1996

Mechanical and chemical weathering of periglacial and non-periglacial forms on the eastern Fosheim Peninsula, Ellesmere Island (Northwest Territories)

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Mechanical and Chemical Weathering of Periglacial and Non-Periglacial Forms, on the Eastern Fosheim Peninsula, Ellesmere Island.

By
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B.Sc , Wilfrid Laurier University, 1992

THESIS

Submitted to the Department of Geography
in partial fulfilment of the requirements
for the Master of Arts degree

Wilfrid Laurier University
1996

ISBN 0-612-11439-2

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Abstract

The purpose of this study is to examine the differences in the mechanical and chemical weathering of different periglacial and non-periglacial forms on the eastern Fosheim Peninsula Forms studied include solifluction lobes, non-sorted stripes, polygons, mudboils, wetted sloped, dry ridge and wet meadow

Most sites including the periglacial forms of solifluction lobes, non-sorted stripes, and polygons show signs of chemical and mechanical weathering The weathering found at all sites was minute but may be significant given the slow rates of weathering in this environment

The individual environmental variables of moisture and temperature levels do not appear to have a direct influence on weathering However, it appears that at most sites there are environmental factors that can be interpreted as both inhibiting and enhancing weathering

Vegetated areas appear to have more chemical and mechanical weathering within the profile when compared to less vegetated sites This is probably a result of many variables including, moisture, albedo, root microbial and chemical activity Vegetation also traps fine aeolian particles which may explain this observation

It is highly probable, given all of the different mechanical and chemical processes, that the soil found here is developed from a combination of these different processes and cannot be attributed to any specific variable

Acknowledgements

The funding for this project was provided by Polar Continental Shelf Project, Natural Resources, Canada, Northern Scientific Training Program, Wilfrid Laurier University, and the Cold Regions Research Centre

Thanks must be extended to my committe members Dr M Stone, Dr H Saunderson, and Dr S Schiff Thanks also to my advisor Dr M English

Laboratory help and analysis was provided by Richard Elgood (Department of Earth Sciences, University of Waterloo), and Jim Mc Andrew (Department of Geology, McMaster University)

Many thanks to those at Cold Regions Resecrch Centre specifically Rich Pyrce, Alistair Wallace, and Corinne Schuster

I am very thankful to those with whom I spent the field season with, specifically LeeAnn Fishback and Paul Wolfe.

Thanks must be extended to those whose time and patience helped in the completion of this thesis. First and foremost my lovely wife Melanie, also the many people that allowed me use of computers, Pat Paulsen, Connie and Doug Wilkinson I am also very grateful to Sean, Lisa and the Kelly clan for allowing me to stay at their humble abode

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1.1 Introduction

Little is known about the active processes in the subarctic and arctic that shape its landscape Soils in the high arctic are classified by Tedrow (1977) as being Polar Desert and are mainly influenced by the severe cold and dry climate This results in soils significantly different from other soils, in terms of physical, mineralogical, chemical and biological properties Polar soils are generally less productive than more temperate soils (Tedrow 1977).

However, Tedrow's classification does not include analysis of small scale features such as slope, hydrology, aspect, relief and albedo, that affect the formation of the soils As a result, this classification oversimplifies soil classification of this region. A more complex classification utilising environmental aspects affecting the soil's development may be more appropriate. The problem with such an approach is that it would be difficult to represent because of the small scale required It is possible that the soils within a small region differ greatly in terms of their physical and chemical properties due to the small scale influences.

The environmental aspects of, permafrost, low precipitation and seasonally low temperatures, of the high arctic are such that they dramatically alter the surface processes. These processes include active layer formation and freezeback, and pedogenesis which are significantly different than more temperate regions. Weathering rates of the regolith, defined as an intermediate form of material between the parent material and a proper soil, and pedogenesis in this region are much slower because of the climatic influences and surface processes. The most noticeable surface processes occurring in this region are collectively lumped together as periglacial processes, and are common to most environments with sufficiently cold climate (Washburn 1973, French 1976) These periglacial processes include, frost action, which involves all processes related to freezing and thawing of the ground, mass wasting, nivation, fluvial action, marine action and aeolian action (Washburn 1973) These processes are well documented by such authors as Washburn (1973, 1979), French (1976), and Tedrow (1977) These periglacial processes produce various periglacial features or forms including: frost boils, sorted ground such as in polygons, circles, stripes, solifluction lobes, active layer detachments, and hummocks There are no reported studies investigating how these features influence weathering within the regolith It is expected that although the features are formed by similar processes, the resulting form may significantly alter the physical and chemical properties of the weathered regolithic material because of the resulting micro-scale features, which include elevation, albedo, slope, aspect and hydrology of the periglacial form

Sposito (1985) states that a soil is changing in response to environmental factors over time. This statement is of importance in the present study, because the microscale features, that are changed by the periglacial environment and processes, including slope, aspect, local hydrology, albedo, are reported and an attempt is made to try to tie these influences to the weathering that is occurring presently. There is little known about the lag time between the environmental controls and the soil properties. Delete?? Although soil development will reflect the changes in the environment, this environment has not undergone significant changes The processes presently acting on the environment have not changed significantly for some time and will continue weathering the regolith and shaping the landscape in the future ??

Some of the main considerations of soil development in an arctic environment include surficial and bedrock geology, macroscale and microscale climate, precipitation type and quantity, elevation, aspect, slope gradient, snowpack spatial and temporal distribution, hydrological processes in the soil column, and the species and density of the vegetation

The main factors controlling the rates of weathering in this environment are physically based processes, although recently it has been stated that chemical processes still have to be considered because they play an important role in the development of the soil (Hill and Tedrow 1961, Foscolos and Kodama 1981, Dixon, Thorn and Darmody 1984). The environmental variables that control the weathering, will affect both the mechanical and chemical weathering rates

Early researchers neglected chemical weathering as being a major contributor for polar soil formation because it was thought that the very cold temperatures would sufficiently hinder any chemical weathering (Campbell and Claridge 1987). More recently, other authors have recognized the significant contribution to the breakdown process made by chemical weathering in addition to the dominant factors of frost shattering, expansion and contraction (Campbell and Claridge 1987, Dixon, Thorn and Darmody 1984). The effectiveness of chemical weathering will be strongly influenced by the amount of precipitation and the temperature (Foth 1978). Chemical weathering occurs even though the cold and dry conditions of polar environments are unfavourable for chemical reactions (Dixon, Thorn and Darmody 1984).

1.2 Periglacial Environment

1.2.1 Introduction

There have been varying definitions and uses of the term "periglacial". The word was introduced by Lozinski (1909) (cited in Washburn, 1973) to define the climate and the features adjacent to the Laurentide ice sheets. The term was later expanded to include most cold regions and their specific features. The word is widely used presently in this form, despite criticism, and no quantifiable characteristics in terms of precipitation and temperature Peltier (1950) attempted to summarize the periglacial morphogenetic region in terms of temperature and precipitation. He reported that in periglacial areas the average annual temperature ranges from -15 to -1°C and average annual precipitation ranges from 0 mm to 1397 mm, excluding snowfall.

Tricart (1970) emphasized permafrost as being the dominant characteristic of the periglacial regime, however, he did not consider permafrost to be a prerequisite in the definition of periglacial. Throughout this paper the term 'periglacial' will be used according to Washburn (1973: 2) "designating cold-climate, primarily terrestrial, non-glacial processes and features regardless of date or proximity to glaciers." Even though periglacial does not mean permafrost, the reciprocal is not the case. The distribution and extent of permafrost is wide spread. French (1976) concluded that approximately 23% of the earth's surface (including subglacial) is underlain by both continuous and discontinuous permafrost. Specifically, Canada has some permafrost beneath 40 to 50 per cent of its land mass (French 1976).

The main independent environmental factors that affect periglacial processes and the resulting forms in the periglacial environment include: climate, in terms of the different scales, zonal, local and micro, topography; rock material, and time. Each of these factors can work together or independently to produce the various periglacial environments. The dependent factors include: snow cover, liquid moisture, and vegetation. These are influenced by the independent variables but they affect the periglacial regime.

1.2.2 Periglacial Processes

Many different processes are active in forming the periglacial environment. These are grouped together in the following categories: mass-wasting; nivation; fluvial action; lacustrine and marine action; wind action and frost action. Despite the fact that some of these processes do not create definable landforms, they are important in terms of the weathering mechanics of the soil

Mass-wasting is defined by Longwell, Flint and Sanders (1969) as "the gravitative movement of rock debris downslope, without the aid of the flowing medium of transport such as air at ordinary pressure, water, or glacier ice" (Washburn, 1973: 163). Although there are many types of mass-wasting that occur in periglacial environments, the most important in this study are frost creep and gelifluction. Frost creep "is the ratchet like downslope movement of particles as the result of frost heaving of the ground and subsequent settling upon thawing, the heaving being predominantly normal to the slope and the settling more nearly vertical" (Washburn 1973: 10) whereas gelifluction is a specific type of solifluction that occurs with frozen ground. Solifluction is the process by which mass flows from higher to lower ground as a result of being saturated with water (this may come from the snow melting or rain) named after *solum*, for soil, and *fluere*, to flow (Washburn, 1973).

Frost creep is dependent upon the following: number and depth of freeze thaw cycles, surface gradient, amount of moisture available to be transformed into ice, and the frost susceptibility of the soil. However, the effectiveness of frost creep in the high arctic is restricted by the limited number of freeze thaw cycles and the shallow active layer depths. (Washburn 1973).

Gelifluction is prominent in cold climates because the permafrost table provides a physical barrier preventing or significantly reducing water from percolating further down therefore fostering soil saturation over the active layer column Another significant factor affecting the effectiveness of this process is the role of snow and water which act as a source of moisture to the system (Washburn 1973). Gelifluction is dependent upon moisture Other variables that influence this process are vegetation cover, gradient, and grain size (fines remain wet longer; silt is particularly susceptible because it does not have the cohesive forces of clay) Frost creep and gelifluction produce deposits such as sheets, benches, and lobes that are of importance to this study.

Nivation is defined by Mathes (1900· Washburn 1973: 204) as "the localized erosion of a hillside as the result of frost-action, mass-wasting, and the sheetflow or rillwork of meltwater at the edges of, and beneath, lingering snowdrifts" (Thorn 1988). The effectiveness of this process is controlled by the size, thickness and duration of the snow bank and the presence or absence of permafrost (Thorn 1988). The presence of permafrost beneath the snowpack limits nivation to the edges of the snowbank and the adjacent snow free areas, whereas if there is no permafrost the ground beneath the snowbank is susceptible to erosion (Berrisford 1991).

Fluvial action is the erosive force of water and in periglacial environments differs from that in other environments due to the influence of frost action (Washburn 1973) This process is not limited to the terrestrial environment but includes erosion in proximity to water bodies such as streams and lakes. An example of this is silt removal in small surficial channels.

However, most fluvial action occurs in terms of ice jams and the backup of water, ice rafting, and ice shove activity Another form of fluvial action is the irregular erosion based on the aspect of the slope i e asymmetric valleys where the steep slope is undermined because of more effective solar radiation (Washburn 1973).

Wind action is essentially the movement of sediment by wind activity. This process is common in periglacial and non-periglacial environments equally because wind in both environments acts in the same manner

The final process, frost action, defined by Howell (1960) as the weathering process caused by repeated cycles of freezing and thawing has a larger influence on the periglacial environment (French 1993), when compared to the other processes. An example of this is that the formation of patterned ground and the presence of frost creep can be directly attributed to freeze thaw cycles. However, little is known if this freeze thaw process is an effective weathering agent in terms of chemically or mechanically altering the regolithic material (French 1993). This process is known to enhance the formation of various periglacial forms (Washburn 1973)

Freeze-thaw will be used to "designate the action of frost during freezing, thawing, and subfreezing temperature fluctuations" (Washburn 1973: 49). Environmental freezing occurs in either an open or closed system. In an open system where the water is free to migrate to the freezing front, the amount of heaving is limited by the available water and overlaying weight on soil surface. The classic work on water freezing in a closed system was performed by Taber (Washburn 1973). In a closed system the soil is desiccated by the build up of the ice lenses (Taber 1930).

Temperature and rate of temperature change is a major factor in the freeze-thaw process. The amount of unfrozen water that remains in sub-zero temperatures is dependent on temperature, pressure, mineralogy of the soil, grain size and chemistry of the soil water. Small pressure changes, that are typical of field observations, alter the freezing point of water by only 0.0073 °C/kg/cm^2 (Washburn 1973). This effect is negligible in most circumstances. Grain size characteristics, and resulting soil porosity, affects the movement of water to the freezing front, the freezing temperature of the phase boundary water, and the water in the small capillaries. Mineralogy of fine particle sizes affects the migration of water and frost heaving. For instance clays that expand in the presence of water can hold more water but the water is less mobile.

Frost wedging, frost heaving and frost thrusting, mass displacement, frost cracking, sorting, and involutions are periglacial processes involving freeze-thaw activity.

Frost wedging, synonymous with splitting and congelifraction, is the breaking apart of rock as a result of the 9% volumetric expansion of water upon freezing (Washburn 1973, McGreevy 1981). The factors that are critical in this process are the presence of moisture, nature of rock, temperature and time. The presence and volume of moisture affect the rate of disintegration. Potts (1970) reports that rocks half immersed in water disintegrate more rapidly than rocks that are surrounded by a small film of water. The nature of the rock is a factor because sedimentary rocks are more permeable and therefore are more susceptible to fracturing. Temperature and time are factors dependent upon other variables. When the freezing rate is rapid, it is more likely to be successful in fracturing saturated rocks. This occurs because a closed system is formed as the freezing would effectively seal the perimeter of the rock which would encourage higher internal pressures. Alternatively, in a fine grained rock a slow freezing rate, and open system, may promote frost wedging because it allows for moisture to migrate into the voids (Washburn 1973).

Frost heaving and thrusting is the result of the pressure exerted by the freezing water and the displacement of the soil in both horizontal and vertical directions, also called the formation of segregated ice. Frost heaving is dependent upon the moisture content in the mineral soil, and usually occurs in the fall freeze-up period (French 1976). Mass displacement is defined by Washburn as "the *en-masse* local transfer of mobile mineral soil from one place to another within the soil as the result of frost action" (Washburn 1973: 90). Frost cracking is the fracturing as a result of thermal contraction at subfreezing temperatures (Washburn 1973).

Particle sorting by frost action is an active process in the periglacial environment. This activity produces areas where stones are forced to the surface. Other processes include work of needle ice, mass displacement due to moisture variability, and possibly cryostatic pressure. Corte (1963) states that the movement of the freezing front affects particle sorting. He reports that the freezing front captures the larger particle sizes quicker than the fines and, therefore, push the fines ahead of the freezing front, regardless of the direction of the freezing front. This occurs because the larger particles may come into contact with the freezing front first and then be held in place.

1.2.3 Periglacial Features

The various periglacial processes develop different significant features within the landscape. including the following patterned ground types: sorted and non-sorted circles, sorted and non-sorted polygons, nets, steps, sorted and non-sorted stripes. Most of these forms are of polygenetic origin, in other words similar forms may result from different processes, and the same processes may result in different forms However, most of the genesis of the various features are still open to debate.

Circular patterns result from differential heaving and cryostatic movement (Washburn 1956). The sorting of the fine particles from the coarse particles, that is sometimes seen with these features is a result of the freeze-thaw process. Polygonal features may result from drying and contraction due to low temperatures (Washburn 1956). Features, such as steps and solifluction lobes, that form on slopes are likely a result of the mass wasting processes of frost creep and gelifluction.

Most circles, polygons, and nets form on horizontal landscapes If these various pattern ground forms occur on slopes, they will become elongated forming stripes (Washburn 1973).

A general factor that emphasizes and enhances the patterned ground is the presence of vegetation. The vegetation is usually located in the hollow of the feature because of available moisture and the efficiency of the depression in retaining water. For instance, in the case of polygons the vegetation is in the furrows as opposed to being on the surface of the form

Another feature of interest in this study of the periglacial landscape are involutions Sharpe defines involutions as "aimless deformation distribution, and interpenetration of beds produced by frost action" (1942: 115). These involutions are widespread throughout the periglacial environment including the study site.

1.2.4 Study Site

The periglacial features are a significant physical feature of the landscape at the study site. There are many different periglacial features that exist within the study basin including: stripes, solifluction lobes, frost boils, and polygons. The remainder of the study site area has various landscape characteristics that are indicative of tundra without any periglacial forms. However, despite the lack of formation of periglacial forms, periglacial processes are still operating in these locations

1.2.5 Active Layer

With respect to periglacial processes, active layer formation and dynamics are important. The major factors of concern here include the heat balance of the active layer and moisture supply. Heat balance includes surface albedo, physical characteristics including particle size distribution and porosity, temporal duration of the snowpack covering the feature, net radiation and precipitation. The two major factors of the active layer that influence the findings of this study are the frequency of freeze-thaw cycles and the length of time that the active layer is unfrozen. The chemical characteristics of the soil body may change depending upon the different freezing and thawing fronts and how the active layer is formed. Vogt (1991) suggests that although little is known about physico-chemical precipitations, in a frozen environment, there is a significant possibility that minerals migrate under frost action. This is of significance because it could change the interpretation of the chemical data.

1.3 Purpose

The purpose of this research is to determine if different microscale environments produced from the formation of periglacial features affect the development of regolith weathering and consequently of soil formation and soil chemistry It is hypothesized that on small scale features such as polygons, there will be differences in both chemistry and particle size distribution, reflecting the effectiveness of chemical and physical weathering processes For instance, one could assume that the wetter region of a polygon area would likely have increased chemical weathering rates, when compared to the dryer centre region of the feature This would be indicated by a particle size distribution that has a larger quantity of fines Similarly, other periglacial features such as solifluction lobes and stripes may have a coarser particle distribution at the margins, indicating mechanical weathering activity Chemically these locations are affected by the hydrology, which includes piping and preferential flow pathways, and the mobile chemical elements may be leached by the water flow Other factors that will affect the soil chemistry and particle size distribution include: temperature differences, moisture levels, flow pathways of water during the annual freeze-back and thaw periods, and freeze-thaw activity. All of these are likely to change within a periglacial feature and most likely to change from feature to feature even within a relatively small area

As the periglacial landform demonstrates notable temporal and spatial variations in terms of soil moisture and temperature, it is expected that this variability will be reflected in soil chemistry. For example, a site that is wet and warm will be more conducive to chemical weathering. However, cold sites may inhibit chemical weathering However, throughout time the temperature and moisture are reflective of the environmental conditions. The environmental conditions will affect the soil/regolith as is seen today.

1.4 Assumptions

This work is based upon the following assumptions. The mechanical weathering results are determined by the particle size analysis and mechanical weathering can only break the rock down into its constituent particle size. The second assumption is that the chemical data are representative of chemical weathering changes within the rock, and profile.

The overall assumptions that apply to both the mechanical and the chemical weathering are the soil was formed from the parent material i.e. the bedrock. Secondly, that the environmental conditions that are relatively constant in recent geological history and will continue to be similar.

1.5 Location of Study Site

The study site is located at 79°33 18′ N, 83°20.17′ W, on the Fosheim Peninsula on the western central coast of Ellesmere Island, NWT. The peninsula extends from the central portion of Ellesmere, 78° N, 82° W, to the northwest 82° N, 87° W. The study site is located approximately 90 km SE of Eureka, in the Sawtooth Mountain Range. This mountain range divides the Fosheim Peninsula from the south west or Eureka Sound to the north east or Canon Fiord (Figure 1.1). The mountain chain has a range of maximum elevation from approximately 1275 m.a.s.l in the northern region to approximately 975 m.a.s.l. in the south western portion.

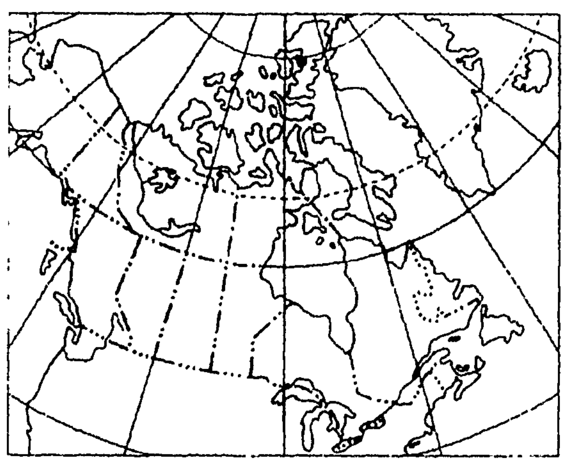


Figure 1.1 Location map of study site, showing Axel Heiberg Island, Ellesmere Island, and the Fosheim Peninsula. A more detailed pit location map is shown in figure 3.1.

The sampling locations for periglacial features were located within 2 drainage basins of a glaciated catchment. The maximum elevation of the study sites region was approximately 1200 m a s l However, most of the samples were collected within the range of 100 m.a s.l. to 650 m a s l

The hydrology of the region is controlled by the Sawtooth Mountain chain and the presence of small valley glaciers. Most of the precipitation that falls on the western portion of the mountains eventually drains to the west The other significant sources of water are melting glaciers and perennial snowbanks and permafrost thaw. However, most of the meltwater from glaciers and perennial snowbanks is confined to channels and does not affect the terrestrial environment. The non-perennial snowpack influences the terrestrial environment (Thorn 1988).

1.5.1 Geology

The Fosheim Peninsula is largely underlain by sedimentary rocks of the Eureka Sound Group (Thorsteinsson 1972). The age of this parent material is Tertiary. However, there have been reports of younger deposits, likely of Neogene age, overlying this parent material (Hodgson, St-Onge, and Edlund 1991) There are some samples collected from the older Eureka Sound deposit, but most samples are collected in deposits that are presently at a higher elevation

The physiography of the region is controlled by the Sawtooth Mountain Range. These mountains are of sedimentary origin resulting from a series of fold faults and thrust faults

(Thorsteinson 1972). The parent material for this chain of mountain ranges in age from upper Cretaceous (i.e. the Kanguk Formation) to the Lower Permian (i.e. Assistance Formation).

The parent material is important for this study because parent material has been found to have the greatest influence on soil development (Kelly and King 1995) and soils in this region are formed largely from materials with sedimentary rock lithology

Even though the samples were collected from a small area, it is believed that the results are directly applicable to a large area on the Fosheim peninsula to the west of the Sawtooth Mountain Range because of similar environmental features, climatic factors, surficial geology, bedrock geology and controlling processes Despite the apparent differences, it is expected that the trends that result from this study are applicable to other arctic regions with similar geology and climate.

1.5.2 Climate

The nearest continuous record of weather data is collected at Eureka, 80°00′N 86°56′W. This station is located approximately 90 km to the northwest of the study site The data are not directly applicable because of the differing physiographic considerations between the two sites, including elevation, proximity to an ocean, and proximity to glaciers

When comparing the sites the first consideration is the elevation The study site was located at a higher elevation than Eureka, which would imply that the temperatures are colder and there is more precipitation, because of lapse rates and orographic effects The second factor is the proximity to an ocean. This influence may minimize the elevation aspect because it increases the study site's temperature because of continental influences. Eureka with its proximity to the ocean would have colder, more marine temperatures and also have a nearby source of water in the summer for precipitation. The final influence would be the proximity to the glaciers This would tend to decrease the study site's temperature, and also may result in more precipitation if the ice mass is large enough because it may decrease the saturation mixing ratio of the air mass above it.

Despite the apparent differences, between the Eureka weather station and the study site, this data is the best long term climate data available. July is the warmest month with a mean temperature of 5 4°C, and the mean annual temperature is -19 7°C (AES 1982).

Precipitation for the region is minimal. Eureka receives 64 mm, most of which is snow. However, this precipitation value may be underestimated given that it is hard to measure trace precipitation, and wind blown snow (Woo, Edlund, and Young 1991). Meterological data were collected during the field season at the Sawtooth Mountain site so that the data from the two sites could be compared. When these data were compared for the summer months during the study period, July temperature's at the study site were higher than Eureka's and there was more precipitation at the study site. The average July temperature at the study site was 9.2°C compared to 7 3°C at Eureka. The recorded precipitation was 33.5 mm at the study site and 10 5 mm at Eureka. These data can be explained by the proximity of Eureka to a cold water body and the orographic influences at the study site.

1.3.3 Glacial History

The glacial history of the region will affect the surface of the environment in terms of any glacial erosion and/or deposition as a result of expansion or contraction of the glacier Another factor, time, has been considered to be a major controlling factor for soil development in the polar regions (Bockheim 1990, and Bockheim, Wilson, and Leide 1990) There has been no evidence that the Fosheim peninsula was glaciated during the last major glacial period of the Late Wisconsin (Hodgson, St-Onge, and Edlund 1985, Andrews 1985) Therefore, it can be deduced that the periglacial features and the soil have developed since this time period without any major changes.

Chapter 2 Literature Review

2.1 Previous Work Performed in the Region

In recent years, the Fosheim Peninsula has been intensively studied. These studies on the processes and features of the Fosheim peninsula include. surficial materials (Hodgson et al 1991), aeolian deposition (Edlund and Woo 1992), effects of climate, vegetation and hydrology and their interactions (Edlund et al 1989, Woo et al 1990), early snow free zones (Woo et al 1991), ground ice (Pollard 1991), and geomorphic processes (Lewkowicz 1994). This base of information is quite comprehensive but less information is available regarding pedogenesis in this region. Edlund and Woo (1992) recently discussed the soil solum when reporting the vegetation and eolian deposition on the Fosheim Peninsula.

