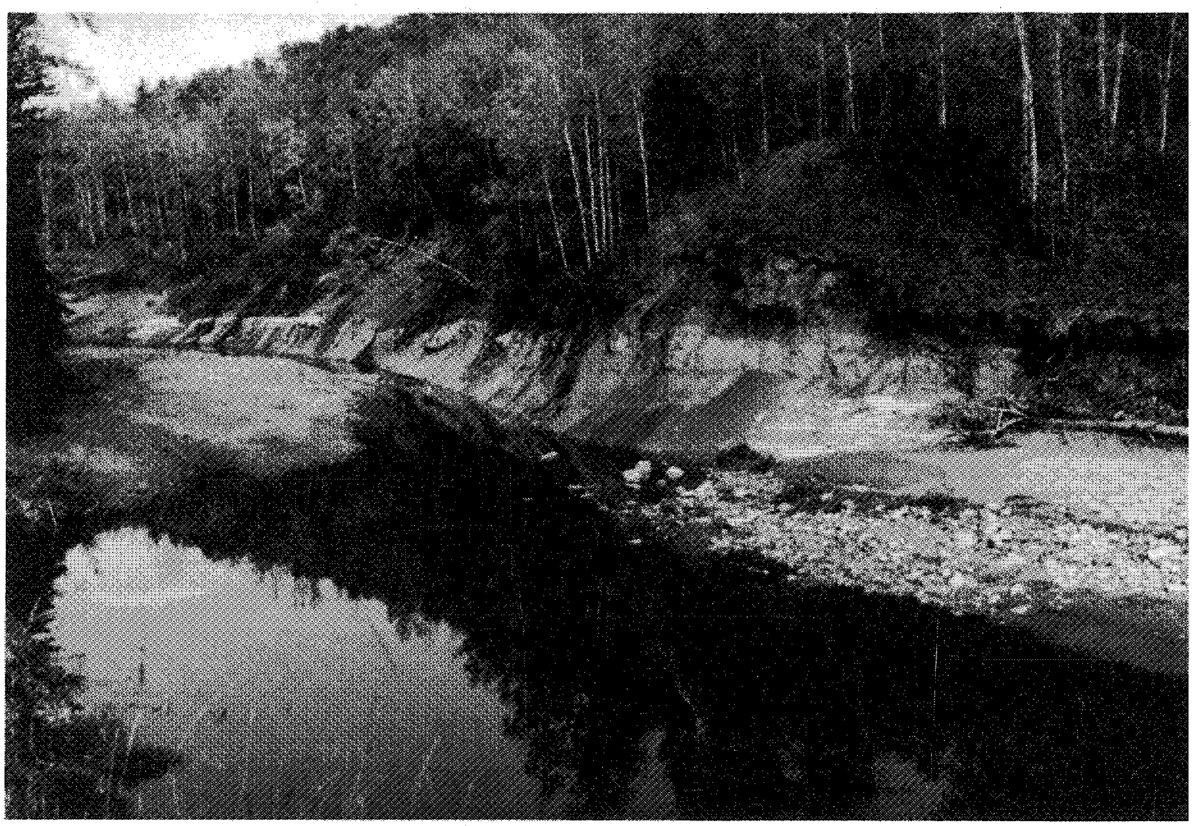
Economic Geology Report 7

The Ceramic Potential of Alberta Clays and Shales

D.W. Scafe



Alberta ENERGY
Alberta Geological Survey

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Cover:
Shales of the Battle Formation are lowest in alkali content of any clay or shale in Alberta, and easily meet the 1.4% maximum specified for manufacturing low alkali cement. The dark material in this photo is at the lower contact of the Battle Formation on Strawberry Creek at 1-6-50-1-W5. Nearby the formation is approximately 10 m thick.

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Contents

Tables

Figures

Appendices

Acknowledgments

The consistent femininity, good humor, scheduling and accurate observations by Marilyn Hnit, Susan Putz, Lovorka Swenson and Dianne Goulet through the uncleanliness of laboratory processing of all samples is worthy of panegyric. The field and editorial assistance of Wylie Hamilton helped smooth the rocky path from inception to fruition of the project. Valuable literary modifications were suggested by Laurence Andriashek, Ken Babcock, Dixon Edwards, Bob Green, and Grant Mossop for this or previous publications associated with this study. Joan Checholik and Diane Harnden confronted the formidable task of typing nearly unwieldly tables in the earlier publications and achieved their usual neat and accurate product. Linda Jones later entered the much-expanded tables into the computer for future manipulation. Mike Shayna, director of research at I.XL Industries, has tested many of the province's clays and shales and always has been generous with his time whenever information was requested.

Abstract

Many geographical areas and geological formations were missed when the ceramic suitability of materials was studied early this century. This study provides new data on the ceramic properties of nearly every geological formation in Alberta with ceramic potential and brings together all previously published data in a consistent format. Geological formations that are useful for the production of structural clay products or pottery are Pleistocene glaciolacustrine sediments, Ravenscrag, Scollard, Eastend, Judith River, Belly River and Kaskapau formations and McMurray Formation basal clays. Units, or selected material from the units, that need more testing to confirm use for the production of structural clay products or pottery are the Brazeau, Paskapoo, Frenchman, St. Mary River, Whitemud, Bearpaw, Cardium, Blackstone and Dunvegan formations and Ft. St. John, Luscar and Kootenay groups. The Porcupine Hills, Horseshoe Canyon, Lea Park and Kaskapau formations could be used for production of expanded aggregate. Further testing of the Paskapoo and Dunvegan formations also is suggested for this use. Selected materials in the Whitemud Formation and McMurry Formation basal clays may be useful for low heat duty refractories. Shales of the Battle Formation can be used in the production of low alkali cement. Units considered to have no ceramic value are Recent fine-grained sediments, Wapiti and Blairmore groups, Willow Creek, Pakowki, Wapiabi, Shaftesbury, Clearwater, Fernie, Siyeh and Grinnell formations.

Introduction

Before Alberta became a province in 1905, entrepreneurs were mining and burning clays. Since the first commercial operation opened in 1881, at least 159 plants have produced ceramic products. The failure of many of these enterprises probably was due to a poor product made from inferior clay. Published data from clays tested in the province in the early part of this century were summarized by Hamilton and Babet (1975). Many geographical areas and geological formations were missed in the earlier tests and commonly it is difficult to compare data from different investigators who sampled the same areas. To obtain data for a wider geographic and stratigraphic base, and to present the results in a uniform manner, a comprehensive program was initiated in 1973 for testing the ceramic properties of Alberta clays and shales. Some of the results on locations, field descriptions, complete unfired and fired data, and preliminary assessments of material have been published (Scafe 1977, 1978, 1980).

Many of the papers containing data for clays in Alberta published over the last 70+ years are out of print and difficult to find, but their data have been collated and formatted in this report (Appendix 1). The appendix contains the ceramic data available for 1:250 000 National Topographic Series (NTS) map areas. Figure 1 illustrates the NTS map sheets in the province that have data. Arrangement of data according to survey boundaries allows rapid location of the data available in a geographic area.

Ceramics In Geological Perspective

Prospectors for clays and shales that are to be used for ceramic purposes quickly realize that geologic maps can be of great help in the search for these commodities. Each map shows the geographic extent and stratigraphic sequence of a number of "formations." The formation is the fundamental unit in rock stratigraphic classification and is a body of rock characterized by lithologic homogeneity. It usually is tabular and is mappable at the earth's surface or traceable in the subsurface (North American Commission on Stratigraphic Nomenclature 1983). Smaller mappable parts of a formation are called members and associated formations having significant lithologic features in common may be recognized as a group. It is assumed in this paper that if a few fundamental tests indicate that most samples from a formation exhibit desirable ceramic properties, similar samples from the formation at other geographic locations also may show desirable ceramic properties. Conversely, if tests indicate that material from a formation exhibits undesirable ceramic properties, much time and effort can be saved by abandoning further testing of material from that formation.

Prospectors for ceramic materials will reject sandstone, siltstone, and highly smectitic or calcareous shales as primary components for ceramic bodies but will bear in mind that variable amounts of sand, silts, and smectite are acceptable ancillary components. In Alberta most rocks older than the Kootenay Group (Figure 2) are unsuitable for ceramic purposes because of their siliceous or carbonate natures. Some younger formations are too rich in the clay mineral montmorillonite (smectite) to be of use except for the production of expanded aggregate. This report attempts to point out the attributes and limitations of most formations in Alberta as potential sources of ceramic material.

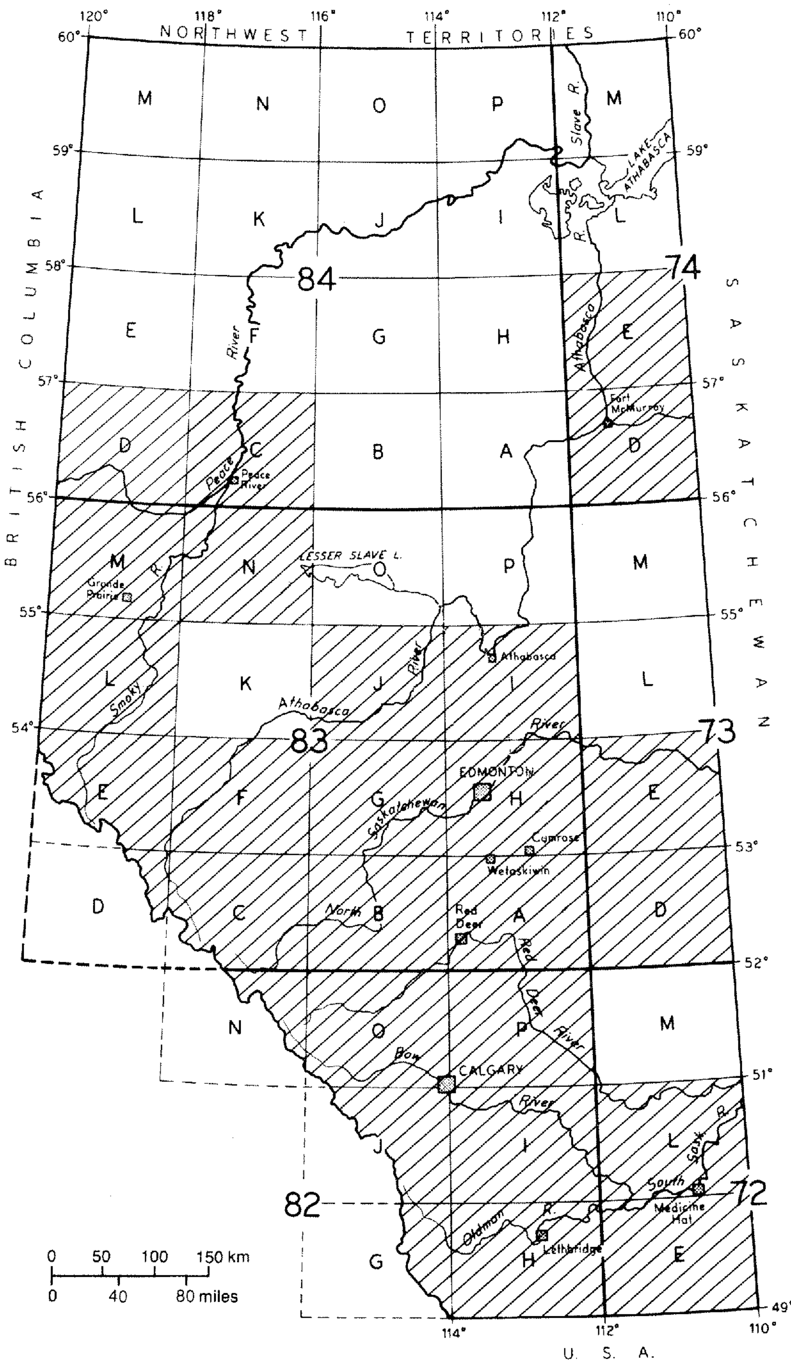

Figure 1. National Topographic Series 1:250 000 map sheets in Alberta that have published ceramic data.

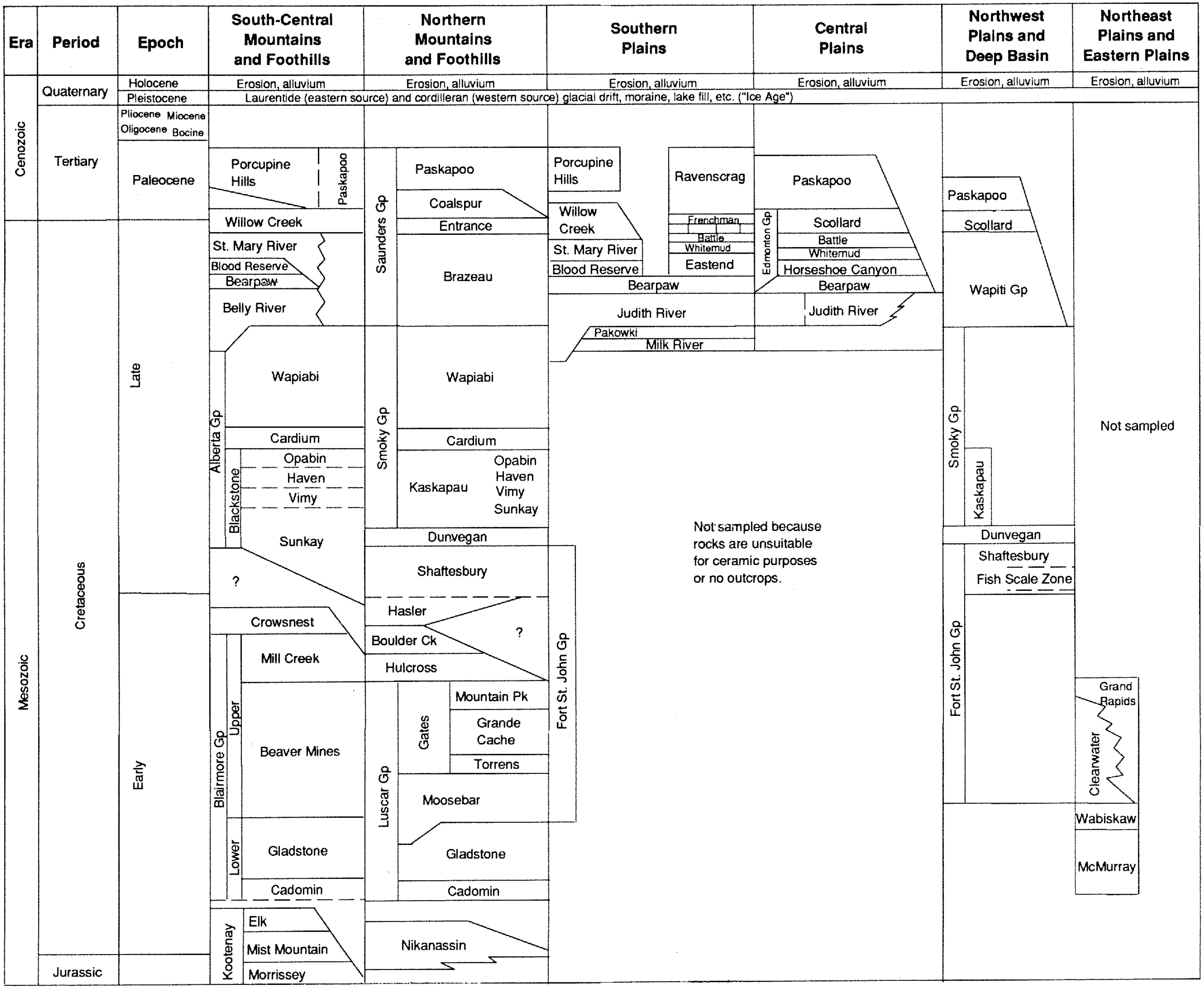

Figure 2. Correlation of Alberta formations sampled in this study.

Ceramic Clays and Shales

Definitions

The term "clay" may be defined differently by people in diverse disciplines. One definition calls clay "a fine-grained rock which, when suitably crushed and pulverised, becomes plastic when wet, leather-hard when dried, and on firing is converted to a permanent rock-like mass." A similar definition adds that the bulk of the mineral components are platy, hydrous aluminosilicates called the clay minerals. Another definition is "soil consisting of inorganic material the grains of which have diameters smaller than 5µm." Other similar definitions would place the size criterion at 4µm or 2µm. Each definition is useful for its required purpose but everyone should be careful when encountering the term "clay" to determine the limits of the definition.

Similar problems are encountered when defining "shale." A common definition is "an indurated, fine-grained, earthy, sedimentary rock with a distinct laminated or layered character." If the indurated material is not laminated it may be called mudstone. Early investigators, whose data are quoted in the appendices of this report, seem to have been fairly flexible in describing whether the material being tested is a clay or a shale. Their main concern is whether the material can be used to manufacture clay products. Such concern places limits on the type of material likely to be considered because certain properties are desired.

Properties

Any definition of clay based only on a size criterion is unacceptable to workers in ceramics because minerals such as quartz and feldspar can be clay-sized but they lack a very important ceramic property: plasticity. **Plasticity** is the property of a moistened material that allows it to be deformed under pressure then retain the deformed shape after the pressure is removed. In ground clays, shales, or mudstones the plastic properties of the material are the result of the interaction of water with the clay minerals present in the material. The clay minerals, such as kaolinite, illite, and smectite, are very fine-grained, platy hydrous aluminosilicates with substitutions of magnesia, iron, etc. in the structure. These structural substitutions cause electrical imbalance in the clay minerals that make them highly reactive in water. Unlike quartz and feldspar, they readily form even finer (colloidal) size particles when mixed with water. It is these colloidal size, electrically charged, platy particles with their large reactive surface area relative to unit mass that give plastic properties to clay materials. Maximum plasticity occurs when the water film around each particle is about 200 nm thick and for most clay material this would be in the water content range of 15 to 25 percent by weight. Water requirements greater than 20 percent commonly indicates a relatively high content of smectite, which gives good plasticity but less desirable workability (stickiness) and drying properties.

Workability is related to plasticity and is the ease with which a moist clay material can be molded without cracking or sticking. Clay workers commonly judge workability by pressing the moist material in the hand. Material with good workability has satisfactory forming properties over a relatively wide range of water contents.

A critical factor in determining the usefulness of a clay material is its **drying behavior**, because high losses of ware can occur due to warping or cracking as the moist material shrinks during the drying process. High **drying shrinkage** is common for clay material that has drying problems. As unbound water (water not rigidly bound to a particle surface) evaporates first, at a fairly rapid rate, particles in the material come closer together, shrinking the body until a rigid structure is formed. Minerals like quartz have no bound water, so the amount, particle size, and gradation of this and similar minerals affect the drying behavior by reducing the amount of water needed for proper workability. The unbound water around clay minerals also evaporates quickly but the thin layer of water bound electrically to the surface of the clay minerals is much more difficult to remove. This is because the heat applied during drying must overcome the strong electrical forces and the vapor generated must follow a tortuous path between quartz grains and other clay mineral particles to the surface of the body. If the clay minerals are not evenly dispersed in the body, variations in moisture content cause differential shrinkage that sets up stresses that cause warping or cracking.

Burned clays may be divided conveniently into soft wares (scratched by steel) and hard wares (harder than steel). Soft wares include building bricks for interior use, unglazed earthenware such as flower pots, and most refractory materials. Hard wares include stoneware, china, floor tile, and building bricks for exterior use. For this report the temperature required to produce **steel hardness** is taken as the lowest desirable firing temperature, because that temperature is considered to be the lower firing limit for clays likely to be used in Alberta. **Maximum recommended firing temperature** in this report is that temperature beyond which a body overfires. Overfiring occurs as the liquid phase becomes prevalent enough to cause the body to collapse or to close pores in the body so that gases generated cannot escape and the body begins to bloat (a condition unacceptable in formed bodies). The temperature range between the temperature to produce steel hardness and the maximum recommended firing temperature is the **firing range** in this report. Other workers may extend the lower limit of the firing range downward if the properties of shrinkage, absorption, and color are acceptable for their product. Lightweight synthetic aggregate is the only product that requires firing beyond the normal recommended firing temperature. However, even with synthetic aggregate severe overfiring is undesirable because if enough liquid phase is produced the pieces of material begin to stick to one another and to the inside of the kiln. In this report a firing range of 5 to 25°C is considered extremely short, 30 to 50°C is short, 55 to 100°C is moderate, and greater than 105°C is long.

During firing of a body, open porosity, as measured by **absorption**, gradually decreases and **shrinkage** increases as firing temperature increases. These changes are caused by decomposition of the clay minerals, chemical reactions that produce new materials of greater specific gravity, formation of a liquid phase that flows into and fills some of the original pore space, and sintering reactions that result in a decrease in pore space and an overall volume reduction. As mentioned above, firing may be stopped whenever acceptable absorption and shrinkage is attained for a product.

Many ceramic materials have no definite melting point. They show progressive sintering, then softening, leading to fusion. The heating rate, particle size, and presence of fluxes all affect the melting point. Therefore to determine the refractoriness of material (the degree to which material will withstand heat without deformation), it is necessary to prepare and heat the test material following standardized procedures and to compare the reaction of the sample to the reaction of mixtures of known properties. The known mixtures (pyrometric cones) are "heat-work" recorders that do not register temperature directly but a combination of temperature and rate of heating. Each test sample, when fired under the standard conditions, has properties that coincide with those of a known pyrometric cone and the melting point of the test sample can be stated as the **pyrometric cone equivalent** (P.C.E.).

The **fired color** of a body is important and at times may take precedence over a characteristic such as absorption or hardness. Iron is the most common coloring agent of fired ceramic bodies and, because of its variable valency states, can be yellow, red, blue, brown, gray, or black. Valency state depends on the fired temperature and the amount of oxygen present in the surrounding atmosphere. Color also is influenced by the particle size of the coloring agent. Colloidal sizes give uniform, evenly distributed color whereas nodules produce blotches. Six to nine percent hematite (Fe_2O_3) generally is necessary to give a pleasing deep red color, but even this depends on impurities such as lime (CaO) or magnesia (MgO) and on the firing temperature. Five percent lime can nullify the red color of a body containing nine percent hematite. This suppression of the red color is due to the growth, during heating, of white calcium silicate crystals, that have no affinity for hematite and expel it to the grain boundaries. This isolation of hematite into small pockets gives a buff color to the body.

Sampling

Two hundred and eighty-six samples from more than 100 locations were analyzed by the author. With the exception of 16 core samples from basal clays of the McMurray Formation, all material was collected from surface exposures. Roadcuts, river cutbanks, open pit coal mines, or other excavations were common sampling locations. At these locations it was possible to assess overburden thickness, clay thickness, access to transport, and the possibility of mining the clay in association with some other commodity such as coal.

Testing

In a survey of basic ceramic properties of the clays and shales from a region as large as Alberta, the property tests of primary interest are those that will suggest whether further testing is warranted. The desirable attributes to be tested are discussed in the Properties section of this report. Fundamental ceramic test procedures have remained relatively unchanged over the years, so it is possible to integrate earlier results obtained for Alberta clays and shales into this report.

Plasticity and workability are judged by an experienced worker according to the "feel" of the damp material. Workers probably are very consistent in their assessment of these properties, but some account should be taken of the possibility that two workers may not describe these properties in exactly the same way. In this report the drying and firing characteristics are determined from bars extruded for firing in a temperature gradient furnace. Extruded samples that did not survive drying were tested from hand-pressed bars. Results published by most previous workers are from hand-pressed bars or tablets. Faults such as warping, cracking, or checking are noted when reporting drying behavior at room and elevated temperature. Linear drying shrinkage is obtained by measuring the distance, before and after drying, between two marks scribed on the body, and the difference is expressed as a percentage.

For testing firing properties, the common procedure formerly was to fire test specimens to temperatures determined by standard cones. The amount of detailed information gathered for a firing curve is dependent on the number of specimens fired at increasing temperatures. Commonly, specimens were fired at four to six different temperatures determined by the standard cones. Now it is convenient to fire a pair of specimen bars in a temperature gradient furnace to determine the firing reactions of material at many temperatures below some predetermined maximum temperature. The electric furnace is programmable to raise the temperature at any desired rate or to hold temperature at a desired level. The tubular muffle furnace holds two bars arranged end to end; the temperature is hottest at the centre of the tube, and temperature sensors imbedded in the floor measure the temperature gradient between the hot and cool ends of each bar. By relating the measured temperatures to lines previously scribed on the bar it is possible to determine the temperature reached at any point along the bar. In addition, at any point on the bar the fired shrinkage can be measured, color can be evaluated, and if one of the two bars of the test specimen is sawed into thin wafers at the scribe marks the 24-hour cold water absorption also can be determined. Graphs of fired shrinkage and absorption versus temperature can be plotted to give a visual representation of changes happening during firing (Figure 3). Such graphs were plotted for each sample tested by the author. Data for shrinkage and absorption in the appendices are taken from those graphs. Representative graphs for selected formations are included with the description of the formation in a succeeding section.

Designations of fired colors by previous workers as red, buff, etc. are less meaningful than the number/letter designation, based on the Munsell System, used by the author (Appendix 2). Using any color chart based on the Munsell System a reader can discern the exact fired color seen by the author.

Pyrometric Cone Equivalent (P.C.E.) of a sample is determined in a P.C.E. furnace following the procedures published in A.S.T.M. Designation C27-70.

In general, bulk chemical analyses of clays and shales do not provide data as useful as other forms, such as mineralogical data. Chemical analysis does not reveal the state in which the various ions are combined. Hence, a clay that contains a very small percentage of calcium, magnesium, potassium, and sodium may actually contain a large proportaion of minerals other than clay minerals and some of these minerals may be very active fluxes. On the other hand, bulk chemical analyses of clays and shales are very useful if the total amount of a component present is a limiting factor for its use. For example, the total sodium, potassium, silica, and aluminum present in a clay is important for its use in burning with limestone to make low alkali cement. Chemical analyses were obtained for 75 samples from 20 formations plus Pleistocene (glacial) materials (Appendix 3).

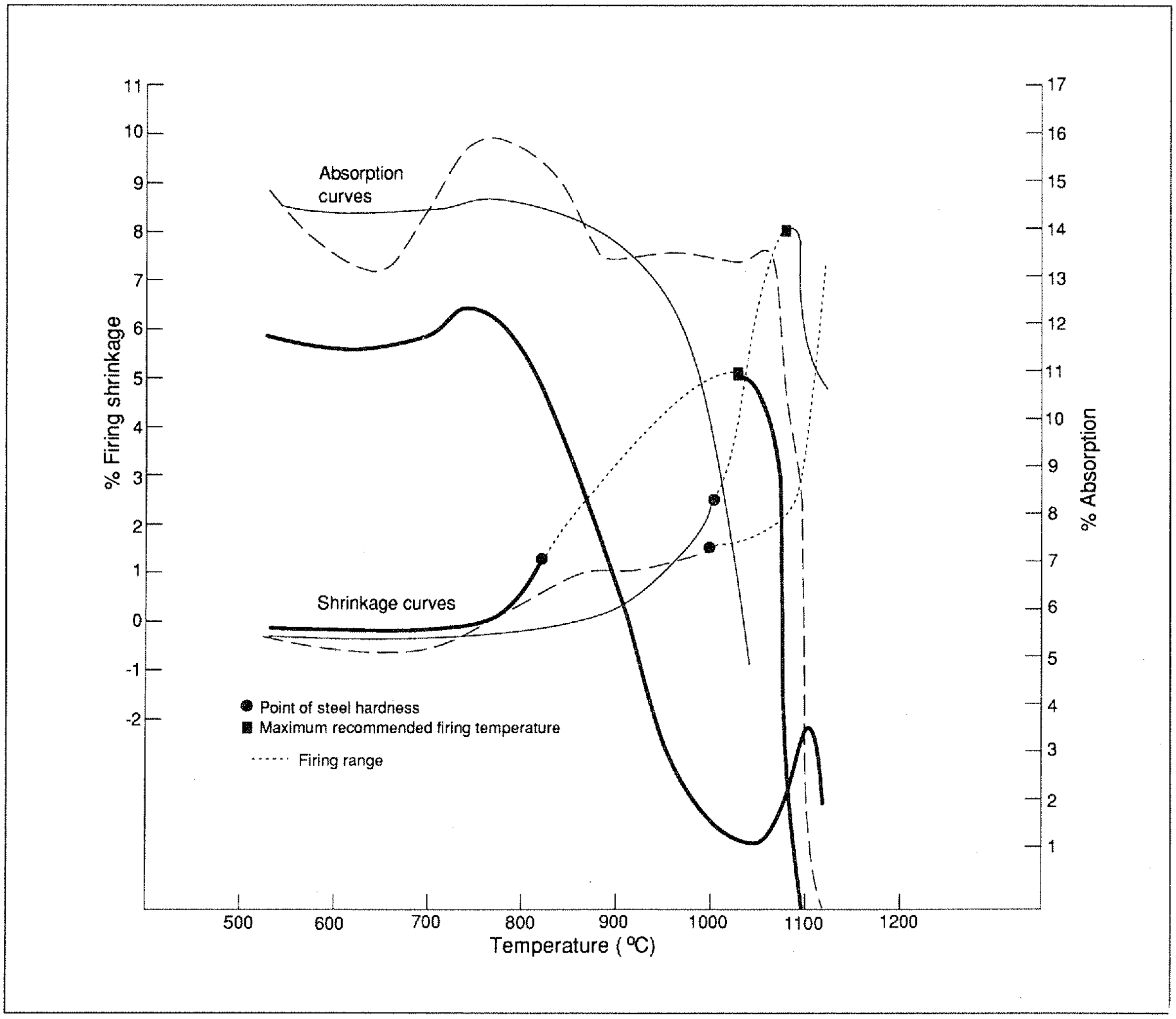

Figure 3. Typical graphs of fired shrinkage and absorption versus temperature curves.

Clay Product Requirements

Generally, the ceramic industry is divided into three divisions: structural clay products, refractories, and whiteware. "Heavy clay products" such as brickware and some stoneware bodies also commonly are called structural clay products. "Refractories" are highly heat-resistant bodies. "Whitewares," in North America, cover earthenware, artware, fireclay, vitreous china, porcelain, and specialized bodies. Of the 37 specific types of ceramic bodies defined in Singer and Singer (1963) only a few types could be produced from Alberta clays and shales. However, these few could come from each of the three general divisions. Because the boundaries of the specific ceramic types are hazy and arbitrary the three general divisions will be used in this report.

Typical requirements for structural clays used in artware (pottery) are given in Table 1. The most common method used in forming structural clay products is the "stiff mud extrusion process," for which good plasticity and workability are essential properties of the raw material, as is uniform drying without warping and cracking. The very high plasticity of many Alberta clays, which causes stickiness and causes difficulty in extruding a body, is deleterious to their working and drying properties. Quartz sand or granular prefired clay called "grog," commonly is added to the raw material to improve the working and drying properties. However, if the amount of sand required is very high, a weak, porous, fired body results. The quartz dilutes the clay mineral concentration and improves the plasticity and drying characteristics but does not melt on firing. Insufficient melt is produced and a weak body

Table 1. Criteria used in evaluating selected clay products.

	Face brick	Sewer pipe	Stoneware	Artware
Unfired Properties				
Workability	good	good	good	good
% water of plasticity	15-40	0-35	not critical	not critical
Drying characteristics	no warping or cracking	no warping or cracking	no warping or cracking	no warping or cracking
% drying shrinkage	0-12	0-8	3-8	0-15
Fired Properties				
Maturing temperature (°C)	980-1200	980-1150	1210-1330	980-1150
Hardness	steel hard	steel hard	steel hard	steel hard
% Absorption (unglazed)	0-15	0-8	0-2	not critical
Color	reds, buffs, creams, etc.	reds, buffs	buffs, grays	variety

results. On the other hand, the grog will melt at temperatures similar to the raw material and a strong body will be formed. Unfortunately, the energy costs to produce grog are high and this raises the cost of the product. Workability and fired color are the most important properties for pottery clays, with color particularly important for wares that must fire white or some other specific color. Clays for pottery formed by throwing, jiggering, or slipcasting must have good plasticity, and the drying and firing shrinkage must be small enough to prevent warping and cracking. Firing ranges quoted in this report should overlap the maturing temperature values of clay products listed in Table 1 if the clays are to be used as raw materials for those products.

The undesirable trait of bloating exhibited by some clays tested for structural clay products is the desirable trait for lightweight (expanded clay) aggregate production. Absorption should be low but more importantly it should be consistent to facilitate proportioning of cement and water in lightweight concrete mixes.

The most important property to be considered in appraising refractory clays is refractoriness. Clays with P.C.E. values from cone 15 to 29 (1430 to 1660°C) are considered low heat duty refractory clays (A.S.T.M. Designation C27-70). Higher refractoriness designations exist but their quotation would be superfluous for the clays tested.

Geology of fine-grained sediments in Alberta

Geologic materials present in Alberta range in age from the Precambrian, with dates determined to be greater than 2.3 billion years, to sands, silts, and clays being deposited today. Those materials of most interest to the ceramist, however, were deposited at various times and in different geographic areas in the province from about 137 million years ago (late Jurassic-early Cretaceous) until the retreat of the continental ice sheet about 10 000 years ago. Before late Jurassic time, most sediments deposited in Alberta were coarse-grained and highly siliceous or were very rich in calcium carbonate. Some of the problems associated with using these types of sediments in ceramics have been noted. After the glaciers retreated and glacial lakes drained, there were neither basins for deposition, nor large sources of fine-grained sediments so recent deposits generally do not contain ceramic raw materials.

Beginning in late Jurassic time, more fine-grained materials were produced and sediments that subsequently became shales were introduced more often into the stratigraphy. Nonmarine sandstones, siltstones, and shales alternate with marine sediments in the Cretaceous and Tertiary successions. On the Plains the beds have a low regional dip to the southwest that increases toward the Rocky Mountains. In the Foothills and Rocky Mountains, steeply dipping folded and faulted sequences are common. The stratigraphic column of formations of Jurassic and younger age that contain materials of interest to the ceramist is shown in Figure 2 and the formations are described in succeeding sections. Covering the bedrock formations at most places in the province are the glacial tills, sands, silts, and clays deposited during Pleistocene time. Those of most interest to the ceramist are the glaciolacustrine clay deposits.

Precambrian rocks

Grinnell Formation

The Grinnell Formation is one of eight formations of unmetamorphosed rocks of Precambrian age that form the Purcell Group in the Rocky Mountains of southwestern Alberta. The Purcell Group is exposed above the Lewis Fault, which thrusts Precambrian rocks over those of Cretaceous age.

The Grinnell Formation is composed mainly of bright red argillite, white and light green quartzite with zones of red argillite-pebble conglomerate, red siltstones, and quartzite (Price 1965). Upper and lower contacts are gradational. Where sampled in the Beaver Mines area (NTS 82G), the formation attains a thickness of 230 m (Hage, 1943).

One sample of the red argillite that is interbedded with white quartzite was taken along Drywood Creek south of Pecten, in NTS area 82G. The data for that sample are listed in Appendix 1. The constant quest for red-burning clays prompted collection of the sample even though beneficiation of the material would be necessary to remove the quartzite.

With 15 percent tempering water, the material has poor plasticity and fair working properties. Bars dry well at room and elevated temperature but are very fragile until fired. The fired color is pale reddish brown at steel hardness and grayish red at maximum recommended firing temperature. Firing range is moderate and fired shrinkage is only 4 percent. Perhaps because the white quartzite is difficult to remove, this argillite does not burn as red as one would expect from field observations. Illite is the only clay mineral and quartz and hematite are the only other minerals identified. The need to beneficiate, poor plastic properties, and distance from manufacturing complexes make this argillite undesirable as a source for ceramic raw material.

Siyeh Formation

The Siyeh Formation overlies the Grinnell Formation and has a similar areal extent (Price 1965). Three lithostratigraphic units are recognizable in the formation. The lower unit, about 10 m thick, consists of green and black argillite with interbeds of green and gray argillaceous and arenaceous dolomite. The middle unit is approximately 300 m thick and is composed of fine-crystalline, thin-bedded, gray dolomite with thin interbeds of gray and black argillite, dolomitic sandstone, and quartzite. The upper unit, which has a sharp upper contact with lava, is 30 m thick and consists of light green argillite and dolomitic argillite with a zone of red, mud-cracked argillite on top.

One sample of dark gray argillite was collected along Drywood Creek in NTS area 82G, not far from where the Grinnell Formation was sampled. Unfired and fired characteristics are listed in Appendix 1. Poor plasticity and fair working conditions are obtained with 15 percent tempering water. Bars dry well at both room and elevated temperatures and drying shrinkage is only one percent. Fired color is grayish yellow for both steel hard and maximum fire. Absorption at maximum fire is very low (0.4 percent), fired shrinkage is high (14.7 percent), and the firing range is extremely short.

Illite is the dominant clay mineral at 75 percent, chlorite is 15 percent and kaolinite is 10 percent. Peak heights for clay minerals in the X-ray diffraction patterns are low, however, and clay minerals probably are not major components of the material. The poor plastic and fair working properties support this suggestion as does the low value (5.91) for Al_2O_3 (Appendix 3). Dolomite is a major component of the sediment and is responsible for the extremely short firing range. This material is of little value for ceramic use.

Paleozoic rocks

Most of the rocks of Paleozoic age in Alberta are limestones, dolostones, or other sediments with very high amounts of calcium carbonate. These rocks are not good sources of raw material for ceramic bodies and have not been tested in this study.

Triassic rocks

In Alberta, sediments of this age are primarily red sandstones and have not been sampled for this study.

Jurassic rocks

Fernie Formation

The Fernie Formation extends along the Rocky Mountain Foothills and Front Ranges from the International Boundary to north of the Peace River in northeastern British Columbia. The formation generally consists of a series of dark-colored marine shale, silty shales, and silty limestone units (Mountjoy 1962) that are remarkably persistent along depositional strike (Stott 1972).

Data are available for three samples from NTS area 82G (Appendix 1). P.C.E. values range from two to 12. With 20 percent tempering water, plasticity is poor and working properties are poor to fair. Some cracking occurs on drying but drying shrinkage is low at five percent. Steel hard colors are red for samples that are not calcareous and steel hardness is reached between 1060 and 1180°C. No data are available for maximum recommended firing temperatures. No clay mineralogical data are available. Poor plasticity, high carbon content in some samples, and high carbonate content in others makes the Fernie Formation a poor choice for ceramic raw material.

Lower Cretaceous rocks

Kootenay Group

The Kootenay Group is present in a narrow, linear band from the International Boundary to the North Saskatchewan River (Gibson 1985) along the Rocky Mountain Foothills and Front Ranges (Figure 4). In cross section the formation is thickest (1100 m) in the Fernie Basin of British Columbia and is eroded to a zero edge along the eastern margin of the Foothills in Alberta. The lowest formation in the group is a massive, cliff-forming sandstone named the Morrissey Formation. The middle formation consisting of an interstratified sequence of mudstone, silty shale, siltstone, sandstone, conglomerate, and seams of economically important low- to high-volatile bituminous coal, is called the Mist Mountain Formation. The upper formation is composed of a thick cliff-forming sequence of conglomerate, siltstone, sandstone, mudstone, shale, and sparse, thin seams of coal and is named the Elk Formation.

Only the mudstones and shales of the Mist Mountain coal-bearing formation were sampled. These mudstones and silty shales are associated with coal seams at many localities and are dark gray to black with variable concentrations of fragmented and macerated vegetal material.

Some ceramic attributes of the formation listed in Table 2 change between the Crowsnest Pass area (NTS sheet 82G) and the Bow River area (NTS sheet 82O). In the Crowsnest Pass area the P.C.E.

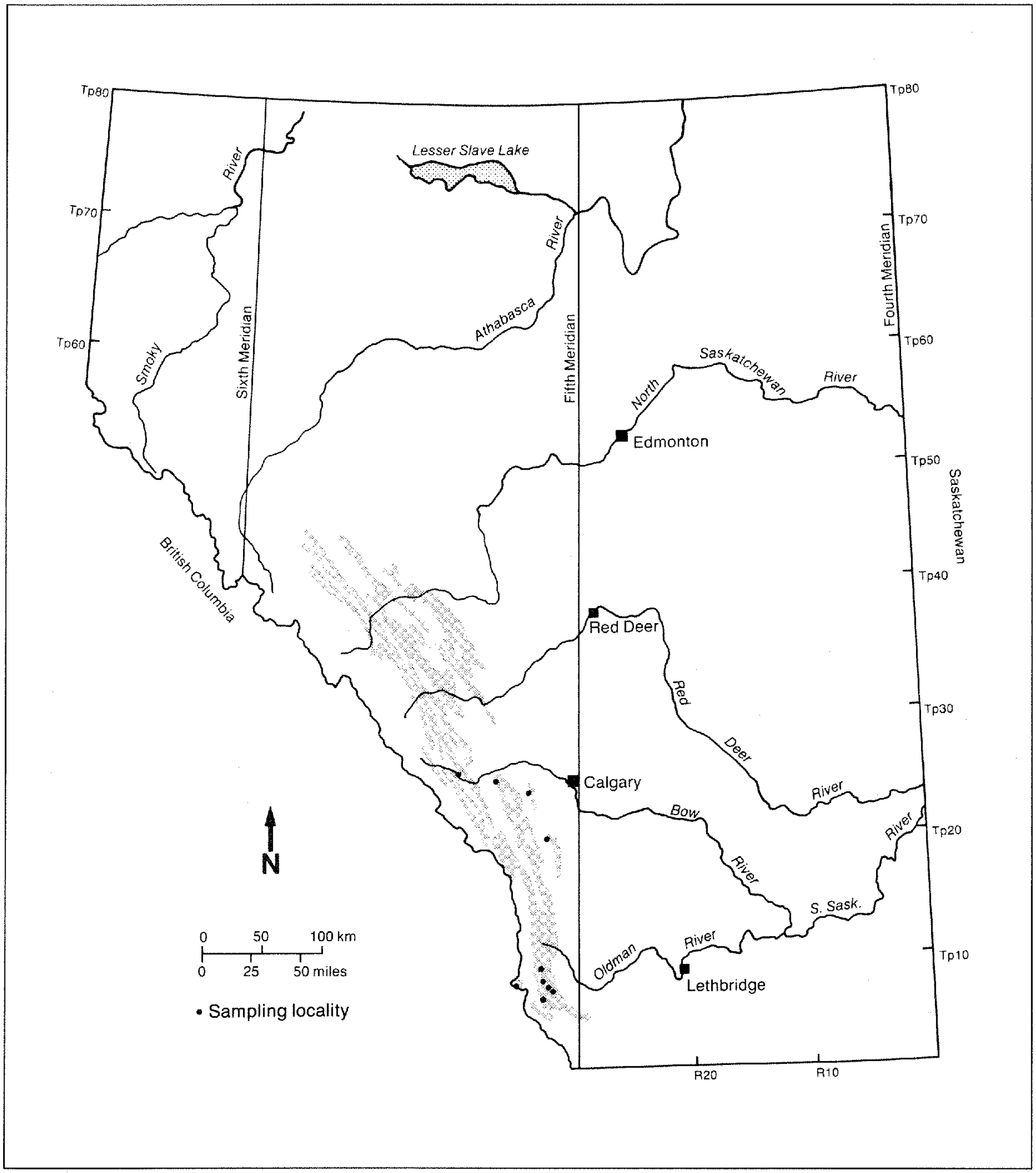

Figure 4. Geologic map of the Blairmore and Kootenay groups in Alberta.

values of 25 samples range from three to 23, eight are 15 or greater and 12 are nine or greater. In the Bow River area the P.C.E. values of 12 samples range from two to 15 and only two are greater than nine. Plasticity and workability, even after fine grinding and extended periods of "souring" (keeping the material damp), are poor. Test specimens made from these poorly plastic clays, especially from the Crowsnest Pass area, are fragile until fired. Drying behavior is good at both room temperature and 105°C. Although drying shrinkage averages almost two percent higher for the Bow River samples, that average is only 3.1 percent. Temperature of steel hardness, for Crowsnest Pass samples, ranges from 1075 to 1260°C (cone 05-7) and averages 1160°C. Bow River samples have a much smaller range (1080 to 1155°C, cone 05 to 02) and the average temperature is 1120°C. The absorption range at steel hardness (2.1 to 11.0 percent) for Crowsnest

Table 2. General Characteristics of Samples from the Kootenay Group.

Location	Description	P.C.E.	Unfired Properties: Tempering Water (%)	Plasticity	Working Properties	Drying Behavior: Room Temperature	Drying Behavior: 105°C	Drying Shrinkage (%)
Crowsnest (25 samples)	shades of dark gray or brown mudstone or shale, hard, silt absent or minor	3-23 (10 average)	17	poor	poor	good	good	1.3
Bow River (12 samples)	shades of dark gray or brown mudstone or shale, hard, silt absent or minor	2-15 (6 average)	17	poor	poor	good	good	3.1

Fired Properties: Steel Hard: Color	Steel Hard: Temperature °C	Steel Hard: Absorption (%)	Maximum Fire: Color	Maximum Fire: Temperature °C	Maximum Fire: Absorption (%)	Maximum Fire: Shrinkage (%)	Remarks
pale brown or pale yellowish brown most common; a few light olive gray	1160 (cone 02)	6.8	light to medium shades of brown or olive gray	1200 (cone 3)	2.2	6.6	no drying problems but poor plasticity and short to moderate firing range
pale brown or pale yellowish brown most common	1120 (cone 04-03)	9.4	light to medium shades of brown or olive gray	1155 (cone 02)	2.7	7.4	no drying problems but poor plasticity and short to moderate firing range

Pass samples is longer than for Bow River samples (4.5 to 11.9 percent). The average absorption value of 6.8 percent, for the Crowsnest Pass samples, however, is 2.2 percent less than the 9.4 percent average for the Bow River samples. The average maximum recommended firing temperature for Crowsnest Pass samples of 1200°C (range 1135 to 1290°C) is 45°C higher than the average of 1155°C (range 1125 to 1225°C) for the Bow River samples. Absorption of 2.2 percent at the maximum recommended firing temperature for the Crowsnest Pass samples is similar to that of the Bow River samples (2.7 percent). Average fired shrinkage is only 6.6 percent for the Crowsnest Pass samples compared to 7.4 percent for the Bow River samples. Typical curves of temperature versus shrinkage and absorption for Kootenay Formation clays are shown in Figure 5.

The differences in ceramic properties between samples from the Crowsnest Pass area and the Bow River area and differences between samples at any location in either area can be explained in part by variations in mineralogy. The more refractory kaolinite and the lesser refractory illite are the only clay minerals present in most samples tested from the Kootenay Formation. Kaolinite ranges from 15 to 55 percent of the minus 2µm fraction and averages 35 percent in samples from the Crowsnest Pass. In samples from the Bow River area kaolinite concentration ranges from zero to 35 percent and averages 20 percent. The greater amount of kaolinite in the Crowsnest Pass samples can account for the generally higher P.C.E. values, steel hardness, and maximum recommended firing temperatures. However, differences in refractoriness between samples from the same pit in either geographic area are due to the presence of other minerals. A sample that contains 35 percent kaolinite can have a P.C.E. of 16 (1490°C); another sample with a similar amount of kaolinite can have a P.C.E. of 4 (1210°C). Invariably, the sample with the lower P.C.E. value contains the fluxes calcite, dolomite, or siderite.

Well-crystallized kaolinite in samples from the Kootenay Group is partly, but not solely, responsible for the poor plasticity and workability. Factors such as particle size, particle size distribution, shape of particles, aggregation, surface area, particle orientation, presence of other materials, and previous history of the rock all interact to influence plasticity (Grimshaw 1971), but were not determined in this study.

