PROPERTIES AND SOURCES OF SOME SASKATCHEWAN LITHIC MATERIALS OF ARCHAEOLOGICAL SIGNIFICANCE

A Thesis
Submitted to the College of Graduate Studies and Research in Partial Fulfilment of the Requirements For the Degree of Master of Arts in the Department of Anthropology and Archaeology by
Eldon Arthur Johnson
Saskatoon, Saskatchewan
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Head of the Department of Anthropology and Archaeology
University of Saskatchewan
Saskatoon, Saskatchewan
Canada S7N 0W0
This study examines nine varieties of lithic material of archaeological significance. These materials were chipped into useful prehistoric artifacts and can be found in southern Saskatchewan. The identity of each variety has been determined by petrographic analyses and features useful for field identification have been described. The source of each material has been related to a geological formation.

For archaeological purposes, it is proposed that chalcedonic silica be regarded as a silica polymorph separate from quartz. This distinction permits more accuracy in developing concepts of rock identity. It also makes way for an explanation for the phenomenon of change in properties of certain varieties of rock by heating to a relatively low temperature. Chalcedonic silica is regarded as the active component of the kinds of rocks that are made easier to chip by heating. Many varieties of material were experimentally heated and the results provide strong support for this concept.
ACKNOWLEDGEMENTS

I would like to express my appreciation to the many people who have given me assistance and encouragement during this study. Foremost among them are the members of the thesis committee: Dr. Ernest G. Walker (supervisor), Department of Anthropology and Archaeology; Dr. Zenon Pohorecky, Department of Anthropology and Archaeology; Dr. Urve Linnamae, Department of Anthropology and Archaeology; Dr. W.A.S. Serjeant, Department of Geological Sciences. I also express appreciation to my mentor Dr. W.O. Kupsch, the external examiner. Dr. J.F.V. Millar of the Department of Anthropology and Archaeology also assisted in very many ways.

Other members of the Department of Geological Sciences have also graciously provided assistance. They include Dr. W.G.E. Caldwell, Dr. F.F. Langford, Dr. H. Hendry, Dr. W.K. Braun and Dr. James F. Basinger. Zbigniew Szczepanik and John Dubetz made the petrographic thin-sections that were so important to this study. Dr. Chris Gilboy gave immeasurable assistance by analysing these thin-sections, and Dr. David McNeil gave an important interpretation regarding microfossils. Allen Holsten made chemical analyses of the rock specimens, and Janet Gunn and Larry Craig helped in the interpretation of materials. Carol Beaulieu did the cartography, David Mandeville the photography, and Lynne Underwood typed the manuscript.

Finally, this study could not have been accomplished without the encouragement and support of my wife, Charlotte.
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CHAPTER 1

INTRODUCTION

Stone, a rock-like substance which usually embodies human use or modification, is one of the most important archaeological materials. It has been used as a tool material for probably millions of years, it can be shaped by several distinctive methods, and it is virtually imperishable. The form and ascribed function of artifacts and their quantity and location in a site contribute to information about past cultures and past activities. The intrinsic properties of the stone itself may also yield important information.

Undoubtedly, the availability of stone and the technology to shape it allowed humans to become active predators and to adapt to very harsh environments. The study of stone is inextricably related to that of the development of prehistoric humans, and it may assist in developing inferences about their cognitive processes and their social organization.

Although cobbles and fragments of stone occurring naturally can be used as simple tools without modification, human ability to shape stone gave a much greater control of the environment. Stone may be shaped by
several methods: by breaking, by pecking, by abrading and by chipping. Heat was used in some quarrying processes to detach portions from the parent rock but mechanical processes are the most important. The nature of the rock entailed the method of shaping. Slates could be split into thin pieces and ground to a desired shape and to produce a sharp edge. Massive granular rocks could be shaped by pecking, and tough materials such as jade could be sawed by slices of sandstone. Certain kinds of brittle rocks could be shaped by the removal of a succession of thin spalls. This process is called chipping.

The flake scars of a chipped artifact are highly distinctive as in the detritus from the manufacture of such an artifact. In some cases the mode of flake removal can be accurately surmised whether it be hard or soft percussion, or pressure flaking. The splitting of symmetrical pebbles or cobbles also represents a distinctive technology. When applied to a suitable rock, chipping is a labour efficient method of reduction and shaping. Chipping is an appropriate way of fashioning tools for cutting and scraping because spalls have naturally sharp edges, and sharp edges can also be easily formed on artifacts.

The class of rocks that may be usefully chipped must have certain properties. They must be hard and
brittle, they must be either fine-grained or amorphous and have no cleavage planes due to unit cell arrangement. Nor may they have voids, fractures or inclusions that unduly interfere with artifact design. Prominent among varieties of rocks that can be usefully chipped are: obsidian and basalt, chert, chalcedony, welded tuff, siltstone, quartzite, fused shale, and siliceous replacements of materials such as wood.

1.1 The Archaeological Significance of Lithic Materials

The forms and functions of artifacts and their spatial arrangement within a site provide an important source of information about ancient activities. Projectile point typology is an essential aspect of site interpretation as are observations of wear and breakage patterns. A knowledge of the lithic materials per se can contribute substantially to that derived from other studies of artifacts.

Archaeological lithic materials have been relatively unexamined but it is proposed that a knowledge of them can contribute in several ways. If the source of the lithic material be known, hypotheses regarding procurement patterns of the site occupants can be derived. Knowledge of physical properties such as ease of chipping, durability and strength may indicate reasons for the
selection and use of a specific material and insights into the technology required to shape it.

*Stone Axe Studies* (Clough and Cummins, 1979) is an excellent example of how a multi-disciplinary scientific approach made it possible to identify the sources of stone from which axes in northwestern Europe were made. This degree of sophistication is rarely possible for materials that can be chipped. Nevertheless if a lithic material can be identified and related to a known source, additional information is given about the users. For example, Knife River flint is a lithic material from North Dakota which occurs as artifacts and flakes in sites on the northern Plains. It is apparent that some groups who occupied Saskatchewan either had recently come from North Dakota, or else had regular contact with this source. Whether a certain cultural group used exotic materials and whether they had become familiar with indigenous sources is useful in order to interpret their travel or contact patterns. It is apparent that separate cultural complexes used lithic varieties in very different proportions and for different tools. Material use by members of a specific cultural group may vary from locality to locality for reasons that are not now apparent. To elaborate, some Besant groups used virtually no Knife River flint and others used it almost exclusively.

In many circumstances material selection must have
depended on local availability but it is the opinion of contemporary flint knappers that some styles of projectile points require a high grade material. A finely chipped Eden projectile point cannot be made from rough material nor is it possible to create the flute on a Folsom projectile point unless the stone chips well. Cultural traditions entailed the manufacture of certain styles of tools, and in some instances this must have entailed the procurement of certain exotic materials.

Varieties of stone vary considerably in the effort required to remove a spall of a given size. On one hand obsidian is very easy to chip, but on the other end of the scale are most andesites, diorites and quartzites. Hence, the end product will depend on the technology available to shape that kind of rock. The technology may be a matter of using or not using soft percussion or pressure flaking, and it may include knowledge of whether properties of a rock could be improved by heating and how to do it.

In summary, a knowledge of the source of a rock may lead to hypotheses regarding its procurement. Whether it be local or exotic will determine the nature of theories regarding its procurement system. It may be postulated that it was obtained in the course of seasonal movement, or that an exchange system existed, or that expeditions were sent to get desirable material. Know-
ledge of properties of a rock may permit its identification and to understand the technology that could have been used to fabricate it into desired artifacts.

1.2 The Goals and Parameters of this Research

This thesis will be concerned with the identification and description of those lithic materials which occur naturally in southern Saskatchewan which could be usefully chipped into artifacts. Only those which appear in significant quantities in the archaeological record will be considered.

The objectives of the research are:
(i) to determine which lithic varieties used by chipped-stone industries had sources within southern Saskatchewan.
(ii) to locate the source or source area of each of these varieties and to correlate it to geological features or events.
(iii) to determine by scientific and other methods the properties of each variety, especially those which may be useful in identification and recognition.
(iv) to empirically evaluate the chipping properties of each variety, both in the natural and heated condition.
1.3 Previous Research

Even though the study of lithic materials in archaeology is still beset by problems, scholarly treatises have illuminated this field considerably. Those relevant to this study will be briefly commented on.

Classes of reports that are germane include: work done by others on specific materials that are studied in this research; reports of materials that are outside of Saskatchewan; geological reports; and archaeological site reports.

Campling (1980) presented *The Identification of Swan River Chert* in which he described this variable and widely dispersed material. His report included petrographic analyses and descriptions of macroscopic properties. As far as is known, this is the only published work to have approached from an archaeological viewpoint a lithic material useful for chipping that has a source at least partly within Saskatchewan.

Several important articles have been published which describe materials exotic to Saskatchewan. In 1970 Clayton *et al* published a classic work on Knife River flint. The authors described properties of this material and gave information regarding its presence in glacial drift and its assumed geological origin. Support was given by petrographic slides of thin sections. Knife River flint
is not known to be indigenous to Saskatchewan; although exotic, it is common as artifacts and flakes in Saskatchewan archaeological sites. Choquette (1980) examined Kootenay lithic materials found in southeastern British Columbia but so far they have not been recognized in Saskatchewan. Fenton and Ives (1982:166-189) described the geology, properties and distribution of Beaver River sandstone whose source is in the Fort Mackay district of northeastern Alberta.

Geological reports have described some lithic materials of value for chipping. Pierce and Hunt (1937:242-244) described "pebble chert" and Broughton (1976:1719-1722) described silicified peat, which he calls "silicified lignite," while Vonhof (1969) described the geology and lithology of Tertiary quartzites.

There is a great deal of variation in the ways in which archaeologists have dealt lithic materials. Wettlaufer (1960) gave brief descriptions of the following materials and indicated their representation in the various levels: chalcedony, jasper, chert, crystalline chert, agate, petrified wood, baked shale, quartzite and crystalline quartz. Some archaeologists have ignored lithic materials in their site reports, others such as Kehoe (1973) have devoted a chapter to a single material, in this case quartzite, and have dealt very scantily with others. There appears to be a lack of confidence in
using lithic materials as a source of information, or as a basis for developing theories about prehistoric activities. These deficiencies may be due to a lack of basic data regarding most lithic materials and their respective sources.

1.4 Problems in Lithic Identification

One of the major problems in studying archaeological lithic materials is to apply consistent names to specific rocks. On this matter Leonoff makes this appropriate observation:

The consistent use of terms applied to raw material identification is the first necessary step [for future research]. It is meaningless to the researcher, when reading archaeological reports, to see a variety of terms applied to the same material or vice versa. The consistent use of terms has ramifications for other areas of research (Leonoff, 1970:80).

Several years later lithic identification was still regarded as a problem by Thomas who states:

A final problem is the difficulty of comparing the
results of the analysis to existing data. Often, raw material data have been completely omitted from archaeological reports. When included, data on raw material selection are usually obfuscated by lack of clear descriptions of the materials and by idiosyncratic systems of lithic classification (Thomas, 1983:21).

The root of this problem lies in the lack of research into materials that are scarce and of no commercial value. Also, there is uncertainty as to what criteria are necessary to identify a specific variety of rock. The matter of identifying the material in artifacts and hand specimens may be especially difficult because rocks suitable for chipping are usually fine-grained or amorphous. Rocks such as granite may be classified according to the kind of minerals present and their proportion but, because individual minerals in chipping materials usually can not be discerned, this method is rarely suitable.

Some rocks have regular features that enable one to identify them but variability within other varieties increases the problem of identification. Swan River chert is an example of a rock that may have a wide range of colours, textures and structures. Campling (1980) raises the question whether it ought to be regarded as
one variety or several.

Heating may cause changes in colour and lustre so that it may be necessary to make an assumption whether a specimen had been heated or not before classifying it. Weathering may also cause changes in appearance.

Where an outcrop of a rock is known to exist it can be regarded as a source type and specimens can be compared with it for identification. Unfortunately, many of the rocks of interest have been distributed by natural action and no primary source is known. Their identification will therefore depend upon observations of their intrinsic properties and by comparison with similar known rocks.

Most of the rocks of value to a chipping industry consist mainly of silica. The failure to distinguish between quartz and chalcedonic silica (both are SiO₂) can lead to misidentification or the application of a less appropriate name. This matter will be discussed more fully in a subsequent chapter.