2.2 Cryogenic Weathering in Polar Regions

Hall and Lautridou (1991) describe cryogenic weathering as the combination of mechanical and chemical processes which cause the in-situ breakdown of rock under cold climate conditions. This type of generalization best describes the conditions that exist in the Fosheim Peninsula. Given the complexity of the processes involved in weathering, this type of generalization needs to be considered.

Historically, most of the weathering information collected was directed at determining the rates of mechanical weathering. More recently Dixon, Thorn and Darmody (1984), and Dredge (1992), have attempted to increase the information base with respect to chemical weathering.

The soils in the polar regions reportedly have a higher concentration of clay sized particles near the surface (Campbell and Claridge 1987). This particle size distribution is indicative of more pronounced weathering at the surface than at depth. Campbell and Claridge (1987) state that there is a higher concentration of clay size particles as the soils increase in age in Antarctica. They also state that there is a particle coarsening downward within a soil horizon as a result of more effective weathering at the surface of the pit.

The increase of fine particle sizes is of interest because it may indicate what type of weathering is occurring. At the soil surface there are different environmental controls which will control the rate and type of soil development that may occur. For instance there will be more temperature fluctuations around the critical freezing temperature of 0 °C, but there may not be enough moisture to allow for effective mechanical breakdown or chemical activity

2.3 Physical or Mechanical Weathering Processes

Physical or mechanical weathering occurs when "the original rock disintegrates to smaller-sized material, with no appreciable change in chemical or mineralogical composition" (Birkeland 1984: 60). Mechanical weathering is reported to be the dominant process governing the breakdown of the parent material in the cold regions of the world i e at both polar regions and at high elevations. Mechanical weathering, in terms of freeze-thaw cycles, has been reported to be successful in breaking parent material down into its constituent size (Konischev and Rogov, 1993).

Various authors have summarized the mechanical weathering studies in terms of the different mechanisms involved and field and laboratory observations (French 1976, Washburn

1979, McGreevy 1981, Whalley and McGreevy 1992). Most of the mechanical weathering studies that have been completed conclude environmental or climatic factors are of primary importance in the breakdown of the parent material Of these climatic controls, the number of freeze-thaw air and ground cycles is cited by the following Rapp (1960), Wiman (1963), and Potts (1970). The effectiveness of the freezing intensity is cited by Tricarte (1956) and Battle (1960), (in McGreevy 1973). The rapidity of freeze-thaw cycles is cited by Battle (1960), Mellor (1973), and Lautridou and Ozouf (1982) (in McGreevy 1981) whereas the slowness of the freezing is cited by Taber (1930), Pissart (1964, 1970) (in McGreevy 1981).

The three most important variables that control the effectiveness of the physical weathering processes are rock type, temperature and moisture (McGreevy 1981). These variables have varying influences depending upon other factors. For instance Battle (1960) proposed that low amplitude temperature fluctuations around 0°C may be effective if prolonged and there is a high water saturation in the rock, and a rapid rate of freezing from the surface down. Also, the rock structure in terms of pore size distribution, permeability, and location and amounts of clay minerals within the rock substance can determine the nature of the breakdown of the rock.

Most theories of mechanical breakdown of parent matter deal with the presence of water and freezing temperatures. Historically, it has been thought that the 9% by volume expansion of water upon freezing is the most effective mechanism for the breakdown (Washburn 1973, French 1976, McGreevy 1981). Other theories include: physical breakdown, capillary, ordered water and hydraulic pressure.

The theory of physical breakdown is based on the premise that ice crystals will grow in directions in which growth is opposed by external forces (McGreevy 1981) These forces in turn become the mechanism for the breakdown as they may exceed the rock's tensile strength This is similar in nature to the process of salt weathering i.e. the growth of a crystal initiating the forces responsible for the rock breakdown.

The capillary theory of frost damage is based on the premises that all the water in soils does not freeze at the same temperature and that the growing crystals displace the overlying soil such as frost heaving in more temperate environments.

The ordered water hypothesis follows a more chemical reasoning This theory involves the dipolar nature of the water molecule and the polar attraction that results This positive charge would then be more attracted to the negative charge of the clay matter in the parent material which would result in the negative dipole forces of the water repelling each other and cause the rock to breakdown.

The final theory of physical breakdown is the hydraulic pressure hypothesis This is based on the osmotic pressure of water moving through a frozen to an unfrozen region of the parent matter. The resulting movement of water would have resistance forces against the movement which in theory may be responsible for the breakdown of matter.

All of these theories have their strengths and weaknesses. The 9% by volume expansion theory can only be effective in a closed saturated system. If the system is open then there will be less pressure generated as the ice forms because there are more voids that can be filled by the expansion. Also, the saturated system requirement follows the same theory but is problematic because of the difficult nature of attaining a water saturated system adds to it a problem of an available moisture source.

The crystallization pressure of ice is effective in an open system but requires an unlimited water source. If there is insufficient moisture then the growth of crystals is stopped and cannot proceed. The capillary theory is effective under a slow freezing rate and also needs a water source. The ordered water hypothesis and the hydraulic pressure hypothesis are plausible processes but appear to be more theoretical and less likely to develop under field conditions (McGreevy 1981).

There are numerous studies that deal with the effectiveness of the preceding processes under different conditions. These studies deal with the rate of freezing, the water saturation levels, the rock mineralogy, etc.. For instance the volumetric expansion of water is believed to be effective if the freezing rate is rapid, there is a high saturation level of the rock, and there are sufficient low amplitude temperature oscillations (Battle 1960). The ordered water hypothesis is reexamined conceptually in terms of wetting and drying, or hydration, by Matsuoka (1990, 1991). Matsuoka states that hydration is most effective in smaller sized particles and, therefore, limited in the arctic because it is primarily sedimentary in origin. Hallet, Walder and Stubbs (1991) found that the ice segregation growth can occur in saturated sedimentary rocks even with sustained sub-zero temperatures.

Hall (1990) studied rates of mechanical breakdown in relation to the atmospheric and weather conditions. He tried to control such variables as degree of exposure to winds and sun, sea spray, shadow effects, cold air drainage, aspect, and longevity of snow cover. This on-going study placed tablets of dolostone and limestone, in the field and then reweighed them at certain time intervals. Some of the assumptions for this study were that freeze-thaw is the dominant agent responsible for the breakdown of the material. Abrasion was unlikely to be a dominant process because the wet Antarctic environment, where the studies were conducted, limits abrasive particles from being incorporated into the wind. The study showed were that the rate of weathering increased with time, and different areas had faster rates because of favourable environmental factors. For instance it was found that the hilltop had higher rates of mechanical weathering because of more frequent temperature oscillations and had a fairly high moisture level . In the valleys, the weathering rates were lower as a result of fewer freeze-thaw cycles despite a higher saturation level.

2.4 Chemical Weathering Processes

Chemical weathering is defined as "weathering, in which the chemical and/or mineralogical composition of the original rock and minerals is changed" (Birkeland 1984. 60). There are other definitions (Thorn 1988, Brady 1974) which range from a specific process orientation to a more general all encompassing statement.

Previously it was thought that the low temperatures present in the polar regions would minimize chemical and biological weathering processes (Washburn 1973) Researchers were under the assumption that chemical reactions were hindered by low temperatures (Dixon et al 1984). However, Tamm (1924) (in Dixon et al 1984) found that chemical reactions range little in effectiveness between the temperatures 2°C to 15°C. This is important for this study because although the environment is classified as a polar desert the temperature required for chemical activity to occur is easily met, as ambient summer temperatures can easily reach 15°C and may underestimate the importance of moisture availability. In Antarctica, bedrock surfaces may reach temperatures suitable for chemical processes (Campbell and Claridge 1987) Recently, it has been reported that chemical activity is important in these polar regions even though it is overlooked in some studies Thorn (1988: 14) states, "If mechanical weathering by freeze-thaw cycles has been too often cited with too little evidence, chemical weathering has been too infrequently cited and all but ignored".

This assumption about the reduced chemical weathering in these cold regions was fairly common and until the mid 1980's. Studies such as Dixon et al (1984), Thorn (1988), Dredge (1992), found some chemical weathering having occurred in the polar environment.

The processes that are active in the chemical environment are significantly more complex than the mechanical processes mentioned above. A general factor that encompasses both the mechanical and physical weathering is the different structure of the rock. Specifically the bond energies between the different elements and compounds that form the rock will alter the rates of chemical and mechanical weathering.

One of the more common chemical weathering processes is leaching. Leaching is solution of the soluble material and allows these mobile constituents to percolate down through the soil column Leaching is thought to be a major factor in the development of soils. If leaching occurred at the site, it would be recognized by the distribution of mobile elements. For instance, there would be relocation or loss of mobile elements downward vertically within the soil profile and horizontally downslope. Therefore the pattern that one would expect to find under a leached environment may not be evident because of the potential for mineral migration upward, vertically in the soil profile, under frozen conditions within this environment

(Vogt 1991). However, this mineral migration is not likely to be a dominant process and leaching should be more prevalent (Vogt 1991)

A second factor for the chemical weathering of the rock and soil is the structure of the water molecule and the process of hydrolysis The water molecule has polar characteristics and this feature enables the process of hydrolysis. Hydrolysis is the interaction of species with water and allows the removal of the more weakly bonded elements of the solid material and is enhanced with increasing solution acidity for some species Temperature affects the solution of minerals by hydrolysis directly, i.e the higher the temperature the faster the rate of solution

Oxidation and reduction are processes that involves the removal or the gain of electrons which changes the form and solubility of some elements Fe^{3+}, and Mn^{2+} Reduction occurs in anaerobic conditions. Oxidation can occur in soils through the action of dissolved oxygen.

Chapter 3 Methodology

3.1 Introduction

The methodology for this study involved both field and lab components. The field component was completed during the summer of 1993, on the Fosheim Peninsula on Ellesmere Island The lab portion of this research was completed after the field season at Wilfrid Laurier University, University of Waterloo and McMaster University

3.2 Field Component Site Selection

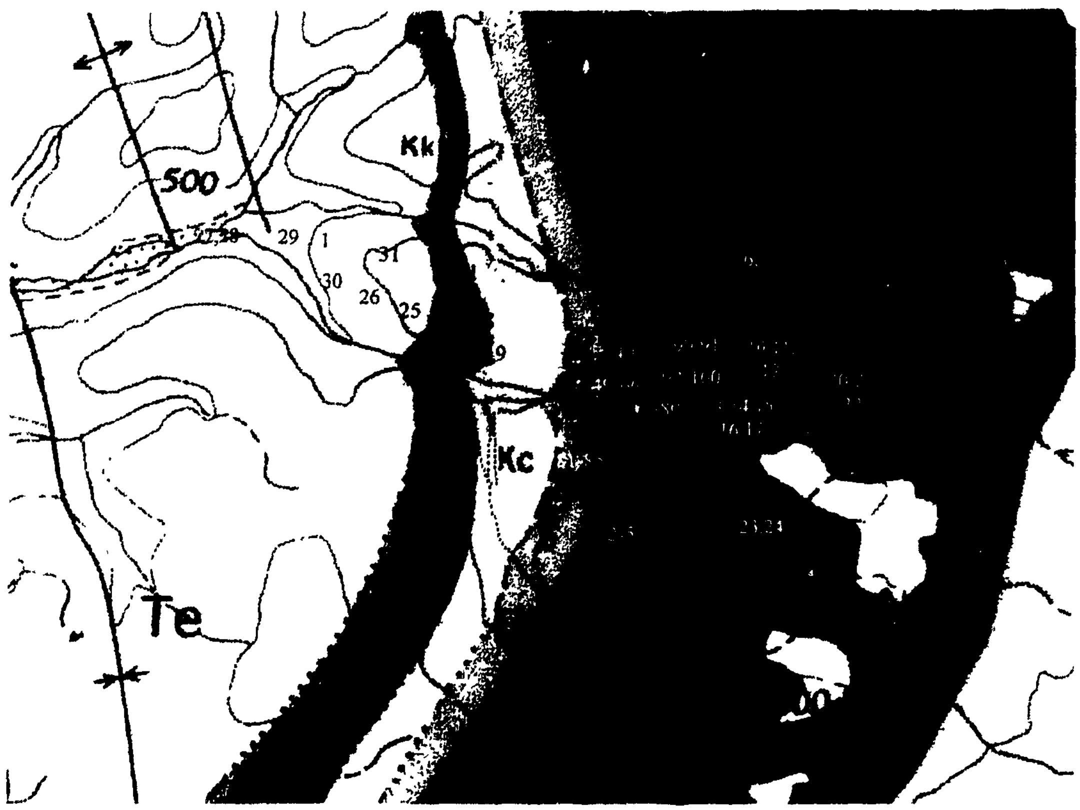
Individual sampling sites were selected to include different periglacial and non-periglacial forms with different environmental features, such as slope, aspect, elevation, drainage, vegetation cover and geology. It is hypothesized that there would be significant differences in terms of the chemical and particle size distribution among similar sites which could be linked to some environmental variable. For instance, given two of the same periglacial features, with the same geology and aspect, the difference in particle size distribution and chemistry between these two sites could potentially be attributed to the micro-elevation. The influence of the micro-elevation on weathering occurs because of the snow distribution. Specifically, in a depressed region there will be a deeper snowpack which will result in a shortened melt season. This is important because it limits the length of time in which chemical and mechanical weathering processes can operate.

Soil samples were collected from different periglacial features including mudboils, stripes, solifluction lobes, and polygons as well as other sites where there were no periglacial features evident such as dry ridge, wetted slope, and wet meadow. It should be noted that even though no periglacial forms are evident, periglacial processes are operating in these areas.

Table 3.1 summarizes the pits in terms of periglacial feature and parent geology. Figure 3.1 is a map of the pit locations with the geological regions. Sites that were selected for data collection ranged in elevation from approximately 300 to 1000 m.a.s.l., had aspects in all directions, slopes from 0-10 degrees, varying vegetation cover: from 0 to 100%, varied in terms of saturation: 0 to 40% soil moisture, and encompassed most of the different geological classifications of the region.

Category	Tertiary		Lower Cretaceous	Jurassic		Triassic	
Geological Formation	Eureka Sound	Hassel	Christopher	Awingak, Savik, Borden Island	Heiberg	Schei Point	Bjorne
major lithology	sandstone, siltstone, shale	sandstone	dark coloured shale	sandstone siltstone	sandstone, siltstone	calcareous siltstone and shale	sandstone (red weathering)
minor lithology	conglomerate, coal	siltstone, shale	siltstone sandstone, mudstone	shale	shale	limestone	siltstone shale
Solifluction Lobes						67 72 81 82 84*,85*-89	
Stripes	30					3,4*	20
Polygons	27*, 28*	41-48					11
Boils						5	10*
Dry Ridge	1,25,26,31		8,9			90	21 23* 24
Wetted Slope							13 16* 20
Wet Meadow						6 7 83* 91	12 18 19
Misc				32-40	49 66	2 67 80 92 100	
summary	1,25-31	41-48	8,9	32-40	49 66	2 3-7 67 100	11 24

Table 3.1 Summary of the pits with regards to where located in geological regions and the corresponding lithology. Misc. category includes samples that did not fit into the other categories. * indicates samples chemically analyzed.



Te Eureka Sound Formation

Kk Kanguk Formation

Kh Hassel Formation

Kc Christopher Formation

Ki Isachsen Formation

J Awingak Formation
Savik Formation
Borden Island Formation

Trh Heiberg Formation

Trs Schei Point Formation

Trb Bjorne Formation

Ptf Trold Fiord Formation

Pa Assistance Formation

Figure 3.1 Map showing individual pit locations and the geological regions pits excavated within.

3.2.1 Sediment Sampling

Sampling pits were excavated to the permafrost table, except on rare occasions when the pit site was too wet or too rocky to allow for further digging. Before excavation, environmental characteristics of the pit site were recorded. These included, slope, aspect, vegetation type and cover, and general environmental classification i.e. wet sloped, or periglacial form. Once the pit had been excavated, the presence of any soil development or structural layers in the pit, depth of active layer and sample depths collection were recorded. Soil samples were taken at the permafrost table and beneath any organic material in the mineral regolith/soil, usually at a depth of 5-10 cm. The bulk density and soil water content measurements were collected in the field by the use of 250 cc bulk density tins. The samples were weighed at base camp on a triple beam balance soon after sampling and, once air dried showing no visible signs of moisture, were reweighed.

A significant number of the samples were collected, during the later part of July and early part of August, when the active layer was most pronounced. Many of these samples were air dried in the lab at Wilfrid Laurier University shortly after returning from the field.

3.3 Laboratory Analysis

Mechanical and chemical analysis procedures were conducted on regolith/soil samples by coning and quartering the original samples to obtain enough quantity of a representative subset for the next procedure (Hesse, 1971).

3.3.1 Particle Size Analysis

For all samples, particle size analysis was performed on a representative subsample by means of the hydrometer and sieve methods This procedure involved sieving the samples according to Black (1965a), Jackson (1965), McKeague (1978), and Millar, Turk and Foth (1966) The portion of sample < 64 microns was then subjected to the hydrometer method to obtain particle size distribution in the fine fraction of the sample. These data were cumulatively graphed and the percentage sand, silt, and clay was read from the graph at particle sizes corresponding to 2 mm, 0 2 mm and 0 0625 mm

These values were then plotted on textural diagrams to show relationships among the samples This relationship between the various sites was used to help determine which samples would be chemically analyzed

3.3.2 Chemical Analysis

The concept of chemical weathering used here comes from Drever (1982) in which he considers weathering as the end product of a cycle of events comparing the parent material and atmospheric inputs to the remaining material. Drever's concept of weathering cannot be completely utilized here as there is no measurement of the atmospheric inputs of these soils. However, we can analyze the parent material and compare it to the surface and the depth sample of the sample pits. This will provide reasonable estimates of the amount of weathering that these soils have undergone.

The following elements, Ca, Na, Mg, and K, are readily removed through leaching (Black 1965b, Paton 1978). Fe and Al are presumed to be relatively immobile but are scavenged and chelated by organic material The solubility of Al and Fe is minimal in neutral pH ranges (pH 6-8) (Faure 1991). Ti is considered immobile (Brady 1974, Faure 1991) and quartz SiO_2 is quite insoluble in natural solution (Faure 1991) As a result, if leaching is occurring, there will be an increase of the basic cations, Ca, Ma, Mg, and K downward in a soil profile.

The chemical weathering indices are introduced by Birkeland (1984) These indices are calculated molar ratio values to determine if weathering has occurred. Specifically the ratios of Bases: Alumina and Bases: R_2O_3 (Fe, Al and Ti) are used in this analysis. These ratios are chosen because the Bases (Ca, Na, Mg, and K) are well known to be quite mobile The second portion of the ratio Al and R_2O_3 are used because they are insoluble in neutral pH ranges The resulting ratio should decrease in value from the parent material to the surface sample to the depth sample in a normal leaching environment indicating the removal of the mobile elements

Samples for chemical analysis were selected based on their representativeness of their classification (i.e periglacial forms or general environmental classification) and particle size The selected subsamples were prepared by crushing, for analysis with X-ray Fluorescence in the Shatterbox at the Earth Science Department at the University of Waterloo following standard methods

This crushed sample was then submitted to the particle analysis lab at the Geology Department at McMaster University for X-ray Fluorescence This procedure provided good results for quantifying the following elements (F, Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Rb, Sr, Y, Zr, Nb, Mo, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, I, Cs, Ba, La, Ce, Pr, Nd, S, Gd, Tb, Ta, W, Ir, Pt, Au, Hg, Tl, Pb, Bi, Th, and U). Two samples were selected for analysis from each pit or from each periglacial feature.

A good review of the X-ray Fluorescence principals, methods, function and reliability is given by Hendry (1975). In this report the author compares the different approaches of measuring the chemical matter of a substance. He states "XRF analysis provides a rapid convenient and accurate method of determining the elements present in a sample both qualitatively and quantitatively. It is particularly useful for the determination of trace elements as the competing techniques are more lengthy and generally more expensive" (Hendry 1975: 175).

Theoretically this technique measures the different energy levels emitted when the electronic configuration of the sample is changed. When energy is applied to the sample, an electron from an inner shell can be bumped off and is replaced with an outer shell electron (different electron orbitals K, L, M, and N). During this process, electromagnetic radiation is emitted and the energy emitted is specific for the different elements.

This chemical analysis was performed in order to compare the chemistry within and among periglacial features. The amount of weathering is then determined by comparing the chemistry of the parent material to the chemistry at the top of the soil column to that at the bottom. This comparison is done by comparing the mobile elements (Ca, Na, Mg and K) within the soil pit (Black 1965b). To determine if weathering was occurring between the parent material and the regolith, the parent materials chemistry is also analyzed. The assumption here is that the soil material was derived from the parent that was collected in the same location. In order for the comparison to be made between the soil pits and the parent material, the samples must have a similar chemical make-up. Specifically there may have been sampling error that produced regolithic material that did not originate from the sampled parent material i.e. different surficial geology. Chemical weathering indices were calculated for the parent material and samples from one pit per periglacial feature (Birkeland 1984).

3.4 Data Analysis

The particle size data from all excavated pits were plotted on graph paper and the sand silt and clay sized components were then calculated.

The chemical analysis data received from McMaster University were expressed as per cent mass of the sample. The weathering indices values were then calculated from these values by taking the per cent mass over the molar mass. These molar values were then used to calculate the weathering indices.

3.5 Errors

There are two sources of error in the chemical analysis. first is the machine error, which is reported to be under five percent (McAndrew, 1996) and second, is the subsample variability. Errors within a sample can be calculated as one sample was analyzed in triplicate Table 3.2, is a list of the values obtained in the three trials with three different subsamples of the same sample. The rare earth elements, mentioned in section 3.3.2, are only measured in trace quantities and therefore no error can be associated with this measurement The percent error by mass was calculated by determining the standard deviation of the three measurements The standard deviation was then divided by the mean mass of each individual element times 100 percent

Elements	Pit 681	centre		S D	Error
	parent	parent	parent		
Units	% mass	% mass	% mass		% by mass
I	0.1600	0.2200	0.1700	0.026247	14.3
Na	0.2800	0.2900	0.3000	0.008165	2.8
Mg	1.2000	1.2000	1.2000	0	0.0
Al	3.2000	3.2000	3.2000	0	0.0
Si	38.400	38.800	39.400	0.410961	1.1
P	0.2300	0.2400	0.2400	0.004714	2.0
S	0.2000	0.1900	0.1800	0.008165	4.3
Cl	0.0180	0.0200	0.0140	0.002494	1.4
K	0.8800	0.8800	0.8800	0	0.0
Ca	14.500	14.700	14.500	0.094281	0.7
Ti	0.2700	0.2600	0.2600	0.004714	1.7
V				na	na
Cr	0.0060	0.0080	0.0070	0.000816	11.7
Mn	0.0120	0.0080	0.0070	0.000471	3.8
Fe	0.6206	0.6400	0.6300	0.008165	1.3
Rb				na	na
Sr	0.0190	0.0190	0.0190	0	0.0
Zr				na	na
Y	0.0560	0.0550	0.0550	0.000471	0.9
Cs				na	na
Ba			0.0051	na	na
Li	0.0150	0.0160	0.0140	0.000816	5.4
Ce	0.0180	0.0170	0.0140	0.0017	10.4
La				na	na
W				na	na
carbonates	39.800	39.200	38.800	0.410964	1.05

Table 3.2 Errors associated with the three subsamples from the same sample.

Chapter 4 Results and Discussion

4.1 Introduction

This chapter will be presented as follows Firstly, possible environmental variables that influence weathering will be examined. Secondly, the individual periglacial forms will be described and then the weathering data will be presented and analysed Thirdly, the non-periglacial form categories will be described and then the weathering data will be presented and analyzed. Finally, a section examining the influence of the individual environmental variables on the mechanical and chemical weathering will be presented and discussed

Analysis of chemical and mechanical weathering will be performed by grouping the data with respect to the periglacial form and nonperiglacial landscapes. For the periglacial forms, it is expected that, because of the significant differences in environmental variables, there will be differences in terms of weathering on a micro-scale, i e. differences in sample site location of less than five metres for the polygons and less than a metre for stripes, solifluction lobes and mud boils. The non-periglacial landscape classification, dry ridge, wetted slope and wet meadow, may display weathering variability on a meso-scale level (10-20 m).

The second method of analysis will compare the sites in terms of the important environmental variables. Wetness and temperature will be qualitatively categorized and then compared to the percentage of silts and clays. The percentage silts and clays are used because the silts are assumed to be the end product of mechanical weathering and the clays are a product of chemical weathering. It is believed that this form of analysis has the potential to determine what variables are more important in terms of weathering

The final section of this chapter will introduce chemical weathering rates from various regions around the world and will summarize the important points discovered.