Mudstones and shales from the Kootenay Group have certain positive traits that make them attractive for use in the production of structural clay products or pottery. Bodies dry without

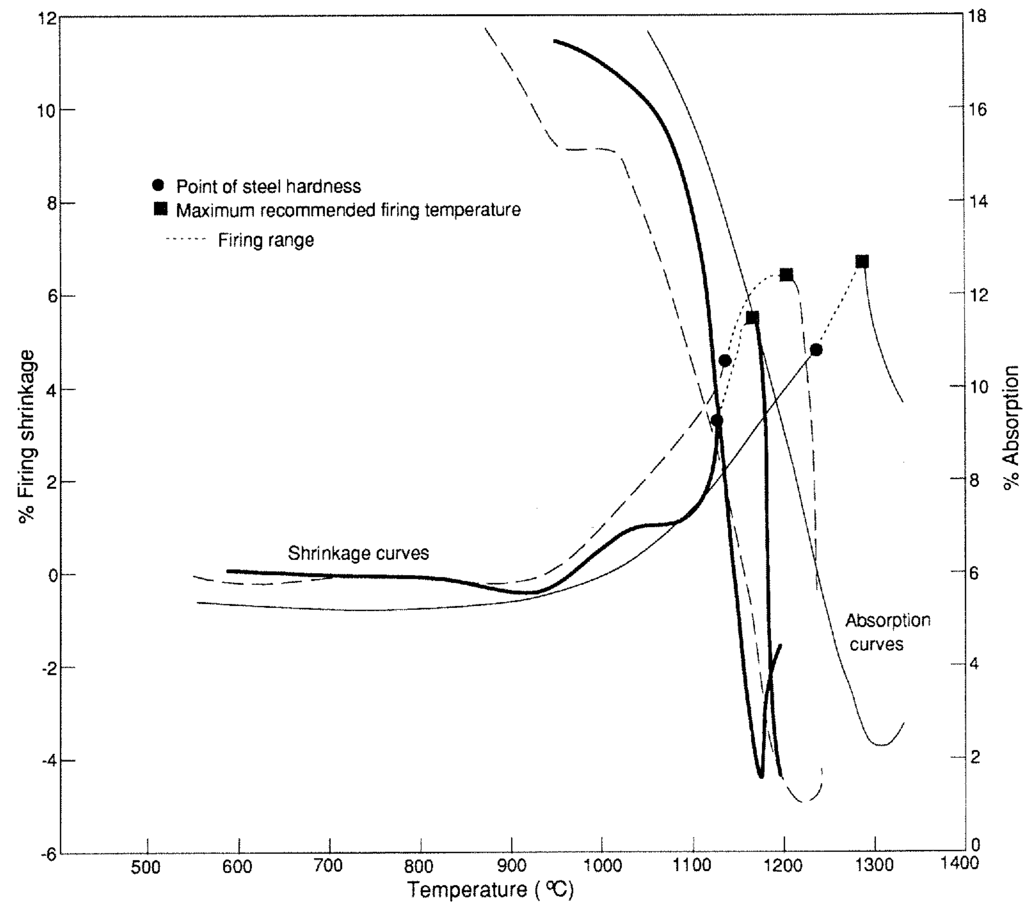

Figure 5. Typical shrinkage and absorption versus temperature curves for Kootenay Group clays.

warping or cracking at room or elevated temperature and drying shrinkage is low. Steel hardness and maximum recommended firing temperatures are low and produce bodies with low levels of absorption and acceptable fired shrinkage. However, certain other traits make the mudstones and shales undesirable for use. Poor plasticity and workability even after fine grinding and extensive periods of souring yields bodies that are fragile until fired. The presence of carbonate in most samples gives pale colors and a short firing range. To counteract the troublesome characteristics of the mudstones and shales they must be blended with clays from other formations that are more plastic and have a longer firing range. Some shales and mudstones from the Kootenay Group are devoid of carbonate, have longer firing ranges, and could be blended with other clays to improve the firing range. Because no sample burned to a white color, Kootenay mudstones or shales cannot be used for the production of white bodies in the pottery industry. The low maximum recommended firing temperatures and the high fired absorption preclude use of these clays for production of stoneware products and high potassium values (Appendix 3) preclude their use for making low alkali cement.

Blairmore Group

Since its introduction as a formation name in 1914 the term Blairmore has evolved with time. Currently the name Blairmore Group is confined to the succession disconformably overlying the Nikanassin Formation in the central Foothills or the Kootenay Group in the southern Foothills (Langenberg and McMechan 1985). The upper contact with the Blackstone Formation is abrupt

Table 3. General Characteristics of Samples from the Blairmore Group.

			Unfired Properties				
					Drying Properties		
Description	P.C.E.	Tempering Water (%)	Plasticity	Working Properties	Room Temperature	105°C	Drying Shrinkage (%)
gray to greenish gray shale or mudstone, limited thickness and extent, high grit content common	1-12 (5 average)	16-21 (18 average)	poor-excellent mostly poor-fair	good	good	good	0.5-8.7 (4.7 average)

			Fired Properties				
	Steel Hard		Maximum Fire				
Color	Temperature °C	Absorption (%)	Color	Temperature °C	Absorption (%)	Shrinkage (%)	Remarks
pale gray, grayish red, moderate reddish brown, bright red, red, dark red	890-1255 (945 avg)	3-19.5 (9.7 avg)	grayish red, brownish red light red	1125-1220 (1165 avg)	0.8-8.1 (3.9 avg)	2.2-8.4 (4.7 avg)	blend for plasticity and strength, long firing range common, appealing dark red-firing samples too rare

and disconformable. Maximum thickness in Alberta is 650 m with a distinct eastward thinning. The Blairmore Group consists of four formations (Figure 2), in ascending order Cadomin, Gladstone, Beaver Mines, and Mill Creek. The exact stratigraphic position of "Blairmore" samples taken by earlier workers relative to current terminology is unknown. Because the ceramic potential of the material sampled is limited the author has not attempted to assign samples to formations in the Blairmore Group. Geographic distribution of the Blairmore Group is similar to that of the Kootenay Group and is shown in Figure 4.

Mudstones and shales tend to have a high silt content in the Blairmore Group and the unfired and fired properties are quite variable. Tempering water varies little from the 18 percent average (Table 3). Plasticity mostly is poor or fair, and workability commonly is very poor to fair. Drying is good at room and elevated temperatures and drying shrinkage varies from 0.5 to 8.7 percent with 4.7 percent the average. Color at steel hardness varies through pale gray, grayish red, bright red to dark red. Steel hardness temperatures range from 890 to 1255°C with 945°C (cone 09-010) as the average. Absorption at steel hardness ranges from 3 to 19.5 percent and averages 9.7 percent. Color at the maximum recommended firing temperature is bright to dark red, temperature varies from 1125 to 1220°C with 1165°C (cone 01) the average, absorption averages 3.9 percent, and firing shrinkage averages 4.7 percent. Pyrometric cone equivalent (P.C.E.) ranges from one to 12 and averages five.

Kaolinite and illite are the dominant clay minerals (up to 45 percent of the minus 2μm size fraction). The relatively high concentration of chlorite in some samples (up to 10 percent of the minus 2μm size fraction) may act as a flux to reduce refractoriness (P.C.E.) and shorten the firing range. Feldspars present also act as a flux (Grimshaw 1971).

The limited amount of "low-silt" shale and mudstone available, poor plasticity and workability, and weak fired bars are limitations to the Blairmore Group as a source for ceramic raw material. High sodium and potassium values (Appendix 3) preclude use of Blairmore Group clays and shales for low alkali cement. The absence of significantly higher quality clays from another formation near the outcrop area of the Blairmore Group reduces the possibility of blending to upgrade the Blairmore material with a longer firing range material that burns to an appealing dark red color.

Luscar Group

The Luscar Group (Langenberg and McMechan 1985) occurs in the Foothills (Figure 6) and extends north from the Clearwater River to the Kakwa River near the British Columbia border. The group consists of, in ascending order, the Cadomin, Gladstone, Moosebar, and Gates formations. The Luscar Group is 585 m thick in the Grande Cache area and thins to the south. The Gates Formation contains the Torrens, Grande Cache, and Mountain Park members. Of most interest in this study is the Grande Cache Member, characterized by thick coal seams inter-

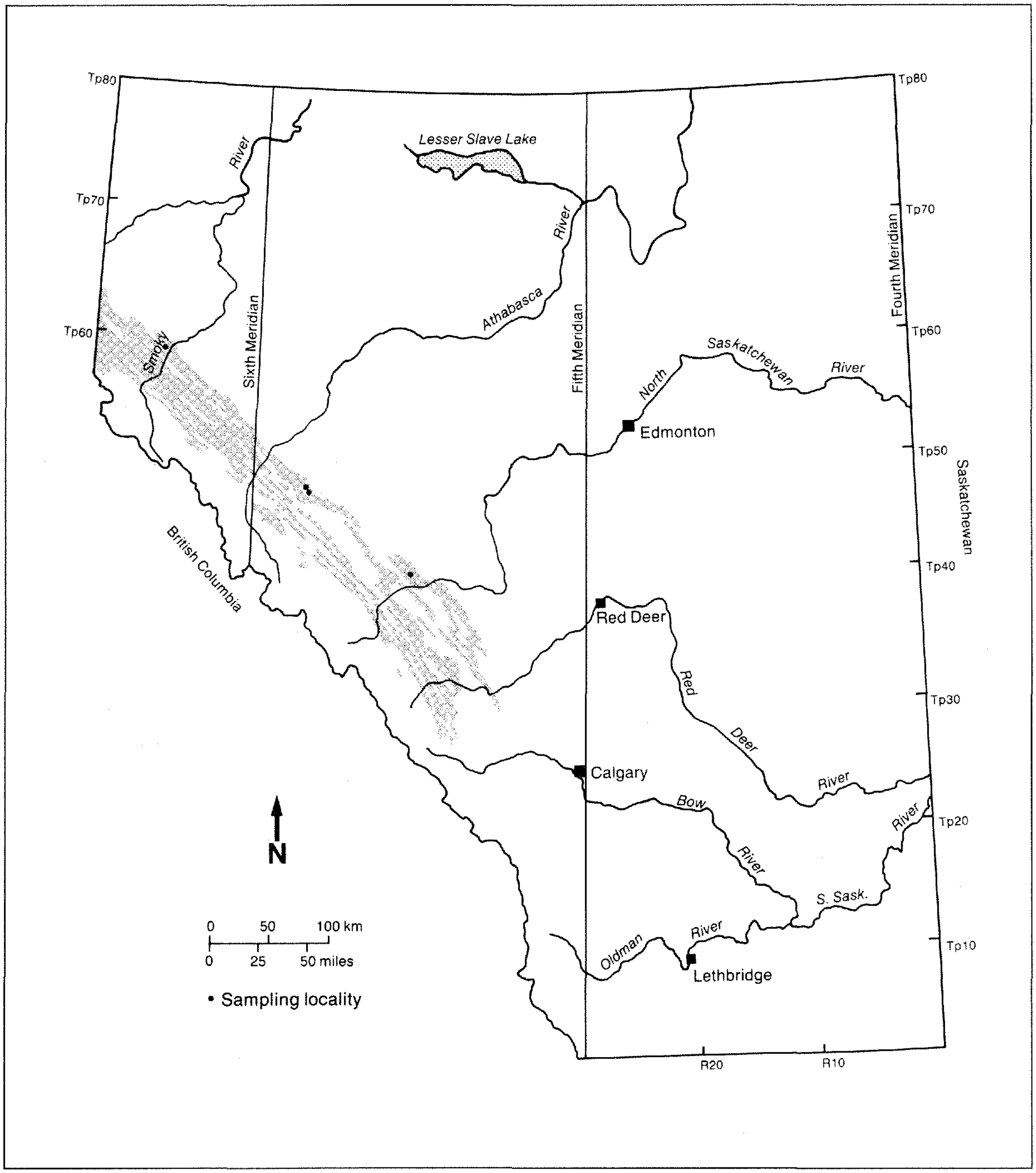

Figure 6. Geologic map of the Luscar Group in Alberta.

bedded with thicker sequences of gray to olive gray mudstones, siltstones, and very fine-grained sandstones. Carbonaceous detritus is abundant throughout. Fresh to brackish water fauna are present. This member contains all the economically important coal seams south of the Grande Cache area.

The ceramic potential of this formation changes along strike from potentially useful in the south to unsuitable in the north. In the Nordegg area P.C.E. values average five, plasticity is poor, workability is only fair to good, but the material extrudes well and strong bars can be produced. Drying behavior is good at room and elevated temperatures and drying shrinkage averages five percent. Temperature of steel hardness ranges from 985 to 1090°C and maximum recommended firing temperature ranges from 1095 to 1145°C to give a moderate firing range. Absorption drops from an average of 9.2 percent at steel hardness temperature to 0.7 percent average at maximum recommended firing temperature. Fired shrinkage averages 7.7 percent. At maximum recommended firing temperature the material is an appealing dark chocolate color.

Northwest of Nordegg in the Cadomin area plasticity ranges from nil to fair, workability ranges from nil to fair to good, but is mostly poor. The material is difficult to extrude and bars tend to be fragile. Bars dry well at room and elevated temperature, with average drying shrinkage of 2.5 percent. The material exhibits a firing range from nil to moderate, absorption at maximum recommended firing temperature averages 3.2 percent and fired shrinkage averages 5.5 percent. Fired colors are light to moderate brown.

Currently, coal is mined in the Grande Cache area from a number of seams in the Grande Cache Member, and tall highwalls are exposed for sampling. Plasticity is nil to fair, workability is nil to fair to good and most material is difficult to extrude. Drying behavior is good at room temperature but small surface cracks may appear if bars are dried at elevated temperatures, even though average drying shrinkage is only 2.1 percent. Steel hardness temperature ranges from 1030 to greater than 1170°C. In a number of samples (the 1170°C sample is one) steel hardness still was not reached where firing was terminated at a temperature 50°C below the P.C.E. temperature. The 50°C temperature is used as a safety factor to protect the temperature gradient furnace from damage due to melting of the bars. Generally, a sample that has not reached steel hardness within 50°C of its P.C.E. value has a short or extremely short firing range, is not a desirable material for ceramic use, and does not warrant further testing. Those samples that can be fired past steel hardness have maximum recommended firing temperatures that range from 1110 to 1205°C and average 1135°C (cone 03). Absorption at maximum recommended firing temperature averages 2.2 percent and firing shrinkage averages five percent.

Some of the changes in ceramic characteristics of the Luscar Group can be related to mineralogy. In the Nordegg area kaolinite concentration averages 30 percent of the minus 2μm fraction, illite averages 60 percent, chlorite ranges between five and 15 percent, trace amounts of feldspar are present, and calcite or dolomite is absent. Material from this area fires to an appealing chocolate brown color that probably is due to the combined iron content of the illite and chlorite. The presence of 30 percent kaolinite and absence of calcite or dolomite contribute to the moderate firing range. In the Cadomin area kaolinite averages 40 percent of the minus 2μm fraction, illite averages 55 percent and chlorite ranges from five to 10 percent. The most refractory sample from this area contains only kaolinite and illite. The sample that has no firing range has a high calcite content. Variations in the firing range of samples from the Grande Cache Member are directly related to the presence or absence of calcite. Siderite and feldspar are present in some samples, but their effect on firing range is not so easily determined. Kaolinite averages 30 percent of the minus 2μm fraction and illite averages 70 percent. No other clay minerals are detected. A sample that contains no calcite may exhibit a P.C.E. of 13 and a moderate firing range, whereas a sample that contains comparable amounts of kaolinite and illite and also contains calcite will exhibit a P.C.E. of four and no firing range.

The Luscar Group in the Nordegg area may have potential for use in structural clay products, particularly if new coal mines are started or old ones reactivated. Further testing would be required on the consistency of potential beds. The poor plasticity plus poor firing characteristics of material from other areas likely precludes its use for ceramic purposes. Alkalis are too high for low alkali cement (Appendix 3).

McMurray Formation basal clays

The McMurray Formation exposed along the Athabasca and Clearwater rivers in the vicinity of Ft. McMurray (Figure 7) is best known for its bitumen impregnation. The formation consists of complexly interbedded sequences of sandstones, siltstones, mudstones, and thin coals (Carrigy 1959). The lower contact at many locations is sharp with the underlying limestone of Devonian age. In some paleotopographic lows on the surface of the limestone, the base of the oil "pay zone" is separated from the underlying limestone by an interval that can be divided into two recognizable units; an upper unit of oil-bearing sand interbedded with silt and clay, and a lower unit of lenticular beds of oil-free clay and sand. The upper unit varies from 1.5 to 15 m in thickness and the lower unit may be absent or up to 15 m in thickness. The clays from the lower oil-free zone are either dark brownish-gray to black, slickensided materials that at many locations contain lignite or are light to dark gray, noncalcareous, poorly laminated clays. The clays

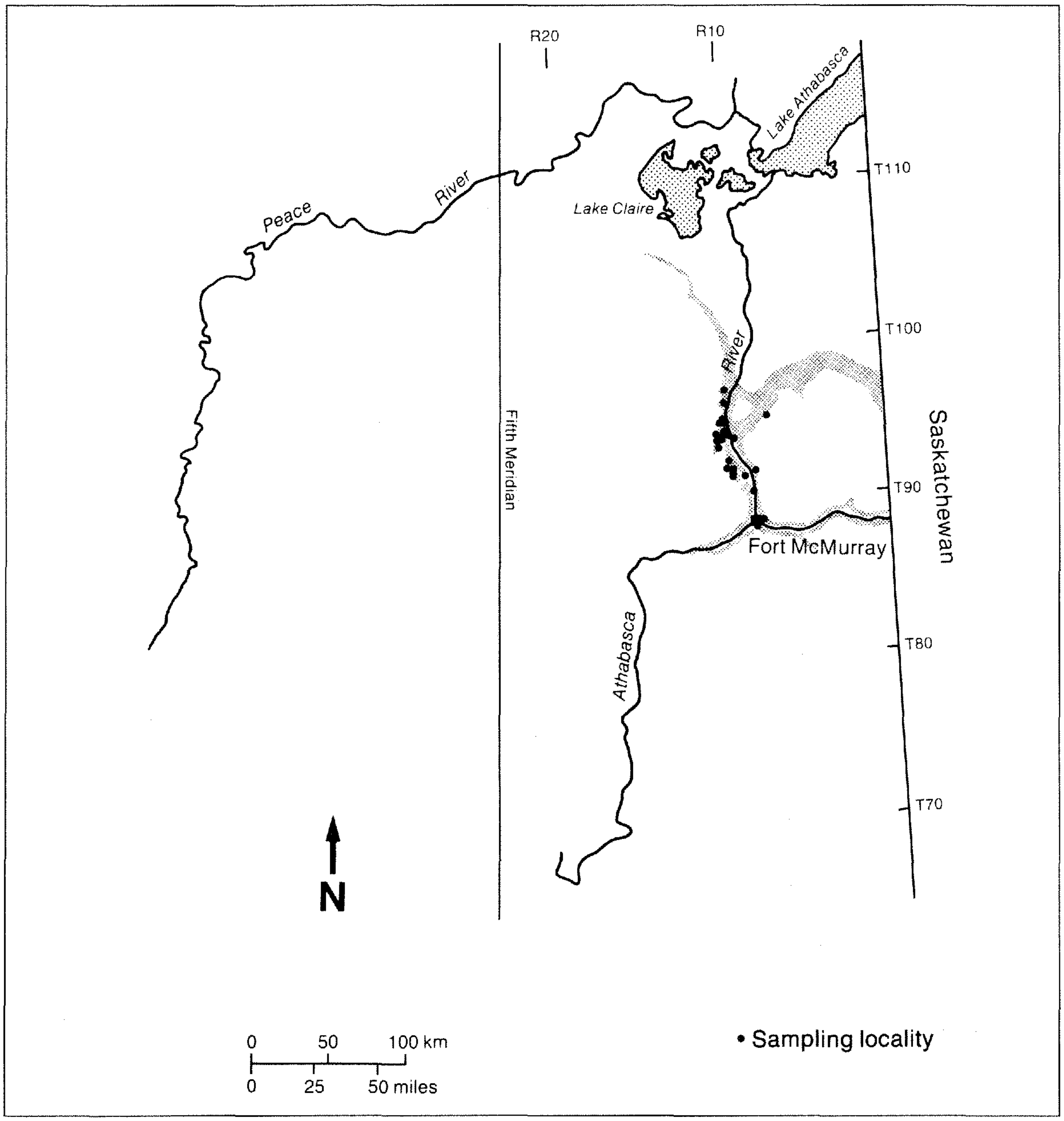

Figure 7. Geologic map of the McMurray Formation in Alberta.

from this lower zone are of interest for their ceramic and engineering properties and have been called "basal clays" (Scafe 1977, Dusseault and Scafe 1979). It is apparent from the work of Ells (1915, 1926), Hume (1924), and Halferdahl (1969) that most clay samples from the area tested previously were taken from the basal clays.

The basal clays contain some of the most refractory material discovered in the province (Appendix 1, 74D,E). P.C.E. values vary from three to 30 but clusters between 12 and 20 (Table 4). Tempering water varies from nine to 37 percent but most samples do not need much more or less water than the 21 percent average to produce good plasticity and working properties. About one quarter of the samples tested for this report have working properties lower than good and these samples commonly are difficult to extrude. Most samples dry well at room temperature. Minor warping occurs in about one quarter of the samples tested. At elevated temperature only about half the samples dry well. The remainder warp, crack, or check during rapid drying even though maximum shrinkage is nine percent and average shrinkage is six percent. Addition of

Table 4. General Characteristics of Samples from the McMurray Formation Basal Clays.

			Unfired Properties				
					Drying Properties		
Description	P.C.E.	Tempering Water (%)	Plasticity	Working Properties	Room Temperature	105°C	Drying Shrinkage (%)
various shades of gray to black clay, non-calcareous, massive to thinly laminated, minor silt	3-30 (most 12-20)	9-37 (21 avg)	good	good	good	about half warp, crack, check	6

Fired Properties							
	Steel Hard			Maximum Fire			
Color	Temperature °C	Absorption (%)	Color	Temperature °C	Absorption (%)	Shrinkage (%)	Remarks
orange, red, gray, brown, buff	890-1275	3-23 (8.4 avg)	gray or brown dominant	975-1360 approx. half 1160-1250	0-18 (2.8 avg)	0-13 (5 avg)	some "slag spots", some black core & bloating, must be mined with oil sands, moderate to long firing range common

sand or grog probably would correct the drying problems.

Colors at steel hardness are shades of orange, red, gray, brown, and buff with no color dominant. Steel hardness temperature ranges widely from 890 to 1270°C. Twenty percent of the samples reach steel hardness by 950°C, 20 percent ranges from 970 to 1030°C, another 20 percent is clustered between 1075 and 1100°C, and the remainder are spread between 1150 and 1275°C. Absorption at steel hardness varies from three to 23 percent but averages 8.4 percent. Colors at maximum recommended firing temperature are shades of orange, red, gray, brown, and buff with gray or brown the color in slightly more than half the samples. Nearly half the samples have a maximum recommended firing temperature between 1160 and 1250°C. Only 20 percent of the samples have maximum recommended firing temperature greater than 1250°C (cone 6). Absorption varies from zero to 18 percent but averages 2.8 percent. Fired shrinkage averages five percent and varies from zero to 13 percent. Typical shrinkage and absorption versus temperature curves for McMurray Formation basal clays are shown in Figure 8.

Some fired bars have black, slag-like inclusions at their surface that probably are "iron spots" that form when carbonaceous matter is present in the body and small siderite ($FeCO_3$) or pyrite (FeS_2) grains are reduced to metallic iron or iron carbide during firing (Grimshaw 1971). This fault is most objectionable if the body is to be glazed, as water from the glaze slip reacts with the reduced iron or iron carbide and releases gases that cause "blow-offs" of large sections of glaze. Another pair of carbon/iron related problems, with a few samples in the basal clays, are "black coring" and bloating. As long as carbon remains in a body during firing the oxidation of iron is prevented or severely retarded. Carbon has a much stronger affinity for oxygen than does iron, so carbon oxidation monopolizes the supply of oxygen and keeps the iron in a ferrous state. The carbon content remaining in a body with a black core commonly is nil or a trace and the black coloration is from the presence of ferrous iron. Bloating associated with a black core indicates that the outer pores present in the body closed before oxidation of carbon, dissociation of sulfides and sulfates by silicic acid, or other gas-forming reactions were completed. The sealing of escape routes for the gases causes buildup of pressure in the body and bloating occurs. Basal clays that exhibit black core, bloating, or slag-like inclusions invariably are darker shades of gray, olive gray, or yellowish brown and easily could be cast aside during mining to avoid the problems inherent with burning these clays. However, these clays probably could be used if they are diluted by mixing with light gray clays and if during firing the temperature is held at 800 to 900°C (Ries 1908) until the carbonaceous matter is burned out.

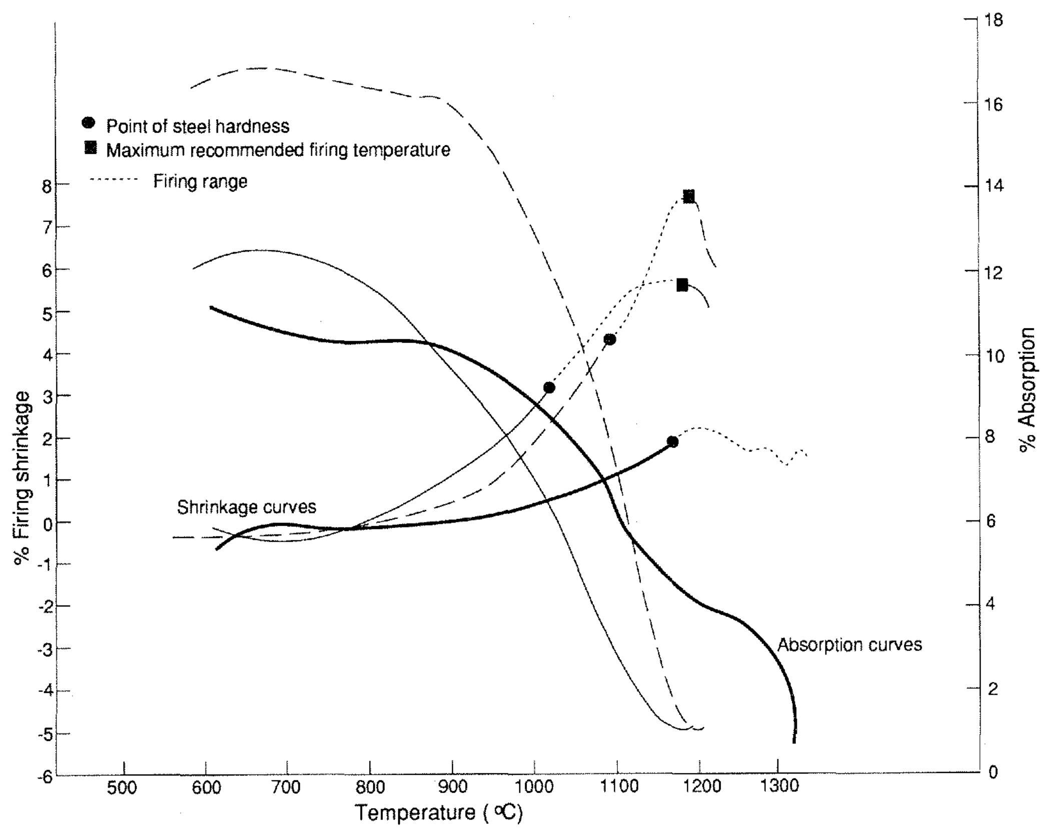

Figure 8. Typical shrinkage and absorption versus temperature curves for McMurray Formation basal clays.

It is not possible, with the data obtained in this study, to relate maximum recommended firing temperature of a sample to a specific percentage of the clay minerals kaolinite or illite. The data do show, however, a good general relationship, such that samples with maximum recommended firing temperature below 1150°C have a kaolinite content averaging 30 percent and an illite content averaging 70 percent. Between 1160 and 1250°C, where nearly half the samples tested are grouped, kaolinite content averages 40 percent and illite 60 percent. Above 1300°C kaolinite content averages 70 percent and illite 30 percent. As expected, refractoriness increases with kaolinite content.

Good plasticity and workability, good or improvable drying properties, gray or brown as the dominant color at maximum recommended firing temperature, low fired shrinkage, and the possibility that the clays could be mined in association with the oil sands are positive characteristics for the basal clays. The wide range of colors at steel hardness may seem detrimental but does add scope for an imaginative entrepreneur to establish a diverse color choice for a product line. Pyrometric Cone Equivalent (P.C.E.) values can be as high as cone 30, the top end of low heat duty refractories (A.S.T.M. Designation C27-70), but 65 percent of the P.C.E. values are concentrated between cones 14 and 18, and 82 percent are clustered between 12 and 20. The most common P.C.E. values, therefore, are near the bottom end of low heat duty refractories (cone 15). In addition, only 20 percent of the samples tested for this study have a maximum recommended firing temperature greater than 1250°C (cone 6). One should be careful, therefore, not to overvalue the high refractoriness (>20) exhibited by a few samples. Average absorption is greater than the two percent allowable for unglazed stoneware and few samples mature at the desired maturation temperature of 1330°C (cone 10) for stoneware (Table 1). No sample fires white. Alkali is too high for use in low alkali cement (Appendix 3). Overburden (oil sands) everywhere covers the basal clays and is too thick to allow recovery of the basal clays as an independent commodity. It is a prerequisite, therefore, that mining of the basal clays be tied to mining the oil sands, a prospect about which the energy extraction companies probably would be unenthusiastic. Although the basal clays have many desirable properties, there are sufficient deficiencies that it is unlikely this raw material could compete with clays available elsewhere.

Clearwater Formation

The Clearwater Formation outcrops extensively along the Athabasca River north and west of Ft. McMurray. Other exposures are present in tributary streams of the Clearwater River. A bed of glauconitic sandstone less than six m thick defines the base of the formation with the underlying McMurray Formation (Carrigy 1959). The upper contact with the Grand Rapids Formation is transitional. Characteristic lithology of the formation is olive gray, massive, slightly silty marine shale. Outcrops commonly are littered with gypsum crystals.

Ceramic data are available for three samples from NTS area 74D. P.C.E. values commonly are three. With tempering water of 20 percent, plasticity is fair to good but the material usually extrudes well. Warping during drying at any temperature is usual and drying shrinkage averages 7.8 percent. Shades of pale to moderate brown are the most common colors both at steel hardness and maximum recommended firing temperature. The moderate brown is an attractive but unconventional color. The firing range of 20 to 25°C is so short that temperature control in a kiln would be very critical. Fired absorption is less than three percent and fired shrinkage is less than eight percent.

Kaolinite concentration ranges from absent to 20 percent, illite 35 to 60 percent, smectite 10 to 45 percent and chlorite ranges from five to 25 percent. The low P.C.E. values reflect the low kaolinite concentration and the presence of feldspar fluxes as a major component. The sample with the greatest amount of smectite extrudes stiffly. The presence of soft white grains after firing that same sample is from breakdown of the gypsum grains present. The poor drying and firing characteristics make shales of the Clearwater Formation undesirable for ceramic use.

Fort St. John Group

In the northwestern Foothills of Alberta near Grande Cache, is a succession of dark gray, rubbly to platy, rusty weathering shales with some interbedded argillaceous siltstones that have a ribboned or striped appearance. These shales lie between the upper part of the Luscar Group and the Dunvegan Formation and are called the Fort St. John Group (Stott 1963). The lower contact with the Luscar Group is abrupt and the upper contact with the Dunvegan Formation is transitional over an interval of six m (Irish 1965). Maximum thickness of the unit is 150 m. To the northwest in British Columbia the Fort St. John Group thickens and is divided into a number of formations (Stott 1982), the uppermost of which is the Shaftesbury Formation.

Only one outcrop of Fort St. John Group was encountered in this study and one sample was taken. The outcrop consists of interbedded shale and argillaceous siltstone and as much of the siltstone as possible was removed in order to assess the value of the more representative shale portion. Fair plasticity and working properties are attained with 17 percent tempering water. Bars extrude and dry well with drying shrinkage only 4.4 percent. The material exhibits a moderate firing range between the temperature of 1030°C (cone 06) for steel hardness and 1120°C (cone 04-03) for temperature of maximum recommended firing. Fired color at the maximum recommended firing temperature is a milk chocolate brown, absorption is 0.6 percent and firing shrinkage is 6.8 percent.

The good drying and firing characteristics can be partially explained by the clay mineralogy, composed of 85 percent illite and 15 percent kaolinite. Feldspar, the only flux detected, is present only in minor amounts. If further testing indicated that this sample is representative of less silty shales from the Fort St. John Group, the good drying properties, moderate firing range, low absorption, and brown coloration would make material from the Fort St. John Group desirable for production of structural clay products and pottery.

Upper Cretaceous rocks

Shaftesbury Formation

Marine shales of the Shaftesbury Formation are present over a wide area of northwestern and north-central Alberta, and are well exposed along the Smoky and Peace rivers. This formation, which straddles the time boundary between Early and Late Cretaceous, can be divided into two members. The lower member, 183 to 320 m thick, consists of soft, black, fissile shale, which upon weathering forms an abundant pale yellow or whitish, powdery efflorescence (natrojarosite $NaFe_3(SO_4)_2(OH)_6$) on outcrop surfaces. The upper member, 91 to 168 m thick, consists of soft, dark gray, fissile to black shale containing scattered siltstone beds a few tens of centimetres thick (Green and Mellon 1962). The formation thins to the west, south, and east and is transitional into the overlying nonmarine Dunvegan Formation (Green and Mellon 1962; Jones 1966).

Three samples were processed from Shaftesbury Formation outcrops along the Peace River near Peace River town (NTS area 84C, Appendix 1) because of the probability that manufacturing facilities would be built in that vicinity if the material showed potential. Some differences in ceramic characteristics between the upper and lower members are suggested from results obtained in processing the two samples from the lower member and the single composite sample from an 11 m cut in the upper member. More sampling and processing would be necessary to determine whether these perceived differences persist over wide areas. Samples from both the lower and upper members exhibit minor warping during drying at room temperature. The lower member samples dry well at elevated temperature, steel hardness is attained between 1020 and 1060°C, and maximum recommended firing temperature is between 1110 and 1125°C, giving a moderate firing range. The upper member sample cracked during drying at elevated temperatures, steel hardness is attained near 1085°C, and the maximum recommended firing temperature of 1100°C gives an extremely short firing range. Long, deep cracks are formed in bars made from the lower member on firing and previously calcined chunks of raw material exploded in the furnace when the material was tested for suitability as a source for synthetic (expanded clay) aggregate.

Extruded bars from the upper member exploded during firing but hand molded bars were fired successfully. The upper member was not tested for suitability as a source for synthetic aggregate because of the other less than satisfactory firings.

It is unknown why samples from the Shaftesbury Formation react so violently to firing. The content of montmorillonite varies from five to 15 percent and would be expected to cause some drying and firing problems especially at the higher concentrations. However, the extruded bars that cracked on drying at elevated temperatures and exploded on firing were from the upper member that has only five percent montmorillonite and should be less susceptible to this bloating. The short firing range of the upper member sample results from the presence of the fluxes calcite and feldspar as major and minor mineralized components respectively.

If the three Shaftesbury Formation samples tested during this study are representative of the formation it is unlikely that any ceramic use can be contemplated. The material cannot be dried or fired successfully after extruding, nor can it be fired successfully in chunks for synthetic aggregate even after calcining. Hand molded bars were fired successfully but the greater pressure applied during commercial pressing operations may cause similar problems to those encountered when using extruded material.

Dunvegan Formation

Extending from just north of the Athabasca River to the British Columbia border in the Foothills (Irish 1965) and on either side of the Peace River from the British Columbia border through approximately one-third of the river's length in Alberta, are rocks of the Upper Cretaceous Dunvegan Formation. The formation is up to 310 m thick in the Foothills (Stott 1963) and 180 m in the Peace River area (Jones 1966). Gray is the predominant color of the fine- to medium-grained, flaggy sandstones, argillaceous sandstones, siltstones, and shales. The relative amount of each lithology varies from one locality to another (Irish 1965). Some shales are dark greenish to black, and weather rubbly or blocky. Sediments vary from marine to nonmarine in origin throughout the formation. Upper and lower boundaries are transitional.

Two samples of shale were collected from the type section of the formation at Dunvegan Crossing on the Peace River (NTS area 83M, Appendix 1) and another from a roadcut northwest of Peace River town on Highway 35 to Manning (NTS area 84C, Appendix 1). With 20 percent tempering water plasticity and working properties are good to very good. Drying at room temperature causes bars to warp and drying at elevated temperature results in severe cracking. Drying shrinkage averages 7.8 percent. One sample bloated so badly during firing (even after hand molding) that firing data were unattainable. Steel hardness temperature averages 1000°C and maximum recommended firing temperature averages 1080°C. Absorption at maximum recommended firing temperature is 1.5 percent and fired shrinkage is 8.1 percent.

The cracking on drying and bloating on firing relates well to differences in smectite content. The two samples from Dunvegan Crossing warped and cracked on drying and only one fired successfully after hand molding. Smectite content is 20 and 30 percent for these samples. The sample from northwest of Peace River town has minor warping when dried at room temperature and some cracking when dried at elevated temperature. Extruded bars fired successfully. Smectite content is five percent.

Further testing might indicate that material from the formation with low smectite content could be improved, by adding grog or other modifiers, so that it could be used for glazed pottery or structural clay products where the fired color is of no consequence. Material with high smectite content probably could be used for expanded aggregate. Because shales do not constitute a large volume of the Dunvegan Formation it may be difficult to find suitable material at readily accessible locations.

Kaskapau Formation

Sediments of the Kaskapau Formation overlie the Dunvegan Formation conformably and gradationally and have a similar geographical distribution from the Athabasca River to the British Columbia border (Figure 9). The sediments consist of dark gray marine shales, fissile to thin bedded, and in part silty, with numerous interbedded, thin, hard, gray, buff to yellow weathering concretionary ironstone beds (Irish 1965). These easily weathered shales generally are expressed in the topography by broad valleys with gentle, commonly grass-covered slopes. Maximum thickness of the formation is 460 m (Stott 1963).

Eighteen samples were tested from NTS areas 83L,M,N, 84C,D (Appendix 1) and with 15 to 21 percent tempering water plasticity and working properties are fair to good. Slight warping occurs during drying at room temperature and at elevated temperature but normally bars dry without cracking. Drying shrinkage varies from 3.5 to 6.9 percent and averages 5.8 percent. Temperature of steel hardness varies from 1000 to 1140°C and maximum recommended firing temperature varies from 1065 to 1150°C. Firing range most commonly is less than 50°C. Absorption at steel hardness averages 4.9 percent. Absorption at maximum recommended firing temperature averages 3.5 percent and fired shrinkage averages 7.9 percent. Pyrometric Cone Equivalent is eight to nine.

Marine shales of the Cretaceous Kaskapau Formation are unusual because smectite is identified as one of the clay mineral components in only two samples. Absence of smectite should contribute to low drying shrinkage and warping and cracking should be minor. The common warping of test bars during drying, and cracking of test bars during firing is because of the high proportion of clay-size material in the material. These faults are corrected easily with the addition of up to 20 percent grog or sand. The presence of abundant sulfur is indicated by gypsum crystals, pyrite, and jarosite (yellow powder) on outcrops and black core on firing. Addition of grog and slow firing should combine to allow complete oxidation of sulfur and the elimination of black core. Calcium carbonate concretions commonly are abundant but calcium carbonate is rare in the fine material. Sieving should remove most of the concretions and calcium carbonate should not be a problem. Kaolinite content varies from five to 40 percent, illite from 60 to 75 percent, and chlorite zero to 20 percent. Clay mineral content does not indicate any consistent relationship to firing characteristics. For example, one sample contains five percent kaolinite, 75 percent illite, 20 percent chlorite, and exhibits a long firing range, whereas another sample contains 30 percent kaolinite, 70 percent illite, and exhibits no firing range. Neither sample contains carbonate or feldspar fluxes. The effect of higher kaolinite concentration ordinarily would be to increase refractoriness and give a longer firing range. The effect of more chlorite should be to shorten the firing range because of the MgO content (Brownell 1976). Why these two samples fire contrary to expectations is unknown.

Tests of shales of the Kaskapau Formation in this study show potential for ceramic use in an area of the province where enegry is abundant, "back

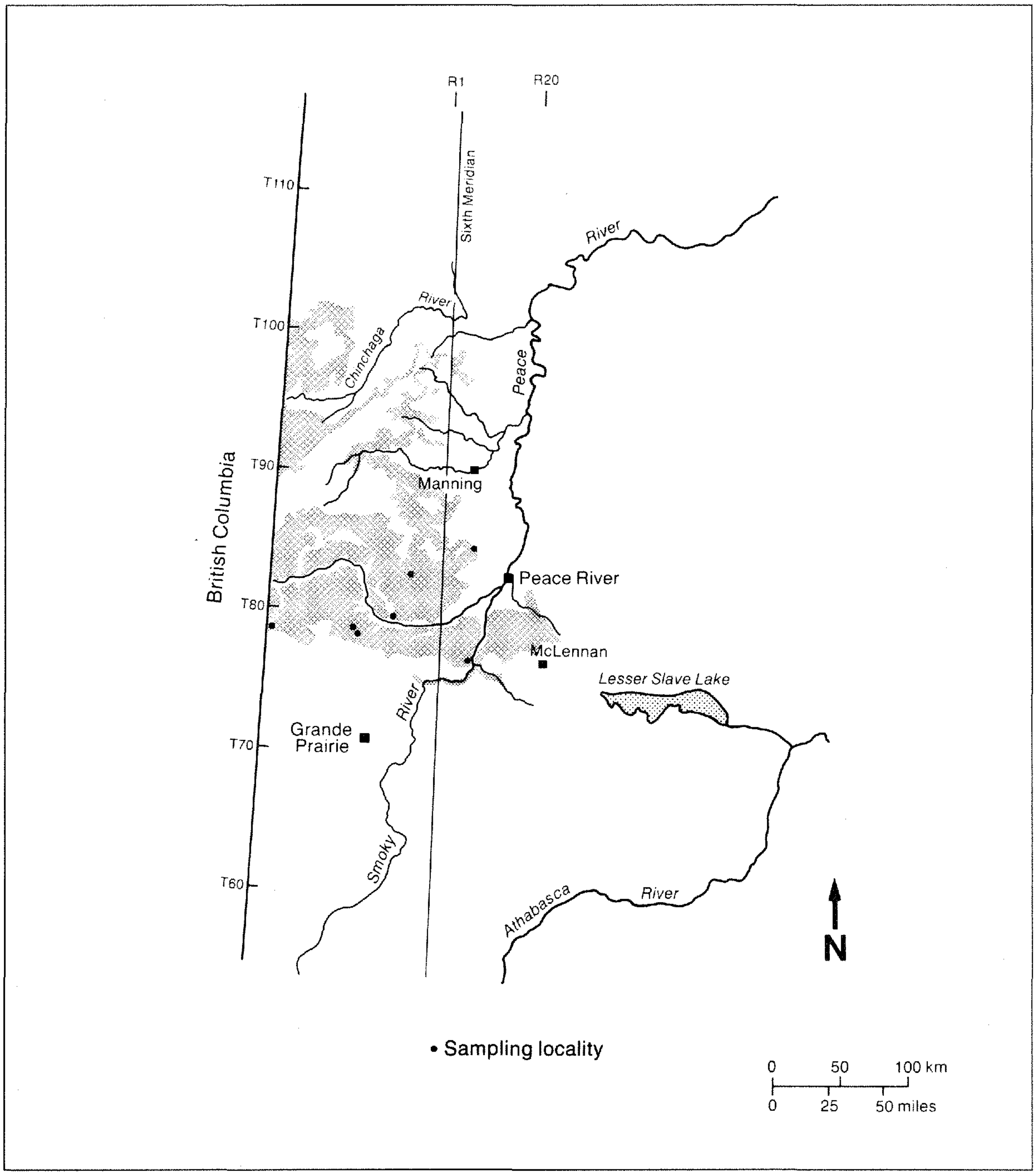

Figure 9. Geologic map of the Kaskapau Formation in Alberta.

haul" transportation rates are likely to be favorable, and the manufacturing base is small. With the addition of grog and slow firing, material from this formation could be used for brick, tile, and for unglazed "earth color" pottery or any pottery fitted with a colored glaze. The material also could be fired to produce a moderate weight synthetic aggregate with low absorption.

Alberta Group

Sediments forming the Alberta Group (Figure 10) in the Rocky Mountains and Foothills were called the Benton Formation in the early part of this century when the first ceramic tests were performed by Ries and Keele (1913), Ries (1914a, b; 1915), Leach (1914), and Keele (1915). When Worcester (1932) published ceramic test data he noted that the rocks between the Blairmore and

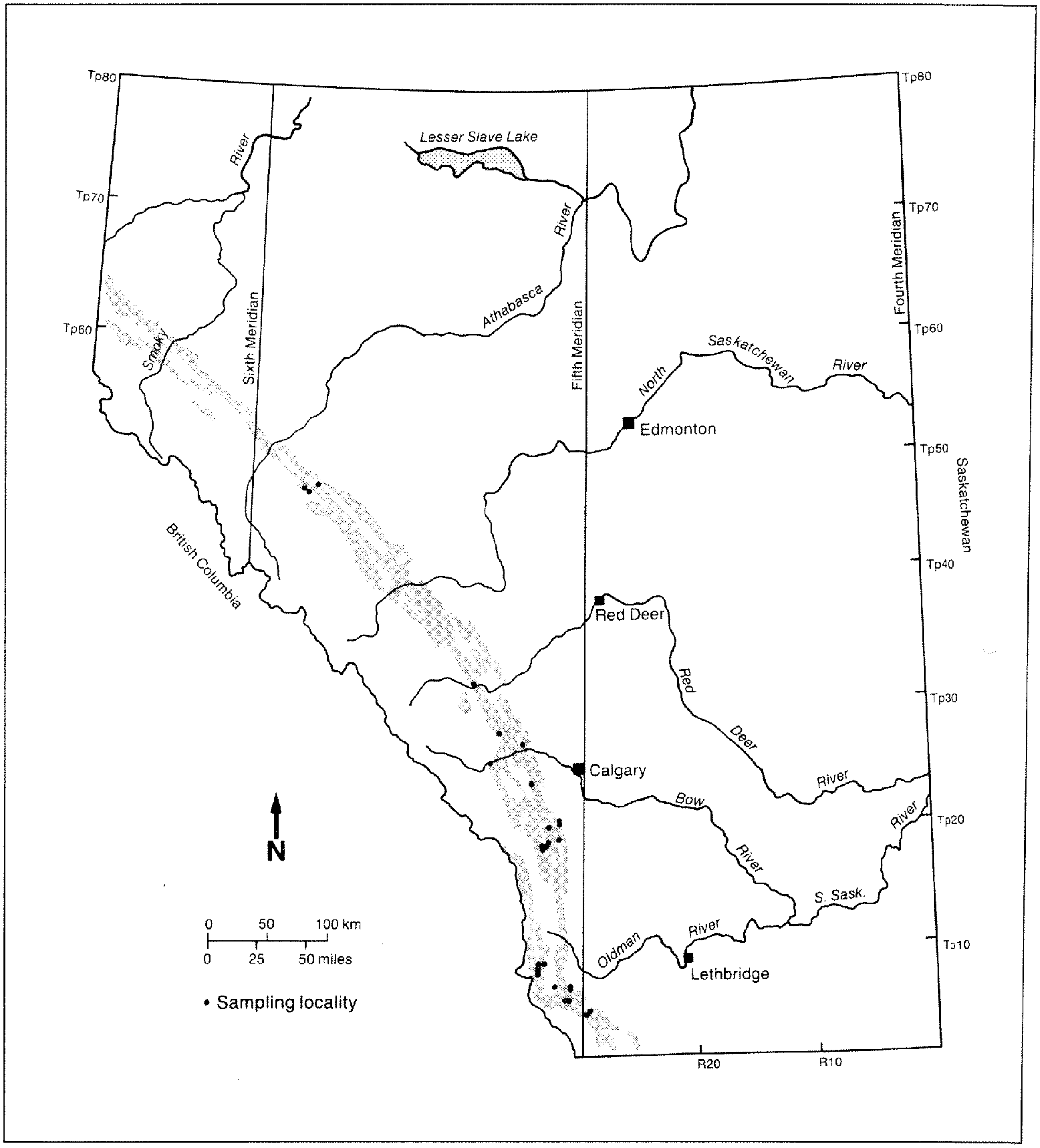

Figure 10. Geologic map of the Alberta Group in Alberta.

Belly River formations in the Southern and Central Foothills recently had been named Alberta Shale (Hume 1930). He noted also that Rutherford (1927) had divided this interval, previously known as the Benton Formation, into the Lower Benton, Cardium, and Upper Benton. However, Worcester used the term Benton Formation and made no attempt to interpret which portion of the section any of his samples came from because ceramically the samples are quite similar. Webb and Hertlein (1934) later suggested that the Alberta Shale be elevated to group status and they recognized the Blackstone, Cardium, and Wapiabi formations within the group. The work of Stott (1963) probably remains the definitive publication on the geology of the Alberta Group and is cited in following sections of this report where data from the Blackstone, Cardium, and Wapiabi formations are discussed.

