous; buff calcareous; light grey, kaolinitic; coarse grains of magnetite, feldspar and quartz at 216; lignite fragments at 216 and 220.
231–235	Shale, carbonaceous, black; lignite at 234 and 235; minor pyrite.
236	Siltstone, light grey, kaolinitic.
237–250	Sandstone and siltstone, light grey.
252	Shale, light grey; interbedded thin lignite seams.
253	Lignite
255–257	Shale, carbonaceous, dark grey; lignite fragments.
258–265	Shale, silty, calcareous and non-calcareous, interbedded light to dark grey.

BOISSEVAIN FORMATION

267–321	Sandstone, fine to medium grained, "salt and pepper", non-calcareous; silty shale at 276, 297 and 306.
324–330	Shale, non-calcareous, grey; siltstone, feldspathic, light grey; plant fragments at 330.
333–360	Sandstone, fine to medium grained "salt and pepper"; grading to siltstone in lower 3 feet.
363	Shale, silty; light grey, lignite fragments.
366	Sandstone, very fine grained, silty; lignite fragments.

RIDING MOUNTAIN FORMATION

369–381	Shale, silty, light grey.
384–391	Sandstone, argillaceous, very fine grained.

The top of the Riding Mountain Formation is picked at 369 feet, at an elevation of 1601 feet; this agrees closely with the +1600 structure contour shown in Figure 31.

BOISSEVAIN FORMATION

OUTCROPS

Several outcrops on the northwest slope of Turtle Mountain show sandstone with kaolinized feldspar, kaolinitic sand, or kaolinitic shale. All these outcrops are thought to be near the top of the Boissevain Formation. As few measured sections are reported in the literature, some outcrop descriptions are listed below.

1) SW corner sec. 3, tp. 3, rge. 21WPM

Outcrop in gully, north side of P.T.H. 3, east side of creek; elevation at top of bedrock estimated at 1765 feet.

Drift: boulder clay and sand.	10 feet
Shale, pale yellowish grey, kaolinitic, slightly silty, non-calcareous, slightly micaceous.	4 feet
Shale, hard, brown, silty, with banded calcareous ironstone concretions.	6 feet
Sandstone, light grey, poorly consolidated, fine grained to silty, kaolinitic (?).	1 foot
Sandstone, kaolinitic, pale greenish grey, moderately consolidated but friable, fine grained to silty.	5 feet
Bedrock total	16 feet

2) SW corner sec. 17, tp. 2, rge. 23WPM

Possibly Boissevain-Turtle Mountain Formation contact; elevation at top of bedrock estimated at 1740 feet.

Low grade lignite; interbedded medium grey shale.	0.5 feet
Siltstone, slightly micaceous, lignitic, greyish brown.	0.5 feet
Siltstone, very fine grain, sandy, slightly micaceous; small amount of kaolinite (auger sample).	2.0 feet
Total	3.0 feet

3) NE corner l.s.d. 15, sec. 33, tp. 2, rge. 19WPM (see Plate 4A)

Outcrop on south bank of road ditch, measured at west end of outcrop; elevation at top of bedrock estimated at 1740 feet.

Shale, calcareous; interbedded slightly calcareous siltstone.	3.0 feet
Shale, slightly calcareous, yellowish grey.	3.0 feet
Shale, non-calcareous, yellowish grey; minor mica, silt.	1.0 foot
Shale, light olive grey; concretionary layers of dolomitic shale and iron oxide.	3.0 feet
Siltstone, sandy, friable; quartz, mica, feldspar, black grains.	1.5 feet
Siltstone, shaly, laminated; fossil plant impressions and carbonized remains.	1.5 feet
Shale, silty, light grey, slightly micaceous.	2.5 feet

Siltstone, shaly, light olive grey, layered, micaceous; indurated in ovoid masses. 5.0 feet

Total 20.5 feet

4) SW¼ sec. 1, tp. 3, rge. 19WPM

Outcrop on north bank of road ditch, into gully. Elevation at top estimated at 1725 feet.

Sandstone, "salt and pepper", consolidated, calcareous cement; fine grained; quartz, feldspar, iron oxide, mafic minerals	0.75 feet
Sand	3.5 feet
Shale, sandy, brown; interbedded purple concretionary layer	1.0 foot
Sand, loose; with indurated layer near top	11.25 feet
Shale, yellowish grey, silty; concretionary layer	1.0 foot
Sandstone, loosely consolidated, cross-bedded in part; some thin concretionary layers; some indurated lenses.	20.0 feet
Total	37.5 feet

Greenish grey sandstone with abundant kaolinized feldspar was seen in an outcrop in l.s.d. 15, sec. 15, tp. 2, rge. 23WPM in the ditch south of the road, and in samples from a dugout in sec. 31, tp. 2, rge.22WPM.

CHEMICAL AND MINERALOGICAL COMPOSITION

A chemical analysis of a sample from a 4-foot bed of kaolinitic shale is reported in Table 18.

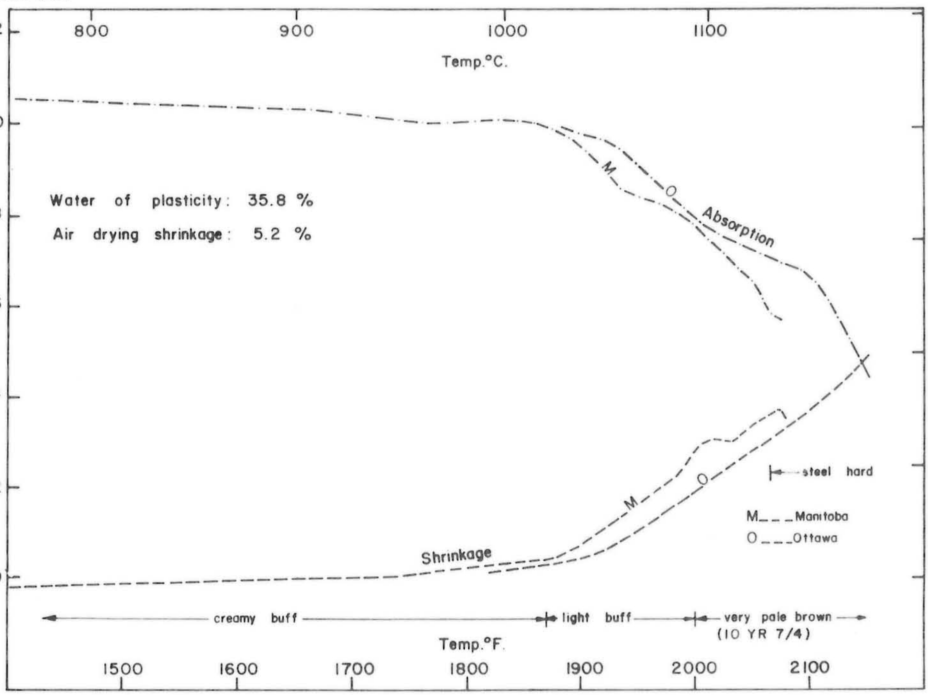


Figure 37. Temperature gradient test, kaolinitic shale, Boissevain Formation.

Table 18	Kaolinitic shale, Boissevain Formation			
Representative of a 4-foot section, SW¼ l.s.d. 4, sec. 3, tp. 3, rge. 21WPM. Analysts: MacKay and Brown	SiO_2	72.20%	K_2O	1.98%
	Al_2O_3	13.83%	MnO	nil
	Fe_2O_3	2.47%	P_2O_5	0.06%
	FeO	0.39%	CO_2	0.2 %
	TiO_2	0.85%	H_2O+ }	5.51%
	MgO	0.32%	H_2O- }	
	CaO	0.34%	Carbon	0.4 %
	Na_2O	0.53%	Total	99.08%

TEMPERATURE GRADIENT TESTS

1) Shale, kaolinitic: SW¼ l.s.d. 4, sec. 3, tp. 3, rge. 21WPM

A temperature gradient test of the light grey kaolinitic shale from a bed 4 feet thick indicated good firing properties, and a sample was submitted to the Ceramic Section of the Mineral Processing Division at Ottawa. The results of the test work were reported by H. Mercier (1966).

"Unfired characteristics: light grey non-calcareous clay, very good workability, good plasticity, water of plasticity 32.7%, tendency to crack with rapid drying (185°F), drying shrinkage 8.3%. Pyrometric cone equivalent: Cone 17; approximately 1477°C or 2690°F."

The fired characteristics are shown in Figure 37; the temperature gradient curves determined by both Ottawa and the writer are plotted.

Mercier's conclusions were: "This sample was found to be a low duty refractory clay, sufficiently refractory only for low duty fire brick. It has a rather high drying shrinkage and would require some care in drying. The firing tests indicate that it is an open-firing clay and consequently it is difficult to vitrify at temperatures common to those associated with brick and sewer pipe.

"This clay, unless combined with easily vitrified shale or low plastic clay, which might reduce its drying shrinkage and open-firing characteristics, is not by itself suitable for the manufacture of such products as facing brick and tile".

J.G. Brady (personal communication) offered the following interpretation "It is moderately refractory because of the kaolin mineral and quartz. I suspect it is open-firing because of the abundance of quartz. It is probably very plastic and difficult to dry because of the presence of a montmorillonoid."

2) Shale, brown sandy; sec. 33, tp. 2, rge. 19WPM and sec. 1, tp. 3, rge. 19WPM

Brown sandy shale occurs interbedded with the sand and sandstone of the Boissevain Formation at several localities. Samples from beds 9 inches and 18 inches thick were collected from l.s.d. 15, sec. 33, tp. 2, rge. 19WPM and SW¼ sec. 1, tp. 3, rge. 19WPM (Fig. 38); these fired hard to steel hard over 2000°F, and are orange brown to brown. The firing range, however, is short. A somewhat similar but sandier material with a greenish brown colour occurs in a 5-foot bed at the former locality, 2½ feet below the brown sandy shale. It fires a finely speckled orange-brown; it has a higher absorption because of the higher content of sand. The narrow firing range and lack of steel hardness preclude its use in face brick.

3) Shale, grey-brown: sec. 33, tp. 2, rge. 19WPM

A grey brown shale from l.s.d. 15, sec. 33, tp. 2, rge. 19WPM, occurring in the 2½-foot bed between the brown and greenish brown sandy shales, has a rather short firing range, and fairly high shrinkage; it fires reddish brown but is not steel hard at the best firing range of 1825° to 1875°F. It is not suitable for face brick.

TURTLE MOUNTAIN FORMATION

OUTCROPS

Only a small part of the total thickness of the Turtle Mountain Formation is exposed.

1) The highest known outcrop of the Turtle Mountain Formation is at NW¼ l.s.d. 15, sec. 32, tp. 1, rge. 22WPM; the estimated elevation at the top of the bedrock is 1970 feet. Test hole MNR No. 1 (p. 67) was drilled at this location. Five feet of fine grained, non-calcareous, light olive brown sand and sandstone, containing three thin iron-stained concretionary layers are exposed.

2) A section of the formation exposed in the mine trench of Deloraine Coal Mines Limited near the centre of sec. 11, tp. 2, rge. 23WPM was measured by F.D. Shepherd in 1931. The elevation at the top of the carbonaceous shale is estimated at 1842 feet.

Alluvial sand and gravel	4.4 feet
Shale, carbonaceous	8.0 feet
Lignite, badly broken	2.0 feet
Sandstone and shale, cream-coloured	5.4 feet
Lignite	2.0 feet
	Total 21.8 feet

3) An exposure along a road allowance in NE¼ sec. 24, tp. 1, rge. 24WPM, showed 10 feet of silty, brown, non-calcareous shale; the elevation at the top is estimated at 1850 feet.

4) Several exposures along a creek bed crossing township 1, range 24WPM were examined.

a) NW¼ sec. 30, tp. 1, rge. 23WPM; elevation at top estimated at 1840 feet.

Shale, silty, slightly calcareous, micaceous, yellowish grey.	2.0 feet

b) NW¼ l.s.d. 4, sec. 30, tp. 1, rge. 23WPM; elevation at top estimated at 1835 feet.

Shale, calcareous, grey; shale, silty calcareous; lignite fragments.	15.0 feet
Limestone, silty, fossiliferous; small black grains.	1.0 foot
Total	16.0 feet

c) SE¼ sec. 25, tp. 1, rge. 24WPM; elevation at top estimated at 1825 feet.

Shale, non-calcareous, grey; iron-stained silty interbands.	3.75 feet
Sandstone, fine grained to silty, olive grey, micaceous.	3.25 feet
Siltsone, argillaceous, olive grey.	1.5 feet
Total	8.5 feet

d) SW¼ sec. 25, tp. 1, rge. 24WPM; elevation at top estimated at 1815 feet.

Shale, very silty, slightly micaceous, olive grey.		0.5 foot
Lignite, shiny black		0.25 foot
Shale, grey; lignite particles.		0.5 foot
Lignite, shiny black.		1.5 feet
Shale, grey, lignite particles		1.0 foot
Lignite, blackish brown, and lignitic shale		0.5 foot
	Total	4.25 feet

CHEMICAL AND MINERALOGICAL COMPOSITION

A sample of light olive grey silty shale from SE¼ sec. 25, tp. 1, rge. 24WPM was tested in detail. The shale occurs interbedded with friable sandstone, and is exposed along the walls of a shallow ravine cutting through the section; at a lower elevation, two lignite seams separated by shale are exposed. The upper silty shale was analyzed (Table 19).