Many terms in common use such as chert, flint, chalcedony and porcellanite have vague or ambiguous meanings. In particular, "chert" is commonly applied to a fine-grained rock of uncertain identity. At times this is justifiable, but in many instances more specific names can be applied such as "chalcedony," "siltstone" or "jasper," according to its properties.
Although archaeology relies on the science of geology for information about rocks, these sciences differ in the information that each requires. For geological purposes it is usually adequate to classify a rock according to the variety of which it is a member, but in archaeology it is not only desirable to indicate the variety but to relate it to a specific source. If a rock is referred to as "chert" a small amount of information is given about its properties, but if it can be called by a proper name such as "Knife River flint" a specific material is implied along with its source.
2.0 Introduction

In general, a rock is composed of one or more minerals and its classification will depend on the kinds and proportions of minerals in it, how it was formed and what forces have subsequently acted on it. Minerals, therefore, are the basic building units of all rocks. Hurlbut and Klein (1971:1) define a mineral as "...a naturally occurring homogeneous solid with a definite (but generally not fixed) chemical composition and an ordered atomic arrangement. It is usually formed by inorganic processes." Chalcedonic silica, even though it has a regular composition (SiO₂), is not regarded by these authors as a "mineral" because it lacks a recognizable crystal structure. However, this view is not held by all petrologists and mineralogists. No mineral, apart from quartz and possibly chalcedony, is useful for chipping.

Igneous rocks have been derived directly from a magma and they may be classified according to which minerals are present, their proportions, and the size and arrange-
ment of the grains. The latter depend on the way the magma cooled. One which cooled slowly would form a coarse texture in which individual mineral grains could be discerned but if the same magma cooled quickly it would form a fine-grained or glassy rock because rapid cooling does not permit individual minerals to segregate as grains. Obsidian is a rhyolite glass that was much used by chipped-stone industries. It was formed by the rapid cooling of a siliceous magma as in volcanic extrusion, but if it had cooled slowly, it would be crystal-line and called a granite.

The main igneous rock found in southern Saskatchewan is granite but small amounts of basalt and vein quartz also occur in the glacial drift. Porphyry is also present in Tertiary gravels. Granite and basalt cobbles were shaped by pecking to form mauls, and basalt and quartz were chipped to form rough chopping tools.

Sedimentary rocks provided the greatest variety and the greatest absolute quantity of lithic materials that were used by chipped-stone industries. Two major classes are: those of detrital origin, and those deposited from aqueous solution. Detrital rocks include: quartzites, sandstones, siltstones, wackes, argillites and tuffs. All of these consist of small fragments of previously formed rocks which have been lithified by cementation or by the recrystallization of component materials. Silica,
in the quartz form, is the most common cementing material. Chalcedonic silica is relatively rare as a cementing material; rocks cemented by it are called "silcrete" by Kempe and Harvey (1983:205). They have a distinctive appearance when the chalcedonic silica patinates in contrast to the unpatinated quartz sand grains.

Sandstones consist of sand deposits of varying lithology and consolidation. Quartzites are usually distinguished from sandstones when fractures go through rather than around the sand grains. However, if materials other than quartz (such as feldspar) are present in sufficiently small quantities the rock may still be regarded as "sandstone." The Wentworth scale (Pettijohn, 1975:30) is useful for designating particle size as clay, silt or sand. In this classification sand ranges from 1/16mm to 2mm. Hence lithified materials may be called claystone, siltstone or sandstone. By definition wackes are poorly sorted and are quite impure.

Sedimentary rocks may be formed by the deposition of silica from aqueous solution rather than from the detritus of other rocks. The chemically (or biologically) formed varieties of silica such as chert, flint, agate and chalcedony may be deposited as beds or nodules, or as cavity filling, and silica may replace other materials such as limestone, wood, lignite or peat.

Metamorphism embraces a wide range of conditions
which include great heat and pressure on one hand but exclude weathering and physical and chemical changes at low temperature and pressure on the other. The wide variety of metamorphic rocks include few that were of value to the prehistoric flint knappers of Saskatchewan. Some having suitable properties are quartzite, altered siltstone, hornfels and argillite.

2.1 The Quartz-Chalcedony Question

The nature of a rock will be determined by the minerals in it, their proportions, the sizes of grains and the grain to grain relationship. Chemical analyses indicate that most rocks of value to chipping industries consist mainly of silica (SiO₂). Quartz is the most common variety of silica but in archaeology it is quite apparent that some kinds do not behave like quartz. Work done in this thesis explored these anomalies. If the properties of a composite material are to be understood it is important to understand the properties of its components. Because of the importance of silica attention was focussed on the properties of its common varieties.

Hurlbut and Klein (1977:411) list nine polymorphs of silicon dioxide and there may well be several more. The best known of these polymorphs are low quartz, which is the form that we normally experience, and chalcedonic
silica. In archaeology it is important to recognize the differences between their respective properties, as well as to distinguish between materials that consist mainly of one or the other. The most important difference between them lies in their respective responses to certain degrees of heat. The high-low inversion of quartz (at about 573°C) has been much studied. Chalcedonic silica does not display this inversion but it does undergo an apparently permanent change in properties upon heating. Temperatures of 250°C cause a slight but noticeable change; heating to 300°C causes a marked decrease in tensile and compressive strengths and the scars of flakes removed after heating are more lustrous than the scar surfaces of flakes removed before heating. The significance of this property is that heating to within a certain range a lithic material that contains a significant amount of chalcedonic silica will make it easier to chip. A second important difference between quartz and chalcedonic silica lies in their comparative chemical stabilities. Quartz is very stable chemically as indicated by crystals in granite that has been exposed for a long time. They will be unpatinated and unaffected by weathering. However, exposure is probably a factor in causing chalcedonies to patinate in time. The kind of patination and the rate of patination depend somewhat on the variety of chalcedony and its impurities as well as some external
factors that are, at this time, not well understood.

The idea that chalcedonic silica ought not be regarded as simply a variety of quartz is by no means unique or recent. Sosman states:

There is enough difference, however, to justify the statement that chalcedony is not quartz, nor even a 'variety of quartz,' if we mean by 'variety' a modification whose properties could have been foretold completely from the properties of the parent substance (Sosman, 1927:154).

In further explication, Sosman states: "...the term 'chalcedonic silica' will be used herein as synonymous with 'natural microfibrous silica'" and at a later date:

The properties of chalcedonic silica more often approach those of quartz than those of any other of the principal phases. There are enough differences, however, to justify the statement that chalcedony cannot correctly be called a 'variety of quartz,' if by variety we mean a modification whose properties could have been foretold completely from the properties of the type substance (Sosman, 1965:219).
Pettijohn (1975:395) supports Sosman's view regarding the distinction between quartz and chalcedony, but does not employ the term "chalcedonic silica." He uses the term "chalcedony" to refer to "natural microfibrous silica."

Frondel defines the term "chalcedonic silica" in this way:

Most of the fine-grained types of quartz that have been distinguished by given names, including agate, carnelian, flint and chert, basically are aggregates of fibrous quartz, for which the term **chalcedonic silica** [emphasis added] is appropriate, and in a sense are variants of chalcedony (Frondel, 1965:171).

He gives further support for the distinction between quartz and chalcedonic silica with this statement:

The anomalous optical properties, in particular the seemingly biaxial character, have led to the description of various types of fibrous silica [chalcedonic silica] as species separate from quartz (Frondel, 1965:198).

In the field of lapidary it is known that chalcedony
can be dyed, whereas quartz cannot unless "crackled."
Crackling refers to heating the quartz and quenching it to produce fine fractures. This observation is a further indication of the porosity of chalcedony and the lack of it in quartz.

My experiments in heating fine-grained materials indicate that the materials that respond to heating to 300°C (i.e. become more glassy and easier to chip) are of chemical (or biological) sedimentary origin and are regarded as chalcedonies. Materials that respond include: Knife River flint (a replacement of lignite); Brandon, England floorstone which is commonly called a "flint" (a marine biological deposition); silicified peat (a replacement of organic material); Montana agate (a cavity filling of vesicles in igneous rock); also, some kinds of silicified wood (chalcedonic replacement of wood).

No quartzite, quartz, obsidian, or any material that was not a silica of low-temperature sedimentary chemical or biological formation showed any change in properties related to chipping qualities after being heated to 300°C. These observations give support to the concept that there are some basic differences between quartz and chalcedonic silica.

Many polymorphs of silica are known. A reasonable explanation for the behavior of chalcedonic silica is that it too is a distinct silica polymorph but is one
in which a certain degree of heat causes a slight molecular adjustment which thereby permanently alters some of its properties. Chalcedony and its variants consist basically of chalcedonic silica, therefore, in order to understand chalcedony it is essential to understand chalcedonic silica which is its main component, and to recognize that it does not behave like quartz.
Figure 1. A map of Saskatchewan showing some geological features.
3.0 Introduction

The properties of a rock depend on its composition and the forces that have subsequently acted upon it. Insights as to its source as a material for human use may be derived from the geological formation which produced it and the subsequent natural forces of transportation which have acted upon it. It is sometimes possible to predict the source of a material from its geological origin.

3.1 The Precambrian Era

Rocks thousands of millions of years old form the basement complex of northern Saskatchewan. They are of igneous, sedimentary and metamorphic origin. Hundreds of millions of years later glacial action ground down the former mountains thus exposing many kinds of rocks and transporting the detritus in a general south-westerly direction into southern Saskatchewan.

Although the territory of the Canadian Shield is
outside the scope of this thesis, some of the rocks derived from it are of interest. Small amounts of quartzite, vein quartz and basalt were glacially transported to parts of southern Saskatchewan and were used for coarse chipped tools.

A pattern of lithic distribution for Saskatchewan (such as that done by Shetsen [1984] for southern Alberta) has yet to be undertaken, so it is not possible to relate a specific variety of glacially transported rock to its source in the Shield. It can only be noted that, as a matter of personal observation, quartzite, vein quartz and basalt are minimally present in west-central and central Saskatchewan but are apparently absent from most of eastern Saskatchewan.

3.2 The Cretaceous Period

During Cretaceous times much of Saskatchewan was inundated by vast inland seas which left a series of sediments (Byers et al., 1969:45).

Whereas the European chalk beds of the late Cretaceous period are well known for the flint they contained there is no evidence that such flint nodules were formed in Saskatchewan at this time. Cretaceous deposits in Saskatchewan, although generally devoid of lithic material suitable for chipping, do yield two distinctive materials.
One is a dense black, fine-grained material that will be called "Gronlid siltstone." This material was found to be present as nodules and lenses in a glacially transported mass of bedrock shale which is exposed a few kilometers north of Gronlid. Foraminifera microfossils in this shale suggest, but do not prove, an origin from the Turonian Favel Formation (Second White-Speckled Shale). [David McNeil, personal communication 1986]. Another exception is the silicified siltstone pebbles which occur in western areas. They are present in some strandline deposits of the western shores of what were probably Bearpaw seas.

3.3 The Tertiary Period

During the Tertiary Period several useful materials were either formed in or transported into southern Saskatchewan. Some of these materials are indigenous to the deposits formed during a specific epoch.

In the Paleocene Epoch, which lasted from about 65 million years B.P. to 54 million years B.P., fine-grained sediments were borne from the western mountains and formed the Ravenscrag Formation of southern Saskatchewan. This formation, as described by Kupsch (1956:24-27), consists of silts, sands and clays, intercalated in places with seams of lignite. None of these materials can be chipped
into tools. However, combusting coal beds fused the shale of the walls and vents into a hard, fine-grained material. This fused shale has been exposed near Rockglen, Big Beaver and Estevan.

The Eocene (54 million years B.P. to 35 million years B.P.) melds into the Oligocene (35 million years B.P. to 23 million years B.P.). The uplift of western mountains caused geological events that have been well described by Vonhof (1969). Vigorous rivers flowed north-easterly from what is now northwestern Montana and bore gravels from the Belt Formation into the Cypress Hills and Swift Current regions of Saskatchewan. These areas that are now uplands were river beds at that time. These gravels that now cap the Cypress Hills uplands are known as the Cypress Hills Formation and they consist mainly of quartzite. These quartzite cobbles are distinctively rounded and many bear circular or crescentic scars resulting from multitides of impacts during swift fluvial transport. Other materials such as silicified wood, porphyry and argillite are among these gravels but as far as is known none of these materials were used for making chipped tools.

The Miocene Epoch lasted from 23 million years B.P. to 4.5 million years B.P. The fluvial transport of gravels from northwestern Montana into southwestern Saskatchewan continued into the Miocene Epoch. The lithology of the gravels is similar to that of the Cypress Hills
Formation but the average size of the rounded clasts is significantly smaller. Miocene gravels comprise the Wood Mountain Formation which caps the plateau south of Rockglen. This plateau was not traversed by the Wisconsin glacier so it must be a relict of Tertiary deposits.