4.2 Environmental Influences on Weathering

The following section will deal with how environemntal variables interact and how they enhance or hinder mechanical and chemical weathering. Some variables such as micro-elevation, temperature, duration and depth of snow cover, and the length of season for active layer development, can be easily grouped together. Variables such as soil moisture, snow depth, and micro-elevation, can also be grouped together under the term relative wetness. These variables would be either positive or negative feedback mechanisms that would generally promote a relatively warm or cold environment, respectively. Weathering would be enhanced where there is: an abundant supply of moisture, warm temperatures (which may be indicated by a deep active layer depth A.L.D.), permeable soil matter, slope and aspect that would enhance receipt of solar radiation, and relatively heavy vegetation cover, which would result in a higher albedo. Conversely, weathering would be hindered by: dry conditions, cold temperatures (indicated by a shallow active layer), few freeze-thaw cycles (minimizing the effectiveness of mechanical weathering), low slope (preventing the flow of water through the system resulting in stagnant water), a northern aspect would retard direct receipt of solar radiation (hence lowering temperatures and energy in the system), and a sparse vegetation cover, which results in a lower albedo.

Generally, the variables that would indicate a cold environment will also inhibit physical or chemical weathering because the time period for weathering to occur is decreased, or conversely a relatively warm environment would enhance weathering. The soil moisture is important for weathering because without water the effectiveness of the physical and chemical processes are limited. Vegetation cover is an example of an environmental variable that could be related to both relatively high temperatures, due to low albedo, and increased wetness.

4.2.1 Conceptual Model

From the preceding section it is hypothesized that there would be increased weathering in regions that have the following characteristics; relatively wet, warm, high vegetation cover, low albedo, southern aspect to maximize receipt of radiation and some slope, to encourage drainage.

Theoretically it is possible that many sample locations have some environmental variables that are and are not conducive to weathering. Specifically, the polygon troughs differ significantly from the raised polygon centres. The topographically depressed troughs are hypothesized to be conducive to more rapid weathering because of the ample moisture supply and drainage, but as the regolith is cooler, weathering could be hindered. The deeper overlying snowpack and the topography results in reduced cumulative annual net radiation.

Table 4.1 is a general summary of the periglacial features, the general landscape types that were sampled, and the environmental variables that are thought to be important in the weathering process. These environmental variables listed in Table 4.1 are qualitative and summarize the conditions at the site as they are presently and may have been for several thousands of years.

From the table it is evident that there is no column or periglacial form which has all of the variables conducive to weathering. In most cases there are variables that would enhance and hinder weathering. Unfortunately, there is no means of weighting the different environmental variables in terms of importance. Factor Analysis or Principle Components Analysis could be used to determine the weighting of the environmental variables, however, this is not possible for this data set because most of the environmental variables are qualitative measures.

Weathering Variables	Sol Lobes		Stripes		Poly-gons		Mud-Boils	Dry Ridge	Wetted Slope	Wet Meadow
	Margin	centre	trough	centre	trough	centre				
Rel Moist	+	-	+	-	+	-	+	-	+	+
Rel Temp	-	+	-	+	-	+	-	+	=	-
ALD	-	+	-	+	-	+	=	+	=	-
Veg Cov	+	-	+	-	+	-	-	-	+	+
Albedo	+	-	+	-	+	-	=	-	=	+
Root Dep	-	+	-	+	-	+	=	+	-	-
Aspect	E/W		S/SW		S/N		na	na	na	N/S
Slope	+		+		-		-	+	+	-

Table 4.1 Qualitative summary of the environmental characteristics of the sampled sites. (+'ve symbols indicate where weathering is enhanced, -'ve symbols indicate where weathering is hindered, and = symbols indicate not a factor at that site).

4.2.2 Individual Environmental Variables Influence on Weathering

The following section introduces how the individual environmental characteristics of moisture, temperature and vegetation cover affect the weathering process. Many of the environmental factors recorded at the studv sites may or may not be representative of the long term average environmental factors. It is difficult to categorize these sites quantitatively in terms of environmental factors based on a small window of time spent at the research site.

4.2.2.1 Limitations

There are two limitations to this type of analysis. First, the assigned variables are qualitative. However, these assigned variables attempts to summarize the general micro-environment of the sites. The meteorological variables of temperature and precipitation are not taken into consideration with regards to the classification of the qualitative variables of moisture and temperature. These meteorological data are not considered because the conditions within the pit are constantly changing with time and environmental activity, such as precipitation and active layer development.

Secondly, the fines defined as the sum of the silt and clay is used to simplifly the particle size data. and are used in this comparison because the weathering rates are slow in this environment (Tedrow 1963). The sum of the silt and clay may be a better measure of the physical weathering that has occurred, than if only clays were used as the end product of weathering. By using the average value of fines from the upper and lower pit samples, it generalizes the particle size of the profile.

4.2.2.2 Moisture

The assigned moisture values are based on the physical attributes of the site. Sites that are typically wet or dry were categorized by field observations with regards to hydrology, and elevation. Specifically, sites that were close to saturation or had water flowing through them for a significant time period of the summer were categorized as wet. These sites are located in depressions or are on flat, poorly drained locations. A specific example of the differences that occur within a few metres are found within the polygons. The polygon troughs were assigned values of 1 (very wet) and the polygon centres were assigned values of 3 (moderately wet). There is a significant difference between these samples in terms of the micro-elevation, ranging from approximately 15 to 50 cm (Figure 4.5). Samples that are categorized as being dry are located on the tops of ridges, and are well-drained. An example of a site that is assigned a value of 5, is Pit #16, (Figure 4.10).

4.2.2.3 Temperature

The qualitative categories of temperature are similar to the moisture categories in terms of how they are defined. Generally, the major environmental variables used to determine the relative temperature of a site are the amount of snow located at the end of the winter and the amount of solar radiation received The variables are classified with regards to micro-elevational differences, slope and aspect of the individual sites.

A cold site is defined as one in which the snow remains for a longer time period, such as depressions which do not receive as much direct solar radiation. The extremes are polygon troughs (very cold =1), ridge tops (very warm =5) with samples ranging in between, including polygon surfaces, (either 2 for a flat west facing slope or 4 with a south facing slope)

In general terms a warm site is one that is free or nearly free of snow at the end of the winter and is exposed to direct solar radiation for most of the summer. These characteristics are thought to enhance the relative warmth of the site because little energy is used in melting the snow. Rather most of the snow is removed by aeolian processes, and therefore the solar radiation is effective in warming the site. An example of a category 4 is the solifluction lobe Pit #84 (figure 4.1). There are not many samples that are category #5 because a lot of the samples such as Pit #16 (Figure 4.10), are well drained but have a deeper snowpack at the end of the winter because of the surrounding topography, which will decrease the relative temperature of the site.

Active layer depth aids in the temperature classification as sites with a greater active layer depth are considered warmer. Pit #85 (class 4) has an active layer depth of 75 cm even though it is at a much higher elevation than Pit #28 with an active layer depth of 45 cm (class 1). Pit #27 has an active layer depth of 52 cm (class 2). Other polygons have a difference of 55 cm (class 4) at the centre and 40 cm in the trough (class 1). More examples can be seen in appendix #1.

4.2.2.4 Vegetation

Vegetation cover is also used to relate to weathering rates It is hypothesized that increased plant cover will increase the weathering rates because vegetation cover increases the albedo thereby enhancing radiation receipt. The roots also encourage chemical and biological activity Also, the vegetation will collect and trap any fine aeolian particles. This is significant because there may be increased fine particles that are not the product of weathering at the site but have been relocated

4.3 Periglacial Features

4.3.1 Solifluction Lobes

Solifluction is the flow of saturated soil from higher to lower ground and results in various forms, including sheets, lobes and terraces (French 1976). In the study area there are examples of solifluction sheets and lobes. The solifluction lobes have maximum dimensions of three metres wide, and one and a half metres deep steps, which are comparatively smaller than the larger solifluction sheets, which can be tens of metres in width. However, the solifluction lobes are analyzed because they were smaller and consequently more manageable.

Solifluction lobes are illustrated in Figure 4.1. In this study there are 15 pits that are classified as solifluction lobe sites. All of the solifluction lobes that were analyzed in this study are located in the Schei Point Geological formation. The lithology of this formation includes; calcareous siltstone and sandstone, shale and minor limestone. Mechanical analysis was performed on all of the samples. Chemical analysis was performed on pits #84 (lobe top) and 85 (margin) because it was hypothesized that there might be pronounced differences in these locations. It is hypothesized that there may be more weathering occurring at the margins of the forms because of the differences in albedo, and hydrology. Also, because of the nature of the

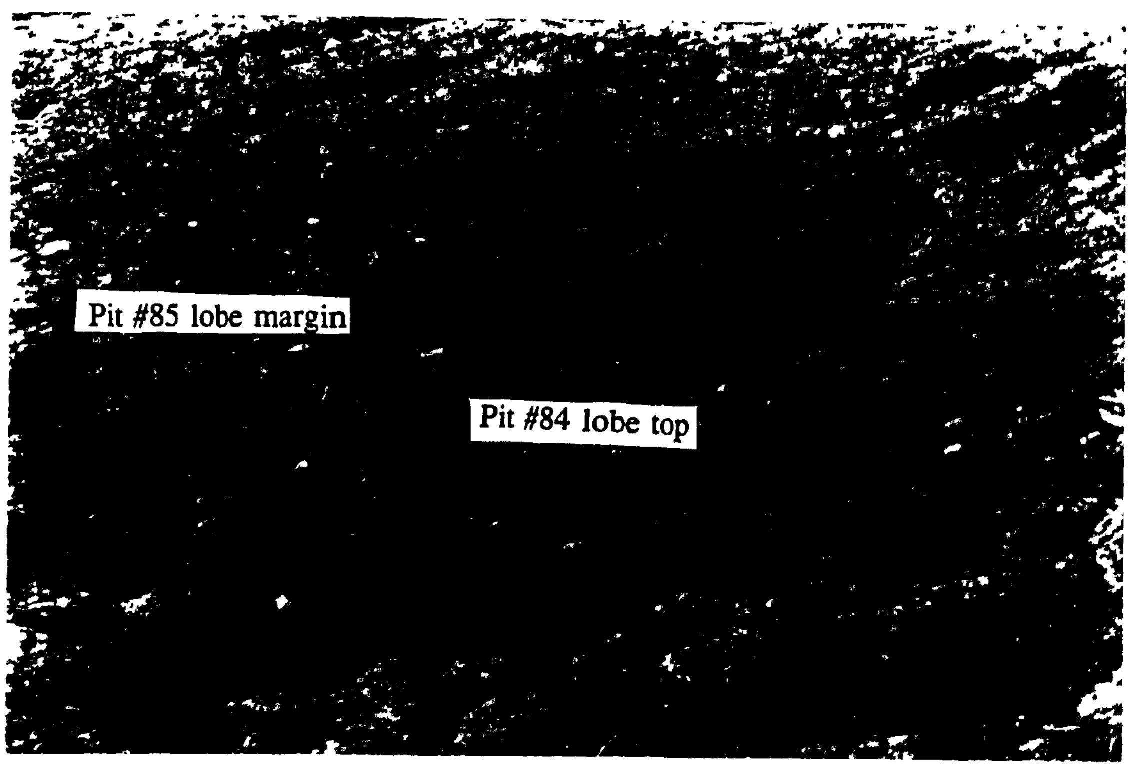


Figure 4.1 Solifluction lobes from a distance (a) and close up (b). Close up photo shows location of margins and lobe top.

formation of these forms, there may be a concentration of highly weathered surface material at the margins

4.3.1.1 Mechanical Weathering

The particle size distribution of these samples is presented in Figure 4 2 Specifically, there are 7 pits which have a larger quantity of fines at the bottom and there are 8 pits where the larger quantity of fines which occurs at the surface. Specifically Pit #70 has a particle size distribution of 63% sand, 26% silt and 11% clay at the surface and 72%, 19%, and 9% at the base Another, Pit #82, has a particle size distribution which indicates more weathering at the base of the pit specifically, 90%, 4%, 6% at the surface compared to 69%, 24%, 7% at depth. The remainder of the samples within this category fall somewhere in between these two extremes

4.3.1.2 Chemical Weathering

The chemical analysis data are shown in table 4.2 The easily leached elements, Ca, and Na appear to have undergone more leaching in Pit #84 As a result of the leaching, the Si values are decreasing with depth, because the Si is relatively immobile and since the values are expressed in % mass, the Si value is increased because other more mobile elements may have been removed Another observation is the carbonate values, both decrease from the parent material This is probably a result of weathering of the carbonate rock material after it has been

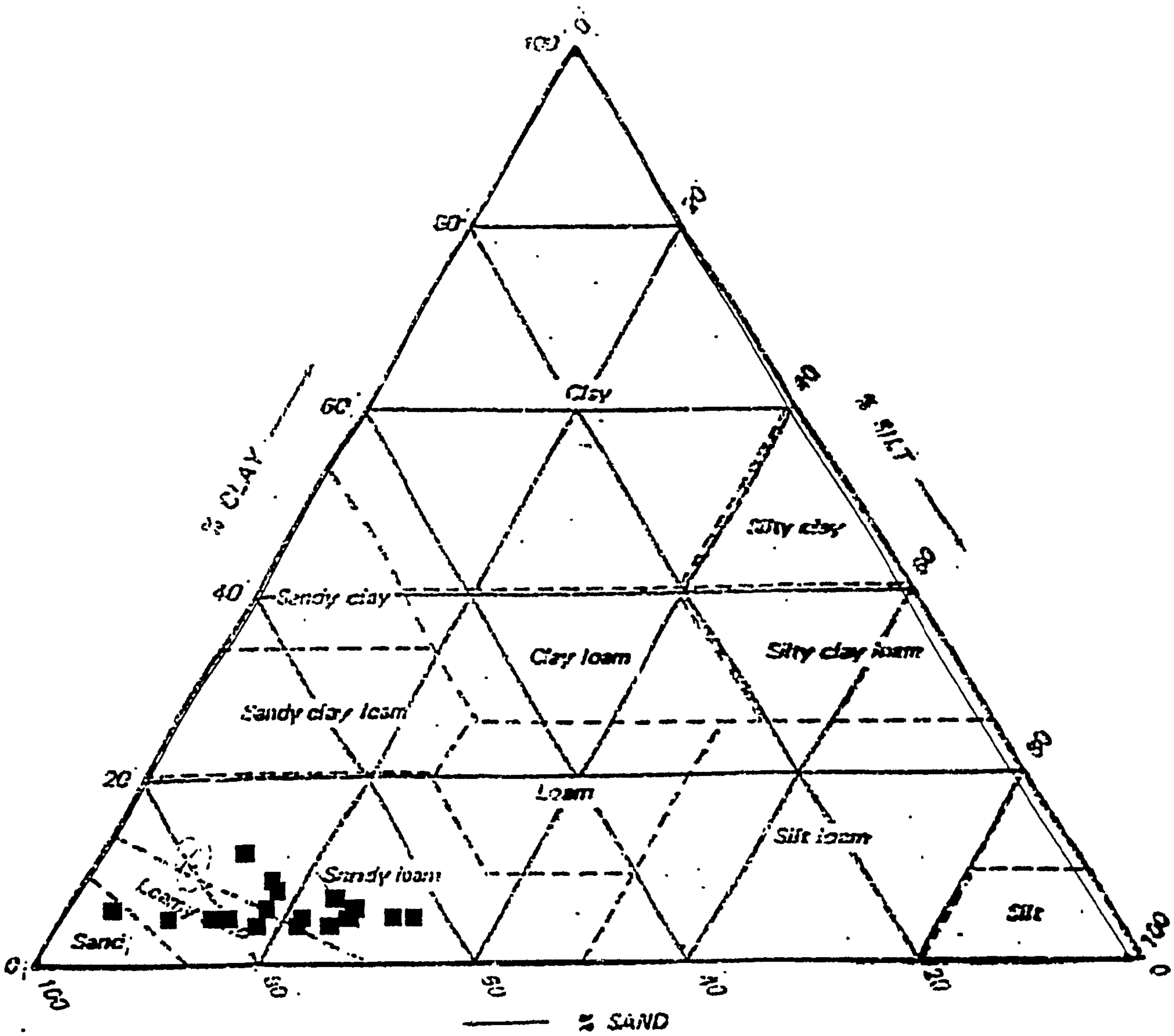


Figure 4.2 Triangular textural diagram for the solifluction lobes

broken down mechanically. Mechanical weathering promotes chemical weathering by exposing new surfaces to chemical activity.

In terms of the weathering indices (Table 4.3), a different chemical pattern occurs in these pits. The weathering indices for the lobe top sample indicates that the surface value is greater than the values at depth of the pit. This pattern of a decreasing ratio from the surface to depth, is indicative of a leaching environment. The margin pit indicates that leaching is not occurring. However, the parent sample does not appear to match with the pit samples. An explanation for the pattern within the margin pit may be that leaching is not effective in this location.

Elements	Pit #84	centre		Pit #85	margin	
	parent	depth	surface	parent	depth	surface
F	0.2100	0.2200	0.1700	0.1833	0.2500	0.1300
Na	0.4400	0.2900	0.3000	0.2900	0.2600	0.2700
Mg	1.3000	1.4000	1.3000	1.2000	1.4000	1.2000
Al	4.7000	5.0000	4.3000	3.2000	5.3000	4.5000
Si	36.700	38.200	41.100	38.867	37.800	39.800
P	0.2400	0.6600	0.3300	0.2367	0.7500	0.3300
S	0.0780	0.3400	0.3900	0.1900	0.2800	0.4000
Cl	0.0280	0.0220	0.0260	0.0173	0.0250	0.0170
K	1.5000	1.2000	1.1000	0.8800	1.3000	1.1000
Ca	14.900	14.700	12.700	14.567	14.700	12.300
Ti	0.3100	0.3200	0.3200	0.2633	0.3300	0.3000
V			<			
Cr	0.0090	0.0100	0.0070	0.0070	0.0120	0.0090
Mn	0.0240	0.0110	0.0130	0.0123	0.0130	0.0150
Fe	1.6000	1.1000	0.9000	0.6300	1.1000	0.9400
Rb	0.0060					
Sr	0.0210	0.0210	0.0170	0.0190	0.0210	0.0180
Zr						
I	0.0520	0.0560	0.0570	0.0553	0.0580	0.0530
Cs					<	
Ba	0.0140	<	<			
La	0.0160	0.0170	0.0110	0.0150	0.0160	0.0120
Ce	0.0130	0.0190	0.0160	0.0163	0.0160	0.0160
Ta	<	<				
W		<	<	<		
carbonates	37.800	36.500	36.800	39.267	36.400	38.500

Table 4.2 The chemical data expressed as % mass of the solifluction lobes, < indicates trace quantity.

Sample	Bases/Al	Bases/R_2O_3
lobe parent	6.96	5.45
lobe depth	6.41	5.24
lobe surf	6.53	5.31
ratios	P S D	P S D
margin parent avg	9.67	7.86
margin depth	6.06	5.00
margin sur	6.01	4.93
ratios	P D S	P D S

Table 4.3 The weathering indices, for the solifluction lobes expressed as molar ratios where R_2O_3 is Al+Fe+Ti, and bases are K+Na+Ca+Mg.

4.3.2 Stripes

There are two distinct types of stripes discussed in the literature, non-sorted and sorted. Within the study site are the non-sorted stripes which are defined by Washburn (1956 p.837) as a "form of patterned ground possessing a striped pattern and non-sorted appearance due to parallel lines of vegetation covered ground and intervening stripes of relatively bare ground oriented down the steepest slope possible." The definition includes two distinct components, first the stripe feature which is emphasized by the presence of vegetation and secondly the fact that these forms only occur on slopes. An example of these non-sorted stripes can be seen in Figure 4.3.

Four pits were excavated in non-sorted stripe formations, see Table 3.1. Mechanical analysis was performed on all four pits and chemical analysis of the stripe sample was performed on Pit #4. This sample is located in the Schei Point formation.

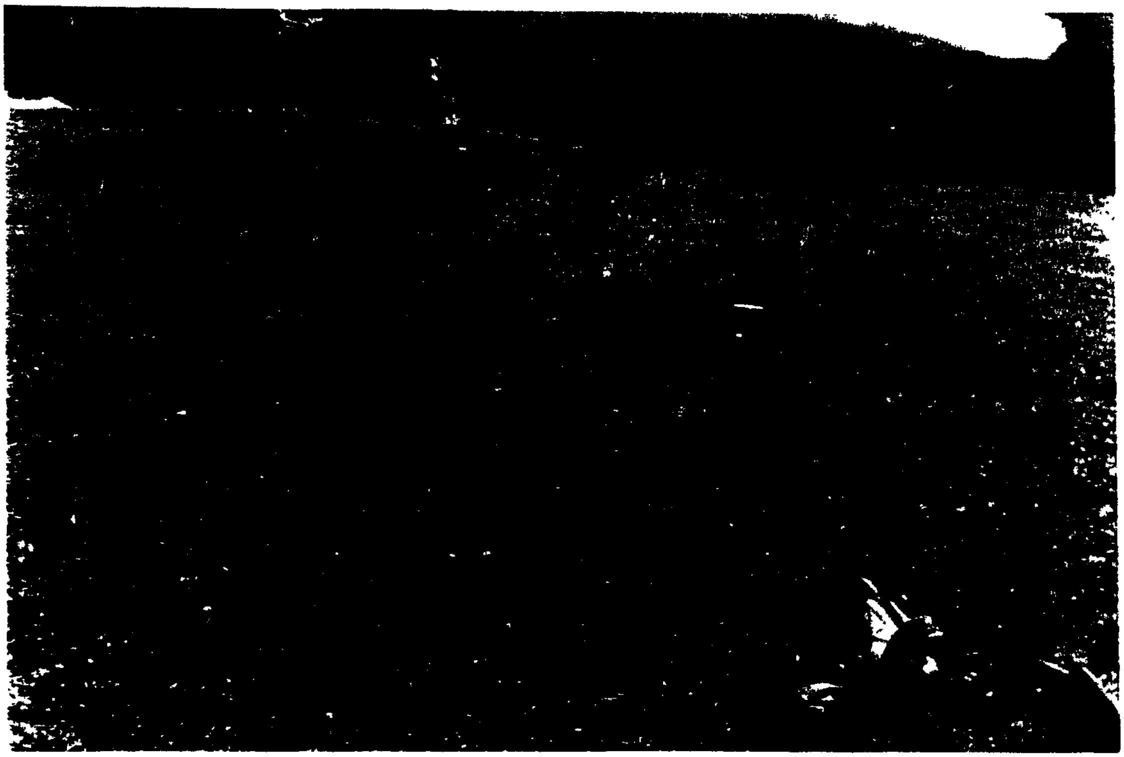
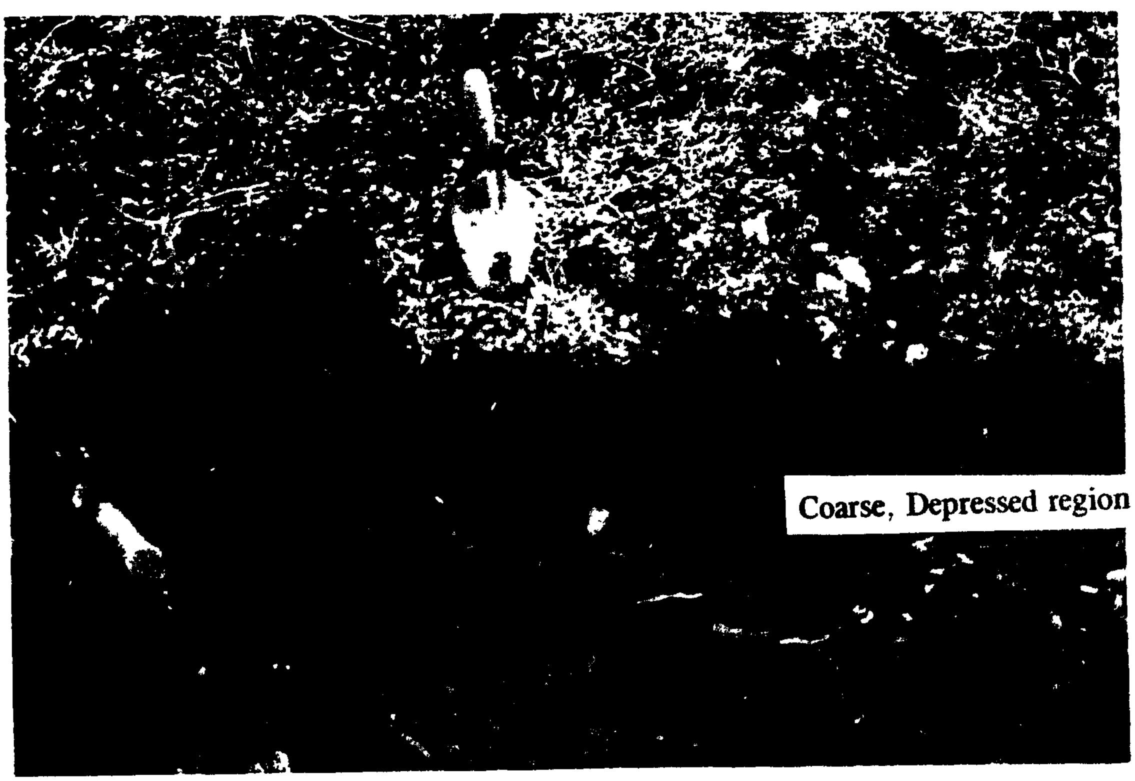


Figure 4.3 Non-sorted stripes from a distance (a) and close up (b). Close up photo shows location of stripes and depressed regions.