Table 19	Silty shale, Turtle Mountain Formation			
Light olive grey silty shale from 3.75-foot section in SE¼ sec. 25, tp. 1, rge. 24WPM; MacKay and Brown.	SiO_2	65.22%	MnO	nil
	Al_2O_3	14.20%	P_2O_5	0.14%
	Fe_2O_3	4.08%	CO_2	nil
	TiO_2	0.62%	H_2O+ / H_2O-	8.03%
	MgO	1.54%		
	CaO	1.20%	Carbon	1.3%
	Na_2O	1.24%	Total	99.90%

A DTA analysis of the same sample indicated the clay mineral is a mixed-layer illite-montmorillonite, with a large amount of calcium and a smaller amount of magnesium as the exchangeable cations. X-ray results indicated the presence of some kaolinite and/or chlorite in addition to illite-montmorillonite. Non-clay minerals present were quartz, forming at least 10 per cent of the shale, plagioclase feldspar, and a trace of pyrite. A small amount of organic material is present also. The shale has a relatively high iron content (Wicks, 1963).

TEMPERATURE GRADIENT TESTS

The firing properties of the sample from SE¼ sec. 25, tp. 1, rge. 24WPM were tested in the temperature gradient furnace (Fig. 39). Although the shale works easily, it has a tendency to warp, and requires slow drying. The shale fires reddish brown (2.5YR 5/6) at 1900°F. The high shrinkage would make this material unsuitable, by itself, for face brick.

Firing tests of samples of grey to brown slightly dolomitic shale from outcrops in NE¼ sec. 24, tp. 1, rge. 24WPM, SW¼ sec. 30, tp. 1, rge. 23WPM, and NW¼ sec. 7, tp. 1, rge. 23 WPM, indicate the shales have too short a firing range, and too high an absorption below 1900°F, to be of value for face brick. A sample of olive-grey argillaceous siltstone from above the two lignite seams exposed in SE¼ sec. 25, tp. 1, rge. 24WPM has similar firing characteristics.

A sample of grey shale from a 6-inch layer between the two lignite seams has a high air drying shrinkage of 10 to 14%, high firing shrinkage above 1750°F, and is steel hard at 1750°F. The fired colour is orange brown to pale light brown. Aside from the thinness of the layer, the shale is unsuitable for face brick.

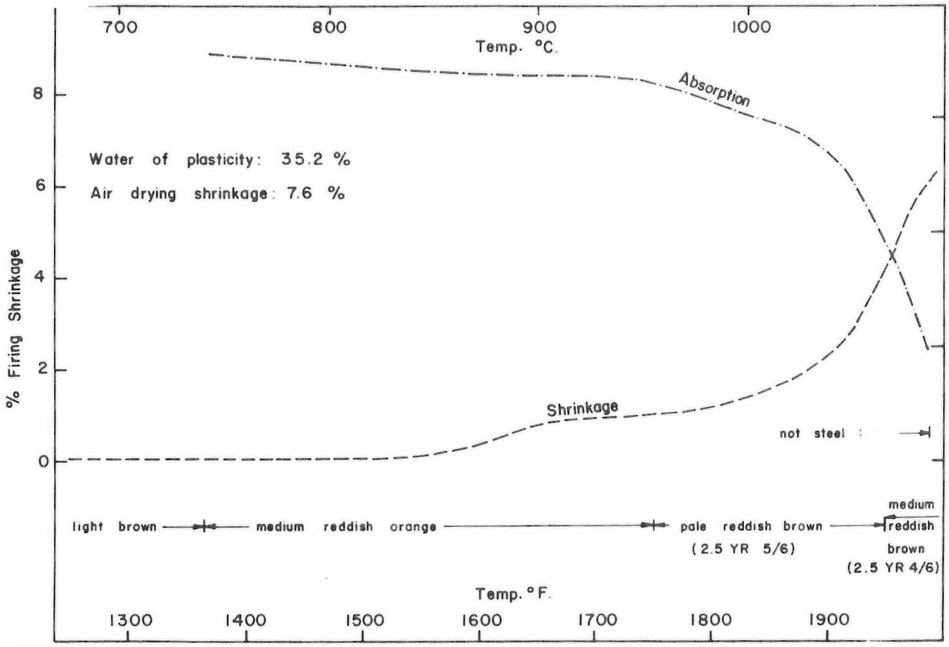


Figure 38. Temperature gradient test, brown sandy shale, Boissevain Formation, SW-1-3-19WPM.

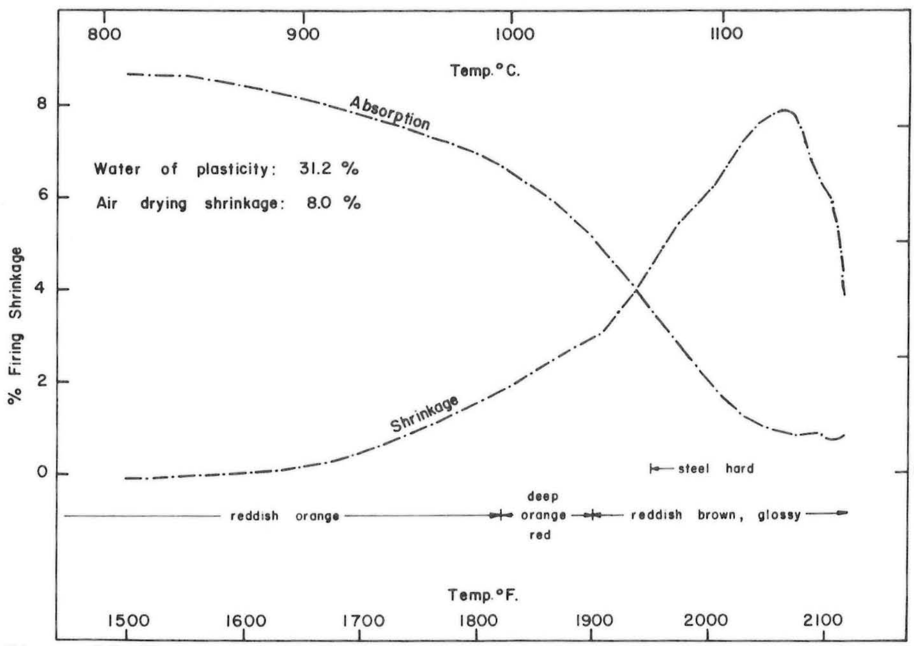


Figure 39. Temperature gradient test, silty shale, Turtle Mountain Formation.

SURFACE CLAY DEPOSITS OF MANITOBA

INTRODUCTION

Surface clays are of widespread occurence in Manitoba and include glacial, alluvial, and flood-plain deposits. Clays of glacial origin occur as thick deposits formed in glacial lakes, as parts of delta or alluvial fan deposits, in glacial outwash plains, and as concentrations formed by the re-working of boulder clay or till deposits. Clays of Recent origin occur as alluvial fillings in abandoned stream channels, as river bank clays, and as flood-plain deposits generally along or near the courses of present rivers. The surface clays show variations in chemical composition. In general they are unconsolidated heterogeneous mixtures of clays and silts; in places sand is mixed or associated with them.

During Pleistocene time, Manitoba was repeatedly covered by thick continental ice sheets which, during their advance, scraped off much of the unconsolidated surface materials, as well as some bedrock, and carried them forward. When the ice sheets melted, the enclosed materials were left behind as moraines, outwash deposits, and eskers. Because of the northeastward sloping land surface, drainage was blocked by the high front of the ice-sheet, and glacial lakes formed over much of Manitoba. Associated with the glacial lakes were beach deposits, large deltas, and in some areas thick deposits of lake clay.

Glacial lake clays occur mainly in several sedimentary basins within the areas covered by the vast glacial Lake Agassiz, the smaller Lake Souris, and associated lakes. Isolated clay areas outside the Lake Agassiz and Lake Souris basins have been reported, e.g. in the Churchill River basin.

In the period from the glacial age to the present time, the glacial deposits have undergone some erosion, while at the same time alluvial and flood-plain deposits, usually silty in nature, have formed along most of the present-day rivers. Alluvial fans have been built where streams issue from the escarpment onto the first prairie level.

LAKE AGASSIZ DEPOSITS: RED RIVER VALLEY AREA

In the area bounded by Emerson, Winkler, Portage la Prairie, and Lac du Bonnet, thick layers of clay were deposited in glacial Lake Agassiz. This vast expanse of almost level plain is broken only by a few isolated outcrops of limestone and granite along its northern and northeastern edges, and by the large sand and gravel deposits in the Birds Hill area.

In the Winnipeg area a generalized section of the material from the surface down to bedrock is given below.

	Thickness
Topsoil	0–2 feet
Recent: flood-plain and alluvial deposits	0–9 feet
Pleistocene:	
Upper unit:	
Sand, fine grained to very fine grained, yellow.	1.0 foot
Clay, greenish brown, poorly developed varves.	2.0 feet
Silt, yellow, carcareous.	0.5 foot
Lower clay unit:	
Clay, brown, well developed varves; gypsum lenses.	15.0 feet
Clay, blue grey, massive, calcareous; silt lenses.	13.0 feet
Till, grey massive, highly calcareous.	9.0 feet

Clay, light grey, pebbly, sandy.	1.0 foot
Bedrock: Paleozoic carbonate rocks	--
Total Pleistocene	41.5 feet

Local variations in this sequence include the occurrence of a 'putty layer' above the hardpan, an unconsolidated till layer overlying a consolidated till layer, and sand and gravel lenses distributed sporadically throughout the section.

The depth to bedrock ranges from a few feet in the north and northeastern parts of the area, to 40 to 60 feet in the Winnipeg area, 100 to 150 feet in the Morris to Portage la Prairie area, and between 200 and 450 feet in the area along the base of the Manitoba escarpment.

In the Red River basin, the glacial lake sediments comprise a lower clay unit deposited in deep water, and an upper silt, clay, and sand unit deposited in shallower water; recent studies have indicated several periods of low water or exposure of lacustrine sediments during the existence of Lake Agassiz.

CHEMICAL AND MINERALOGICAL COMPOSITION

a) Lower clay unit

This lower unit of the Lake Agassiz deposits is a laminated, highly colloidal clay of fairly uniform composition. It ranges in thickness from 20 to 40 feet in the Winnipeg area to 40 to 85 feet near the International Boundary. The clay unit has been divided into an upper brown slightly calcareous varved clay, thinly laminated, and a lower softer and siltier calcareous grey or blue-grey clay. The clay is very sticky when wet, and is generally referred to as "gumbo".

The mineralogy of the lower clay unit has been studied by Wicks (1965). The blue-grey clay is composed predominantly of randomly interstratified dioctahedral illite-montmorillonite, with the illite-montmorillonite ratio close to 50:50; calcium is the dominant exchange cation. The principal non-clay mineral present is mainly dolomite (increasing with depth), with minor calcite, quartz, and feldspar; traces of gypsum, limonite, and pyrite occur. The non-clay mineral content decreases from 40 per cent at the base of the bed to 25 per cent at the top. The brown varved clay has essentially the same composition, except that a minor amount of kaolinite is present. Calcium is again the dominant exchange cation, except in the upper few feet. The non-clay minerals present are the same as those in the blue grey clay, but the content decreases from 25 per cent at the base to 10 per cent at the top.

b) Upper silt, clay and sand unit of Lake Agassiz

At the base of the unit is a one-foot bed consisting of interbedded bands of medium brown clay and a slightly brownish yellow silt. Some very fine cross-bedding is present in the silt bands. Mineralogically, the lower part of the bed consists of less than 50 per cent illite-montmorillonite; some kaolinite is present. The non-clay minerals present are mainly quartz and feldspar, with some dolomite and calcite, and 2 to 3 per cent limonite. Wicks (1965, p. 32, 183) interprets the silt as being a wind-blown deposit or loess, and the clay layers as being river or intermittent lake deposits.

The overlying greenish brown clay is a few feet thick, and is very finely varved and banded in different colours: greenish brown, greenish grey, and yellowish brown. The calcareous content is low and the grain size is in the fine silt and clay ranges. The clay is composed mainly of dolomite, with calcite, quartz, feldspar, a trace of gypsum and limonite, and minute traces of pyrite.