In summarizing the ceramic data of the 27 samples tested by the authors listed above one finds that the amount of tempering water used ranges from 14 to 31 percent and averages near 20 percent. Plasticity fluctuates from poor to very good but workability commonly is poor. Most samples dry safely due to drying shrinkage that averages only 4.6 percent. Minimum fired shrinkage is zero and maximum fired shrinkage is 5.6 percent. Minimum fired absorption is 4.4 percent and steel hardness is reached at the maximum fired temperature. Common fired colors reported are buff, grayish red, or red. The most commonly recommended use is for dry-press brick. Typical shortcomings are the problems associated with mining vertical or steeply dipping beds and the tendency for the material to scum during firing.

Blackstone Formation

Extending northward from the Castle River in the southern Rocky Mountains and Foothills, rocks that are age equivalent to the combined Shaftesbury, Dunvegan, and Kaskapau formations are called the Blackstone Formation (Figure 2). This formation is the lower of three units that form the Alberta Group (Figure 10) in the south-central Rocky Mountains and Foothills. It consists of a succession of marine shales and siltstones with some beds of dolomitic limestone, sandstone, bentonite, and ironstone concretions (Stott, Gibson, and Ollerenshaw 1968). More westerly sections contain higher silt content in siltstone beds and hard, platy, silty shales. Easterly shales are rubbly, flaky, or fissile. All shales contain abundant carbonaceous matter. The lower boundary is a well-defined disconformity and the upper boundary is transitional into the Cardium Formation sandstone. The formation thickens from southeast to northwest to a maximum thickness of 530 m. Four members are recognized (Stott 1963) and are named, from lowest to highest, Sunkay, Vimy, Haven, and Opabin. Three of the four members (Sunkay, Vimy, Haven) were sampled for this study.

Five samples of Blackstone shales were collected in NTS areas 82G and 83F (Appendix 1). A sample from the Haven member has a P.C.E. of 12 but six is a more common value for samples from other members. With 15 percent tempering water, plasticity and working properties generally are poor to fair. All samples dry well and maximum drying shrinkage is 4.6 percent.

It was possible to fire only one sample from the Sunkay member and the sample from the Haven member to completion. For the three other samples, either steel hardness was not reached before firing was terminated (to protect the furnace as the P.C.E. value was approached), or the bars curved so badly that the firing was terminated to protect the furnace from a bar sticking to the muffle.

Mineral data from the limited number of samples from the Blackstone Formation seem to indicate that the members may be recognizable from mineralogic as well as stratigraphic data. The Sunkay member contains only five percent kaolinite, illite is 85 percent, and chlorite is 10 percent. Feldspar and calcite also are present in minor and trace amounts. The Vimy member contains 25 percent kaolinite and 75 percent illite. Calcite is present in both samples and dolomite is present in one. The single sample from the Haven member has 25 percent kaolinite, 75 percent illite, and only minor feldspar. The minor amount of flux would help account for the higher P.C.E. value for this sample than for samples from the other members.

If the data from the single sample tested from the Haven member are typical, further testing of this member is warranted, because it has the highest P.C.E., plasticity and workability are very good, it dries well, fires to a milk chocolate brown through a long firing range, and has fired absorption of only 0.7 percent. Only one of two samples from the Sunkay member fired to completion but that sample exhibits a moderate firing range. Fine grinding may improve plasticity and workability of raw material from the Sunkay member. Material from the Vimy member has no ceramic potential.

Cardium Formation

A formation that is widely recognized in western Alberta, the Cardium Formation is characterized by sandstones but does contain both marine and nonmarine shales. Six members are recognized in the formation (Stott 1963), but only the Moosehound Member (second from top) was encountered and sampled in this study. This member, recognized in outcrop from the Muskeg River near Grande Cache southward to the North Saskatchewan River, is thick (40 m) in the north and along the Front Range, but thins eastward. Along the Front Range, it consists of greenish to brownish rubbly shale with beds of carbonaceous sandstone. The shales are generally soft and crumbly and contain nonmarine invertebrate fossils.

One sample from the Moosehound Member was collected in NTS area 83F (Appendix 1). With 14 percent tempering water, plasticity is fair, working properties are good, but the material is difficult to extrude. Drying properties are good and drying shrinkage is 3.6 percent. At the temperature of steel hardness (1010°C, cone 07), the bars are a light brown color and absorption is 0.6 percent. At the maximum recommended firing temperature (1100°C, cone 04), the color is a pleasant moderate reddish-brown, absorption is 3.2 percent, and shrinkage is 6.4 percent. The moderate firing range, reddish fired color, low shrinkage, and acceptable absorption suggest that further testing of material from this member is warranted.

Wapiabi Formation

The Wapiabi Formation is the upper of three units that form the Alberta Group in the south-central Rocky Mountains and Foothills and the Smoky Group in the northern Rocky Mountains and Foothills. The formation outcrops in the Front Ranges from the Canada-U.S. boundary to the British Columbia-Alberta boundary (Figure 10) and extends east beneath the Plains. Maximum thickness is 655 m (Stott 1963) and only a slight disconformity separates it from the underlying Cardium Formation.

The dark gray shales of the Wapiabi Formation contain abundant organic material, weather from gray to rust color, and vary from fissile to rubbly and platy (Stott 1966). Prominent outcrops of the formation are uncommon (Irish 1965). Reddish-brown-weathering sideritic concretions are plentiful in the basal and upper third of the formation. Glauconite is present in these concretionary shales. Dark gray, argillaceous, massive siltstone is present in the lower part of the formation near the top. Beds of argillaceous, dolomitic limestone are present in the central part.

A P.C.E. value near six is common for shales of the Wapiabi Formation. Although the plasticity is poor and the working properties are only fair, the material generally extrudes well. Drying properties are good and drying shrinkage averages only 4.6 percent. Steel hardness is reached near 1115°C (cone 04) but the maximum recommended firing temperature is only 1140°C (cone 02), which gives an extremely short firing range. Also, bars tend to curl and expand rapidly on overfiring. Both average absorption and firing shrinkage at maximum recommended firing temperature are low at 2.6 and 5.4 percent respectively.

The clay mineral content of Wapiabi Formation shales, commonly averaging 25 percent kaolinite and 75 percent illite, would suggest a desirable raw material for structural clay products. The combination of calcite or dolomite and feldspar in each sample, however, is sufficient to reduce the firing range dramatically and to produce only a pale brown fired color. The presence of abundant organic material in most of the shales and gypsum in a few samples also are deleterious characteristics. Shales of the Wapiabi Formation are of little value as ceramic raw materials. Lafarge Canada Inc. uses material for Portland cement production at Exshaw.

Lea Park Formation

The Lea Park Formation in central and eastern Alberta is in part age equivalent to the Pakowki Formation of the southern Plains. The formation is a uniform series of marine, gray, silty shales with local intercalations of sandy shale, ironstone concretionary bands, and bentonite (Shaw and Harding 1954). Thickness is 137 to 247 m, increasing northeastward. The lower boundary is at the top of the "First White Speckled Shale" zone of the Colorado Group marine shales and the upper boundary is gradational into the sands of the Judith River Formation. The Judith River Formation formerly was called the Belly River Formation in this area (McLean 1977).

Five samples from the upper part of the formation were taken in NTS area 73E (Appendix 1). However, two of these samples bloated so badly during P.C.E. testing that they were not tested further. With 23 percent tempering water, the three other samples have good plasticity and good working properties. Extruded bars warp when dried at room temperature and crack badly when dried at elevated temperatures. Drying shrinkage averages 8.4 percent. To obtain bars for firing that did not warp or crack on drying, hand-molded bars were made. One sample bloated so badly on firing that it was discarded, and firing data are available from only two samples. Color at steel hardness is light to moderate brown and absorption averages 5.9 percent. Color at maximum recommended firing temperature is moderate brown, absorption is 2.7 percent, and average fired shrinkage is 7.4 percent. Firing range is short.

Kaolinite comprises 20 percent of the clay mineral suite, illite is 55 percent, and smectite is 25 percent. Feldspar is abundant and gypsum is present in four of the five samples tested. The high amount of smectite is responsible for the good plasticity and working properties as well as the drying problems. Feldspar fluxes account for the short firing range. Gypsum is likely to cause efflorescence in any structural clay product (pressed bricks?) even if it could be fired successfully. The tendency to bloat at low temperatures is advantageous in the production of lightweight aggregate and this material could be considered for this use.

Pakowki Formation

The Pakowki Formation (Dowling 1917), consisting primarily of marine shale, is well exposed in the eastern Milk River valley and continues in an arc to the International Boundary west of Coutts (Green 1972). The lower contact is marked by a thin (15 to 30 cm) bed of dark gray to black, well-rounded chert pebbles (Russell and Landes 1940). The upper contact is gradational. Maximum thickness is 275 m. The formation is divisible into a lower shale member and an upper member composed of impure shales and sandstones. The Lower Pakowki consists primarily of dark gray and brown, friable to coarsely fissile shale that commonly weathers to fine flakes in talus along streams with steep cutbanks. Characteristic sediments of the Upper Pakowki are alternating shales and sandy shales with thin beds of fine-grained sandstone. These sediments disintegrate rapidly, the outcrop surface characteristically is covered by a layer of finely mud-cracked wash, slopes of outcrops usually are low, and badlands form readily.

With 22 percent tempering water, plasticity is fair to good and working properties are good in the five samples taken from the Lower Pakowki in NTS area 72E (Appendix 1). Bars warp when dried at room temperature and crack when dried at elevated temperatures. Average drying shrinkage is 8.7 percent. The common color at steel hardness is light brown. Steel hardness temperatures vary from 975 to 1115°C (cone 08-04) and absorption varies from two to 11.3 percent with an average absorption of 7.7 percent. Color at maximum recommended firing temperature is moderate brown, maximum recommended firing temperature varies from 1080 to 1120°C (cone 05-03), absorption averages 1.5 percent, and fired shrinkage averages 7.9 percent.

Certain unfired and fired characteristics change in samples of the Pakowki Formation with changes in mineral composition. The average clay mineral concentrations are kaolinite 20 percent, illite 40 percent, and smectite 40 percent. Feldspars are present in all samples, dolomite is a major component in one sample, and gypsum commonly is present as a major mineral. The sample with smectite concentration of 60 percent could not be extruded, samples that contain gypsum have soft white grains on the surface of a bar after firing, and the sample with major concentrations of dolomite and feldspars has no firing range. The presence of gypsum could cause efflorescence of a fired product exposed to weathering.

Firing ranges from zero to moderate, poor drying properties, difficult extrusion characteristics, and the presence of gypsum suggest that material from this formation is of little value for ceramic purposes.

Belly River Formation

The Belly River Formation, a sequence of continental mudstones and sandstones up to 760 m thick, is recognized in the Foothills from the International Boundary to about the Clearwater River (Stott 1963). The basal contact is gradational with the underlying Wapiabi Formation. North of the Bow River the overlying Bearpaw Formation does not reach as far west as the outcrop belt and the Belly River sediments become indistinguishable from the Brazeau Formation (Lerbekmo 1963). Mudstone predominates and is dark greenish gray to grayish green, poorly bedded and nonfissile. Interbedded sandstone is medium light gray, light brown weathering, cross-laminated, massive to platy, fine- to medium-grained and moderately indurated (Lerbekmo 1963). A minor part of the formation consists of thin coal seams, bentonites, and nodular limestones.

No samples were collected by the author but Worcester (1932) processed nine samples from the Foothills in NTS area 82J (Appendix 1). With 22 percent tempering water, plasticity and working properties are fair to poor. Drying properties are good and drying shrinkage averages 5.8 percent. Steel hardness commonly is attained near 890°C, absorption is 14.8 percent and medium dark red is the most common color. Average maximum recommended firing temperature is 1150°C, absorption is 5.1 percent, shrinkage is 4.6 percent, and medium dark red remains the most common color. The material dries well, burns well with a long firing range, color is good, and scumming is minor. All samples collected by

Worcester (1932), however, were from steeply dipping beds and this could cause problems for mining.

From eight samples, Lerbekmo (1963) determined that all contain illite. Average illite concentration is 65 percent but two mudstones contain 100 percent illite. Maximum smectite content is 25 percent but only half the samples contain smectite. Mixed-layer illite-smectite is present in five of the eight samples and kaolinite is present in six. Maximum kaolinite content is 20 percent. The good drying properties, color, and firing range is related to the high illite content and presence of kaolinite in the raw material. Smectite or mixed-layer illite-smectite does not seem to be abundant enough to degrade the positive characteristics of the illite and kaolinite.

Judith River Formation

Sediments of the Judith River Formation underlie a major area of southeastern and east-central Alberta. North of the International Boundary the formation outcrops in a wide arc that extends as far west as Lethbridge, forms the badlands of Dinosaur Provincial Park, extends into Saskatchewan at Empress, and reenters the province in a wide band from south of Provost to north of Marwayne. Northeast of Edmonton the Judith River sediments become indistinguishable from sediments of the Wapiti Group (Figure 11). Before the work of McLean (1971; 1977) these sediments were called the Foremost and Oldman formations or the Belly River Formation.

The lower boundary is gradational into the Pakowki Formation in southern Alberta and into the Lea Park Formation in east-central Alberta. The upper contact with the dark sediments of the Bearpaw Formation commonly is abrupt. The formation consists of a wedge of brackish and freshwater sediments, between marine sediments, that thins eastward from a thickness of 260 m (Russell and Landes 1940). Sandstones commonly are fine- to medium-grained, argillaceous, poorly cemented and light gray in color. Rust-colored concretionary bands, pale yellow silts, lignite seams, greenish gray, brown and dark gray shales, and carbonaceous shales form a variable succession (Crockford 1949). In general, sediments in the lower part of the formation are darker than those in the upper part. Beds vary from centimetres to metres thick. Calcareous fossil shells occur in disseminated form or as major beds. The formation is world famous for the dinosaur remains it contains.

No clays from the lower part of the Judith River Formation, (formerly known as the Foremost Formation), have been used in regular brick manufacture in the Medicine Hat area (Lindoe 1984). The upper part of the formation, (formerly the Oldman Formation), however, has supplied material for the production of red bricks for over 60 years, even though the sandy, smectitic shales employed are far from ideal. A brick plant in the Smoky Lake area of east-central Alberta operated from 1919 to 1925 (Manson 1983) using material from the Judith River Formation (Allan 1921) that was called the Pakan Formation of the Belly River Series at that time. Many schools and homes around Smoky Lake were built with brick produced at the plant, but the bricks tended to explode on firing (Manson 1983).

The abrupt horizontal and vertical changes in lithology and the variable mineralogy from lens to lens requires special mining and stockpiling techniques to produce a uniform plant feed. General characteristics of the formation, however, are similar stratigraphically and geographically. Data for the Judith River Formation from NTS areas 72E,L, 82H are in Appendix 1. The most common value for P.C.E. is four. Tempering water of 25 percent usually gives good plasticity but only fair or sticky working properties that make the material hard to extrude. Drying is a problem at any temperature and cracking is pronounced at elevated temperatures. Drying shrinkage averages more than eight percent. Steel hardness normally is attained near 1025°C, the most common fired color is light brown, and absorption averages eight percent. Maximum recommended firing temperature seldom exceeds 1140°C, color regularly is moderate brown, absorption is less than 6.5 percent and fired shrinkage is near four percent.

Unfired and fired characteristics of Judith River Formation sediments relate well to the mineralogy. In the Medicine Hat area, the clay mineralogy of the lower part of the formation (Foremost) averages 20 percent kaolinite, 35 percent illite, and 45 percent smectite. The abundant smectite causes the material to extrude poorly and crack badly on drying. Samples that contain calcite or dolomite exhibit lime-popping on firing. Clay mineralogy of the upper part of the formation (Oldman) averages 10 percent kaolinite, 60 percent illite, and 30 percent smectite. The lesser amount of smectite makes this upper material slightly more useful as a ceramic raw material. Any sample containing abundant feldspar and

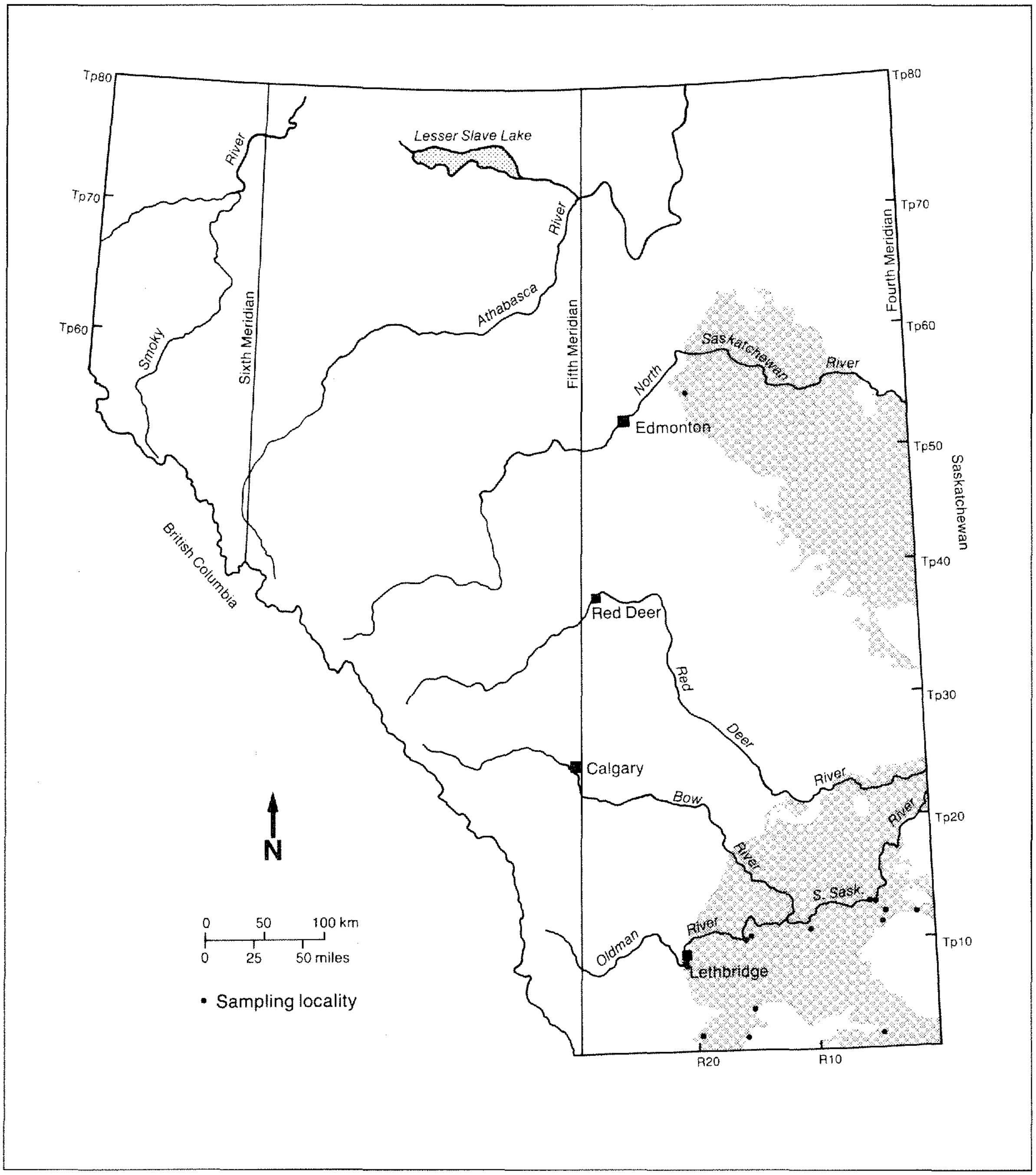

Figure 11. Geologic map of the Judith River Formation in Alberta.

dolomite has a short firing range and lime-popping occurs in samples containing abundant calcite. The high losses of brick during firing of the Judith River material used in the brickyard at Smoky Lake can be explained by the common presence of gas-forming calcite and carbonaceous material in those sediments. It is a wonder that any brick survived drying, because the average clay mineralogy consists of 20 percent kaolinite, 20 percent illite, and 60 percent smectite. The bricks are reported by Allan (1921) to be somewhat soft, so it is likely that they contain considerable sand, which would reduce drying shrinkage and cracking.

Using material from the Judith River Formation taxes the ingenuity of a manufacturer. Even if a homogeneous mixture of raw material is attained, extrusion commonly is difficult because of the stickiness resulting from the high amount of tempering water required by the high smectite content. The lower tempering water requirement for the dry-press method renders this method superior for forming and successfully drying bodies. Carbonate from disseminated oyster shells and sulfate from disseminated gypsum crystals cause lime-popping and scumming of bodies after firing. Fired color is more brown than red. One positive characteristic of the material is a firing range that commonly is moderate. Even though sediments of the Judith River Formation have been used for many years in the Medicine Hat area, they are not recommended for ceramic use if they can be replaced by other material that has fewer deleterious characteristics.

Brazeau Formation

The Brazeau Formation, extending northward along the Foothills from the International to the British Columbia boundary (Figure 12), is a thick wedge of continental sediments that is homologous to Upper Cretaceous rocks of the Plains above the base of the Judith River Formation or its equivalents (Figure 2). The formation is composed of sandstones and conglomerates, gray to greenish gray shales and thin bentonite beds, with some coal seams near the base (Stott, Gibson, and Ollerenshaw 1968). The formation has a gradational contact with the underlying Wapiabi Formation (Workum 1978). The gradational contact consists of distinctive pebble beds and conglomerate that change upward into sandstone (Irish 1965).

Defining the top of the Brazeau Formation can be a problem north of the North Saskatchewan River and commonly the Brazeau and overlying Paskapoo formations are mapped as one unit, the Saunders Group, in that area (Workum 1978). Over 3350 m of Brazeau sediments are present in the Hinton area and more than 1500 m of this thickness are considered to be of Tertiary age (Lang 1947). Lesser thicknesses of Brazeau sediments are present elsewhere.

Data are available for 47 samples from NTS areas 82G,J,O, 83E,F (Appendix 1). P.C.E. values range from three to 15, but most values are seven or lower. With average tempering water of 22 percent, plasticity and workability are mostly good. Drying characteristics at low temperature usually are good. Bars drying at elevated temperatures, however, either dry successfuly or crack in about equal numbers. Average drying shrinkage is 6.2 percent. Steel hard colors, commonly medium to dark red, are reached between 890 and 1150°C and no temperature is typical for steel hardness. Average steel hardness absorption is 10.8 percent. Colors at maximum recommended firing temperature commonly are medium to dark red and are attained between 1090 and 1225°C. Average fired absorption is 1.8 percent and average shrinkage is 9.1 percent.

Unfired and fired characteristics of samples collected from the Brazeau Formation, at first, seem to correlate poorly with clay mineral data. Kaolinite varies from nil to 100 percent, illite varies from nil to 80 percent, and smectite varies from nil to 100 percent. Some samples with smectite as the only clay mineral, work and dry well and have moderate to long firing ranges. Other samples from the same stratigraphic section, with similar mineralogy, work poorly, crack on drying, and have short firing ranges. The former samples, however, commonly are very hard and the smectite peaks are poorly developed on X-ray diffraction patterns whereas the latter samples commonly are soft, rich in carbon and have better developed peaks on x-ray diffraction patterns. It is possible, therefore, that a factor such as high content of silica cement in the hard samples counteracts the usual effects of smectite. Other samples from the formation that contain kaolinite and illite as the only clay minerals exhibit unfired and fired characteristics that one anticipates with the presence of these minerals. Samples work, dry, and fire well as kaolinite content increases, P.C.E. values increase, and firing ranges are moderate to long. Feldspars are trace to minor components of samples from the formation and calcite or dolomite are identified as trace or minor components in only three samples.

The association of coal and mudstones in the Brazeau Formation could be a positive association. The wide fluctuation in clay mineral assemblages and the sometimes unpredictable drying and firing characteristics of these assemblages are not positive aspects for the formation. Further investigation of mudstones associated with coal beds possibly could yield positive results for a structural clay products industry. The cost of shipping to distant markets, however, would require very good raw materials that could be burned with relatively inexpensive coal as the energy source. The materials are too high in alkalis (Appendix 3) to be used in making low alkali cement.

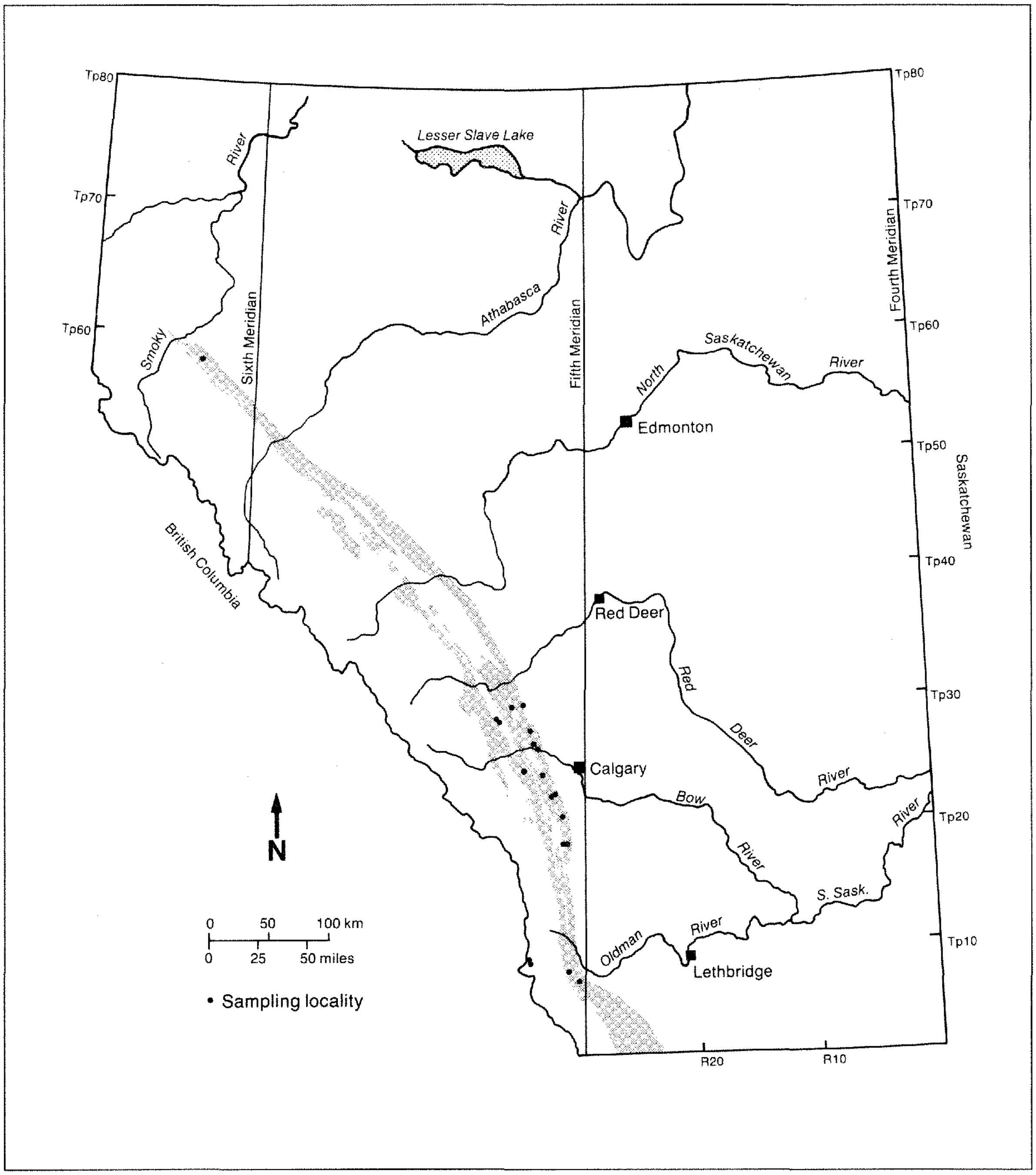

Figure 12. Geologic map of the Brazeau Formation in Alberta.

Bearpaw Formation

The almost exclusively marine shales of the Bearpaw Formation extend in a long arc from the International Boundary near Del Bonita to as far north as Edmonton. This arc widens to touch the Saskatchewan border east of Oyen. The formation also surrounds the Cypress Hills and is present north of Irvine. A western outlier is present in the Foothills north of Lundbreck on the Crowsnest River. The rocks are dark gray or brownish-gray shales that tend to weather into small angular fragments with rusty stains (Russell and Landes 1940). Spheroidal ironstone concretions are present in irregular zones and thin bentonite beds have wide lateral persistence. Selenite crystals are locally abundant on outcrop surfaces. Sandstone beds characteristically are fine grained, poorly indurated and argillaceous. Maximum thickness of the formation is 260 m in the central arc (Irish 1968) and 320 m surrounding the Cypress Hills (Byrne and Farvolden 1959). These shales are known to have a high smectite content (ibid), so only two samples from this formation were tested. One sample was collected from the outlier on the Crowsnest River in the Foothills (NTS area 82G, Appendix 1) to determine whether tectonic stresses may have changed the ceramic characteristics of the shales. The second sample, from near Del Bonita on the Plains (NTS area 82H, Appendix 1), should be unaffected by tectonics. Data from a second Plains sample in NTS area 72E (Crockford 1951) also are considered. As shown in Table 5, there are some differences in characteristics between the Plains and Foothills samples and between the two Plains samples. The comment of Lindoe (1984) that some zones in the Bearpaw Formation are fairly refractory is supported by P.C.E. values of eight and 10. The Foothills sample requires only 19 percent tempering water to produce fair plasticity and working properties, whereas the Plains samples consume 23 to 32 percent tempering water for good to excellent plasticity and fair to sticky working properties. The Foothills sample dries well at room temperature, but minor cracking is caused by drying at elevated temperatures. The Plains samples warp or crack badly at room and elevated temperatures and support Lindoe's statement that Bearpaw samples cannot be dried safely under production conditions.

At steel hardness temperature (925°C, cone 08) absorption is 9.3 percent for the Foothills sample. Steel hardness is reached at higher temperatures for the Plains samples (980 and 1180°C) but absorption is lower (7.2 and 1.4 percent respectively). Maximum recommended firing temperature, absorption, and shrinkage are similar for the Plains and Foothills samples. Bad scumming, a problem with one of the Plains samples, is not an unusual occurrence because of the presence of gypsum.

After analyzing 201 samples, Byrne and Farvolden (1959) firmly established that smectite is the most abundant clay mineral (64 percent) associated with the Bearpaw Formation. Because the smectite content is so high, it is impossible to correct the drying problems. Consequently, material of the Bearpaw Formation from the Plains is of no value for ceramic purposes. Foothills material, however, with its lower requirement for tempering water, good drying characteristics that probably can be improved easily, and long firing range, deserves further testing.

Table 5. General Characteristics of Samples from the Bearpaw Formation.

		Unfired Properties					
					Drying Properties		
Description	**P.C.E.**	**Tempering Water (%)**	**Plasticity**	**Working Properties**	**Room Temperature**	**105°C**	**Drying Shrinkage (%)**
Plains dusky yellowish brown shale, thin laminae, minor silt, noncalcareous, ironstone concretions, selenite	5-10	23-32	good-excellent	fair-sticky	minor warp-cracks badly	cracks	8.4-13.1
Foothills olive gray shale, thin laminae	8	19	fair	good	good	minor cracks	7.0

	Fired Properties							
	Steel Hard			Maximum Fire				
Color	**Temperature °C**	**Absorption (%)**	**Color**	**Temperature °C**	**Absorption (%)**	**Shrinkage (%)**	**Remarks**
Plains light brown	980-1180	1.4-7.2	moderate brown	1040	1.2	8.4	moderate firing range, scums badly
Foothills light brown	925	9.3	light brown	1050	0.8	6.9	long firing range

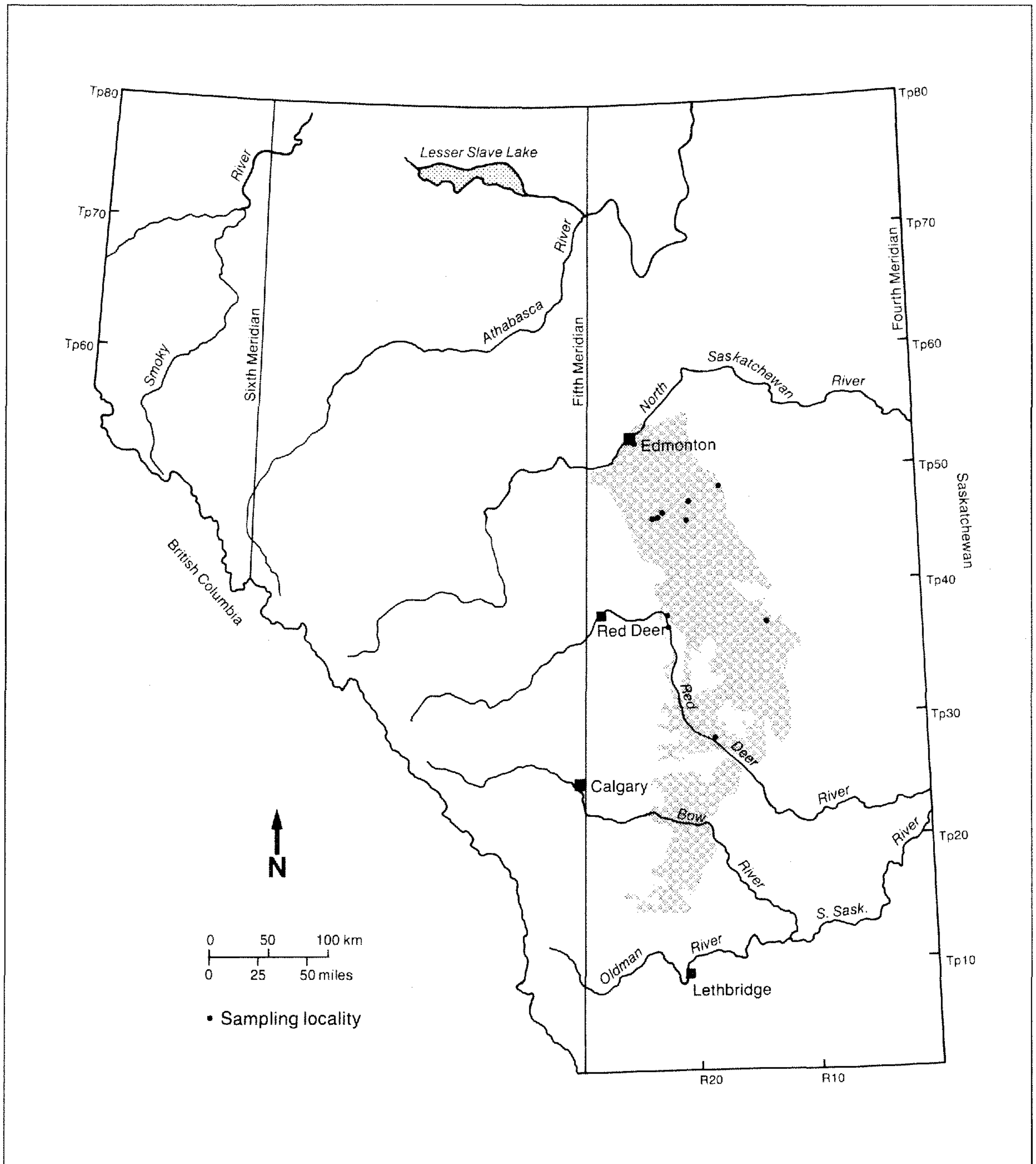

Figure 13. Geologic map of the Horseshoe Canyon Formation in Alberta.

Horseshoe Canyon Formation

The Horseshoe Canyon Formation, consisting of an eastward-thinning wedge of mainly non-marine sediments, outcrops in an arcuate band (Figure 13) in the south-central Plains from approximately Carmangay in the south to Edmonton in the north (Gibson 1977). The Horseshoe Canyon Formation consists of fluvial and deltaic, lensing, interbedded deposits of sandstone, siltstone, and shale. Sandstones are the most common rocks and typically are soft, gray- and white-weathering, fine-grained, feldspathic, and smectitic. Shales, mudstones, and claystones are gray, green or brown, smectitic, and are most conspicuous in the lower 130 m of the formation, although they occur in relatively high concentration throughout much of the formation. The shale is fissile and commonly is interbedded and interlaminated with small amounts of coal. Mudstone or claystone commonly is smectitic and carbonaceous. Ironstone concretions, coal and bentonite also are present.

Even though highly smectitic materials are known to be of little value in the production of ceramic ware, data for a number of samples from the Horseshoe Canyon Formation are available from NTS areas 73D, 82P, 83A,H (Appendix 1). The renewed interest in exploiting the coals in the formation make these data important for ancillary exploitation.

The high average tempering water requirement (29 percent) commonly gives good to excellent plasticity, but only fair to poor workability because of the tendency toward stickiness. Warping and cracking during drying is common. Average drying shrinkage is 8.4 percent. Pyrometric Cone Equivalent (P.C.E.) values as high as 15 are reported, although three to five is most common. One sample did not reach steel hardness until 1255°C (cone 6), but most samples are steel hard near the average temperature of 1015°C (cone 07). Average steel hardness absorption is 10.1 percent. Results from samples tested by the author suggested that the "red" color commonly given for the steel hardness color by early investigators probably is light brown in the Munsell system used in this study. Average recommended firing temperature is 1065°C, absorption is nine percent, and fired shrinkage is 3.8 percent.

Semiquantitative estimates of clay mineral abundance for the Horseshoe Canyon Formation are listed in Table 6. The high abundance of smectite explains the deep cracking during drying. The deep cracking is unacceptable in formed bodies such as bricks, thus material from the formation is not recommended for such use. The cracking, however, may be of less consequence in the production of synthetic aggregate. Chunks or pellets of more silty shale from the formation also crack, but are not as fragile as less silty material. These materials could survive travel through the kiln relatively intact to yield synthetic aggregate of two to three centimetres in size and relative density less than one. More fragile material yields a smaller size product. With careful attention to the kiln feed rate to prevent overfiring this material can be particularly useful as aggregate for lightweight concrete blocks. The smaller pieces need less crushing and require less cement to produce a block of the required strength. The Horseshoe Canyon Formation shales and argillaceous siltstones may have some promise for synthetic aggregate production.

Table 6. Semiquantitative Estimates of Clay Mineral Abundance for the Horseshoe Canyon Formation.

Mineral	Low	High	Average (%)
Smectite	70	100	85
Illite	trace	20	15
Kaolinite	absent	5	trace
Chlorite	absent	10	trace

Wapiti Group

Sediments that are indistinguishable from the combined Horseshoe Canyon and Judith River formations northwest of Edmonton (Figure 14) are called the Wapiti Group (Kramers and Mellon, 1972). Sediments are present in a shallow arc from Edmonton to the British Columbia border (Green 1972) and thickness is as great as 1370 m near the Foothills. The Wapiti Group is a succession of nonmarine fluviatile deposits consisting of thick, pale gray, crossbedded, smectitic sandstones with scattered conglomerate beds and medium to dark gray, laminated siltstones and blocky mudstones with locally developed coal seams. The strata are lenticular and contain, in places, scattered, thin bentonite and tuff beds (Kramers and Mellon 1972).

Because the sediments of the Wapiti Group contain abundant smectite no previously published data were available. The group contains exploitable coals, however, and samples were taken in NTS areas 83G,H,J (Appendix 1) to determine whether clay-rich sediments could be exploited in association with coal mining. With tempering water of 20 percent, plasticity is mostly good but working properties are mostly poor to fair. Warping and cracking is common during slow drying and is usual during rapid drying. Average drying shrinkage is 7.3 percent. Half the bars tested are either too fragile to fire or they bloat before steel hardness is reached. For the remainder that fire successfully, steel hardness color is light to moderate brown and is reached near 1020°C. Color change is minor over the short firing range. Average fired absorption is 6.1 percent and fired shrinkage is three percent.

Kaolinite commonly is present only in trace amounts but may reach a maximum of 15 percent. Illite averages 20 percent, smectite averages 70 percent, and chlorite commonly is less than five percent of the clay minerals present. Neither calcite nor feldspar are identified in any of the

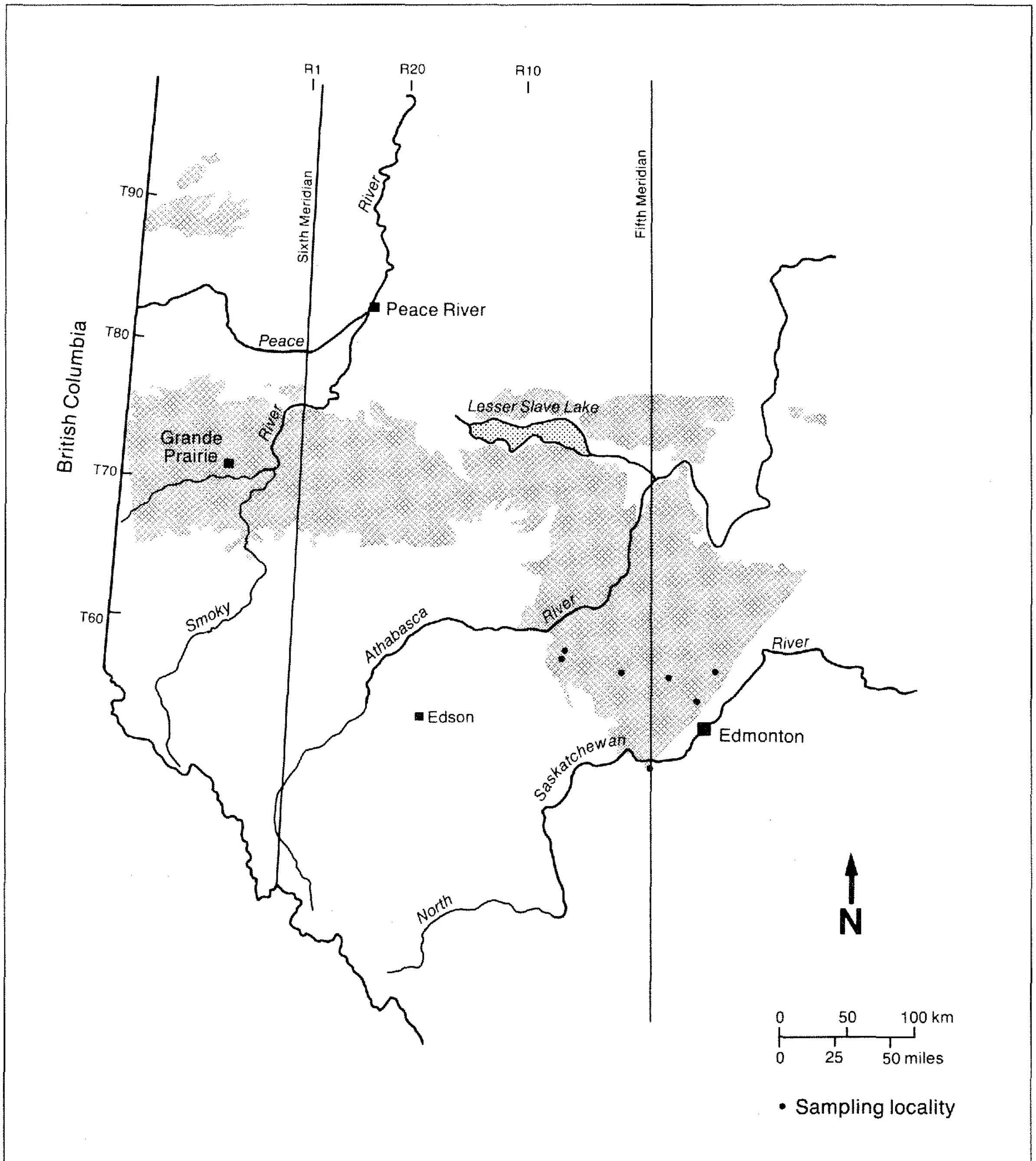

Figure 14. Geologic map of the Wapiti Group in Alberta.

samples tested. The high smectite content causes deep cracks during drying that result in fragile bars. Pellets made for synthetic aggregate tests also are fragile and probably would not survive passage through a rotary kiln. Material from the Wapiti Formation is not a good choice for either formed ceramic bodies or synthetic aggregate production.

Eastend Formation

Confined to the Cypress Hills area of Alberta, in an outcrop belt at the foot of the main escarpment, are the sediments of the Eastend Formation (Russell 1932). Outcrops are not common, because the sands, silts, and soft shales tend to form gentle slopes covered with soil and vegetation (Lindoe 1965). Maximum thickness is 100 m, through which the sediments change from marine at the base to nonmarine at the top (Irish 1968). Paralleling the change in environment is a change in clay mineralogy as smectite is replaced progressively by illite (Lindoe 1984). The dominance of illite is sufficient about 21 m below the top of the formation, at the major coal seam in the area, to make the upper clays useful as ceramic raw material. The coal seam was mined extensively in the vicinity of Elkwater Lake (Russell and Landes 1940). The yellowish gray to olive-black soft shales above the coal seam are silty, partings tend to be iron stained, and zones of ironstone concretions are common (Lindoe 1984).

Published data are available for four samples from NTS area 72E (Appendix 1). Average P.C.E. is seven. With tempering water ranging from 18 to 31 percent, plasticity is fair to excellent and working properties are good to sticky. Samples with good working properties tend to dry well, whereas sticky samples tend to have higher drying shrinkage and tend to crack when drying. Color at steel hardness varies from light salmon through moderate brown to dark red. Temperature of steel hardness usually is near the 1140°C average. Average steel hardness absorption is 9.6 percent. Maximum recommended firing temperature averages 1210°C (cone 4), color is dark moderate brown to dark red, average absorption is 1.1 percent, and shrinkage is 6.7 percent.

The clays are used extensively at present in the manufacture of brick to upgrade clays from the Judith River Formation. They also are used as a fluxing agent in the material used to produce sewer pipe (Lindoe 1984).

Whitemud Formation

Lying above the sediments of the Eastend Formation in the Cypress Hills area are the economically important nonmarine sediments of the Whitemud Formation (Figure 15). Between Gleichen and Grande Prairie equivalent beds occur above the Horseshoe Canyon Formation, but so far these beds are not of economic importance. In the Cypress Hills area the formation can be divided into three zones that start from the base with a white sandy zone, and ascend through a brown shale zone to a white clay zone. The white clay zone is not present at all outcrops of the formation. Each of these zones consists of an orderly cycle of deposition that begins with a sand member and ends with a carbonaceous clay member. The first cycle consists of partly kaolinized sands at the base that grade upward into brown to black plastic clays that fire dark buff to brown but frequently contain too much smectite to be useful (Lindoe 1984). The second cycle is the thickest of the three, has the least abrupt changes in lithology, and is the most constant stratigraphic marker in the formation. The clay material is dominantly kaolinitic, particularly where some thickening has taken place. The third cycle has dark gray and black fire clays at the top that grade into the Battle Formation above.

Studies of the ceramic properties of the Whitemud Formation in Alberta and Saskatchewan have tended to be performed near areas where the formation already is quarried for the concentrations of higher quality clays, and Lindoe (1965) points out that data from these reports tend to give a false impression of the quality of most clays in the formation. He believes that typical Whitemud deposits are of low quality and too high in sand for ceramic use. Results of the tests published by Crockford (1951) on samples from many outcrops of Whitemud Formation material in the Cypress Hills area support this belief.

More published ceramic test data are available for the Whitemud Formation than for any other formation in the province. Data from 95 samples from NTS area 72E (Appendix 1) were used to outline the general characteristics of the formation shown in Table 7. Samples from this formation generally are more refractory (average P.C.E. 16) than from any other formation in the province. With tempering water of 26 percent, plasticity is good to excellent, working properties commonly are good but stickiness is not uncommon. Cracking during slow drying is common and usual for drying at elevated temperatures. Fired colors range through grays, creams, buffs, browns, and reds. Steel hardness temperature averages 1210°C and maximum recommended firing temperature averages 1255°C to give a short firing range.