4.3.2.1 Mechanical Weathering

The particle size distribution for the non-sorted stripes is shown in Figure 4.4. From the four pits analyzed for particle size distribution two pits have more fine material at the base than the surface, one pit has the depth being slightly coarser, and the last pit has an uniform distribution. One important observation is that the regolith in the depressed region of the stripe is somewhat coarser than the regolith below the elevated portion (Figure 4 3).

In three of the pits there is a significant portion of the sample that is greater than 2mm. For example, Pit #4 has 1% at the base to 25% at the surface of the sample larger than sand sized material. Also Pit #20 has from 0% at the base to 61% at the surface of the sample in this large particle size fraction. However, the greater than 2mm sized material does not appear to correlate with either the depressed or elevated regions. In other words there are large quantities of greater than 2mm sized material in both the elevated and depressed regions of the stripes.

4.3.2.2 Chemical Weathering

The chemical weathering data for the stripe pit is shown in Table 4.4. The most noticeable difference among the three samples is the amount of carbonates. The samples collected in the pit do not contain any carbonates, however, the parent material has 43% by mass. This sample was collected in a geological region that has calcareous sandstone and siltstone as the major rock type. There are two possible explanations for this observation. First the parent material may not be representative of the geological material with which the stripes

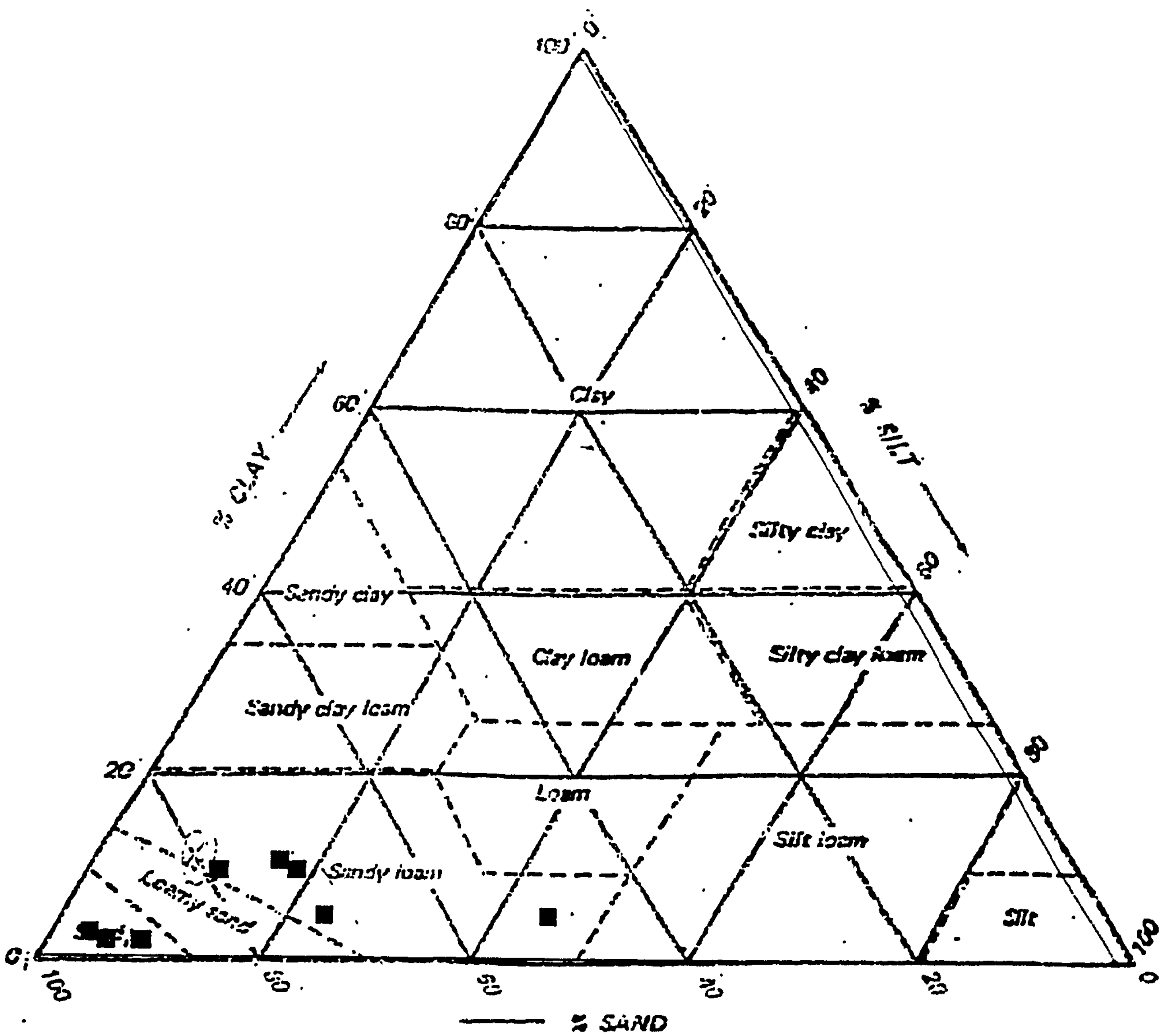


Figure 4.4 Triangular Textural Diagram for the Non-sorted Stripes

Elements	Pit #4	Stripe	
	parent	depth	surface
F	0 1500	0 0730	0 1100
Na	0 0160	0 5700	0 5200
Mg	0 1400	1 4000	1 5000
Al	1 1000	14 300	12 300
Si	38 300	71 300	71 900
P	0 0630	0 5000	0 5900
S			
Cl	0 0100	0 0410	0 0310
K	0 3300	2 9000	2 5000
Ca	15 900	2 7000	4 5000
Ti	0 0680	0 9000	0 8400
V		0 0140	0 0090
Cr	0 0050	0 0190	0 0200
Mn	0 0340	0 0620	0 0690
Fe	0 4200	5 1000	4 9000
Rb		0 0090	0 0080
Sr	0 0060	0 0140	0 0180
Zr		0 0340	0 0300
I	0 0640	0 0410	0 0460
Cs			
Ba		0 0210	0 0220
La	0 0210		
Ce	0 0200	0 0090	0 0140
Ta			
W			
carbonates	43 300	0	0

Table 4 4 The chemica! data expressed as % mass of the stripes, < indicates trace quantity.

were formed. The other explanation is that the carbonates have been removed after the rock material has been mechanically weathered thus exposing the easily weathered Ca.

Within the pit there appears to be leaching occurring, because the Na and K values are greater at depth than at the surface of the pit. Also the weathering indices, see Table 4.5, support this conclusion because there is a decreasing ratio when the parent material is compared to soil material. However, some of the easily leached elements do not support this observation. For example the Ca and Mg values are greater at the surface than at depth of the pit. One explanation of this is that, since the Ca values in the parent material are high, it would take a lot of time to leach downward in the profile

Sample	Bases Al	Bases R_2O_3
parent	29.95	20.38
depth	0.88	0.67
surface	1.26	0.94
ratios	P · S D	P S D

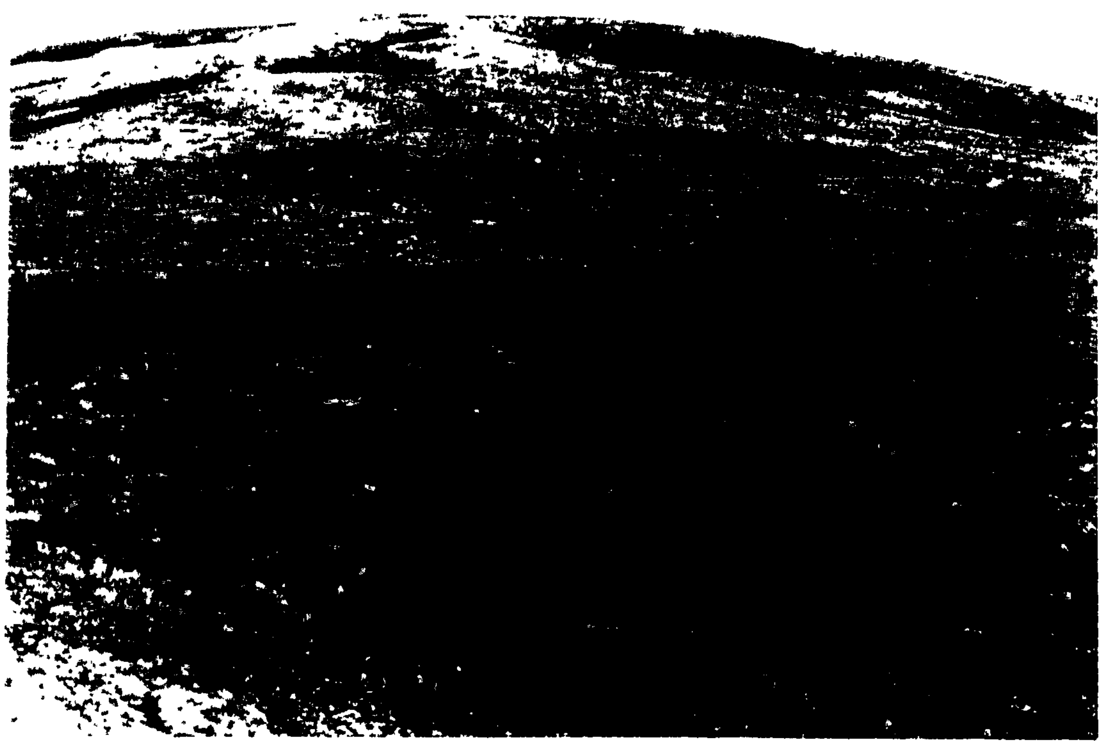
Table 4.5 The weathering indices, for the stripes, expressed as molar ratios where R_2O_3 is Al+Fe+Ti, and bases are K+Na+Ca+Mg.

4.3.3 Polygons

A polygon is a type of patterned ground consisting of a closed, roughly equidimensional figure bounded by straight sides (Harris 1988) which occurs on flat or nearly flat slopes (French, 1976). There are 11 pits sampled representative of polygons, see Table 3.1 and Figure 3.1 for their location. Of these pits there are 5 sets of samples which are sampled in the center of the polygon as well as in an adjacent trough. Figure 4.5 is an example of the pit locations and the differences in the micro-environment of the centre of the polygon is elevated and the trough is in a topographically depressed region.

The particle size or mechanical analysis was performed on all eleven pits. The polygon trough and centre that are used in the chemical analysis are pits #27 and 28.

Figure 4.5 Polygon centre and polygon trough. Notice the difference in elevation in the trough when compared to the polygon centre.



It is hypothesized that there is greater weathering in the regolith/soil below the troughs than at the centre of the polygon because it is a wetter environment, which should be more conducive to both chemical and mechanical weathering activity. However, the wetness and the cool temperatures of the troughs may be an obstacle to elevated weathering rates because, being a significant depression on the landscape, they accumulate a significant amount of snow which slowly melts in the spring. Therefore, this increased the length of the melt season may decrease the active layer depth when compared to the drier elevated polygon centre

4.3.3.1 Mechanical Weathering

The particle size distribution for the polygons is shown in Figure 4.6. Three of the five polygon centre samples were finer at the base than at the surface. Four of the five polygon trough samples were finer at the base than at the surface.

4.3.3.2 Chemical Weathering

The chemical data for the polygons is shown in table 4.6. There are virtually no differences in the readily leached cations Ca, Na, Mg and K, in the polygon centre site The polygon trough has exactly the same pattern as does the drier polygon centre When the polygon parent material is compared to the polygon centre, and trough locations, the parent material has Si values of 62% compared to 67%-69% for the samples within the pits, and much higher Fe values 15% compared to 7%-8% for the samples within the pits. This may be a result of the iron being relatively mobile in this environment after the initial breakdown of the

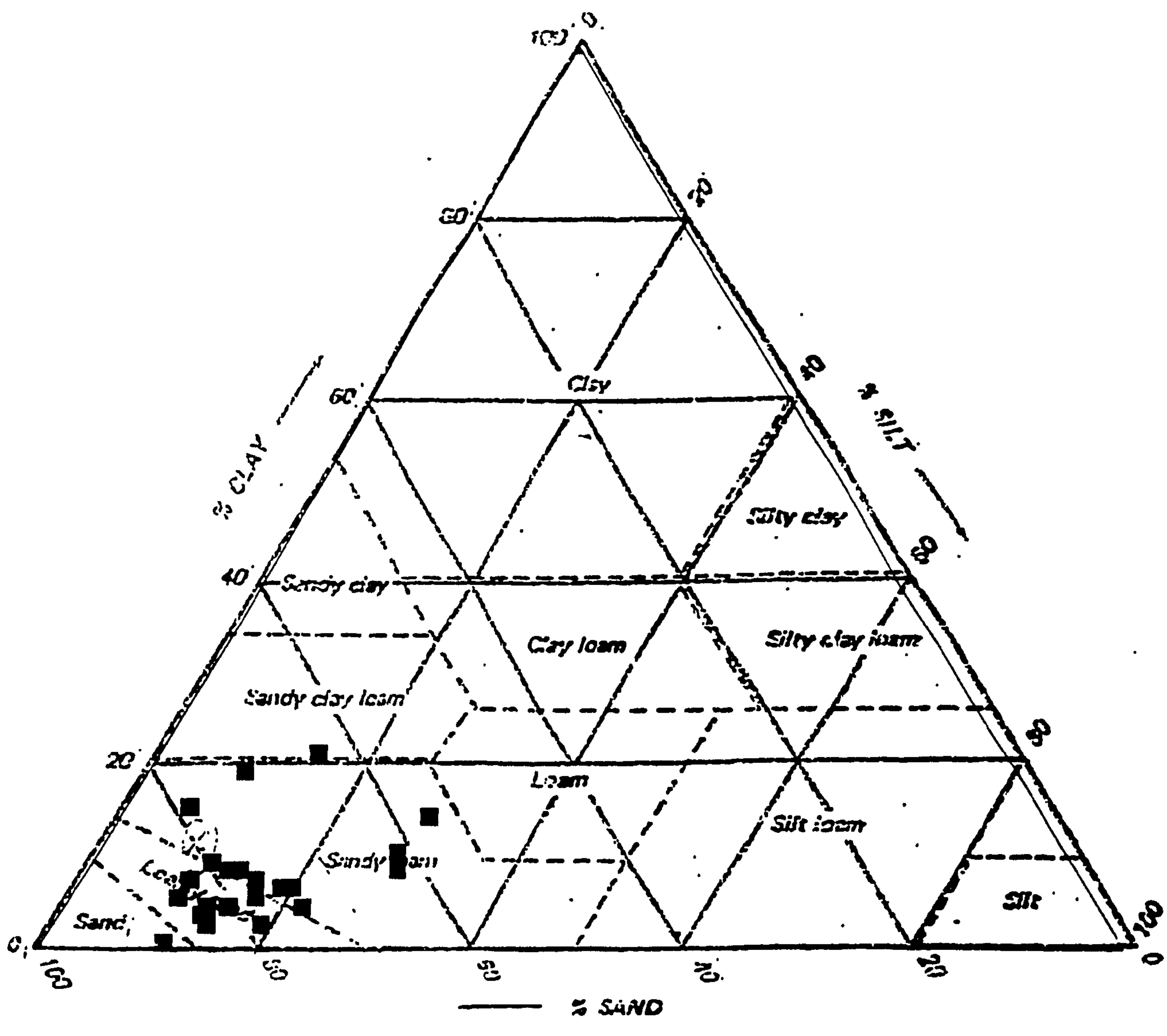


Figure 4 6 Triangular Textural Diagram for the polygon sites.

Elements		Pit 27	Centre	Pit 28	Trough
	parent	depth	surface	depth	surface
F	0.0510	0.0710	0.0430	0.0790	0.0870
Na	0.5100	0.5800	0.5700	0.5200	0.5400
Mg	1.3000	1.3000	1.3000	1.3000	1.3000
Al	16.200	18.400	16.700	17.600	16.700
Si	61.200	67.100	69.000	67.600	69.100
P	0.3400	0.2500	0.2500	0.2600	0.2500
S					
Cl	0.0230	0.0130	0.0470	0.0200	0.0230
K	2.2000	2.5000	2.5000	2.5000	2.4000
Ca	1.2000	0.7300	1.1000	1.3000	1.2000
Ti	1.5000	1.7000	1.6000	1.7000	1.6000
V	0.0150	0.0080	0.0100	0.0080	0.0050
Cr	0.0170	0.0180	0.0160	0.0170	0.0150
Mn	0.6300	0.0580	0.0600	0.0620	0.0600
Fe	14.800	6.9000	6.4000	6.9000	6.5000
Rb	0.0090	0.0100	0.0090	0.0100	0.0090
Sr	0.0190	0.0200	0.0210	0.0210	0.0210
Zr	0.0290	0.0380	0.0310	0.0400	0.0400
I	0.0470	0.0390	0.0420	0.0410	0.0420
Cs	0.0050		0.0050		
Ba	0.0510	0.0530	0.0480	0.0530	0.0480
La					
Ce	0.0130	0.0080	0.0110	0.0070	0.0090
Ta					
W					
carbonates	0.00	0.00	0.00	0.00	0.00

Table 4.6 The chemical data expressed as % mass of the polygons, < indicates trace quantity

parent material, as the iron decreases 7%-8% by mass The Si in the form of quartz may produce a higher relative concentration without being removed or added to the system as the Fe is depleted

The samples extracted from the polygon show that for the chemical weathering indices there is little difference in the weathering between the trough region of the polygon and the centre, see Table 4 7 The values for the calculations are very similar showing almost no change within the individual sites, specifically the trough or the centre.

Sample	Bases/Al	Bases/R_2O_3
parent	0 54	0 32
centre depth	0 48	0 33
centre surf	0 53	0 39
ratios	P S D	S D P
trough depth	0 52	0 38
trough surf	0 54	0 39
ratios	P S D	S D P

Table 4.7 The weathering indices, for the polygons, expressed as molar ratios where R_2O_3 is Al+Fe+Ti, and bases are K+Na+Ca+Mg.

4.3.4 Mud boils

Another genetic form of patterned ground are mud boils or non-sorted circles (French 1976). This feature is formed possibly by the cryostatic pressure, which involves the injection of subsurface material into the surface layer because of the resultant hydrostatic pressure buildup during freeze-up, (Figure 4.7). This periglacial feature was not common in the study area, therefore only 2 samples were collected and only one analyzed, Pit #10, (Figure 4.8)

It is hypothesized that there would be little difference in terms of both chemical and mechanical weathering, between the surface and depth samples because of the nature of the formation of mud boils.

4.3.4.1 Mechanical Weathering

No trend can be determined for the mechanical weathering of the mud boils possibly, as a result of the small number of samples collected from this feature, (Figure 4.9) However there does appear to be an almost uniform particle size distribution within the pit. The surface sample has a particle size distribution of 74% sand, 18% silt, and 8% clay and the depth sample particel size distribution is 78% sand, 14% silt and 8% clay at depth

4.3.4.2 Chemical Weathering

The chemical distribution within the mud boil appears to be very similar (Table 4.8) As well the chemical weathering indices indicate that there is little difference between the surface and the depth of the pit, see Table 4.9. There is a slight difference between these numbers but these differences are not significant

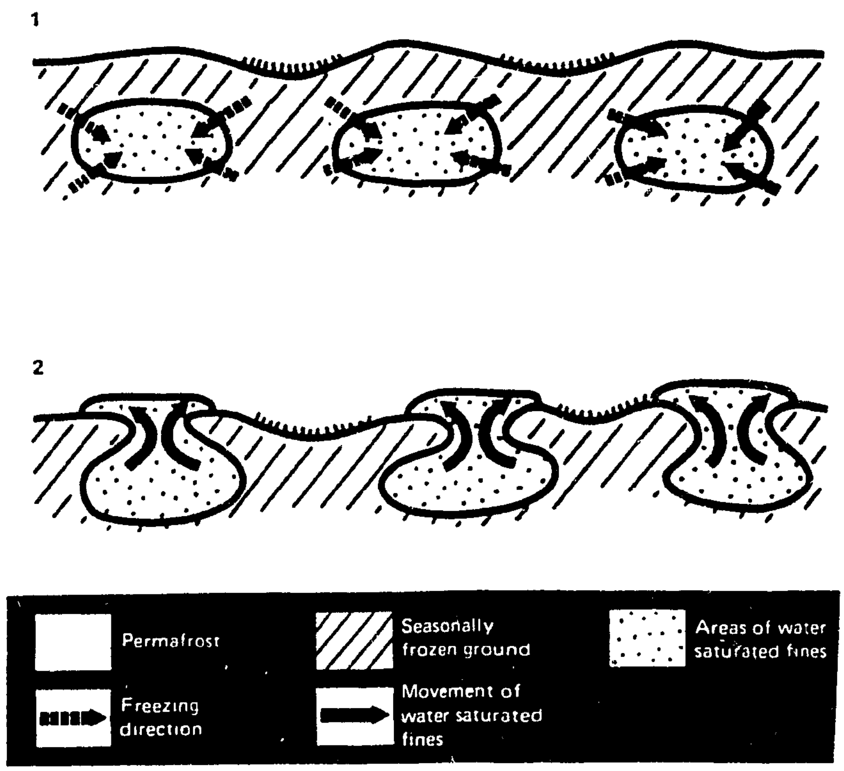


Figure 4 7 Mud Boil Formation from French (1976) pg 193 The Periglacial Environment, Longman Group Limited, London

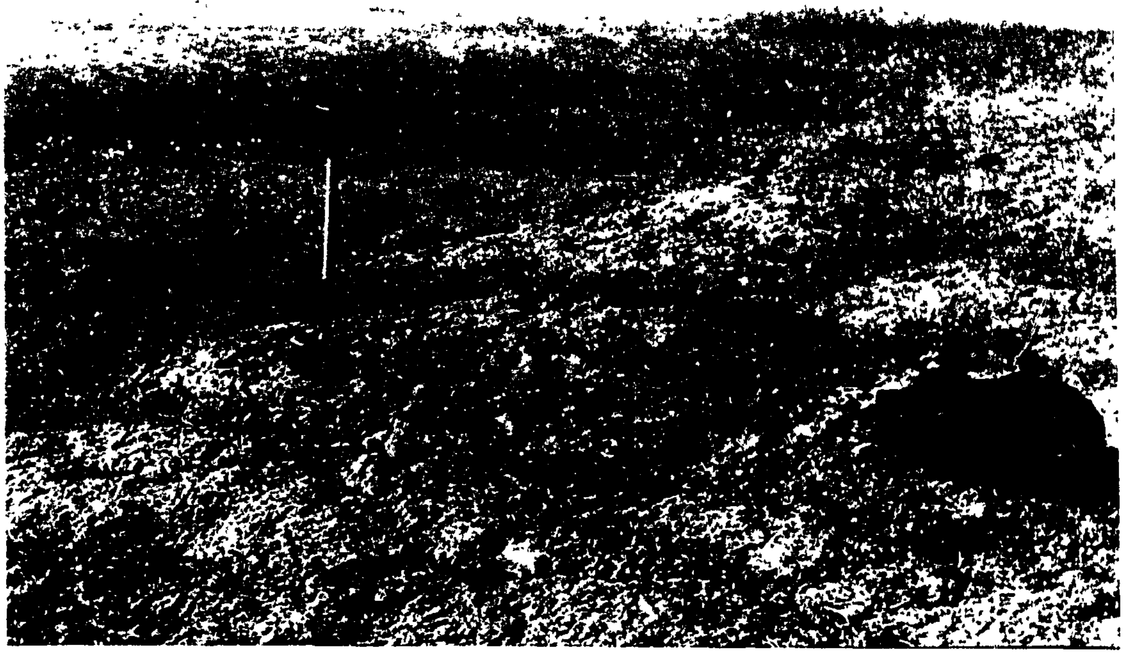
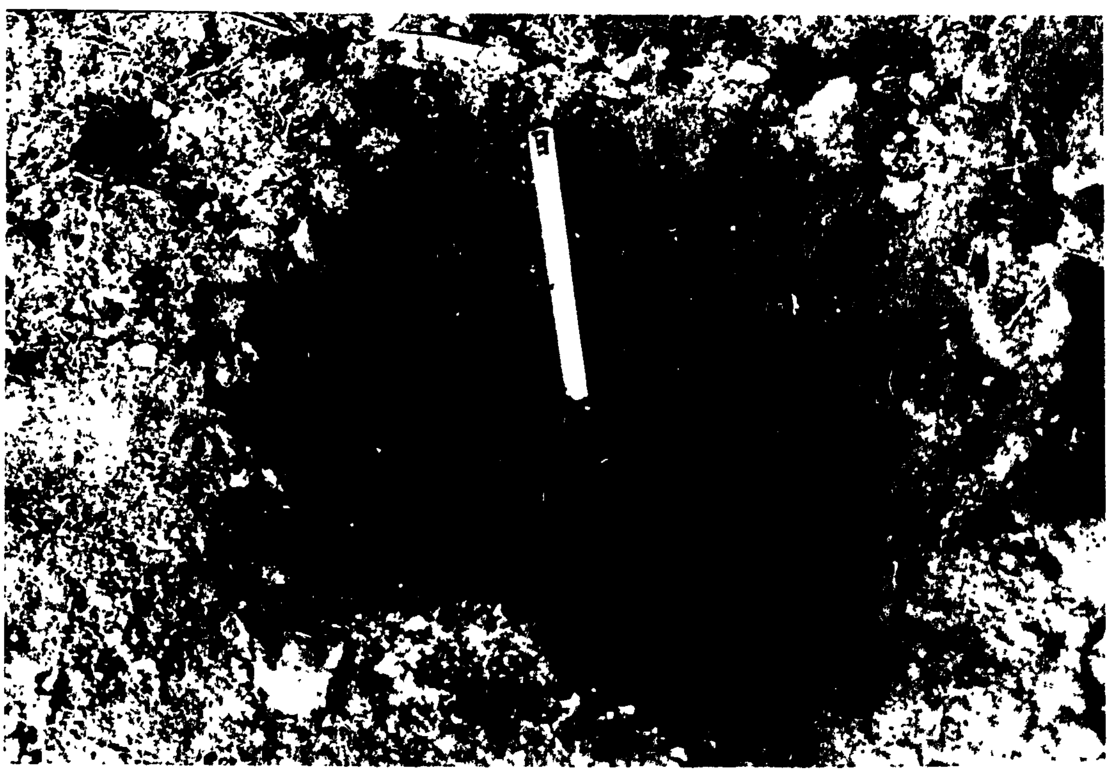


Figure 4.8 Mud Boil visual of site and the actual pit itself notice the upwelling of fine sediment in the centre of the form.