Table 20 Chemical analyses of Lake Agassiz sediments

%	Grey Till	Lower clay unit			Upper unit		
		Blue-Grey Clay		Brown Clay	Silty Loess	Greenish Clay	Sand
SiO_2	34.57	48.85	51.38	52.55	60.57	55.09	40.55
Al_2O_3	6.27	14.25	15.31	18.73	11.77	18.26	6.30
Fe_2O_3	1.59	5.27	5.96	7.02	4.67	7.73	1.61
TiO_2	0.10	0.57	0.62	0.73	0.61	0.81	0.20
MgO	8.22	4.65	4.26	2.91	2.03	2.69	9.43
CaO	22.50	8.26	6.32	3.90	5.07	2.15	14.73
Na_2O	0.82	0.61	0.60	0.50	0.90	0.54	0.92
K_2O	1.64	2.58	2.62	2.97	2.54	3.11	1.41
MnO	0.02	0.05	0.07	0.14	0.15	0.06	0.04
P_2O_5	0.06	0.14	n.d.	n.d.	0.16	n.d.	0.15
CO_2	23.04	9.71	7.05	3.53	5.78	2.01	22.87
H_2O-	0.97	3.93	4.42	5.45	3.25	5.58	0.94
Organic Carbon ?	0.50	1.08	1.81	1.90	2.59	2.03	0.49
Total	100.30	98.85	100.42	100.34	100.09	100.06	99.64
Depth of sample	39.5 ft.	33 ft.	26.3 ft.	13 ft.	8.1 ft.	7 ft.	5 ft.

(Samples from a test hole drilled at 194 Yale Avenue, Winnipeg; analyses reported by Wicks, 1965, p. 155. The log of the hole indicates till below 36.2 feet; blue grey clay from 36.2 to 23.0 feet; brown clay from 8.3 to 23.0 feet; silty loess from 7.8 to 8.3 feet; greenish clay from 5.6 to 7.8 feet; sand from 4.9 to 5.6 feet, and topsoil and fill from 4.9 feet to surface.)

The upper sand layer is composed of fine-grained to very fine-grained yellow sand showing a crude bedding. It is composed of 46 per cent dolomite, 30 per cent quartz, about 20 per cent feldspar, about 3 per cent calcite, and only a minor amount of clay minerals, mainly illite-montmorillonite.

TEMPERATURE GRADIENT TESTS

The grey-blue gumbo clay of the lower clay unit is sticky when wet, and is difficult to dry without cracking or warping. It has a high air drying shrinkage, and when burned it has a tendency to warp and crack; it will bloat if fired too rapidly. It is thus not suitable for brick when used alone. The results of a firing test of a sample collected from a five-foot section at a depth of 25 to 30 feet in the diversion channel at the Greater Winnipeg Floodway inlet are shown in Figure 40.

The brown varved clay has poor drying properties as it warps badly. The firing test on a sample from the Floodway inlet (Fig. 41) indicates the clay has low absorption and is hard at the low temperature of 1450°F. A yellowish scum developed on the brick above 1650°F. This clay also is unsuitable for brick.

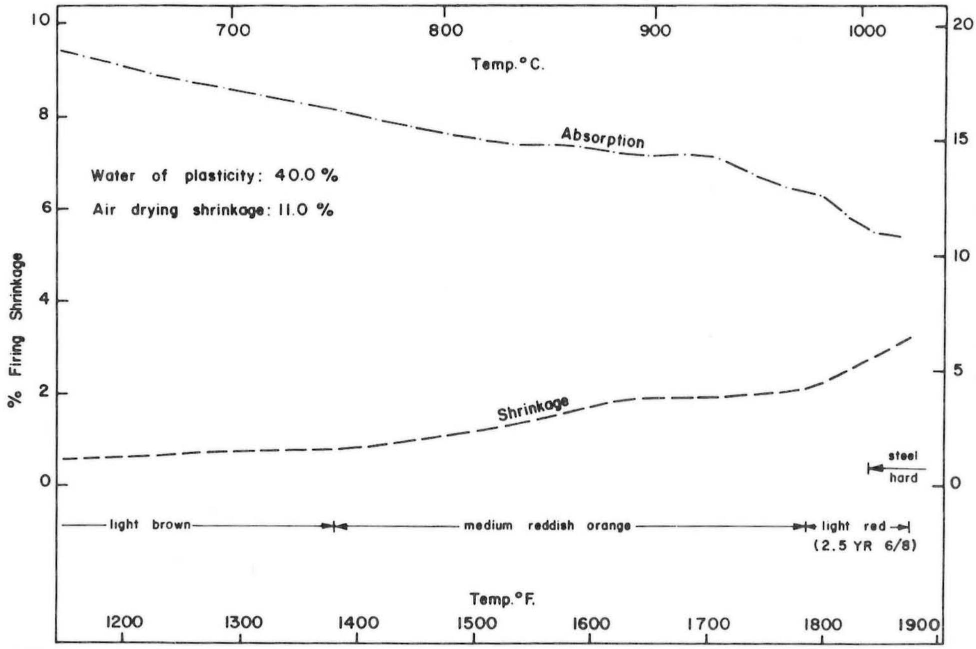


Figure 40. Temperature gradient test, grey clay, Floodway Inlet.

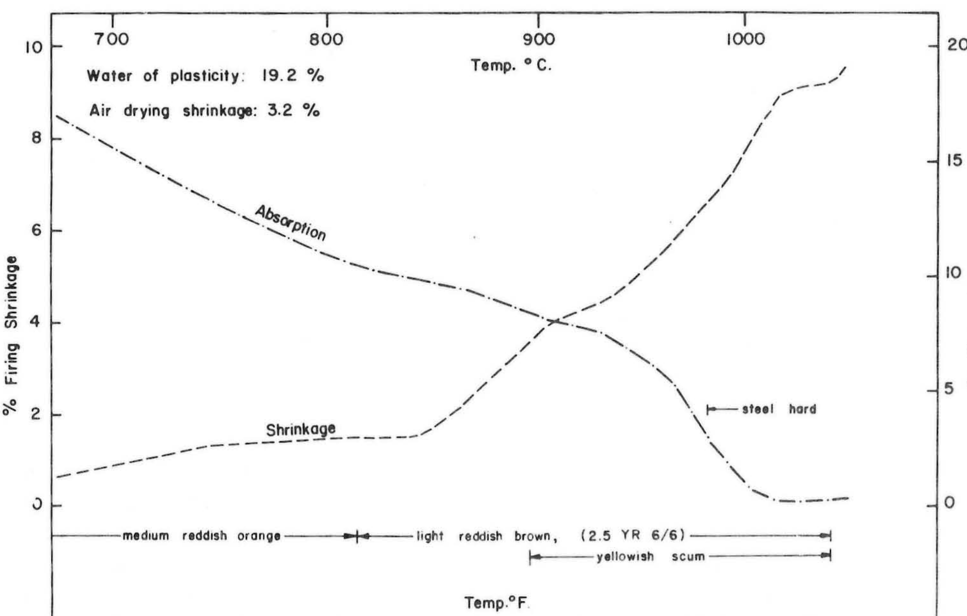


Figure 41. Temperature gradient test, brown varved clay, Floodway Inlet.

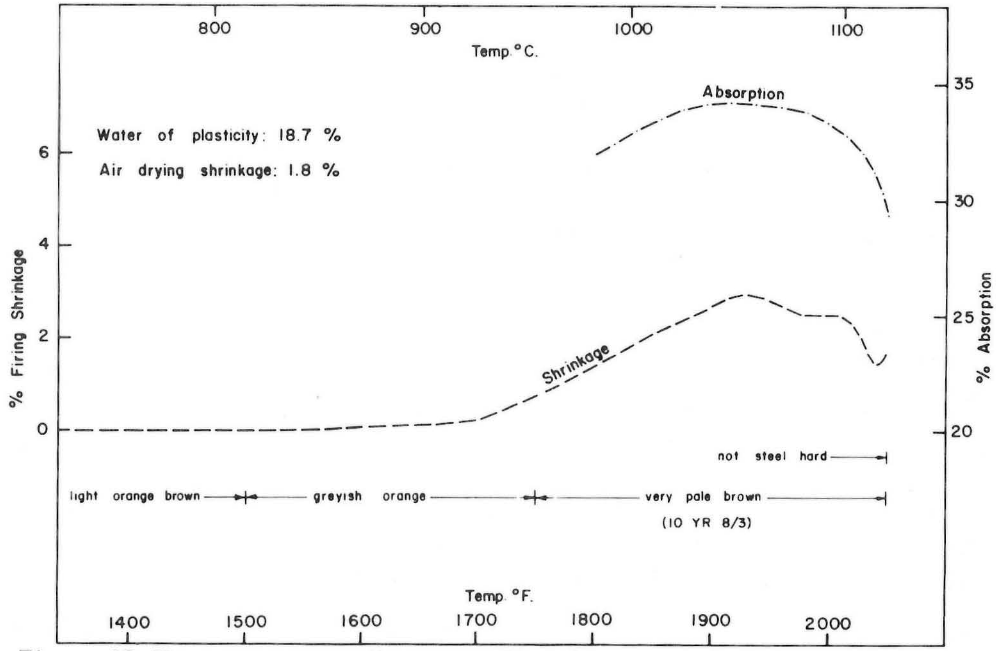


Figure 42. Temperature gradient test, silt unit.

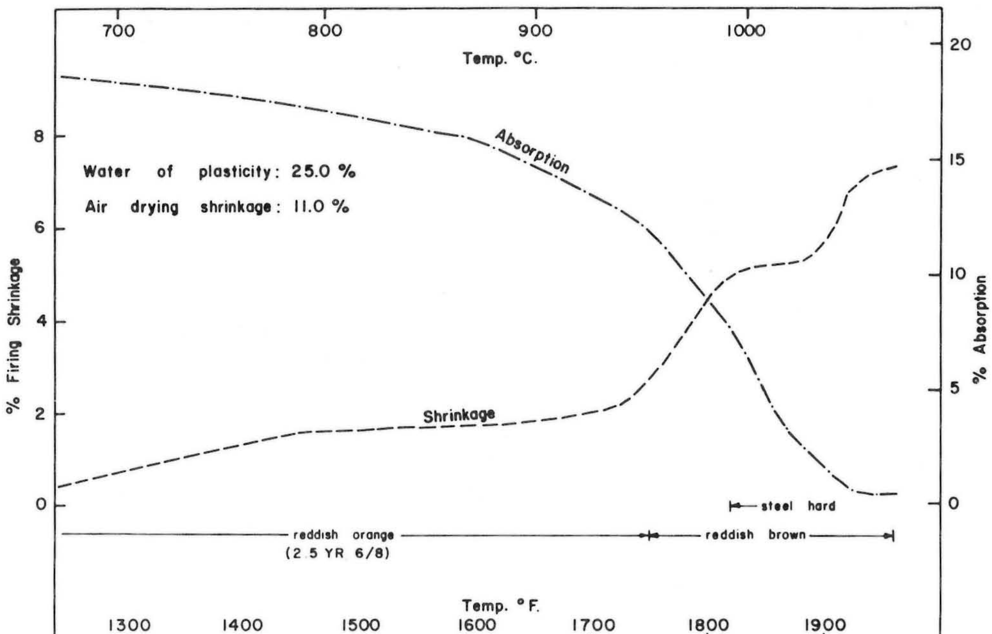


Figure 43. Temperature gradient test, upper varved clay.

Various attempts have been made to improve the drying properties of these clays (Frechette and Phillips, 1929).

1) The addition of a non-plastic material (sand or grog) in amounts up to 40 or 50%, together with chemical additives such as sodium chloride and ferric chloride improved the properties but the process may not be economic.
2) The addition of 5 to 6% hydrated lime to calcined clay or 3% caustic lime to the raw clay improved the working and drying properties, but the lime weakens the burned body and increases scumming.
3) Preheating the clay to 570°F, before molding, improves the clay, and a red, dry-press brick possibly could be produced.

The brown varved clay and the grey-blue gumbo clay are suitable for the production of lightweight aggregate as they have excellent bloating properties.

A sample of the silt unit, collected from a bed of 3 feet 5 inches thick exposed in a sanitary landfill pit in West Kildonan, has too high an absorption (Fig. 42) to be of value for brick.

The overlying varved clay, a test sample of which was collected from a 2-foot bed at the above location, has a high drying shrinkage and requires slow firing to prevent carbon coring and bloating (Fig. 43). It is not suitable by itself for use in brick.

ALLUVIAL AND FLOOD-PLAIN DEPOSITS IN LAKE AGASSIZ BASIN

Overlying the glacial lake deposits in many parts of the Red River basin is a layer of flood-plain alluvium, composed generally of silt and sand, with variable amounts of clay. The sandy clays and clayey sand are of irregular distribution, but occur notably along the Red, Assiniboine, Seine, and Morris (Boyne) rivers, in places extending several miles out from the main river channels. These materials, generally yellow and calcareous, were formerly used in the manufacture of common brick in St. Boniface, Winnipeg, Morris, Carman, and Portage la Prairie.

Elson (1961) notes that the alluvium of the Red River resembles some deposits of Lake Agassiz. It forms terraces below the Lake Agassiz plain and up to as much as 25 feet above river level. After the final draining of Lake Agassiz, the Red River eroded a valley somewhat deeper than the present one, which is adjusted to a smaller channel within the partly filled larger valley. Alluvium, mainly silty clay, is accumulating on relatively narrow trenches within the orginal valley. The change from erosional to aggradational stages is probably the result of post-glacial differential uplift of the northern part of the Lake Agassiz basin, which is still in progress.

Following the final drainage of Lake Agassiz, the Assiniboine River has been building an alluvial fan composed of sandy channel deposits, clay fillings of abandoned channels, natural levees of silty material, and backswamp deposits of clay, which are superimposed to form a considerable thickness of alluvium that has filled what was originally the south end of Lake Manitoba (Elson, 1963). Aerial photographs of the Portage la Prairie area show many of the filled, abandoned channels, and it is the clay and silty clay from these channels that has been used in common brick made at Portage la Prairie.