Byers (1969) was the most recent author to recognize the relatively high kaolinite content of Whitemud Formation sediments. Lindoe (1965, 1984), however, relates the drying problems to smectite and justifiably so. Smectite is estimated as high as 20 percent in samples taken by the present author. Illite ranges from 15 to 80 percent and kaolinite ranges from 20 to 65 percent. In general, Whitemud Formation clays in Alberta are not very useful as ceramic raw materials. However, tectonic movement and hydrothermal alteration of sediments in the Eagle Butte area immediately northwest of the Cypress Hills has

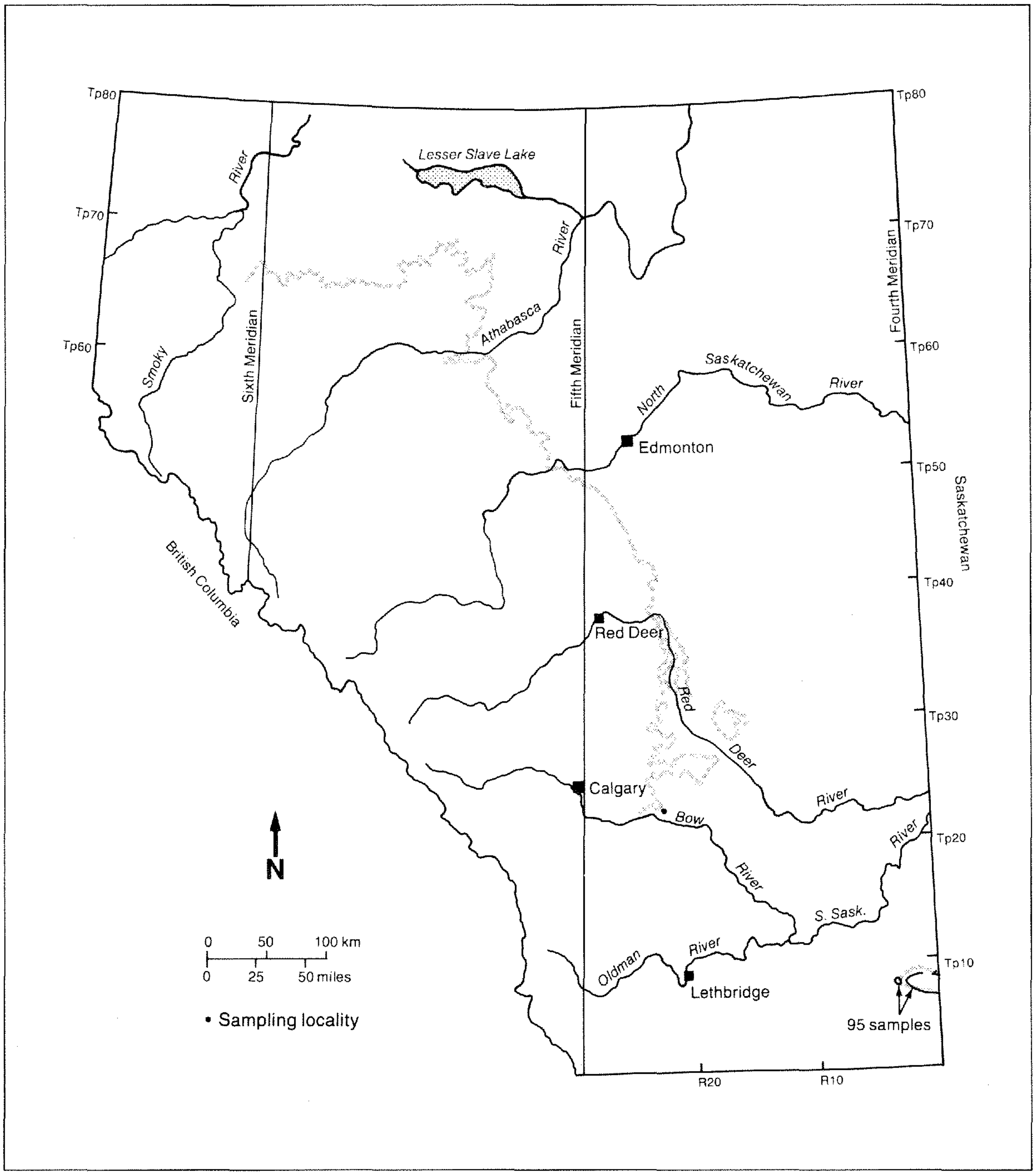

Figure 15. Geologic map of the Whitemud and Battle formations in Alberta.

upgraded beds of the Whitemud Formation by increasing kaolinite, reducing carbon and smectite, and oxidizing iron compounds to such an extent that some of the best ceramic clays in the province are mined from quarries at that location. Away from the Eagle Butte structure, drying problems are too severe to be overcome in production.

Battle Formation

The dark shales of the Whitemud Formation, originally called "Zone 4" of the Whitemud Formation (Fraser, et al. 1935), were named the Battle Formation by Furnival (1950). On large-scale maps the two formations are commonly undivided because their combined thickness is less than 20 m and they have the same areal extent

Table 7. General Characteristics of Samples from the Whitemud Formation.

Description	P.C.E.	Tempering Water (%)	Unfired Properties: Plasticity	Working Properties	Drying Properties: Room Temperature	105°C	Drying Shrinkage (%)
ascend from a white sandy zone through a brown shale zone and a white clay zone	16	26	good-excellent	good, stickiness not uncommon	commonly cracks	usually cracks	8.8

Steel Hard: Color	Temperature °C	Absorption (%)	Fired Properties, Maximum Fire: Color	Temperature °C	Absorption (%)	Shrinkage (%)	Remarks
gray, cream, buff, brown, red	1210	3.5	buff, brown gray, red	1255	1.4	6.0	needs grog to prevent cracking, some scumming, short to long firing range

(Figure 15). The upper contact of the formation is commonly an erosional unconformity with the Frenchman Formation in the Cypress Hills and with the Scollard Formation elsewhere. Visually, the lower contact of the mauve-gray weathering, dark brown to purplish-black, smectitic shales with fine silt is sharp with the underlying Whitemud Formation. Lindoe (1965) suggests from evidence gained from firing samples, however, that the Whitemud-Battle contact is gradational. Within the upper part of the Whitemud Formation, feldspar and mica decrease upward toward the contact with the Battle, kaolinite remains high but smectite appears and modifies the drying characteristics. Smectite increases upward until montmorillonite becomes the dominant clay mineral in the Battle Formation.

Published ceramic data are available for seven samples from NTS areas 72E and 82I (Appendix 1). The average P.C.E. of 13 is high for Battle Formation clays (M. Shayna, personal communication). Average tempering water of 29 percent gives fair to excellent plasticity and fair to very good working properties. Bodies crack when dried at any temperature and average drying shrinkage is 9.7 percent. Fired colors are light to dark browns with some reddish overtones. Lindoe (1984) says that some material from the lower parts of the formation burn almost white. Average steel hardness temperature is 1150°C (cone 02) and average absorption is 7.3 percent. Only one sample survived a full firing cycle. This sample exhibits a long firing range, which supports Lindoe's (1984) statement that after drying samples commonly have a fairly long firing range.

Irish and Havard (1968) indicate that clay-size material composes 51 to 96 percent of the size fractions of the Battle Formation. Their work also identifies smectite as the most abundant clay mineral (90 to 97 percent). Illite is determined to form zero to five percent, kaolinite zero to three percent and chlorite zero to two percent. The present author determined that smectite is the only clay mineral present in samples collected for this study. The overwhelming amount of smectite is responsible for the high amount of tempering water required, the fair to excellent plasticity, and the drying problems. It is surprising that stickiness is not reported as a problem during working. The author supports Lindoe's (1984) statement that the shales of the Battle Formation have no normal ceramic application. However, the low Na_2O and K_2O contents reported in Scafe (1980) and Appendix 3 have generated interest in the use of Battle Formation clays in the production of low alkali cement.

St. Mary River Formation

The St. Mary Formation is present in a narrow band from the International Boundary to the vicinity of Carmangay, where it becomes indistinguishable from the Horseshoe Canyon Formation. The formation is overlain conformably by the Willow Creek Formation and the lower contact is distinct with the ledge-forming Blood Reserve Formation to just north of the Oldman River. With the disappearance of the Blood

Reserve Formation, the St. Mary River Formation overlies the Bearpaw Formation. St. Mary River strata consist of hard, green-, gray- and buff-weathering, gray, fine-grained, lenticular, calcareous sandstone, friable, green and gray, sandy shale, fissile, gray shale, carbonaceous shale, and coal (Irish 1967). Freshwater and terrigenous molluscs are present in most of the formation. Brackish water molluscs are present only near the base of the formation. Maximum thickness of the formation is 455 m.

Shales of the St. Mary River Formation tested in NTS area 82H (Appendix 1) are low refractory sediments with P.C.E. values that average four. With average tempering water of 16.5 percent, plasticity and workability are fair. Drying characteristics generally are good and average drying shrinkage is 6.4 percent. Temperature of steel hardness averages 1025°C and temperature of maximum recommended firing averages 1090°C. Firing range is moderate but two samples bloated before steel hardness was reached. Average maximum fired absorption is 0.1 percent and average maximum fired shrinkage is 7.8 percent.

Ceramic properties reflect mineralogy well in samples from the St. Mary River Formation. Kaolinite averages only 10 percent and P.C.E. values are low. Smectite varies from five to 70 percent and the sample with the greatest smectite content cracks badly on slow drying and crumbles during fast drying. Illite ranges from 15 to 80 percent. The good firing characteristics anticipated in the sample with the highest illite content are not attained because major amounts of the fluxes dolomite, calcite, and feldspar are present. Chlorite averages 10 percent.

Clays from the St. Mary River Formation could be used for low temperature structural clay products such as brick. Colors, however, are more brown than red and potential for bloating would require close attention during the firing cycle. The potential for bloating could be useful in the production of expanded aggregate. Alkali content is too high for use of the material for production of low alkali cement.

Frenchman Formation

The Frenchman Formation, latest Late Cretaceous in age, is present in the Cypress Hills area, but commonly is concealed by slumped beds or vegetation (Crockford 1951). Coarse, cross-bedded sands with concretions and limonite stain are the most common sediments. Only in the top half of the formation do beds of clay have extensive distribution (Lindoe 1984). Materials from the formation burn to brilliant red colors (Lindoe 1984). No published ceramic data from this formation are available.

Willow Creek Formation

The outcrop pattern of the Willow Creek Formation extends northward from the International Boundary southeast of Cardston and opens into a "Y" configuration with the characteristics of the formation in the wider eastern arm distinguishable to the vicinity of the Little Bow River north of Stavely, where it becomes indistinguishable from the Paskapoo Formation. Rocks in the narrower western arm pinch out along the Foothills north of Cowley in Township 13.

The general color of the formation is pink with gray and yellow bands (Russell and Landes 1940). Sediments are interbedded, soft, gray-weathering, medium-grained, argillaceous sandstone, and gray, maroon, and light brick-red-weathering clay (Irish 1967). The lower part of the formation is predominantly smectitic shale containing small white calcite concretions, with sandstone beds becoming more numerous and thicker in the upper part (Carrigy 1971). Freshwater mollusc, fish and turtle fossils are present in the upper part of the formation (Russell and Landes 1940). The formation overlies the Battle Formation on the Oldman River and the St. Mary River Formation elsewhere. The upper contact with the Porcupine Hills Formation is erosional (Carrigy 1971). Maximum thickness of 1260 m is in the Foothills (Tozer 1953).

There are no persistent lithologic horizons, but four clay samples were collected in NTS area 82H (Appendix 1) from a thick section on Mokawan Butte east of Stand Off on Blood I.R. 148. Tempering water required for poor to excellent plasticity is 17 to 20 percent and working properties are poor to good. One set of bars warped when dried at room temperature but the other three sets dried well. All bars crack when dried at elevated temperatures. Average drying shrinkage is 8.2 percent. Temperature of steel hardness varies from 852°C (cone 016) to 1100°C (cone 04), colors range from light to moderate brown, and absorption varies from nine to 13.5 percent. Three of the four samples have a maximum recommended firing temperature of 1120°C (cone 03) and colors are mostly drab, yellowish browns. With one exception, absorption at maximum recommended firing temperature is low (zero to 1.3 percent).

Average firing shrinkage is 6.6 percent. Pyrometric Cone Equivalent values are three or four. Firing ranges vary from extremely short (20°C) to extremely long (200°C).

Unfired and fired characteristics do not relate well to the mineralogy. The sample with the least amount of smectite exhibits the greatest drying shrinkage and is the only one tested that warped on slow drying, although all samples cracked on rapid drying. Kaolinite concentration averages 10 percent, illite 65 percent, smectite 20 percent, and chlorite five percent. Calcite and dolomite are major fluxes present in each sample and feldspars are minor fluxes. The major presence of calcite or dolomite, however, may not affect the firing range if those minerals are present as discernible grains rather than being finely divided. This seems to be the case as lime popping is common and firing range follows no discernible pattern related to mineralogy. The nonpersistence of the beds, poor drying and firing characteristics, and drab fired colors are not assets for potential ceramic production nor is the high alkali content an asset for producing low alkali cement.

Scollard Formation

The Scollard Formation, recognizable at the surface and in the subsurface in a long narrow arc between the Bow River and the Swan Hills (Figure 16), consists of an interbedded, interfingering sequence of argillaceous sandstone, siltstone, mudstone, and shale. Coal, bentonite and tuff also occur in the formation (Gibson 1977). The coal mined for the power plants at Genesee and Wabamum is from this formation. Maximum thickness of the formation is 85 m. The upper and lower contacts, with the Paskapoo and Battle formations respectively, are conformable. Light greenish gray weathering, smectitic, sandy to silty mudstone and argillaceous siltstone contrast with dark gray to dark purplish gray weathering, very smectitic silty to sandy claystone and mudstone. The dark weathering strata, although more sandy and silty, resemble the claystone of the underlying Battle Formation (Gibson 1977).

P.C.E. values for samples from the Scollard Formation are variable. Of the 11 samples from NTS area 83G and 82P (Appendix 1) for which data are available, two samples are just below low heat duty refractoriness with values of 12 and 13 and one sample is just above low heat duty refractoriness at 30. The six other samples range between three and seven and probably are the most common values for refractoriness of the formation. Tempering water averaging 24 percent gives good plasticity and good working properties, although stickiness is reported for some samples requiring more tempering water than the average value. Only samples requiring more tempering water than the average crack on slow drying but cracking, checking, or warping is common in these samples during rapid drying. Average drying shrinkage is 7.2 percent. Colors at steel hardness are moderate brown or light shades of red. Steel hardness temperatures range from 890°C, but temperatures ranging from 1000 to 1080°C are most common. Absorption at steel hardness ranges from one to 14.6 percent. Shades of brown are the most common colors at the maximum recommended firing temperature, which averages 1120°C (cone 03). Firing ranges either are short (30 to 50°C) or long (greater than 105°C) with long firing ranges more abundant. Average absorption and fired shrinkage values at maximum recommended firing temperature are 2.0 and 6.9 percent respectively.

Drying and firing characteristics, of five samples for which mineralogical data are available, are unexpected. All samples are mudstones and contain no or only minor amounts of silt. Therefore, with little dilution of the clay content by silt, the clay mineral estimates should be close to the actual clay mineral content of each sample. Kaolinite content averages 10 percent, illite averages 40 percent, smectite averages 50 percent, and chlorite is absent or less than five percent. The samples should exhibit, therefore, all the bad characteristics associated with abundant smectite content. Such is not the case! For the five samples, tempering water does not exceed 20 percent, plasticity is good, working properties are good, only the sample with 70 percent smectite warps during drying, none of the samples crack during drying at low or elevated temperatures, and maximum drying shrinkage is 9.8 percent. During firing tests, one of the two bars from the sample with 70 percent smectite bloated, but the other did not. Bars from other samples curve upward at the hot end in the temperature gradient furnace but no bars crack on firing. Firing ranges, however, are unpredictable and range from short to long. During firing to test the material for use as synthetic aggregate, most of the material can be fired as chunks and this is extremely rare for most clay material from the province. Pelletizing was required for only one sample. Although the chunks crack deeply on

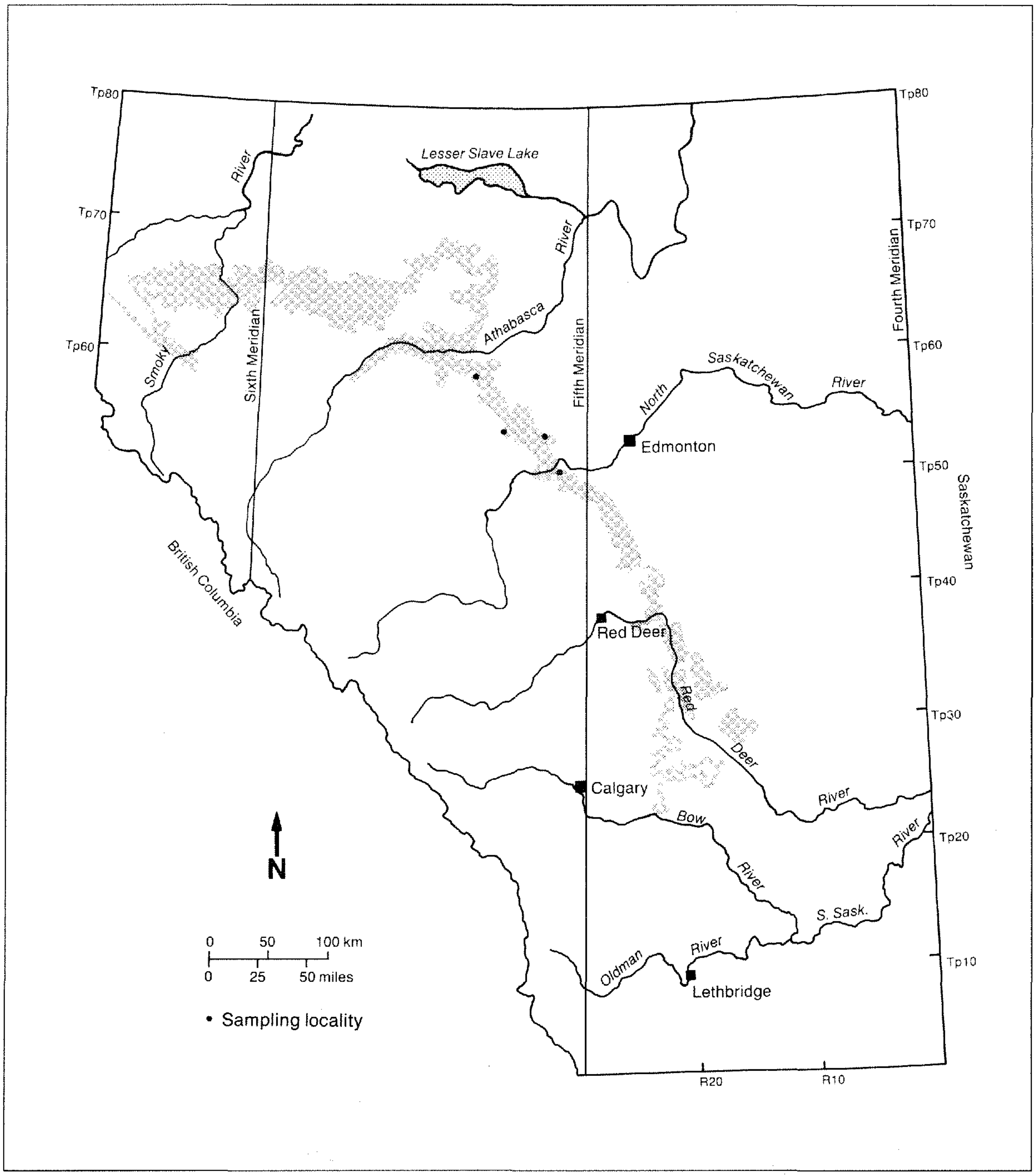

Figure 16. Geologic map of the Scollard Formation in Alberta.

drying most probably would survive the trip through a rotary kiln to make good coated synthetic aggregate.

The unexpected unfired and fired characteristics are a puzzle. Further testing should be performed to determine whether the data gathered are unique and misrepresent the general characteristics of the formation. The fact that coal is extracted from large open pit mines in the formation is further incentive for additional testing because the clay material can be won as part of the mining procedure and coal could be used as the heat source for firing. Favorable chemical data for one sample (Appendix 3) suggest that more samples should be tested as possible sources for clay in producing low alkali cement.

Tertiary rocks

Ravenscrag Formation

In Alberta, Ravenscrag sediments are confined to a narrow rim around upper elevations of the Cypress Hills. Maximum thickness of the formation is 102 m (Crockford 1951). These sediments of Paleocene age consist of an upper buff facies of weak sandy silts and sands. A lower gray facies approximately 45 m thick consists of regular repetitions of gray and buff carbonaceous clays and silts (Lindoe 1965). Lignite coal seams, bentonite layers, and thin beds of ironstone also are present in the formation (Irish 1967). Buff-weathering materials offer no ceramic properties that cannot be exceeded with other clays (Lindoe 1984). The gray-weathering materials may contain more than 25 percent calcium carbonate. Calcium carbonate usually is considered detrimental. When finely divided and uniformly dispersed, however, it can produce pink and buff shades from red-burning clays and reduce the colloidal properties of smectite. The gray sediments of the Ravenscrag Formation are a natural lime-clay mixture that work, dry and fire very well and are very inexpensive relative to commercial blends (Lindoe 1984).

No samples were collected by the author from the Ravenscrag Formation. Data from six samples were published by Crockford (1951) from NTS area 72E (Appendix 1). In general, gray-colored samples exhibit a P.C.E. value of 14, whereas buff-colored samples exhibit a P.C.E. value of three. With tempering water of 24 percent, plasticity and working properties are good. All samples dried by Crockford (1951) cracked. Average drying shrinkage is 9.8 percent. Fired colors are light reds and buffs, average steel hardness temperature is 1170°C (cone 01), and firing range is short. Crockford (1951) sees little use for clays from the Ravenscrag Formation. However, the long experience of Lindoe with these clays convinces that author that as a specialty clay the Ravenscrag gray sediments are very valuable.

Porcupine Hills Formation

The Porcupine Hills Formation occurs in a band approximately 30 km wide from the southern border of Peigan I.R. 147 to Airdrie (Figure 17). Lithologically, this formation consists of cross-bedded, buff-weathering, gray sandstone with interbedded gray and dark gray, calcareous, smectitic clay shale (Irish 1967). The upper boundary is an eroded surface. Present maximum thickness is 915 m. Abundant freshwater molluscs of Paleocene age are present in the formation (Carrigy 1971). North of the Little Bow River in the vicinity of Stavely, the formation overlies the Paskapoo Formation and to the south it overlies the Willow Creek Formation. North of Airdrie rocks of the formation are indistinguishable from those of the Paskapoo Formation.

Ceramic data are available for samples from NTS areas 82I, J and O (Appendix 1). Average P.C.E. is four. One anomalous sample has a P.C.E. of 15. Tempering water averages 23 percent, plasticity ranges from poor to excellent and is mostly good. Working properties also range from poor to excellent and are mostly good. The material dries well at low temperatures, but cracking is usual at elevated temperatures. Most samples exhibit drying shrinkage close to the average of 7.1 percent. Steel hard colors are numerous shades of red and steel hardness temperature varies from 920 to 1180°C. Average steel hardness absorption is 12.7 percent. Color at maximum recommended firing temperature commonly is only slightly darker than at steel hardness temperature. Maximum recommended firing temperature, unlike steel hardness temperatures, commonly are close to the average value of (1145°C). Average fired absorption is 3.5 percent and fired shrinkage is six percent.

Unfired and fired characteristics relate to the mineralogy determined from samples of the Porcupine Hills Formation. Kaolinite averages 15 percent, illite 50 percent, smectite 25 percent, chlorite 15 percent, calcite or dolomite may be major components, and feldspars are present. Relatively high tempering water requirements and cracking during rapid drying are related to the smectite content. Samples containing minor carbonate exhibit longer firing ranges than those with abundant carbonate.

Material from this formation has been used by Consolidated Concrete for production of expanded aggregate and, in the past, several plants fired the material for bricks. Poor drying characteristics, the tendency for bars to warp on firing, the presence of carbonate, and a tendency for some red colors to have a gray overtone are liabilities for using this material in formed products. Chemical data (Appendix 3) do not suggest use in making low alkali cement. Its use in making expanded aggregate may continue to be its best value.

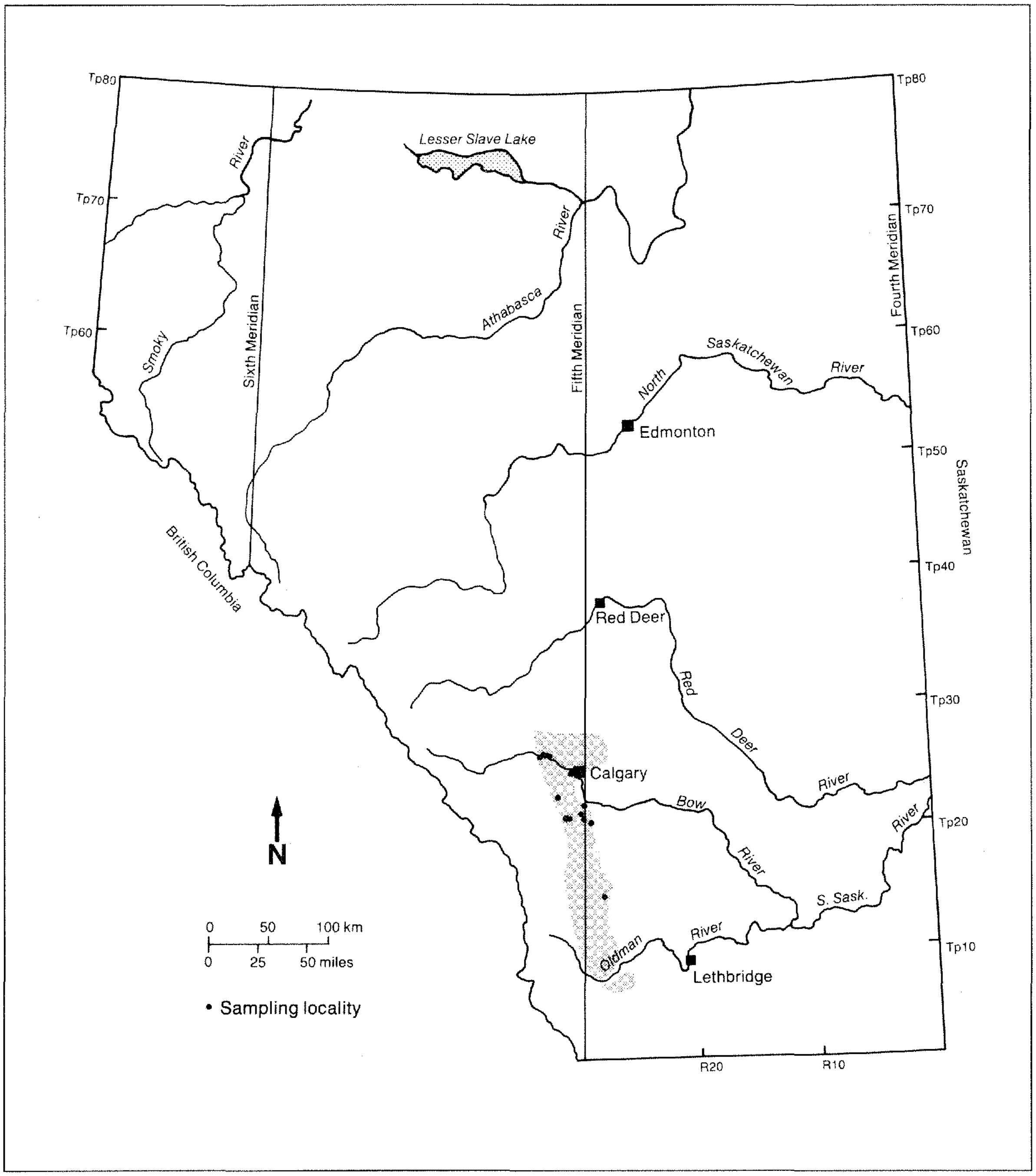

Figure 17. Geologic map of the Porcupine Hills Formation in Alberta.

Paskapoo Formation

Outcropping over a large area of central Alberta (Figure 18) are the Paleocene nonmarine sandstones, siltstones, mudstones, and lignites of the Paskapoo Formation. Sediments of the formation become indistinguishable from those of the Willow Creek Formation in the vicinity of the Little Bow River north of Stavely, and indistinguishable from those of the Porcupine Hills Formation near Airdrie (Carrigy 1971). Maximum sediment thickness of 915 m is reached in the Foothills area where sediments equivalent to the Paskapoo Formation form the upper part of the Saunders Group (Figure 2). The northern limit of the formation reaches to approximately 80 km south of Grande Prairie (Green 1972). Sediments are characterized in the lower part by thick, buff-weathering, pale gray, crossbedded, cliff-forming sandstones (Kramers and Mellon 1972). Laurel leaf imprints and petrified or partly

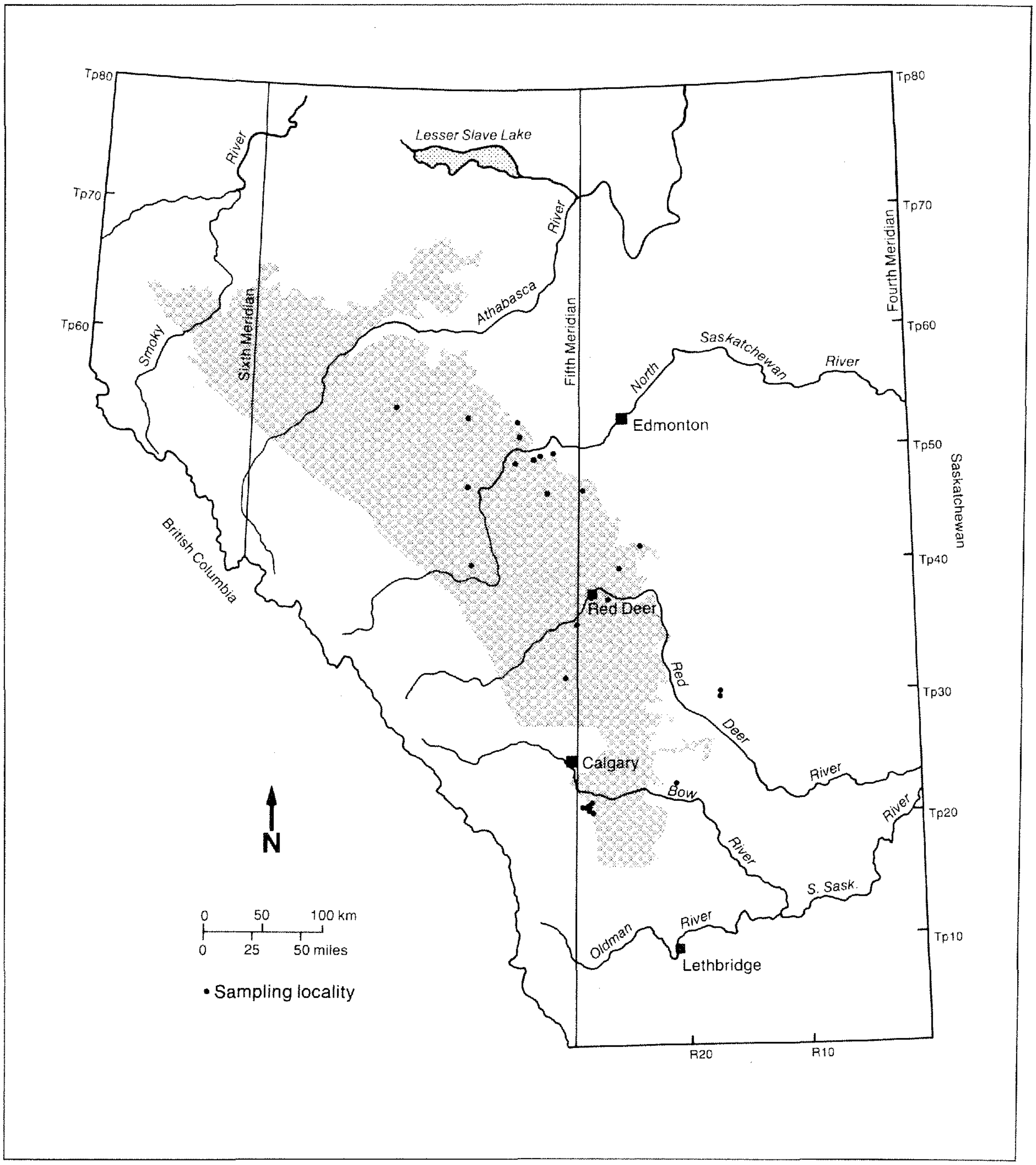

Figure 18. Geologic map of the Paskapoo Formation in Alberta.

coalified wood fragments are common in massive, coarse-grained sandstones from the middle part of the formation. Oxidized bog iron deposits and minor lignite seams also are present (Budrevics, 1978). Sandstones of the upper part are soft, pale gray and interbedded with blocky, green and gray siltstones and silty mudstones. Lignitic coal and carbonaceous shale beds also are present in the upper part (Kramers and Mellon 1972).

Laboratory data are available for 46 samples of the Paskapoo Formation taken from locations within eight NTS sheets (82I,P,O, 83A,B,F,G,H Appendix 1). General characteristics of the formation are shown in Table 8. With 23 percent tempering water, plasticity and working properties are good. Drying characteristics at room temperature commonly are good, but at elevated temperatures drying characteristics are unpredictable. Samples that dry well at room tempera-

Table 8. General Characteristics of Samples from the Paskapoo Formation.

			Unfired Properties				
					Drying Properties		
Description	P.C.E.	Tempering Water (%)	Plasticity	Working Properties	Room Temperature	105°C	Drying Shrinkage (%)
gray, olive, buff shales and mudstones, iron stain usual	5	23	good	good	good	either dries well or cracks	8

Fired Properties							
Steel Hard			Maximum Fire				
Color	Temperature °C	Absorption (%)	Color	Temperature °C	Absorption (%)	Shrinkage (%)	Remarks
mostly light brown or shades of red	890-1125	10.5	mostly moderate brown or shades of red	1080-1100 and 1165-1185 most common	1.4	7.2	scum not uncommon, firing range variable, extrusion inconsistent

ture may continue to dry well or they may crack unexpectedly. Average drying shrinkage is eight percent. Steel hardness colors mostly are light brown or shades of red from temperatures that range from 890 to 1125°C. One-quarter of the samples are steel hard at 890°C, but no other temperature can be designated as a typical steel hardness temperature. Colors at maximum recommended firing temperature mostly are moderate brown or shades of dark red from temperatures that range from 1050 to 1185°C. More than half of the maximum recommended firing temperature values fall within two 20°C temperature ranges (1080 to 1100°C and 1165 to 1185°C). Absorption averages 1.4 percent and shrinkage averages 7.2 percent respectively.

With a few exceptions, the unfired and fired characteristics of most samples from the Paskapoo Formation relate well to the mineralogy. Kaolinite averages 10 percent, illite 40 percent, smectite 45 percent, and chlorite zero to five percent of the clay minerals present. Illite ranges from 10 to 70 percent and smectite ranges from 15 to 75 percent. Calcite or dolomite is present in a few samples and feldspars are present in trace to major amounts in nearly half the samples. Samples with high concentrations of smectite commonly are difficult to extrude and usually warp or crack during drying. Samples with lower concentrations of smectite and commensurate high concentrations of illite, commonly extrude well, dry successfully, and have moderate to long firing ranges. Two samples appear to be anomalous because both calcite and feldspar are identified as major components yet the samples exhibit a moderate and a long firing range. The P.C.E. of each sample, however, is considerably lower than the neighboring samples that contain no calcite or feldspar.

The extensive areal expanse of the formation, good drying characteristics, moderate to long firing ranges, and acceptable colors of some samples are tantalizing assets for manufacturers of structural clay products and pottery. Many other samples, however, are hard to extrude, crack during drying, and have short firing ranges. Rigid quality control would be necessary for use of material from this formation for formed bodies. The possibility exists to use some material from this formation for production of synthetic aggregate. Some samples are steel hard at low temperatures (890°C), coating is common, carbonate as grains is uncommon, and 40 percent of the samples can be fired to a relative density of less than one. The provocatively low sodium present in some samples is offset by abundant potassium (Appendix 3) to eliminate Paskapoo materials from consideration for use in making low alkali cement.

Pleistocene and younger rocks

Pleistocene lacustrine clays

Few locations in the province are without a mantle of sediments deposited by the ice sheets that covered Alberta during the Pleistocene age or the resulting meltwaters when they retreated. Of the eolian, glaciolacustrine, outwash, and till materials, the most useful as potential ceramic raw materials are the glaciolacustrine deposits.

Although sands and silts are common lacustrine sediments, and unsuitable for ceramic use, clays or silty clays cover extensive areas of the province and are or have been used for ceramic products.

Data are available for 45 samples from 17 NTS map areas in the province and a summary of characteristics is in Table 9. Browns, grays, and yellows are the common colors exhibited by the raw materials in the field and most samples are slightly to decidedly calcareous. Average P.C.E. is four. With 24 percent tempering water, plasticity and working properties usually are good. With slow drying, there is an equal chance for drying successfully as for warping or cracking. The chances, however, during rapid drying are weighed heavily toward warping and cracking. Average drying shrinkage is 7.3 percent. Colors at steel hardness temperatures mainly are shades of light red or brown and are attained at temperatures between 890 and 1180°C. Absorption at steel hardness ranges from 1.5 to 23.7 percent. Colors at maximum recommended firing temperature are darker shades of red or brown and are reached at temperatures between 1005 and 1220°C. A majority of the samples, however, have maximum recommended firing temperatures between 1100 and 1150°C. Fired absorption is as low as 1.0 and as high as 10.5 percent. Shrinkage ranges from 0.7 to 11 percent. The firing range typically is short and scumming is common. A few samples exhibit lime popping.

Considerable data are available (Edwards, Hudson and Scafe 1985) for using glaciolacustrine silt and clay sediments as raw material to produce synthetic aggregate. Pellets of the material commonly can be fired to a relative density less than one at temperatures of 1120°C and occasionally as low as 1090°C. Coating of the pellet surface and walls of cracks is usual. Lime popping is uncommon.

Mineral data are available for 84 samples that have been tested for synthetic aggregate or formed ceramic characteristics. Illite, the dominant mineral, averages 50 percent, smectite averages 35 percent, kaolinite averages 10 percent, and chlorite averages five percent. Calcite or dolomite is present in trace to major amounts and feldspars are present in trace to minor amounts in almost every sample. Gypsum is identified in a few samples. The high smectite content is responsible for the drying problem and the calcite, dolomite, and feldspars act as fluxes to shorten the firing range. Calcite also reduces the intensity of red coloration one would expect from iron associated with the substantial illite content.

Glaciolacustrine silts and clays were used extensively in the past as ceramic raw materials and continue to a lesser degree today. In Edmonton, Northwest Brick and Tile Ltd. uses this material for brick production. Consolidated Concrete Ltd. uses it to make synthetic aggregate for concrete blocks and Inland Cement Ltd. uses it to make normal Portland cement. Grog can be added to improve drying characteristics of formed bodies but adds to production costs. The almost universal presence of calcite requires close attention to the firing schedule and the presence of gypsum can require the addition of chemicals to counteract scumming. Although these sediments are not the best raw materials they commonly are the best materials in the area and are used to make the best product possible.

Recent sediments

Recent sediments were deposited after the retreat of the Pleistocene glaciers and commonly are present as floodplain deposits in river and creek valleys. Data are available for five samples from three map areas. Samples commonly are very silty and all are abundantly calcareous. Extruded bodies crack either during drying or firing. Only the more porous bodies made by the soft mud or dry press methods survive to give highly absorbent, relatively weak bodies. The high carbonate content gives extremely short firing ranges and commonly an unattractive, dirty yellow-green fired color. No mineral data are available but the cracking problems probably result from a high smectite content. This suggestion is supported by the observation that material from one locality was used as rotary drilling mud in the area.

Table 9. General Characteristics of Samples from Pleistocene Glaciolacustrine Clays

			Unfired Properties				
					Drying Properties		
Description	P.C.E.	Tempering Water (%)	Plasticity	Working Properties	Room Temperature	105°C	Drying Shrinkage (%)
brown, gray, yellow silty clays or clayey silts, usually calcareous	4	18-36	good	good	good-warp & crack	warp & crack	4-9.4

Fired Properties							
Steel Hard			Maximum Fire				
Color	Temperature °C	Absorption (%)	Color	Temperature °C	Absorption (%)	Shrinkage (%)	Remarks
mainly shades of light red or brown	890-1180	1.5-23.7	darker shades of red or brown	commonly 1100-1150	1.0-18.5	0.7-11.0	scumming relatively common, firing range typically short

Economic Summary

The primary purpose of this study is to indicate to potential users of clays in Alberta, which formations are the most likely to warrant investigation and testing for their needs. Table 10 summarizes potential uses for material from each formation. For those uses that are shown as ?, consult the appropriate section in the text for details of the formation's characteristics.

Table 10. Potential uses for material tested from each formation in Alberta.

Formation	B.orT.	Stone.	Ref.	Pot.	L.A. Cem.	Exp. Agg.	No Val.
Recent							x
Pleistocene	x			x			
Brazeau	?			?			
Wapiti Group							x
Paskapoo	?			?		?	
Porcupine Hills						x	
Ravenscrag	x			x			
Scollard	x			x			
Willow Creek							x
Frenchman	?			?			
St. Mary River	?						
Battle					x		
Whitemud	?	?	?	?			
Eastend	x						
Horseshoe Canyon						x	
Bearpaw	?			?			
Judith River	x			x			
Belly River	x			x			
Pakowki							x
Lea Park						x	
Wapiabi							x
Cardium	?			?			
Blackstone	?			?			
Alberta Group	x						
Kaskapau	x			x		x	
Dunvegan	?			?		?	
Shaftesbury							x
Ft. St. John Group	?			?			
Clearwater							x
Mc Murray basal	x		?				
Luscar Group	?						
Blairmore Group							x
Kootenay Group	?			?			
Fernie							x
Siyeh							x
Grinnell							x

B.orT.= brick or tile, Stone.= stoneware, Ref.= refractories, Pot.= pottery, L.A. Cem.= low alkali cement, Exp. Agg.= expanded aggregate, No Val.= no value, x= recommended use, ?= see text for details.

Conclusions

1. Of the 36 units sampled, nine are useful for the production of structural clay products or pottery. The units are Pleistocene glaciolacustrine sediments, Ravenscrag, Scollard, Eastend, Judith River, Belly River, and Kaskapau formations and McMurray Formation basal clays.
2. From the data available, 12 units, or selected material from the units, have characteristics that suggest use for the production of structural clay products or pottery but more testing is needed to confirm the suggestion. The units are Brazeau, Paskapoo, Frenchman, St. Mary River, Whitemud, Bearpaw, Cardium, Blackstone, and Dunvegan Formations and Fort. St. John, Luscar, and Kootenay groups.
3. The Porcupine Hills, Horseshoe Canyon, Lea Park, and Kaskapau formations could be used for production of expanded aggregate. Further testing of the Paskapoo and Dunvegan formations is suggested for this use.
4. Selected materials in the Whitemud and McMurray Formation basal clays may be useful for low heat duty refractories.
5. Material from the Battle Formation can be used in the production of low alkali cement.
6. Of the 36 units sampled, 11 are considered to have no ceramic value. The units are Recent fine-grained sediments, Wapiti, and Blairmore groups, Willow Creek, Pakowki, Wapiabi, Shaftesbury, Clearwater, Fernie, Siyeh, and Grinnell formations.

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Appendix 1

Explanatory Notes

Deposit location

The most complete description possible, from the information available, of the legal location of a sample site. Sites are arranged in each NTS map area first by increasing Township followed in sequence by increasing Range, Section and Legal Subdivision or Quarter.

Group or Formation

The geologic rock unit from which the tested sample was taken. Current terminology is used if stratigraphic terminology has changed since the original data were published.

Unfired characteristics

Those first tested properties of material that are very important in suggesting the methods used to form and dry a body before it reaches the kiln.

Description

A brief, field, lithologic description of the material sampled.

Tempering water

The weight percent of water added to the dry clay to develope its plasticity and reveal its workability.

Plasticity

The property of a moistened material that allows it to be deformed under pressure then retain the deformed shape after the pressure is removed.

Workabilty

The ease with which moist clay can be molded without cracking or sticking.

Drying properties

Clays that dry without cracking at room and elevated temperatures are highly valued for low production losses.

Drying shrinkage

Percent decrease in length of a molded specimen on drying.

Pyrometric Cone Equivalent (P.C.E.)

A measure of clay refractoriness determined by heating test material at a standard rate and comparing that material to mixtures of known properties.

Steel hardness temperature

The temperature required to produce a body that is not scratched by steel as that temperature is considered to be the lower firing limit for clays likely to be used in Alberta.

Maximum recommended firing temperature

The temperature at which the liquid phase in a body becomes prevalent enough to cause the body to collapse or to close pores in the body so that gases generated cannot escape and the body begins to bloat.

Remarks

Suggested ceramic use, availability of chemical analyses and other miscellaneous information.

References

Original paper from which data are quoted. An undated reference means the data were generated by the author of this paper since his last published report.

In tests reported in the older literature, samples usually were fired progressively to cone 010, 07, 04, 02, 3, and 4 with fired characteristics noted after each firing. Similar firings today would be from cone 012 to cone 01 (890 to 1165°C) using Orton cones. Older test results have been translated to °C wherever possible for this paper.

+ after the Steel Hard temperature indicates that in the original source the fired sample was "very hard" therefore, "steel hard" must be higher.

- after the Maximum Fire temperature indicates that in the original source the fired sample was "nearly vitrified or fused" therefore, "maximum recommended firing temperature" must be lower.

Characteristics of Unfired Samples from Map Sheet 72E.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties: Room Temperature	Drying Properties: 105°C	Drying Shrinkage (%)
14	14	1	11	W4	Pakowki	5YR3/2 (grayish brown) shale, 5Y3/4 (moderate olive brown) stain on joints, minor silt, some gypsum crystals on surface	20	fair-good	good	minor warp	minor cracks	9.1
						5Y3/2 (olive gray) shale, minor 5YR4/4 (moderate brown) stain	24	good	good	warps	cracks	7.8
						5Y3/2 (olive gray) shale, 5YR4/4 (moderate brown) stain prominent, minor silt	20	fair	good	warps	cracks	8.1
14	4	2	6	W4	Judith River	10YR2/2 (dusky yellowhish brown) shale, minor silt, 100m below top of bank & first shale seen, 0.75m	22	excellent	fair	warps	warps & cracks	-
Few shales in 145m section along Milk River						5Y4/1 (olive gray) shale, minor silt, ~1m below sample above, 0.5m	23	very good	very good	warps	cracks badly	9.2
						5Y3/2 (olive gray) shale, minor silt, alligator weathering, 1m	18	fair	poor	warps	cracks badly	7.9
						10YR2/2 (dusky yellowish brown) shale, alligator weathering, 15m	20	fair	poor	warps & cracks	cracks badly	-
10	20	2	10	W4	Pakowki	10YR2/2 (dusky yellowish brown) shale, minor silt in places, gypsum crystals on surface, 5YR3/4 (moderate brown) stain on joints	27	good	good	warps	cracks	9.6
3	21	3	15	W4	Pakowki	5Y3/2 (olive gray) shale, sandy, 5YR4/4 (moderate brown) stain on joints, 3-7m	20	fair	fair	warps	cracks	8.9
8	5	7	1	W4	Whitemud	Gray silt, white weathering, ~1.1m.	24	good	good	-	cracks badly	8.3
						Grayish brown grading to yellowish green clay, gritty, ~0.8m.	27	excellent	sticky	cracks badly	-	9.6
						Gray silt, argillaceous, ~0.6m.	26	good	good	-	cracks badly	8.1
						Grayish green silt with yellowish iron stain streaks, ~1.6m.	23	fair	good	good	cracks	7.3
						Green clay, slightly silty	28	excellent	good	-	cracks badly	10.0
8	5	7	1	W4	Whitemud	Grayish green clay, silty calcareous, 0.3m.	25	excellent	good	-	cracks	8.8
						Greenish brown clay, silty, 1.4m	34	excellent	good	cracks	cracks badly	12.1
						Greenish gray clay, 0.5m	31	excellent	good	-	cracks	8.6
						Pale gray clay, silty, slightly calcareous, 0.3m	25	fair	fair	good	good	6.5
6	18	7	2	W4	Whitemud	Pale gray shale with greenish cast, 0.4m	36	excellent	fair	-	cracks badly	12.0
						Chocolate brown shale, 0.5m	35	good	good	-	cracks badly	12.8
						Dark brown and black shale, 0.2m	30	good	slightly sticky	-	cracks badly	11.0

Characteristics of Fired Samples from Map Sheet 72E.