Quartzite cobbles and pebbles are abundant in the Wood Mountain Formation, but also present are siliceous replacements of wood and peat. Small fragments of silicified wood are relatively common, and tree stumps of over a meter in height have also been recovered. Nodules of silicified peat over .5m in length have been observed.

This thesis proposes that the silicified peat and silicified wood were formed in the locality after the deposition of the Wood Mountain gravels. The Wood Mountain gravels are well-rounded and have cortical chatter marks. The silicified wood and silicified peat tend to fracture easily and show no signs of rounding, hence, they could not have been transported for any significant distance by the same fluvial action that brought the quartzite. If the area was not glaciated then this material could not have been brought in by that means.

The Pliocene Epoch lasted from 4.5 million years to 1.5 million years ago. As deposits from this period are not recognized in Saskatchewan it will not be considered. Storer (1978:600) indicates that the Hand Hills Plateau of Alberta is Pliocene; deposits capping this plateau
yield a fine-grained lithic material known as Hand Hills agate.

Exposed Tertiary deposits in southern Saskatchewan were a source of several lithic materials that were utilized by prehistoric people for chipped tools. Quartzite was abundant, and significant amounts of feldspathic siltstone, silicified wood, silicified peat and fused shale were also available.

3.4 The Quaternary Period

The Quaternary Period consists of the Pleistocene and Holocene Epochs. The several ice ages of the Pleistocene lasted from about 1.5 million years ago until glacial retreat. Deglaciation took place in Saskatchewan some 10,000 to 20,000 years before present. The continental glaciers of this period ground down the Canadian Shield and transported the debris in a general south-westerly direction. This drift constructs the landforms of southern Saskatchewan with the exception of parts of the Cypress Hills which were lightly glaciated, and an area south of Rockglen which was not traversed by the last glacial event, the Wisconsin. The Quaternary was not a rock-forming period, but it is of interest because some rocks that could be chipped were transported from the Shield into the area of this study.
CHAPTER 4

METHODS OF EXAMINATION

4.0 Introduction

This chapter will be concerned with the methods of examination of lithic materials, especially those that describe properties that are useful for identification or which, in some way, indicate the value of a material for making chipped artifacts.

Even though scientific geology has a long history as a source of background information for archaeology, many aspects of petrology (the branch of geology dealing with the origin, occurrence, structure and history of rocks) have been relatively neglected. On this subject Kempe and Templeman state:

Today a wide variety of physical and chemical techniques exist which can assist the archaeologist in establishing the nature and provenience of his artifacts. They range from simple physical tests, which require little or no special equipment and give results easily interpreted by the layman, to complex and esoteric methods, which often need
elaborate apparatus and considerable experience to obtain and interpret meaningful results... (Kempe and Templeman, 1983:26).

Tests for hardness and specific gravity are simple, and are non-destructive if a scratch is acceptable. Thin-section microscopy and chemical analyses provide the most important information about a lithic material but they require special equipment and considerable interpretive skill. The petrographic microscope, which has been used as a tool of analysis since the latter part of the 19th century, can give important information about the composition of a lithic material by determining crystal forms and optical properties. "Wet" chemical analysis has also a long history as a reliable method but it is being replaced by modern spectrographic techniques.

In selecting a test one must be concerned with the kind of information that is required and the destructiveness of the test. Thin-section analysis requires the destruction of a small amount of material, but it is capable of providing a great deal of information about the composition of a material. Most chemical analyses also require the destruction of material. Unless a small portion can be removed and sacrificed, as has been done in studies of European stone axes, such tests may not be acceptable for artifact analyses.
A fine-grained lithic material, such as obsidian or chalcedony, may not be sufficiently distinctive under thin-section examination to relate it to a specific source but chemical analyses may make it possible. The presence of distinctive trace elements, or distinctive combinations of elements, may make it possible to relate a specimen to a known source.

Physical and chemical tests are valuable to obtain basic information about a lithic material, but the identification of some materials in artifacts or hand specimens may be accomplished by visual examination alone. Some rocks have features that make identification relatively easy, but many are difficult to identify unless further tests can be made. Identification is largely a matter of comparing an unknown variety with a known one and the greater the number of features in common, the greater the probability that the two are of the same variety.

Each lithic material of this study was examined with the objective of deriving information that will assist the archaeologist to identify it and to understand its properties. Apart from the similarity of the quartzites, little problem can be expected in distinguishing between the varieties themselves. However, some materials of this study may resemble an exotic variety. For example, the best quality of silicified peat may resemble Knife
River flint, and some fused shale and some siltstones may resemble jasper. Jasper, an impure chalcedony, cannot have visible spherical pores as does fused shale, and it will patinate whereas siltstones do not. Tests, such as heating to 300°C, will enable one to distinguish between materials that are basically chalcedonic silica and those that are not. Attention will be drawn to special identifying features of each variety or rock in this study.

4.1 Nomenclature of Lithic Materials

There are systems in several fields for naming lithic materials. Minerals may be named by an international committee; the Commission on New Minerals and New Mineral Names of the International Mineralogical Association. Rocks may be named according to a type exposure or formation. Unfortunately for the matter of nomenclature, most of the rocks that were used for chipping do not have type exposures and only one, quartz, is a mineral. Thus, many of them have been named by common usage or by first descriptive publication. Unidentified fine-grained rocks are commonly called "chert" or some other general name but further examination may enable one to apply a more specific name. Three of the rock varieties in this study are siltstones and, with the exception of Gronlid silt-
stone, two of them are called descriptively "feldspathic siltstone" and "silicified siltstone pebbles," the third has been called "Gronlid siltstone."

In this report, the definition of chert by Pettijohn will be followed. He says:

Chert is a dense rock composed of one or several forms of silica—opal, chalcedony (microcrystalline fibrous quartz), or microcrystalline quartz. It has a tough, splintery to conchoidal fracture. It may be white, or variously colored gray, green, blue, pink, red, yellow, brown and black (Pettijohn, 1975: 394).

This definition for chert excludes detrital rocks such as sandstones and siltstones. Although a chalcedony may be regarded as a variety of chert, any material that consists mainly of chalcedonic silica will be called chalcedony. The identities of sub-varieties of chalcedony are based on colour or banding. Reddish colours may be called carnelian, brownish ones sard, and greenish chalcedony may be called chrysoprase or prase.

Because of the variety of meanings attributed the term "flint" it will not be applied to materials in this study except where it is part of a generally accepted name. This practise is in accord with the view expressed
by Pettijohn (1975:394). It is commonly applied to European chalcedonies, and some regard flint as a "dark coloured chert."

Although silica can replace many materials this report will consider only those that have some significance for chipped stone industries. Many cherts are replacements of carbonate rocks or have been deposited contemporaneously with them. Silica replacements of wood, peat and lignite will be called "silicified wood," or "silicified peat" except where a proper name has been applied or is in common use.

4.2 Prehistoric Use

The most important aspect of studies of an archaeological lithic material is the way it was used by prehistoric people. It is apparent that there are temporal as well as spatial differences in material use. Also, some materials were used mostly for projectile points and minimally for knives and scrapers. Other materials were made into cutting and scraping tools but not points. Different technologies are apparent from a study of artifacts and chipping residue. For example, some groups practised thermal alteration while others did not, some groups understood pebble splitting better than others, some materials were shaped only by percussion methods.
and rarely, if ever, by pressure flaking. These matters will be discussed more specifically as aspects of each lithic material.

4.3 Specific Gravity

Specific gravity is the ratio of the weight of a specimen in air compared to that of an equal volume of water at room temperature. A simple balance is used for this determination and the procedure consists of weighing the specimen in air, and then in distilled water at room temperature. From these measurements the specific gravity can be calculated. When used for identification, the specific gravity of the unknown material is compared with specific gravities of known materials. This test is inexpensive, non-destructive and quick, but its utility is limited because many materials that can be chipped consist mainly of chalcedonic silica or quartz. Quartz has a specific gravity of 2.65 and chalcedonies are slightly lower (2.55 to 2.60), hence an accurate test might distinguish between quartz and chalcedony but it would not distinguish between varieties of chalcedony. Opal, which may resemble chalcedony, is significantly lighter (s.g. = 2.0-2.25), hence a specific gravity test could distinguish between them.
4.4 Hardness

Hardness refers to the relative ease with which a material can be scratched. The Mohs hardness scale represents a sequence of common minerals in order of increasing hardness as follows:

1. talc
2. gypsum
3. calcite
4. fluorite
5. apatite
6. orthoclase
7. quartz
8. topaz
9. corundum
10. diamond

The Mohs scale is useful for materials other than minerals but it can only indicate relative hardness. Its usefulness lies in that it is very inexpensive, it is only very mildly destructive and can be used in the field. Because of the narrow range of hardness of members of the chalcedony group, which are all very close to 7, it is of no value to distinguish between them. However, opal has a hardness of 5-6, hence a scratch test may allow one to distinguish it from chalcedony which it resembles. Ignimbrite, argillite and obsidian are about 6, hence they can be distinguished from members of the chalcedony or quartz varieties by scratch tests.

The Knoop test is capable of measuring hardness in
a quantitative way. The process consists of pressing a
diamond point into the specimen; the hardness of the spec-
imen is inversely related to the length of the indentation. This measurement along with the applied pressure
can give a quantitative value for hardness by means of
tables. The disadvantage of the Knoop test lies mainly
in the expensive machine that is necessary to do it.
Also, the size of the specimen is limited to about 3cm,
and the test can only be applied to a polished surface,
hence its value is limited for purposes of lithic identi-
fication. Knoop tests done by the Department of Mechanical Engineering at the University of Saskatchewan indi-
cated a slight decrease in hardness of chalcedonies after
heating, but no change in the hardness of siltstones.
This is not conclusive but it gives support to the idea
that changes in mechanical properties take place upon
heating chalcedony but not other rock varieties.

4.5 Fracture and Chipping Quality

To be suitable for chipping, a rock must be hard,
brITTLE and free from inherent cleavage planes and from
fractures or other flaws that are unduly limiting. Ma-
terials that are glassy or fine-grained may have these
required properties and they can be rated according to
the ease with which they can be chipped.
Chipping refers to the process of applying a force to an appropriate platform on suitable rock so that a spall is removed. Failure in tension along the face of separation allows its removal. The chipping quality of a rock is one of the most important variables that determine the nature of spalls that can be removed by a specific process. The successful removal of a spall is also dependent on tool qualities such as hardness and shape, the direction and velocity of the force, and the degree of immobilization of the objective piece. A chipped artifact is formed by the removal of a succession of spalls in a planned manner. In general, a flint knapper will want to remove flakes that are long and thin compared to their thickness. This is so because thin artifacts are generally preferred to thick ones; hence desired flakes must be long compared to their thickness.

The evaluation of chipping quality was assessed according to these factors: (i) the tendency of flakes to be long compared to their thickness; (ii) the force required to remove a flake of given dimensions; (iii) the tendency of flakes to terminate in a certain way—feather termination is desired and step or hinge fractures are not; and (iv) the ability to sustain compressive force without crumbling as when applied to a small pressure platform.

Efforts to develop scientific, reproducible tests
of chipping quality have been made but they are inevitably hampered by the lack of a useful theory of fracture. Bonnichsen (1977) used a mechanical device which he called a "stainless steel Indian" by means of which chipping force could be varied and measured. Bleed and Meier (1980:502-507) tumbled uniformly shaped blocks of different lithic materials and compared the sizes and weights of flakes that were knocked off each material. In practice, the evaluation of materials is done by experimental chipping according to the above criteria.

The empirical assessment of chipping quality will always be important but it may be possible to relate measurable properties to chipping quality. Some measurable properties are: compressive and tensile strengths, the ratio of stress to deformation, and elasticity.

Obsidian is one of the easiest materials to chip; it rates high in the criteria outlined. Chalcedony requires somewhat more force than obsidian but, because the term encompasses a wide range of materials, it is difficult to apply anything more than a general relative rating. Quartz crystal rates lower than chalcedony as it tends to be brittle and it is not mechanically isotropic, that is, flakes do not separate uniformly in all directions. On the more difficult end of materials that can be chipped are the detrital rocks such as quartzites. Basalts vary widely—the fine-grained and glassy varieties chip quite
well, but coarser varieties are so tough that they make excellent hammers.

The prehistoric flint knapper was commonly compelled by circumstances to use whatever material was at hand which, if it was tough to chip, resulted in artifacts that may be regarded as crude. By means of stone-chipping experiments inferences can be made about which materials would be preferred for certain kinds of tools. It is apparent that certain complexes required materials that were of a very good quality in order to make artifacts such as the finely-chipped Eden points or the Pelican Lake points with deep, narrow notches. On the other hand the sturdy basally-notched McKean points are commonly made from materials that would not have been used for points by other cultural complexes.