Alluvial deposits of somewhat similar silty clays occur along the Whitemouth River and northwards along the Winnipeg River. The material has been used in the manufacture of common brick at Whitemouth and Lac du Bonnet.

CHEMICAL ANALYSES

Analyses of alluvial clays are listed in table 21.

Table 21	Alluvial clay, Red River valley area			
		(1)	(2)	(3)
1) Light yellow calcareous alluvial clay, Winnipeg area (MacKay and Brown).	SiO_2	35.95%	54.00%	45.43%
	Al_2O_3	6.89%	9.25%	10.67%
	Fe_2O_3	2.20%	2.77%	4.78%
	MgO	11.10%	3.51%	6.03%
2) Yellow-grey unstratified clay, alluvial; Portage la Prairie (Ries and Keele, 1912).	CaO	16.70%	9.77%	10.50%
	Na_2O	0.90% }	2.34%	2.04%
	K_2O	1.58% }		
	H_2O	0.63%	8.66%	3.35%
3) Yellowish clay from open cut, Lac du Bonnet Brick works (Wells, 1905).	SO_3	n.d.	0.05%	0.13%
	By difference	24.05%	9.95%	17.07%
Total		100.00%	100.30% [sic]	100.00%

TEMPERATURE GRADIENT TESTS AND FIRING PROPERTIES

Walsh (1931) reported results of firing tests on a sample of calcareous silty clay from the St. Boniface plant of Alsip Brick, Tile & Lumber Company Limited. The clay has a water of plasticity of 28%, and an air drying shrinkage of 4.5%. Between 2000°F and 2100°F, the clay burns to a buff colour with an expansion during firing of 2.4%; absorption decreases from 31.4% to 28.3%. The fired clay at 2100°F is not steel hard.

At Portage la Prairie, a hard, buff-coloured common brick is produced when the clay is fired in the 1900°F to 2000°F range (Fig. 44). Until recent years, annual production averaged 2,000,000 bricks at the Alsip Brick, Tile & Lumber Company Limited plant.

The Lac du Bonnet clay fires a light reddish brown colour and has low firing shrinkage and low absorption in the 1875°F to 1950°F range; however, it is not steel hard, and has high air drying shrinkage (Fig. 45).

ASSINIBOINE DELTA AREA

A large delta was deposited during the early stage of Lake Agassiz at the mouth of the Assiniboine River, at that time near Brandon. The upper surface of the delta correlates with the highest or Herman Beach of glacial Lake Agassiz. The delta is of great size, covering the area bounded by Brandon, Cypress River, Lavenham, and Neepawa.

Near Brandon, the west wind of the delta consists of gravel and coarse sand. To the east, the topset beds over large areas are medium to coarse sands, which at present form the dune area extending south from Carberry. The eastern slope of the delta consists of

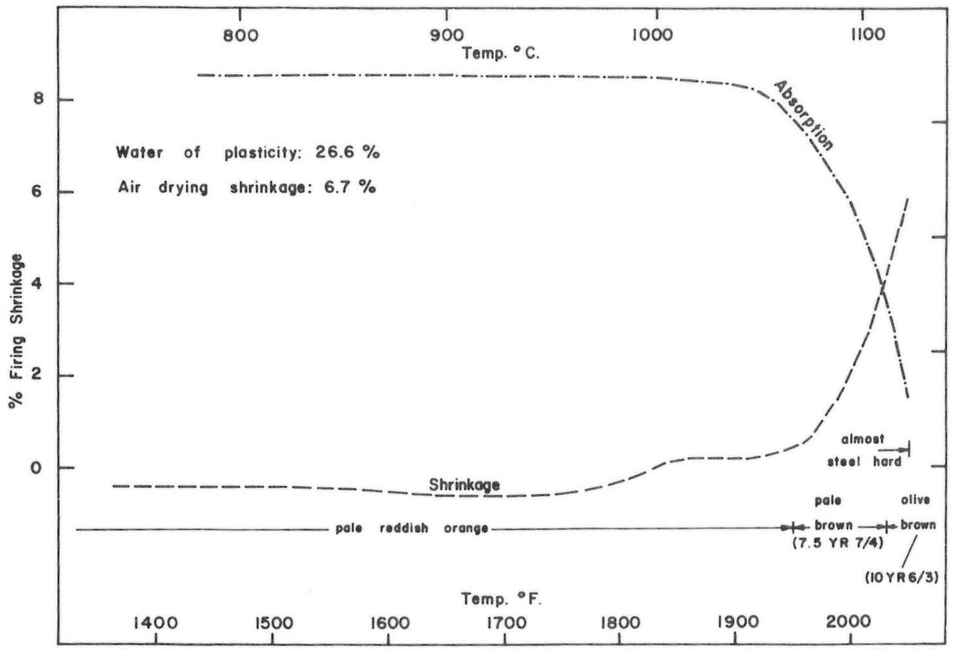


Figure 44. Temperature gradient test, buff-burning clay, Portage la Prairie.

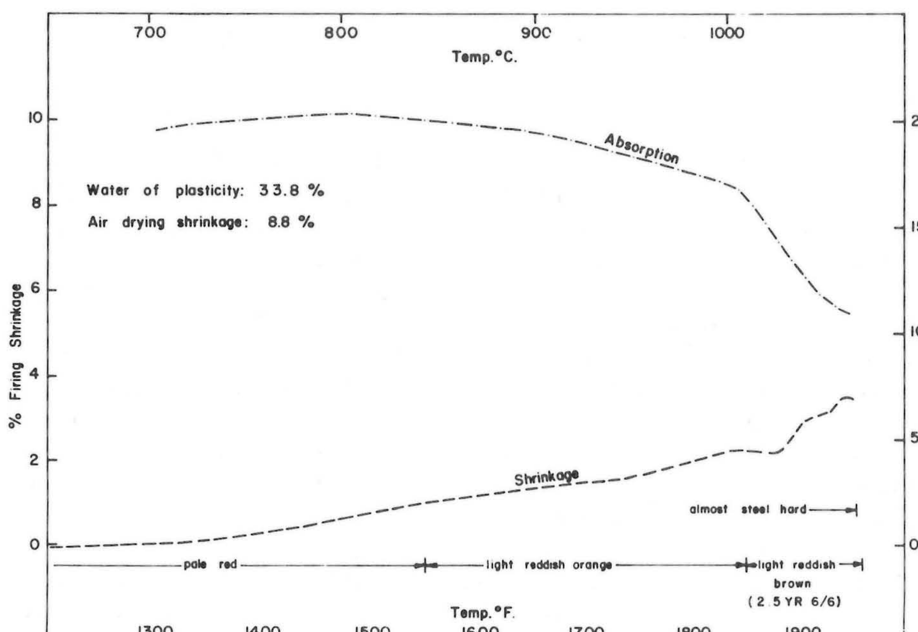


Figure 45. Temperature gradient test, Lac du Bonnet clay.

clayey silt and very fine sand. The deltaic sediments range from a few feet to more than 500 feet thick, and at their eastern end over-lap clay and silt deposited in deep water in Lake Agassiz. The delta sediments were derived both from erosion by the river and from material released by the melting ice-sheet.

CHEMICAL AND MINERALOGICAL COMPOSITION

A sample of silty clay from the pit in NE¼ sec. 6, tp. 11, rge. 12WPM, at the site of the former brick plant at Sidney, was analyzed by Brady (1961).

A DTA curve indicated the presence of illite, a small amount of montmorillonite, quartz, dolomite, calcite, and organic material. X-ray diffraction patterns confirmed the montmorillonite, and indicated the presence of chamosite or septechlorite, quartz, a mica mineral or illite, calcite, dolomite, and a small quantity of feldspar.

A chemical analysis is shown in Table 22.

Table 22	Silty clay, Sidney			
Silty clay from Sidney, NE¼ sec. 6, tp. 11, rge. 12WPM; from Brady (1961).	SiO_2	65.00%	K_2O	1.92%
	Al_2O_3	10.86%	CO_2	4.15%
	Fe_2O_3	3.57%	S	0.018%
	FeO	0.58%	H_2O (to 110°C)	1.67%
	TiO_2	0.47%	H_2O (+110°C)	3.17%
	MgO	2.24%	Organic C	0.24%
	CaO	5.23%		
	Na_2O	1.29%	Total	100.408%

Brady combined the chemical, DTA, and X-ray diffraction results to determine the mineralogical composition as quartz, 47.80%; dolomite, 4.00%; calcite, 5.10%; remainder, 43.50% (feldspar, montmorillonite-illite mixed layer clay, probably septechlorite, trace of kaolin group clay, and micaceous material).

TEMPERATURE GRADIENT TEST

A sample of the Sidney clay was studied in detail by Brady (1961), from whose report the following information is extracted.

The sample is representative of a 6- to 8-foot section of calcareous clay occurring below the surface top soil. The clay is plastic and extrudes satisfactorily under vacuum. It has a water of plasticity of 22% and an air drying shrinkage of 7%; it cracks badly when dried rapidly.

The temperature gradient curves (Fig. 46) indicate the Sidney clay is a low-fusion material with a short firing range. Both the shrinkage and absorption curves change rapidly in the temperature range where a hard to very hard red-brown brick is obtained.

The montmorillonite content of the clay is chiefly responsible for the high plasticity and difficulty in drying. The amounts of CaO, MgO, Na_2O, K_2O, and Fe_2O_3 are relatively high; these materials are active fluxes in conjunction with SiO_2 and Al_2O_3, and result in a low melting point and a short firing range. Sidney clay has a PCE of cone 4 (2167°F,

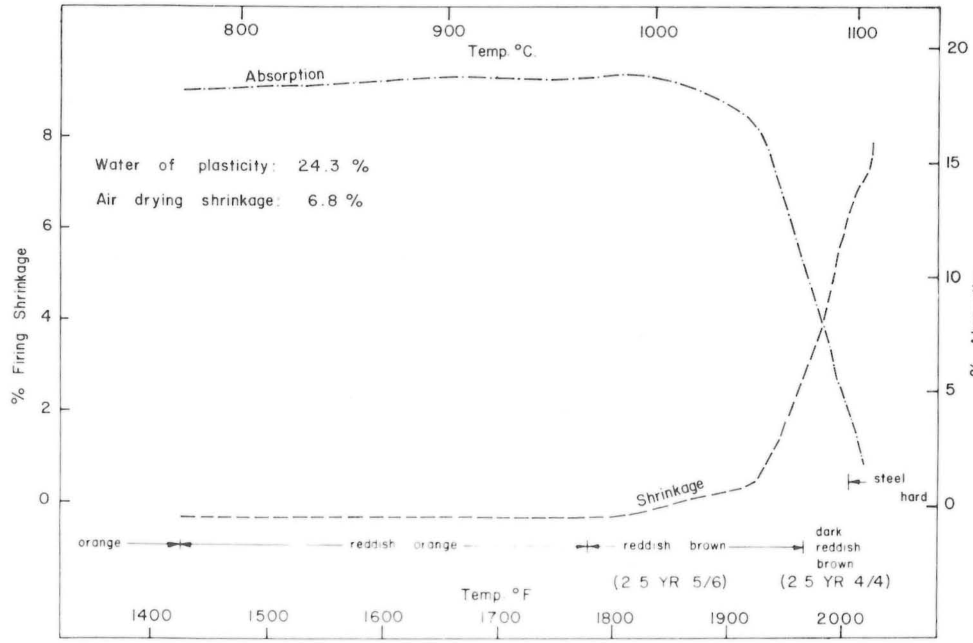


Figure 46. Temperature gradient test, Sidney clay.

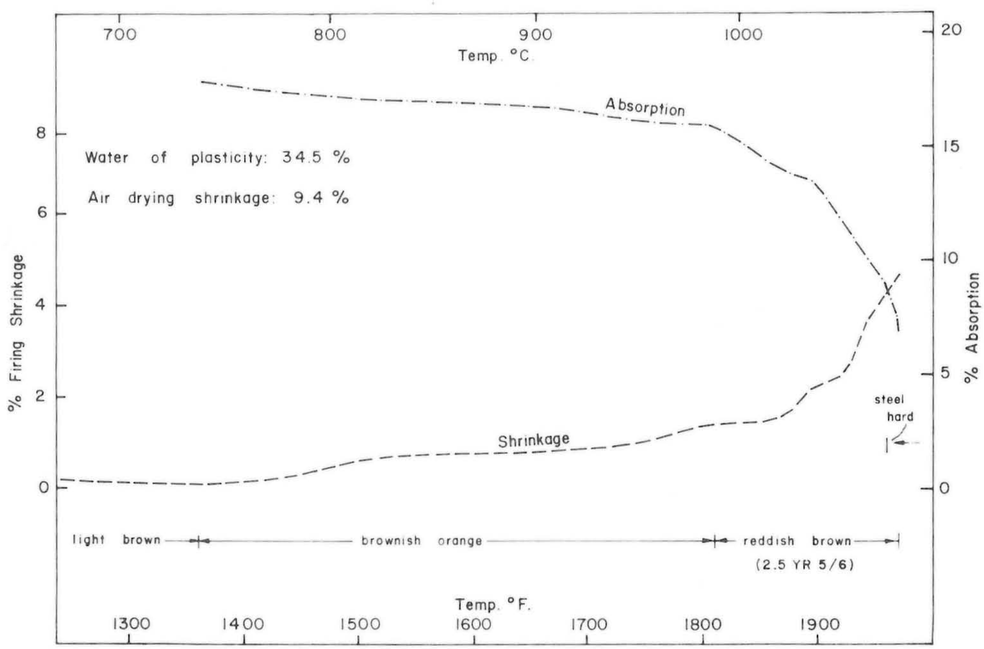


Figure 47. Temperature gradient test, surface clay, Boissevain.