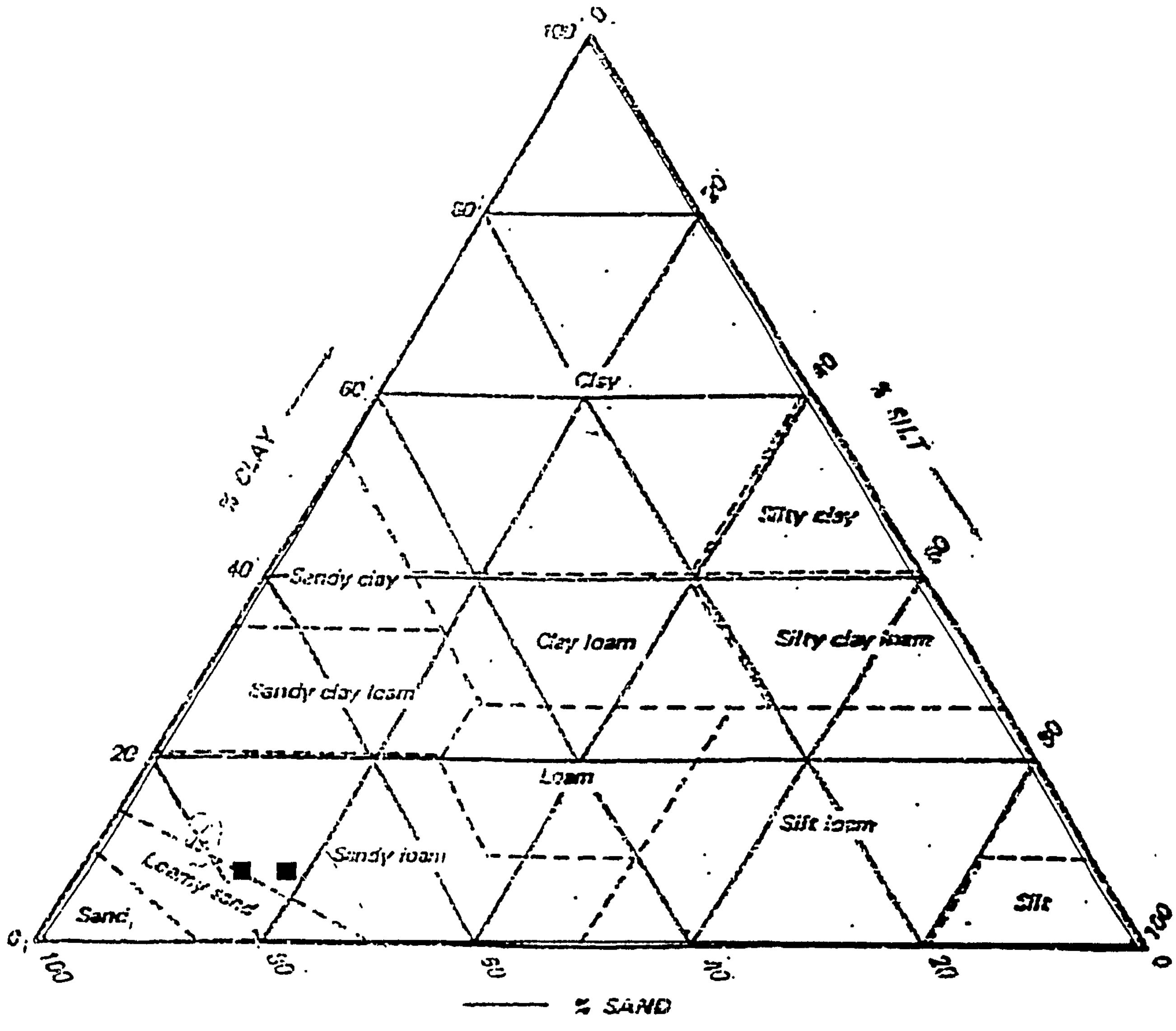


Figure 4 9 Triangular Textural Diagram for Mud Boils.

Elements	Pit #10	Mud Boil
	depth	surface
F	0.0150	0.0460
Na	0.8900	0.9400
Mg	1.5000	1.5000
Al	17.800	17.900
Si	65.000	65.100
P	0.2600	0.2700
S		'
Cl	0.0270	0.0240
K	2.7000	2.7000
Ca	2.4000	1.8000
Ti	1.2000	1.2000
V	0.0120	0.0160
Cr	0.0200	0.0200
Mn	0.1200	0.1300
Fe	7.8000	8.2000
Rb	0.0100	0.0100
Sr	0.0200	0.0200
Zr		
I	0.0480	0.0490
Cs		0.0050
Ba	0.0390	0.0350
La		'
Ce	0.0140	0.0140
Ta		
W	'	
carbonates	0.00	0.00

Table 4.8 The chemical data expressed as % mass of the mud boils, ' indicates trace quantity

Sample	Bases/Al	Bases/R_2O_3
depth	0.70	0.52
surf	0.64	0.47
ratios	D- S	D S

Table 4.9 The weathering indices, for the mud boils, expressed as molar ratios where R_2O_3 is Al+Fe+Ti, and bases are K+Na+Ca+Mg.

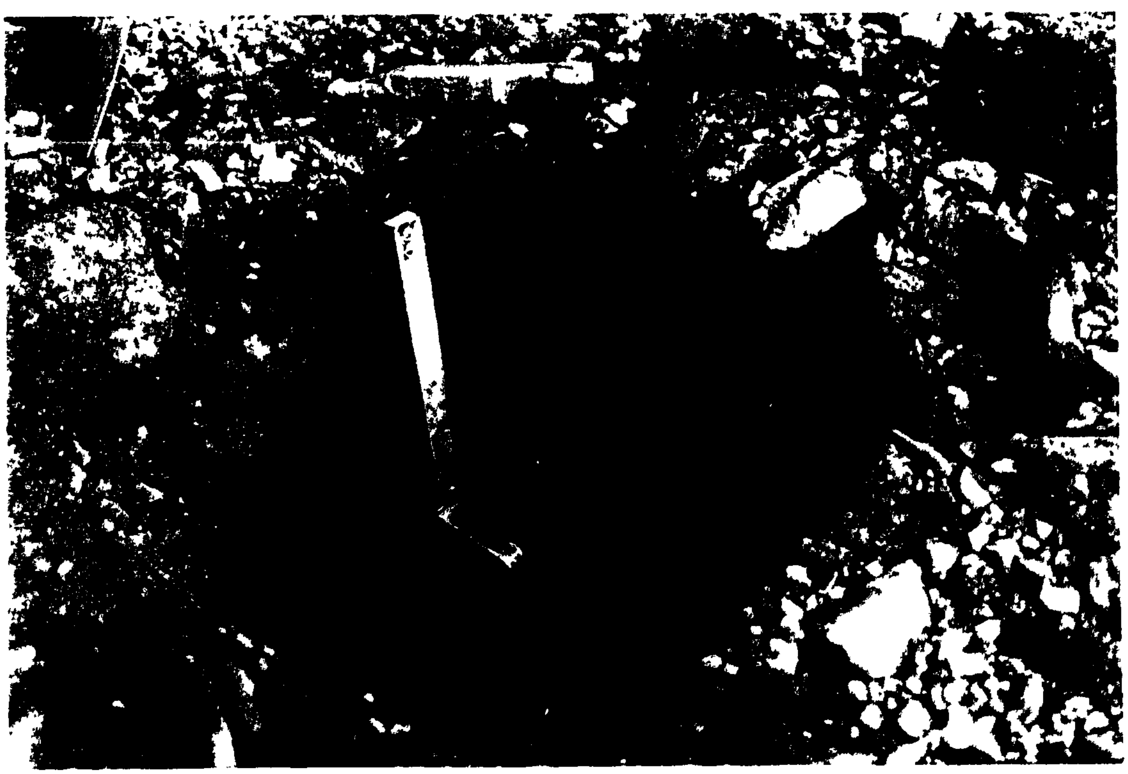
4.4 Non-Periglacial Feature Categories

4.4.1 Dry Ridge

This sample category can best be described as being located on slopes, is very well drained, and usually poorly vegetated (Figure 4.10). The well drained nature is a result of relatively permeable regolith and the rocky base and primarily steep slope. Eleven pits were dug in this type of environment, see Figure 3.1 and Table 3.1. which summarize the locations, geological regions, and lithology.

It is hypothesized that this region will be relatively ineffective in terms of both chemical and mechanical weathering because of the relative dryness and the efficient drainage. However, any weathering that does occur may be noticeable at the base because, near the permafrost table, the regolith has a higher soil moisture and the flushing or leaching from the surface and upslope may contribute fines to the base.

Figure 4.10 Dry Ridge site, showing sparse vegetation.



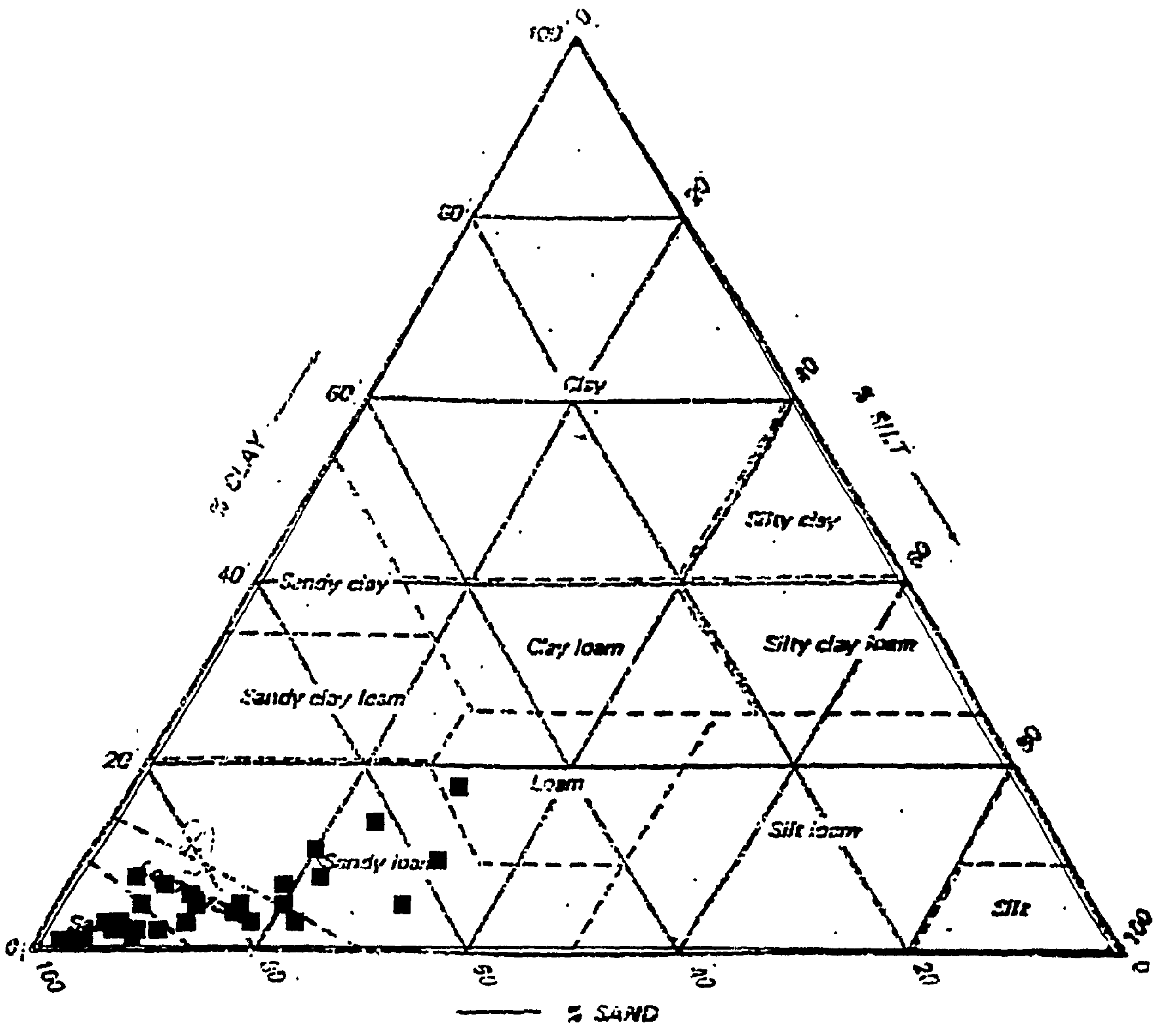
4.4.1.1 Mechanical Weathering

The triangular representation of the particle size distribution is seen in Figure 4.11. In eight of the eleven sampl. there are more fines at depth when compared to the surface samples of the pits.

4.4.1.2 Chemical Weathering

Unfortunately, the surface sample for this region was not analyzed. However, the data that result from the rock material and the sample at the base of the pit is interesting. Table 4.10 indicates that the rock sample has a significantly higher level of Si than the regolith sample. Correspondingly Mg, Al, K, Ca, Ti, and Fe have significantly higher values at depth compared to the parent material. These data can be easily explained by the parent material not being completely representative of the material that formed this soil. This explains the fact that the Si levels are lower in a weathered region compared to the p.istine rock used for the chemical analysis

As a result of the surface sample not being analyzed, there is no determination of any leaching or weathering in the profile.



4.11 Triangular textural diagram for the dry ridge samples.

Elements	Pit #23	Dry Ridge
	parent	depth
I	0.1200	0.0170
Na	0.0740	0.1100
Mg	1.4000	3.2000
Al	4.5000	13.600
Si	86.500	66.900
P	0.1200	0.2100
S		
Cl	0.0340	0.0240
K	1.3000	3.8000
Ca	4.3000	7.8000
Ti	0.3700	0.9700
V		
Cr		0.0150
Mn	0.0320	0.0490
Fe	1.2000	3.1000
Rb		0.0110
Sr	0.0090	0.0170
Zr	0.0380	0.0530
I	0.0470	0.0680
Cs	0.0060	0.0050
Ba	0.0066	0.0130
La		0.0080
Ce		0.0130
Ta	0.0120	
W		
Carbonates	0.00	0.00

Table 4.10 The chemical data expressed as % mass of the dry ridge, < indicates trace quantity.

Sample	Bases/Al	Bases/R_2O_3
parent	3.00	2.33
depth	1.95	1.58
ratios	P/D	P/D

Table 4.11 The weathering indices, for the dry ridge, expressed as molar ratios where R_2O_3 is Al+Fe+Ti, and bases are K+Na+Ca+Mg.

4.4.2 Wetted Slope

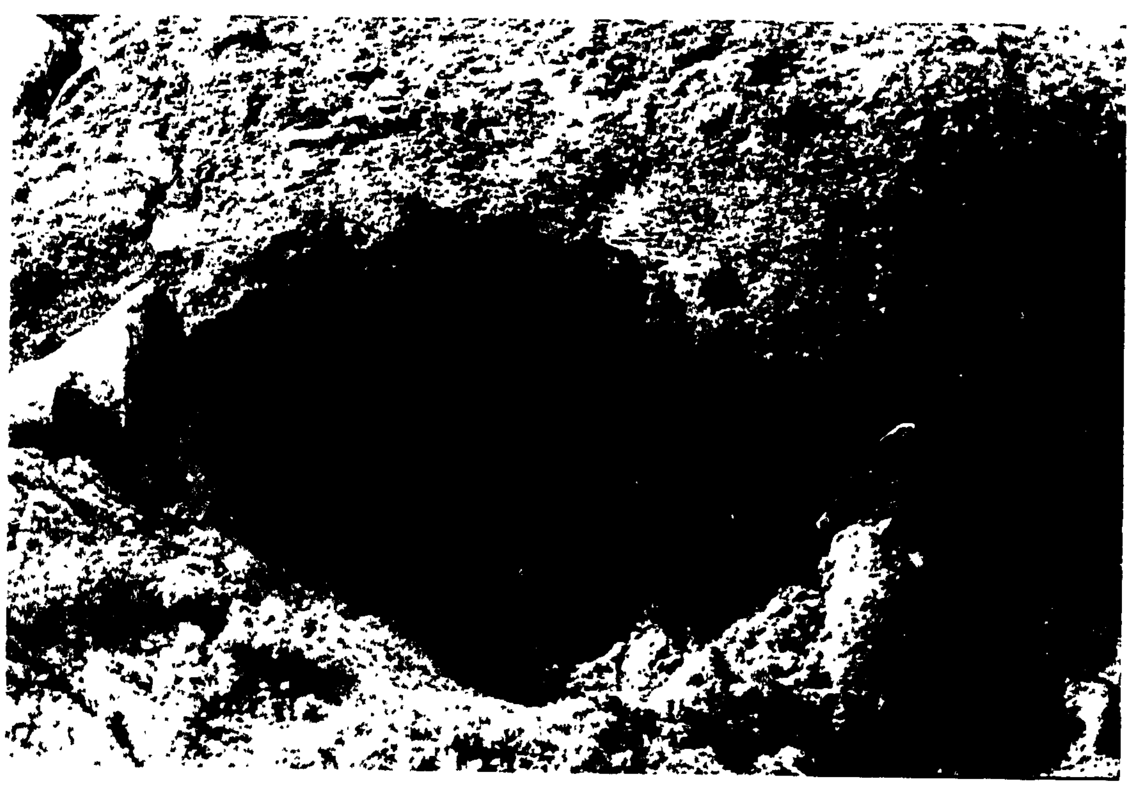
This group of samples are located on relatively steep slopes. Characteristic of these sites are steep slopes (6-12 degrees) that are well drained with preferential hydrological flow pathways throughout the melt season, and have relatively large particle size (predominantly sand size). Eight pits (pits 13-20 inclusive) were excavated which are representative of this classification (Table 3.1, Figure 3.1).

It is hypothesized that these regions may be very effective in terms of weathering because of the large amount of water present and the established flow pathways (Figure 4.12) However, the main problem with determining weathering in this region is the fact that sediment may be flushed from the system by the water. Hence it is difficult to measure the end products of weathering. Another aspect of this environment is the relatively low temperatures and the shallow active layer, average 40 cm. The temperatures are low because the melt water that flows in these regions originates from either snow or ground ice.

4.4.2.1 Mechanical Weathering

Of the seven pits, three indicate finer material at the base, two have virtually no difference in particle size and in the other two pits the bedrock was near the surface so only a surface sample was taken (regolith depth 27 cm), see triangular textural diagram Figure 4 13

Figure 4.12 Wetted slope environmental classification. Notice preferential flow pathways and dense vegetation



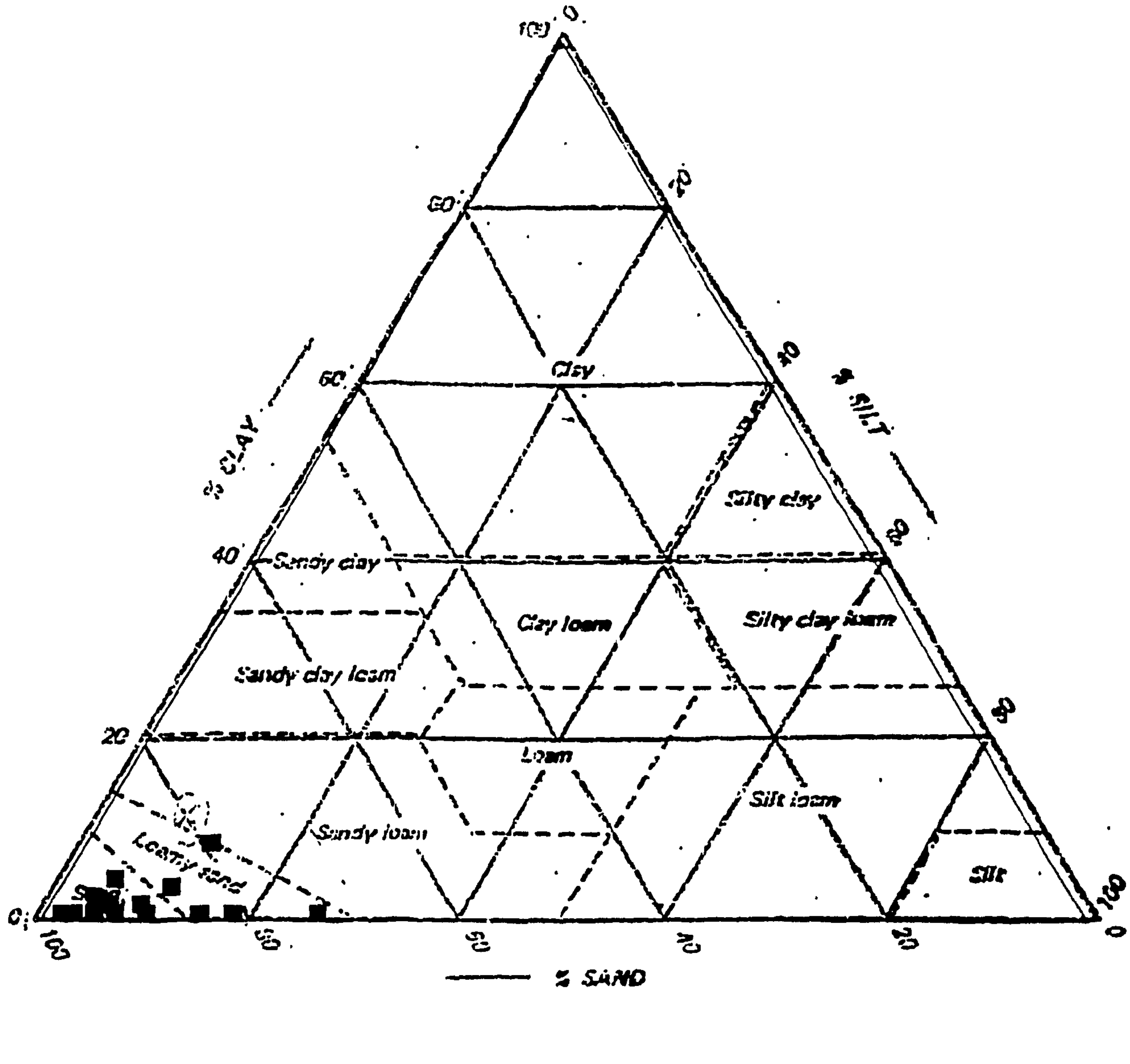


Figure 4.13 Triangular textural diagram for the wetted slope samples

4.4.2.2 Chemical Weathering

The following mobile elements, Mg, K, and Ca have a higher concentration at depth when compared to the surface, (Table 4.12) This is a product of leaching occurring in this region The increased water flow through the profile and down slope removes these highly mobile elements down in the profile. The biggest difference in terms of % mass is the Si. At the surface, Si accounts for 91.3% of the sample and at the depth of the pit, it only accounts for 86 3% This is a result of the Si being immobile and the other elements being removed from the surface As such the relative importance of Si increases. The Al is also greater at depth, 0.99% compared to 0.59%, but this may be a result of the how the data are expressed.

The weathering indices indicate that the surface values are greater than the values at depth (Table 4.13). This indicates that this is a leaching environment. This observation is supported by the data from the mobile chemical elements Na, Mg, K, and Ca. These elements all have higher concentrations at depth when compared to the surface of the pit.