Specimens of lithic materials studied in this research were fashioned into the types of tools and projectile points that were used by prehistoric people of Saskatchewan. Where necessary, hard percussion was used to split a pebble or cobble or to remove a large flake to serve as a blank. Soft percussion modes for thinning were done by a portion of antler stalk. Pressure flaking by an antler time or portion of rib was used to finish the artifact. The quality of a heated specimen was compared with that of one in the natural state.
4.6 Changes in Properties due to Heating

It has been known for some time in archaeology that some properties of certain varieties of rock could be changed by heating. It has been observed that some rocks became easier to chip and that this improvement was accompanied by a more vitreous appearance of scars of flakes removed after heating. A change in colour sometimes accompanied these changes, but colour change is independent of changes in mechanical properties. Thermal alteration is of interest as an aspect of prehistoric technology, but it is also culture-specific in that it was practised by some cultural complexes but not by others. The ability to transform a tough material into one that can be more readily chipped widened the range of availability of lithic materials and facilitated the manufacture of better tools and weapons. Because lithic materials respond in different ways to heat, the nature of the response (or lack of tangible response) can be used as a feature of classification. As will be explained, chalcedony undergoes changes in properties when heated to 300°C, but materials that are not chalcedony do not. The search for an explanation for this phenomenon has intrigued lithic experimenters such as Crabtree as well as many archaeologists.

Purdy and Brooks (1971:322-325) did an early, in-
depth research on the effects of heat on Florida chert and other materials. They concluded that: "The critical temperature for Florida chert is about 350°C to 400°C" and that over 1100 ppm of iron was necessary for a colour change to be caused. Their explanation for the smoother flake scars of altered lithic material was that the grains of microcrystalline quartz were held more firmly together in heated specimens. They reasoned that fusion had taken place at this very low temperature due to the eutectic effect of impurities even though it was understood that the melting point of quartz is over 1700°C.

Mandeville (1973:177-202) agrees with Purdy and Brooks that impurities are the key to understanding thermal alteration. He expresses concern that the melting point of any of the impurities expected in chert is too high for them to melt, but assumes that the lower eutectic temperature of combinations may produce a "flux." The disappearance of water in heated specimens is not regarded by Mandeville as a cause of change in properties, but as a "peripheral phenomenon."

The eutectic flux explanation for changes in properties of some lithic materials must be questioned. The discrepancy between the melting temperature of silica (over 1700°C) and the observed temperature of property change is much too great to be explained by a eutectic lowering. Even if a solid state interaction could occur
between the silica and unspecified impurities, it would seem to be impossible for the marked changes in mechanical properties to be produced in the very short time which is necessary to cause a change in properties.

4.6.1 Experiments in thermal alteration were carried out as part of this research. Several independent variables must be taken into account when experimenting with thermal alteration of lithic materials. They are: the material type, the temperature range of the experiments, and the length of time for the application of heat. The materials selected for the experiment included: Knife River flint, Brandon (England) floorstone, Swan River chert, silicified wood, silicified peat, fused shale, quartzite, obsidian, Montana agate, and other agates and jaspers.

An electric oven designed for hobby enamelling and the burning out of investments in lost wax metal casting was used to apply heat in a controlled manner. The electric input can be adjusted by very small increments to regulate the rate of temperature rise. A pyrometer indicates the temperature in the top of the oven. Electrical input was adjusted to raise the temperature of the oven from room temperature to 300°C in approximately 90 minutes, and temperature was stabilized at 300°C for approximately 15 minutes. In order to minimize localized heat
shock the specimen of rock was wrapped in light sheet copper. Even though the pyrometer registers accurately, a polished steel strip was placed in contact with the lithic specimen undergoing heating. The colour of the oxide indicated the highest temperature that the specimen reached during heating. A pale yellow indicated a temperature of 226°C, and a dark blue indicated 298°C. Other colours indicated intermediate temperatures (Johnson, 1980:82-88).

A hand held antler pressure flaker was used to remove spalls from the samples. Heated specimens were compared with unheated specimens of the same material and differences in the ease with which flakes could be removed; differences in the lustre of new flake scars, and differences in colour were observed.

The class of materials that showed significant changes in properties included chalcedonies of chemical or biogenic deposition (Knife River flint and Brandon flint), chalcedonies of replacement (silicified wood and silicified peat), chalcedonies of cavity filling (agates), and chalcedonies of uncertain origin (jaspers). The classes of rocks that were unchanged by heating include detrital varieties such as quartzites and siltstones, igneous rocks such as obsidian and basalt, and those of other origin such as fused shale. The lack of response of Swan River chert indicates that it consists mainly of
quartz rather than chalcedonic silica.

These experiments support the hypothesis that chalcedonic silica is the active component of rocks whose flaking quality can be improved by heating to 300°C. Experiments of heating chalcedonies to higher temperatures indicate that they deteriorate in quality by becoming too weak, and many cracked and shattered at higher temperatures.

An archaeological question remains regarding how prehistoric craftsmen attained this narrow temperature target. To be sure, not all chalcedonies were commonly heated. Knife River flint does not need heat treatment, nor do other high quality materials such as Brandon floorstone. On the other hand, tough materials such as silicified peat were nearly always heated before pressure flaking. A prehistoric craftsman, before heating a piece of rock, would have to weigh the chances of benefit against the risk of utterly ruining it unless he had great confidence in attaining the right temperature.

Contemporary experimenters bury lithic material under an intended fire pit. With experience it is possible to gauge matters such as depth and soil composition, and the duration of the fire in order to beneficially effect the chipping quality. Archaeological evidence that this method was actually practised by prehistoric artificers seems to be lacking. It is possible to anneal chalcedony
by holding a flake with tweezers of green wood near a bed of hot coals. It is also possible to test the temperature by the reaction of organic material such as hair against the heated flake.

4.7 Petrographic Analyses

The petrographic microscope is designed to study the crystal structure and optical properties of rocks and minerals in thin-section. The identity of the specimen can be deduced from the information thus obtained. However, glasses such as obsidian and some chalcedonies are difficult to analyse as they lack a crystalline structure. However, contained crystallites in some obsidians make identification possible. Even with these limitations, petrographic analysis is an essential procedure for analysing archaeological lithic materials.

Thin-section slides were made of each variety of lithic material studied in this research and the analyses of these slides provided information that was, for the most part, not hitherto available. Some materials that had been called cherts or quartzites were found to be siltstones; organic substances that had been replaced by silica were identified; and differences between Tertiary and Quaternary specimens of quartzites could be distinguished.
4.8 Chemical Analyses

The chemical analysis of a rock will indicate the concentration of major elements (those that are greater than 2%), minor elements (from 2 to 0.01%), and trace elements (less than .01%). The major elements determine the character of the material, while the trace and minor elements may help to ascertain its identity and even its source. Clough and Cummins (1979) demonstrate how chemical analyses have made it possible to identify sources of the materials of stone axes in Europe. However, they indicate that, at that time, the chemical analysis of flint was not sufficiently advanced to enable them to identify its sources.

Qualitative and quantitative analysis of rocks by the wet method has been almost entirely superseded by physical methods such as optical emission spectrometry, atomic absorption spectrometry, X-ray fluorescence spectrometry, and by neutron activation analysis (Tite, 1972: 259).

The compositions of rocks studied in this thesis were determined by the Geochemical Laboratory of the Saskatchewan Research Council by ICP/AA procedures described by Kempe and Harvey (1983:42-43). The results of these analyses are presented in Table 1. The determination of SiO₂ is not particularly accurate by these methods and
<table>
<thead>
<tr>
<th>Oxides</th>
<th>Montane Agate</th>
<th>Silicate Flute</th>
<th>Silicate People</th>
<th>Feldspathic Silicate I</th>
<th>Feldspathic Silicate II</th>
<th>Tertiary-Quartzite</th>
<th>Knife River Flint</th>
<th>Knife River Flint</th>
<th>Knife River Flint</th>
<th>Knife River Flint</th>
<th>Knife River Flint</th>
<th>Knoll</th>
<th>Silicified Knoll</th>
<th>St. Croix</th>
<th>Dacite Bear</th>
<th>Dark Brown Fused Glass</th>
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<td>0.050</td>
<td>0.040</td>
<td>0.010</td>
<td>0.001</td>
<td>0.020</td>
<td>0.010</td>
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<td>5.040</td>
<td>%</td>
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<td>Mo</td>
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<td>Cr</td>
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<td>Ba</td>
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<td>Ni</td>
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<td>0.41</td>
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<td>Total ppm</td>
<td>1227</td>
<td>1980</td>
<td>662</td>
<td>1596</td>
<td>1273</td>
<td>1205</td>
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<td>Total ppm=</td>
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<td>0.20</td>
<td>0.06</td>
<td>0.16</td>
<td>0.13</td>
<td>0.12</td>
<td>0.04</td>
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<td>Total impurities</td>
<td>1.09</td>
<td>0.55</td>
<td>4.87</td>
<td>3.22</td>
<td>20.4</td>
<td>21.51</td>
<td>1.36</td>
<td>0.91</td>
<td>1.00</td>
<td>1.73</td>
<td>3.60</td>
<td>0.92</td>
<td>0.95 43.00 %</td>
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<td>SiO₂</td>
<td>96.91</td>
<td>99.45</td>
<td>95.13</td>
<td>96.78</td>
<td>79.59</td>
<td>78.49</td>
<td>98.64</td>
<td>99.09</td>
<td>99.00</td>
<td>98.27</td>
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<td>99.07</td>
<td>99.05 57.00 %</td>
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Table 1. Chemical Analyses
they do not measure water, carbon or sulfur. In these tests, the percentage of SiO₂ was calculated by subtracting the total of all other materials from 100%. In addition to the ICP/AA tests, the carbon and sulfur contents of Gronlid siltstone were also measured.

4.9 Colour

Colour is the most striking property of most rocks but it is not always a reliable means of identification. Its limitations lie in the variety of colours that may occur within a specific rock type and numerous materials may have a given colour range.

Chromophores such as Fe, Mn, Cr, Co, Ni and U may impart distinctive colours as do certain ionic groups. Hematite is a very common impurity that imparts a red colour, but iron sulfides produce black. Heat causes some iron compounds to change colour to a reddish hue. Multitudes of very minute cavities in milky quartz disperse the light so as to impart a whitish appearance. The black colour of some English flints is said to be due to finely dispersed carbon particles, but this is disputed by Shepherd (1972:23).

Colour may be a useful identifying feature if its range for a specific variety of rock is known. For some rocks this range is wide indeed as fused shale may occur
in yellow, red, brown, green, grey and black, or a single piece may show several of these colours. On the other hand, Swan River chert may only be white or light shades of practically all colours except green. A wide range of colours in a variety of rock indicates that it is chemically complex.

Colour charts such as Munsell are capable of indicating the intensity of a colour as well as its hue. It has not been applied in this thesis because of the difficulty in applying it to rocks that are not uniform in colour. Colours given are a matter of personal judgment.

4.10 Lustre

The reflectivity of a surface depends on the nature of the material and the regularity of its surface condition. Although some minerals have metallic, silky or pearly lustres, these qualities are unlikely to be encountered in lithic materials that can be chipped. Their lustre may be classified as:

- vitreous - having the lustre of glass
- waxy - having a dull lustre such as that of wax
- earthy - not lustrous such as shale

Lustre is useful in rock identification. Obsidian is immediately recognizable because of its vitreous lustre. A rock that consists mainly of chalcedony will usually
have a waxy lustre in its natural state, but heating to a certain range will cause fresh flake scars to be quite lustrous, even glassy. The natural lustre may be increased by external factors such as use or sand polish.

4.11 Texture

The texture of a rock describes the micro-relief of an unweathered or unaltered surface of a break not controlled by joints or residual platy structures. It depends on the following factors: (Pettijohn, 1975:24-99)

(1) grain size
(2) grain shape
(3) degree of crystallinity (from glassy to crystalline)
(4) contact relationship of the grains.

Texture terminology depends somewhat on the genesis of the rock. Igneous rocks may be described as aphanitic where separate grains cannot be distinguished by the unaided eye; or phaneritic where separate grains can be visually distinguished. Also, the texture may be holohyaline (glassy) in which separate grains are not formed.

Chalcedony has a characteristic smooth, fine-grained texture regardless of the way it was formed. The presence of anhedral, subhedral or euhedral quartz in cherty rocks usually imparts a rough texture to fractured surfaces.
such as is common in Swan River chert.