1186°C). The Sidney clay fires to a salmon to red-brown colour because of the low ratio of CaO and MgO to FeO and Fe_2O_3.

GLACIAL LAKE SOURIS AREA

During the retreat of the Wisconsin glaciers from the southwest part of Manitoba, several glacial lakes formed on the second prairie level. Lake Souris, which originally covered part of North Dakota, spread northward into Manitoba. Other temporary glacial lakes in the area have been named Lake Hind, Carroll Lake, and Brandon Lake; other glacial lakes formed in the Boissevain, Killarney, Wawanesa, and Glenboro areas (Elson, 1958). The deposits of these lakes are generally silty to sandy, with some clay. Deltaic deposits formed in many places throughout the area where streams entered the glacial lakes. Recent alluvial deposits occur in the valleys of the Souris, Pembina, and Assiniboine rivers.

A temperature gradient test of a clay sample from NW¼ sec. 14, tp. 3, rge. 20WPM, southwest of Boissevain, is shown in Figure 47. This clay has the best firing properties of several surficial clay samples tested from the area around the base of Turtle Mountain. The firing properties of these clays are good for common brick, but do not meet face brick specifications.

A sample of surface clay from south of Whitewater Lake (sec. 12, tp. 3, rge. 22WPM) contains dissolved salts that form a heavy greyish yellow efflorescence on the fired brick. At 1985°F, the brick has an absorption of 16.71%, a firing shrinkage of 1.6%, and is not steel hard; it is not suitable for face brick.

Other calcareous, silty clays are present west of the Manitoba Escarpment and in the Valley River and Swan River delta areas; they have been used for common brick manufacture at Virden, Gilbert Plains, and elsewhere.

SURFICIAL CLAYS FROM AREAS WITHIN THE PRECAMBRIAN SHIELD

Lake Agassiz covered much of the Precambrian Shield in Manitoba, and lacustrine deposits are present in several sedimentary basins in the area. A comprehensive study of these deposits has never been made; the results of firing tests from selected samples are reported below.

1) Surface clay, Fort Alexander

A 10-foot section of varved clay deposited in Lake Agassiz is exposed along the south bank of the Winnipeg River near the west boundary of the Fort Alexander Indian Reserve. The clay consists of bands of smooth grey clay in layers 1/8- to 1/4-inch thick, separated by thin films of white clay. The varved clay is non-calcareous.

The temperature gradient test (Fig. 48) indicates the clay has a much lower air drying shrinkage than the varved Lake Agassiz clays in the Winnipeg area and the firing properties are superior. However, the clay requires slow firing to prevent carbon-coring and bloating.

2) Clay from Manigotagan

Two types of clay are present at the Manigotagan River Settlement, the site of a brick plant that operated from 1909 to 1913. The upper clay, approximately 30 inches thick, has poor drying qualities and high drying and firing shrinkage, but fires steel hard with low absorption at 1550°F. The underlying clay has better drying qualities and moderate shrinkage, but has a moderately high absorption when fired and is steel hard at 2075°F.

A half-and-half mixture of the two clays gives a product with good firing properties (Fig. 49). The two clays complement one another and should be suitable for face brick when mixed in the proper proportions.

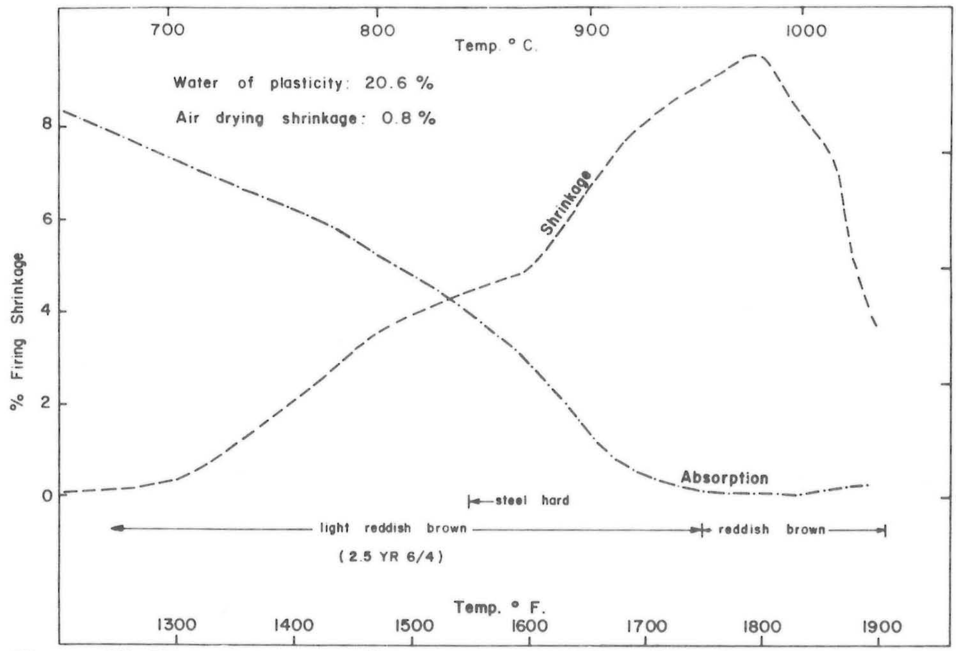


Figure 48. Temperature gradient test, varved clay, Fort Alexander.

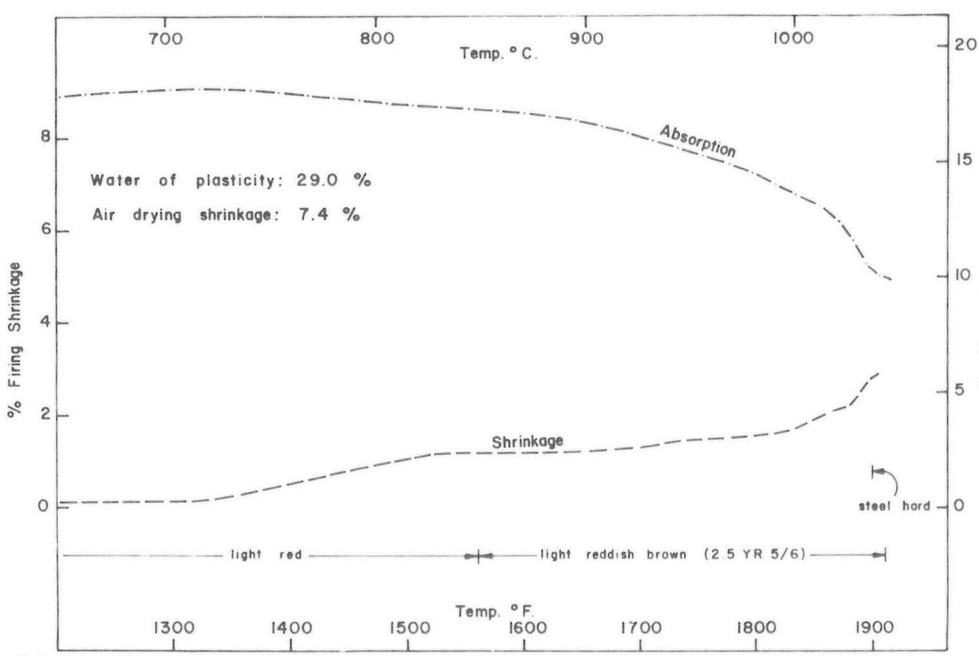


Figure 49. Temperature gradient test, mixture of two clay layers, Manigotagan.

3) Clay from Herb Lake area

A clay sample from the south end of Herb Lake has good firing properties, and meets the specifications for face brick. The sample indicates the possibility of finding clays of reasonably good quality within the Shield area; exact extent of the above deposit is not known.

4) Clay from the Thompson area

Eight samples of glacial lacustrine clays from the Thompson area were submitted by T.T. Quirke, Jr., of The International Nickel Company of Canada, Limited. The sample with the best firing properties was a weathered clay collected 1 to 3 feet below the surface, ¼ mile south of the entrance to the gravel pit on Provincial Road 391, between the town of Thompson and the airport.

The clay has good firing properties but the combined air drying and firing shrinkage is slightly high for the clay to be used by itself in face brick; the results of a temperature gradient test are shown in Figure 51.

The other samples of clay were unweathered varved clay and brown glacial clay; they are not suitable for face brick because of either high absorption, caused by high lime content, or too short a firing range at the temperatures at which the fired clays become steel hard.

PRODUCTION HISTORY OF SURFICIAL CLAYS

LIGHTWEIGHT AGGREGATE

The Lake Agassiz clays of the Red River valley are used in the production of lightweight aggregate as they are good natural bloaters. Concrete blocks made with lightweight aggregate have better thermal and insulation properties and are more fire-resistant than standard blocks, in addition to the advantages of its lighter weight.

The blue-grey laminated gumbo is a suitable raw material for the production of lightweight aggregate as it has good bloating properties and a wide vitrification range. Matthews (1952) tested the clay in a rotary kiln with an average kiln temperature of 1925°F; the product showed a volume expansion of 30%, a bulk density of 44 lbs/cu. ft., and a crushing strength of 636 p.s.i. Agglomeration of the charge started when the temperature was increased beyond 1950°F.

Similar clay from Lac du Bonnet was tested also and gave excellent results (Matthews, 1952).

Additional samples from the Winnipeg area were tested by F.S. Gamey of the Manitoba Mines Branch in 1953 and 1954. The best results were obtained by drying the blue-grey gumbo, crushing to 1/8- to 1/4-inch size, preheating to 800°F, and flash firing from 1980° to 2060°F in 8 minutes. This procedure produced rounded, coated particles with a bulk density of 17 lbs/cu. ft., but inclusion of unbloated fine particles raised the bulk density to 24 lbs/cu. ft. The degree of bloating can be varied by using different time intervals of flash firing. Hand-molded briquettes were tested in the 2000° to 2060°F range; bloated briquettes, with bulk density ranging from 35 to 65 lbs/cu. ft., were produced.

Atlas Light Aggregate Limited, in affiliation with Supercrete Limited, built a plant for light aggregate at 468 Panet Road, St. Boniface and production began in 1955. A 160-foot gas-fired rotary kiln, with a capacity of 325 cubic yards per day, is used to produce the aggregate from the clay excavated in pits up to 45 feet deep beside the plant. A second, similar kiln is present if required in the future. The clay, heated to 2200°F, expands and partially melts; the resulting clinker is crushed to sizes required for concrete block (-1/4 inch) of for pre-cast lightweight concrete (1/4 inch to 3/8 inch). Concrete blocks made with this material weigh only 25 lbs., compared with 40 lbs. for standard blocks of sand, gravel, and cement. This plant was acquired by Kildonan Concrete Products Limited in September 1965. A concrete block is made with aggregate composed of 50% regular aggregate and 50% lightweight aggregate.

Winnipeg Light Aggregate Limited began production in 1956, with a plant and quarry in Transcona; operations ceased in 1958.

Echo-Lite Aggregate Limited erected a plant at 1525 Dugald Road in St. Boniface, and production began in the fall of 1961. Based on a 24-hour operation, the plant is capable of producing 250 cubic yards per day. Grey-blue gumbo clay is processed and sized at the pit and taken to the plant where it is forced into an 8-foot by 115-foot gas-heated rotary kiln and bloated at a constant temperature of 2100°F. The product is a highly cellular, structurally strong lightweight aggregate with a vitreous coating.

The combined annual production of the companies has ranged from 2,500 to 60,240 cu. yds. of lightweight aggregate material that weighs approximately 1,600 lbs. per cu. yd.

CLAY FOR PORTLAND CEMENT

Canada Cement Company Limited uses the glacial lake clays at their Fort Whyte plant to mix with high calcium limestone from Steep Rock in the manufacture of Portland cement. The clay pits are adjacent to the plant; the clay layer is over 40 feet thick. Some of the upper silty and sandy layers are used, but as these clays generally have a higher content of magnesium than in the lower clay unit, only small quantities are used. The amount of clay used annually has increased from 45,471 tons in 1946 to over 150,000 tons in recent years. (See Plate 4B).

Inland Cement Company opened a modern highly automated plant in Tuxedo in late 1965; 50,000 to 60,000 tons of glacial lake clays are used at this plant annually.