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
4	5YR5/6 (light brown)	1000	9.0	5YR4/4 (moderate brown)	1100	2.2	8.9	could not extrude, soft white grains in fired bar, no value	Scafe (1980)
3	5YR5/6 (light brown)	975	11.3	5YR4/4 (moderate brown)	1080	1.1	9.6	only hand molded bars survive drying, no value, chemical analysis	
10	5YR4/4 (moderate brown)	1115	2.0	coincides with steel hard				no firing range, soft, white grains in fired bar, no value	
5	bars too warped to fire							no value	Scafe (1980)
4	5YR5/6 (light brown)	1065	8.3	5YR4/4 (moderate brown)	1100	1.3	4.8	short firing range, chemical analysis, no value	
5	5YR5/6 (light brown)	1050	7.2	5YR4/4 (moderate brown)	1085	4.0	2.5	hard to extrude, short firing range, chemical analysis, no value	
5	no bars survived drying							no value	
7	5YR5/6 (light brown)	1000	7.2	5YR5/4 (moderate brown)	1080	0.8	10.4	moderate firing range, add grog to improve drying, brick, chemical analysis	Scafe (1980)
4	5YR4/4 (moderate brown)	1080	9.0	10R4/2 (grayish red)	1120	1.8	2.5	short firing range, bricks	Scafe (1980)
13	brownish buff	1180	0.1	-	-	-	-	scums badly, tile if scumming corrected	Crockford (1951) sample 104
13	brownish red	1180	2.3	-	-	-	-	scums, tile if scumming corrected	sample 105
11	brown	1180	0.4	dark brown	1255	0.3	7.0	some scum, moderate firing range, tile	sample 106
9	dark red	1180	0.9	brownish red	1255	0.8	5.9	slight scum, dry slowly, brick and tile	sample 107
9	-	-	-	brownish red	1130	0.0	6.8	scums, blend to improve drying for brick and tile	sample 108
12	brownish salmon	1180	1.9	-	-	-	-	building brick & tile	Crockford (1951) sample 109
26	dark gray	1350	1.0	-	-	-	-	blend to correct poor drying, brick and tile	sample 110
13	dark buff	1180	0.0	-	-	-	-	warps on firing, brick and tile	sample 111
15	dark cream	1300	6.2	-	-	-	-	blend to improve plasticity, brick and tile	sample 112
30	brown salmon	1330	5.6	-	-	-	-	fireclay, needs grog to prevent cracking	Crockford (1951) sample 101
28+	light brown	1330	2.8	-	-	-	-	needs grog, fireclay	sample 102
15	brownish buff	1180	1.4	-	-	-	-	needs grog, low duty refractory	sample 103

Characteristics of Unfired Samples from Map Sheet 72E. (continued)

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
11	18	7	2	W4	Whitemud	Pale gray clay, 0.3m	32	good	good	-	cracks badly	11.0
						Pale gray clay, silty in places, 1.2m	26	good	good	-	cracks badly	9.7
						Brownish green and pale gray intercalated clay, 1.2m	26	good	good	-	cracks badly	9.0
						Dark brown to black shale, 0.75m	31	excellent	good	-	cracks badly	11.2
						Light greenish gray clay, 0.75m	27	excellent	fair	-	cracks	9.3
						Pale gray silt and clay, 1m +	27	excellent	slightly sticky	-	cracks badly	9.3
8	31	7	3	W4	Whitemud	Green and white silt and shale, 3.4m	-	good	quite sticky	good	good	6.3
					Eastend	Gray, green and brown shales, 1.8m	-	good	sticky	cracks	cracks	8.3
15	31	7	3	W4	Whitemud	Light gray clay, 0.3m	27	excellent	fair-sticky	-	cracks badly	8.8
						Dark gray shale, 0.3m	25	good	good	-	cracks badly	7.6
16	31	7	3	W4	Whitemud	Gray, green and brown clays and shales	25	excellent	fair	-	cracks badly	7.4
						Light gray, silty clay, 1.4m	22	fair	good	-	cracks badly	6.4
2	32	7	3	W4	Whitemud	Light buff clay, silty, calcareous, 0.45m	26	fair	fair	good	good	6.2
11	32	7	3	W4	Whitemud	Gray and brownish green clays and silts, 2.9m	27	excellent	fair-sticky	-	cracks badly	9.2
8	34	7	3	W4	Ravenscrag	Light buff and gray clay, calcareous	39	excellent	sticky	cracks	cracks	14.0
						Gray buff clay, silty, calcareous	25	poor	poor	-	good	6.7
16	24	7	4	W4	Whitemud	Light gray clay, calcareous, 0.6m	26	good	good	-	cracks badly	9.2
						Brownish green clay, calcareous, 0.6m	31	excellent	sticky	cracks	cracks	12.0
1	25	7	4	W4	Whitemud	Light gray clay, alligator weathering, 0.6m	31	excellent	slightly sticky	-	cracks badly	12.4
						Two light gray, white weathering, silty clays, 1.3m total thickness	25	good	good	-	cracks	8.7
						Two light greenish gray to brownish green clays, 2.1m total thickness	27	excellent	sticky	-	cracks badly	10.1
						Medium to dark gray shale, slightly silty, 1.3m	37	good	fair	-	cracks badly	14.8
						Brownish green clay, silty, 0.9m	31	excellent	slightly sticky	-	cracks badly	12.5
						Pale gray very sandy clay, 0.4m	20	poor	poor	good	good	2.5
						Brownish green shale, slightly silty, 1.5m	29	good	good	-	cracks badly	9.7
6	25	7	4	W4	Whitemud	Pale greenish gray clay, yellow stain, 1m	27	good	good	-	cracks badly	8.4
						Dark brown to black shale, silty, brittle, 0.9m	30	good	good	-	cracks badly	11.7
12	25	7	4	W4	Whitermud	Pale gray clay, white weathering	25	good	good	-	minor cracks	6.4

Characteristics of Fired Samples from Map Sheet 72E. (continued)

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
18	dark gray	1330	-	-	-	-	-	dry slowly or add grog, stoneware	Crockford (1951) sample 95
16	gray	1330-	0.5	gray	1330	0.5	-	dry slowly or add grog stoneware	sample 96
15	dirty buff	1180	2.5	-	-	-	-	structural clay products	sample 97
27	buff	1330	-	-	-	-	-	dry slowly or add grog, face brick or tile	sample 98
14+	buff	1180	3.1	-	-	-	-	face brick & tile	sample 99
13	brown	1180	0.6	dark brown	1255	0.5	6.5	moderate firing range add grog to improve drying	sample 100
-	-	-	-	dark red	1220	-	6.3	possibly useful for dry pressed bricks	Crockford (1951) sample 74
-	-	-	-	dark red	1220	-	2.1	dry pressed bricks ?	sample 76
28	dark cream	1255	6.5	gray	1330	4.2	4.4	overburden 10.8m, light duty refractories	Crockford (1951) sample 68
14+	dark buff	1255	1.2	-	-	-	-	face brick	sample 69
14+	brown	1255	0.3	-	-	-	-	possible flue lining	Crockford (1951) sample 71
18	gray buff	1330	3.0	-	-	-	-	overburden 10.8m, light duty refractories	sample 72
12	buff	1255	9.2	gray	1330	1.3	4.3	best for structural clay products	Crockford (1951) sample 78
16	dirty salmon	1255	3.0	gray	1330	0.3	-	overburden 18.6m, light duty refractories	Crockford (1951) sample 77
4	no steel hard							cracked, no value	Crockford (1951) sample 93
14	-	-	-	light brown	1330	1.2	6.9	little value	sample 94
16	buff	1255	2.4	-	-	-	-	possibly structural clay products	Crockford (1951) sample 82
11	brownish buff	1180	0.8	-	-	-	-	possibly dry pressed bricks	sample 83
18	dirty buff	1255	1.9	-	-	-	-	overburden 5m, stoneware	Crockford (1951) sample 84
15	buff	1255+	4.2	gray	1330	0.3	5.4	moderate firing range, stoneware	samples 85, 86
14+	salmon	1130+	5.0	brownish red	1180	0.2	5.5	poor color, short firing range, possibly brick	samples 87, 88
20+	salmon	1180	1.9	-	-	-	-	no value	sample 89
15	light red	1180+	4.5	-	-	-	-	dry press face bricks	sample 90
15	salmon gray	1330+	6.6	-	-	-	-	use for blending	sample 91
11	salmon	1130	0.0	-	-	-	-	structural clay products	sample 92
15	salmon buff	1180+	5.0	-	-	-	-	overburden 6.9m, dry pressed brick	Crockford (1951) sample 80
16	pinkish red	1180+	7.6	-	-	-	-	dry press brick	sample 81
14	dark buff	1180	0.0	-	-	-	-	from slump block, must find in place, stoneware	Crockford (195) sample 79

Characteristics of Unfired Samples from Map Sheet 72E. (continued)

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties: Room Temperature	Drying Properties: 105°C	Drying Shrinkage (%)
14	35	7	4	W4	Whitemud	Brownish green to greenish gray shale, 0.75m	30	excellent	slightly sticky	-	cracks badly	10.0
						Brownish green to greenish gray silt, 0.75m	23	fair	fair	-	cracks badly	7.9
						Green shale, plastic, 2.2m	23	excellent	sticky	cracks	-	7.7
-	13	8	1	W4	Whitemud	Cream clay	23	good	good	-	good	6.5
						White clay, noncalcareous.	25	excellent	good	-	minor cracks	7.3
						Pinkish clay, noncalcareous.	26	good	good	-	cracks	7.3
5	13	8	1	W4	Whitemud	Interbedded black and white clay, noncalcareous 1.2m.	27	excellent	good	-	cracks badly	8.8
						White clay, noncalcareous, 0.7m.	25	excellent	fair	-	cracks badly	7.4
5	23	8	1	W4	Whitemud	Light gray clay, silty, calcareous, 2.1m	26	fair	good	good	good	7.2
						Yellowish green clay, 0.3m	24	excellent	fair	cracks	cracks	8.4
						Light gray clay, silty, 0.4m	26	good	good	-	cracks	9.2
						Yellowish green clay, 1.7m	28	excellent	fair	-	cracks badly	10.3
2	26	8	1	W4	Whitemud	Chocolate brown shale	32	excellent	good	-	cracks badly	11.0
5	26	8	1	W4	Whitemud	Light green shale, gritty, lm	33	excellent	sticky	cracks badly	-	11.6
						Light gray clay, slightly gritty, 0.6m	28	good	good	-	cracks badly	9.1
						Light gray clay, silty, 0.7m	15	low	fair	good	good	5.8
15	30	8	1	W4	Eastend	Gray clay, calcareous, carbonaceous fragments, 0.6m	31	good	good	good	good	8.2
						Green shale, gritty, 0.6m	29	excellent	sticky	-	cracks badly	10.2
7	18	8	2	W4	Ravenscrag	Gray green, red clay mixture in slump block, ~0.6m	32	good	good	cracks badly	cracks badly	9.2
2	6	8	3	W4	Whitemud	Gray and brownish green clay interbeds, 1.6m	25	excellent	good	-	cracks badly	8.0
						White weathering clay silty, 3.1m	22	fair	fair	good	good	5.5
						Dark brown to black clay, 0.3m	28	excellent	fair	-	cracks badly	10.0
						Pale gray clay, slightly calcareous, 1.2m	23	fair	good	good	good	8.3
						Pale gray clay, white weathering, 0.9m	31	good	fair	-	cracks badly	10.3
2	6	8	3	W4	Whitemud	Brownish green shale composite sample from 1.4m section	23	good	good	-	cracks	7.9
2	9	8	3	W4	Ravenscrag	Light gray to cream clay, very calcareous, 0.75m	23	-	good	-	cracks badly	9.3
1	14	8	3	W4	Ravenscrag	Pink, maroon, green clays composite sample, 3.9m	26	excellent	good	-	cracks badly	11.0
2	14	8	3	W4	Ravenscrag	Gray shales, very calcareous, 1.8m composite sample	24	good	good	-	cracks badly	8.7

Characteristics of Fired Samples from Map Sheet 72E (continued)

P.C.E.	Steel Hard			Maximum Fire				Remarks	Reference
	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)		
9	brownish red	1130	0.2	-	-	-	-	overburden 7m, possibly structural clay products	Crockford (1951 sample 52
11	light brownish red	1255+	2.8	-	-	-	-	structural clay products	sample 53
9	red	1130+	3.2	dark red	1180	1.2	5.7	short firing range, doubtful value	sample 54
18+	dark cream	1255+	6.3	light gray	1330	1.6	4.7	moderate firing range stoneware clay	ARC files (1949)
19	buff	1180+	5.9	-	-	-	-	salt glazed sewer pipe if cracking overcome	
17+	salmon buff	1180+	5.3	-	-	-	-	add grog to overcome cracking for sewer pipe	
19	buff	1180+	6.4	-	-	-	-	common brick, thick overburden	Crockford (1951) sample 1
19	buff	1180+	5.4	-	-	-	-	common brick, thick overburden	sample 2
15	light gray	1330	1.1	-	-	-	-	blend with clays below for stoneware	Crockford (1951) sample 4
10	dark red	1180	0.2	-	-	-	-	pressed brick, quarry tile	sample 5
14	dark buff	1180+	3.9	-	-	-	-	face brick	sample 6
11	brownish red	1180	0.4	-	-	-	-	tile, face brick	sample 7
26+	salmon buff	1255	2.8	gray brown	1130+	1.1	8.3	moderate firing range, slumped outcrop, low duty refractory	Crockford (1951) sample 8
11	brownish red	1180	2.4	-	-	-	-	13.5m overburden, blend for brick and tile	Crockford (1951) sample 9
14	dark buff	1180	1.4	brown buff	1255+	0.8	7.3	stoneware	sample 10
15	light gray	1255	1.5	-	-	-	-	blend with clay above	sample 11
3	light salmon	1130	15.8	brown buff	1180-	0.1	10.0	short firing range, no value	Crockford (1951) sample 12
9	dark red	1180	2.1	dark red	1255+	1.9	6.3	dry slowly for face brick	sample 13
14	red	1180	1.3	-	-	-	-	add grog to improve drying, doubtful value	Crockford (1951) sample 14
13	salmon red	1180	2.3	-	-	-	-	overburden to 18m, face brick	Crockford (1951) samples 61, 62
15	pinkish buff	1330+	3.4	-	-	-	-	use for blending for face brick	sample 63
16	brown	1330	2.4	-	-	-	-	tile, face brick	sample 64
13+	salmon buff	1180+	6.3	gray	1330	0.9	3.1	stoneware, slight scum	sample 65
12	light red	1130	0.2	brownish red	1180	0.1	6.7	scums, brick, tile and possibly stoneware if treated for scum	sample 66
14+	red	1255+	4.2	-	-	-	-	face brick, section mostly covered	Crockford (1951) sample 67
2	salmon buff	1180+	7.0	-	-	-	-	hard to extrude, warps on firing, no value	Crockford (1951) sample 17
14	light red	1130	4.5	brownish red	1180	0.9	5.4	short firing range, thin overburden, dry press brick and quarry tile	Crockford (1951) sample 15
3+	light buff	1180+	2.5	-	-	-	-	no value	Crockford (1951) sample 16

Characteristics of Unfired Samples from Map Sheet 72E. (continued)

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
16	17	8	3	W4	Whitemud	Light gray clay, sandy, 1.1m	17	fair	fair	-	minor cracks	9.0
						Dark brown clay, 1.9m	23	excellent	good	-	cracks badly	8.7
						Light gray and white mottled clay, 0.9m	23	good	good	-	good	6.2
						White weathering clay, silty, 1.8m	22	good	good	-	cracks badly	6.1
						Gray and light brownish green clay, 2m	23	good	good	-	cracks badly	7.8
4	19	8	3	W4	Whitemud	White weathering clay, sandy, 1.9m	24	good	fair	-	cracks badly	8.2
						Brownish green clay, 0.75m	30	excellent	good	-	cracks badly	11.1
						Chocolate brown clay, slightly silty, 1.5m	33	excellent	good	-	cracks badly	11.8
						White weathering clay, silty, 0.8m	24	poor	fair	good	good	6.0
						Greenish white mottled shale, 0.9m	29	excellent	fair	-	cracks badly	8.1
						Brown shale, 0.3m	31	excellent	good	-	cracks badly	10.7
5	20	8	3	W4	Whitemud	Green to brown clay, silty, 0.9m	28	excellent	good	-	cracks badly	8.7
						White weathering clay, silty, 1.7m	21	fair	fair	good	good	6.4
NW	20 I.XL Quarry 34	8	3	W4	Battle	10YR2/2 (dusky yellowish brown) shale, minor silt, slickensides, alligator weathering, 3m	28	very good	good	warps, cracks	cracks badly	10.2
					Whitemud	5YR8/1 (pinkish gray)clayey sand, small pods and stringers of 10YR2/2 (dusky yellowish brown) slickensided material, 1m	16	fair	fair	good	cracks	7.3
						N9 (white) clayey sand, dark slickensided material along joints, 1.5m	16	good	very good	excellent	excellent	6.9
						N9 (white) clayey sand, thin bedded, 7m	12	nil	nil	very good	good	0.5
					Eastend	5YR7/2 (grayish orange pink) clayey silt, worm burrows filled with dark, slickensided material, 10m	18	fair	good	good	good	3.5
2	2	8	4	W4	Whitemud	Gray shale, silty, composite sample, 3.6m	27	excellent	sticky	-	cracks badly	8.7
2	2	8	4	W4	Whitemud	Brownish green shale, composite sample, 2.3m	31	excellent	sticky	-	cracks badly	10.0
4	2	8	4	W4	Whitemud	Brownish green clay, silty, composite sample, 5.2m	28	good	sticky	cracks	cracks badly	10.8
4	2	8	4	W4	Whitemud	Light greenish gray clay, 0.6m	24	fair	good	-	cracks badly	8.0
						Pale gray clay, silty, 0.9m	23	poor	poor	good	good	4.7
						Greenish gray shale, plastic, 0.6m	28	excellent	sticky	-	cracks badly	9.1
16	4	8	4	W4	Whitemud	Dark green, brown, gray shales, composite sample, 1.9m	31	good	good	-	cracks badly	10.0

Characteristics of Fired Samples from Map Sheet 72E. (continued)

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
20	buff	1330+	5.8	-	-	-	-	overburden 6.9m, low duty refractories	Crockford (1951) sample 18
19	light red	1255	3.0	brown	1330+	1.9	5.4	moderate firing range, structural clay products	sample 19
17	dark cream	1255	2.9	gray	1330-	0.0	6.0	stoneware	sample 20
16	dark cream	1255+	6.8	light gray	1330-	0.3	6.4	stoneware if blended to stop cracking,	sample 21
15	brown	1255	0.1	-	-	-	-	poor drying, structural clay products	sample 22
19	dark buff	1330+	4.8	-	-	-	-	overburden 5m, blend for structural clay products	Crockford (1951) sample 25
13	brownish red	1180	0.6	-	-	-	-	add grog for drying, structural clay products	sample 26
18+	light brownish red	1180	1.7	-	-	-	-	add grog for drying, structural clay products	sample 27
16	dark cream	1255+	4.9	light gray	1330	0.1	7.2	stoneware	sample 28
12	dark buff	1130+	0.4	-	-	-	-	blend with non plastic material for stoneware	sample 29
16	light brownish red	1180	2.9	-	-	-	-	add grog for drying, structural clay products	sample 30
28	light buff	1255+	4.6	brown	1330	1.8	7.3	overburdem 21m, low duty refractory	Crockford (1951) sample 23
19	white	1255+	8.0	light gray	1330	2.8	4.5	blend to improve workability & drying for stoneware	sample 24
15	steel hardness not reached by 1335°C							poor drying, low duty refractory	Scafe (1980)
23	10YR8/2 (very pale orange)	1150	7.0	10YR7/4 (light orange brown)	1325+	6.5	3.0	long firing range, low duty refractory	
26	steel hardness not reached by 1335°C							extrudes well, low duty refractory	
14	10YR6/2 (pale yellowish brown)	1250	2.2	5Y6/1 (light olive gray)	1270	1.5	4.4	use for blending, stoneware	
9	5YR4/4 (moderate brown)	1100	10.8	5YR3/4 (moderate brown)	1175	1.3	8.2	moderate firing range, pleasant brown color, bars curl on firing, brick & tile	
11	light red	1130+	4.0	-	-	-	-	overburden 14.4m, light scum, structural clay products	Crockford (1951) sample 56
10	brownish red	1130	0.3	dark red	1180-	0.0	-	overburden 6m, probable slump, blend for structural clay products	Crockford (1951) samples 57, 58
9+	brownish red	1130	1.2	dark red	1180-	0.4	5.6	overburden 9.6m, structural clay products	Crockford (1951) samples 50, 51
12	dark salmon	1130+	3.5	brownish red	1180	0.5	5.4	overburden 12m, brick if blend with less plastic clay	Crockford (1951) sample 47
14	light brown	1300-	1.2	-	-	-	-	very short firing range, brick if blended	sample 48
10	brownish red	1130	0.1	-	-	-	-	face brick	sample 49
16	buff	1130+	7.3	salmon	1180	3.5	6.4	thick overburden, stoneware	Crockford (1951) samples 45, 46

Characteristics of Unfired Samples from Map Sheet 72E. (continued)

Location					Group or		Tempering			Drying Properties		Drying Shrinkage
LSD	Sec	Tp	R	Mer	Formation	Description	Water (%)	Plasticity	Workability	Room Temperature	105°C	(%)
1	9	8	4	W4	Battle	Gray shale, rusty yellow and black stain, very calcareous, 3.6m	25	excellent	fair	-	cracks	8.3
					Whitemud	Brownish green shale, plastic, 1.1m	20	excellent	sticky	cracks	cracks	12.1
						Pale gray clay, white weathering, 0.8m	27	good	good	-	cracks	7.6
						Dark cream clay, 0.8m	30	excellent	good	-	cracks badly	8.6
						Light brownish gray clay, plastic, 0.8m	26	excellent	fair	-	cracks badly	10.4
7	9	8	4	W4	Whitemud	Light gray shale, plastic, 0.9m	28	good	good	-	cracks badly	8.8
						Dark brown to black shale, 1.4m	32	excellent	good	cracks	cracks	11.4
						Light gray shale, plastic, 2.3m	26	good	good	-	cracks	7.8
						Chocolate brown shale, plastic, 0.9m	28	good	good	-	cracks	9.3
-	32	10	11	W4	Judith River	Shale	30	excellent	-	cracks	-	11.3
						Shale	25	good	-	good	-	10.6
						Clay shale	25	fair	-	-	-	9.6
						Clay from coal seam	22	fair	-	good	-	9.6
-	31	11	2	W4	Judith River	Red shale, 15m,	37	excellent	-	cracks	-	9.7
						Gray clay	36	good	sticky	cracks badly	-	9.4
						Gray clay, hard, gypsiferous	33	excellent	-	checks badly	-	11.6
16	4	11	4	W4	Bearpaw	Grayish brown shale	32	excellent	sticky	cracks badly	-	13.1
-	8	11	5	W4	Judith River	Light gray shale, 2.1m	-	good	-	cracks	-	6.8
						Dark brownish gray shale, 3.6m	21	good	-	good	cracks	8.0
						Yellow shale, soft	20	good	-	fair	cracks	7.0
-	3	12	5	W4	Judith River	Gray clay, sandy	24	excellent	sticky	-	cracks	8.0
						Black clay, numerous plant remains, 2m	21	excellent	sticky	-	-	8.5
						Buff shale	22	excellent	good	good	good	7.0
-	3	12	5	W4	Judith River	Yellowish shale, soft, sandy, limonite nodules	20	fair	fair	-	cracks	5.0
						Light yellowish gray clay	22	excellent	sticky	cracks	-	7.0

Characteristics of Fired Samples from Map Sheet 72E. (continued)

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
4	red	1130+	7.4	-	-	-	-	overburden 6.9m, brick	Crockford (1951) sample 40
14+	brownish red	1180	3.6	red	1255+	3.0	5.6	doubtful value	sample 41
16	buff	1180	2.0	dark buff	1255+	1.7	7.4	moderate firing range, structural clay products	sample 42
14	buff	1130	0.8	dark buff	1180	0.1	8.0	moderate firing range, structural clay products	sample 43
18+	light brown	1330	2.1	-	-	-	-	short firing range, dry pressed bricks	sample 44
14	dark buff	1180	0.7	dark buff	1255+	0.7	6.5	overburden 5.1m, moderate firing range, stoneware	Crockford (1951) sample 35
18+	dark salmon	1180+	4.1	-	-	-	-	short firing range, structural clay products	sample 36
15	dark buff	1180	0.0	-	-	-	-	short firing range, stoneware	sample 37
20+	light buff	1255+	5.8	-	-	-	-	blend for use in stoneware & structural clay products	sample 38
-	bright cherry red	1005	3.9	-	1095+	0.0	6.0	good color, moderate firing range, dry press brick	Ries (1914a) sample 1851
4	red	1095	0.3	red	1155	-	-	dry press brick	sample 1852
-	-	-	-	reddish brown	-	-	-	some scum, dry press brick	sample 1853
-	-	-	-	light red	-	-	-	good for bricks	sample 1854
-	-	-	-	red	1050	2.1	5.3	doubtful value	Ries & Keele (1912) sample 1698
-	-	-	-	red	1050	6.9	2.3	scums, doubtful value	sample 1697
-	-	-	-	red	1050	10.5	2.0	doubtful value	sample 1699
10	red	1180	1.4	-	-	-	-	scums badly, doubtful value sample 113	Crockford (1951)
-	red	1050	3.3	-	1180	-	-	dries poorly, brick	Ries & Keele (1913) sample 1756
-	red	1005	9.5	deep red	1050	5.2	4.0	dry press brick	sample 1757
-	red	1005	9.6	red	1095	4.2	3.0	moderate firing range, blend to improve drying, dry press brick	sample 1758
-	light red	1050	7.3	dark red	1135	2.0	4.6	moderate firing range, blend to improve working & drying, brick	Ries & Keele (1912) sample 1691
-	-	-	-	gray	1180	2.3	3.6	brick	sample 1692
-	red	900	12.9	red	1050	2.6	4.6	long firing range, brick	sample 1693
-	salmon	1005	15.2	brown	1135	1.5	4.0	long firing range, brick	Ries & Keele (1913) sample 1754
4	light red	1005	6.5	red	1095	2.3	3.3	moderate firing range, chemical analysis, dry press brick	sample 1755

Characteristics of Unfired Samples from Map Sheet 72L.

Location LSD	Sec	Tp	R	Mer	Group or Formation	Description	Water (%)	Tempering Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
13	28	12	5	W4	Pleistocene	Interbedded stiff clay, silty clay and sand	-	-	stiff	cracks	-	high
NW	31	12	5	W4	Pleistocene	Blue clay, less silty than most in area	18	good	-	-	-	5.2
SW	35	12	6	W4	Judith River	Clay-shale, 0.6m, above lignite, greasy appearance	-	good	-	good	-	6.7
7	4	13	6	W4	Judith River	Shale, ~7.5m, approx. 3/4 way up coulee, a few thin sands & lignite streaks	24	good	-	-	-	6.6
4	5	13	6	W4	Judith River	Yellow & gray clay, mottled, 6m below surface in coulee, noncalcareous	31	good	smooth	-	-	10.8
13	5	13	6	W4	Judith River	Shale, composite sample from Red Cliff Brick Co. pit	19	good	-	-	cracks	7.2
						Yellow clay-shale near top of pit	30	excellent	sticky	cracks badly	-	11.0
						Dark gray shale	43	excellent	sticky	checks badly	-	11.6
						Light buff shale, sandy, ~1.2m	28	poor	springy	-	cracks	4.4

Characteristics of Unfired Samples from Map Sheet 73D.

Location LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
-	35	37	14	W4	Horseshoe Canyon	Gray shale, soft to hard, rusty streaks	-	excellent	poor	cracks badly	-	-
						Dark brown clay, lignite particles	-	excellent	poor	-	-	-

Characteristics of Fired Samples from Map Sheet 72L

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
-	red	920	-	red	1180	-	-	long firing range, brick	Keele (1915)
-	red	920+	12.5	red	1130+	9.8	0.7	heavy overburden, brick	Ries & Keele (1912) sample 1700
3+	red	1130+	6.9	deep red	1180+	0.7	7.4	short firing range, mine with lignite, brick	Ries & Keele (1912) sample 1695
6	brown	1180+	7.0	-	-	-	-	high absorption, short firing range, brick	Ries (1914a) sample 1857
3	red	1130	2.1	-	-	-	-	clay lens, thick overburden, dry press brick	Ries & Keele (1912) sample 1696
5	red	920	11.6	red	1180	3.4	3.0	long firing range but no good vitrified body, little value	Ries & Keele (1912) sample 1688
5+	dark red	1130	4.2	dark red	1195	0.0	4.6	moderate firing range, works & dries better with 50% grog, sewer pipe	sample 1686
5	light red	920	10.8	brown	1180	3.4	0.0	no value	sample 1687
3	pale red	1130	22.3	-	1180-	14.0	1.3	doubtful value	sample 1685

Characteristics of Fired Samples from Map Sheet 73D

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
3	-	-	-	red	-	-	-	submitted by Coalbeck Colliery, no value	Keele (1915)
5	red	1005+	-	-	-	-	-	as above	

Characteristics of Unfired Samples from Map Sheet 73E.

Location LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	105°C	Drying Shrinkage (%)
16	11	54	3	W4	Lea Park	5Y3/2 (olive gray) shale, 5YR4/4 (moderate brown) stain on laminae & joints, minor silt, noncalcareous	P.C.E. cones bloated so badly that further testing was not warranted					
(20m of shale on Vermillion River)						As above, slightly silty	23	good	good	minor warp	cracks	7.3
						As above, minor silt	P.C.E. cones bloated so badly that further testing was not warranted					
						As above, slightly silty	23	good	good	warps	cracks badly	7.8
1	5	54	7	W4	Lea Park	5Y4/4 (moderate olive brown) mudstone, 5YR4/4 (moderate brown) stain on joints, slightly silty, 2m	24	good	good	warps	cracks badly	10.2

Characteristics of Fired Samples from Map Sheet 73E.

P.C.E.	Steel Hard Color	Steel Hard Temp. (°C)	Steel Hard Absorption (%)	Maximum Fire Color	Maximum Fire Temp. (°C)	Maximum Fire Absorption (%)	Maximum Fire Shrinkage (%)	Remarks	Reference
-	P.C.E. cones bloated so badly that further testing was not warranted							expanded aggregate	Scafe (1978)
5	5YR4/4 (moderate brown)	1055	5.0	5YR4/4 (moderate brown)	1075	2.8	7.9	extruded bars bloat badly, expanded aggregate	
-	P.C.E. cones bloated so badly that further testing was not warranted							expanded aggregate	
5	bars bloat badly even when hand molded							expanded aggregate	
4	5YR5/6 (light brown)	1035	6.8	5YR4/4 (moderate brown)	1080	2.6	6.9	extruded bars bloat badly, expanded aggregate	Scafe (1978)

Characteristics of Unfired Samples from Map Sheet 74D.

Location					Group or			Tempering		Drying Properties		Drying
LSD	Sec	Tp	R	Mer	Formation	Description	Water (%)	Plasticity	Workability	Room Temperature	105°C	Shrinkage (%)
15	8	89	9	W4	McMurray	Brownish gray clay, noncalcareous	25	good	fair	-	cracks badly	8.0
						Dark gray clay, calcareous	29	good	good	-	cracks badly	7.8
						Brownish black clay, noncalcareous	25	good	good	cracks badly	-	7.3
						Creamy gray clay, noncalcareous	24	good	good	cracks badly	-	7.8
						Light gray buff clay, noncalcareous	31	good	good	cracks badly	-	8.0
						Pink clay, noncalcareous	28	good	good	-	cracks	7.1
SW	9	89	9	W4	Clearwater	5Y2/1 (olive black) clay, massive, minor grit, iron stain, gypsum crystals, ~6m	17	fair	fair	warps	good	7.4
-	14	89	9	W4	McMurray	Light brown clay	26	good	fair	-	-	6.5
SW	19	89	9	W4	Clearwater	5Y5/2 (light olive gray) clay, massive, slightly silty, iron stain	23	good	good	warps	warps	8.6
						5Y4/1 (olive gray) clay, massive, breaks into 2.5cm blocks	19	fair-good	good	warps	warps	7.5
-	17	91	9	W4	McMurray	Dark gray clay, laminated, noncalcareous, 2.8m	21	good	fair	-	-	6.3
-	17	91	9	W4	McMurray	Light gray clay	23	poor	poor	-	-	3.0
						Dark gray clay	24	fair	good	-	-	8.0
NW	17	91	9	W4	McMurray Basal Clay	5Y4/1 (olive gray) massive, noncalcareous, slightly silty	P.C.E. cones bloat so badly further testing unwarranted					
						5Y3/2 (olive gray) clay, massive, noncalcareous	18	fair	fair	good	good	6.7
						5Y4/1 (olive gray) clay, very silty, massive, noncalcareous	12	excellent	good	minor warp	good	5.8
						N1 (black) clay, slightly silty, waxy, massive, coal fragments	32	fair-good	fair	minor warp	minor cracks	6.1
NW	14	92	10	W4	McMurray Basal Clay	10YR4/2 (dark yellowish brown) clay, minor lamination, minor silt, ~3.6m	13	good	good	minor warp	minor cracks	4.7
						5Y4/1 (olive gray) clay, thin laminations, minor silt, ~3m	16	good	good	good	minor cracks	4.7
						5Y4/1 (olive gray) clay, minor silt, thin laminations, ~3m	13	good	good	minor warp	minor cracks	8.0
16	19	92	10	W4	McMurray Basal Clay	5Y5/1 (medium olive gray) clay, silty	25	fair	poor-fair	warps	warps	8.7

Characteristics of Fired Samples from Map Sheet 74D.

P.C.E.	Steel Hard Color	Steel Hard Temp. (°C)	Steel Hard Absorption (%)	Maximum Fire Color	Maximum Fire Temp. (°C)	Maximum Fire Absorption (%)	Maximum Fire Shrinkage (%)	Remarks	Reference
18	medium brown	1180+	3.9	-	-	-	-	difficult to dry, structural clay products, chemical analysis	Halferdahl (1969) sample 1
14	brown	1150+	5.4	-	-	-	-	bars bloat & have black core, doubtful value, chemical analysis	sample 2
15+	brown	1220+	11.2	-	-	-	-	difficult to dry, structural clay products if blended, chemical analysis	sample 3
17+	buff	1120+	6.9	-	-	-	-	as above, chemical analysis	sample 4
14+	medium red	1100	2.7	brownish red	1180	0.0	6.3	as above, scums, chemical analysis	sample 5
16	light red	1180	4.2	red	1220+	2.3	6.3	difficult to dry, structural clay products	sample 6
2	5YR4/4 (moderate brown)	1040	7.5	5YR4/4 (moderate brown)	1075	3.0	7.5	slightly stiff to extrude, very short firing range, soft white grains after firing, little value	Scafe (1977)
7+	reddish buff	1025	-	reddish buff	1130+	-	-	long firing range, structural clay products	Ells (1926) sample E3
3	5YR5/6 (light brown)	1030	6.0	5YR4/4 (moderate brown)	1050	2.5	7.5	extrudes well, very short firing range, bars curl at hot end, bricks if blended	Scafe (1977)
3	5YR5/2 (pale brown)	1115	6.0	5YR5/2 (pale brown)	1125	0.0	8.0	extrudes well, very short firing range, bricks if blended	
16	-	-	-	light buff	980	-	-	explodes or breaks on firing because hard to dry completely, no value	Hume (1924)
27	not fired high enough to reach steel hard							blend with more plastic clays for brick	Ells (1926) sample 2
7+	reddish buff	1080	6.0	-	-	-	-	face brick or possibly vitrified ware	sample 3
-	P.C.E. cones bloat so badly that further testing unwarranted							no value	Scafe (1980)
27	10YR7/4 (grayish orange)	980	3.0	10YR7/4 (grayish orange)	1050	1.8	5.5	extruded bars bloat severely, moderate firing range,low duty refractories, chemical analysis	
20	5Y8/4 (grayish yellow)	1155	4.4	5Y7/2 (yellowish gray)	1325	1.0	2.0	long firing range, low fired shrinkage, chemical analysis, stoneware	
30	steel hardness temperature exceeds furnace limit							burned coaly fragments leave vugs, chemical analysis, refractories	
17	5Y7/2 (yellowish gray)	1100	7.0	5Y7/2 (yellowish gray)	1200	2.5	4.5	extrudes stiffly, black core, fire slowly, chemical analysis, stoneware	Scafe (1977)
14	5YR5/2 (pale brown)	1175	4.8	10YR4/2 (dark yellowish brown)	1225	0.5	7.5	extrudes & fires well, stoneware	
15	5YR7/2 (grayish orange pink)	1205	5.3	10YR6/2 (pale yellowish brown)	1250	2.0	6.0	extrudes & fires well, stoneware	
16	5YR6/4 (light brown)	940	5.5	5YR6/4 (light brown)	975	3.0	6.0	blend with grog to improve drying, black core, fire slowly, short firing range, low duty refractories	Scafe (1977)

Characteristics of Unfired Samples from Map Sheet 74E.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties: Room Temperature	Drying Properties: 105°C	Drying Shrinkage (%)
SE	29	92	9	W4	McMurray	Gray clay, carbonaceous	28	excellent	good	good	cracks	8.0
SW	29	92	9	W4	McMurray	Light gray clay, calcareous	27	good	good	good	good	5.8
13	30	92	10	W4	McMurray	Medium gray clay	13	good	good	good	good	3.3
-	31 (Suncor pit)	92	10	W4	McMurray	5Y4/1 (olive gray) clay, slightly silty, noncalcareous, minor sand laminae with minor bitumen, ~2m mineable oil sand below	15	very good	good	minor warp	minor cracks	4.7
						5Y4/1 (olive gray) clay, slightly silty, thin-medium laminae, minor sand laminae with minor bitumen	15	excellent	good	good	minor cracks	4.9
4	31	92	10	W4	McMurray	Medium gray clay, minor silt	22	fair-good	fair	minor warp	minor warp & cracks	7.5
5	31	92	10	W4	McMurray	5Y5/1 (medium olive gray) clay, silty	18	very good	good	good	minor warp	4.5
5	31	92	10	W4	McMurray	Black clay, soft, minor silt	17	fair-good	good	warps	warps	4.5
6	31	92	10	W4	McMurray	5Y4/1 (olive gray) clay, minor silt	9	fair	fair	good	good	0.8
13	31	92	10	W4	McMurray	N8 (very light gray) clay, minor silt	17	good	fair-good	good	good	4.6
13	31	92	10	W4	McMurray	5Y4/1 (olive gray) clay, minor silt	19	good-very good	good	minor warp	warps	6.1
16	36	92	11	W4	McMurray	Medium gray clay	16	good	sticky	good	good	5.2
NE	13	93	12	W4	McMurray	Clay	23	good	good	good	cracks	7.0
-	-	94	10	W4	McMurray	Light gray clay	-	excellent	good	good	good	-
						Light gray clay	27	good	good	good	good	8.0
						Clay	37	-	good	-	-	10.0
SW	17	94	10	W4	McMurray	5Y5/2 (light olive gray) clay	22	good	fair	good	good	6.1
NW (Shell road, Athabasca River intersect)	31	94	10	W4	McMurray	5Y4/1 (olive gray) & 5GY6/1 (greenish gray) clay, massive, nonsilty, noncalcareous	18	fair	fair	good	good	5.8

Characteristics of Fired Samples from Map Sheet 74E.

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
-	-	950	10.0	-	1030	4.0	4.6	carbonaceous matter causes bloating or voids on burning, doubtful value	Ells (1915) sample 302
3	buff	1090	23.0	-	-	-	-	calcareous clay that needs careful burning, brick	Ells (1915) sample 303
18	5Y5/2 (light olive gary)	1275	4.5	5Y5/2 (light olive gray)	1360	4.0	3.5	black slag-like inclusions, low duty refractories	Scafe (1977)
15	5YR6/4 (light brown)	1200	4.2	10YR6/2 (pale yellowish brown)	1240	1.2	7.2	extrudes very well, short firing range, stoneware	Scafe (1980)
8	10R4/2 (grayish red)	1075	7.9	5YR3/4 (moderate brown)	1160	1.7	7.7	extrudes well, moderate firing range, structural clay products	
20	10YR8/2 (very pale orange)	900	10.5	5Y6/4 (dusky yellow)	1175	1.0	6.0	improve drying with grog, stiff to extrude, low duty refractories	Scafe (1977)
14	5YR5/6 (light brown)	1100	9.0	10YR4/2 (dark yellowish brown)	1240	1.0	6.0	black core, fire slowly, stoneware	Scafe (1977)
15	10YR7/4 (grayish orange)	1125	9.0	5Y6/1 (light olive gray)	1235	1.0	5.5	long firing range, slightly stiff to extrude, stoneware	Scafe (1977)
17	-	-	-	5Y6/4 (dusky yellow)	1350	3.0	5.4	many black slag-like inclusions, no steel hard by 1350°C, low duty refractories	Scafe (1977)
16	5Y7/2 (yellowish gray)	1160	10.0	5Y7/2 (yellowish gray)	1250	3.5	4.0	moderate firing range, chemical analysis, low duty refractories	Scafe (1977)
16	10YR7/4 (grayish orange)	950	13.5	10YR7/4 (grayish orange)	1100	6.0	6.0	long firing range, black core, fire slowly, chemical analysis, low duty refractories	Scafe (1977)
15	10YR5/4 (moderate yellowish brown)	990	9.7	5Y5/2 (light olive gray)	1140	3.0	5.5	long firing range, fire slowly, stoneware	Scafe (1977)
15	-	-	-	gray	1230	0.0	2.0	works well, cracks on firing, no value	Ells (1915) sample 310
27	cream	1190	-	-	-	-	-	Scafe unable to find similar clay	Ells (1915) sample 190
-	-	-	-	dark red	1190	0.0	4.0	add 20% sand to reduce shrinkage, structural clay products	sample 305
-	light red	950	12.0	red	-	-	-	add 25% sand to reduce shrinkage, bricks	sample 306
6	10R6/6 (moderate reddish orange)	970	13.0	5YR4/4 (moderate brown)	1050	3.0	9.5	some cracking, chemical analysis, bricks	Scafe (1977)
10	bars begin bloating at point of steel hardness							expanded aggregate	Scafe (1980)

Characteristics of Unfired Samples from Map Sheet 74E. (continued)

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
9	15	94	11	W4	McMurray	Dark clay, lignite, core AOP-90 220-225	21	poor	poor	good	good	2.6
NE	29	94	11	W4	McMurray	Clay	23	good	good	good	cracks	7.0
6	34	94	11	W4	McMurray	Green clay, core AOP-17 110-115	19	fair-good	good	good	good	5.3
1	35	94	11	W4	McMurray	5GY6/1 (greenish gray) clay, massive, slightly silty, noncalcareous, 30cm	18	fair	fair	minor warp	good	5.8
-	6	95	10	W4	McMurray	Light gray clay, noncalcareous, ~1.8m, overburden ~6m	19	fair	-	good	good	6.2
SW	19	95	10	W4	McMurray	Light gray clay, overburden 3-6m	-	excellent	good	good	checks	5.5
						Clay, carbonaceous	-	excellent	sticky	good	cracks	9.0
4	2	95	11	W4	McMurray	5Y4/1 (olive gray) clay, nonsilty, noncalcareous, 5m	17	good	fair	minor warp	good	6.4
7	4	95	11	W4	McMurray	5Y3/2 (olive gray) clay, nonsilty, noncalcareous, 0.5m	19	good	good	minor warp	minor cracks	6.1
12	10	95	11	W4	McMurray	Gray green shale, core AOP -23 150-155	21	fair-good	good	good	good	4.8
NW	13	95	11	W4	McMurray	Light gray clay, between oil sand beds, lignite, noncalcareous	17	fair	good	good	good	5.0
SW	34	95	11	W4	McMurray	Clay, sandy	14	poor	poor	-	-	3.0
						Gray clay, soft	-	good	good	good	good	6.0
						Gray clay, soft, carbonaceous, ~4.8m	-	good	stiff	-	-	-
NW	34	95	11	W4	McMurray	Clay	21	good	good	good	checks	6.0
SE	35	95	11	W4	McMurray	Clay, ~2.7m, overburden ~4.5m	25	excellent	good	good	checks	7.5
14	9	96	8	W4	McMurray	Dark clay, lignite, core AOP-96 205-210	28	fair-good	good	good	good	6.0
SE	2	96	11	W4	McMurray	Light gray clay, slight reddish tinge	17	good	stiff	-	-	5.0
8	11	97	11	W4	McMurray	Gray brown clay, core AOP-40 223-230	23	fair-good	good	good	good	6.4
9	1	98	11	W4	McMurray	Gray clay, sandy, core AOP-58 220-225	17	good	good	good	good	3.8

Characteristics of Fired Samples from Map Sheet 74E. (continued)

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
17	10YR5/4 (moderate yellowish brown)	1225	19.0	10YR4/2 (dark yellowish brown)	1260	18.0	13.0	bars fragile, warps badly on firing, little value	Scafe (1977)
15	-	-	-	dark buff	1150	2.0	3.4	add grog to improve drying, burn slowly, brick & tile	Ells (1915) sample 310
23	5YR4/4 (moderate brown)	1025	11.0	5YR4/4 (moderate brown)	1100	3.3	6.3	moderate firing range, chemical analysis, low duty refractories	Scafe (1977)
10	5YR5/6 (light brown)	975	4.1	5YR5/6 (light brown)	1075	0.6	5.4	moderate firing range, brick & tile	Scafe (1977)
15	light red	890	11.0	cream	1030	8.1	1.0	long firing range at low temperatures, stoneware	Hume (1924) deposit 2
17	-	-	-	gray	1310	0.0	4.0	stoneware, pottery	Ells (1915) sample 319
4	dull salmon	950	-	-	-	-	-	carbon causes burning problems, no value	sample 320
15	5YR8/4 (moderate orange pink)	1010	6.3	10YR6/2 (pale yellowish brown)	1160	1.0	5.6	long firing range, good thickness, structural clay products	Scafe (1980)
15	10YR7/4 (grayish orange)	930	6.1	10YR7/4 (grayish orange)	1000	4.0	3.5	moderate firing range, structural clay products	Scafe (1980)
14	10YR7/4 (grayish orange)	1085	11.7	10YR6/2 (pale yellowish brown)	1200	1.0	8.5	long firing range, structural clay products	Scafe (1977)
16	light cream	970	10.2	light cream	1030+	8.9	0.3	probably hard to separate from oil sand interbeds, perhaps structural clay products	Hume (1924) deposit 3
18	-	-	-	buff	1230	7.0	0.0	blend 50:50 with sample 315 for good body, sewer pipe	Ells (1915) sample 313
-	-	-	-	gray	1230	0.0	4.6	low shrinkage, burns well stoneware	sample 314
-	-	-	-	gray	-	-	-	fire checks, brittle at high temperatures, burn slowly for carbon, sewer pipe if blended	sample 315
13	-	-	-	gray	1150	0.0	4.0	dry & burn slowly, stoneware	Ells (1915) sample 316
-	salmon	950	-	-	-	-	-	burn very slowly to counter carbon, brick	Ells (1915) sample 318
15	10YR7/4 (grayish orange)	1275	11.0	coincides with steel hard				fragile body, little value	Scafe (1977)
16	gray	1230+	3.0	gray	1310	0.0	4.0	moderate firing range, stoneware	Ells (1915) sample 317
15	5YR6/4 (light brown)	950	9.0	5YR4/4 (moderate brown)	1100	2.9	7.3	many slag-like inclusions, structural clay products	Scafe (1977)
18	10YR7/4 (grayish orange)	1075	10.0	5Y7/2 (yellowish gray)	1275	2.8	5.5	long firing range, chemical analysis, low duty refractories	Scafe (1977)

Characteristics of Unfired Samples from Map Sheet 74E. (continued)

Location					Group or		Tempering			Drying Properties		Drying Shrinkage
LSD	Sec	Tp	R	Mer	Formation	Description	Water (%)	Plasticity	Workability	Room Temperature	105°C	(%)
-	17	99	7	W4	Pleistocene	Gray clay, carbonaceous, slightly calcareous	21	poor	-	good	-	6.3
16	35	99	8	W4	Pleistocene	Pink clay, noncalcareous	28	good	good	-	cracks	7.1
-	10	100	8	W4	Pleistocene	Pink clay, slightly calcareous	33	good	-	-	-	6.0
-	19	100	8	W4	McMurray	Light red clay, mottled	-	good	sticky	-	-	-

Characteristics of Fired Samples from Map Sheet 74E. (continued)

P.C.E.	Steel Hard Color	Steel Hard Temp. (°C)	Steel Hard Absorption (%)	Maximum Fire Color	Maximum Fire Temp. (°C)	Maximum Fire Absorption (%)	Maximum Fire Shrinkage (%)	Remarks	Reference
1	reddish brown	1020	16.9	Dark reddish brown	1098	-	5.7	burn slowly, blend to improve plasticity, bricks	Ells (1926) sample 5
16	light red	1180	4.2	red	1220	2.3	6.3	add grog to reduce cracking, chemical analysis, brick	Halferdahl (1969)
15	pinkish buff	1020	-	dark red	1080	-	-	scums, brick & tile	Ells (1926) sample 4
10	-	-	-	red	1190	-	high	sewer pipe	Ells (1915) sample 189

Characteristics of Unfired Samples from Map Sheet 82G.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties: Room Temperature	Drying Properties: 105°C	Drying Shrinkage (%)
7	4	4	1	W5	Siyeh	N3 (dark gray) argillite, weathers 10YR7/4 (grayish orange), noncalcareous, thin bedded	15	poor	fair	good	good	1.0
7	9	4	1	W5	Grinnell	5R4/2 (grayish red) argillite, weathers 10R5/4 (pale reddish brown), interbedded with N9 (white) quartzite, only argillite sampled	15	poor	fair	good	good	3.5
NE	11	5	2	W5	Alberta Group	Shale, sandy	22	good	good	-	-	5.6
15	12	5	2	W5	Wapiabi	N3 (dark gray) shale, noncalcareous, minor silt to sandy bands, some ironstone concretions	P.C.E. cones bloat so badly that further testing was not warranted					
13	7	6	1	W5	Blackstone (Sunkay mbr)	~30m 5Y2/1 (olive black) shale with 5YR3/2 (grayish brown) stain on laminae, silty interbeds, sulfur smell when disturbed, noncalcareous	16	poor	fair	good	minor cracks	4.6
					(Vimy mbr)	~30m 5Y2/1 (olive black) shale, weathers N6 (medium light gray), thin bedded to fissile, few silty interbeds, calcareous	17	fair	good	good	good	3.7
SW	7	6	1	W5	Alberta Group	Shale, highly carbonaceous, gritty, interbedded sandstone	-	fair	-	-	-	6.4
						~30m shale, slightly calcareous, gritty	24	good	-	checks	-	6.5
						Shale, gritty, noncalcareous	21	fair	-	good	-	6.3
						Greenish gray shale, some grit	21	good	-	cracks	-	4.5
4	18	6	1	W5	Blackstone (Haven mbr)	~15m N3 (dark gray) shale, weathers 5YR3/4 (moderate brown), low silt, noncalcareous	15	very good	very good	good	good	4.3
-	27	6	1	W5	Brazeau	~4.5m light gray, shaly clay, calcareous	28	-	-	checks	-	8.9
NE	23	6	3	W5	Alberta Group	Yellowish gray clay, calcareous, granular	30	fair	-	-	-	8.0
						Yellowish gray clay, calcareous, granular	28	good	-	-	-	6.9
NE	24 (Abandoned Adanac strip mine)	6	4	W5	Kootenay	Dark brown shale, hard, silty, slabby-blocky, 40cm, directly below upper coal.	17	poor	poor	good	good	0.2
						Gray brown shale, platy, minor silt, 1.3m	18	poor	poor	good	good	0.5
						Gray brown shale, abundant plant fragments, nodular siltstone at top, 30cm	18	poor	poor	good	good	1.1

Characteristics of Fired Samples from Map Sheet 82G.