Sandstones have a distinctly granular texture, but the intergrowth of sand grains in many quartzites makes it difficult to recognize grains as separate entities. Quartzites fracture with a rough texture that depends on the sizes of the grains and the processes of lithifaction.

4.12 Structure

Whereas texture describes the grain-to-grain relationship within a rock or the absence of visible grains, structure refers to the larger features such as bedding, flow banding, parting and brecciation. Ideally, the brittle rocks that are suitable for chipping into artifacts are massive, nevertheless, the structure of a rock may provide clues for its identification. For example, silicified peat commonly has a distinctive structure of sub-parallel parting planes and some silicified woods have planes of weakness along growth rings. Vugs or cavities lined with quartz crystals are distinctive structural features of some rocks.

Spherical cavities in a rock indicate that it is of igneous origin or has undergone a melting process. Commonly basalts have such a structure, and small spherical voids may enable one to identify fused shale. Although chalcedony can have sub-microscopic pores, those that
are visible with low magnification or by the naked eye are invariably irregular. The distinctive shapes of voids enable one to visually distinguish between jasper and fused shale.

4.13 Cortex

The cortex is the naturally formed exterior layer of a nodule. The cortex often has differences of colour, texture and structure that set it apart from the basic material of the nodule. Some rocks do not display a cortex, but other varieties have a cortex sufficiently distinctive that it is a useful feature of identification. Pristine nodules of Knife River flint commonly have a light-coloured, opaque cortex that contains relict plant forms, and Tertiary cobbles commonly have cortical impact scars which are highly distinctive. Cortex ought not be confused with caliche, a carbonate that forms and adheres to a rock under certain soil conditions, nor is cortex a patination which is an external layer of the material that has become altered.

4.14 Patination

Patination refers to environmentally induced visible changes, usually a whitening, of surface layers. As some
rock varieties patinate and others do not, they can be classified accordingly. Those that patinate can be classed according to the rate and nature of the change. The reasons for patination are not well understood but it is apparent that different materials may patinate for different intrinsic reasons and under different circumstances.

The patination of chalcedony is of special interest to archaeology. Van Nest (1985:336) offers this explanation for the patination of Knife River flint which is basically a chalcedony: "Dissolution of silica is seen to be an important process acting to produce the optical effect we perceive as patination." Chemical analyses of Knife River flint and its patina, as shown in Table 1, show virtually the same composition and give support to the concept of Van Nest. That chalcedonic silica is porous, as explained by Folk and Weaver (1952), and that it is soluble in water, as stated by Frondel (1962:154), also support the solubility hypothesis. However, observations of patinated Knife River flint artifacts indicate that more information is necessary regarding the processes that cause patination. Recently exposed nodules of Knife River flint are not patinated, nor are projectile points of it that are of types less than about 2000 years old. Many have observed that Cody artifacts are commonly heavily patinated and that patination may be present on one or both sides. One may assume that if conditions within the
soil were the only factors causing patination then such artifacts would be uniformly patinated on all sides. These observations do not discount the solubility theory, but suggest that other factors—exposure and time—are also necessary.

4.15 **Special Identifying Features**

Distinctive features may aid in the identification of some fine-grained lithic materials. These features may be structural such as pores or vesicles, vugs, phenocrysts, fossils or healed fractures. They may also be diaphaneity, triboluminescence, or unusual colourations.

Rapidly cooled igneous rocks commonly contain spaces left by bubbles of gas. Some of these vesicles, as in basalt, may be quite large and subsequently become occupied by other materials. Spherical pore spaces, sometimes discernible only with the aid of magnification, indicate that the rock had undergone melting and relatively rapid cooling.

Chalcedony cannot have visible spherical voids, but it can have ones that are irregular. Irregular voids, called vugs, may be distinctive, and in some rocks they are lined with drusy quartz. Drusy vugs are common in Swan River chert and are one of its identifying features. Geodes of agate were formed by the filling of voids by
chalcedony in rock such as basalt. Such geodes commonly have a lining of quartz crystals.

Some chalcedonies were formed by the replacement of other minerals or organic material by silica, hence pseudomorphs of crystals and plant forms may provide features of identification. Silicified wood is a replacement of wood cells by silica. Knife River flint, which is regarded as a replacement of lignite, may contain fossils of plant material as does silicified peat. Fossils of marine organisms are present in many European flints and in Gronlid siltstone.

A distinctive feature of some rhyolites and many intrusives are phenocrysts. They are usually of feldspar which fuses at a high temperature and thus forms crystals at an early stage of cooling. The light coloured inclusions in some nodules of Knife River flint are apparently unique to that variety of rock and their presence enables one to identify it with some confidence.

Diaphaneity refers to the ease with which one can see through a material. Most lithic materials are transparent to translucent in thin-section, and diaphaneity varies inversely with thickness. Unless the thickness of a material be given and the amount of light transmitted per unit area be measured, diaphaneity can only be described in rather imprecise terms. In this thesis four grades of diaphaneity are used.
#1 Transparent: as clear as window glass; objects can be clearly discerned on the other side. Quartz crystal has this rating.

#2 Translucent: admits the passage of light but objects on the other side cannot be clearly discerned. Colourless Montana agate and light coloured Knife River flint are examples.

#3 Slightly translucent: the edges of thin flakes transmit light. Dark Knife River flint would be an example.

#4 Opaque: no light is transmitted, even along flake edges. Basalt is an opaque material.

When certain lithic materials are vigorously rubbed or crushed, light is produced on the contacting surfaces. This light is called "triboluminescence" and it is due to concentrations of electrons which leap across the space between the faces under stress. This phenomenon can also be observed when cutting with a diamond saw. Unlike the spark produced by striking with steel, the light produced is cold. This property is displayed by relatively few rocks such as quartz and sphalerite, hence it may be of value as an identifying feature. Quartzites are strongly triboluminescent, chalcedony slightly less so, but this property is absent in obsidian and in most other rocks of archaeological interest. To test for triboluminescence, portions of the same material may be rubbed together and its presence or absence observed in darkness or low light.
4.16 The Shapes and Sizes of Rocks

The shape of a pebble or cobble may be likened to a regular geometric shape such as a sphere, ellipsoid, cylinder, cube or prism, but in general, shapes are difficult to describe. A quality that is apart from shape is roundness which applies to the sharpness of edges and corners of clastic fragments. This property is useful in describing the form of a rock. Pettijohn (1975:56-57) classifies this feature as: angular, subangular, sub-rounded, and well-rounded. Roundness comparisons have some value in distinguishing between quartzite cobbles of Tertiary and those of Quaternary deposits. Tertiary cobbles, in general, are well-rounded whereas those of Quaternary deposits are generally subangular to sub-rounded. Hence, shape may be used to indicate the probable source of a quartzite cobble.

Pettijohn (1975:30) gives the following size ranges for rocks:

- boulder  256mm and over
- cobble   64mm to 256mm
- pebble   4mm to 64mm

This classification, which follows the Wentworth scale, will be used to indicate size ranges in this
thesis. The size of clasts or nodules of lithic material as well as their shapes controlled the kind of artifact that could be made from them.

4.17 Known Sources

Apart from fused shale which occurs as a bedrock outcrop, all other materials described in this thesis are secondary deposits and have been transported by natural action from their primary sources. Figure 2 shows known sources of lithic materials of this study. The map shows only those locations where I have observed specimens of material that I was confident had occurred there naturally. Nodules that showed signs of human working did not necessarily indicate that their provenience coincided with their natural deposition and were not considered.

As previously mentioned, the distribution of some materials by glacial action aggravates the problem of defining a source. Swan River chert was particularly troublesome in this regard. It is apparent that it was widely transported by humans but pristine nodules were observed only at the places indicated which are the Armit River region, the Coronach district, and a gravel pit north of Preeceville.

Gronlid siltstone can be ascribed with some confi-
dence to the Turonian Favel Formation of the Upper Cretaceous. Much of this formation was ground up by glacial action and the siltstone was distributed in a region that so far lacks clear definition. The discovery of a plate of it near Wynyard and the report by artifact collectors that it was observed in the vicinity of Lake Lenore indicates that there was a small but possibly significant deposit in that area.

Figure 2 represents a simplification of the map of Bedrock Geology from Richards and Fung (1969:46-47). It shows some Tertiary exposures which, as has been pointed out, yield specific varieties of rock studied in this thesis. A shaded area indicates possible sources of quartzite in the Shield, but this is admittedly imprecise and probably not complete. It purports to indicate that quartzite, as found in glacial drift in southern Saskatchewan, could have come from many places in a very wide area. It must suffice at this time to indicate that some rocks that could be usefully chipped had their origin in the Shield and were transported to southern Saskatchewan by glacial action.
Figure 2. A map of southern Saskatchewan indicating known sources of lithic materials of this study.
CHAPTER 2

DESCRIPTIONS OF LITHIC MATERIALS OF THIS STUDY

5.0 Introduction

This chapter consists of a presentation of the information derived about each of the nine varieties of rock examined in this research.

5.1 Athabasca Quartzite

1) Name: This rock is simply known as quartzite.

2) Prehistoric use: Quartzite is the most common lithic material in archaeological sites in southwestern Saskatchewan but it is much less common to absent in sites in east-central areas. It was used for coarser tools such as choppers and scrapers but was very rarely made into projectile points. Grooved mauls were made from cobbles which had suitable sizes and shapes, and unmodified and slightly modified cobbles were used as percussors.

3) Specific gravity: 2.65

4) Hardness: 7

5) Chipping quality: This quartzite is tough, and
detritus from chipping indicates that hard percussion was the main mode of manufacture.

6) Response to heating to 300°C: No change in properties, except reddening of some specimens.

7) Petrographic analysis: Tests of specimens EJ-5 and EJ-6 from Boutin's gravel pit at Domremy indicate that they were derived from a metamorphic source area (C. Gilboy, personal communication, 1986).

8) Chemical analysis: Not available.

9) Colour: Tan and white are the most common colours, mauve is also present.

10) Lustre: Fractured quartz sand grains have a glassy lustre.

11) Texture: Fractures have a rough texture and individual sand grains usually cannot be distinguished.

12) Structure: Massive, occasionally with colour banding.

13) Cortex: This material does not have a distinctive cortex.

14) Patination: This material does not patinate.

15) Special features: Strong triboluminescence.

16) Size and shape of clasts: Clasts range from pebble to boulder size; the typical shape is subangular to subrounded (Pettijohn, 1975:57).

17) Source: The primary source of this quartzite is the Precambrian Shield of northern Saskatchewan. Expo-
sures of psammites (which include quartzites) are shown by Whitaker and Pearson (1972) in the vicinity of Wollaston Lake and Geikie River, and in an area east of LaRonge. Glacial flow was in a general south-westerly direction, thus quartzite was transported as part of the glacial drift to southwestern Saskatchewan.

5.2 Rocky Mountain Quartzite

1) No specific name has been applied to this variety of rock; it is simply called "quartzite."

2) Prehistoric use: Quartzite artifacts and flakes are common in archaeological sites in southern and western Saskatchewan. Artifacts of quartzite consist mainly of coarser tools, but some projectile points were made from this variety.

3) Specific gravity: 2.6+

4) Hardness: 7

5) Chipping quality: In general this quartzite is tough, but fine-grained specimens can be shaped by soft percussion and by pressure flaking.

6) Response to heating to 300°C: None, apart from reddening of rocks that contain iron compounds.

7) Petrographic analysis: A specimen indicates that sand grains maintain their individual nature, thus suggesting sedimentary formation.
8) Chemical analysis: +98% silica; minor elements are P, Ti, Al, Fe, Na, Ca, Mg, K and Ba. Trace elements are also present.

9) Colour: Tan is most common, but white, shades of blue, grey, purple and pink also exist.

10) Lustre: Fractured sand grains have a glassy lustre.

11) Texture: Sand grains are well-sorted but individual grains usually cannot be distinguished without magnification.

12) Structure: Massive, colour banding is common.

13) Cortex: Because these rocks have been fluvially transported a considerable distance from their primary source, they have well polished surfaces. A significant proportion show impact scars, also called percussion marks, which are vestiges of Hertzian cones resulting from innumerable forceful impacts against other rocks. Their presence indicates high velocity flow in a rocky environment (Pettijohn, 1975:63).

14) Patination: This rock does not patinate.

15) Special identifying features: Symmetrical, well-rounded shapes; impact scars; slightly translucent; strongly triboluminescent.