COMMON BRICK

Surficial clays, including both alluvial and Pleistocene deposits, were used in numerous brick plants throughout southern Manitoba. Much of the historical details in the following sections were derived from the unpublished report by Walsh (1931).

a) Winnipeg and St. Boniface

Major brick plants were formerly operated in the Winnipeg area by Alsip Brick, Tile & Lumber Company Limited and by Marion Brick, Tile & Clay Products Limited.

The Alsip Brick, Tile & Lumber Company Limited was founded by William Alsip and his 3 sons in 1898; the original plant operated at Nairn and Wolfe streets. The company was incorporated in 1905. The main brick plant was located in St. Boniface, south of Marion Street. The clay pit, located 1 mile from the plant, showed 3 feet of loose organic clay, underlain by 18 inches to 3 feet of calcareous silty clay used for brick; lime pebbles occurred in pockets throughout the deposit. Sand for molding was obtained from a pit at Beausejour.

Capacity of the plant was 90,000 common brick per day, burnt in scove kilns. Face brick, drain tile, hollow blocks and bricks, and sand-lime bricks were also produced at the plant. Rough textured face brick was produced by the stiff-mud process from a mixture composed 80% of Sidney clay and 20% of glacial clay occurring below the common brick clay. The brick was a good buff to red shale.

The St. Boniface plant was closed in 1958. Production of common brick varied. In 1907 it was 17,000,000 bricks; in 1930, 7 million, in 1942, less than 2 million, and in 1956, 1/2 million. Face brick production ranged between 3/4 million and 2 million annually from 1944 to 1957.

The Marion Brick, Tile & Clay Products Limited operated a plant for soft-mud common clay brick on Plinquet Street, St. Boniface. The clay pit was located about 1 mile from the plant. The molding sand was obtained from a pit at Mile 80, Greater Winnipeg Water District Railway. The capacity of the plant was 45,000 brick per day, burnt in scove kilns. This plant operated until 1936. Silty calcareous clay, 1 to 4 feet in thickness was used for brick; it contained pockets of limestone pebbles.

The Marion Brick, Tile & Clay Products Limited opened a new plant in 1947 on Lots 22 and 23, in Old Kildonan, south of the Bergen cut-off. It was planned to make common brick and tile using a mixture of 80% clay, obtained adjacent to the plant, and 20% Odanah shale from La Riviere. Some cracking occurred during air drying of the bricks. The plant produced 350,000 common bricks in 1947, but was destroyed by fire in 1948 and never re-opened.

b) Portage la Prairie

Alluvial clays that fill abandoned channels of the Assiniboine River, north of its present course in the Portage la Prairie area, have been used for 65 years in the manufacture of common brick.

A. Snyder and Company operated a brick plant at Lee St. and Pacific Ave. in Portage la Prairie from 1903 to 1941. The plant was purchased in 1945 by Alsip Brick, Tile & Lumber Company Limited but has operated only intermittently in recent years (1964-1968).

Common brick was produced by the soft-mud process. About 5 to 9 feet of brick clay occur under 2½ feet of soil; the deposit, located beside the plant, is about 600 feet wide and extends for some distance east and west. The deposit contains grey to light yellowish plastic clay, with some silty zones; the average mixture is satisfactory for soft-mud common brick. Lime pebbles occur with the clays. Sand from pits at Beausejour and Ste. Rose du Lac was used in molding the bricks.

The clay from the pit is brought to the plant, passes through a pug mill into a standard soft-mud brick machine with a capacity of 4,000 bricks per hour. Covered drying racks have a capacity of 400,000 bricks; the bricks normally require 8 to 10 days to dry. Three double-chamber down-draft kilns have a combined capacity of 720,000 bricks. The bricks are water-smoked for 3 days in the kiln, and then fired over a period of 12 days. The burning temperature must be carefully controlled to prevent overburning. (See Plate 3B).

Annual production between 1934 and 1941 varied from 350,000 to 636,000 common bricks. In the period from 1945 to 1960, average annual production was over 2 million bricks; in this period the value of the bricks increased from $20 per 1000 to $35 per 1000. Between 20,000 and 25,000 tons of clay were used annually. In the early 1960s, clay from the Sidney pits was brought to Portage la Prairie for use in a high quality common brick. The plant has operated intermittently in recent years because of fluctuating market demand, and is idle at present.

Stephens Brick Company formerly operated two of the largest brick plants in Manitoba, one in Lot 70 north of the Canadian Pacific Railway and one in Lot 119, south of the Canadian National Railway. The clay occurrence was similar to that at the Alsip plant. The combined production in 1909 was recorded at 8,500,000 bricks; production ceased in 1922.

Whimster's Brick plant was located in Lot 120, Portage la Prairie, south of the Canadian National Railway. The operation was similar to the other plants; it closed about 1915.

c) Whitemouth

A brick plant, one mile west of Whitemouth, in N½ sec. 35, tp. 11, rge. 11EPM, was operated by D.M. Wardrop before 1923; it was inactive during World War II, and was purchased in 1945 by Alsip Brick, Tile & Lumber Company Limited; it was closed in 1957. Soft-mud common buff brick was produced. The thickness of the calcareous, silty clay bed ranges from 2 feet to 6 feet. It contains numerous sand and pebble deposits, including some pebbles of limestone.

Annual production from 1937 to 1945 ranged from ½ million to 1 million bricks and from 1946 to 1957 from 1 million to 1.7 million bricks. The plant closed in 1958.

d) Lac du Bonnet

At the Lac du Bonnet Brick yards, a yellow calcareous clay from a 10-foot bed on the banks of the Winnipeg River, was used in production of a cream coloured common brick by the soft-mud process. An underlying 8-foot bed of black stiff clay, with the addition of ground brick as grog, produced a reddish, hard common brick by the dry-press method (Wells, 1905).

Walsh (1931) described McIntosh's Brick Plant at Lac du Bonnet, located at NE¼ sec. 17, tp. 15, rge. 11EPM.

e) Other plants in Red River Valley

Ries and Keele (1912) reported a brick plant at Morris, operated by McCutcheon, about ½ mile south of the town. The yellow surface clay was used to produce buff common brick.

Another plant was reported to have operated at one time at Carman, using flood-plain, sand, silt, and clay along the banks of the Boyne (Morris) River. The bricks were light red in colour, and soft.

f) Assiniboine delta

Silty clays within the eastern part of the Assiniboine delta have been used for brick-making at several locations.

At Sidney, a silty clay was used alone in the production of red face brick and common brick at a local plant, and was also shipped to St. Boniface by Alsip Brick, Tile & Lumber Company Limited where it was mixed with 20% of the Lake Agassiz gumbo clay and used in face brick. In the mid-1960s clay from the Sidney deposit was trucked to the Alsip plant at Portage la Prairie and used in common brick. The clay pit is located in NE¼ sec. 6, tp. 11, rge. 12WPM.

A deltaic clay deposit at Edrans, 20 miles southeast of Neepawa, has been worked periodically by several companies. National Clay Products Limited produced both face brick and common brick in 1930 and 1931. Western Clay Products operated the plant from 1938 to 1940 and again, under W.E. Hales, in 1949, when the last kiln load was fired. The clay deposit at sec. 35, tp. 12, rge. 13WPM, consists of an upper layer of calcareous silty clay not suitable for face brick (because of high absorption, very short

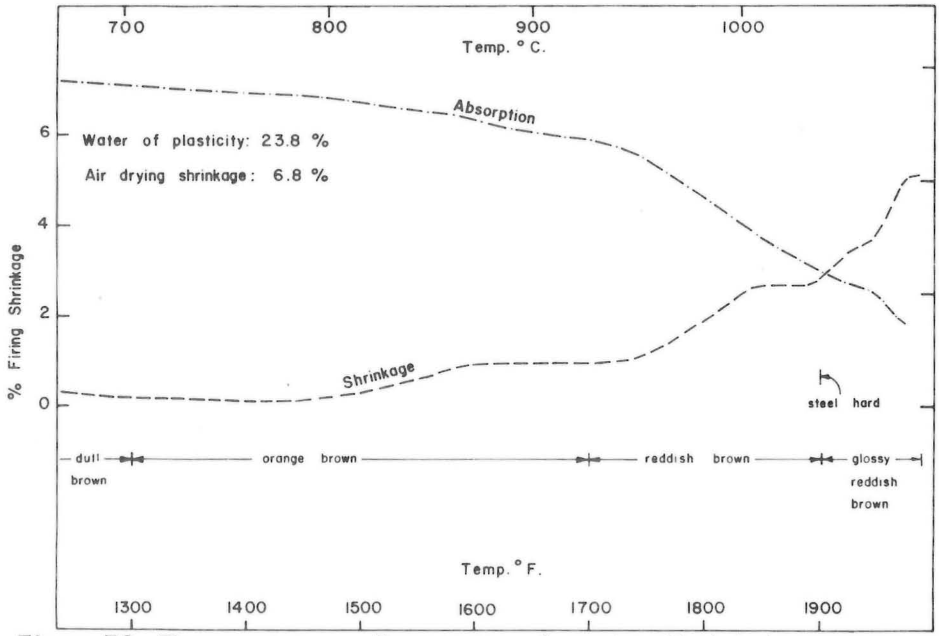


Figure 50. Temperature gradient test, surface clay, Herb Lake.

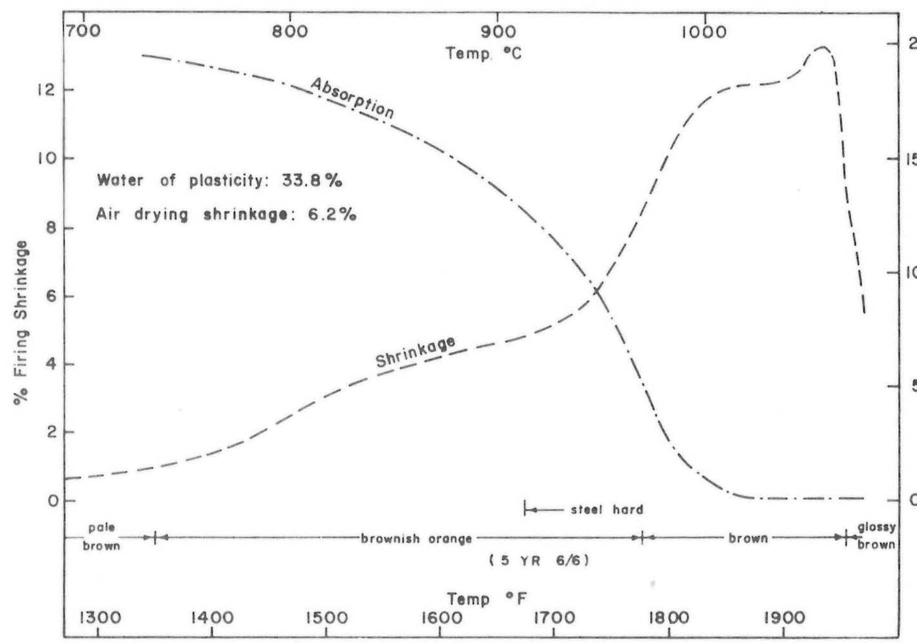


Figure 51. Temperature gradient test, weathered surface clay, 2 miles north of Thompson.

firing range, and lack of hardness), and a lower layer of greyish to yellowish brown clay somewhat similar to the clay at Sidney. The lower clay requires slow air drying and has a short firing range (1975° to 2025°F) in which a hard brick of red colour is produced. Brick from the plant has been used in several buildings in Winnipeg, Brandon, Regina, and elsewhere.

Several other brick plants operated at one time in the Assiniboine delta area at Neepawa (NW¼ sec. 21, tp. 14, rge. 15WPM), Gladstone, Brookdale (NE¼ sec. 26, tp. 12, rge. 16WPM), Lavenham (SW¼ sec. 6, tp. 10, rge. 10 WPM), and Cypress River (NE¼ sec. 1, tp. 7, rge. 13WPM and NW¼ sec. 8, tp. 7, rge. 12WPM). Most of these brick plants produced common brick sometime in the period between 1905 to 1915. The clay used in most cases was a calcareous surface clay such as that found in the upper part of the Edrans deposit. In general, light red to buff, soft bricks with high absorption were produced.

The clay from a deposit 1½ miles west of Firdale was once shipped to Winnipeg by Alsip Brick Tile & Lumber Company Limited, until a better burning clay was obtained from Sidney.

Temperature gradient tests on other samples collected within the Assiniboine delta area indicate the red-burning silty to sandy clay is of widespread occurrence.

g) Other areas

In the area west of the Manitoba Escarpment, common brick was formerly produced from the surface clays (some of alluvial, some of glacial origin) at Virden, Brandon, Hartney, Melita, Souris, Souris City, Deloraine, Wawanesa, Gilbert Plains and Killarney. The deposits consist generally of a few feet of silty calcareous clay, underlain by stiffer, bluish clay. The bricks produced were light red to buff soft-mud common bricks, usually with fairly high absorption.

Parkinson (1957, pp. 169-171) describes the brick-making operations atHartney. Reddish common brick of good quality were produced from a deposit west of Hartney in 1895. In 1897, a clay deposit north of town suitable for the production of hard white bricks was discovered, and operated for several years. Bricks from this plant were used in the legislative building in Regina.