P.C.E.	Steel Hard Color	Steel Hard Temp. (°C)	Steel Hard Absorption (%)	Maximum Fire Color	Maximum Fire Temp. (°C)	Maximum Fire Absorption (%)	Maximum Fire Shrinkage (%)	Remarks	Reference
8	5Y8/4 (grayish yellow)	1190	8.4	5Y8/4 (grayish yellow)	1210	0.4	14.7	extrudes poorly, extremely short firing range, chemical analysis, no value	Scafe (1980)
4	10R5/4 (pale reddish brown)	975	7.0	10R4/2 (grayish red)	1040	3.4	4.0	quartzite probably impossible to remove, bars fragile until fired, little value	Scafe (1980)
3	red	-	-	deep red	1180	5.5	2.7	brick, fireproofing	Ries (1914a) sample 1913
-	P.C.E. cones bloated so badly that further testing was not warranted							no value	Scafe (1980)
7	5YR5/6 (light brown)	1010	10.0	5YR4/4 (moderate brown)	1105	2.1	6.8	grind finely to improve workability and texture, moderate firing range, chemical analysis, structural clay products	Scafe (1980)
5	bars curled so badly firing terminated before steel hardness reached							no value	
-	light red	920	11.5	deep red	1130-	0.9	6.6	long firing range, brick	Ries & Keele (1912) sample 1668
5	red	920+	-	dark red	1180+	6.0	2.0	color poor for brick, long firing range, blend for structural clay products	sample 1669
-	red	1130	7.6	brown	1180+	3.3	2.7	excellent color at steel hard, brick	sample 1670
-	red	920	12.4	red	1180-	2.6	3.0	good bright red at 1130°C, brick	sample 1671
12	5YR6/4 (light brown)	1000	8.5	5YR4/4 (moderate brown)	1125	0.7	5.5	difficult to extrude, long firing range, chemical analysis, blend for structural clay products	Scafe (1980)
5	red	1130	13.8	gray	1195	4.8	3.8	poor color above steel hard, possibly pressed brick or sewer pipe	Ries & Keele (1912) sample 1675
-	buff	1060	14.0	buff	1195	9.8	5.0	remote, underground mining, only good for pressed brick	Ries (1915) sample 1929
7	buff	1060	19.5	buff	1180	15.6	1.3	as above	sample 1925
16	5Y6/1 (light olive gray)	1300	6.5	maximum firing temperature not reached				high refractoriness, low plasticity, low duty refractories	Scafe (1978)
16	5Y6/1 (light olive gray)	1235	6.6	N7 (light gray)	1290	2.7	6.8	moderate firing range, low duty refractories	
13	10YR4/2 (dark yellowish brown)	1240	5.3	5Y5/2 ((light olive gray)	1275	2.4	6.9	short firing range, stoneware	

Characteristics of Unfired Samples from Map Sheet 82G. (continued)

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties: Room Temperature	Drying Properties: 105°C	Drying Shrinkage (%)
						Gray shale, minor silt	13	fair	fair	good	good	1.4
NE	26	7	2	W5	Bearpaw	~10m 5Y3/2 (olive gray) shale, thin laminae, noncalcareous, a few ironstone concretions, 5m glacial overburden	19	fair	good	good	minor cracks	7.0
16	21	7	2	W5	Brazeau	Dark slaty shale, gritty, first railroad cut east of Burmis	-	poor	-	-	-	4.0
						Green shale near western end of railroad cuts, slightly gritty	-	good	-	-	-	5.5
						Light gray shale, calcareous	-	excellent	-	-	-	5.4
						Shale, hard, between heavy sandstones in first railroad cut west of Lundbreck	-	good	-	-	-	4.7
9	27	7	2	W5	Alberta Group	Dark shale, gritty, no overburden	-	fair	-	-	-	4.6
15	10	7	3	W5	Blairmore	Greenish gray shale, sandy, blocky	17	fair	fair	good	good	4.7
-	11	7	3	W5	Blairmore	Soft gray shale at top of section, 1.5m thick	-	good	good	-	-	8.7
						Clay-shale, silty, 1.2m thick, location in section indeterminate	-	good	good	-	-	7.0
						Light gray shale, 1.2-2.4m	-	excellent	good	-	-	6.6
						Shale, 1.2m, 6m below sample above	-	good	-	-	-	8.5
						Clay-shale, soft, sandy, 3m, 4.5m below shale above	-	low	fair	-	-	7.0
NE	11	7	3	W5	Blairmore	Greenish gray shale, sandy, blocky, 3.6m	16	poor	poor	-	good	3.4
						Greenish gray shale, ~15m below sample above, beds dip steeply west	21	fair	good	-	minor cracks	5.5
SW	16	7	3	W5	Blairmore	Green shale, sandy, blocky, steep west dip	15	poor	poor	-	good	2.4
-	31	7	3	W5	Blairmore	Gray shale, splintery, hard	-	none	-	-	-	-
5	31	7	3	W5	Blairmore	Green shale, sandy, very calcareous	18	poor	fair	-	minor cracks	4.4
						Brownish buff shale	19	good	good	-	good	4.9
12	27	7	4	W5	Alberta Group	Black shale, slaty, 30m+ thick, dip 58°	-	poor	-	-	-	2.7
14	34	7	4	W5	Alberta Group	Dark gray shale, slightly carbonaceous	17	poor	-	-	excellent	3.0

Characteristics of Fired Samples from Map Sheet 82G. (continued)

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
16	5Y6/1 (light olive gray)	1225	5.3	5Y6/1 (light olive gray)	1250	3.8	3.7	volume change low on overfiring, chemical analysis, low duty refractories	
8	5YR6/4 (light brown)	925	9.3	5YR6/4 (light brown)	1050	0.8	6.9	long firing range, bars curl on firing, chemical analysis, structural clay products	Scafe (1980)
6	red	1180	4.3	red	1195	7.6	0.4	poor plasticity, extremely short firing range, dry press brick	Ries & Keele (1912) sample 1684
4	dark red	1130	1.4	dark red	1180	0.0	2.3	building brick	sample 1683
1	red	1130	12.8	-	-	-	-	small deposit, brick	sample 1682
1	red	1130	5.8	-	-	-	-	brick?	sample 1680
-	red	1130	7.8	brown	1180	1.9	5.5	good brick material	Ries & Keele (1912) sample 1679
6	dark red	1180	1.3	-	-	-	-	excellent for face brick	Crockford (1951) locality 46
1	-	-	-	red	1130	7.4	3.0	brick	Ries (1915) sample 1936
3	red	1060	8.5	-	1180	1.6	5.0	long firing range, steel hard at low temperature, face brick, tile	sample 1939
3	red	1060	6.2	dark red	1180-	2.0	5.4	brick, drain tile	samples 1920, 1921
7	brownish red	1060	9.2	brownish red	1195	3.4	5.0	long firing range, sewer pipe	sample 1938
7	red	1060	14.2	red	1195	1.5	8.0	long firing range, sewer pipe	sample 1937
6+	dark red	1180	3.4	dark red	1220	1.0+	5.0	short firing range, poor plasticity, dry press brick	Crockford (1951) locality 47
5	red	1130	8.1	dark red	1180-	0.9	6.0	short firing range, might blend with sample above for soft mud or dry press bricks	
9	red	1255	6.6	-	-	-	-	doubtful value	Crockford (1951) locality 45
2	-	-	-	-	-	-	-	no value	Ries & Keele (1913) sample 1767
8	pale gray	1255+	19.5	-	-	-	-	no value	Crockford (1951) locality 44
12	red	1180+	3.4	-	-	-	-	face brick	
7	gray buff	-	porous	-	-	-	-	no value	Ries (1914a) sample 1886
-	red	1150	7.5	dark red	1195	6.0	3.0	burn off carbon slowly, dry press brick	Keele (1915)

Characteristics of Unfired Samples from Map Sheet 82G. (continued)

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
-	35	7	4	W5	Fernie	Black shale, gritty	-	poor	-	-	-	-
16	35	7	4	W5	Fernie	Dark gray shale, fossiliferous	20	poor	poor	-	good	5.2
						Dark brown shale, very calcareous	20	good	fair	-	minor cracks	5.0
SW (Tent Mtn. strip mine)	13	7	6	W5	Kootenay	Dark gray mudstone, hard, massive, directly above #7 seam	19	poor	poor	good	good	1.1
						As above, 9m above #7 seam, calcareous	18	poor-fair	poor	good	good	0.7
						As above, 13m above #7 seam, noncalcareous	17	poor	poor	good	good	1.8
						Dark gray mudstone 70% plus siltsone 30%, 40-55m above #7 seam	16	poor-fair	poor	good	good	0.5
						Dark brownish gray mudstone, massive, 1.5m, directly above seam #6	18	fair	poor	good	good	0.9
						Dark brown gray shale, hard, 10-15m above seam #6	18	poor-fair	poor	good	good	1.5
						Gray mudstone, hard, directly below seam #6	16	poor	poor	good	good	0.6
						Dark gray mudstone, hard, 0.7m, directly above #5 seam	20	fair	poor	good	good	2.5
						Dark gray mudstone, 30cm, 6m above #5 seam	19	poor	poor	good	good	1.6
						Dark gray mudstone, massive, 1m, 17m above #5 seam	17	poor	poor	good	good	1.1
						Dark gray mudstone, massive, 0.8m, thin coal bands above & below, 29m above #5 seam	18	poor-fair	poor	good	good	0.9
						As above, blocky weathering, typical of interval 32-47m above #5 seam	17	poor-fair	poor	good	good	0.8
						Dark brownish gray mudstone, rubbly weathering, 1.3m, directly below #4 sean on access road	18	poor	poor	good	good	1.6
						Dark gray mudstone, slabby, 1.8m, 13m below #4 seam	21	poor-fair	poor	good	good	2.9
						Medium dark brown mudstone, recessive, 15m below #4 seam	19	fair	poor	good	good	2.4
-	5	8	4	W5	Alberta Group	Black shale, slaty, sandy, dip 25°, ~15m thick	18	poor	-	-	-	3.0
SW	7	8	4	W5	Alberta Group	Black shale, weathered 1 year before testing	-	poor	poor	-	-	-
						Clay, slightly calcareous	22	poor	-	-	-	4.3
2	9	8	4	W5	Alberta Group	Gray shale, gritty	-	poor	-	-	-	4.0
NE	36	8	4	W5	Kootenay	Greenish gray shale, platy, 2m	16	very poor	very poor	good	good	0.7

Characteristics of Fired Samples from Map Sheet 82G. (continued)

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
9	red	1060+	7.5	-	-	-	-	burn off carbon slowly, dry press brick	Ries & Keele (1913) sample 1766
12+	red	1180+	5.9	-	-	-	-	blend with more plastic clay for face bricks	Crockford (1951) locality 43
2	greenish buff	1180+	1.3	-	-	-	-	no value	
14	5YR7/2 (grayish orange pink)	1130	10.3	5Y6/1 (light olive gray)	1200	3.8	7.0	1% absorption at 1240°C, stoneware	Scafe (1978)
4	10YR6/2 (pale yellowish brown)	1130	7.6	10YR6/2 (pale yellowish brown)	1145	0.5	6.8	extremely short firing range, little value	
12	5YR5/2 (pale brown)	1160	3.4	coincides with steel hard				body fragile until fired, no value	
6	5YR3/4 (moderate brown)	1150	6.0	5YR3/4 (moderate brown)	1175	2.4	5.4	body fragile until fired, blend with plastic clay for bricks	
4	5YR5/2 (pale brown)	1125	3.6	5YR5/2 (pale brown)	1140	1.0	5.8	extremely short firing range, little value	
8	10YR6/2 (pale yellowish brown)	1125	10.4	5Y5/1 (medium olive gray)	1175	2.5	5.8	short firing range, stoneware	
14	10YR6/2 (pale yellowish brown)	1215	6.6	10YR6/2 (pale yellowish brown)	1240	4.4	5.7	body fragile until fired, blend with plastic clays for structural clay products	
8	5R6/2 (pale red)	1075	10.4	10R4/2 (grayish red)	1135	3.3	7.3	moderate firing range, structural clay products	
15	10YR6/2 (pale yellowish brown)	1180	7.2	10YR6/2 (pale yellowish brown)	1225	2.8	7.0	short firing range, stoneware, sewer pipe	
8	5YR5/2 (pale brown)	1140	8.0	5Y4/1 (olive gray)	1215	1.0	6.4	unusual gray fired color, decorative face brick	
4	5YR5/2 (pale brown)	1135	2.9	5YR3/2 (grayish brown)	1145	0.4	7.6	extremely short firing range, blend for structural clay products	
8	10YR6/2 (pale yellowish brown)	1150	7.7	10YR6/2 (pale yellowish brown)	1175	2.8	4.6	extremely short firing range blend for structural clay products	
16	5Y6/1 (light olive gray)	1260	2.1	coincides with steel hard		-	6.8	body fragile until fired, chemical analysis, no value	
23	5Y7/2 (yellowish gray)	1190	7.1	5Y7/2 (yellowish gray)	1290	1.1	10.1	moderate firing range, low duty refractories	
4	10R4/2 (grayish red)	1135	5.2	firing terminated at 1160°C, bars curling				blend for structural clay products	
9	grayish brown	1180	12.0	-	-	-	-	blend with plastic clays, burn off carbon slowly, structural clay products	Ries (1914a) sample 1885
-	red	1180	10.7	-	-	-	-	not recommended	Ries (1915) sample 1940
-	dark pink	1060	15.0	dark pink	1180+	14.7	1.4	fused spots, cracks slightly on firing, structural clay products	sample 1926
2	-	-	-	-	-	-	-	not recommended	Ries & Keele (1913) sample 1768
4	5YR3/4 (moderate brown)	1160	6.7	maximum firing temperature not reached				chemical analysis, blend for structural clay products	Scafe (1978)

Characteristics of Unfired Samples from Map Sheet 82G. (continued)

Location					Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties		Drying Shrinkage (%)
LSD	Sec	Tp	R	Mer						Room Temperature	105°C	
(Abandoned strip mine on top of Grassy Mtn.)						Dark gray shale, slabby-papery, 3.7m	11	poor	poor	good	good	0.9
						Dark gray brown shale, 4m	19	fair	poor	good	good	1.9
						Brown black shale, 1.5m	14	fair	good	good	good	2.3
						Dark gray brown shale, platy, 1.5m	20	poor-fair	fair	good	good	2.0
						Same bed 100m north	17	poor	poor	good	good	1.1
13	9	8	5	W5	Brazeau	Shale, slickensides, interbedded with sandstone	19	fair	-	-	-	5.0
6	17	8	5	W5	Brazeau	Shale, sandy, dip 40°	-	fair	-	-	-	5.5

Characteristics of Fired Samples from Map Sheet 82G. (continued)

P.C.E.	Steel Hard Color	Steel Hard Temp. (°C)	Steel Hard Absorption (%)	Maximum Fire Color	Maximum Fire Temp. (°C)	Maximum Fire Absorption (%)	Maximum Fire Shrinkage (%)	Remarks	Reference
8	bars overfire at 1125°C but steel hardness is not reached by 1225°C							brown, glassy slag spots by 1000°C, no value	
3	10R4/2 (grayish red)	1095	12.8	5YR3/4 (moderate brown)	1150	0.0	9.0	moderate firing range, bricks	
16	10YR6/2 (pale yellowish brown)	1175	6.4	10YR6/2 (pale yellowish brown)	1210	4.8	5.4	short firing range, chemical analysis, low duty refractory	
15	5YR5/2 (pale brown)	1190	6.2	5YR4/1 (brownish gray)	1240	1.4	8.5	short firing range, low duty refractory	
7	5YR5/2 (pale brown)	1125	11.0	5YR4/1 (brownish gray)	1200	1.3	7.9	body fragile until fired, blend for structural clay products	
-	reddish brown	1060+	8.2	reddish brown	1180+	4.0	4.7	long firing range, blend for brick & sewer pipe	Ries (1914a) sample 1882
5	red	1060	5.6	red	1180	3.1	5.0	long firing range, blend for brick & sewer pipe	Ries (1914a) sample 1881

Characteristics of Unfired Samples from Map Sheet 82H.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties: Room Temperature	Drying Properties: 105°C	Drying Shrinkage (%)
16	22	1	21	W4	Bearpaw	~5m 10YR2/2 (dusky yellowish brown) shale, thin laminae, minor silt, noncalcareous, small gypsum crystals on surface, ironstone concretions, band of volcanic ash?	23	good	fair	minor warp	cracks	8.4
4	3	2	17	W4	Judith River	~3m 5Y5/2 (light olive gray) mudstone, massive, 5YR4/4 (moderate brown) stain on joints, noncalcareous, a few carbon impressions	13	very good	very good	minor warp	minor warp	6.3
10	10	2	21	W4	Judith River	~5m 10Y4/2 (grayish olive) shale, silty, medium laminae, noncalcareous	17	good	very good	minor warp	cracks	7.6
9	17	4	16	W4	Judith River	~3m N1 (black) shale, 5YR3/4 (moderate brown) & 5YR4/4 (moderate brown) stain on fissile planes, no silt, small gypsum crystals on outcrop surface, noncalcareous	23	poor	good	good	good	5.5
						~1m 5Y4/1 (olive gray) shale, 5YR5/6 (light brown) stain, minor silt, noncalcareous, massive	22	very good	good	warps-cracks	cracks	9.3
						~2m 5Y5/2 (light olive gray) clay, thin laminae, noncalcareous, minor silt	20	very good	very good	warps	cracks	9.1
9	9	4	30	W4	Wapiabi	7m 5Y3/2 ((olive gray) shale, N6 (medium light gray) weathering on joints, calcareous, thin bedded to fissile, ~5m till overburden	13	poor	poor	good	good	2.1
10	24	4	30	W4	Wapiabi	6m 10YR4/2 (dark yellowish brown) and 10YR2/2 (dusky yellowish brown) interbedded shale, minor silt to silty	18	fair	fair	good	good	5.7
-	-	6	21	W4	Pleistocene	Clay, silty, calcareous pebbles	19	fair	fair	-	-	4.0
-	30	6	24	W4	Willow Creek (Mokowan Butte on Blood IR 148)	5R6/2 (pale red) weathering clay, ~30cm, minor silt, calcareous	17	excellent	good	good	cracks	8.2
						N3 (dark gray) clay weathers N5 (medium gray), silty, thin bedded, noncalcareous	20	good	good	minor warp	cracks	9.1
						5Y6/4 (dusky yellow) & 5R4/2 (grayish red) weathering clay, no silt, calcareous	18	good	fair	good	cracks	7.6
						10R4/2 (grayish red) & 10R6/6 (moderate reddish orange) clay, no silt, calcareous	19	poor	poor	good	cracks	7.8
-	16	6	30	W4	Tertiary	Shale, calcareous	24	excellent	-	-	-	7.7
-	1	7	30	W4	Pleistocene	Clay, very calcareous plus limestone pebbles	29	excellent	fair	scums	-	8.8

Characteristics of Fired Samples from Map Sheet 82H.

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
5	5YR5/6 (light brown)	980	7.2	5YR4/4 (moderate brown)	1040	1.2	8.4	moderate firing range, cracks at hot end, structural clay products	Scafe (1980)
5	5YR4/4 (moderate brown)	1040	8.0	10YR4/2 (dark yellowish brown)	1125	0.9	8.2	extruded bars bloat badly, expanded aggregate	Scafe (1980)
4	5YR4/4 (moderate brown)	1075	8.8	5YR4/4 (moderate brown)	1110	2.6	3.4	low firing shrinkage, short firing range, chemical analysis, blend for structural clay products	Scafe (1980)
4	10R4/6 (moderate reddish brown)	1040		bars crack severely immediately after steel hardness				soft white grains in fired bar, no value	Scafe (1980)
12	5YR5/6 (light brown)	1000		bars crack severely immediately after steel hardness				extrudes poorly, no value	
5	5YR6/4 (light brown)	-		bars crack severely immediately after steel hardness				soft white grains in fired bar, no value	
3	no steel hard							no value	Scafe (1980)
6	5YR3/4 (moderate brown)	1100	3.2	5YR3/4 (moderate brown)	1125	1.8	5.9	some lime popping, extremely short firing range, chemical analysis, grind finely and blend for bricks	Scafe (1980)
-	no steel hard							made very porous brick in 1910	Ries & Keele (1912) sample 1667
4	5YR4/4 (moderate brown)	1100	9.0	10YR4/2 (dark yellowish brown)	1120	7.0	7.0	fine texture, lime popping when fired, little value	Scafe (1980)
4	5YR5/6 (light brown)	825	10.7	5YR4/4 (moderate brown)	1025	1.3	5.0	extrudes well, cracks badly on firing. little value	
3	5YR6/4 (light brown)	995	13.5	10YR6/2 (pale yellowish brown)	1120	0.0	7.3	some lime popping when fired, little value	
3	5YR6/4 (light brown)	1025	11.6	5YR5/2 (pale brown)	1120	0.0	7.0	soft white grains when fired, little value	
-	deep red	1050+	4.5	-	1095-	-	-	short firing range, dry press brick	Ries & Keele (1912) sample 1672
-	red	1050	1.5	-	1095-	-	-	lime popping, made poor bricks in 1912	Ries & Keele (1912) sample 1673

Characteristics of Unfired Samples from Map Sheet 82H. (continued)

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
-	3	8	22	W4	Judith River	Shale	28	fair	-	good	checks	7.1
						Shale	-	fair	-	-	-	5.0
						Shale	29	fair	fair	-	cracks	8.7
1	13	8	22	W4	Judith River	~10m 5Y5/2 (light olive gray) shale, silty, calcareous, waxy	20	very good	very good	minor warp	cracks	8.7
-	36	8	22	W4	Judith River	Shale, carbonaceous, gritty	25	excellent	-	-	-	6.3
-	17	10	16	W4	Judith River	Dark gray shale, 2m	26	excellent	fair	-	cracks	8.0
-	18	10	16	W4	Judith River	Black shale, 1m, gypsiferous	27	excellent	fair	-	-	8.0
-	1	10	17	W4	Judith River	Brownish shale, soft, much gypsum	22	good	sticky	-	-	8.0
						Dark gray shale, soft	-	good	-	cracks	-	0.0
-	5	10	21	W4	Judith River	Shale, sandy, 6m	-	fair	-	-	-	8.0
						Shale, sandy, 22.5m	-	fair	-	-	-	7.0
2	3	10	24	W4	St. Mary River	~1m 5GY4/1 (dark greenish gray) shale, 10YR5/4 (moderate yellowish brown) stain on joints, minor silt, thin laminae to massive, slightly calcareous	15	poor	fair	good	good	4.0
						~1.5m 5GY3/2 (grayish olive green) shale, silty, noncalcareous, thin laminae	11	fair	very good	very good	fair	5.7
10	4	12	23	W4	St. Mary River	~3m 5Y3/2 (olive gray) shale, slightly silty, thin laminae, calcareous	20	fair	fair	good	poor	7.6
						~0.5m 5Y5/2 (light olive gray) shale, silty, noncalcareous, 5YR5/6 (light brown) on joints and laminae	20	poor	fair	cracks badly	crumbles	8.3

Characteristics of Fired Samples from Map Sheet 82H. (continued)

P.C.E.	Steel Hard Color	Steel Hard Temp. (°C)	Steel Hard Absorption (%)	Maximum Fire Color	Maximum Fire Temp. (°C)	Maximum Fire Absorption (%)	Maximum Fire Shrinkage (%)	Remarks	Reference
-	red	1095	1.8	-	1135-	-	-	scums, short firing range,	Ries (1914a)
-	brown	1095	11.7	-	1200	-	-	poor color, little value	samples 1863, 1864
-	red	1005	6.7	-	1095-	6.6	7.7	moderate firing range, dry press bricks	samples 1871, 1874
5	5YR6/4 (light brown)	935	6.5	5YR5/2 (pale brown)	1100	2.5	2.3	does not extrude well, soft white grains when fired, no value	Scafe (1980)
-	dark red	1050	3.2	deep red	1135	1.9	6.3	moderate firing range, good color, dry press bricks	Ries & Keele (1912) sample 1666
2	light red	1050	5.2	light red	1095	-	-	scums badly, brick & tile is treated for scumming	Ries & Keele (1913) sample 1791
-	red	1005	5.0	-	-	-	-	fire slowly to burn off carbon, brick	Ries & Keele (1913) sample 1792
2	red	1005	9.8	-	1060	-	-	gypsum present in both samples, burn both slowly for brick,	Ries & Keele (1913) samples 1793, 1794
3	red	1005	6.3		-	-	-	chemical analyses	
-	dull red	1005	9.6	-	1095	8.1	1.0	moderate firing range, high fired	Ries (1914a)
-	pinkish	1005	18.5	-	-	-	-	absorption, common brick	samples 1868, 1870
3	5YR5/6 (light brown)	1055	10.6	10YR4/2 (dark yellowish brown)	1100	0.0	7.8	extrudes well, short firing range, chemical analysis, structural clay products	Scafe (1980)
4	5YR4/4 (moderate brown)	1000	10.6	5YR4/4 (moderate brown)	1080	0.2	7.8	extrudes well, bars curl on firing, chemical analysis, brick	
4	bloated before steel hardness reached							expanded aggregate	Scafe (1980)
4	bloated before steel hardness reached							expanded aggregate	

Characteristics of Unfired Samples from Map Sheet 82I.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
2	17	14	28	W4	Porcupine Hills	Interbedded gray, green, and black shale, ~1.5m, slightly calcareous	28	good	good	-	cracks badly	9.3
						Gray green shale, iron stained, highly calcareous, ~2.1m	27	good	slightly sticky	-	slight cracking	7.0
2	13	16	28	W4	Pleistocene	Dark brown clay, varved, highly calcareous, ~1.5m	20	fair	fair	-	cracks badly	5.2
12	21	18	29	W4	Pleistocene	Light brown to black clay, highly calcareous	22	good	good	-	cracks badly	6.5
SW (North bank of Highwood River)	8	20	28	W4	Paskapoo	Chocolate & gray shale, slightly gritty, ~3m, conchoidal fracture	30	excellent	excellent	good	-	9.4
2	18	20	28	W4	Paskapoo	Dark gray shale, gritty, calcareous, some iron stain	24	excellent	good	good	-	6.6
NE	19	20	28	W4	Paskapoo	Gray green shales, ~7.2m, hard to soft	30	good	very good	good	-	9.7
SE	20	20	28	W4	Paskapoo	Greenish to dark gray shale, sandy, conchoidal fracture	29	good	good	warps	cracks	9.2
						Green shale, fine grained, greasy, slickensides	36	good	good	cracks badly	-	12.6
SE	30	20	28	W4	Paskapoo	Light & dark gray shales, soft, iron stain, calcareous	28	excellent	very good	good	-	6.6
1	32	20	28	W4	Paskapoo	Dark gray to black, buff and greenish gray shales from 4m of section	33	excellent	excellent	cracks	-	11.2
						Dark gray shale, iron stain, gritty, calcareous, from 7m section	24	good	good	good	-	6.6
NW	22	20	29	W4	Paskapoo	Buff shale, calcareous, sandy, soft, ~5m	27	good	good	good	-	7.5
NE	24	20	29	W4	Paskapoo	Buff shale, iron stain, some carbonate, ~5m	31	excellent	very good	good	-	9.4
						Dark greenish gray shale, sandy, 7m	28	good	good	good	-	8.9
SW	29	20	29	W4	Porcupine Hills	Buff, greenish & black shales, hard, gritty, minor carbonate	28	good	good	good	-	7.8
2	7	22	21	W4	Pleistocene	Dark gray to black & light brown varved clay, calcareous, ~4m	-	-	sensitive	cracks	-	high
14	8	22	21	W4	Paskapoo	Olive shale, siltier laminae have yellow cast, noncalcareous, ~4m	22	good-very good	very good	minor warp	cracks	9.5

Characteristics of Fired Samples from Map Sheet 82I.

P.C.E.	Steel Hard Color	Steel Hard Temp. (°C)	Steel Hard Absorption (%)	Maximum Fire Color	Maximum Fire Temp. (°C)	Maximum Fire Absorption (%)	Maximum Fire Shrinkage (%)	Remarks	Reference
5+	red	1150	4.1	-	-	-	-	short firing range, brick	ARC Files (1953)
4	red	1150+	9.8	-	-	-	-	short firing range, common brick	
6+	not fired to steel hardness							no value	ARC Files (1953)
-	steel hardness not reached							no value	ARC Files (1953)
-	dark red	890	12.9	dark red	1095	1.7	6.7	3.9m overburden, scums badly, structural clay products if scumming treated	Worcester (1932) sample 2958
-	dark red	890	13.2	dark red	1165	0.2	6.6	long firing range, thick overburden, interbedded sandstone, structural clay products	Worcester (1932) sample 2953
-	dark red	890	13.5	dark red	1165	0.4	5.3	long firing range, good red, wide variety of red products	Worcester (1932) sample 2957
-	brownish red	890	12.9	brownish red	1165	0.5	4.4	thick overburden, poor drying, little value	Worcester (1932) sample 2963
-	brownish red	890	11.9	brownish red	1050	0.7	7.6	poor drying, little value	sample 2962
-	dark red	890	14.9	dark red	1165	2.2	6.1	thick overburden, slight scum, long firing range, structural clay products	Worcester (1932) sample 2956
-	dark brown	890	13.8	dark brown	1165	0.6	5.6	overburden 30m, heavy scum, oxidation slow, burn carefully, structural clay products	Worcester (1932) sample 2954
-	medium red	890	15.0	medium red	1165	0.5	6.7	heavy scum, oxidation slow, burn carefully, structural clay products	sample 2955
-	dark grayish red	890	17.2	dark grayish red	1165	3.6	7.0	slight scum, thick overburden, sandstone interbeds, structural clay products	Worcester (1932) sample 2959
-	dark red	890	14.2	dark red	1165	0.7	6.8	thin overburden, long firing range, structural clay products	Worcester (1932) sample 2960
-	orange red	890	13.5	orange red	1145	0.7	5.2	mix with sample above	sample 2961
-	orange red	890	16.0	orange red	1125	2.4	6.7	interbedded sandstone, little value except for structural clay products	Worcester (1932) sample 2966
-	medium red	985	15.3	dark red	1130	14.2	2.6	scums, high drying shrinkage, suitable for lightweight aggregate	ARC Files (1952)
4	5YR4/4 (moderate brown)	1015	8.3	5YR3/4 (moderate brown)	1085	0.0	7.6	extrudes very well, moderate firing range, chemical analysis, bricks	Scafe (1980)

Characteristics of Unfired Samples from Map Sheet 82I. (continued)

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties: Room Temperature	Drying Properties: 105°C	Drying Shrinkage (%)
SW	18	22	22	W4	Pleistocene	Light gray clay, hard, calcareous, ~2m	36	good	slightly sticky	warps	cracks	8.8
SW	13	22	23	W4	Battle	Gray black shale, hard, ~4.5m	26	fair	-	cracks	cracks	7.0
					Whitemud	Light gray shale, 2.1m, slightly calcareous	34	good	-	cracks	cracks	12.3
5	24	22	23	W4	Battle	Dark gray shale, 10.6m	46	fair	fair	cracks	cracks	13.1
					Whitemud	Greenish gray shale, weathers pale gray, sandy, 1.2m	29	good	sticky	cracks	-	8.5
						Green shale, 1m	31	good	good	-	cracks	9.9
NW	25	22	23	W4	Battle	~4m 5Y2/1 (olive black) shale, thin laminae, slightly silty	18	good	fair	minor warp	-	8.5
						~1.5m 10YR2/2 (dusky yellowish brown) mudstone, slightly silty, waxy, massive, noncalcareous, soft	29	very good	very good	cracks	-	11.0
					Whitemud	~0.75m 5Y6/1 (light olive gray) clay, massive, slightly silty, noncalcareous	19	good	good	cracks	-	8.7

Characteristics of Fired Samples from Map Sheet 82I. (continued)

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
-	light red	1100	11.5	medium red	1150+	6.0	4.2	brick, drain tile	ARC Files (1950)
7	unreported whether steel hardness reached, absorption high							doubtful value	Ries (1914a) sample 1875
4	light red	920	11.9	deep red	1180	1.0	6.3	doubtful value,	sample 1865
15	light brownish red	1180	6.9	-	-	-	-	doubtful value	Crockford (1951)
15	salmon	1180+	7.3	-	-	-	-	doubtful value	locality 48
11	red	1180	2.3	-	-	-	-	doubtful value	
16	10R5/4 (pale reddish brown)	1150	7.5	5YR5/6 (light brown)	1300	3.2	8.8	excellent firing range, some glassy slag spots above steel hard, chemical analysis,low duty refractories	Scafe (1980)
12	bars crack so badly they cannot be fired							no value	
18	5Y7/2 (yellowish gray)	1165	4.0	5Y7/2 (yellowish gray)	1235	1.9	5.5	dries poorly but fires well, low duty refractories	

Characteristics of Unfired Samples from Map Sheet 82J.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties: Room Temperature	Drying Properties: 105°C	Drying Shrinkage (%)
10	36	17	4	W5	Alberta Group	Dark gray shale, thinly laminated, ironstone concretions and many bands of hard, sandy shale ~5cm thick, ~21m, vertical dip	16	poor	poor	good	-	3.7
6	8	18	2	W5	Brazeau	Greenish gray shales, minor ironstone & sandstone, ~30m	27	good	good	good	-	8.4
7	8	18	2	W5	Braxeau	Dark gray, greenish and rusty brown shale, minor ironstone, steep dip	28	good	good	good	-	8.2
7	9	18	2	W5	Brazeau	Dark gray to black, fissile shale, highly distorted, many thin ironstone seams, salt encrusted	30	good	sticky	cracks	-	9.9
						Dark, rusty gray to black, fissile shale, sandy	29	good	fair	warps & cracks	-	9.4
7	10	18	2	W5	Brazeau	Dark gray shale with some iron stain, sandy	27	sticky	fair-good	warps & cracks	-	8.3
						Greenish gray shale, sandy, some bentonite lenses	30	sticky	fair	warps and cracks badly	-	10.3
5	6	18	3	W5	Belly River	Greenish gray shale, massive, blocky, much iron stain, noncalcareous, ~10.2m	22	good	good	good	-	6.0
12	6	18	3	W5	Alberta Group	Dark gray to black shales, some iron stain, hard, conchoidal fracture, ~13m	20	poor	fair	good	-	5.7
4	20	18	3	W5	Alberta Group	Dark slate colored shales, heavily iron stained, hard, massive, many ironstone interbeds, ~75m	16	poor	poor	good	-	3.7
13	25	18	3	W5	Alberta Group	Dark gray shale, hard, breaks into thin slaty pieces, many thin sandy interbeds, ~26m	17	poor	poor	good	-	3.8
						Rusty red shale, thinly laminated, ~16m, one sand body ~1m thick	17	poor	poor	good	-	3.8
2	1	18	4	W5	Alberta Group	Dark slate to lead gray shales, blocky, much iron stain, conchoidal fracture, ~24m	21	good	good	good	-	5.7
10	29	19	3	W5	Alberta Group	Dark gray shale, finely laminated, much carbonate, ~12m	16	poor	poor	good	-	3.4
						Iron stained shale, hard, thinly laminated, ~35m	17	poor	poor	good	-	2.9
10	29	19	3	W5	Blairmore	Red shale with grayish green mottles, massive, ~0.3m	18	good	good	good	-	4.5
						Greenish gray shale, some grit, massive, ~0.3m	19	poor	fair	good	-	4.8
11	29	19	3	W5	Blairmore	Greenish shale, gritty, some slickensides and iron stain, ~8.4m	17	poor	fair	good	-	4.1

Characteristics of Fired Samples from Map Sheet 82J.

P.C.E.	Steel Hard Color	Steel Hard Temp. (°C)	Steel Hard Absorption (%)	Maximum Fire Color	Maximum Fire Temp. (°C)	Maximum Fire Absorption (%)	Maximum Fire Shrinkage (%)	Remarks	Reference
-	light pink	975	14.1	light pink	1145	8.6	1.7	poor plasticity, strength & color, little value	Worcester (1932) sample 2905
-	light red	890	15.6	light red	1145	2.7	5.6	burn slowly to prevent black core, blend with sample below for brick & tile	Worcester (1932) sample 2912
-	medium red	890	16.5	medium red	1145	0.7	5.4	slight scum, high green strength, brick & tile	Worcester (1932) sample 2911
4	medium red	975	10.4	medium red	1145-	2.2	4.8	little value	Worcester (1932) sample 2903
-	medium red	890	12.3	medium red	1145-	2.6	3.6	little value	sample 2904
-	light red	975	14.4	light red	1135-	0.9	5.2	badly scummed, structural clay products	Worcester (1932) sample 2901
-	medium red	975	12.1	medium red	1135-	2.2	5.2	little value	sample 2902
-	dark red	890	14.4	dark red	1180	3.2	5.5	fires well, good color, quarry tile, face brick	Worcester (1932) sample 2908
-	medium red	890	13.4	medium red	1145	4.8	3.7	scum, overburden ~4m, roofing tile, face & paving brick	Worcester (1932) sample 2907
-	light red	975	13.2	light red	1145	7.8	2.8	some scum, high absorption, poor plasticity, little value	Worcester (1932) sample 2909
-	greenish gray	1050	19.4	greenish gray	1145	7.3	4.2	poor color, long oxidation period, little value	Worcester (1932) sample 2913
-	medium red	890	14.0	medium red	1145	10.1	1.3	high absorption, low plasticity, dry press bricks	sample 2914
-	dark red	890	15.3	dark red	1145	4.7	3.7	fires well, good color, slight scum, face, paving & common brick	Worcester (1932) sample 2906
-	gray buff	1050	20.3	gray buff	1145	15.1	1.3	spalls badly, no value	Worcester (1932) sample 2936
-	dirty red	975	15.8	dirty red	1165	11.7	1.0	poor color & plasticity, little value	sample 2935
-	bright red	890	13.1	bright red	1145	4.5	5.1	burns well, good for hard service wares, limited supply	Worcester (1932) sample 2937
-	bright red	975	13.5	bright red	1180	7.1	3.5	limited supply, good for wide range of red products	sample 2938
-	bright red	890	12.6	bright red	1145	4.8	3.2	burns well, a few black specks, structural clay products	Worcester (1932) sample 2939

Characteristics of Unfired Samples from Map Sheet 82J. (continued)

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties: Room Temperature	Drying Properties: 105°C	Drying Shrinkage (%)
4	25	20	1	W5	Porcupine Hills	Greenish shale, buff weathering, angular, gritty, calcareous, ~6m	28	good	very good	good	-	8.0
						Greenish shale, rusty, ~3m	31	excellent	very good	good	-	9.3
15	6	20	2	W5	Alberta Group	Rusty red brown to dark gray shale, steep dip, ~11m below 9m of overburden	20	fair	fair-good	good	-	5.2
						Dark slaty shale with minor bands of ocherous material, bentonite, soluble salts, ironstone concretions. ~16m	17	poor	fair	good	-	4.2
						Rusty brown shale, some selenite & clay-ironstone layers	21	fair	fair-good	good	-	5.1
2	7	20	2	W5	Alberta Group	Dark slate gray shale, breaks into angular, flinty pieces, interbedded with red brown shale, sandy, blocky	19	poor	fair	good	-	4.8
						Hard slaty shale, some sandy shale interbeds & lenticular fossiliferous masses	19	good	poor-fair	good	-	3.7
						Slate gray to black shales, much iron stain, some sand	21	good	good	good	-	5.2
						Dark gray shale interbedded with clay-ironstone	19	fair	good	good	-	4.6
2	17	20	2	W5	Brazeau	Greenish shale, fine grained, becomes sandy, steeply dipping, overburden to 3m, maximum exposure 3.5m	22	poor	poor	good	-	4.0
						Bluish green, buff & gray shales, hard, some iron stain, laminated	21	poor	fair	good	-	4.4
						Greenish shale, iron stained, some sandy portions, some ironstone	23	poor	fair-good	good	-	4.3
						Dark green shales, fine to coarse grained, minor ironstone	23	fair	fair-good	good	-	5.7
						Gray to greenish shale, iron stain, well stratified	26	poor	poor-fair	good	-	6.4
9	21	20	2	W5	Porcupine Hills	Gray shale, ~5m, concretions & a nodular sandstone layer, interbedded, overburden 3m	27	good	good	good	-	7.7
2	33	20	2	W5	Porcupine Hills	Gray shale at base grading to nearly black at top, slightly gritty, slightly calcareous, sandstone cap ~1m	23	poor	fair	good	-	5.5
						Dark gray shale, ~1.1m, iron stained, calcareous, soft sandstone cap ~0.6m	26	good	very good	good	-	6.6
						Light gray shale, iron stained, very calcareous, gritty, ~1.2m	21	poor	fair	good	-	4.9

Characteristics of Fired Samples from Map Sheet 82J. (continued)

P.C.E.	Steel Hard Color	Steel Hard Temp. (°C)	Steel Hard Absorption (%)	Maximum Fire Color	Maximum Fire Temp. (°C)	Maximum Fire Absorption (%)	Maximum Fire Shrinkage (%)	Remarks	Reference
-	medium red	920	15.9	medium red	1195	1.6	7.0	slight scum, a few yellow specks, long firing range, structural clay products	Worcester (1932) sample 2964
-	medium red	920	15.0	medium red	1195	0.3	7.7	as above	sample 2965
-	medium red	890	15.1	medium red	1080	6.5	5.1	yellow specks, little value	Worcester (1932) sample 2932
-	light grayish red	890	12.9	light grayish red	1195	7.8	2.1	high absorption, poor color, little value	sample 2933
-	medium red	890	15.1	medium red	1195	6.1	4.8	dry press bricks	sample 2934
-	grayish red	890	14.4	grayish red	1145	6.7	3.1	scums, poor color, little value	Worcester (1932) samples 2927, 2928
-	light grayish red	1050	17.5	light grayish red	1145	13.4	1.7	slight scum, yellow specks, high absorption, little value	sample 2929
-	medium red	890	16.0	medium red	1165	2.6	5.3	heavy scum, long oxidation required, structural clay products	sample 2930
-	medium red	975	12.4	medium red	1145	4.0	4.7	scums, structural clay products	sample 2931
-	dark red	1050	14.9	dark red	1145	2.5	5.7	may be useful for structural clay productts if blended	Worcester (1932) sample 2915
-	dark red	890	16.7	dark red	1145	7.4	3.7	bricks, tiles	sample 2916
-	dark red	890	16.0	dark red	1165	2.7	5.4	wide range of ware	sample 2917
-	dark red	975	14.2	dark red	1165	2.0	5.5	wide range of ware	sample 2918
-	purple red	1050	16.5	purple red	1165	5.5	5.2	blend for structural clay products	sample 2919
-	dark grayish red	890	17.0	dark grayish red	1145	1.4	6.6	brick & building tile	Worcester (1932) sample 2945
-	grayish red	975	16.6	grayish red	1145	7.5	4.5	slight scum, poor color, structural clay products	Worcester (1932) sample 2944
-	grayish red	975	18.3	grayish red	1145	0.7	7.2	specks, poor color, as above	sample 2943
-	pinkish buff	1095	18.7	pinkish buff	1145	10.6	4.3	short firing range, high absorption, as above	sample 2942

Characteristics of Unfired Samples from Map Sheet 82J. (continued)

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
3	35	20	2	W5	Porcupine Hills	Greenish gray to black shales, lighter shales calcareous, some grit, ~18m with 3 sandstone interbeds, overburden to 6m	24	good	very good	good	-	6.3
						Light to dark gray shale, some iron stain, overburden to 30m	25	very good	excellent	good	-	7.2
5	1	20	3	W5	Belly River	Dark gray to black shales, hard, gritty, 3 thick sandstone interbeds, ~6m	22	fair	fair	good	-	6.2
						Dark gray shales, heavily iron stained, 6 sandsone interbeds, ~30m	23	good	good	good	-	6.4
9	2	20	3	W5	Belly River	Dark gray shale, some iron stain, poorly stratified, ~11m	23	good	good	good	-	6.9
9	2	21	1	W5	Porcupine Hills	Gray & blue shale mixture as used in brick making, calcareous	19	good	sticky	good	cracks	6.0
(Abandoned quarry for brick & cement clay)						Black through yellowish green shales, some carbonate & sand, ~6m	23	good	good	good	-	7.9
						Greenish gray shales from upper bench	26	good	fair	good	-	8.0
						Greenish gray shales from lower bench, sandstone interbeds to 0.6m thick, some carbonate	26	good	very good	good	-	7.9
						0.75m 10Y6/2 (pale olive) mudstone parting in sandstone, slightly calcareous, massive to thin laminae	16	poor	poor	good	cracks	7.3
10	36	21	1	W5	Porcupine Hills	30cm 5Y5/2 (light olive gray) mudstone, massive, minor silt, noncalcareous, directly below till	16	poor	poor	good	minor cracks	7.4
(Raw clay for Consolidated Concrete "Herculite" expanded aggregate)						2m 5Y3/2 (olive gray) mudstone, massive to slightly laminated, noncalcareous	21	fair	fair	good	cracks	8.0
						N3 (dark gray) mudstone, massive, calcareous, at bottom of pit	22	fair	poor	cracks	cracks	8.1
						~3m 5Y5/2 (light olive gray) mudstone, massive, noncalcareous	18	fair	good	good	cracks	8.7
5	5	21	3	W5	Belly River	Greenish shales, rusty, uneven fracture, ~36m, sandstone interbeds to 4m, steeply dipping	23	fair	fair	good	-	6.0
						Slate gray shale, some iron stain, splintery, gritty, ~37m, 3 thin sandstones	20	poor	poor	good	-	5.7
						Dark slate gray shale, hard, splintery, ~20m	17	poor	fair	good	-	4.1
14	5	21	3	W5	Belly River	Light buff to gray shale, gritty, massive, ~15m, steeply dipping	21	poor	fair	good	-	4.9