16) Size range and shapes of typical rocks: The size ranges from pebble to boulder; clasts are typically symmetrical and well-rounded.
17) Known sources: The uplands of the Cypress Hills are capped by gravels transported in Eocene-Oligocene times by fluvial action from the Belt Formation in northern Montana. These gravels are mainly quartzite whose composition and transportation have been described by Vonhof (1969). The gravels that cap much of the Wood Mountain area are of Miocene deposition, and likewise consist mainly of quartzite but are generally of a smaller size range. These materials were transported from the southwest by vigorous fluvial action due to western up-lift at a time when the elevations of the Cypress Hills and Wood Mountains were possibly much lower than their present-day heights. Gravel deposits such as those west of Ponteix on SW 31 T9 R12 W3 and north of Cadillac on NW 17 T10 R13, and east of Buffalo Gap on SW 2 T2 R26 W2 have been reworked by glacial action yet consist predominantly of Tertiary quartzite. Mollard (personal communication, 1984) has indicated that Tertiary gravels in the form of gravel deposits of commercial significance are present in a block consisting of townships 1 to 8 in ranges 22 to 30 west of the 2nd meridian, and a block consisting of townships 1 to 16 in ranges 1 to 30 west of the third meridian (see Figure 2).

The abundance of quartzite in Tertiary deposits can account for its presence in most sites in southwestern Saskatchewan.
5.3 **Swan River Chert**

1) **Name:** Swan River chert derived its name from Swan River, Manitoba where it was observed as a distinctive lithic material. There is no essential relationship between Swan River chert and the Swan River Formation. The report by Campling (1981:291-301) on Swan River chert will provide the basis for this section.

2) **Prehistoric use:** Even though Swan River chert is rather difficult to work and nodules are commonly unsound due to many voids, it has been used by all the prehistoric cultural complexes that have occupied southern Saskatchewan with the apparent exception of the fluted point traditions. Swan River chert was used for the manufacture of all types of projectile points common to this area and for choppers and cutting and scraping tools as well. The dominance of Swan River chert as a lithic material in east-central Saskatchewan is shown by the high proportion of it in collections from this area. The proportion of it dwindles in collections that are farther south and farther west. The collection of S. Durr of Bromhead consists of artifacts mainly of Knife River flint; very few are of Swan River chert. Similarly, the collection of H. Liboiron of Ponteix contains very few that are of this material. It is estimated that about 2% of artifacts from central and west-central Saskatchewan are made
from Swan River chert.

The large amount of detritus of Swan River chert on the Campbell strandline of Lake Agassiz, where it meets the Armit River, indicates that natural deposits of it had been abundant in the vicinity, and the abundance of coarse flakes and shatter indicates that extensive reduction and probably tool manufacture had been done there. Swan River chert flakes comprise the most obvious archaeological residue in many fields and sites in east-central Saskatchewan, and cores of Swan River chert in western Saskatchewan, where pristine nodules have not been found, strongly indicate an extensive pattern of human transportation far from its known source.

3) Specific gravity: Variable due to porosity, about 2.6

4) Hardness: 7

5) Chipping quality: Generally, Swan River chert is difficult to chip. Fine-grained varieties chip reasonably well, but the more crystalline varieties are very difficult to work.

6) Effects of heating to 300°C: No improvement in flaking quality has been observed due to heating.

7) Petrographic analysis: Campling has noted the tri-modal crystallinity of Swan River chert and makes this statement about it:
Swan River chert is macroscopically variable but microscopically distinctive. Under cross polarized light, it exhibits a tri-modal crystallinity of granoblastic quartz, chalcedony spherulites and anhedral crypto-crystalline quartz. Varieties of chert not exhibiting this crystallinity are not considered to be Swan River chert (Campling, 1981: 301).

From the thin-sections of two specimens, Gilboy (personal communication, 1986) has observed that there are several distinct generations of quartz.

8) Chemical analysis: 99% silica, minor elements are P, Al, Ti, Fe, Na, Ca, Mg and K. Several trace elements are also present.

9) Colour: Swan River chert is mainly light colored but there may be cortical tinges of black. Shades of pink, orange, grey and blue are common, and it may have mottled colours or banding.

10) Lustre: The fractured surfaces of quartz crystals have a glassy lustre; fine-grained specimens have a waxy lustre.

11) Texture: The texture ranges from very fine-grained to coarsely crystalline.

12) Structure: Most Swan River chert is porous and vuggy. Vugs are commonly lined with subhedral quartz
crystals. The best grade is amorphous and is usually pink in colour.

13) Cortex: Swan River chert does not have a distinctive cortex.

14) Patination: Swan River chert does not patinate.

15) Special identifying features: Light colour, drusy vugs and crystalline texture. Opaque and strongly triboluminescent.

16) Size range and shape of typical nodules: Cobble to boulder. Nodule shape is angular to subrounded.

17) Known sources and geological origin: Campling describes a material which has wide variability and which occurs naturally in a large area which has yet to be reasonably well defined. No formation has so far been discovered which yields in situ nodules of Swan River chert in bedrock outcrop, hence there are problems in giving this variable material a real identity. The wide distribution of Swan River chert in glacial drift exacerbates the already difficult problem of identity.

It is generally assumed that Swan River chert is a replacement of limestone or that it was formed by cavity filling in the limestone which has since disappeared. The location of its formation is uncertain but it was probably in west-central Manitoba and the chert nodules were transported southward and westward by glacial action. Campling (1980:292) states: "It [Swan River chert] is
especially abundant in archaeological deposits in the re-
gion west of Lakes Manitoba and Winnipegosis." Unworked
nodules of Swan River chert have been observed in the bed
of the Armit River and its vicinity. Cobbles have been
recovered from a gravel pit north of Preeceville and from
piles of rocks collected from fields in the vicinity of
Coronach. Boulders of Swan River chert have been observed
in the riprap lining the banks of the causeway over the
Little Poplar River. It must be concluded that these
specimens of Swan River chert were deposited in this area
by glacial action rather than by human transport. The
presence of Swan River chert is very uneven as it appeared
to be absent from gravels at Canora. The actual sources
of Swan River chert that existed must have been very sub-
stantial and it is possible that in some areas this re-
source has been entirely depleted by prehistoric users.
It is apparent that better quality material was heavily
exploited because the only nodules that can be found to-
day are very low grade.

5.4 Silicified Peat

1) Other names: Petrified bog, silicified lignite,
South Saskatchewan River chalcedony, petrified wood and
sard.

2) Prehistoric use: The utility of silicified peat
for projectile points is limited by its inherent parting planes, hence large points are rare. Projectile points classified as Duncan, Hanna, Pelican Lake, Besant, Avonlea, and late side-notched made of silicified peat have been recovered as well as numerous cutting and scraping tools. Artifacts made from silicified peat are common in sites along the shore of Lake Diefenbaker, and are present in many collections in southern Saskatchewan. A distant recovery of this material was made at an Avonlea site at Turtle Lake. This material was usually heated before pressure flaking. There is evidence that nodules were subjected to heat which caused them to disintegrate into thin fragments. These thermally altered fragments could then be pressure flaked to form artifacts.

3) Specific gravity: 2.59

4) Hardness: 7

5) Chipping quality: Even though natural silicified peat is fine-grained it is tough to chip. Sound portions have a good conchoidal fracture. Inherent parting planes may limit the usefulness of the material in any specific nodule but, on the other hand, where the parting planes were suitably spaced and reasonably parallel, they permitted a nodule to be separated into thin pieces that could be shaped by pressure flaking without resort to percussion modes.

6) Response to heating to 300°C: Heating silicified
peat to 300°C permits a reduction in the force required to remove a flake of a given size and there is less tendency for hinge fractures to occur; fresh flake scars will be lustrous and the cortex may take on a reddish hue.

7) Petrographic analysis: Thin-section specimen EJ-6 is described as follows:

Under crossed polars, the rock is seen to be made up of a very fine-grained mosaic of quartz crystals with intermittent thin layers dominantly composed of flaky minerals—probably illite. Granular opaque minerals of unknown composition are concentrated along foliation planes cutting across the foliation. Several ovoid patches of coarser-grained silica may represent silicified organic matter. A veinlet of fibrous quartz is oriented sub-parallel to the planar fabric of the rock (Gilboy, personal communication, 1986).

8) Chemical analysis: A chemical analysis of silicified peat showed 98% silica. There were 280 ppm (parts per million) of barium, 0.5% of Al₂O₃, 0.12% of Fe₂O₃, 0.14% of Na₂O, and small amounts of other metals and ions.

9) Colour: The range is from a greyish tan to dark brown.

10) Lustre: Waxy in the natural state to glassy
Sweet are the uses of adversity;
Which, like the toad, ugly and venomous,
Wears yet a precious jewel in his head;
And this our life; exempt from public haunt,
Finds tongues in trees, books in running brooks,
Sermons in stones, and good in everything.

William Shakespeare. As You Like It. ActII, Scene 1
after heating.


12) Structure: Silicified peat typically separates along irregular, sub-parallel parting planes which may be so close and so irregular as to render the material nearly useless for the manufacture of chipped artifacts. Fossil plant forms are commonly recognizable in the material as well as in the cortex. Vugs and other voids have not been observed.

13) Cortex: Commonly a tan coloured cortex is present on unworked nodules. Fractured nodules will usually have this cortex on opposite parallel faces thus indicating that the material was formed as a bed. Portions of fossil plants may be discerned in this cortex which has some resemblance to that of Knife River flint.

14) Patination: Silicified peat patinates to a white to creamy colour which is commonly mottled or uneven. It is assumed that exposure to atmospheric conditions for an extended period of time is necessary to induce patination as freshly exposed clasts or nodules are not patinated. Pelican Lake type points and those that are older are usually patinated but more recent types do not have patination.

15) Special features: Irregular parting planes, plant fossils in cortex, strong triboluminescence.
Slightly translucent to opaque.

16) Size and shape of nodules: Tabular nodules of silicified peat of over 500mm have been observed. However, most silicified peat represents fragments of such nodules, and they are commonly of cobble size.

17) Source and origin: Naturally deposited nodules and clasts of silicified peat have been observed (i) south of Rockglen, (ii) on portions of the western shore of Lake Diefenbaker, and (iii) in gravel deposits in the vicinity of Macrorie.

Although it might be assumed that silicified peat was transported from northern Montana as part of the Tertiary gravels, there is good reason for inferring that it was formed after this deposition. Vonhof (1965) and (1969) has convincingly explained the geological reasons for the presence of the gravels that cap the uplands of the Cypress Hills Formation and the Wood Mountain Formation. He states that western uplift of the Rocky Mountains caused vigorous rivers that transported gravels, which consist mainly of quartzites, from northern Montana into the region of southwestern Saskatchewan. These events took place during the Eocene-Oligocene and Miocene Epochs of the Tertiary Period. The clasts thus transported are well-rounded and many show the circular scars derived from innumerable impacts against other rocks. Whereas the fluvially-transported gravels borne from northern
Montana are well-rounded, the nodules of silicified peat show no evidence of battering and are sometimes of considerable size. Broughton (1976:1719) reports clasts that have an area of 0.28 m². Fragments of nodules are angular and in no way show the rounding and battering of fluvial transport. Furthermore, the tendency of silicified peat to separate into thin layers argues against the fluvial transport of intact pieces for any significant distance. The Wood Mountain uplands were not modified by the Wisconsin glacier and they show none of its deposits. It must be assumed that silicified peat was formed, more or less in situ, in the Wood Mountain region in post-Miocene times, and that it was not transported there by either fluvial or glacial action. Murata (1940: 586-596) has described the role of volcanic ash as a probable factor in the replacement of organic material by silica, and Crawford (1955) has noted the presence of pumicite near Rockglen and at other places in southern Saskatchewan. A reasonable hypothesis is that silicified peat, which may now be found amongst the Wood Mountain gravels, was formed at some time after their deposition, but the presence of this material in the Birsay-Macrorie district awaits a more detailed geological explanation.
5.5 **Silicified Wood**

1) **Names:** Sometimes called petrified wood or agatized wood. If the rock was formed by the replacement of the wood cell structure by silica, "silicified wood" is preferable to the term "petrified wood" because the latter includes replacement by materials other than silica such as carbon or goethite.

2) **Prehistoric use:** Silicified wood is relatively common in archaeological sites in southern Saskatchewan both as artifacts and as chipping debris, but it is uncertain how much of the material is from a source within Saskatchewan. Two distinct varieties of silicified wood have been observed and it is probable that intermediate varieties exist. The distinction lies in the form of silica in the replacement; it may be in the chalcedonic or the quartz polymorph. The chalcedonic-replacement variety is of good quality and was used for projectile points and for cutting and scraping tools, but the extent that the quartz-replacement variety was used is quite uncertain.

3) **Specific gravity:** 2.56-2.60

4) **Hardness:** 7

5) **Chipping quality:** The chalcedonic silica variety of silicified wood chips quite well even if not heated, but heating makes it chip much easier. The flaking
quality of the quartz replacement is very poor as it is very tough and the material separates in a blocky way so that pieces of a usable size and shape are exceedingly difficult to obtain.