Numerous other small brick plants operated in Manitoba, but few traces remain of these plants that supplied the brick required during the period of rapid development and settlement of the province.

GLOSSARY

Absorption: the relationship of the weight of the water absorbed to the weight of the dry brick, expressed as a per cent.

Air drying shrinkage: the relationship of the amount of shrinkage to the length of the plastic brick, expressed as a per cent; measured at 185°F.

Common brick: brick used for rough work, or for filling in or backing; requirements are outlined in CSA specifications, under which grade NW is classed as common brick.

Down-draft kiln: an enclosed kiln in which the hot gases are forced to the crown, pass down through the brick by the draft, and discharge into a stack.

Drain tile: short length pipes of fired clay laid with open joints to collect and remove drainage water.

Dry-press brick: clay or shale is mixed with sufficient water to make them coherent; bricks are formed under pressure in a steam-heated mold.

Efflorescence: surface deposits formed on brick after exposure to weather, caused by soluble salts in either the brick or the mortar.

Firing shrinkage: the percentage change in length during the firing process, measured in respect to the pre-fired length; in some cases, expansion occurs during firing.

Green strength: the strength of molded or formed ceramic material before it is fired; measured either in wet or dry state.

Grog: ground up brick or burned clay, used to reduce the shrinkage of plastic clays.

Pyrometric cone eouivalent (PCE): the number of that standard pyrometic cone whose tip would touch the supporting plaque simultaneously with a cone of the refractory material being investigated, determined by standard test procedures; the approximate fusion point of a ceramic material.

Scove kiln: an updraft non-permanent kiln built of unfired brick.

Scum: surface deposits formed during drying or firing process, caused generally by presence of soluble salts in raw material.

Sewer pipe: an impervious clay pipe, with or without a glazed surface, used in sewage disposal.

Soft-mud brick: water is added to a sandy clay until the mix will flow into sand-dusted molds.

Stiff-mud brick: sufficient water is added to ground shale or clay to yield a stiff plastic mix which is extruded through a die; bricks are cut in batches from the extruded strip.

Tapestry brick: stiff-mud brick having surfaces roughened by wire cutting, and generally used for exteriors.

Water of plasticity: the percentage of water required to render clay or ground shale plastic, related to the dry weight of material.

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VALUE OF CLAY PRODUCTS OF MANITOBA: 1886 to 1969

APPENDIX I

Production figures for clay products in Manitoba are available only from 1886; figures for 1871 to 1885 and from 1893 to 1897 have not been recorded.

Production of bentonite began in 1937; the value of its production is not included in the figures for 1937 to 1963, but is included from 1964 to 1969 as separate figures for bentonite are not available for these years.

1886		$14,475
1887		8,125
1888		2,400
1889		19,636
1890		15,300
1891		13,300
1892		65,450
1893–1897		no data
1898		34,000
1899		25,000
1900		25,000
1901		20,000
1902	Includes Sask. and Alta.	150,000
1903	Includes Sask. and Alta.	150,000
1904	Includes Sask. and Alta.	150,000
1905		588,735
1906		517,065
1907		466,432
1908		265,091
1909		559,008
1910		781,605
1911		834,428
1912		1,018,051
1913		514,358
1914		317,488
1915		93,674
1916		104,248
1917		114,651
1918		116,417
1919		131,737
1920		206,764
1921		208,982
1922		210,740
1923		160,134
1924		117,450
1925		173,794
1926		248,497
1927		201,464
1928		291,791
1929		362,240

1930	215,967
1931	122,628
1932	49,773
1933	20,966
1934	37,916
1935	74,755
1936	55,564
1937	94,377
1938	105,344
1939	78,301
1940	100,883
1941	83,487
1942	42,090
1943	21,954
1944	37,115
1945	100,366
1946	165,348
1947	138,732
1948	181,178
1949	154,114
1950	157,340
1951	177,295
1952	189,640
1953	152,919
1954	219,424
1955	250,554
1956	424,563
1957	374,405
1958	174,592
1959	226,742
1960	279,721
1961	188,903
1962	218,184
1963	209,512
* 1964	519,726
* 1965	482,620
* 1966	487,172
* 1967	526,405
* 1968	451,358
* 1969(p)	448,719

*Figures include value of bentonite production.

APPENDIX II

DIFFERENTIAL THERMAL ANALYSIS CURVES

A report on DTA and X-ray powder photograph analyses on selected clay and shale samples was prepared in 1963 for the Manitoba Mines Branch by F. Wicks at the Geology Department, University of Manitoba.

The DTA unit used was a model DTA 13M manufactured by Robert T. Stone Co. of Austin, Texas. A dynamic gas atmosphere was used, resulting in reactions occurring at slightly lower temperatures than in a static atmosphere. The three gases used were nitrogen (to suppress oxidation), oxygen (to induce oxidation), and carbon dioxide (to suppress the decomposition of carbonates).

The heating rate of the furnace was approximately 9.5°C per minute up to 600°C and approximately 10°C per minute up to 1000°C. Each pip on the thermogram indicates 100°C; endothermic peaks go down and exothermic peaks go up. The curves obtained are reproduced in Figs. 53, 54, and 55; the atmosphere used is indicated for each curve. The results of their interpretation, together with data from X-ray analyses have been reported under the section describing the clay or shale tested.

The samples tested are listed in Table 23 in the order in which they are discussed in this report.

Table 23. Samples tested by DTA and X-ray powder photograph methods.

Sample	Description	Location
D-3	Swan River dark grey shale	SW¼ sec. 10, tp. 37, rge. 26WPM
D-4	Swan River light grey shale	SW¼ sec. 10, tp. 37, rge. 26WPM
D-6	Arborg kaolin	NW¼ sec. 14, tp. 24, rge. 1EPM
D-5	Pine River kaolin	l.s.d. 3, sec. 2, tp. 33, rge. 20WPM
D-9	Ashville shale, middle	SW¼ sec. 24, tp. 25, rge. 21WPM
D-16*	Ashville shale, top	SW¼ sec. 13, tp. 24, rge. 20WPM
D-8	Favel shale, Riding Mtn.	SW¼ sec. 13, tp. 24, rge. 20WPM
D-15*	Favel shale, Pembina Mtn.	NE¼ sec. 26, tp. 8, rge. 11WPM
D-2	Morden shale, Learys	SW¼ sec. 13, tp. 6, rge. 8WPM
D-17*	Morden shale, Pembina R.	l.s.d. 4, sec. 6, tp. 3, rge. 5WPM
D-20*	Morden shale, Riding Mtn.	SW¼ l.s.d. 15, sec. 23, tp. 23, rge. 20WPM
D-7	Boyne shale, Pembina R.	l.s.d. 5, sec. 8, tp. 1, rge. 6WPM
D-12	Boyne shale, Riding Mtn.	SW¼ l.s.d. 15, sec. 23, tp. 23, rge. 20WPM
D-13*	grey Boyne shale	NW¼ sec. 11,tp. 6, rge. 8WPM
D-14*	buff Boyne shale	NW¼ sec. 11, tp. 6, rge. 8WPM
D-11	Pembina shale	l.s.d. 5, sec. 21, tp. 2, rge. 6WPM
D-1	Odanah shale, Pembina Mtn.	NE¼ l.s.d. 13, sec. 12, tp. 5, rge. 8WPM
D-18*	Odanah shale,Pembina R.	E½ sec. 30, tp. 3, rge. 9WPM
D-19*	Odanah shale, Riding Mtn.	SW¼ sec. 19, tp. 13, rge. 26WPM
D-10	Turtle Mountain shale	SE¼ sec. 25, tp. 1, rge. 24WPM

*Tested by DTA only

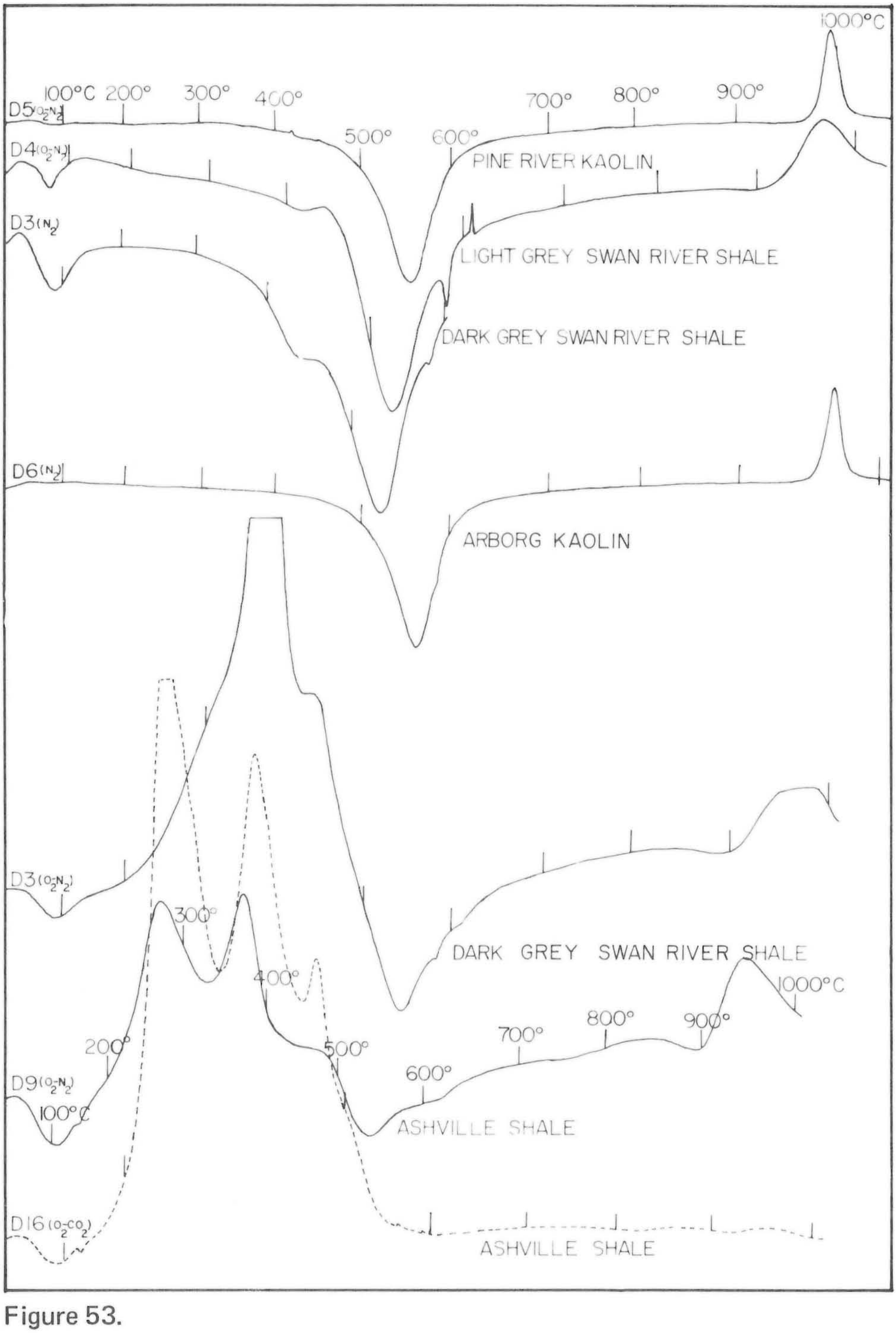


Figure 53.
DTA curves, kaolinitic clays, Swan River Group, and Ashville Formation.