Elements	Pit #16	wetted slope
	depth	surface
F	0.0620	0.0890
Na	0.2100	0.1400
Mg	0.9900	0.5900
Al	6.1000	4.3000
Si	86.300	91.300
P	0.2700	0.1900
S		
Cl	0.0260	0.0160
K	1.5000	1.1000
Ca	1.4000	0.6100
Ti	0.5400	0.2700
V		
Cr	0.0070	
Mn	0.0390	0.0240
Fe	2.4000	1.2000
Rb		<
Sr	0.0100	0.0080
Zr	0.0140	
I	0.0410	0.0400
Cs	<	<
Ba	0.0110	0.0052
La	<	
Ce		
Ta	0.0110	0.0120
W	<	0.0080
carbonates	0.00	0.00

Table 4.12 The chemical data expressed as % mass of the wetted slope, < indicates trace quantity.

Sample	Bases/Al	Bases/R_2O_3
depth	1.18	0.84
surface	0.74	0.74
ratio	[illegible]	[illegible]

Table 4.13 The weathering indices, for the wetted slope, expressed as molar ratios where R_2O_3 is Al+Fe+Ti, and bases are K+Na+Ca+Mg

4.4.3 Wet Meadow

This region has a very low slope angle, poor drainage and is well vegetated (Figure 4.14). Four pits representative of this classification were excavated (Table 3.1 and Figure 3.1).

It is hypothesized that there is a significant amount of weathering occurring here because of the dark surface (high vegetation cover) and near saturation of the soils. The vegetation may indicate that the soils in this location are further developed because it would be necessary for the soil to support the plant life. The problem with interpretation of the data is the mobility of readily weathered elements out of the system due to the near saturation of the regolith in these regions.

4.4.3.1 Mechanical Weathering

Of the four samples collected in this category, two indicate slightly finer particle sizes at the surface, one has a slightly finer particle size at the base, and at one site only one sample was analyzed, see triangular textural diagram (Figure 4.15). The differences among these pits is small. As the error may be greater than the measured quantity, there are no discernible

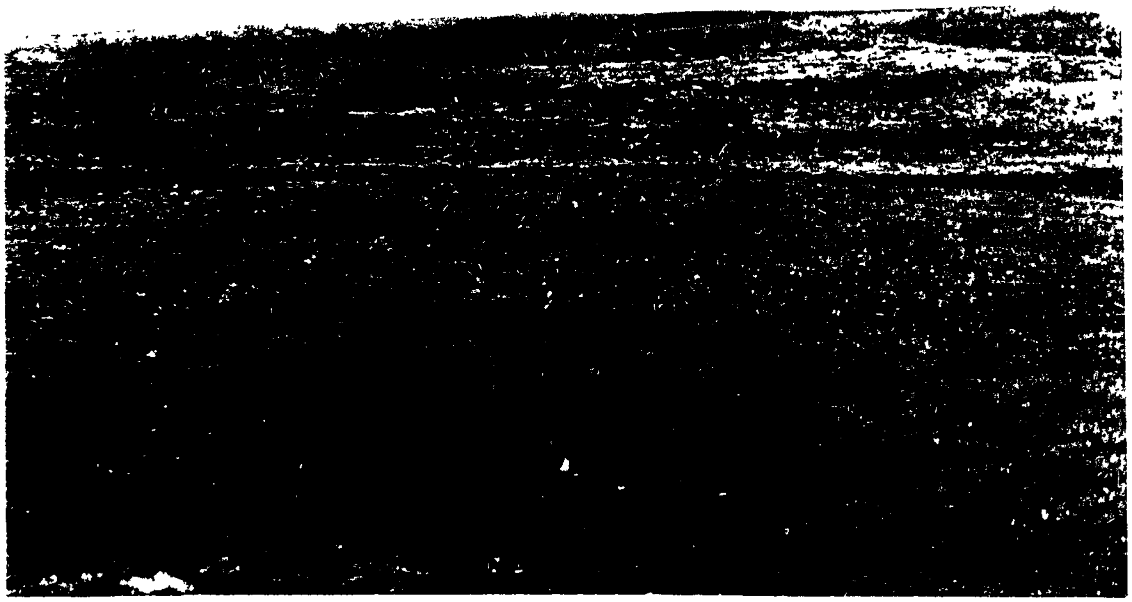


Figure 4.14 Wet meadow site. Shows high vegetation cover, and the relatively flat slope.

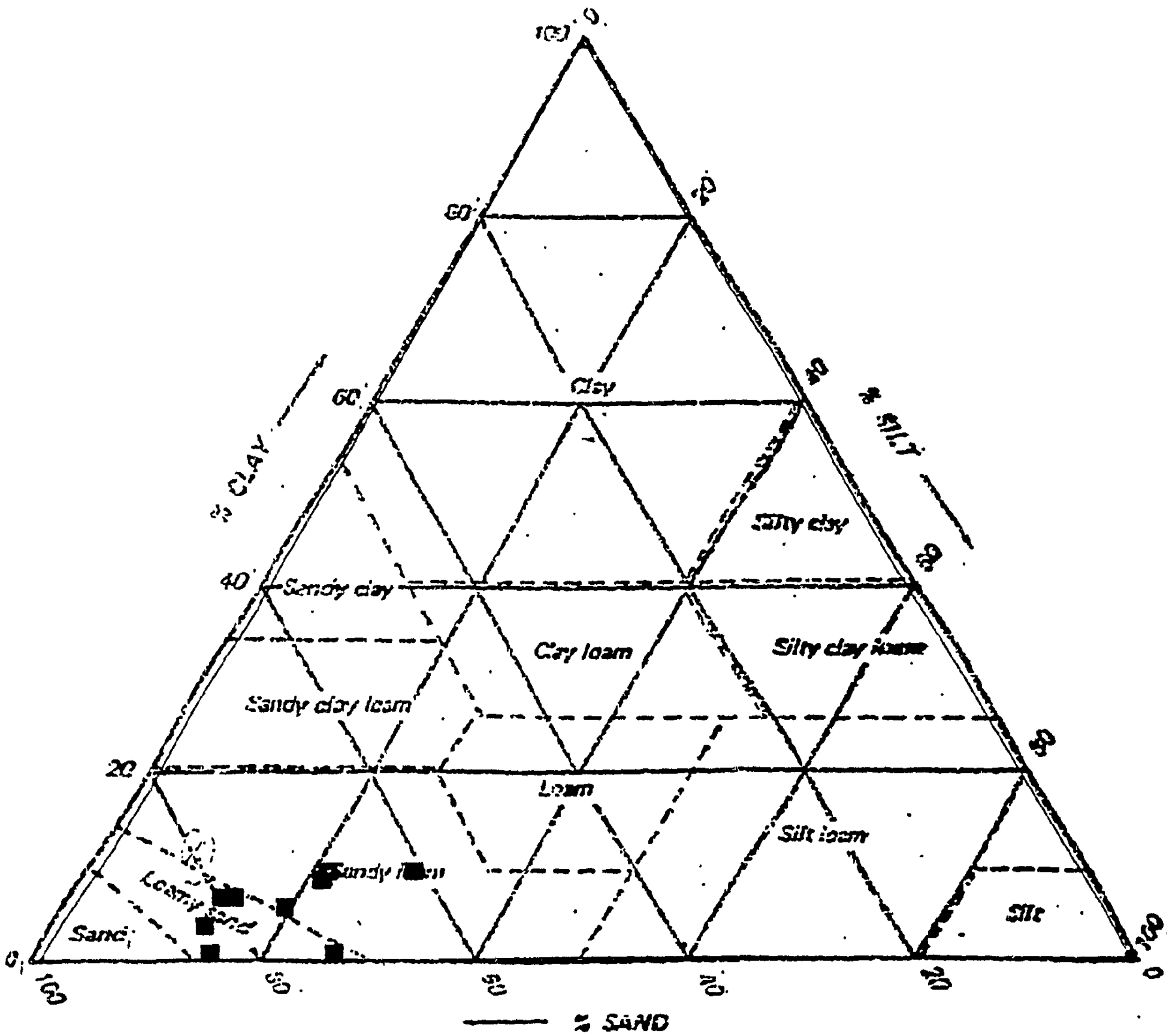


Figure 4.15 Triangular textural diagram for Wet Meadow samples.

differences from surface to depth in the study pits. For instance Pit #90 has a particle size distribution of 61% sand, 29% silt and 10% clay at the surface compared to 69% sand, 21% silt, and 10% clay at the base. Pit #83 is even more similar, 79% sand, 14% silt, and 7% clay at the surface and 80% sand, 13% silt, and 7% clay at the base.

4.4.3.2 Chemical Weathering

The chemical data for the wet meadow are shown in Table 4.14. The two things that are interesting are the low level of Si and the high carbonates in the depth sample The carbonate complexes could either be from the calcareous siltstone and sandstone geological material, i.e. calcareous parent material at the base of the pit being weathered, or leaching Ca down in the profile where it forms carbonate complexes. The primary soil concept is more plausible because the parent material for these samples is calcareous siltstone and sandstone

Within the profile itself, the Mg, K, Ca, and Fe values are all greater at depth than at the surface (Table 4.14). The Mg, K and Ca are three of the four readily removed elements in leaching therefore this pattern indicates that leaching is occurring at this location.

The weathering indices also indicate that leaching is occurring within the soil profile, (Table 4.15).

Elements	Pit #83	Wet	Meadow
	parent	depth	surface
F	0.1400	0.1100	0.0500
Na	0.2100	0.2300	0.2300
Mg	0.9600	1.5000	0.8600
Al	7.2000	11.400	8.5000
Si	79.400	49.100	83.100
P	0.2800	0.3200	0.3000
S	0.0850	0.3500	0.1200
Cl	0.0360	0.0100	0.0270
K	1.9000	2.4000	2.2000
Ca	6.2000	6.1000	1.1000
Ti	0.5300	0.6300	0.5900
V		0.0120	
Cr	0.0100	0.0160	0.0080
Mn	0.0370	0.0190	0.0430
Fe	3.0000	3.0000	2.8000
Rb	0.0060	0.0100	0.0060
Sr	0.0110	0.0110	0.0100
Zr	0.0170		0.0240
I	0.0590	0.0440	0.0430
Cs			
Ba	0.0093	0.0190	0.0150
La			
Ce	0.0050	0.0090	0.0070
La			
W			
carbonates	0.00	24.70	0.00

Table 4.14 The chemical data expressed as % mass of the wet meadow, < indicates trace quantity.

The weathering indices also indicate that leaching is occurring within the soil profile, (Table 4.15).

Sample	Bases Al	Bases R_2O_3
parent	2 24	1 64
depth	1 57	1 27
surface	0 82	0 63
ratios	P D S	P D S

Table 4.15 The weathering indices, for the wet meadow, expressed as molar ratios where R_2O_3 is Al+Fe+Ti, and bases are K+Na+Ca+Mg.

4.5 Environmental Variables Results

Figure 4.16 illustrates the percentage of fines (silt + clay) vs the qualitative ranking of wetness for all of the study pits. The expected trend of increased weathering, as shown by an increase of fine particles, with increased wetness is not evident. The pattern that exists is representative of near normal distributions of fine particle sizes within the five wetness categories.

Figure 4.17 demonstrates the distribution of qualitative temperature ranking vs the % fines. A slight trend of increasing particle size with colder temperatures is demonstrated but is not statistically significant. This increase may be explained by a higher rate of mechanical weathering because the mechanical weathering is thought to need colder temperatures. However, the variability of the data is such that it is difficult to interpret and consequently to conclude how temperature relates to weathering.

The vegetation cover vs fines figure illustrates a very slight trend of increasing fines with increasing vegetation cover, (Figure 4.18). This trend is probably statistically insignificant but given that weathering rates are low in the arctic may be indicative of a relationship between weathering and vegetation cover This increase in fine particles may be a function of a two variables First, there could be eolian deposition and entrapment of fine airborne particles Secondly, there could be increased weathering where there is more vegetation cover.

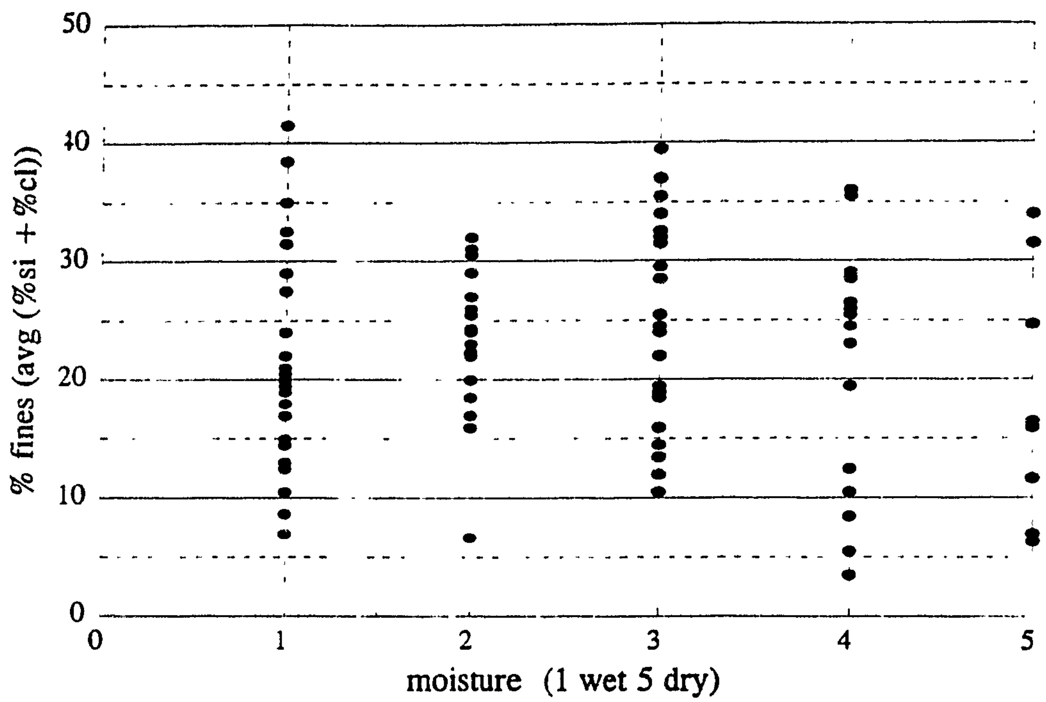


Figure 4.16 Qualitative wetness vs fines.

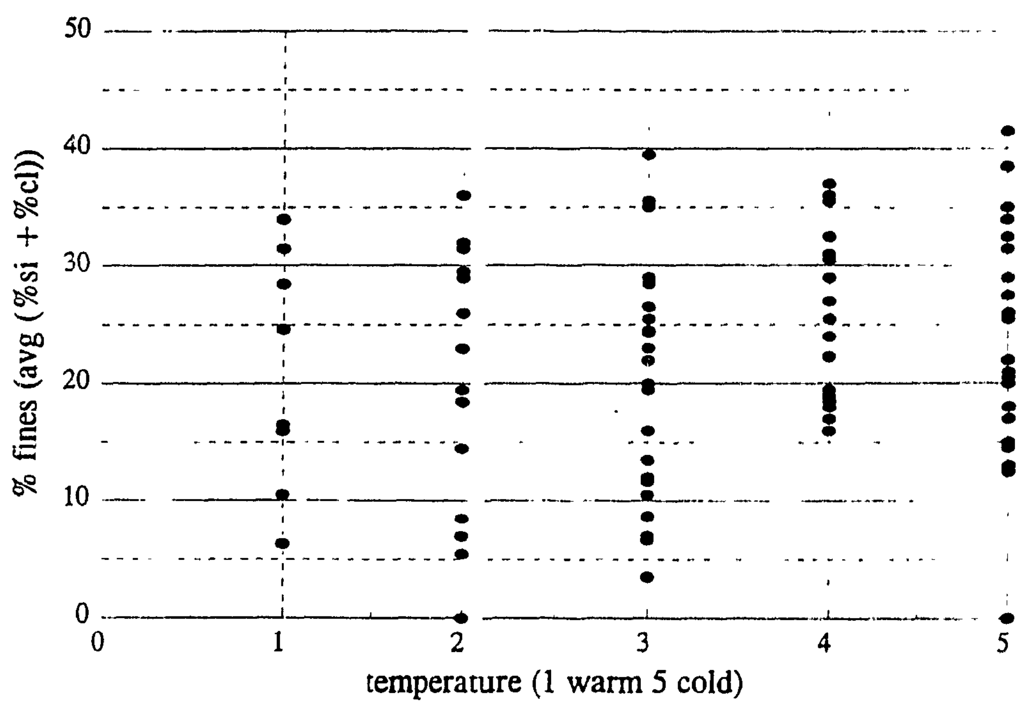


Figure 4.17 Qualitative temperature vs fines

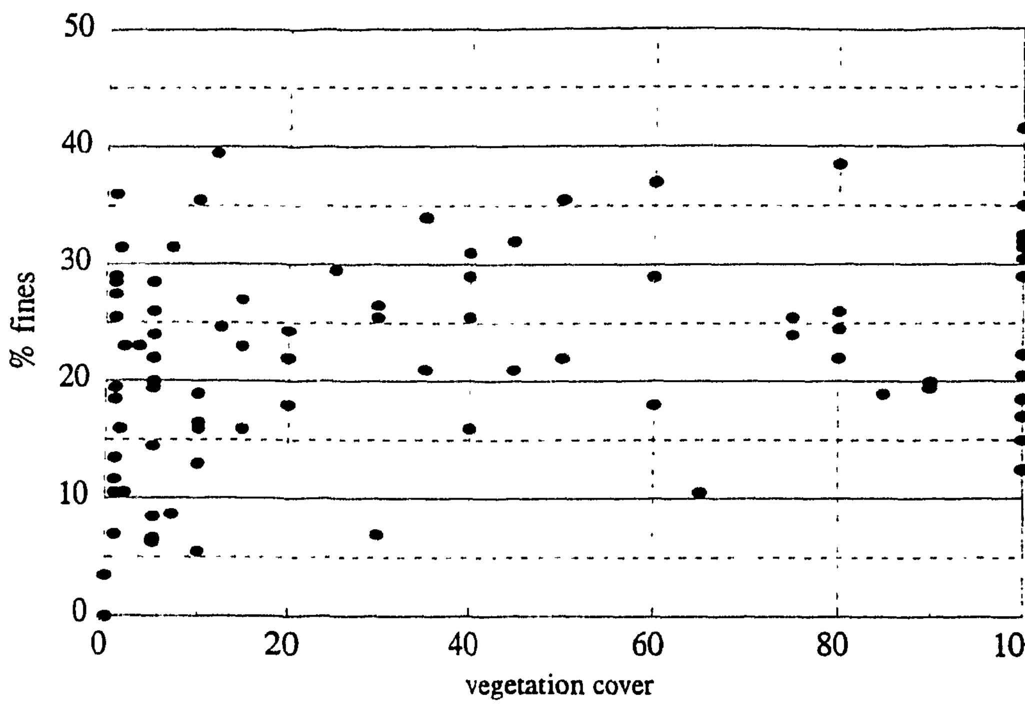


Figure 4 18 Vegetation cover vs fines.

4.5.1 Summary

There is no trend with the moisture vs fines. The temperature vs fines figure indicates a slight reverse trend of what was expected. These results could be attributed to the periglacial and environmental processes that operate within the study site. Periglacial and environmental variables that influence the mechanical weathering and distribution of the products of weathering include cryoturbation, particle sorting by repeated freeze-thaw activity, variability in the active layer depths, and hydrological flow Cryoturbation and particle sorting promote mixing of the soil profile. This would tend to limit the variation within periglacial features and particle size distribution within a soil profile. The variability in the active layer depths and hydrological flow may influence the particle size distribution by relocating fine particles within the profile. The hydrological flow provides the mechanism for fine particle movement while the permafrost table may provide an impermeable bottom layer The permafrost table or active layer depth may vary from year to year depending upon the meteorological conditions and this may have an impact on the fine particles that are flushed downward.

It is hypothesized that weathering would be enhanced in a warm and wet environment However, given the location of the study site, these conditions do not apply Generally, most study sites are either warm and dry, or wet and cold. Figure 4.19 illustrates the average values of the qualitative variables of temperature and moisture. This graph indicates that there are few sites that can be considered conducive to weathering, given these variables in this location

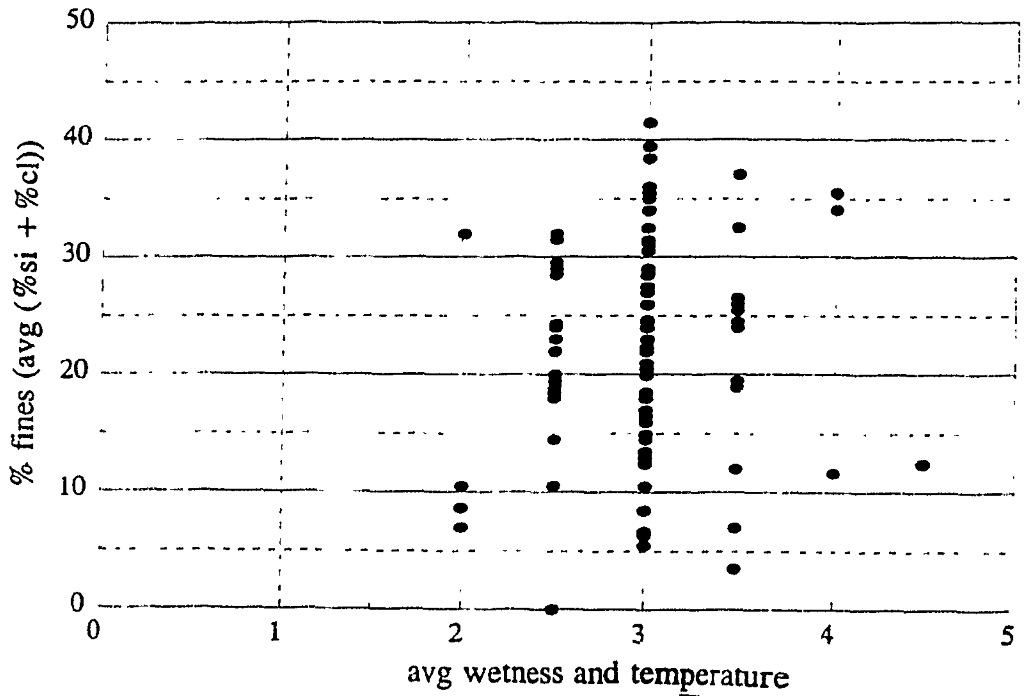


Figure 4 19 Average value of relative temperature and relative wetness vs fines.

There appear to be some trends with regards to vegetation cover and temperature vs % fines. One trend is that weathering is increased with increased vegetation cover. However, these slight trends are unquantifiable and the amount of variability within the samples makes interpretation quite difficult.

From this analysis it seems evident that the individual environmental variables do not explain the weathering that is occurring. The weathering can only be explained by some combination or interaction of the individual variables. Since most of the sites have variables that are both conducive and hindering to the weathering process, it is difficult to differentiate among them. As a result, the final weathering products are likely to be formed by a combination of the following variables or processes: moisture, temperature, vegetation cover, albedo, parent material, chemical reactions, salt weathering, and biological activity. The weathering products can be redistributed vertically by leaching or periglacial processes.

4.6 General Particle Size Distribution

The particle size distribution of all the samples reflects the sedimentary parent material. A majority of the samples occur in the sand, loamy sand and sandy loam classification, (Figure 4.20). This distribution is a product of the predominantly sand and silt sized sedimentary parent material. It can be concluded that the weathering that is occurring is breaking the material down into its constituent sizes, i.e. mainly mechanical weathering is occurring.