6) Effect of heating to 300°C: Chalcedonic silica replacements become easier to flake, flake scars are more lustrous, and shades of brown become somewhat redder. Heating the quartz replacement variety has no apparent effect on chipping qualities.

7) Petrographic analysis: A thin-section analysis of specimen "Rockglen 1" (a chalcedonic silica replacement) includes the following statement:

The original wood's fine-laminated texture is well preserved.

Specimen "Rockglen 2" (mainly a quartz replacement) shows a more clearly defined cell structure; the quartzitic nature of the cell replacement is indicated by the following statement:

Open vugs in the rock are lined first by finely-radiating quartz crystals upon which are developed either large, clear quartz crystals with euhedral terminations facing into open space or, when vugs are completely infilled, polygonal, unstrained
quartz grains (Gilboy, personal communication, 1986).

8) Chemical analysis: Not available.

9) Colour: Chalcedonic silica pseudomorphs after wood are generally translucent and may be white or have shades of brown or grey. Annual growth layers may not be apparent in hand specimens. This material resembles agate, hence may be called "agatized wood."

Much more common than the wood replaced by chalcedonic silica is the variety which has been replaced by quartz. Its colour is commonly shades of brown or grey, it is usually opaque, annual growth rings are prominent and usually represent planes of weakness. Commonly sparkles from minute subhedral quartz crystals can be discerned. As previously stated it is uncertain that this variety was used for chipped tools.

10) Lustre: The chalcedonic silica replacement variety (agatized) has a waxy lustre, but that of the quartz-replacement type may be waxy but it also has sparkles from the reflection from its subhedral quartz crystals.

11) Texture: Chalcedonic silica replacements have an amorphous texture; those of quartz replacement commonly have a gritty or granular texture.

12) Structure: Chalcedonic silica replacements usually do not separate along annual growth layers but
they may have random fractures. On the other hand, the quartz replacements separate along growth rings in such a way as to make the value of this material very limited or even useless for chipping purposes.

13) Cortex: Neither variety of silicified wood has a distinctive cortex.

14) Patination: Chalcedonic silica replacements patinate to a white or creamy white upon exposure to atmospheric conditions. Silicified woods formed by quartz replacement do not patinate.

15) Special features: It is justifiable to apply the term "silicified wood" to a lithic material if a wood structure can be recognized either microscopically or macroscopically.

16) Nodule size: Chalcedonic silica pseudomorphs of wood have been recovered that have a maximum dimension of 30cm and a weight of 10kg. This is not to say that such pieces are sound throughout. Quartz replacement tree stumps of a meter in height have been recovered south of Rockglen and small fragments of this material are common on uplands in the vicinity of Eastend.

17) Sources and geological formation: The Wood Mountain Formation south of Rockglen is well known as a source of silicified wood. It is impossible for it to have been transported by fluvial action to its present-day provenience, and it is unlikely that it was brought there
by glacial action. Therefore, the best a priori hypothesis regarding the presence of silicified wood in the Rockglen area is that it was formed approximately in situ at some time after the deposition of the fluvially transported gravels of the Wood Mountain Formation. It is possible that the silicified wood was formed at the same time and due to similar conditions as was silicified peat.

5.6 Silicified Siltstone Pebbles

1) Names: Quigg (1978) refers to "pebble cherts;" Pierce and Hunt (1937:242) call them "chert pebbles," They are also called "black pebbles."

2) Prehistoric use: The maximum size of these pebbles limits the type of artifact that can be made from them. Small to medium-sized projectile points and end-scrapers are common in artifact collections from western Saskatchewan. Recoveries have been made of silicified siltstone points of Oxbow type and of all later cultural complexes that occupied this region.

The first necessary step in chipping these pebbles was to split them through their major axes. Knowledge of how to do this was not possessed by all the groups who used them, and to judge by the detritus from working them, this skill may be culture-specific. A poor technology resulted in many orange-segment shaped fragments and a high
proportion of unusable pieces. A successful technology shows evidence of a high proportion of splits through the major axes of pebbles. The desired result is to split a pebble to produce similar halves, or at least to drive off a long, thin spall. These portions can then be shaped by pressure flaking to form tools or projectile points. The pitting on some stone mauls suggests that they were used as anvils for pebble splitting.

3) Specific gravity: 2.55 to 2.61

4) Hardness: 7

5) Chipping quality: After having been split, a pebble can be pressure flaked without undue difficulty, and feather-terminated flakes can be removed.

6) Response to heating to 300°C: No change in mechanical properties was observed.

7) Petrographic analyses: Analyses of thin-sections of specimens EJ-1, EJ-2, EJ-3 and EJ-4 indicate that these pebbles are silicified siltstone rather than chert. Silica has replaced other materials in some places, and traces of zircon, probably chlorite, probably epidote and apatite have been observed (C. Gilboy, personal communication, 1986).

8) Chemical analyses: These siltstone pebbles are high in silica—95% to over 99%. Barium is a prominent minor element—up to 0.14%; \( \text{Al}_2\text{O}_3 \) ranges from 0.10 to 3.1% and \( \text{Fe}_2\text{O}_3 \) from 0.01% to 0.59%. Many other metals
and metal oxides are also present as shown in Table 1.

9) Colours: The most common colour is black throughout, but grey or brown pebbles are also present. Some pebbles have a black coating and interiors of green, grey, tan, pink, red, yellow or mauve.

10) Lustre: Dull waxy.

11) Texture: Mostly amorphous, but some pebbles have a very fine-grained texture.

12) Structure: Massive, with no vugs, inclusions or parting planes.

13) Cortex: With the exception of the relatively few pebbles that are grey or brown, and those that are black throughout, silicified siltstone pebbles have a dense black cortex that is one to two millimeters in thickness. Pierce and Hunt (1937:244) suggest that this coating is black iron oxide. Pebble surface is well polished.

14) Patination: This material does not patinate.

15) Special features: The well-rounded ellipsoidal shapes are distinctive as is the cortex. The material is opaque, and is not triboluminescent.

16) Size and shape: The pebbles are of "pebble" size (i.e. up to 64mm maximum dimension), and the typical shape is a flattened ellipsoid.

17) Known sources: Silicified siltstone pebbles are sparsely present in the glacial drift of parts of
west-central Saskatchewan. They are fairly abundant on the shore of Grassy Island Lake which is east of Compeer, Alberta; many have been split or broken by human action. Quigg (1977) describes other areas in the Neutral Hills that yield these pebbles. Pierce and Hunt (1937:244) describe "chert pebbles" in Eagle sandstone and the Claggett shale of Montana.

Although black pebbles are common in some horizons of the Viking Formation, there is no reason to assume that they are the same as the silicified siltstone pebbles used as a prehistoric lithic material. Regarding the origin of the silicified siltstone pebbles it seems probably that they are part of an ancient formation and that they were washed down from western uplands during Cretaceous times and are now found in the gravels of the strandlines of these ancient seas (W.O. Kupsch, personal communication, 1967).

5.7 Gronlid Siltstone

1) Names: It has been called "altered felsic lava" and Meyer and Carter (1978:88) referred to "River House chert" that is probably Gronlid siltstone but this name has not come into common use. The name "Gronlid siltstone" is applied in this thesis because of the bedrock erratic containing this siltstone which was discovered
north of Gronlid.

2) Prehistoric use: Projectile points are the most common type of artifact made from Gronlid siltstone and the oldest type recognized is Oxbow. It was also used for knives and scrapers. The greatest proportion of Gronlid siltstone in collections is in those of east-central Saskatchewan. For example, 2% of artifacts in the collection of A. Campbell of Bjorkdale are made from it. An Oxbow point of Gronlid siltstone has been recovered from eastern Alberta and artifacts made from it are present in collections from central and western Saskatchewan.

3) Specific gravity: Not available.

4) Hardness: 6

5) Chipping quality: Gronlid siltstone is rather brittle, but long, thin, feather-terminated flakes can be removed by soft percussion and hand-held pressure modes.

6) Response to heating to 300°C: No discernable change in properties, but nodules freshly exposed from the shale bedrock emit a rubbery odour upon heating.

7) Petrographic analyses: The grey siltstone which embeds the black Gronlid siltstone has the striking microscopic feature of clear circular patches which consist of a single, clear carbonate crystal. Some of the carbonate has been replaced by silica, but the groundmass is mainly made up of microcrystalline carbonate.
Regarding the "cherty layer" (Gronlid siltstone)

Gilboy states:

This is texturally similar to the adjacent siltstones, especially in that the dominant microscopic features are clear circles (cross-sections of spheres), which here are made up almost entirely of quartz, with microcrystalline rims enclosing coarser-grained, radiating-fibre interiors. All the carbonate in the siltstone groundmass has been replaced by pale brownish microcrystalline silica, with opaques and dusty ore minerals about as abundant as in unsilicified areas (C. Gilboy, personal communication, 1986).

8) Chemical analysis: A specimen of Gronlid siltstone consisted of 96% silica; minor amounts of Al₂O₃, Fe₂O₃, K₂O, Na₂O and P₂O₅. CaO made up 0.387%, and there was 1.5% carbon and 0.41% sulfur. Water was not measured.

9) Colour: Dense, opaque black.

10) Lustre: Waxy.

11) Texture: Amorphous.

12) Structure: Massive, with no vugs, pores, spaces or banding. Some specimens have small chalk specks.

13) Cortex: A light-coloured calcareous shale adheres to nodules which have been recently exposed from
the bedrock. A remnant of this shale remains on pristine nodules as a gritty, buff-coloured cortex. Some cortex may remain on artifacts and, where present, positively identifies the material as Gronlid siltstone.

14) Patination: Gronlid siltstone has a distinctive patination consisting of a very fine mottling which gives the material a grey appearance. Freshly exposed nodules are not patinated, but Oxbow points show patination which indicates that exposure plus time are factors in causing patination.

15) Special identifying features: Where present, the mottled patination gives positive identification; the gritty grey cortex is also distinctive. The material does not display triboluminescence and it is opaque.

16) Size and shape of nodules: Gronlid siltstone was formed as lenses in the embedding shale, but tabular masses may also have been formed. Stresses in the shale during glacial transportation have caused the fragmentation of nearly all nodules. The greatest thickness known is 50mm, and the piece with the greatest known lateral dimensions measures 150mm by 109mm by 15mm. This piece was recovered from the SE-SE S27-T33-W3 but it is uncertain whether its presence there is due to human or natural action.

17) Formation and source: Recent petrographic analyses of Gronlid siltstone indicate that it is a silt-
stone in which silica has replaced carbonate material. Minute carbonate spheres, which are probably the remains of coccolithophorid algae (Caldwell, 1982:298) are present in the enveloping shale and have been largely replaced by silica. The carbonate in the groundmass has also been largely replaced by microcrystalline silica.

Microfossils consisting of foraminifera suggest but do not prove an origin from the Turonian Favel Formation of the Upper Cretaceous and that the matrix is Second White-Speckled Shale (McNeil, personal communication, 1986).

James Finnigan, of the Nipawin Dam Archaeological Project, in 1985 reported an outcrop of shale on S24-T49-R18 W2 which yielded nodules of Gronlid siltstone. This site is on the north side of what was then the Saskatchewan River, and it lies some 32 km west of Codette. This body of shale is a bedrock erratic that has been transported by glacial action from its primary source that most likely lies in a north-east-by-easterly direction from this exposure.

Fragments of Gronlid siltstone are present in very small amounts in the glacial drift in an area that extends south-westerly from Nipawin; these small fragments have been observed as far away as western Saskatchewan.
5.8 Fused Shale

1) Names: Fused shale is sometimes called porcellanite or silicified siltstone. Of these names, "fused shale" is preferable because of the variety of meanings attributed to "porcellanite," a few of which are presented. Pettijohn (1975:394) does not include fused shale among rock varieties called porcellanite. Although the Dictionary of Geological Terms (1957:338) includes "fused shale" as one of the meanings of porcellanite, it also gives: "A light-colored, porcellaneous rock resulting from the contact-metamorphism of marls." Nockolds, Knox and Chinner (1978:291) state: "Porcellanous chert or porcellanite [emphasis added] is a porous rock of low density and with dull fracture; it often contains fine clay or carbonate inclusions." Kempe and Harvey (1983:177) refer to "...a porcellanite resulting from the thermal metamorphism of an inter-basaltic soil horizon or bole...." Thus, "fused shale" as a name is descriptive of the origin of this material and is therefore preferable to a name which simply indicates that it looks like porcelain.