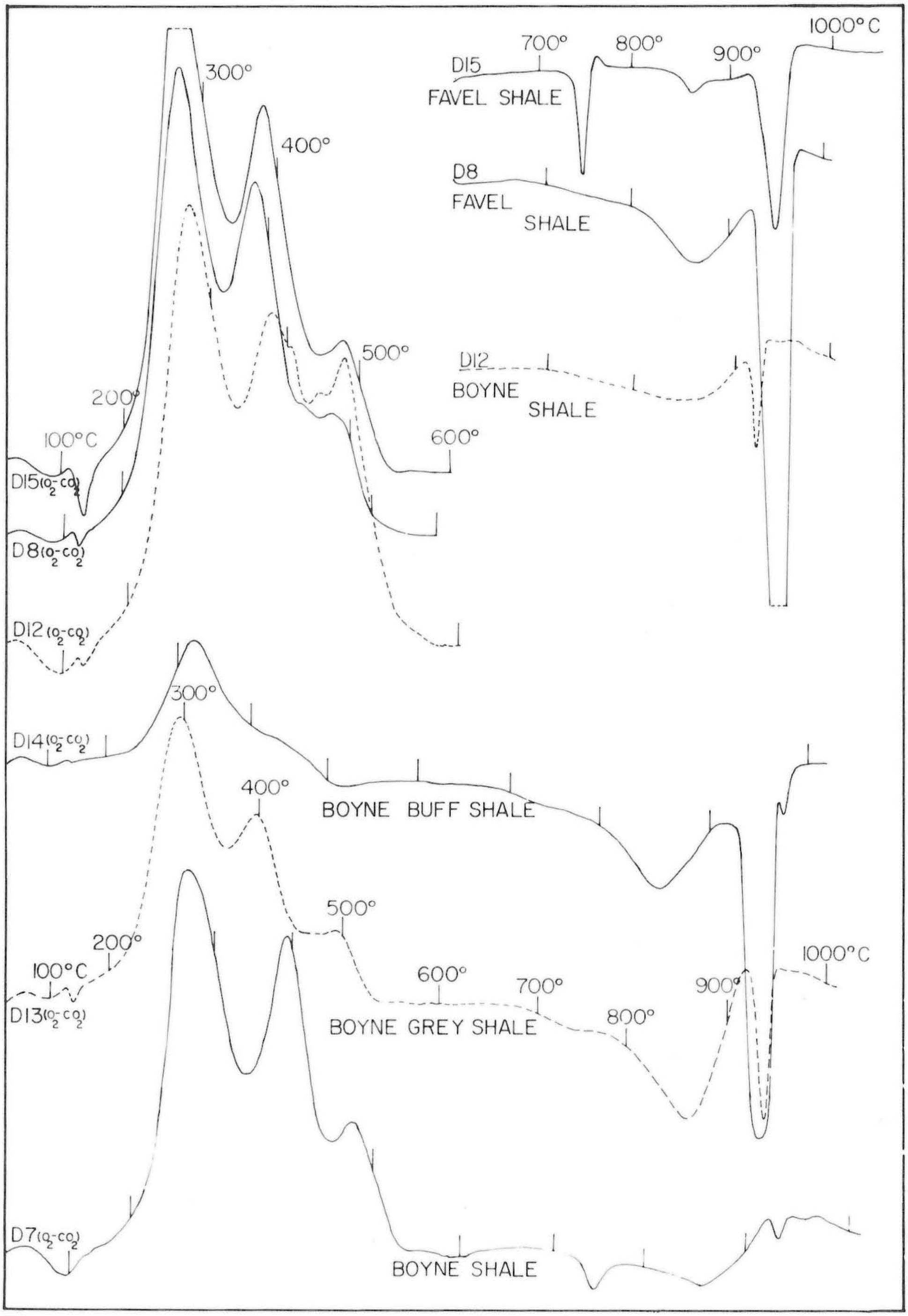


Figure 54.
DTA curves, Favel Formation and Boyne Member shales.

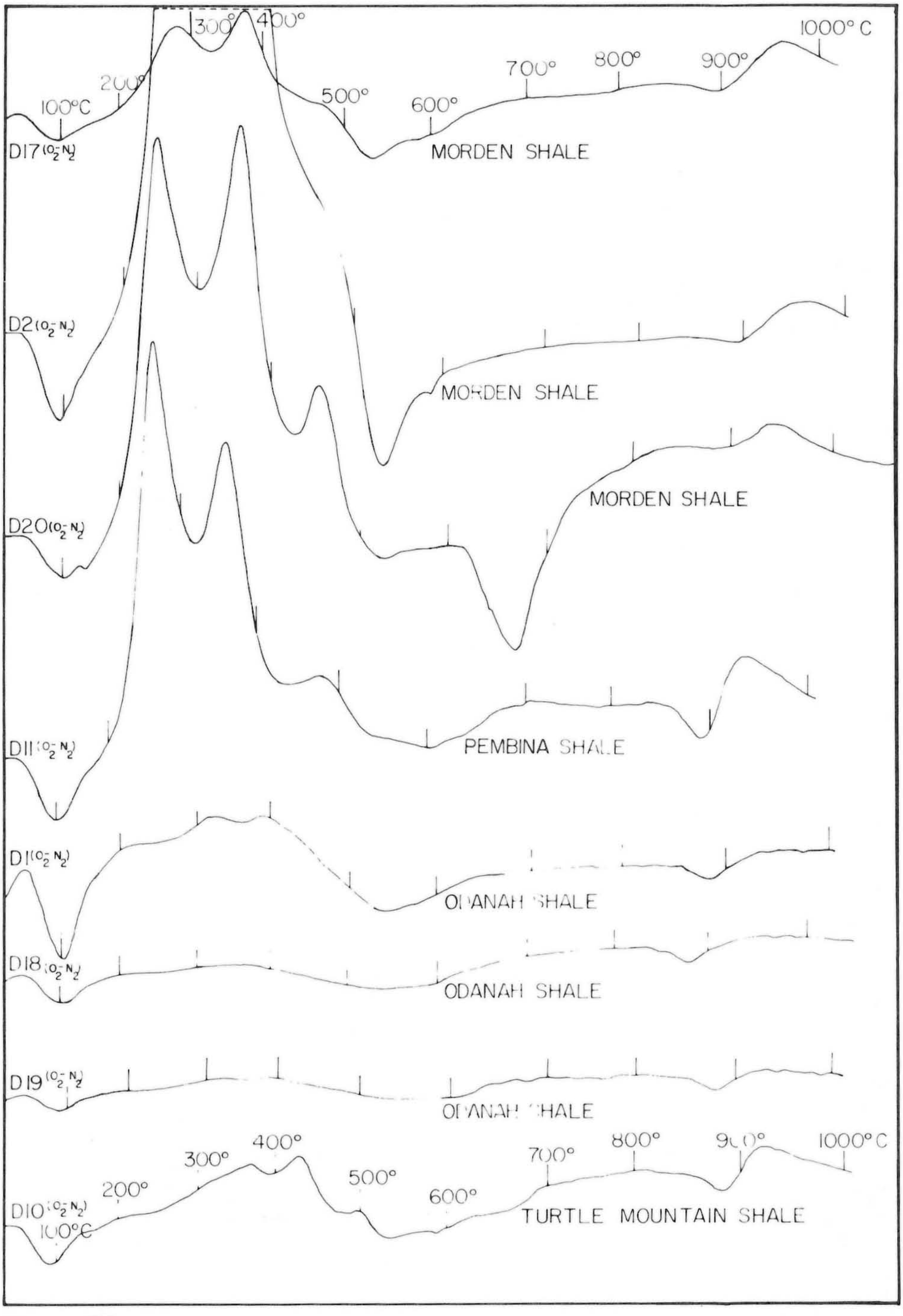


Figure 55.

DTA curves of Morden, Pembina, Odanah, and Turtle Mountain shales.

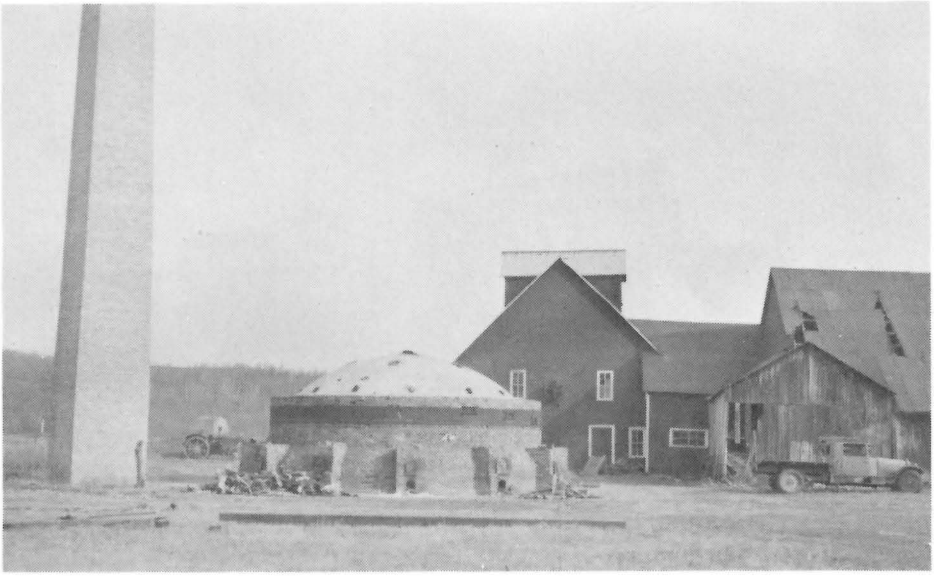
PLATE 1

1A. Sandstone and shale beds of the Swan River Group outcropping along Swan River.

1B. Buff and grey calcareous shale Boyne Member, Boyne River valley near Babcock.

PLATE 2

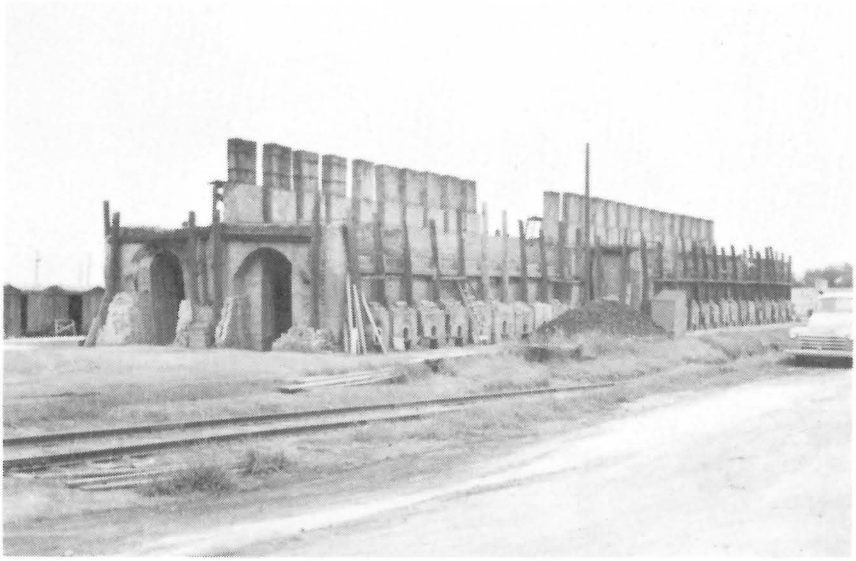
2A. Boyne and Morden Members exposed along Vermilion River, l.s.d. 15, sec. 23, tp. 23, rge. 20WPM.



2B. Beehive kiln and stack at Leary's brick plant.

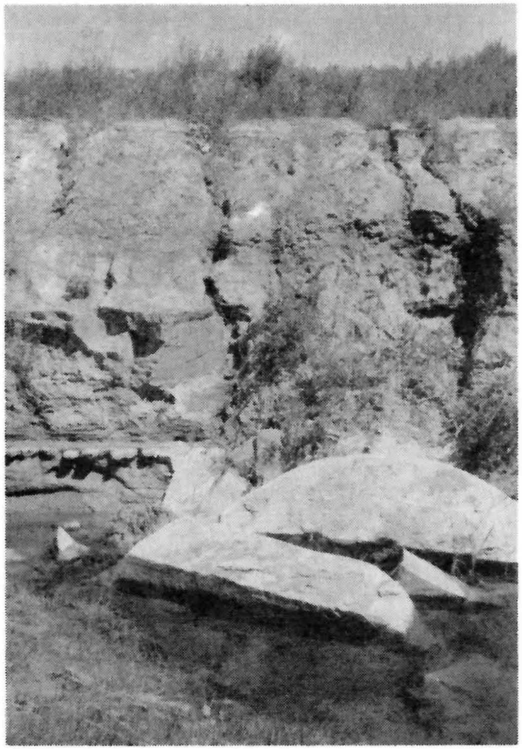
PLATE 3

3A. Twin Sisters Buttes on the Manitoba Escarpment, eroded from the Millwood Member.

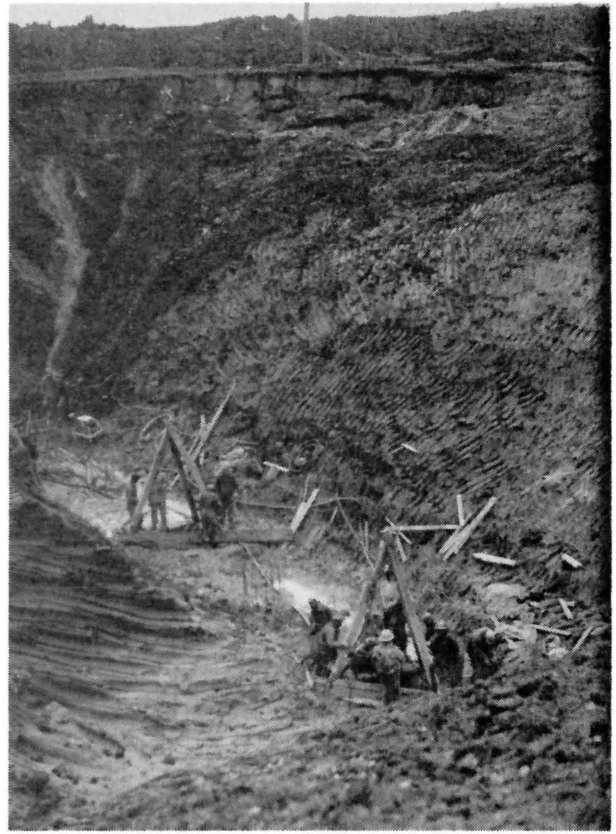


3B. Double chamber down-draft kiln at the Portage la Prairie brick plant, Alsip Brick, Tile & Lumber Company Limited.

PLATE 4



4A. Sandstone and shale. Boissevain Formation; south ditch of P.T.H. 3 east of Boissevain.



4B. Early photograph of clay pit, Canada Cement Company, Fort Whyte.