Characteristics of Fired Samples from Map Sheet 82J. (continued)

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
-	light grayish red	975	16.9	light grayish red	1145	1.8	6.1	specks, poor color, structural clay products	Worcester (1932) sample 2952
-	medium red	975	11.8	medium red	1125	2.4	6.0	slight scum, structural clay products	sample 2951
-	medium dark red	1050	10.9	medium dark red	1145	3.4	5.2	burns well, good color, face brick, quarry tiile	Worcester (1932) sample 2921
-	medium dark red	975	14.8	medium dark red	1145	3.7	4.8	slight scum, burns well, face brick, quarry tile	sample 2922
-	dark red	890	12.8	dark red	1145	0.0	5.3	burns well, excellent color, good strength, most red wares	Worcester (1932) sample 2920
1	red	1130	9.5	-	-	-	-	short firing range, made porous bricks, sandstone interbeds abundant	Ries & Keele (1912) sample 1704
-	medium grayish red	920	17.4	medium grayish red	1180	10.7	3.1	yellow specks, high absorption, structural clay products	Worcester (1932) sample 2967
-	dark red	920	14.7	dark red	1195	0.5	6.1	slight scum, long firing range, structural clay products	sample 2969
-	dark red	920	14.8	dark red	1180	0.5	6.3	slight scum, yellow specks, structural clay products	sample 2968
3	5YR5/6 (light brown)	1005	10.6	5YR4/4 (moderate brown)	1110+	0.0	7.0+	hard to extrude, dry press brick	Scafe (1980)
3	5YR5/6 (light brown)	1005	9.6	5YR4/4 (moderate brown)	1080	0.0	8.0	bars warp badly at hot end, chemical analysis, expanded aggregate	Scafe (1980)
3	5YR5/6 (light brown)	1005	10.5	5YR4/4 (moderate brown)	1100	0.0	9.9	as above	
4	bloats badly even when hand molded							excellent for expanded aggregate	
4	5YR5/6 (light brown)	950	10.6	5YR4/4 (moderate brown)	1085	0.0	6.5	long firing range, chemical analysis, bricks	
-	medium dark red	890	15.2	medium dark red	1145	3.6	4.8	burns well, good color, face brick, quarry & roofing tile	Worcester (1932) sample 2923
-	medium light red	890	15.0	medium light red	1165	5.8	4.0	burns well, brick	sample 2924
-	grayish red	890	14.2	grayish red	1145	7.3	2.7	slight scum, poor color, little value	sample 2925
-	medium red	890	16.2	medium red	1165	5.3	4.5	burns well, good color, face brick, quarry & roofing tile	Worcester (1932) sample 2926

Characteristics of Unfired Samples from Map Sheet 82J. (continued)

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
4	12	21	3	W5	Recent	Olive green clay, soft, very calcareous, ~5m	40	excellent	sticky	cracks	-	14.8
						Olive green clay, soft, slightly silty, calcareous, conchoidal fracture, ~5m	32	good	very good	good	cracks	11.2
9	4	22	3	W5	Brazeau	Light & dark gray shales, dense, fine grained, some iron stain. ~3.6m, overburden ~3m	25	excellent	very good	good	-	6.9
7	10	22	3	W5	Brazeau	Buff & greenish dark gray shales, iron stain, fine grained, ~2.4m, overburden 3-6m	25	good	very good	good	-	7.9
12	23	22	3	W5	Porcupine Hills	Buff to greenish gray shales, fine grained, sandy in some parts, noncalcareous, much iron stain, ~5m	26	poor	fair	good	-	5.1
						Bluish green shale, fine grained, ~5.4m, massive sandstone overburden ~7.5m	28	fair	good	good	-	7.1
					Brazeau	Light to dark gray shale, some iron stain, slightly laminated, fine grained, ~3.3m	33	good	very good	good	-	10.0
1	34	22	4	W5	Brazeau	Gray green shale, some iron stain, ~8.6m, overburden 1.5-3m	22	excellent	good	good	cracks	8.0
						Light gray grading to dark gray shale, ~8.6m	23	good	good	good	cracks	7.2
10	19	23	4	W5	Belly River	Buff to gray shales, gritty, ~16m, overburden to 5.5m, outcrop extends only 1.2m above low water	28	fair	fair	good	-	6.4
7	11	23	5	W5	Alberta Group	Slate gray to black shale, iron stain, fissile, hard, ~12m	18	poor	poor	good	-	4.0
12	12	23	5	W5	Blairmore	Dark red to chocolate shale, gritty, irregular fracture, ~0.6m, outcrop is in bed of stream	17	poor	very poor	good	-	3.8
						Green shale adjacent to sample above	18	poor	poor-fair	good	-	4.4
						Greenish shales, fine grained, hard, gritty, massive, ~9m	17	poor	very poor	good	-	3.8
2	13	23	5	W5	Blairmore	Green, purple, yellowish and gray shale, considerable iron stain, gritty, irregular fracturing, ~15m	19	fair	fair	good	-	4.9

Characteristics of Fired Samples from Map Sheet 82J. (continued)

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
-	medium bright red	890	12.2	medium bright red	1125	5.8	1.4	bloats on firing, lightweight aggregate	Worcester (1932) sample 2940
-	medium red	890	14.0	medium red	1145	0.2	6.6	scums badly, little value	sample 2941
-	brownish red	890	15.5	brownish red	1125	3.2	5.8	excessive time for complete oxidation, all kinds of red ware	Worcester (1932) sample 2950
-	medium red	890	13.5	medium red	1095	1.2	5.1	burn slowly, good color & strength at low firing temperature, all kinds of red ware	Worcester (1932) sample 2949
-	medium red	890	19.1	medium red	1145	7.4	5.7	blend with 2946 for improved burning, face brick, quarry & roofing tile	Worcester (1932) sample 2948
-	light red	890	17.2	light red	1145	3.8	6.4	face brick	sample 2947
-	dark red	890	15.6	dark red	1095	2.9	6.7	blend with 2948 for improved drying, face brick, quarry & roofing tile	sample 2946
7	red	1150	0.3	-	-	-	-	expanded aggregate	ARC Files (1954) sample 263
6+	dark red	1150+	0.9	-	-	-	-	expanded aggregate	sample 264
6	light red	890	19.5	light red	1145	8.8	4.2	limited amount of material, high absorption, poor color, structural clay products	Worcester (1932) sample 2975
-	light orange	890	15.3	light orange	1145	7.4	3.5	poor working & firing properties, little value	Worcester (1932) sample 2970
-	dark velvet red	890	15.2	dark velvet red	1145	7.4	4.0	blend for plasticity, excellent color, wide range of products	Worcester (1932) sample 2971
-	dark velvet red	975	9.3	dark velvet red	1180	3.7	2.5	as above	sample 2972
-	light red	890	14.8	light red	1145	6.5	3.5	blend to improve plasticity, color & strength for brick	sample 2973
-	medium red	890	13.9	medium red	1180	8.1	2.2	slight scum, high absorption, mix with more fusible material for better burned properties, structural clay products	Worcester (1932) sample 2974

Characteristics of Unfired Samples from Map Sheet 82O.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
16	23	24	2	W5	Porcupine Hills	Buff to greenish brown shale, some grit, ~7m, 2 major sandstone interbeds, some calcareous bands	24	good	very good	good	-	8.0
SE	24	24	2	W5	Porcupine Hills	Gray green shale, sandy, interbedded sandstone, ~5.4m of shale visible	22	very good	good	-	cracks	8.0
13	24	24	2	W5	Porcupine Hills	Brown & blue shale, soft to hard, sandy, ~9m, numerous sandstone interbeds	17	good	good	good	-	5.0
13	24	24	2	W5	Porcupine Hills	Dark gray shale, soft, sandy, ~2m	18	good	good	-	good	6.0
2	26	24	2	W5	Porcupine Hills	Buff to greenish brown shale, gritty, ~5.5m, overburden 2-4m	22	good	fair	good	-	6.0
6	7	24	5	W5	Brazeau	Olive green shale, ~1m	19	good	good	-	cracks	6.0
						Dark gray to black shale, ~1.5m	21	good	good	-	cracks badly	6.7
						Olive green shale, sandy, ~1.5m	20	good	good	-	cracks	6.1
						Dark gray to black shale, carbonaceous, ~1.5m	19	good	good	-	cracks	5.4
SE	26	24	8	W5	Blairmore	Dark gray green mudstone, splintery, 30m stratigraphically highter than sample below	18	poor-fair	poor	good	good	0.5
						Green mudstone, hard, slightly, silty, massive, taken at base of exposure	17	fair	poor	good	good	1.2
NE	33	24	8	W5	Wapiabi	Dark gray shale, thin bedded	17	poor-fair	poor	good	good	-
15	33	25	4	W5	Recent	Light gray to buff clay, silty, very calcareous, soft, ~10m	20	good	poor	good	-	4.7
SE	1	25	11	W5	Kootenay	Dark gray mudstone, plant remains, 1.8m	16	very poor	very good	warps	good	4.3
(Abandoned "Walker" strip pit. Sampling down section from below 15 m of massive sandstone & siltstone)						Mudstone & coal interbedded. Mudstone 3m	17	poor	fair	good	good	2.3
						Dark gray mudstone, minor silt	17	poor-fair	fair	good	minor warp	4.3
						Dark brownish gray underclay	17	poor	fair	good	good	1.8
						Dark gray to brownish gray mudstone, minor silt, 3m	15	fair	good	good	very good	4.9
						As above, 3m	14	poor	fair	good	good	1.0

Characteristics of Fired Samples from Map Sheet 82O.

P.C.E.	Steel Hard Color	Steel Hard Temp. (°C)	Steel Hard Absorption (%)	Maximum Fire Color	Maximum Fire Temp. (°C)	Maximum Fire Absorption (%)	Shrinkage (%)	Remarks	Reference
5	medium light red	975	15.1	grayish red	1145	1.3	5.1	used many years for dry press brick, poor color	Worcester (1932) sample 2982
5+	light red	1150+	5.2	-	-	-	-	brick & tile if cracking eliminated	ARC Files (1954)
1	red	1080+	8.7	-	-	-	-	many sandstone interbeds, try for stiff mud bricks	Ries & Keele (1912) sample 1703
15	red	1145	4.5	dark red	1180	4.5	4.0	sewer pipe	Ries & Keele (1913) sample 1759
-	medium red	975	16.2	dark red	1145	1.6	5.2	thick overburden, gray tint, sandstone interbeds, slightly calcareous, structural clay products	Worcester (1932) sample 2981
5+	dark red	1150+	1.3	-	-	-	-	overburden 8.4m, brick & tile if cracking corrected	ARC Files (1954)
5	dark red	1150+	0.3	-	-	-	-	as above	
4	red	1150+	1.5	-	-	-	-	as above	
4	red	1150+	5.3	-	-	-	-	as above	
2	10R4/6 (moderate reddish brown)	1085	8.0	10R4/2 (grayish red)	1125	0.8	6.0	bars curl on firing, chemical analysis, structural clay products	Scafe (1978)
3	10R4/2 (grayish red)	1130	3.0	10R4/2 (grayish red)	1140	1.1	8.4	bars curl on firing, extremely short firing range, blend for structural clay products	
6	10YR4/2 (dark yellowish brown)	1180		steel hardness reached after bars overfire				mined as Al source for cement manufacture, chemical analysis	Scafe (1978)
-	cream	975	29.4	expands on firing, fuses suddenly at 1145°C				no value	Worcester (1932) sample 2980
5	5R6/2 (pale red)	1080	9.5	maximum fire not reached				plasticity improves markedly with souring for 2 weeks, blend for structural clay products	Scafe (1978)
9	5YR8/1 (pinkish gray)	1090	10.4	5YR8/1 (pinkish gray)	1190	4.9	5.5	moderate firing range, 10YR6/6 (dark yellowish orange) patina on upper surface of fired bar, blend for structural clay products	
9	5Y7/2 (yellowish gray)	1155	6.3	5Y6/1 (light olive gray)	1215	1.9	6.8	bars fragile until fired, stoneware	
2	5YR3/4 (moderate brown)	1110	8.5	5YR3/4 (moderate brown)	1125	1.0	10.5	extrudes poorly, extremely short firing range, blend for structural clay products	
4	5YR5/2 (pale brown)	1110	9.8	5YR3/4 (moderate brown)	1125	1.6	7.6	extrudes very well, extremely short firing range, blend for bricks	
5	5YR3/4 (moderate brown)	1130	4.5	coincides with steel hard				no firing range, little value	

Characteristics of Unfired Samples from Map Sheet 82O. (continued)

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
						As above, 3m	15	poor-fair	fair	good	good	4.8
						Dark gray mudstone below coal seam, 1m	18	poor	very good	good	-	1.8
						Dark gray mudstone, abundant plant remains, 2m	17	poor-fair	fair	good	-	1.8
						Dark gray mudstone, rubbly weathering, 4m	15	fair-good	good	good	good	4.8
						Dark gray to dark brownish gray mudstone, blocky, 4m	16	poor	poor	good	good	0.9
						As above	15	fair	good	good	good	4.7
4	1	26	4	W5	Porcupine Hills	Brownish gray shale, very calcareous	26	good	good	-	cracks	6.6
1	2	26	4	W5	Porcupine Hills	Gray shale, slightly calcareous, gritty, ~12m	21	good	good	-	minor cracks	5.1
8	3	26	4	W5	Porcupine Hills	Dark gray clay, calcareous	19	excellent	good	good	-	7.0
14	5	26	4	W5	Brazeau	Dark gray shale, hard, calcareous, gritty,	23	good	good	good	-	6.8
						Dark gray shale, gritty	23	good	good	good	-	5.8
-	13	26	5	W5	Brazeau	Dark gray shale, soft, gritty, noncalcareous, ~10m without sandstone interbeds	17	good	good	-	good	5.0
9	13	26	5	W5	Brazeau	Green shales, some rust, soft to hard, some grit, some carbonaceous material, ~10m	28	good	good	good	-	7.4
11	17	26	5	W5	Alberta Group	Gray shale, hard, gritty, massive, noncalcareous, ~10m	16	poor	poor	good	-	2.9
8	22	27	5	W5	Brazeau	5Y3/2 (olive gray) mudstone, 2m	18	fair	fair-good	warps	warps	8.6
2	17	27	7	W5	Wapiabi	Dark gray shale, quite silty, near top of exposure	15	very poor	poor	fair	fair	2.8
						Dark gray shale, silty, splintery weathering, taken at base of exposure	17	very good	excellent	good	good	5.0
15	23	28	2	W5	Pleistocene	Light brown clay, very calcareous, a few small pebbles	21	good	good	-	good	6.0
3	4	27	3	W5	Porcupine Hills	5Y3/2 (olive gray) mudstone, minor silt, calcareous, 3m	14	poor	fair	warps	good	5.0

Characteristics of Fired Samples from Map Sheet 82O. (continued)

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
5	5YR5/2 (pale brown)	1125	9.5	5YR3/4 (moderate brown)	1145	5.0	5.8	extremely short firing range, blend for bricks	
15	5YR6/1 (light brownish gray)	1150	11.9	5Y6/1 (light olive gray)	1225	4.9	7.6	moderate firing range, expands rapidly on overfiring, low duty refractories	
3	5YR3/4 (moderate brown)	1110	14.0	5YR3/2 (grayish brown)	1125	2.2	8.4	extremely short firing range, blend for bricks	
4	5YR6/4 (light brown)	1110	10.8	10YR4/2 (dark yellowish brown)	1125	2.4	7.5	vitrifies quickly on overfiring, blend for bricks	
11	10R4/2 (grayish red)	1130	10.0	10R4/2 (grayish red)	1165	2.9	5.5	short firing range, structural clay products	
3	5YR3/4 (moderate brown)	1125	7.6	5YR3/4 (moderate brown)	1135	0.5	9.0	extrudes well, extremely short firing range, blend for bricks	
3+	brownish red	1180	1.3	-	-	-	-	common brick if cracking corrected	ARC Files (1948)
1	red	1180	15.6	-	-	-	-	high absorption, face brick, dry press brick	Ries & Keele (1912) sample 1707
-	-	-	-	red	1125	2.7	4.0	brick & tile	Ries (1915) sample 1948
-	medium red	890	15.6	medium red	1125	0.0	6.3	brick & tile, sandstone cap ~12m	Worcester (1932) sample 2979
-	medium red	890	14.5	medium red	1145	4.5	4.9	blend with material above	sample 2978
3	red	890+	11.1	red	1125	3.1	5.0	excellent red for brick	Ries & Keele (1913) sample 1760
-	dark red	890	17.9	dark red	1145	2.6	6.6	high drying shrinkage, high carbon content requires slow burn, blend for improved properties	Worcester (1932) sample 2977
-	medium red	890	14.7	medium red	1145	8.3	2.2	best for grog in more plastic & short firing range clays	Worcester (1932) sample 2976
3	5YR5/6 (light brown)	960	11.0	5YR4/4 (moderate brown)	1075	0.2	8.5	long firing range, thin overburden, bricks, tile	Scafe (1978)
11	5YR3/4 (moderate brown)	1185	6.9	5YR3/4 (moderate brown)	1250	2.3	4.4	bars fragile until fired, blend for bricks, tile, pottery	Scafe (1978)
11	5YR4/4 (moderate brown)	1070	7.4	5YR3/4 (moderate brown)	1115	2.4	4.6	extrudes well, short firing range, attractive brown color, blend for bricks, tile, pottery	
4	not fired to steel hardness							highly calcareous, no value	ARC Files (1954)
3	5YR5/6 (light brown)	1080	3.5	5YR4/4 (moderate brown)	1100	0.5	6.5	extremely short firing range, chemical analysis, 8m overburden, bricks, tile	Scafe (1978)

Characteristics of Unfired Samples from Map Sheet 82O. (continued)

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
NE	1	28	8	W5	Brazeau	Light brown & dark gray interbedded mudstone	20	fair	fair-good	minor warp	-	7.8
SE	14	28	8	W5	Brazeau	Medium to dark gray mudstone, soft, minor silt	18	fair	fair	minor warp	-	7.0
						Light brown to greenish gray mudstone, soft, blocky weathering	17	fair	fair-good	good	good	7.4
13	25	29	6	W5	Brazeau	5Y3/2 (olive gray) shale, thin laminae	15	good	good	good	good	7.2
1	13	29	7	W5	Brazeau	5YR2/2 (dusky brown) shale, silty, hard	16	fair	good	good	-	2.6
-	18	31	1	W5	Paskapoo	Yellowish shale, calcareous	-	good	good	good	-	5.6
4	18	31	1	W5	Paskapoo	Dark gry shale, ~2m	-	good	good	fair	-	5.0
						Gray shale, calcareous, ~1m, ~6m below upper sample	21	very good	very good	good	-	5.0
SE	18	31	9	W5	Wapiabi	Dark gray shale, thin siltstone laminae, scattered ironstone nodules	15	good	excellent	good	good	4.5
(Red Deer River crossing on Forestry Trunk Road. ~150m exposed. Sampled down section at 15m intervals						As above	15	poor	fair	good	good	5.2
						As above	16	poor	fair	good	minor warp	4.9
						Dark gray shale, abundant siltstone laminae	16	poor	fair	good	minor warp	5.0
						Dark gray shale, papery laminae, contorted, thin siltstone laminae	16	poor	fair	-	good	5.0
						Dark gray shale, thin siltstone laminae	15	poor	fair	good	good	5.0
						As above	16	poor	fair	good	good	5.4
						As above	14	poor	fair-good	good	good	4.4
						As above, siltstone bands increase in number & thickness	15	poor	fair	good	good	4.5
						Shale as above resting on siltstone at base	16	poor	fair	good	good	5.0

Characteristics of Fired Samples from Map Sheet 82O. (continued)

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
11	5YR6/4 (light brown)	940	12.0	5YR4/4 (moderate brown)	1105	0.8	7.8	long firing range, attractive brown color, extrudes poorly, bricks, tile, pottery	Scafe (1978)
4	5YR4/4 (moderate brown)	1040	7.0	5YR4/4 (moderate brown)	1090	0.6	7.8	short firing range, blend for bricks, tile	Scafe (1978)
7	10YR6/6 (dark yellowish orange)	950	12.4	5YR4/2 (pale grayish brown)	1105	0.4	7.6	long firing range, attractive brown color, extrudes well, brick, tile, pottery	
11	5YR5/6 (light brown)	985	10.5	5YR4/4 (moderate brown)	1080	1.4	7.3	moderate firing range, does not overfire rapidly, stoneware, pottery	Scafe (1978)
14	5YR4/4 (moderate brown)	1150	8.4	5YR4/4 (moderate brown)	1225	2.8	5.3	moderate firing range, chemical analysis, stoneware, pottery	Scafe (1978)
-	buff	1125	13.2	-	-	-	-	high absorption, sandstone cap, dry press brick	Ries & Keele (1912) sample 1702
3+	dark red	1080	9.2	brown	1125	0.0	6.0	good for brick, good for tile at highest temperature	Ries (1915) sample 148
3+	cream	1110	16.0	-	-	-	-	mix with shale above to make attractive rough-faced, speckled brick	sample 149
6	5YR5/6 (light brown)	1100	7.3	5YR5/2 (pale brown)	1125	1.7	5.2	extremely short firing range, extrudes well after ageing, structural clay products	Scafe (1978)
7	5YR5/2 (pale brown)	1125	3.5	5YR5/2 (pale brown)	1150	1.8	5.3	extrudes well, extremely short firing range, structural clay products	
5	5YR5/2 (pale brown)	1110	6.0	5YR5/2 (pale brown)	1130	3.3	5.3	extrudes well, bars soft, extremely short firing range, structural clay products	
5	5YR4/4 (moderate brown)	1095	8.9	5YR5/2 (pale brown)	1130	3.9	6.1	short firing range, structural clay products	
5	5YR5/2 (pale brown)	1110	5.9	5YR5/2 (pale brown)	1120	3.2	6.6	extremely short firing range, extrudes well, structural clay products	
5	5YR5/2 (pale brown)	1095	8.0	5YR5/2 (pale brown)	1125	2.8	5.9	short firing range, structural clay products	
3	5YR5/2 (pale brown)	1100	7.7	5YR5/2 (pale brown)	1125	2.9	6.3	extrudes poorly, structural clay products	
7	5YR5/2 (pale brown)	1115	11.2	5YR5/2 (pale brown)	1160	2.5	3.0	expands quickly on overfiring, expanded aggregate	
6	5YR5/2 (pale brown)	1125	9.4	5YR5/2 (pale brown)	1140	3.1	5.0	extremely short firing range, expands quickly on overfiring, little value	
5	5YR5/2 (pale brown)	1100	7.8	5YR5/2 (pale brown)	1130	2.4	6.7	curves upward on firing, hard to extrude, structural clay products	

Characteristics of Unfired Samples from Map Sheet 82P.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties: Room Temperature	Drying Properties: 105°C	Drying Shrinkage (%)
1	33	26	18	W4	Scollard	10YR2/2 (dusky yellowish brown) & 5Y2/2 (olive gray) interbedded shale, 5m	22	poor	fair	good	-	9.7
13	33	26	18	W4	Scollard	5Y5/2 (light olive gray) mudstone, slightly silty	18	very good	very good	some warp	-	9.4
2	25 (8m section)	26	23	W4	Pleistocene	5Y7/2 (yellowish gray) clay, nonsilty, calcareous "summer" varve	20	excellent	excellent	good	minor cracks	9.4
-						5Y5/2 (light olive gray) clay, nonsilty, calcareous, "winter" varve	could not produce P.C.E. cones because material bloated on calcining at 850°C					
12	23	27	23	W4	Battle	6m 5YR2/1 (brownish black) shale, minor silt, massive to medium laminae, slickensides	28	fair-good	fair	cracks	crumbles	-
						2m 5Y4/1 (dark olive gray) clay, slightly silty, massive	23	very good	fair-good	warps	cracks	9.3
5	7	28	18	W4	Horseshoe Canyon	Pale gray shale, sandy, ~3.6m, overburden ~9m	33	good	fair	cracks badly	-	10.0
16	32	29	17	W4	Paskapoo	10Y4/2 (grayish olive) mudstone, minor silt, iron stain, overburden ~4.5m	16	fair-good	fair-good	good	cracks	7.6
NW	16 (~30m of section)	30	17	W4	Paskapoo	5Y2/2 (dark olive gray) mudstone, slightly silty, calcareous, massive to slightly laminated, ~4.5m	20	very good	good-very good	-	cracks badly	8.8
						10Y4/2 (grayish olive) clay, minor silt, slightly calcareous locally, ~1.5m	20	good	fair	warps	cracks badly	9.3
						5Y5/2 (light olive gray) shale, minor silt, minor carbon, ~3.6m	22	good	good	cracks	cracks	10.8
						10YR2/2 (dusky yellowish brown) shale, minor silt	20	fair-good	fair	fair	fair	2.0
						10YR2/2 (dusky yellowish brown) & 5Y2/2 (dark olive gray) shale, silty, breaks into <1 cm tabular blocks	21	poor	poor	warps	cracks	10.0
						5Y2/2 (dark olive gray) shale, minor silt	16	fair	fair	good	cracks badly	7.9
						5Y5/2 (light olive gray) clay, minor silt, some iron stain	23	good	fair	warps	cracks	8.0
						5Y5/2 (light olive gray) clay, slightly silty, iron stain, breaks into <1 cm tabular blocks	21	fair	fair	good	cracks badly	5.4

Characteristics of Fired Samples from Map Sheet 82P.

P.C.E.	Steel Hard Color	Steel Hard Temp. (°C)	Steel Hard Absorption (%)	Maximum Fire Color	Maximum Fire Temp. (°C)	Maximum Fire Absorption (%)	Maximum Fire Shrinkage (%)	Remarks	Reference
11	5YR5/6 (light brown)	1050	6.7	5YR4/4 (moderate brown)	1185	2.8	7.2	long firing range, chemical analysis, overburden 5m, stoneware, pottery	Scafe (1978)
4	5YR5/6 (light brown)	1000	10.7	5YR4/4 (moderate brown)	1085	1.0	6.0	volume change low in overfiring, moderate firing range, bricks, stoneware, pottery	Scafe (1978)
4	5YR4/4 (moderate brown)	1050	7.6	5YR4/4 (moderate brown)	1090	0.0	9.0	synthetic aggregate?	Scafe (1980)
-	could not produce P.C.E. cones because material bloated on calcining to 850°C							synthetic aggregate?	
19	cracked so badly on drying that bars could not be fired							low alkali cement?	Scafe (1980)
10	5YR6/4 (light brown)	1100	6.4	coincides with steel hard				bars enlarge & crack above steel hard, blend for sewer pipe	
10	brownish red	1180	2.2	-	-	-	-	cracks badly, test for synthetic aggregate	Crockford (1951) Locality 49
3	5YR5/6 (light brown)	1040	5.3	5YR4/4 (moderate brown)	1090	0.0	7.5	short firing range, 5m overburden, bricks, tile	Scafe (1978)
3	5Y7/2 (yellowish gray)	1070	8.5	5Y6/4 (dusky yellow)	1100	0.4	6.8	short firing range, chemical analysis, structural clay products	Scafe (1978)
6	5YR5/6 (light brown)	975	9.3	5YR4/4 (moderate brown)	1080	0.7	7.0	a few soft white inclusions when fired, structural clay products	
11	5YR5/6 (light brown)	1050	3.2	5YR4/4 (moderate brown)	1100	1.0	7.0	volume change low in overfiring, stoneware, pottery, sewer pipe	
14	10YR6/6 (dark yellowish orange)	1050	2.5	5YR4/4 (moderate brown)	1140	0.6	6.2	stiff to extrude, moderate firing range, chemical analysis, stoneware, sewer pipe	
14	5YR5/6 (light brown)	1050	2.7	5YR4/4 (moderate brown)	1100	1.5	7.2	as above	
10	5YR6/4 (light brown)	950	9.5	5YR4/4 (moderate brown)	1085	0.0	5.2	long firing range, stoneware, sewer pipe	
4	5YR5/6 (light brown)	1015	11.0	5YR4/4 (moderate brown)	1090	0.7	9.4	volume change low in overfiring, moderate firing range, chemical analysis, bricks, tile	
3	5YR5/6 (light brown)			bars cracked longitudinally so could not take measurements				soft white inclusions, little value	

Characteristics of Unfired Samples from Map Sheet 83A.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties: Room Temperature	Drying Properties: 105°C	Drying Shrinkage (%)
-	23	37	22	W4	Horseshoe Canyon	Cream shale, lower part silty, ~2.1m	32	good	fair	cracks badly	-	-
						Steel gray shale, flaky, ~0.8m	30	good	fair	cracks badly	-	-
1	28	38	22	W4	Horseshoe Canyon	Cream shale, sandy, ~1.4m	40	good	fair	cracks	-	3.5
						White weathering sandstone, argillaceous, ~3.5m	35	good	poor	cracks badly	-	-
4	3	38	26	W4	Paskapoo	10Y4/2 (grayish olive) shale, 10YR4/2 (dark yellowish brown) stain on joints, no silt, noncalcareous	18	fair	fair	good	minor cracks	6.8
						As above	22	good	good	good	minor cracks	8.7
						5Y4/1 (olive gray) shale, ~30cm, no silt, noncalcareous, some carbonaceous material	23	fair	poor	good	good	7.4
-	17	38	27	W4	Pleistocene	Clay, sandy, laminated, calcareous, <2m	22	good	good	good	-	4.8
						Yellowish clay, jointed, silty, <1m	25	good	good	good	-	7.6
1	17	38	27	W4	Paskapoo	Gray shale, very calcareous, ~3m, overburden ~3m	25	good	good	-	cracks	5.5
N	15	39	22	W4	Whitemud?	White clay, hard, massive, sandy, ~1m	22	good	sticky	poor	-	6.0
14	8	39	23	W4	Pleistocene	Interbedded hard gray clay & soft yellowish silt, slightly calcareous, ~6m	24	good	good	-	-	8.0
4	27	40	25	W4	Paskapoo	5Y3/2 (olive gray) shale, 5YR3/2 (grayish brown) stain on joints & laminae, no carbonaceous impressions	20	good	good	good	minor cracks	7.9
13	16	42	23	W4	Paskapoo	10Y4/2 (grayish olive) mudstone, slightly silty	22	very good	very good	good	cracks badly	9.5
-	19	46	22	W4	Horseshoe Canyon	Gray shale, soft, ~4m, no overburden but many sand lenses interbedded	24	fair	sticky	cracks	-	8.0
-	21	46	20	W4	Horseshoe Canyon	Shale above upper lignite seam, some small ironstone concretions	29	excellent	sticky	cracks badly	-	8.8
						Yellowish shale between lower lignites	26	good	poor	cracks badly	-	7.0
						Dark brown shale below lower lignite	-	-	-	cracks	-	5.6
-	23	46	23	W4	Horseshoe Canyon	Olive shale, soft, ~4.5m, overburden ~0.6m	25	good	poor	cracks	-	8.5

Characteristics of Fired Samples from Map Sheet 83A.

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
9	too badly cracked to fire							no value	Crockford (1951) sample 126
15	too badly cracked to fire							no value	sample 127
9	light brown	1255+	14.5	-	-	-	-	no value	Crockford (1951) sample 128
15	too badly cracked to fire							no value	sample 129
3	5YR6/4 (light brown)	925	11.0	5YR4/4 (moderate brown)	1060	0.4	7.8	some upward curvature at hot end of bars, long firing range, bricks, tile	Scafe (1980)
2	5YR6/4 (light brown)	900	11.0	5YR4/4 (moderate brown)	1050	0.0	9.0	extrudes well, bars crack during firing, long firing range, bricks, tile	
3	5YR6/4 (light brown)	925	13.0	5YR4/4 (moderate brown)	1080	0.4	10.0	bars curve upward when fired, long firing range, chemical analysis, bricks, tile	
1	buff	1080	23.7	same as steel hard				clays were mixed to produce common brick early in century	Ries & Keele)1912) sample 1664a
-	light red	1080+	13.2	same as steel hard				as above	sample 1664
1	pinkish	1080	18.5	same as steel hard				very short firing range, brick	Ries & Keele (1912) Red Deer sample
16	cream	1080	9.4	cream	1180	4.3	4.0	dry press buff bricks, chemical analysis	Keele (1915) sample 144
2	light red	890+	18.7	light red	1005	18.5	0.3	scums, shrinkage too great if burned harder, brick	Keele (1915) Stone siding sample
2	5YR5/6 (light brown)	975	13.0	10R4/2 (grayish red)	1075	0.0	9.5	plasticity improves as material worked, moderate firing range, bricks, structural clay products	Scafe (1980)
4	5YR5/6 (light brown)	1025	9.7	5YR4/4 (moderate brown)	1100	1.0	6.0	extrudes well, moderate firing range, chemical analysis, brick	Scafe (1978)
-	red	890+	14.5	red	1080-	-	-	poor drying, sand interbeds, brick	Ries & Keele (1913) sample 1801
3	red	1080	3.6	-	-	-	-	soluble salts, grog may improve drying, dry press brick	Ries & Keele (1913) sample 1796
1	red	1080	-	-	-	-	-	improve with grog, brick	sample 1797
3	red	890	10.7	-	-	-	-	improve with grog, brick	sample 1790
1	red	890+	10.6	-	-	-	-	no value	Ries & Keele (1913) sample 1800

Characteristics of Unfired Samples from Map Sheet 83B.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
14	36	35	1	W5	Paskapoo	Shale, ~4.5m	-	excellent	good	-	-	-
5	7	38	6	W5	Pleistocene	5Y5/2 (light olive gray) clay, slightly silty, carbonaceous, 6m	20	good	good	good	good	7.4
NW	36	40	10	W5	Paskapoo-Brazeau	5Y3/2 (olive gray) shale, slightly silty, 6m	17	poor	fair	good	good	6.7
-	18	44	8	W5	Pleistocene	Light gray clay, very calcareous	33	good	sticky	-	cracks	9.0
SE	18	46	11	W5	Paskapoo	5Y3/2 (olive gray) shale, slightly silty, 5m	18	poor	poor	good	good	7.3

Characteristics of Unfired Samples from Map Sheet 83C.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
NE (Abandoned "Stewart" pit)	22	40	15	W5	Luscar	Dark gray shale, abundant siltstone lenses	15	poor	good	good	good	4.4
						Greenish gray mudstone, scattered ironstone nodules	15	poor	fair	very good	good	4.9
						As above	16	poor	fair	good	good	5.3
						Medium gray mudstone, soft, directly above coal, 1.3m	17	fair	good	good	-	5.4

Characteristics of Unfired Samples from Map Sheet 83E.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
-	28	57	5	W6	Brazeau	5Y5/2 (light olive gray) shale, massive, slightly silty	23	good	good	cracks	cracks badly	6.8

Characteristics of Fired Samples from Map Sheet 83B.

P.C.E.	Steel Hard Color	Steel Hard Temp. (°C)	Steel Hard Absorption (%)	Maximum Fire Color	Maximum Fire Temp. (°C)	Maximum Fire Absorption (%)	Maximum Fire Shrinkage (%)	Remarks	Reference
4	red	1005	-	-	-	-	-	brick or fire proofing, thick overburden, Innisfail area	Keele (1915)
3	10YR6/2 (pale yellowish brown)	1110	12.3	10YR5/4 (moderate yellowish brown)	1150	0.0	9.5	extrudes well, very short firing range, structural clay products	Scafe (1978)
3	10R4/6 (moderate reddish brown)	1090	6.5	10R4/2 (grayish red)	1125	0.2	8.8	short firing range, structural clay products	Scafe (1978)
3	salmon	1150+	12.2	same as steel hard				scums, no value	ARC Files (1971)
3	5YR5/6 (light brown)	1050	11.0	5YR4/4 (moderate brown)	1115	0.0	8.0	extrudes poorly, moderate firing range, bricks, tile	Scafe (1978)

Characteristics of Fired Samples from Map Sheet 83C.

P.C.E.	Steel Hard Color	Steel Hard Temp. (°C)	Steel Hard Absorption (%)	Maximum Fire Color	Maximum Fire Temp. (°C)	Maximum Fire Absorption (%)	Maximum Fire Shrinkage (%)	Remarks	Reference
3	10R4/2 (grayish red)	1090	8.0	5YR3/4 (moderate brown)	1125	1.5	7.9	difficult to extrude, short firing range, dry press brick	Scafe (1978)
5	5YR5/6 (light brown)	1030	11.7	5YR3/4 (moderate brown)	1125	0.4	6.8	extrudes well, moderate firing range, brick, tile	
6	5YR5/6 (light brown)	1055	13.7	10YR4/2 (dark yellowish brown)	1145	0.9	6.9	as above	
5	5YR6/4 (light brown)	985	10.8	5YR3/4 (moderate brown)	1095	0.0	9.2	long firing range, overfires slowly, stoneware, pottery	

Characteristics of Fired Samples from Map Sheet 83E.

P.C.E.	Steel Hard Color	Steel Hard Temp. (°C)	Steel Hard Absorption (%)	Maximum Fire Color	Maximum Fire Temp. (°C)	Maximum Fire Absorption (%)	Maximum Fire Shrinkage (%)	Remarks	Reference
3	10R6/6 (moderate reddish orange)	900	10.5	10R4/6 (moderate reddish brown)	1050	1.0	7.5	long firing range, blend to improve drying, chemical analysis, brick, tile, pottery	Scafe (1978)

Characteristics of Unfired Samples from Map Sheet 83F.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
6	30	47	22	W5	Cardium (Moosehound mbr)	10YR2/2 (dusky yellowish brown) mudstone, slightly silty, non-calcareous, 5Y7/6 (moderate yellow) stain	14	fair	good	good	good	3.6
SE	5	47	23	W5	Luscar	5Y3/2 (olive gray) mudstone, 50cm, noncalcareous, carbonaceous stringers	12	fair	fair-good	good	good	2.7
						5Y2/1 (olive black) mudstone, carbonaceous impressions, 2.5m	12	nil	nil	good	good	-
						5YR2/1 (brownish black) shale, thin laminae, noncalcareous, 4m	15	poor-fair	poor	excellent	excellent	4.3
						5YR2/1 (brownish black) shale, thin laminae, calcareous, 3m	14	poor	poor	good	good	0.6
8	8	47	23	W5	Blactstone (Vimy mbr)	5Y2/1 (olive black) shale, weathers N4 (medium dark gray), slightly calcareous, some silt & sand stringers, 15m	12	poor	fair	good	good	0.9
8	24	47	24	W5	Blackstone	5YR2/1 (brownish black) ahale, slightly silty, thin laminae, 10m	13	poor-fair	poor	good	good	2.2
-	26	47	24	W5	Luscar	N3 (dark gray) mudstone, hard, some carbonaceous impressions, noncalcareous, 20cm	12	nil	nil	good	good	0.7
16	20	49	21	W5	Brazeau	5Y4/1 (olive gray) clay, slightly silty, noncalcareous, some 5YR4/4 (moderate brown) stain on joints	16	good	good	very good	very good	5.5
(Abandoned Bryan Mtn. Coal Co. pit)						5Y5/2 (light olive gray) clay, slightly silty, noncalcareous,	14	fair	good	very good	very good	4.5
						5Y4/1 (olive gray) clay, 10YR4/2 (dark yellowish brown) stain on joints, slightly silty, noncalcareous,	15	good	good	very good	minor cracks	6.2
						Carbonaceous shale, 0.75m, 5Y8/4 (grayish yellow) stain, thin laminae	16	poor	fair	good	fair-good	6.4
						5Y4/1 (olive gray) shale, slightly silty, massive, noncalcareous, 2m	15	fair	fair	good	good	5.0
						5Y4/1 (olive gray) shale, 5YR3/4 (moderate brown) stain on joints, slightly silty, noncalcareous, 1m	14	poor	fair	very good	very good	4.6
9	24	51	19	W5	Pleistocene	5Y5/2 (light olive gray) clay, massive, calcareous, slightly silty	20	good	good	minor warp	minor warp	8.4
10	20	53	16	W5	Pleistocene	10YR5/4 (moderate yellowish brown) clay, massive, slightly silty	20	good	good	good	minor warp	7.4
5	3	54	16	W5	Paskapoo	Shale, ~1.5m, overburden ~10m	33	good	-	-	-	8.5

Characteristics of Fired Samples from Map Sheet 83F.

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
7	5YR5/6 (light brown)	1010	10.6	10R4/6 (moderate reddish brown)	1100	3.2	6.4	hard to extrude, moderate firing range, dry press brick, quarry tile	Scafe (1980)
8	5YR5/6 (light brown)	1010	8.0	5YR4/4 (moderate brown)	1080	1.6	6.0	hard to extrude, moderate firing range, sewer pipe, pottery	Scafe (1980)
4	bars too fragile to fire							no value	
14	5YR6/4 (light brown)	980	8.8	5YR5/6 (light brown)	1075	4.8	5.0	hard to extrude, rough surface on bars, chemical analysis, blend for sewer pipe	
4	10R4/2 (grayish red)	1125	1.3	coincides with steel hard				bars fragile, no firing range, no value	
4	steel hardness not reached by 1120°C							no value	Scafe (1980)
7	steel hardness not reached by 1205°C							no value	Scafe (1980)
3	bars too fragile to fire							no value	Scafe (1980)
15	5YR6/4 (light brown)	1075	6.0	10YR6/2 (pale yellowish brown)	1090	0.0	8.4	extrudes well, long firing range, sewer pipe, low duty refractories	Scafe (1980)
12	5YR6/4 (light brown)	1010	11.0	10YR4/2 (dark yellowish brown)	1150	0.4	8.3	extrudes well, long firing range, fired bars curve upward, chemical analysis, sewer pipe	
12	5YR6/4 (light brown)	1010	6.4	5YR5/6 (light brown)	1090	0.0	7.7	extrudes very well, sewer pipe	
10				bloats & cracks badly				no value	
10	5YR5/6 (light brown)	1025	6.4	5YR4/4 (moderate brown)	1125	0.0	8.4	excellent plasticity with extra water, moderate firing range, stoneware, pottery	
8	5YR5/6 (light brown)	1005	10.0	10YR4/2 (dark yellowish brown)	1105	0.0	7.8	moderate firing range, chemical analysis, stoneware quarry tile	
2	5YR6/4 (light brown)	1080	17.0	5YR4/4 (moderate brown)	1125	1.0	8.5	short firing range, chemical analysis, brick, tile	Scafe (1978)
2	5YR6/4 (light brown)	1100	14.5	5YR6/4 (light brown)	1125	6.5	6.0	extremely short firing range, structural clay products	Scafe (1978)
-	deep red	1030	0.0	deep red	1125	0.0	9.3	mix with sandy materials above in section to reduce drying shrinkage, good color, pottery bricks, tile	Ries (1914a) sample 1860

Characteristics of Unfired Samples from Map Sheet 83G

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
8	4	47	3	W5	Paskapoo	5Y3/2 (olive gray) mudstone, breaks into 1-2cm chunks, noncalcareous, ~2m, till cover <0.5m	16	fair	fair	good	good	6.9
-	22	47	10	W5	Paskapoo	5Y4/4 (moderate olive brown) shale, minor silt, 1m	20	poor	fair-good	good	cracks badly	7.7
						5YR4/1 (brownish gray) shale minor silt, 30cm	26	fair-good	very good	good	-	9.4
						5Y4/4 (moderate brown) shale	22	good	good	good	good	7.0
9	31	49	4	W5	Paskapoo	5Y3/2 (olive gray) mudstone lens 50 x 0.5m, noncalcareous, breaks into 2cm chunks	20	good	good	good	good	8.5
16	15	49	6	W5	Paskapoo	10Y4/2 (dark yellowish brown) mudstone, thin bedded, non-calcareous, breaks into 2cm pieces	19	good	good	good	good	9.4
7	11	49	7	W5	Pleistocene	5Y5/6 (light brown) massive, slightly silty clay, calcareous, 5-6m	19	very good	good	good	good	7.7
1	15	50	1	W5	Wapiti	5Y3/2 (olive gray) clayey siltstone, noncalcareous, breaks into 3cm chunks	16	good	fair	good	good	6.5
4	14	50	3	W5	Paskapoo	5Y3/2 (olive gray) mudstone, slightly silty, noncalcareous, ~1m	17	very good	good	good	good	8.0
9	24	50	3	W5	Scollard	5Y2/1 (olive black) mudstone, hard to dig, noncalcareous, very slightly silty	19	good	good	good	good	8.9
						5Y2/1 (olive black) mudstone, slightly silty, noncalcareous	17	good	good	warps	warps	7.8
1	3	50	4	W5	Paskapoo	5Y4/1 (olive gray) mudstone, very slightly silty, noncalcareous, ~0.75m	18	good	good	minor warp	good	9.0
4	2	51	3	W5	Pleistocene	10YR4/2 (dark yellowish brown), massive, slightly silty clay, calcareous, 3-5m	22	fair-good	good	warps	-	-
15	25	51	6	W5	Paskapoo	10Y4/2 (grayish olive) mudstone, slightly silty, calcareous lens 15 x 0.75m	22	fair	fair	cracks	cracks	5.9
13	35	52	6	W5	Paskapoo	5Y3/2 (olive gray) shale, slightly calcareous, ~2m	21	good	good	good	good	7.8
						5Y5/6 (light olive brown) clay, noncalcareous	23	good	good	minor warp	longitudinal cracks	10.6
13	10	53	4	W5	Scollard	5Y4/1 (olive gray) mudstone, noncalcareous, ~35cm	20	good	good	good	good	9.8

Characteristics of Fired Samples from Map Sheet 83G.