2 of/de 2

PM-1 3½"x4" PHOTOGRAPHIC MICROCOPY TARGET
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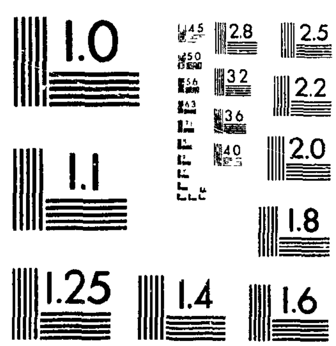

PRECISION[SM] RESOLUTION TARGETS

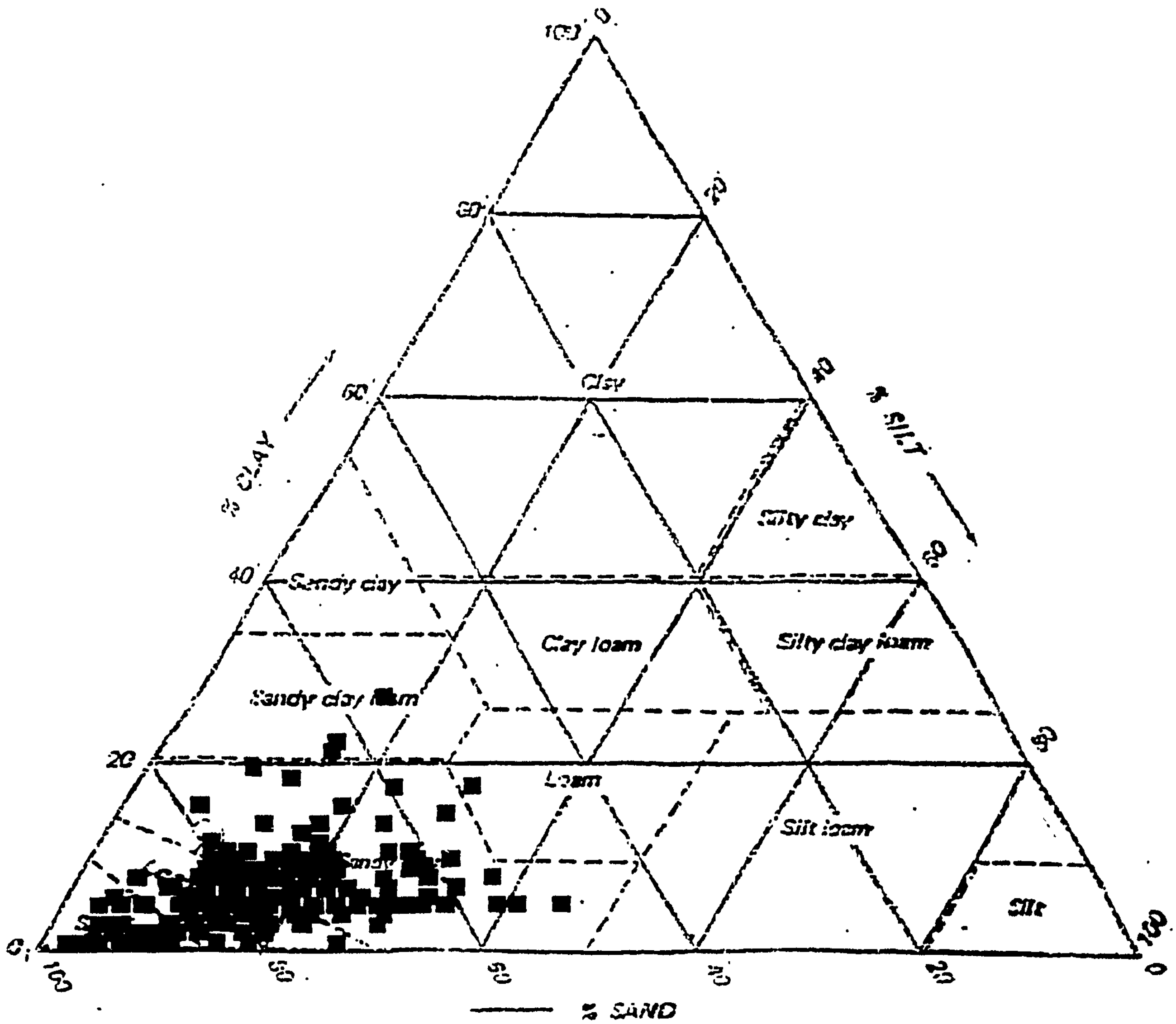

Figure 4.20 Triangular textural diagram for all the samples

4.7 Results and Discussion Summary

Chemical weathering rates were calculated using the Ca values, active layer depth and the bulk density of the samples. The chemical weathering rates for this environment are low when compared to other world data sets, see Table 4.16. The values for both 10000 years and 100000 years are presented because it is not known definitively when the last glaciation occurred in the study site. It is believed that the 100000 year value is applicable as there is no evidence of glaciation during the last ice age.

The important points from the previous analysis are the following: there is some chemical weatherng occurring at most sites, and there is great variability from site to site specifically the solifluction lobes. Within forms there are areas where increased weatheriing is occurring. For example: the solifluction lobes centre sample has greater chemical weathering than at the margin, the polygons indicate that there is increased weathering at the base of the form and this is substantiated from both the chemical weathering rates and an increase in fine material.

In some instances the turbulent nature of the environment makes interpretation difficult. Mudboils have little difference when comparing the surface to the depth sample for both the chemical and mechanical weathering data because of the mixing of material in the fabrication of the form. The stripes have an irregular distribution of coarse material as a result of frost processes pushing coarse material to the surface.

Site	gm m^2 yr			
world avg	12.346			
Huangho	8.64			
Mississippi	11.56			
Amazon	9.38			
Yangtze	27.16			
Phillipines	49.38			
Brahmaputra	27.16			
Mekong	20.99			
Study Site	surface to parent	surface to parent	depth to parent	depth to parent
	10000 yr	100000yr	10000yr	100000yr
sollifluction Lobes center	2.046	0.2046	0.2655	0.02655
margin	1.574	0.1574	0	0
Stripes	5.982	0.5982	8.9839	0.89839
Polygon center	0.0577	0.00577	0.3959	0.03959
Wet Meadow	5.22954	0.522954	0.09834	0.009834

Table 4.16 Chemical Weathering rates for study site and other selected sites world data (modified after Berner and Berner 1996).

In some forms (polygons, stripes, dry ridge and wetted slope) the fine material at the base may be the result of hydrology or less likely increased weathering at the base. This observation can be explained two ways either the system is more effective at weathering at the base of the pit, or more likely that the weathering is occurring at the surface of the pit and the fines are being flushed downward. It is highly probable that weathering at the surface and the flushing is a more reasonable explanation than having increased weathering at the base of the pit. Weathering at the base of the pit is limited by the number of freeze-thaw cycles, low temperatures and a short non-frozen time period. By contrast, the surface is only temperatures and a short non-frozen time period. By contrast, the surface is only limited by the lack of moisture, as all of these other variables will be at a maximum given the site location.

Unfortunately there is no way of determining this type of sediment movement for this study The weathering at the base is possible given the likelihood of increased mechanical weathering in locations that are wet. However, the need for increased freeze-thaw cycles is not met at this location, as it is likely the temperature only crosses freezing once during active layer development and once during freeze-back.

The hydrology of the different forms plays an integral part of the distribution that is now there Specifically the fines are flushed down within the profile because of a coarser material and preferential flow pathways i.e. the depressed region of the stripes, polygon troughs, dry ridge, and wetted slope sites.

There is little difference in weathering when comparing different parts of different periglacial forms, solifluction lobes, polygons and stripes. As a result weathering cannot be associated with a specific set of environmental conditions. This finding may be attributed to the fact that no feature has a set of environmental factors that are all conducive or a hinderence to weathering. It appears that the resultant weathering product is a combination of both positive and negative influences on weathering. i.e. polygon trough wetter but colder.

Chapter 5 Summary and Conclusions

5.1 Introduction

The purpose of this study is to examine the differences in the mechanical and chemical weathering in different periglacial and non-periglacial forms on the eastern Fosheim Peninsula Periglacial and non-periglacial forms studied include solifluction lobes, non-sorted stripes, polygons, mudboils, wetted sloped, dry ridge and wet meadow.

5.2 Conclusions

Generally, within the solifluction lobes, there is to be no apparent trend in terms of the mechanical weathering and there is some leaching occurring at both the centre of the form and at the margins The mechanical and chemical analysis indicates that the variability within this site cannot be presently attributed to a specific environmental factor, such as aspect, slope, drainage, or vegetation cover. The weathering is likely to be a function of the interaction of these different variables because the centre and the margins of the form have different conditions that are both conducive to weathering and inhibit weathering.

Within the non-sorted stripes, there does not appear to be increased mechanical weathering in either the elevated or depressed regions. The chemical weathering data are limited because of the small distance between the elevated and depressed region of the stripe and by the fact that only one location was analyzed. However, there is chemical leaching occurring at this site. There do not appear to be measurable differences in the mechanical or chemical weathering at these sites that can be attributed to the micro-environmental differences

Within the polygons, there are samples that have an increase in fine particles at the base of the pit Evidence indicates that these fines probably have been hydrologically flushed to depth from the surface. The chemical data indicate that there is chemical weathering occurring at the sites but the differences between the polygon trough and the polygon centre are not notable in assessing the differences in weathering between the two sites.

Mudboils are the only periglacial form that provided expected results. Specifically, since the formation of these features requires mixing and upwelling of material, it was expected that there would be no differences in terms of particle size distribution and chemistry within the feature.

For the non-periglacial feature of the dry ridge, the mechanical weathering data indicates, a slight increase in the amount of fines at the base of the pits. A trend in the chemical data is not defined because only one sample was analyzed.

The data from the wetted slope non-periglacial classification indicate that there is more fine material at the base of the pit than at the surface. The chemical weathering data also indicate more enrichment of elements at the base. These patterns agree with each other and can be explained either as more effective weathering at the base of the pit, or, the more likely explanation as weathering occurring at the surface of the pit and the fine material being flushed down in the profile by hydrological processes.

The wet meadow non-periglacial area should be most conducive to weathering because of the availability of moisture and dense vegetation cover However, it is difficult to quantify the mechanical weathering in terms of differences in mechanical weathering rates or patterns However, the chemical weathering data indicate that there is weathering going on in terms of leaching.

Comparisons were conducted on sites within the same geological region There is considerable chemical variability, from site to site that is much greater than the variability within a specific site. Therefore the chemical data are difficult to compare from site to site within the same geological region. The particle size distribution does not exhibit the same variability as the chemical data from site to site because the parent material is all sedimentary However, given that most of the samples are of sedimentary origin, the differences in the particle size distributions are also quite small.

Some general conclusions can now be made. The lack of clay sized particles may indicate that chemical weathering in this environment is limited. Vegetated areas appear to have more chemical and mechanical weathering within the profile when compared to less vegetated sites. This is probably a result of many variables including, moisture, albedo, root microbial and chemical activity. Vegetation also traps fine aeolian particles which may explain this observation. Wet meadow regions which have a high vegetation cover have a shallow active layer and, relative to other regions, significant amounts of chemical and mechanical weathering occurring.

The individual environmental variables of moisture and temperature levels do not appear to have a direct influence on weathering However, it appears that at most sites there are environmental factors that can be interpreted as both inhibiting and enhancing weathering, such as low temperatures and higher levels of moisture respectively. These conflicting mechanisms make interpretation of the data difficult and are likely the reason why the micro-scale environmental differences do not account for any measurable differences.

It is highly probable, given all of the different mechanical and chemical processes, that the soil found here is developed from a combination of the different processes and cannot be attributed to any specific variable.

5.3 Limitations

A problem with data interpretation at this site is the complexity of the natural environment. This environment is influenced by periglacial processes that redistribute and change the distribution of the products of weathering. The dominant periglacial processes of frost-heaving, cryoturbation, nivation and particle sorting by frost action change the vertical and horizontal distribution of the weathering byproducts and makes interpretation difficult.

Flushing and hydrological processes have the potential to redistribute fine particles within the regolith. This potential for flushing of fine particles inhibits the interpretation of the data because it is unclear where the fine materials are produced. For instance these particles may be produced at the surface and then flushed down, or they may be produced at the bottom without any particle movement occurring.

Changing active layer depths from year to year makes this region even more complex. Given that different climatological conditions will affect the depth of the active layer over time, the sample taken just above the permafrost table in any given year may be within the confines of the permafrost the next year. This is a major factor because this change may influence any flushing of material within the profile.

Given the complexities and the interactions of these variables, the data do not allow for simple explanations.

5.4 Further Studies

1. This study indicates that the weathering changes that have occurred in this environment are of a small scale. It would be of interest to conduct a further detailed study of the variability of the soil in a small scale region and to see if the changes of spatial variability are greater than those found here.

2. Another interesting aspect for further work would involve examining the patterns that are found in the periglacial features and determine if they are consistent over a larger region. There would be different chemical signatures corresponding to the differences in the parent material and geological formations of the new sites but would the pattern be similar

3. Another approach could be to experimentally expose the soil material to different conditions of precipitation and temperature to possibly simulate future trends. The results have implications for soil development and water quality.

4 Comparison of leaching and or flushing environments would indicate how and where the flushed sediment gets trapped in the active layer. From this study, it is not known if the flushing occurs horizontally, vertically or both, within the profile. Another aspect of the flushing is the variability from year to year in active layer depths and how this influences the chemical distribution

References

Andrews, J.T. ed (1985) Quaternary Environments Eastern Canadian Arctic, Baffin Bay and Western Greenland, Allen and Unwin, London, 774 pgs

Atmospheric and Environment Service (1982) Canadian Climate Normals - Volume 2 - Temperature 1951-1980. Canadian Climate Program, Environment Canada, Ottawa 306 pgs

Aubert, H. and Pinta, M. (1977). Trace Elements in Soils Developments in Soil Science 7, Elsevier Scientific Publishing Company, New York, 395 pgs

Battle, W.R.B. (1960). Temperature observations in bergschrunds and their relationship to frost shattering, in Lewis, W.V. ed., Norwegian cirque glaciers, London, Royal Geog Soc Research Ser. 4: 83-95.

Berner, E.K. and Berner, R.A. (1996) Global Environment: Water, Air, and Geochemical Cycles, Prentice Hall, New Jersey, 376 pgs.

Berrisford, M.S. (1991). Evidence for Enhanced Mechanical Weathering Associated with Seasonally Late-lying and Perennial Snow Patches, Jotunheimen, Norway in Permafrost and Periglacial Processes, Vol 2: 331-340.

Birkeland P.W. (1984). Soils and Geomorphology, Oxford University Press, New York, 372 pgs.

Black, C.A. ed. (1965a). Methods of Soil Analysis Part 1 Physical and Mineralogical Properties, Including Statistics of Measurement and Sampling American Society of Agronomy, Inc Madison, Wisconsin, 770 pgs.

Black, C.A. ed. (1965b). Methods of Soil Analysis Part 2 Chemical and Microbiological Properties American Society of Agronomy, Inc Madison, Wisconsin, 1572 pgs.

Bockheim, J.G. (1990). Soil Development Rates in the Transantarctic Mountains in Geoderma, Vol 47: 59-77.

Bockheim, J.G., Wilson, S.C. and Leide, J.W. (1990). Soil Development in the Beardmore Glacier Region, Antarctica, in Soil Science, Vol 149 No.3: 144-157.

Brady, N.C. (1974). The Nature and Properties of Soils 8th Edition, Macmillan Publishing Co., New York, 592 pgs.

Campbell, I.B. and Claridge, G.G.C. (1987). Antarctica: Soils, Weathering Processes and Environment, Elsevier Science Publishers, Amsterdam, 368 pgs.

Corte, A E (1963). Particle Sorting by Repeated Freezing and Thawing, in Science, 149. 499-501

Dixon, J C , Thorn, C.E. and Darmody, R G. (1984). Chemical Weathering Processes on the Vantage Peak Nunatak, Juneau Icefield, Southern Alaska, in Physical Geography Vol.5 No 2.: 111-131

Dredge, L A (1992). Breakup of Limestone Bedrock by Frost Shattering and Chemical Weathering, Eastern Canadian Arctic, in Arctic and Alpine Research, Vol. 24 No.4: 314-323.

Drever, J.I (1982). The Geochemistry of Natural Waters, Prentice Hall, Inc., Englewood Cliffs, N J U.S A., 388 pgs.

Edlund, S.A. Alt, B.T. and Young, K.L (1989). Interaction of climate, vegetation, and soil hydrology at Hot Weather Creek, Fosheim Peninsula, Ellesmere Island, Northwest Territories; in Current Research, Part D, Geological Survey of Canada, Paper 89-1D: 125-133.

Edlund, S.A. and Woo, M-K, (1992). Eolian deposition on Western Fosheim Peninsula, Ellesmere Island, Northwest Territories during the winter of 1990-91; in Current Research, Part B; Geological Survey of Canada, Paper 92-1B: 91-96.

Elliot, D.H. Ed (1992). Contributions to Antarctic Research III, American Geophysical Union, Washington, 155 pgs.

Faure, G. (1991). Principles and Application of Inorganic Chemistry A comprehensive textbook for geology students, New York , MacMillan Publishing Co., 626 pgs.

Flint, R.F. (1971). Glacial and Quaternary Geology John Wiley and Sons, New York, 892 pgs.

Foscolos, A.E. and Kodama, H. (1981). Mineralogy and Chemistry of Arctic Desert Soils on Ellef Rignes Island, Arctic Canada, in Soil Sci. Soc. Am. J., Vol 45: 987-993.

Foth, H. D. (1978). Fundamentals of Soil Science Sixth Edition, John Wiley & Sons, New York, 427 pgs.

French, H.M. (1976). The Periglacial Environment, Longman Publishing, New York, 309 pgs.

French, H.M. (1993). Cold Climate Processes and Landforms, in Canada's Cold Environments ed. by French, H.M. and Slaymaker, O., Montreal, McGill-Queen's University Press, 143-170.

Hall, K (1990). Mechanical Weathering Rates on Signy island, Maritime Antarctic, in Permafrost and Periglacial Processes, Vol 1: 61-67.

Hall, K. and Lautridou, J P (1991) Introduction-Cryogenic Weathering, in Permafrost and Periglacial Processes, Vol 2: 269-270

Hallet, B Walder J.S. and Stubbs, C W (1991) Weathering by Segregation Ice Growth in Microcracks at Sustained Sub-zero Temperatures Verification from an Experimental Study Using Acoustic Emissions, in Permafrost and Periglacial Processes, Vol 2 283-300

Harris, S.A. (1988) Glossary of Permafrost and Related Ground-Ice Terms, Permafrost Subcommittee, Associate Committee on Geotechnical Research, National Research Council of Canada, 156 pgs.

Hendry, G.L. (1975). Chapter3 X-ray Flourescence, in Physicochemical Methods of Mineral Analysis, Edited by Nicol, A.W. Plenum Press, New York, 87-152 pgs

Hesse, P.R. (1971) A Textbook of Soil Chemical Analysis, Chemical Publishing co , Inc, New York, 520 pgs.

Hill, D.E. and Tedrow, J.C.F (1961) Weathering and Soil Formation in the Arctic Environment, in American Journal of Science, Vol 259 84-101.

Hodgson, D.A., St-Onge, D.A and Edlund, S.A. (1991) Surficial Materials of How Weather Creek basin, Ellesmere Island, Northwest Territories; in Current Research, Part E, Geological Survey of Canada, Paper 91-1E. 157-163.

Howell, J.V., (1960). Glossary of Geology and related Sciences, 2 ed. Washington, D C Am Geol. Inst. 32 pgs

Jackson, M.L. (1965) Soil Chemical Analysis, Prentice Hall Inc., Englewood Cliffs, N.J , 498 pgs.

Kelly, P.E. and King, R.H. (1995). Factors Controlling Soil Development on a Sequence of Raised Beaches, Truelove Lowland, Devon Island, N.W T , Canada, in Arctic and Alpine Research, Vol. 27. No.1: 54-74.

Konischev, V.N. and Rogov, V.V. (1993) Investigations of Cryogenic Weathering in Europe and Northern Asia, in Permafrost and Periglacial Processes, Vol. 4. 49-64.

Lautridou J.L. (1988). Recent Advances in Cryogenic Weathering, in Advances in Periglacial Geomorphology, Edited by M.J. Clark, John Wiley and Sons, 481 pgs

Lautridou J.L. and Ozouf, J.C. (1982). Experimental Frost Shattering 15 Years of Research at the Centre de Geomorphologie du CNRS, in Progress in Physical Geography, 5 56-75

Longwell, C.R., Flint, R.F , and Sanders, J.E. (1969) Physical Geology, New York, John Wiley, 685 pgs

Matsuoka, N (1990). Mechanisms of Rock Breakdown by Frost Action: An Experimental Approach, in Cold Regions Science and Technology, Vol. 17: 253-270.

Matsuoka, N. (1991). A Model of the Rate of Frost Shattering: Application to Field Data from Japan, Svalbard and Antarctica, in Permafrost and Periglacial Processes, Vol 2: 271-281.

McAndrew, J (1996). Personal Communication, McMaster University, Geology Department

McGreevy, (1981). Some Perspectives on Frost Shattering, in Progress in Physical Geography, Vol. 5. 56-75.

McKeague, J.A. ed. (1978). Manual on Soil Sampling and Methods of Analysis, 2nd Edition, Canadian Society of Soil Science.

Millar, C.E., Turk, L.M. and Foth, H.D. (1966). Fundamentals of Soil Science John Wiley and Sons, New York, 491 pgs.

Paton, T.R. (1978). The Formation of Soil Material, George Allen and Unwin, London, 143 pgs.

Peltier, L.C. (1950). The geographic cycle in periglacial regions as it is related to climatic geomorphology, Annals of Association of American Geographers, 40: 214-236.

Pollard, W.H., (1991). Observations on massive ground ice on Fosheim Peninsula, Ellesmere Island, Northwest Territories, in Current Research, Part E; Geological Survey of Canada, Paper 91-1E: 1-9.

Potts, A.S. (1970). Frost action in rocks, some experimental data, Transactions, Institute of British Geographers, 49. 109-124.

Rapp, A. (1960). Recent development of Mountain slopes in Karkevagge and surroundings, northern Sweden, in Geografiska Annaler, 42: 71-200.

Sharpe R. (1942). Periglacial involutions in north-eastern Illinois, in Journal of Geology, 50: 113-133.

Sposito, G. (1989). The Chemistry of Soils, Oxford University Press, New York, 277 pgs.

Taber, S (1930). The Mechanics of Frost Heaving, in Journal of Geology, 38: 303-317.

Tedrow. J.C.F. (1977). Soils of the Polar Landscape, Rutgers University Press, New Jersey, 570 pgs.

Thorn (1988). Nivation A Geomorphic Chimera, in Advances in Periglacial Geomorphology, Edited by M.J. Clark, John Wiley and Sons, 481 pgs

Thorsteinsson, R. (1972). Map 1308A Geology Canon Fiord District of Franklin, 1 250,000, Surveys and Mapping Branch, Geological Survey of Canada.

Tricarte, J. (1970). Periglacial landscapes, in Encyclopedia of Geomorphology, (ed R.W Faribridge), Reinhold Book Co., 829-833 pgs.

Vogt, T. (1991). Cryogenic Physico-chemical Precipitations: Iron, Silica, Calcium carbonate, in Permafrost and Periglacial Processes, Vol. 1: 283-293.

Washburn, A.L. (1956). Classification of Patterned Ground and Review of Suggested Origins, in Bull. Geol. Soc. Amer., 67: 824-861.

Washburn, A.L. (1973). Periglacial Processes and Environments, Edward Arnold Publishers Ltd. London, 262 pgs.

Washburn, A.L.(1979). Geocryology: A Survey of Periglacial Processes and Environments, New York, John Wiley, 406 pgs.

Whalley, W.B. and McGreevy (1992). Short Communication: The Contribution of W R.B to Mechanical Weathering Studies, in Permafrost and Periglacial Processes, Vol 2: 341-346.

Wiman, S. (1963). A preliminary study of experimental frost weathering, Geografiska Annaler, 45: 113-121.

Woo, M-k, Edlund, S.A. and Young, K.L. (1991). Occurrence of early snow-free zones on Fosheim Peninsula, Ellesmere Island Northwest Territories, in Current Research, Part B, Geological Survey of Canada, Paper 91-1B: 9-14.