2) Prehistoric use: Fused shale was popular for the manufacture of projectile points and to a lesser degree for tools for cutting and scraping. A Folsom point of fused shale was recovered from the vicinity of the Great Sand Hills, and a Scottsbluff point was recovered
from the Napao site near Ponteix. Projectile points made from fused shale from later complexes are relatively common in artifact collections from southern and western Saskatchewan. However, it is not certain how much of this material has a source in Saskatchewan.

3) Specific gravity: Up to 2.6, depending on porosity.

4) Hardness: 6 to 7

5) Chipping quality: Fused shale is not a uniform material, but in general it has a good conchoidal fracture and it can be chipped by percussion and pressure modes to produce long, thin flakes.

6) Response to heating to 300°C: No changes in properties have been detected.

7) Petrographic analysis: A thin-section of a very fine-grained specimen, although clear under polarized light, is virtually opaque under crossed polars. This indicates that it had been converted to glass. Silt-sized grains were barely discernable.

8) Chemical analysis: A specimen of dark brown fused shale showed 57% silica, over 17% of Al₂O₃, 7.4% of CaO, 6.8% of Fe₂O₃, 5.0% of MgO, and lesser amounts of other oxides. Barium was high at 0.08%, other metals were in the trace range.

9) Colour: Specimens vary immensely in appearance; it can range from a light grey to black, and colours of
yellow, red, green and brown are relatively common.

10) Lustre: The lustre of fused shale may range from earthy for specimens that have not been highly heated, to glassy for those that have been heated to fusion.

11) Texture: The texture may vary from very fine granular to glassy.

12) Structure: Minute spherical voids can be detected with the aid of magnification in nearly all fused shale. Colour banding is not rare, and there may be a variety of colours in any one specimen.

13) Cortex: Outside layers may be more porous, but there is no cortex as such.

14) Patination: Fused shale does not patinate.

15) Special features: Fused shale is opaque, it is not triboluminescent, and can be distinguished from jaspers if spherical voids can be detected. The unusual colouration of fused shale may distinguish it from most other materials.

16) Size and shape of clasts: Because lumps of fused shale were broken or pried off the exposure of the main mass, they cannot be said to have any particular shape or size.

17) Known sources: Fused shale can be formed wherever coal beds combust and in doing so heat the walls of the borehole to the point of melting. The Ravenscrag Formation of the Paleocene Era of the Tertiary provided coal
beds near the surface, hence, it is a source of fused shale in Saskatchewan. Known exposures of fused shale are on NW 10 T3 R25 W2, and on SW 11 T3 R35 W2 and NE 1 T2 R8 W2. The two sites northwest of the village of Big Beaver have been extensively exploited by prehistoric people. The exposure on NE 1 T2 R8 W2 to the south of Estevan has been disturbed by the historic removal of the reddened, friable heated shale and it is uncertain that it was exploited by prehistoric people. It can be assumed that other outcrops of fused shale have existed or still may exist in Saskatchewan in places such as along the Frenchman River valley but they have not come to my attention.

5.9 Feldspathic Siltstone

1) Name: Feldspathic siltstone is a generic name for a material which has been called quartzite, red quartzite, maroon quartzite or argillite. As far as is known, it lacks a specific name in spite of its distinctive appearance.

2) Prehistoric use: Feldspathic siltstone was used for the manufacture of relatively large flaked artifacts. The collection of Henri Liboiron of Ponteix contains Agate Basin, Hell Gap and other large points made of feldspathic siltstone. Smaller points of Oxbow or
later types of this material have not been recognized which indicates that percussion flaking was the main mode of fabrication, and that pressure flaking was used minimally if at all. The most common artifact of feldspathic siltstone is the large end-scraper which is usually between 50mm and 100mm in maximum dimension.

3) Specific gravity: Not available.
4) Hardness: 6 to 7
5) Chipping quality: Finer-grained specimens chip better than coarser ones. Even the better qualities are quite tough but they can be shaped quite well by soft percussion. Pressure flaking is difficult and, if one is to judge by the dimensions and shapes of artifacts in collections, prehistoric artisans did not use this mode of reduction to any extent.
6) Response to heating to 300°C: No change in properties has been observed.
7) Petrographic analysis: Gilboy (1986) presents this interpretation of a thin-section:

About half the rock is composed of subangular to angular detrital quartz grains which have well-oriented long axes. About 3 percent muscovite is present, as well-oriented flakes, along with about 5 percent fresh to weakly-altered, multiply twinned plagioclase (probably albite). The remainder of
the rock is made up of fine-grained quartz and clay minerals, as well as, possibly, altered feldspar, and about 3 percent opaque are grains which also show parallel orientation of their long axes where their shapes are not equant (C. Gilboy, personal communication, 1986).

8) Chemical analysis: A specimen of feldspathic siltstone had 79% silica; 12% Al₂O₃, 4.29% Na₂O, 0.07% barium, and other oxides and elements that are mostly in the trace range.

9) Colour: Maroon is by far the most common colour, but cobbles of a grey colour have been recovered.

10) Lustre: The basic material has a low lustre, but unweathered fractures display small sparkles from mica flakes.

11) Texture: Fine-grained, individual grains cannot be discerned without magnification.

12) Structure: Macroscopically massive.

13) Cortex: Feldspathic siltstone does not have a distinctive cortex, but many cobbles show impact scars resulting from vigorous fluvial transport.

14) Patination: No patination, but weathered surfaces lose the mica sparkles displayed by fresh fractures.

15) Special features: Mica sparkles on fresh fractures vanish on weathering. Hertzian cone impact scars
on some cobbles.

16) Size and shapes of clasts: Clasts are mostly in the cobble size range; they are typically well-rounded.

17) Known sources: Feldspathic siltstone is a sedimentary rock consisting mainly of silt-sized particles. Feldspathic siltstone is present in Tertiary gravels which originated in the Belt Formation in northern Montana and were fluvially transported into southwestern Saskatchewan during Eocene-Oligocene and Miocene Epochs (Vonhof, 1969). This material is not particularly abundant but it is present in small but significant amounts in gravels in the Ponteix district and to a lesser extent in Tertiary gravels of other areas.
DISCUSSION

Early immigrants to Saskatchewan must have been dismayed by the scarcity of lithic material suitable for chipping. Although quartzite is abundant in some areas, the fine-grained chalcedonies and like materials are very scarce and usually not of high quality. Lithic materials are an important source of information for archaeology and it is desirable in an early step in this type of research to distinguish between exotic and indigenous lithic materials. Because the indigenous lithic varieties are few in number and their properties are distinctive this task is made relatively easy in Saskatchewan.

This study has determined that in southern Saskatchewan there are nine archaeologically significant varieties of rock that can be usefully chipped. As part of the research their identities have been established by means of petrographic analysis. The corresponding macroscopic properties useful for the identification of materials in artifacts and hand specimens have been described. Also, the source and geological context of each material has been indicated, with the reservation that the provenience of most glacially distributed materials remains ill-defined.

The quest to identify lithic variety led to an examination of the main components of materials that can
be usefully chipped. Silica, as quartz or chalcedonic silica, is a major constituent of most of these materials. Although the concept of a distinction between quartz and chalcedonic silica is by no means new, it has rarely been applied to archaeological lithic materials. This thesis proposes that chalcedonic silica is a polymorph or variety of silica distinct from quartz. This theory largely originated as a result of the observation that some silica materials undergo a change in properties upon heating quite different from that of quartz. Many prehistoric artisans knew, and recent experimenters have discovered, that heating causes some rock to be easier to chip. My own experiments indicated that a temperature range of 250°C to 300°C caused changes in properties of rocks that consisted mainly of chalcedonic silica. By distinguishing between quartz and chalcedonic silica, it becomes possible to predict that only those materials which consist mainly of chalcedonic silica would become easier to chip upon heating.

Intrinsic information about a lithic material at a site begins with its identification. An expanded way of examining amorphous and fine-grained materials has been presented in this research. These materials are commonly difficult to identify and in many instances probability is all that can be achieved. But the more features that are observed, the greater the accuracy of identification.
If a lithic material at a site can be related to a specific source, some information can be given about the users of that material. Silicified siltstone pebbles at a Saskatoon site, for example, indicate that the users had contacts far to the west. The varieties of lithic materials at a site may indicate whether the occupants had recently arrived, or whether they had been able to discover local lithic resources. Immigrants must have brought with them raw materials and artifacts from their parent territory. As they became more familiar with the resources of an area, in this case southern Saskatchewan, lithic materials were discovered. Thus, the indigenous materials must show up at sites whose occupants had become knowledgable about the lithic resources of this area.

Hunting economies are highly dependent on sharp edged tools and the manufacture of such tools similarly depends upon the availability of suitable rock. The need for material that could be usefully chipped entailed a system of lithic procurement. Those who failed to have such a system in a lithic-deficient area had much reduced chances of survival. The source of the lithic material may be exotic or local; knowledge of its identity and source can provide the basis for a theory of its procurement system. Such a theory could postulate that some groups had a transhumance pattern which included a lithic resource. The considerable amount of Knife River flint
in Saskatchewan sites can be regarded as evidence of extensive trading. Furthermore, expeditions could have gone to sources of favoured material to bring back blanks and preforms such as those found in rare caches.

There is interest in the reasons why certain lithic materials dominate the residue of certain sites or of specific cultural groups. The properties of materials may provide a basis for preferential use by a cultural group or for certain tools. Edge durability is desirable for cutting and scraping tools, but this quality is not necessary for projectile points. The ease with which an edge can be rejuvenated will influence the selection of materials for scrapers. The structure and composition of a nodule will have a bearing on the amount of debitage from manufacture. A large quantity of detritus from manufacture may indicate not preference but a low material quality. The nature of Swan River chert is such that a nodule of a kilogram or more may produce very few flakes useful for further manufacture; the rest remains as residue.

In addition to the above, the properties of a rock, including its shape, may entail recognizable reduction procedures and shaping strategies. Tough rocks such as quartzite were shaped mainly by hard percussion. Ovoid pebbles required a splitting technique, and difficult chalcedonies were made more tractable by heating. High
quality materials like Knife River flint can be shaped by any chipping mode, without having been heated. Since it may readily be shaped by soft percussion, Knife River flint was especially desirable for large, thinned artifacts. It can also be pressure flaked to form Eden or deeply notched projectile points and it is suitable for the manufacture of fluted Folsom projectile points.

There is need for continuing research in archaeological lithic materials. A theory of fracture applicable to archaeological artifacts would enhance the interpretation of manufacture and breakage patterns. Many tests may be required before it can be resolved whether Athabasca quartzite is, in reality, distinguishable from the Rocky Mountains variety. It would also be worthwhile to examine sedimentary rocks for microfossils and pollen.

This work has made me aware of the extensive use of Swan River chert. Its presence, far from sources that are presently known, indicates that it was widely transported by humans who belonged to nearly all cultural complexes that occupied this province. This observation indicates that theories of lithic procurement systems and of diffusion of lithic materials are desirable in archaeology. The concept that chalcedonic silica is a separate variety of silica has been empirically supported, but further research in the fields of radiometry and electronic spin resonance research may provide a fundamental
explanation of the phenomenon of thermal alteration. Even though basic research is essential, a major problem confronting the archaeologist lies in making a field or laboratory identification of lithic materials. The comparison of field specimens with recognized varieties should be more practically facilitated. It is therefore suggested that, along with continuing research pertaining to properties, a repository of lithic specimens be established. Although this research is preliminary in scope, it is hoped that it has made some contribution to understanding prehistoric lithic procurement and stone tool production across southern Saskatchewan.
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Figure 3. An incomplete cobble of Athabasca quartzite. From Boutin's gravel pit, Domremy.

Figure 4. A typical cobble of Rocky Mountain quartzite showing percussion marks. From the Cypress Hills.
Figure 5. A portion of a boulder of Swan River chert. From near Armit.

Figure 6. A nodule of silicified peat. The flake beside it was struck off, heated to 290°C, and partially flaked. From south of Rockglen.
Figure 7. Wood replaced by chalcedonic silica. From south of Rockglen.

Figure 8. Wood replaced mainly by quartz. From south of Rockglen.
Figure 9. Silicified siltstone pebbles, some of which have been experimentally split. From Grassy Island Lake, Alberta.

Figure 10. A broken nodule of Gronlid siltstone. From a glacial erratic exposure north of Gronlid on the Saskatchewan River.
Figure 11. A patinated fragment of Gronlid siltstone from western Saskatchewan.

Figure 12. Fused shale from an exposure north of Big Beaver.
Figure 13. Feldspathic siltstone cobble, and an experimentally removed flake. From a gravel deposit east of Ponteix.