P.C.E.	Steel Hard Color	Steel Hard Temp. (°C)	Steel Hard Absorption (%)	Maximum Fire Color	Maximum Fire Temp. (°C)	Maximum Fire Absorption (%)	Maximum Fire Shrinkage (%)	Remarks	Reference
-	5YR5/6 (light brown)	950	10.5	5YR4/4 (moderate brown)	1075	0.1	7.1	unfired & fired bars chip easily, long firing range, blend to improve plasticity for brick, tile	
4	5YR5/6 (light brown)	1025	7.5	5YR4/4 (moderate brown)	1175	0.0	8.5	long firing range, brick, tile	Scafe (1978)
3	5YR5/6 (light brown)	1010	8.5	5YR4/4 (moderate brown)	1125	2.0	10.0	long firing range, brick, tile	
2	5YR5/6 (light brown)	1090	1.5	5YR4/4 (moderate brown)	1125	0.0	10.0	short firing range. chemical analysis blend for brick, tile	
-	5YR5/6 (light brown)	1005	8.2	5YR3/4 (moderate brown)	1055	0.8	10.0	green bars chip easily, curves up at hot end, short firing range, blend for brick & tile	
-	5YR5/6 (light brown)	1030	5.4	5YR4/4 (moderate brown)	1080	0.8	6.8	curves up at hot end, short firing range, blend for brick & tile	
4	5Y6/4 (dusky yellow)	1100	2.0	5Y5/6 (light olive brown)	1125	0.0	8.5	extremely short firing range, chemical analysis, blend for stoneware	Scafe (1978)
-	5YR4/4 (moderate brown)	1075	5.2	5YR4/4 (moderate brown)	1100	2.7	5.9	difficult to extrude, extremely short firing range, blend for brick & tile	
-	bars exploded in furnace							no value	
-	5YR5/6 (light brown)	1045	6.0	5YR4/4 (moderate brown)	1095	0.3	8.5	curves up at hot end, short firing range, bricks, tile	
-	5YR5/6 (light brown)	1065	9.0	5YR4/4 (moderate brown)	1085	8.8	3.4	one bar bloated other did not, extremely short firing range, little value	
-	bars exploded in furnace							no value	
3	10R6/6 (moderate reddish orange)	1080	9.0	5YR3/4 (moderate brown)	1115	0.0	7.5	extrudes well, short firing range, bricks, tile	Scafe (1978)
-	bars too fragile to fire							cannot be extruded, no value	
-	5YR5/4 (light brown)	1030	0.4	5YR4/4 (moderate brown)	1050	0.0	9.5	green bars soft & chip easily, short firing range, blend for brick & tile	
-	5YR5/6 (light brown)	975	8.5	5YR4/4 (moderate brown)	1070	14.0	6.8	longitudinal cracks on firing, hot end curves up, blend for brick & tile	
-	10YR7/4 (grayish orange)	1040	5.0	10YR6/6 (dark yellowish orange)	1150	0.6	7.5	curves up at hot end, long firing range, structural clay products	

Characteristics of Unfired Samples from Map Sheet 83G. (continued)

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties: Room Temperature	Drying Properties: 105°C	Drying Shrinkage (%)
2,3	15	53	4	W5	Scollard	Gray clay, noncalcareous, ~0.4m between coal beds,	30	good	good	cracks	cracks	8.3
						Dark brown clay, coaly, noncalcareous, ~0.3m between coal beds	36	low	poor	good	cracks	4.7
SE	21	53	7	W5	Pleistocene	10YR4/2 (dark yellowish brown) and 10YR2/2 (dusky yellowish brown) thinly laminated clay, 1.5m	P.C.E. cones bloated so badly that further testing was not warranted					
-	29	53	7	W5	Scollard	Yellowish shale, soft, much fine grit, 2.1m	24	good	good	good	good	6.0
						Gray shale, 3.3m	22	good	good	good	cracks	5.7
15	30	53	7	W5	Scollard	Gray, blue & green shales, slightly calcareous, some grit, ~3m	24	good	good	good	cracks	6.7
						Brown clay shales, gray & brown sandy shales, calcareous, ~2.7m	22	good	-	good	checks	4.7
						Gray, brown & green shales, slightly calcareous, ~4.9m	22	good	-	good	cracks	4.8
						Dark shale, carbonaceous, beneath lignite seam, ~1m	35	excellent	sticky	cracks	cracks badly	10.2
15	30	53	7	W5	Scollard	Gray shale, calcareous, much fine grit, ~2m	24	fair	-	good	good	5.4
NW	12	53	8	W5	Pleistocene	10YR4/2 (dark yellowish brown) and 10YR2/2 (dusky yellowish brown) thinly laminated clay, 30cm	P.C.E. cones bloated so badly that further testing was not warranted					
13	9	53	10	W5	Paskapoo	5Y4/4 (moderate olive brown) shale, noncalcareous, ~2m	16	good	good	good	good	7.5
13	22	57	3	W5	Wapiti	10YR2/2 (dusky yellowish brown shale, interbedded with sandstone & siltstone, noncalcareous, breaks into flaggy chips ~2cm diameter	21	fair	good	good	warps & cracks	6.1
5	10	58	10	W5	Scollard	10Y4/2 (grayish olive) mudstone, 5YR4/4 (moderate brown) stain on joints, noncalcareous	19	good	good	good	good	8.8
						5Y3/2 (olive gray) mudstone, 5Y4/4 (moderate olive brown) stain on joints, noncalcareous, breaks into 2-3cm blocks	18	good	good	good	good	9.0

Characteristics of Fired Samples from Map Sheet 83G. (continued)

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
12	light buff	1025	11.7	light brown	1150	0.5	6.8	long firing range, extrudes very well, difficult to dry, chemical analysis, sewer pipe	ARC Files (1972)
30+	steel hardness not reached by 1220°C							extrudes poorly, weak bars, chemical analysis, low duty refractories	
-	P.C.E. cones bloated so badly that further testing was not warranted							no value	Scafe (1978)
7	light red	890	14.5	brown	1145	0.0	7.3	long firing range, good color, dries well, bricks, tile	Ries & Keele (1913) sample 1762
3	light red	890	12.0	dark red	1125	0.0	7.3	dry press bricks, drain tile	sample 1763
3	light red	890	14.6	brown	1125-	0.0	-	dry press bricks	Ries & Keele (1912) sample 1660
3	red	1080	8.7	red brown	1125	0.8	9.0	dry press bricks	sample 1663
5	red	1080	6.6	brown	1125	0.0	5.0	brick or sewer pipe	sample 1662
13	red brown	1080	1.0	brown	1180	1.0	5.0	grog or salt to improve drying, sewer pipe	sample 1661
5	light red	1030	11.2	dark red	1125	3.5	6.4	good brick shale, overburden ~15m, mine with lignite	Ries & Keele (1913) sample 1761
-	P.C.E. cones bloated so badly that further testing was not warranted							no value	Scafe (1978)
-	5YR5/4 (light brown)	1075	4.4	5YR4/4 (moderate brown)	1095	0.7	7.0	green bars chip easily, extremely short firing range, blend for brick & tile	
-	bars too fragile to fire							cannot be extruded, no value	
-	5YR5/6 (light brown)	1020	5.5	5YR4/4 (moderate brown)	1080	0.0	8.4	curves up at hot end, moderate firing range, blend for brick & tile	
-	5YR5/6 (light brown)	1000	4.9	5YR5/6 (light brown)	1050	0.4	8.7	curves up at hot end, short firing range, blend for structural clay products	

Characteristics of Unfired Samples from Map Sheet 83H.

Location					Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties		Drying Shrinkage (%)
LSD	Sec	Tp	R	Mer						Room Temperature	105°C	
2	36	46	22	W4	Horseshoe Canyon	5Y4/4 (moderate olive brown) shale, very slightly silty, non-calcareous, alligator weathering, ironstone concretions, ~2m	20	good	poor	warps	good	8.4
1	3	47	20	W4	Pleistocene	Gray clay, sandy, very calcareous	25	fair	fair	-	good	6.0
16	12	47	28	W4	Paskapoo	5Y5/2 (light olive gray) shale, slightly silty, slightly calcareous lens ~10m long and 0.75m thick surrounded by siltstone	20	good	good	good	minor warp	5.4
-	2	48	20	W4	Horseshoe Canyon	Shale, hard, above lignite seam, south side of valley	-	-	sticky	cracks	-	7.5
6	9	49	17	W4	Horseshoe Canyon	5YR2/1 (brownish black) clay, slightly silty, slightly laminated, 30cm	22	fair	fair	minor warp	cracks badly	8.9
8	7	50	27	W4	Pleistocene	10YR4/2 (dark yellowish brown) clay, massive, silty, calcareous, 3-5m	20	good	very good	good	cracks badly	8.7
12	24	51	25	W4	Pleistocene	5Y5/2 (light olive gray) clay, massive, slightly silty, calcareous, 5m	18	good	very good	minor warp	cracks badly	8.7
-	18	52	14	W4	Pleistocene	Brownish gray clay, very sandy, noncalcareous, ~3.6m	-	good	very good	poor	cracks badly	7.0
2	33	52	24	W4	Horseshoe Canyon	Gray shale, calcareous,	35	excellent	poor	-	-	13.1
						Gray shale, brownish streaks	29	excellent	-	-	cracks	10.4
						Gray shale, brownish streaks, much fine grit	33	excellent	sticky	cracks	-	8.1
2	33	52	24	W4	Horseshoe Canyon	Blue shale, scattered concretions in upper part, below shales tested for entry above	25	good	-	good	cracks	10.0
-	30	52	24	W4	Pleistocene	Clay	34	good	poor	-	-	8.9
NE	32	52	24	W4	Recent	Clay, calcareous, very gritty, run of bank	20	good	-	-	-	5.6
						Clay, more clayey than material above	25	-	-	cracks	-	8.0
NE	15	53	25	W4	Pleistocene	Clay	25	good	good	good	good	6.5
16	21	53	25	W4	Pleistocene	10Y4/2 (grayish olive) clay, laminated, silty, 3m	21	very good	very good	good	good	8.0

Characteristics of Fired Samples from Map Sheet 83H.

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
-	5YR5/6 (light brown)	1025	10.1	5YR5/6 (light brown)	1040	10.0	3.5	hand molding required, very fragile bars, extremely short firing range, blend for structural clay products	
1	pale red	1080	13.4	same as steel hard				no firing range, blend for structural clay products	Ries & Keele (1913) sample 1795
2	light red	890	12.5	red	1080	7.5	4.0	cracks too badly on drying to be of value	Ries & Keels (1913) sample 1799
-	10R4/6 (moderate reddish brown)	1075	8.2	10R3/4 (dark reddish brown)	1100+	1.7	8.2	hand molding required, dry press bricks	
8	5YR6/4 (light brown)	910	11.3	5YR6/4 (light brown)	1000	9.5	1.2	bloats, moderate firing range, chemical analysis, expanded aggregate	Scafe (1978)
4	10R4/6 (moderate reddish brown)	1075	8.0	5YR4/4 (moderate brown)	1125	0.0	7.8	short firing range, bricks, tile	Scafe (1978)
3	10YR7/4 (grayish orange)	1100	9.5	5Y6/4 (dusky yellow)	1150	0.0	10.0	short firing range, blend for stoneware	Scafe (1978)
-	Red	1025+	-	-	-	-	-	used for bricks by Vegreville Brick Co., 1913	Keele (1915)
5+	-	-	-	dark red	1145	1.2	6.0	very high shrinkage, doubtful value	Ries & Keele (1912) sample 1658
5+	red	1080	9.2	dark red	1145	1.5	6.7	high drying shrinkage doubtful value	sample 1656
-	-	-	-	-	-	-	-	cracks on burning, doubtful value	sample 1657
3	red	1030	11.0	brown	1125	0.0	6.6	used 1911 for dry press bricks	Ries & Keele (1913) sample 1772
5	light red	890	13.8	red	1080	4.6	4.3	good color, steel hard at low temperature, dry press brick	Ries & Keele (1912) sample 1659
2	light red	1125	1.8	-	-	-	-	no firing range, made soft, porous bricks	Ries & Keele (1912) sample 1653
1	dark red	1080	5.9	-	-	-	-	extremely short firing range, made dry press bricks	sample 1654
5	light red	890	14.7	red	1080	8.8	2.3	25% sand gives better drying & firing data for structural clay products	Ries & Keele (1912) sample 1655
6	10R4/6 (moderate reddish brown)	1075	9.0	10R3/4 (dark reddish brown)	1130	2.0	7.5	extrudes & dries well, moderate firing range, brick & tile	Scafe (1978)

Characteristics of Unfired Samples from Map Sheet 83H. (continued)

Location LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	105°C	Drying Shrinkage (%)
						5Y3/2 (olive gray) clay, massive, silty, calcareous, 1m	31	fair	fair	warps	cracks	8.0
NE	21	53	25	W4	Pleistocene	Yellow clay, very sandy, dense, some gypsum, ~4.5m	-	fair	fair	-	-	7.2
13	23	54	22	W4	Pleistocene	5Y3/2 (olive gray) clay, laminated, slightly silty	P.C.E. cones bloated so badly that further testing was not warranted					
2	28	54	22	W4	Pleistocene	5Y2/2 (dark olive gray) clay, massive, calcareous, 1m	20	fair-good	good	minor warp	cracks	8.6
8	7	54	25	W4	Pleistocene	5Y3/2 (olive gray) clay, slightly silty, calcareous	19	good	good	minor warp	cracks badly	9.3
2	27	55	19	W4	Judith River	5Y3/2 (olive gray) shale, slightly calcareous, alligator weathering,. ~1.1m	22	good	good	warps minor cracks	warps minor cracks	10.6
						10YR4/2 (dark yellowish brown) shale, abundant organic fragments on laminae, noncalcareous, alligator weathering	23	good	good	warps minor cracks	warps minor cracks	9.8
1	17	55	24	W4	Wapiti	5Y4/1 (olive gray) shale, slightly silty, noncalcareous, gradational lower contact, ~0.25m	19	good	fair	warps	warps	8.5
						10YR2/2 (dusky yellowish brown) shale, noncalcareous, ironstone nodules at contact with siltstone above	21	good	fair	-	-	-
4	28	57	23	W4	Wapiti	5Y3/2 (olive gray) shale, slightly silty, thin laminae, noncalcareous, some lenses of clayey siltstone, ~2m	19	good	poor	warps & cracks	warps & cracks	7.7
13	8	57	26	W4	Wapiti	5Y4/1 (olive gray) shale, a few silt laminae & numerous carbon impressions near top, ~0.75m, below 1.75m till	22	good	fair	cracks	cracks	6.3

Characteristics of Fired Samples from Map Sheet 83H. (continued)

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
6	bloats before reaches steel hard							expanded aggregate	
5	light red	890	22.0	red	1145-	0.0	10.6	made common brick in 1911	Ries & Keele (1913) sample 1764
-	P.C.E. cones bloated so badly that further testing was not warranted							no value	Scafe (1978)
3	5YR8/4 (modserate orange pink)	1100	6.5	5Y6/4 (dusky yellow)	1150	0.0	11.0	short firing range, stoneware	Scafe (1978)
3	5YR5/6 (light brown)	1050	4.0	5YR5/6 (light brown)	1075	1.5	6.8	bloats even after long soak, expanded aggregate	Scafe (1978)
-	5YR5/6 (light brown)	1040	3.5	5YR5/6 (light brown)	1040	3.5	3.9	bloats, no firing range, hard to extrude, little value	
-	5YR4/6 (light brown)	1100	4.0	5YR5/6 (light brown)	1050	7.5	11.0	hard to extrude, bloats, maximum fire below steel hard, little value	
-	bars bloated before steel hardness reached							difficult to extrude, easily chipped after firing, expanded aggregate	
-	5YR6/4 (light brown)	1040	10.6	5YR6/4 (light brown)	1055	9.0	1.6	hand molding required, very deep cracking at hot end, black core, synthetic aggregate	
-	5YR5/6 (light brown)	1035	4.3	Coincides with steel hard				deep cracks & spalling on fired bars, no firing range, no value	
-	bars so fragile they cannot be fired							no value	

Characteristics of Unfired Samples from Map Sheet 83I.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
NE	9	66	22	W4	Pleistocene	Brownish gray clay, very calcareous	31	good	good	-	cracks	7.5
						As above	31	good	good	-	cracks	8.4
						As above, silty	28	fair	fair	good	good	6.5

Characteristics of Unfired Samples from Map Sheet 83J.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
2	18	58	7	W5	Wapiti	10YR2/2 (dusky yellowish brown) clay, slightly silty, calcareous, ~2m	20	poor	poor	minor cracks	cracks badly	8.4
4	3	59	6	W5	Wapiti	10YR2/2 (dusky yellowish brown) clay, silty, noncalcareous, ~2m, sandstone above & below, thin till overburden	18	fair	good	good	cracks	7.8

Characteristics of Fired Samples from Map Sheet 83I.

P.C.E.	Steel Hard Color	Steel Hard Temp. (°C)	Steel Hard Absorption (%)	Maximum Fire Color	Maximum Fire Temp. (°C)	Maximum Fire Absorption (%)	Maximum Fire Shrinkage (%)	Remarks	Reference
-	-	-	-	brownish red	1195-	0.0	7.5	very short firing range,	ARC Files (1969)
-	-	-	-	brownish red	1195-	0.0	8.3	yellowish or cream scum.	
-	dirty brownish buff	1195	2.8	-	-	-	-	these clays were blended with other local clays in Edmonton for bricks	

Characteristics of Fired Samples from Map Sheet 83J.

P.C.E.	Steel Hard Color	Steel Hard Temp. (°C)	Steel Hard Absorption (%)	Maximum Fire Color	Maximum Fire Temp. (°C)	Maximum Fire Absorption (%)	Maximum Fire Shrinkage (%)	Remarks	Reference
-	bars too fragile to fire							cannot extrude, no value	
-	5YR6/4 (light brown)	935	9.1	5YR5/6 (light brown)	970	6.6	1.6	short firing range, bars fragile, blend for brick & tile	

Characteristics of Unfired Samples from Map Sheet 83L.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
?	26	58	8	W6	Kaskapau	5Y2/1 (olive black) shale, noncalcareous, some silt bands <10 cm thick	15	fair-good	fair	slight warp	good	3.5
SE	28	58	8	W6	Ft. St. John Group	5Y2/1 (olive black) shale, silty, 5YR4/4 (moderate brown) stain on joints, siltstone stringers <3 cm	17	fair	fair	good	good	4.4
NW	24	58	9	W6	Luscar	5Y2/1 (olive black) shale, organic impressions on laminae, nonsilty	11	nil	nil	good	good	3.4
(McIntryre #9 South Pit, sampled upward from #4 seam as 3m combination samples unless noted otherwise)						As above, slightly silty, calcareous	13	nil	nil	good	good	0.8
						5Y4/1 (olive gray) shaly siltstone, calcite along joints, 17 m	16	nil	poor	minor surface cracks	minor surface cracks	1.4
						5Y2/1 (olive black) silty shale, thin bedded, calcareous	12	nil	nil	good	good	0.2
						N4 (medium dark gray) shale, organic impressions on partings, a few slightly calcareous mudstone bands, 0.5m coaly material at top	14	fair	fair-good	good	good	3.2
						5Y2/1 (olive black) shale, silty, organic impressions on laminae, 0.5m coal at top	14	nil	nil	good	good	0.8
						5Y3/1 (dark olive gray) shale, nodular weathering, 2.7m	12	nil	nil	good	good	0.7
						5Y2/1 (olive black) shale, minor silt, a few slightly calcareous nodules parallel to laminae	13	poor	poor	minor crazing	minor crazing	2.6
						5Y2/1 (olive black) shale, silty, a few slightly calcareous nodules	14	poor	poor-fair	minor crazing	minor crazing	2.8
						5Y2/1 (olive black) shale, silty, a few slightly calcareous nodules, 2.2m	14	poor-fair	fair	minor crazing	good	2.3
						5Y3/2 (olive gray) shale, minor silt, 2.2m, noncalcareous, 0.3m lensy sandstone in centre	18	fair	fair-good	minor crazing	good	4.9
						5Y3/1 (dark olive gray) shale, prominent 5Y4/4 (moderate olive brown) stain, minor silt, noncalcareous, 3.5m	13	nil	nil	good	good	1.5
						5Y2/1 (olive black) shale, slightly silty, organic impressions on laminae, 1.5m	14	fair	fair-good	good	good	3.6
						5Y2/1 (olive black) shale, organic impressions on laminae, noncalcareous, nonsilty, 3.4m	15	fair	fair	good	good	3.4
						5Y2/1 (olive black) shale, mainly nonsilty but has a few silt bands 2-3cm thick, 3.5m	12	nil	nil	good	good	0.6
						5Y2/1 (olive black) mudstone, nonsilty, noncalcareous, 1.5m	12	nil	nil	good	good	0.9
						5Y2/1 (olive black) shale, knobby weathering, nonsilty to minor silt, 1.8m	13	fair	fair	good	minor cracks	3.0
-	-	63	2	W6	Pleistocene	10YR4/2 (pale yellowish brown) & 10YR2/2 (dusky yellowish brown) clay, laminated, slightly calcareous, 3m	22	good	good	good	good	7.5

Characteristics of Fired Samples from Map Sheet 83L.

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
9	5YR6/4 (light brown)	1010	10	5YR4/4 (moderate brown)	1150	1.7	7.0	tempering water critical for good extrusion, long firing range, bricks, tile, pottery	Scafe (1980)
7	5YR6/4 (light brown)	1030	9.1	5YR4/4 (moderate brown)	1120	0.6	6.8	extrudes well, moderate firing range, bricks, tile	Scafe (1980)
4	steel hardness not reached by 1130°C							P.C.E. cones collapse suddenly, extrudes poorly, little value	Scafe (1980)
3	steel hardness not reached by 1140°C							extrudes poorly, bars very fragile, blend for brick & tile	
5	steel hardness not reached by 1140°C							as above	
-	bars too fragile to fire							no value	
4	10YR6/2 (pale yellowish brown)	1115	7.3	maximum fire not reached by 1220°C				minor cracks on surface, stoneware	
13	steel hardness not reached by 1270°C even though bars are expanding and absorption is reduced to 3.5%							blend for stoneware	
5	steel hardness not reached by 1170°C eventhough absorption is reduced to 2.0%							blend for stoneware	
4	5YR4/4 (moderate brown)	1075	9.3	5YR3/4 (moderate brown)	1115	4.5	5.6	extrudes stiffly, short firing range, blend for brick & tile	
4	5YR4/4 (moderate brown)	1100	8.0	5YR3/4 (moderae brown)	1140	1.8	5.8	short firing range, bricks, tile	
4	5YR5/2 (pale brown)	1125	8.0	5YR5/2 (pale brown)	1150	2.2	5.7	fine grit, extrudes well, structural clay products	
10	5YR6/4 (light brown)	1030	13.7	5YR5/2 (pale brown)	1150	0.7	8.2	extrudes well after fine grinding, long firing range, sewer pipe	
5	5YR4/4 (moderate brown)	1100	9.0	coincides with steel hard				could not extrude, no value	
15	5YR7/2 (grayish orange pink)	1090	9.5	5Y6/1 (light olive gray)	1205	2.4	5.8	extrudes well, finer texture than samples above, long firing range, stoneware, sewer pipe	
7	5YR6/4 (light brown)	1030	10.2	5YR4/4 (moderate brown)	1110	1.4	6.4	extrudes stiffly, moderate firing range, quarry tile	
5	5YR3/4 (moderate brown)	1100	8.2	coincides with steel hard				could not extrude, no value	
4	5YR3/4 (moderate brown)	1150	3.5	coincides with steel hard				could not extrude, no value	
8	5YR6/4 (light brown)	1110	4.8	5YR5/2 (pale brown)	1135	2.7	4.8	extrudes well, extremely short firing range, blend for stoneware	
3	5YR6/4 (light brown)	1070	18.0	5YR4/4 (moderate brown)	1125	0.0	7.5	moderate firing range, chemical analysis, bricks, tile	Scafe (1978)

Characteristics of Unfired Samples from Map Sheet 83M.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
NE	14	71	6	W6	Pleistocene	Yellowish clay, silty, calcareous	-	poor	poor	good	good	low
13	8	71	9	W6	Pleistocene	10YR4/2 (dark yellowish brown) & 10YR2/2 (dusky yellowish brown) clay, minor silt, calcareous, 3m	22	good	good	minor warp	warps	8.3
						10YR2/2 (dusky yellowish brown) clay, silty, laminated, calcareous, 3.5m	21	good	good	minor warp	fine cracks	6.0
13	3	72	1	W6	Pleistocene	10YR2/2 (dusky yellowish brown) clay, minor silt, slightly calcareous, 3m	drying shrinkage so great that further testing unwarranted					
15	1	79	7	W6	Kaskapau	10YR2/2 (dusky yellowish brown) thinly laminated, noncalcareous, nonsilty shale. 5Y7/2 (yellowish gray) powder on laminae & joints	20	good	good	warps to side		5.9
						~10m below sample above. 5Y2/1 (olive black) thinly laminated, nonsilty shale. Weathers N5 (medium gray). Noncalcareous, but scattered calcareous concretions & gypsum crystals. 5Y6/4 dusky yellow) powder.	20	good	good	minor warp		6.1
						~13m below sample above. 5Y2/1 (olive black) thinly bedded, nonsilty, noncalcareous shale. Flattened, spherical, calcareous concretions scattered along bedding planes. Gypsum crystals to 3cm long in joints.	19.5	good	good	warps to side		5.5
						~10m below sample above. 5Y2/1 (olive black) thinly laminated to thinly bedded shale & sandstone. Weathers N5 (medium gray). Noncalcareous, but flattened, shperical, calcareous concretions scattered along bedding planes. 5Y5/2 (light olive gray) powder on beds	18	good	good	warps to side		5.4
8	15	79	7	W6	Kaskapau	~2.5m of 5Y3/2 (olive gray) thinly laminated, nonsilty, noncalcareous shale. Weathers N6 (medium light gray). A few gypsum needles. Some 5Y6/4 (grayish yellow) powder on joints	18.5	good	good	warps to side		5.8
10	23	79	13	W6	Kaskapau	5Y2/1 (olive black) slightly silty, thinly laminated shale, 10YR4/2 (dark yellowish brown) stain, 5Y6/4 (dusky yhellow) powder on laminae & joints	18	good	good	warps to side		6.2

Characteristics of Fired Samples from Map Sheet 83M.

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
-	-	-	-	light pink	1130	17.0	6.5	narrow tempering range, unfired bars fragile, scums, high absorption, once used for sand-mold brick	Allan & Carr (1946) sample 1383
2	5YR5/6 (light brown)	1080	8.5	5YR4/4 (moderate brown)	1125	0.0	9.0	short firing range, bricks, tile	Scafe (1978)
2	5YR4/4 (moderate brown)	1100	3.5	5YR4/4 (moderate brown)	1125	1.0	9.3	extremely short firing range, chemical analysis, bricks, tile	
3	drying shrinkage is so great that further testing in unwarranted							no value	Scafe (1978)
-	5YR4/4 (moderate brown)	1070	3.6	-	1100	0.6	10.0	black core, longitudinal crack on firing, white specks throughout, add grog, fire slowly, grind finely, brick	
-	10R4/6 (moderate reddish brown)	1040	6.1	-	1090	2.6	9.5	black core, longitudinal crack on firing, add grog, fire slowly, brick & tile	
-	5YR5/6 (light brown)	1030	5.5	-	1060	2.0	7.9	black core, longitudinal crack on firing, a few white specks, add grog, fire slowly, brick & tile	
-	5YR4/4 (moderate brown)	1080	5.4	5YR4/4 (moderate brown)	1090	4.5	8.0	black core, fire slowly, brick, tile, pottery	
-	5YR4/4 (moderate brown)	1090	4.1	5YR4/4 (moderate brown)	1090	4.1	9.3	steel hard & maximum fire coincide, black core, longitudinal crack on firing, white specks throughout, not recommended	
-	5YR5/6 (light brown)	1110	4.4	5YR5/6 (light brown)	1125	3.6	6.8	black core, longitudinal crack on firing, add grog, fire slowly, brick & tile	

Characteristics of Unfired Samples from Map Sheet 83M .

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties: Room Temperature	Drying Properties: 105°C	Drying Shrinkage (%)
						~10m below sample above. 5Y2/1 (olive black) nonsilty, thinly laminated shale, 5YR3/4 (moderate brown) stain, 5Y6/4 (dusky yellow) powder on laminae. Noncalcareous.	18	good	slightly sticky	warps to side	-	6.4
						~10m below sample above. 5Y2/1 (olive black) thinly laminated, slightly silty shale. Weathers N4 (medium dark gray), some 10YR2/2 (dusky yellowish brown) stain. Noncalcareous.	18	good	good	warps to side	-	6.3
14	8	80	4	W6	Kaskapau	5Y2/1 (olive black) shale, minor silt, noncalcareous, 2m, uppermost visible shale	18	good	fair-good	good	minor warp	5.7
						As above, 1.5m, 300cm sandstone stringer between the two shales	17	good-very good	good	good	good	5.6
					Dunvegan	5Y3/2 (olive gray) shale, slightly silty near top, noncalcareous, 3m	20	good-very good	good	warps	cracks badly	7.8
						5Y2/1 (olive black) shale, minor silt, noncalcareous, some 5YR5/6 (light brown) stain on joints, 1.5m	19	good	good	good	cracks	7.6

Characteristics of Fired Samples from Map Sheet 83M. (continued)

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
-	5YR4/4 (moderate brown)	1140	3.6	5YR4/4 (moderate brown)	1110	4.8	5.2	maximum fire temperature below steel hard, black core that disappears by steel hard, add grog, fire slowly, brick & tile	
-	5YR5/6 (light brown)	1095	3.7	-	1065	3.4	6.5	maximum fire temperature below steel hard, black core, add grog, fire slowly, brick & tile	
8	5YR5/6 (light brown)	1050	9.8	5YR4/4 (moderate brown)	1135	0.2	7.5	extrudes well, moderate firing range, sewer pipe, quarry tile	Scafe (1980)
9	5YR6/4 (light brown)	1000	12.5	5YR4/4 (moderate brown)	1140	2.9	5.0	extrudes very well, long firing range, sewer pipe, quarry tile	
4	5YR5/6 (light brown)	1040	9.7	5YR4/4 (moderate brown)	1030	1.1	8.2	extruded bars bloat badly, must be hand molded, lightweight aggregate	
7	bars bloat badly before reaching steel hardness							lightweight aggregate	

Characteristics of Unfired Samples from Map Sheet 83N.

Location LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	105°C	Drying Shrinkage (%)
3	28	74	17	W5	Pleistocene	5Y3/2 (olive gray) clay, massive, slightly silty, calcareous, 2.5m	P.C.E. cones bloat so badly that further testing unwarranted					
16	20	77	24	W5	Kaskapau	~5.5m 5Y2/1 (olive black), weathers N4 (medium dark gray) thinly laminated to thinly bedded, noncalcareous, nonsilty shale. Calcareous pelecypod shells to 3cm dia. and abundant calcareous, spherical concretions. Minor pyrite.	19	good	fairly good	warps to side	-	5.0

Characteristics of Fired Samples from Map Sheet 83N.

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
-	P.C.E. cones bloat so badly further testing unwarranted							expanded aggregate	Scafe (1978)
-	10R4/2 (grayish red)	1095	12.1	10R4/2 (grayish red)	1095	12.1	6.0	steel hard & maximum fire coincide, black core with thin, oxidized skin, intense sulfur smell on cutting, a few white specks, add grog, fire slowly, brick & tile	

Characteristics of Unfired Samples from Map Sheet 84C.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
4	29	81	20	W5	Pleistocene	5Y3/2 (olive gray) clay, massive, 1m	19	good	good	warps	cracks	6.6
2	19	83	21	W5	Lower Shaftesbury	10YR2/2 (dusky yellowish brown) shale, 5Y8/4 (grayish yellow) flecks (natrojarosite), noncalcareous, gypsum crystals on surface, 10m	25	good-very good	good-very good	minor warp	good	6.7
7	20	83	21	W5	Upper Shaftesbury	10YR2/2 (dusky yellowish brown) shale, minor silt near bottom to silty near top, calcareous, 11m	20	very good	fair-good	minor warp	minor cracks	8.1
1	29	83	21	W5	Lower Shaftesbury	5Y2/1 (olive black) shale, 5Y8/4 (grayish yellow) flecks (natrojarosite), a few ironstone nodules <30cm diameter, 5m	22	fair-good	fair	minor warp	good	7.4
16	4	85	21	W5	Pleistocene	10YR4/2 (dark yellowish brown) clay, slightly silty, laminated, calcareous	P.C.E. cones bloat so badly further testing unwarranted					
6	36	85	24	W5	Kaskapau	5Y3/2 (olive gray) shale, slightly silty, much 5Y6/4 (dusky yellow) stain on laminae, 5m	21	good	good	minor warp	good	6.9
6	36	85	24	W5	Kaskapau	10YR2/2 (dusky yellowish brown) abundant 5Y8/4 (grayish yellow) stain, thinly laminated, nonsilty shale. Slightly calcareous.	20	good	fairly good	warps to side	–	5.3
						~5m below sample above. 10YR2/2 (dusky yellowish brown) thinly laminated to thinly bedded, nonsilty shale. Abundant 5Y6/4 (dusky yellow) powder on laminae. Noncalcareous.	20.5	good	fairly good	warps to side	–	5.0
5	5	90	23	W5	Dunvegan	10YR2/2 (dusky yellowish brown) & 5Y4/1 (olive gray) clay, slightly calcareous, slightly silty, 10m	20	very good	very good	minor warp	warps & cracks	7.8
16	23	91	23	W5	Pleistocene	5Y4/4 (moderate olive brown) & 5Y3/2 (olive gray) clay, laminated, silty, calcareous, 2m	21	good	good	warps	warps	7.2

Characteristics of Fired Samples from Map Sheet 84C.

P.C.E.	Steel Hard Color	Steel Hard Temp. (°C)	Steel Hard Absorption (%)	Maximum Fire Color	Maximum Fire Temp. (°C)	Maximum Fire Absorption (%)	Maximum Fire Shrinkage (%)	Remarks	Reference
3	5YR5/6 (light brown)	1040	9.5	5YR4/4 (moderate brown)	1100	1.5	7.5	moderate firing range, bricks, tile	Scafe (1978)
7	10R6/6 (moderate reddish orange)	1020	18.2	10R4/6 (moderate reddish brown)	1110	2.4	14.3	longitudinal cracks common on firing, quarry tile	Scafe (1980)
5	5YR5/6 (light brown)	1085	2.2	5YR4/4 (moderate brown)	1100	1.0	8.6	extruded bars explode in furnace, hand molding necessary, dry press bricks	Scafe (1980)
8	10R4/6 (moderate reddish brown)	1060	4.3	10R4/6 (moderate reddish brown)	1125	1.0	9.7	extruded bars split on firing, hand molding necessary, quarry tile	Scafe (1980)
-	P.C.E. cones bloat so badly further testiung unwarranted							expanded aggregate	Scafe (1978)
8	10R5/4 (pale reddish brown)	1090	1.5	5YR4/4 (moderate brown)	1125	0.0	12.3	short firing range, chemical analysis, quarry tile	Scafe (1978)
-	10R4/6 (moderate reddish brown)	1085	1.7	-	1120	0.0	10.4	oxidized throughout bar, bricks tile, pottery	
-	10R5/4 (pale reddish brown)	1050	8.2	-	1070	4.9	8.0	minor black core, rusty grains to 1mm common which would be detrimental to bodies, grind finely, add minor grog, fire slowly, brick & tile	
8	5YR5/6 (light brown)	975	7.0	5YR4/4 (moderate brown)	1075	1.8	8.0	extrudes well, grog will help drying, moderate firing range, quarry tile	Scafe (1978)
3	5YR5/6 (light brown)	1040	13.0	5YR3/4 (moderate brown)	1110	0.0	9.0	soft white inclusions when fired, moderate firing range, chemical analysis, grind finely for brick & tile	Scafe (1978)

Characteristics of Unfired Samples from Map Sheet 84D.

LSD	Sec	Tp	R	Mer	Group or Formation	Description	Tempering Water (%)	Plasticity	Workability	Drying Properties Room Temperature	Drying Properties 105°C	Drying Shrinkage (%)
15	33	83	3	W6	Kaskapau	5Y4/1 (olive gray) thinly laminated, jointed, very slightly silty shale. Conchoidal fracture on laminae faces. Noncalcareous	19	good	good	warps to side	-	5.8
						~2m below sample above. 5Y4/1 (olive gray) jointed, thinly laminated, very slightly silty shale. Noncalcareous.	19.5	good	good	warps to side	-	6.1
						~3.5m below sample above. 5Y4/1 (olive gray) very slightly silty, jointed, thinly laminated shale. Noncalcareous.	19.5	good	slightly sticky	warps to side	-	6.2

Characteristics of Fired Samples from Map Sheet 84D.

	Steel Hard			Maximum Fire					
P.C.E.	Color	Temp. (°C)	Absorption (%)	Color	Temp. (°C)	Absorption (%)	Shrinkage (%)	Remarks	Reference
-	5YR5/6 (light brown)	1090	2.8	-	1025	1.8	7.4	black core, short fiting range, fire slowly for brick	
-	5YR6/4 (light brown)	1055	4.0	-	1110	2.6	8.3	black core, moderate firing range, fire slowly for brick & tile	
-	5YR5/6 (light brown)	1090	4.0	5YR5/6 (light brown)	1100	4.0	7.1	black core, extremely short firing range, fire slowly for brick	

Appendix 2. Colors Encountered in Unfired and Fired Clays from Alberta

Color designations based on the Munsell system as interpreted by the Rock-Color Chart Committee are used in this report to provide a standard to which any reader can refer.

Hue 5R

5R6/2	pale red
5R4/2	grayish red

Hue 10R

10R4/2	grayish red (slight orange tint)
10R2/2	very dusky red
10R5/4	pale reddish brown
10R3/4	dark reddish brown
10R6/6	moderate reddish orange
10R4/6	moderate reddish brown

Hue 5YR

5YR8/1	pinkish gray
5YR6/1	light brownish gray
5YR4/1	brownish gray
5YR2/1	brownish black
5YR7/2	grayish orange pink
5YR5/2	pale brown
5YR4/2	pale grayish brown
5YR3/2	grayish brown
5YR2/2	dusky brown
5YR8/4	moderate orange pink
5YR6/4	light brown
5YR5/4	light brown
5YR4/4	moderate brown
5YR3/4	moderate brown (darker than 5YR4/4)
5YR5/6	light brown (more yellowish red than 5YR6/4)

Hue 10YR

10YR8/2	very pale orange
10YR6/2	pale yellowish brown
10YR4/2	dark yellowish brown
10YR2/2	dusky yellowish brown
10YR7/4	grayish orange
10YR5/4	moderate yellowish brown
10YR6/6	dark yellowish orange

Hue 5Y

5Y6/1	light olive gray
5Y5/1	medium olive gray
5Y4/1	olive gray
5Y3/1	dark olive gray
5Y2/1	olive black
5Y7/2	yellowish gray
5Y5/2	light olive gray
5Y3/2	olive gray (greener than 5Y4/1)
5Y2/2	dark olive gray
5Y8/4	grayish yellow
5Y6/4	dusky yellow
5Y4/4	moderate olive brown
5Y7/6	moderate yellow
5Y5/6	light olive brown

Hue 10Y

10Y6/2	pale olive
10Y4/2	grayish olive

Hue 5GY

5GY8/1	yellowish gray (lighter than 5Y7/2)
5GY6/1	greenish gray
5GY4/1	dark greenish gray
5GY3/2	grayish olive green

Hue 10GY

10GY5/2	grayish green

Hue N

N9	white
N8	very light gray
N7	light gray
N6	medium light gray
N5	medium gray
N4	medium dark gray
N3	dark gray
N1	black

Appendix 3. Chemical Analyses of Clays and Shales from Alberta

Formation	Map	Lsd	Sec	Tp	R	Mer	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5	MnO	CaO	MgO	Na_2O	K_2O	S	H_2O	L.O.I.
Pleistocene	74E	16	35	99	8	W4	84.53	7.41	1.64	0.30	.	.	0.67	0.86	0.28	1.12	0.00	1.62	.
	83F	9	24	51	19	W5	49.50	14.80	4.78	0.64	0.13	0.07	10.10	2.66	0.73	2.58	0.22	1.39	12.40
	83G	7	11	49	7	W5	44.17	12.64	3.19	0.49	0.12	0.06	13.41	3.93	0.61	2.18	0.12	1.04	17.02
	83L	-	-	63	2	W6	52.16	16.95	4.02	0.67	0.23	0.06	6.57	2.53	0.59	3.09	0.90	1.00	11.13
	83M	13	8	71	9	W6	52.77	19.33	5.17	0.72	0.20	0.06	3.85	2.29	0.46	3.38	1.00	0.78	10.01
	84C	16	23	91	23	W5	50.54	17.76	5.24	0.70	0.20	0.08	6.07	2.72	0.73	3.16	0.23	1.03	9.56
Brazeau	82O	1	13	29	7	W5	73.96	13.30	2.44	0.70	0.16	0.01	0.27	0.98	0.37	2.40	0.26	0.70	4.15
	83E	-	28	57	5	W6	64.26	17.21	4.69	0.61	0.26	0.01	1.18	1.75	0.11	4.06	0.19	1.25	4.08
	83F	7	36	49	21	W5	64.68	18.14	4.61	0.87	0.05	0.03	0.48	0.92	0.88	2.70	0.01	1.13	5.20
							64.31	17.55	3.66	0.84	0.18	0.02	0.88	1.43	0.75	2.55	0.02	1.14	6.20
Paskapoo	82I	14	8	22	21	W4	57.38	21.07	4.30	0.63	0.11	0.05	1.73	1.94	1.28	2.90	0.03	2.36	5.59
	82P	1	33	26	18	W4	62.64	19.03	5.44	0.56	0.07	0.02	0.71	1.59	0.39	1.82	0.18	1.55	5.72
		NW	16	30	17	W4	46.83	10.93	2.49	0.42	0.14	0.05	13.89	3.54	0.26	1.87	0.25	1.31	17.10
							67.10	16.99	2.71	0.62	0.07	0.02	1.41	1.82	0.21	2.53	0.30	1.46	4.89
							64.67	18.73	3.72	0.62	0.03	0.01	0.72	1.58	0.21	2.31	0.23	1.59	5.82
	83A	13	16	42	23	W4	67.09	16.09	3.45	0.67	0.14	0.03	1.47	1.71	1.59	2.56	0.27	1.23	3.82
		4	3	38	26	W4	61.49	14.22	6.79	0.65	0.15	0.03	0.81	1.81	0.99	3.31	0.06	2.52	6.06
	83G	-	22	47	10	W5	59.70	17.23	6.33	0.78	0.17	0.07	1.95	2.48	1.21	3.04	0.23	1.24	5.06
Porcupine	82J	10	36	21	1	W5	61.41	17.26	5.58	0.78	0.27	0.03	0.90	2.08	1.22	2.41	0.04	2.68	5.18
Hills							62.29	16.48	5.72	0.66	0.18	0.03	0.89	1.95	0.71	2.62	0.04	2.57	5.63
	82O	3	4	27	3	W5	53.59	14.12	3.72	0.55	0.18	0.04	7.85	2.68	0.22	2.78	0.29	0.80	11.74
Scollard	83G	2,3	15	53	4	W5	64.41	16.44	4.37	0.70	.	.	0.99	1.06	0.76	2.42	.	5.09	2.70
							50.96	27.66	1.74	0.52	.	.	1.01	0.16	0.25	0.42	.	8.88	8.48
Willow Ck.	82H	-	30	6	24	W4	59.34	16.59	4.33	0.54	0.05	0.02	3.07	2.02	0.87	2.42	0.03	2.46	7.52
St. Mary	82H	2	3	10	24	W4	59.08	15.17	4.21	0.53	0.09	0.03	4.01	2.93	1.20	3.43	0.05	0.88	7.60
River							66.12	15.63	4.65	0.55	0.08	0.02	0.99	1.69	1.43	2.86	0.06	1.75	3.63
Battle	82I	NW	25	22	23	W4	64.71	17.20	2.88	0.40	0.04	0.01	0.81	0.56	0.69	0.25	0.02	5.45	6.79
	82P	8	29	34	21	W4	69.91	17.39	3.68	0.48	.	.	0.94	1.39	1.55	0.46	.	.	4.2
							64.63	20.52	4.17	0.45	.	.	1.20	1.65	1.66	0.32	.	.	5.4
	83A	12	23	39	22	W4	62.63	23.38	3.81	0.77	.	.	0.74	0.62	0.71	0.34	.	.	7.1
	83G	4	5	50	1	W5	60.86	20.54	4.13	0.39	.	.	1.02	1.14	1.42	0.58	.	.	9.92
							61.60	20.35	4.38	0.45	.	.	0.97	1.03	1.66	0.35	.	.	9.21
							64.86	17.97	4.41	0.46	.	.	0.84	1.09	1.28	0.39	.	.	8.70
							68.05	16.46	3.36	0.59	.	.	0.74	0.87	1.40	1.15	.	.	7.38
		5	9	53	4	W5	62.01	23.25	3.16	0.58	.	.	0.94	0.73	0.71	0.20	.	.	8.42
Whitemud	83A	N	15	39	22	W4	66.37	26.62	1.28	.	.	.	0.42	.	0.42	.	.	.	5.15
Horseshoe	83H	6	9	49	17	W4	63.60	17.11	3.26	0.64	0.08	0.05	0.80	1.32	1.30	3.12	0.23	0.81	7.07
Canyon																			
Bearpaw	82G	NE	26	7	2	W5	64.66	16.87	5.07	0.77	0.11	0.02	0.52	1.15	0.83	2.60	0.04	1.86	5.35
Judith	72E	14	4	2	6	W4	59.15	13.95	3.78	0.56	0.14	0.05	3.98	3.26	1.56	2.72	0.02	1.30	8.66
River							58.14	17.95	6.26	0.74	0.21	0.12	1.71	1.53	1.57	2.01	0.12	2.41	6.78
		-	3	12	5	W4	74.25	14.29	2.89	.	.	.	0.37	.	1.19	2.52	.	.	4.21
	82H	10	10	2	21	W4	60.35	12.22	3.79	0.48	0.14	0.02	4.95	3.80	0.66	2.75	0.01	1.26	9.14
		9	17	4	16	W4	65.40	16.93	4.38	0.76	0.09	0.01	0.31	0.96	0.80	2.13	0.18	2.14	5.69
		-	1	10	17	W4	63.20	19.20	5.40	.	.	.	0.60	1.20	.	.	.	.	9.00
							68.40	18.00	4.00	.	.	.	0.40	1.00	.	.	.	.	7.70
Pakowki	72E	14	14	1	11	W4	58.06	17.69	6.21	0.77	0.21	0.03	0.84	1.84	0.75	2.53	0.52	2.88	7.12
		10	20	2	10	W4	55.82	17.47	6.72	0.72	0.18	0.02	1.24	1.48	0.75	2.36	0.85	4.00	7.07

Formation	Map	Lsd	Sec	Tp	R	Mer	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5	MnO	CaO	MgO	Na_2O	K_2O	S	H_2O	L.O.I.
Wapiabi	82H	10	24	4	30	W4	69.29	14.94	1.62	0.65	0.35	0.02	1.44	1.07	0.33	2.62	0.31	0.98	6.08
	82O	NE	33	24	8	W5	66.22	15.53	4.07	0.68	0.00	0.01	0.99	1.68	0.56	2.98	1.15	0.49	6.02
Blackstone	82G	13	7	6	1	W5	68.21	14.32	4.24	0.69	0.36	0.01	0.15	1.10	0.66	2.87	0.44	1.14	6.38
		4	18	6	1	W5	68.15	15.42	3.95	0.78	0.31	0.02	0.44	1.00	0.39	2.81	0.14	1.07	5.64
Kaskapau	84C	-	36	85	24	W5	61.47	18.06	5.13	0.86	0.19	0.01	0.11	0.80	0.51	3.27	0.37	0.89	8.56
McMurray	74D	15	8	89	9	9W4	68.42	16.20	3.16	0.92	0.11	.	0.50	0.65	0.33	1.37	0.00	5.45	0.96
Basal Clays							61.49	16.01	4.00	1.06	0.19	.	2.02	1.09	0.49	2.14	0.16	5.21	2.15
							67.18	10.12	4.87	1.29	0.18	.	0.84	0.74	0.37	0.66	0.00	5.11	2.42
							74.69	13.38	0.85	1.25	0.03	.	0.31	0.59	0.35	0.96	0.00	4.24	0.32
							61.89	18.01	2.57	1.09	0.14	.	0.42	1.45	0.42	3.45	0.00	4.71	1.14
		NW	17	91	9	W4	51.12	28.07	2.84	0.80	0.33	0.01	0.23	1.15	0.96	2.13	0.07	2.36	9.50
							66.37	16.78	1.58	1.00	.	.	0.23	1.42	0.84	1.43	<0.01	2.82	7.58
							51.59	24.68	3.07	0.85	.	.	0.24	0.78	1.43	2.78	<0.01	4.06	8.71
		NW	14	92	10	W4	65.71	13.99	6.36	1.06	0.02	0.09	0.24	0.72	0.39	2.34	.	0.00	8.30
	74E	13	31	92	10	W4	76.56	11.34	2.87	1.39	0.02	0.02	0.16	0.46	0.48	0.84	.	0.00	5.33
							67.51	15.74	2.24	1.13	0.05	0.02	0.19	0.93	0.56	0.84	.	0.00	8.77
		SW	17	94	10	W4	59.24	20.25	4.43	0.89	0.02	0.02	0.29	2.52	0.18	5.08	.	0.00	6.91
		11	21	94	11	W4	62.56	11.30	9.80	0.91	0.00	0.01	0.13	1.55	0.47	4.14	.	0.00	8.32
		6	34	94	11	W4	66.35	14.62	3.68	0.83	0.03	0.01	0.79	1.24	0.38	3.35	.	0.00	7.85
		SW	35	94	11	W4	66.66	18.44	2.23	1.17	0.03	0.01	0.14	1.17	0.47	3.16	.	0.00	6.33
		9	1	98	11	W4	55.03	24.69	3.05	1.25	0.04	0.02	0.19	1.40	0.51	3.29	.	0.00	9.82
Luscar	83F	SE	5	47	23	W5	60.06	20.04	3.91	0.87	0.50	0.02	0.50	0.91	0.20	3.00	0.09	1.50	8.20
Blairmore	82O	SE	26	24	8	W5	60.60	18.18	6.57	0.78	0.02	0.08	0.99	2.56	2.16	2.67	0.41	0.51	4.49
Kootenay	82G	NE	24	6	4	W5	71.35	16.12	1.96	0.78	0.00	0.01	0.21	0.63	0.25	2.57	0.18	0.62	5.30
		NE	36	8	4	W5	60.12	14.11	5.70	0.66	0.06	0.08	2.45	2.22	0.20	2.60	0.25	0.56	10.95
							66.84	13.84	4.68	0.73	0.06	0.06	1.09	1.59	0.26	2.40	0.15	0.50	7.44
		SW	13	7	6	W5	66.75	17.11	1.71	0.75	0.12	0.01	0.94	0.91	0.27	3.42	0.17	0.57	7.74
Siyeh	82G	7	4	4	1	W5	41.47	5.91	2.03	0.20	0.07	0.07	13.33	11.86	0.24	1.82	0.04	0.23	22.24