Woo, M-k, Young, K.L. and Edlund, S.A. (1990). 1989 observations of soil, vegetation, and microclimate, and effects on slope hydrology, Hot weather Creek basin, Ellesmere Island Northwest Territories, in Current Research, Part D, Geological Survey of Canada, Paper 90-1D: 85-93

Appendix #1 Pit Data

SAMPLE	SOIL	BUL	% of	%SA	%SI	% C	ASPE	SLOP	HORI	VEGE	WET/	A L D	MEC	avg.	Wetn	Temp	Avg
	%	Den	>2m					<	# of	%	dry or	CM	WEA	fine			temp
		gm/c									wet		Bot or		1 wet	1 war	moist
													Top		5 dry	5 cold	
Pit #67 C							S	3	1	80	W	59	B	24.5	4	3	3.5
5-13 cm	20.3	1.39	2.04	77	18	5									4	3	3.5
48-56 cm	13.4	1.89	4.01	74	16	10									3	4	3.5
Pit #68 C							S	3	1	75	W	78	B	24	3	4	3.5
5-13 cm	12.7	1 51	9	79	13	8									3	4	3.5
70-78 cm	13	1 78	11.61	73	18	9									2	5	3.5
Pit #69 C							S	3	1	80	W	58	T	26	2	5	3.5
14-22 cm	5.68	1.79	1.96	72	18	10									2	5	3.5
51-59 cm	11.4	1 88	14.12	76	15	9									1	5	3
Pit #70 C							S	3	1	100	W	66	T	32.5	1	5	3
4-12 cm	16 4	1.59	0.26	63	26	11									1	5	3
43-51 cm	12.6	1.86	1.24	72	19	9									2	5	3.5
Pit #71 C							S	3	1	30	W	73	T	25.5	2	5	3.5
7-15 cm	12 4	1.71	3.85	72	20	8									2	5	3.5
60-68 cm	12.3	1.69	6.26	77	15	8									4	5	4.5
Pit #72 C							S	3	1	100	W	55	B	12.5	4	5	4.5
10-15 cm	14.2	n/a	45.01	90	8	2									4	5	4.5
don't kno	11 2	n/a	40.32	85	13	2									3	5	4
Pit #81							E	6	1	1	D	79	T	36	4	2	3
4-12 cm	10.6	1.4	33.2	63	32	5									4	2	3
61-69 cm	11.8	1.78	5.79	65	30	5									2	4	3
Pit #82							E	6	1	100	LW	56	B	22.3	2	4	3
5-13 cm	9.83	1.29	69.54	90	4	6									2	4	3
16-24 cm	14.3	1.19	55.56	74	18	8									2	4	3
rocky	11.3	1.71	28.29	69	24	7									1	5	3
Pit #84							E	6	1	1	W	75	T	29	4	2	3
5-13 cm	13.7	1.24	73.3	69	26	5									4	2	3
67-75 cm	2.36	1.77	32.77	73	22	5									2	2	2
	18	1.61													2	4	3
Pit #85							E	6	1	100	W	56	B	30.5	2	4	3
4-12 cm	15.5	1.24	54.56	71	25	4									2	4	3
45-33 cm	12.1	1.83	19.32	68	26	6									2	4	3

goes with	21 5	0 76													2	4	3
Pit #86							W	3 5	1	100	W	58	B	17	2	4	3
6-14 cm	39 7	0.75	51.24	85	10	5									2	4	3
50-58 cm	15.8	1.42	26.46	81	14	5									4	2	3
Pit #87							W	3.5	1	3.5	W	69	T	23	4	2	3
6-14 cm	14.8	1.45	46.42	76	18	6									4	2	3
61-69 cm	15.6	1.55	28.66	78	18	4									4	3	3.5
Pit #88							W	3.5	1	90	W	51	B	19.5	4	3	3.5
6-14 cm	14	1.54	19.47	81	14	5									4	3	3.5
43-51	15 1	1.58	9.29	80	15	5									1	4	2.5
Pit #89							W	3.5	1	100	W	48	B	29	1	4	2.5
10-18 cm	17 6	1.26	49.83	74	22	4									1	4	2.5
40-48 cm	14.9	1.54	54.89	68	26	6									5	1	3

Non-Sorted Stripes

SAMPLE	SOIL	BUL	% of	%SA	%SI	% C	ASPE	SLOP	HORI	VEGE	WET/	A.L.D	MEC	avg.	Wetn	Temp	Avg
	%	Den	>2m					<	# of	%	dry or	CM	WEA	fine			temp
		gm/c									wet		Bot or		1 wet	1 war	moist
													Top		5 dry	5 cold	
Pit #3							SE	1	1	12	W	52	B	39.5	3	3	3
35-40 cm	9 88	1.62	0	50	45	5									3	3	3
4-13 cm	4 46	1.4	0	71	24	5									3	3	3
Pit #4							S	6	1	90	W	41	B	20	2	3	2.5
4-13 cm	14	1.28	25.84	82	11	7									2	3	2.5
31-40 cm	16.3	1.66	0.7	78	12	10									2	3	2.5
Pit #20 C							W	6	1	7	W	76	0	8.67	1	3	2
11-19cm	13.7	1 73	60.57	92	6	2									1	3	2
5-13 cm s	16.9	1.52	5.35	89	9	2									1	3	2
68-76cm	15 8	1.74	0	93	4	3									5	3	4
chem for	21.2	n/a													5	1	3
Pit #30 St							W	4	1	1	W	68	T	28.5	3	3	3
6-14 cm	13.1	1.46	3.37	72	17	11									3	3	3
60-68 cm	15.1	1.64	12.64	71	19	10									1	3	2
Depressio															1	3	2
6-14 cm	13.9	1.21	2.42	78	12	10							1		3	4	3.5

Polygons

SAMPLE	SOIL	BUL	% of	%SA	%SI	% C	ASPE	SLOP	HORI	VEGE	WET/	A.L.D.	MEC	avg.	Wetn	Temp	Avg
	%	Den	>2m					<	# of	%	dry or	CM	WEA	fine			temp
		gm/c									wet		Bot or		1 wet	1 war	moist
													Top		5 dry	5 cold	
Pit #11 P							FLAT	0	1	35 AN	D	18 T	B	24	2	4	3
8-15 cm d	21.2	0.75	1.09	78	19	3									2	4	3
5-13 cm t	19.2	0.84	1.6	74	19	7									4	4	4
Pit #27 W							W	1	1	50	W	52	B	35.5	4	4	4
5-13 cm	15.1	1.11	0.8	73	22	5									4	4	4
42-50 cm	12.4	1.62	0.96	56	29	15									1	5	3
Pit #28 W							W	0.5	1	80	W	45	B	38.5	1	5	3
5-13 cm	19.5	1.31	6.82	62	29	9									1	5	3
37-45 cm	20.5	n/a	0.29	61	28	11									3	2	2.5
Pit #41 P							N	7.5	1	45	D	44	T	21	1	5	3
4-12 cm	21.7	1.24	1.85	76	16	8									1	5	3
36-44 cm	23.7	1.46	11.28	82	13	5									3	2	2.5
Pit #42 P							N	7.5	1	45	W	44	B	32	3	2	2.5
4-12 cm	21.1	1.24	4.96	65	18	17									3	2	2.5
36-44 cm	5.67	1.63	0.91	71	9	20									3	2	2.5
Pit #43 P							ENE	6	2	25	W	65	B	29.5	3	2	2.5
7-15 cm	10	1.49	8.13	78	6	16									3	2	2.5
57-65 cm	-18	1.85	2.29	63	15	22									1	5	3
Pit #44 P							ENE	6	1	50	D	29-41	B	22	1	5	3
7-15 cm	21	1.06	11.19	77	14	9									1	5	3
21-29 cm	5.67	1.59	0.17	79	11	10									3	2	2 5
Pit #45 P							ENE	6	1	5	D	55	T	14.5	3	2	2.5
3-11 cm	18.5	1.03	10.06	83	14	3									3	2	2.5
47-55 cm	10.3	1.15	16.47	88	11	1									1	5	3
Pit #46 P							ENE	6	1	5	D	40	B	20	1	5	3
5-13 cm	6.83	1.29	2.92	82	10	8									1	5	3
32-40 cm	12.3	1.48	0.98	78	13	9									3	2	2 5
Pit #47 P							S	6	1	1	D	70	T	18.5	3	2	2 5
7-15 cm	11.7	1.04	0.15	80	15	5									3	2	2 5
62-70 cm	29.4	1.18	26.5	83	13	4									1	2	1 5

shale	4 44	0 9													1	5	3
Pit #48 P							S	6	2	5	W	37	B	22	1	5	3
6-14 cm	16 4	1 04	1.03	77	17	6									1	5	3
29-37 cm	20.2	1 06	0.28	73	20	7									1	5	3
extra	13 8	n/a	5.78	84	10	6									1	5	3

Mud Boils

SAMPLE	SOIL	BUL	% of	%SA	%SI	% C	ASPE	SLOP	HORI	VEGE	WET/	A.L.D.	MEC	avg.	Wetn	Temp	Avg
	%	Den	>2m					<	# of	%	dry or	CM	WEA	fine			temp
		gm/c									wet		Bot or		1 wet	1 war	moist
													Top		5 dry	5 cold	
Pit #5							S	6	1	65	W	44	U		1	4	2.5
3-10 cm	13.6	1 69													1	4	2.5
32-40 cm	12.1														1	4	2.5
Pit #10 M							FLAT	0	1	5	W	53	T	24	1	4	2.5
6-14 cm	11.1	1.58	4.98	74	18	8									1	4	2.5
36-44 cm	12.3	1.59	14.14	78	14	8									1	4	2.5

Dry Ridge

SAMPLE	SOIL	BULK	% of s	%SA	%SIL	% CL	ASP	SLO	HORIZ	VEGE	WET/	A.L.D.	MECH	avg.	Wetne	Temp	Avg
	%	gm/cm	>2mm					<	# of	%	dry or	CM	WEAT	fine			moist
											wet		Bot or		1 wet	1 war	temp
													Top		5 dry	5 cold	
PIT #1 LOW							W	1-2	4	25	D	70	B	34	5	1	5
1-8 cm 1	6 948	1.522	0	75	20	5								34	5	1	5
12-17 cm	7.878	1.468	10.65	62	24	14								34	5	1	5
40-47 cm	2.727	n/a	0	58	32	10								34	5	1	5
65-70 cm	14.08	1.477	1.96	69	20	11								34	5	1	5
Pit #8 Lake							N	13	2	15	D	65	B	16	5	1	5
8-13 cm 1	5.034	1.506	0	88	10	2								16	5	1	5
50-58 cm	6 712	1.499	0	80	16	4								16	5	1	5
Pit #9 The H							S	8	1	10	D	100	T	16.5	5	1	5
0-10 cm 1	5.427	n/a	0	75	22	3								16.5	5	1	5
60-65 cm	7.231	n/a	0	92	5	3								16.5	5	1	1.5
Pit #21 Alpin							FLAT	0	3	5	D	78	B	6.333	5	1	5
2-10 cm 1	6.396	1.546	10.86	95	4	1								6.333	5	1	5
24-32 cm	6.229	1.551	11.62	95	4	1								6.333	5	1	4
70-78 cm	14.01	1.708	5.8	91	6	3								11.67	5	3	4
Pit #22 Alpin							FLAT	0	3	1	D	78	B	11.67	5	3	4
22-30cm gol	7.879	1.465	26.87	92	6	2								11.67	5	3	4
22-30cm red	11.17	1.739	32.49	85	8	7								11.67	5	3	3
68-74cm	14.64	1.54	1.42	88	7	5									3	3	3
														13.5	3	3	3
Pit #23 Glaci							N	17	1	1	D	25	B	13.5	3	3	3
3-11 cm 1	10.25	1.399	25.43	90	8	2								13.5	3	3	3.5

17 cm 2	11.15	n/a	4.18	83	12	5								3.5	4	3	3.5
Pit #24 Vista							ENE	1	2	0	D	67	B	3.5	4	3	3.5
5-13 cm 1	11.52	1.474	0.39	97	2	1								3.5	4	3	3.5
57-65 cm	20 33	1.472	0	96	3	1									4	3	4
														23	4	2	4
Pit #25 Yello							S	16	3	2	D	44	B	23	4	2	4
0-8 cm 1	7.578	0.894	34.62	74	19	7								23	4	2	4
17-25 cm	26.59	1.14	5.77	87	5	8								23	4	2	4.5
32-40 cm	16.23	1.099	26.88	70	22	8								7	5	2	4.5
Pit #26 Brow							SW	1	1	1	D	97	T	7	5	2	4.5
5-13 cm 1	3.298	1 476	15.23	91	8	1								7	5	2	3
80-88 cm	14.55	1.644	6.96	95	4	1								35.5	4	4	3
32-40 cm	16.23	1 099	26.88	70	22	8								7	5	2	4.5
Pit #31 Cass							W	2	2	85	W	77	B	19	3	4	2 5
7-15 cm 1	19.4	1.079	0	79	18	3								19	3	4	3
65-73 cm	15 53	1.71	0	83	11	6									4	4	4.5
Pit #90							ENE	3.5	3	12.5	W	76	T	24.67	5	1	5
0-38 cm 1	11.63	1.854	19.92	64	31	5								24.67	5	1	5
38-64 cm	16 07	1.41	37.92	79	16	5								24.67	5	1	1
64-76 cm	9 772	2.201	35.92	83	12	5								35	1	5	1

Wetted Slope

SAMPLE	SOIL	BULK	% of s	%SA	%SIL	% CL	ASP	SLO	HORIZ	VEGE	WET/	A.L.D.	MECH	avg.	Wetne	Temp	Avg
	%	gm/cm	>2mm					<	# of	%	dry or	CM	WEAT	fine			moist
											wet		Bot or		1 wet	1 war	temp
													Top		5 dry	5 cold	
Pit #13 Over							WS	11	2	100	W	40	B	17	1	5	3
4-12 cm 1	28.76	1.171	0	81	18	1								17	1	5	3
bottom 2	n/a	n/a	11.9	85	11	4								7	1	3	2
Pit #14 The							WS	11	1	30	W	92	B	7	1	3	2
9-17 cm 1	8.346	1.376	38.91	94	5	1								7	1	3	2
85-93 cm	14.71	1.732	14.67	92	7	1								10.5	1	3	2
Pit #15 Red							S	7	1	65	W	64 +	B	10.5	1	3	2
8-16 cm 1	23.54	1.366	0	89	10	1								10.5	1	3	2
46-54 cm	1.442	1.641	10.71	90	5	5								12	4	3	3.5
Pit #16 Glaci							SE	1	1	5-10	D	25	B	12	4	3	3.5
2-10 cm 1	7.667	1.297	0	97	2	1								12	4	3	3.5
15 cm bl.bnd	13.55	n/a	0	79	12	9								6.667	3	3	3
Pit #17 Old							S	11	3	5	W	27	U	6.667	3	3	3
0-8 cm 1	9.594	1.219	0.81	92	7	1								6.667	3	3	3
br san bot 2	7.412	n/a	6.81	96	3	1								6.667	3	3	3
white sand	6.801	n/a	0	92	7	1								16	2	4	3
Pit #18 Sand							WS	12	1	15	W	27	1	16	2	4	3
5-13 cm 1	25.63	1.388	1.02	84	15	1								27	2	4	3
Pit #19 Sand							WS	1.5	1	15	W	23	1	27	2	4	3
7-15 cm 1	30.55	1.089	0	73	26	1								8.667	1	3	2
Pit #20 Colla							W	6	1	7	W	76	0	8.667	1	3	2
11-19cm de	13.73	1.732	60.57	92	6	2								8.667	1	3	2

5-13 cm str	16 88	1.524	5 35	89	9	2								8.667	1	3	2
68-76cm	15.76	1.739	0	93	4	3								8.667	5	3	4
chem for sa	21.17	n/a												6.333	5	1	3

Wet Meadow

SAMPLE	SOIL	BULK	% of s	%SA	%SIL	% CL	ASP	SLO	HORIZ	VEGE	WET/	A.L.D.	MECH	avg.	Wetne	Temp	Avg
	%	gm/cm	>2mm					<	# of	%	dry or	CM	WEAT	fine			moist
											wet		Bot or		1 wet	1 war	temp
													Top		5 dry	5 cold	
Pit #6 Caribo							WS	5	2	60	D	18TO 3	U		4	4	4
5-13 cm 1	10.75	1 118													4	4	4
25-33 cm	10 3	1.501													4	4	4
Pit #7							FLAT	0	2	35	W	48	B	21	1	5	3
5-13 cm 1	11.17	1.461	44.01	83	13	4								21	1	5	3
34-38 cm	19.23	n/a	0	75	19	6								21	1	5	3
Pit #12 Pond							FLAT	0	1	100	W	44	B	15	1	5	3
5-13 cm 1	29 56	0.98												15	1	5	3
30-38 cm	14.32	1.575	20.56	70	21	9								15	1	5	3
Pit #18 Sand							WS	12	1	15	W	27	1	16	2	4	3
5-13 cm 1	25 63	1.388	1.02	84	15	1								16	2	4	3
Pit #19 Sand							WS	1.5	1	15	W	23	1	27	2	4	3
7-15 cm 1	30 55	1.089	0	73	26	1								27	2	4	3
Pit #83							N	2	2	100	W	60	T	20.5	1	5	3
5-13 cm 1	14.82	1.709	4.65	79	14	7								20.5	1	5	3
49-57 cm	14.62	1.639	0.67	80	13	7								20.5	4	2	3
Pit #91							S	2	1	100	W	59	T	35	1	5	3
5-13 cm 1	18.64	1.486	0.625	61	29	10								35	1	5	3
43-51 cm	10.99	1.968	64.17	69	21	10								35	1	5	3

Misc

SAMPLE	SOIL	BULK	% of s	%SA	%SIL	% CL	ASP	SLO	HORIZ	VEGE	WET/	A.L.D.	MECH	avg.	Wetne	Temp	Avg
	%	gm/cm	>2mm					<	# of	%	dry or	CM	WEAT	fine			moist
											wet		Bot or		1 wet	1 war	temp
													Top		5 dry	5 cold	
Pit #2							N	2	1	7	D	64	B	31.5	5	1	3
40-48 cm	8.51	1.552	0	52	30	18								31.5	5	1	3
5-13 cm 2	5.701	1.566	0	85	12	3								31.5	5	1	3
Pit #32 Cairn							SE	3	1	2	D	80	N	10.5	4	1	2.5
5-13 cm 1	16 35	1.514	10 85	90	9	1								10.5	4	1	2.5
40-48 cm	17 42	1 522	1.03	89	10	1								8.5	4	2	3
Pit #33 Cairn							SE	9	1	5	D	100	N	8.5	4	2	3
5-13 cm 1	6 044	1.518	45.58	91	8	1								8.5	4	2	3
88-96 cm	12.37	1.5	4.71	92	7	1								29	2	3	2 5
Pit #34 Cairn							ESE	4	2	60	W	78	T	29	2	3	2.5
surf horiz 1	34.48	[illegible]	7.25	79	17	4								29	2	3	2.5
7-15 cm 2	12 37	[illegible]	10.46	59	23	18								29	2	3	2.5
64-72 cm	14 77	1 967	13.32	75	16	9								24.5	3	3	3
Pit #35 Cairn							ESE	4	1	3-5	W	87	T	24.5	3	3	3
4-12 cm 1	6 982	1.87	3.22	70	17	13								24.5	3	3	3
68-74 cm	3 002	1 928	9.59	81	10	9								16	3	3	3
Pit #36 Cairn							W	2	2	40	W	84	N	16	3	3	3
5-13 cm 1	10 28	1.515	15.06	83	13	4								16	3	3	3
59-66 cm	13 96	1.909	2.62	85	10	5								0	3	5	4
71-79 cm	25 33	0.76													1	5	3
Pit #37 Peat							FLAT	0	1	35	W	24	1		1	5	3

5 13 cm 1	40 71	0 666												0	1	5	3
Pit #38 Peat							FLAT	0	1	35	W	32	1		1	5	3
5-13 cm 1	43.17	0 614												18	1	4	2 5
Pit #39 Cairn							E	2.5	3	60	W	64	B	18	1	4	2 5
5-13 cm 1	21 76	0.991												18	1	4	2.5
9-17 cm 2	16	1.64	25.86	83	14	3								18	1	4	2 5
47-64 cm	20 28	n/a	18.61	81	11	8								12.5	1	5	3
Pit #40 Cairn							E	3.5	2	100	W	32	U	12.5	1	5	3
6-14 cm 1	40.85	0.783												12.5	1	5	3
24-32 cm	26.7	1.254	0.13	75	21	4								21	1	5	3
Pit #49 Pond							S	1	1	1	W	30+	1	27.5	1	5	3
4-12 cm 1	7.869	1.752	0.74	80	10	10								27.5	1	5	3
pond bottom	n/a	n/a	0.29	65	19	16								22	2	3	2.5
Pit #50 Pond							N	3	1	80	W	35	B	22	2	3	2.5
4-12 cm 1	19.12	1.427	4.44	80	10	10								22	2	3	2.5
28-36 cm	25.52	1.219	1.05	76	15	9								10.5	3	3	3
Pit #51 Pond							E	2	2	1	W	77	T	10.5	3	3	3
4-10 cm 1	7.16	n/a	3.55	87	10	3								10.5	3	3	3
60-70 cm	18.37	n/a	1.15	92	7	1								18	1	5	3
Pit #52 Pond							W	2	1	20	W	50+	1	18	1	5	3
surface 1	20 9	n/a	25.06	82	14	4								14.5	1	5	3
Pit #53 Pond							E	2	2	5	W	66	B	14.5	1	5	3
Surface 1	21.73	n/a	39.58	90	8	2								14.5	1	5	3
58-66 cm	4.87	1.921	1.79	81	10	9								26.5	4	3	3.5
Pit #54 Pond							E	1	1	30	W	63	T	26.5	4	3	3.5
5-13 cm 1	n/a	1 694	1.75	68	13	19								26.5	4	3	3.5
49-57 cm	4.571	1.844	0.3	79	9	12								5.5	4	2	3

Pit #55 Pond							ESE	2	1	10	D	102	B	5.5	4	2	3
5-13 cm 1	8.289	1.593	17.94	95	4	1								5.5	4	2	3
92-100cm	11 32	1.616	3.3	94	4	2								0	1	5	3
Pit #56 Pond							E	1.5	1	100	W	?	1		1	5	3
surface 1	55.89													29	1	5	3
Pit #57 Pond							E	2	1	40	W	?	1	29	1	5	3
4-12 cm 1	1 943	1.901	7.16	71	9	20								19.5	3	2	2.5
Pit #58 Pond							SW	1	2	1	W	80	B	19.5	3	2	2.5
4-12 cm 1	12.14	1.664	3.02	82	13	5								19.5	3	2	2.5
62-70 cm	26.6	1.285	11.39	79	16	5								22	3	3	3
Pit #59 Pond							SW	1.5	1	20	W	55	T	22	3	3	3
5-13 cm 1	0 885	1 642	1.27	78	11	11								22	3	3	3
47-55 cm	9.952	1.888	36.32	78	17	5								13	1	5	3
Pit #60 Pond							N	1	1	10	W	35	1	13	1	5	3
5-13 cm 1	15.15	1.578	1.67	87	10	3								13	1	5	3
Pit #61 Pond							N	0.5	2	100	W	24	1	13	1	5	3
14-22 cm	21 4	1.611	1.1	73	13	14								41.5	1	5	3
Pit #62 Pond							W	2.5	3	100	W	43	B	41.5	1	5	3
4-12 cm 1	3 793	1.776	1.76	62	15	23								41.5	1	5	3
19-37 cm	2.278	1.687	0.95	55	17	28									1	5	3
36-43 cm	31.41	0 926													4	5	4 5
														25.5	4	3	3.5
Pit #63 Pond							SWS	6	1	75	W	51	T	25.5	4	3	3.5
5-13 cm 1	35 84	0.953	12.05	68	29	3								25.5	4	3	3 5
39-47 cm	16.02	1.489	0.26	81	11	8								35	3	3	3
Pit #64 Pond							WS	1	2	100	W	26	1	35	3	3	3
14-21 cm	33 77	1	1.36	65	27	8								18.5	2	4	3

Pit #65 Pond							W	4	1	100	W	40	T	18.5	2	4	3
7-15 cm 1	17.35	1.48	1.02	82	11	7								18.5	2	4	3
32-40 cm	22.26	1.39	0.52	81	14	5								16	3	3	3
Pit #66 Pond							W	8	1	10	W	80	B	16	3	3	3
5-13 cm 1	10.2	1.409	4.85	92	3	5								16	3	3	3
don't know	7.003	1.704	5 56	76	13	11									4	3	3.5
														24.5	4	3	3.5
Pit #67 Cam							S	3	1	80	W	59	B	24.5	4	3	3 5
5-13 cm 1	20.34	1.388	2.04	77	18	5								24.5	4	3	3.5
48-56 cm	13.36	1.893	4.01	74	16	10								24	3	4	3.5
Pit #68 Cam									1	75	W	78	B	24	3	4	3.5
5-13 cm 1	12.74	1.509	9	79	13	8								24	3	4	3.5
70-78 cm	12.99	1.782	11.61	73	18	9								26	2	5	3.5
Pit #69 Cam									1	80	W	58	T	26	2	5	3.5
14-22 cm	5.677	1.794	1.96	72	18	10								26	2	5	3.5
51-59 cm	11.36	1.875	14.12	76	15	9								32.5	1	5	3
Pit #70 Cam									1	100	W	66	T	32.5	1	5	3
4-12 cm 1	16.44	1.587	0.26	63	26	11								32.5	1	5	3
43-51 cm	12.63	1.863	1.24	72	19	9								25.5	2	5	3.5
Pit #71 Cam									1	30	W	73	T	25.5	2	5	3.5
7-15 cm 1	12.35	1.707	3.85	72	20	8								25.5	2	5	3.5
60-68 cm	12.34	1.685	6.26	77	15	8								12.5	4	5	4.5
Pit #72 Cam									1	100	W	55	B	12.5	4	5	4.5
10-15 cm	14.22	n/a	45.01	90	8	2								12.5	4	5	4.5
don't know	11.17	n/a	40.32	85	13	2								34	3	5	4
Pit #73 Cam								5	2	35	W	62	B	34	3	5	4
10 cm 1	16.32	n/a	18.97	82	15	3								34	3	5	4

25-33 cm	14.92	1.783	0.21	61	31	8								34	3	5	4
60 cm 3	13.98	n/a	0.24	55	37	8								25.5	2	5	3.5
Pit #74 Cam									1	40	W	54	B	25.5	2	5	3.5
6-14 cm 1	15.7	1.477	2.89	77	16	7								25.5	2	5	3.5
50 cm 2	33.78	n/a	3.85	72	18	10								31.5	1	5	3
Pit #75 Cam									1	100	W	75	B	31.5	1	5	3
6-14 cm 1	16.02	1.649	3.24	83	12	5								31.5	1	5	3
bottom 2	13 34	2.261	3.17	54	41	5								31	2	4	3
Pit #76									1	40	W	63	B	31	2	4	3
6-14 cm 1	12.49	1.751	1.57	72	20	8								31	2	4	3
bottom 2	14.23	1.916	5.77	66	29	5								37	3	4	3.5
Pit #77									1	60	LW	53	B	37	3	4	3.5
8-16 cm 1	21 86	1.167	0.68	65	28	7								37	3	4	3.5
45-33 cm	24 07	1.5	3.22	61	34	5								35 5	3	3	3
Pit #78									1	10	W	75	B	35.5	3	3	3
6-14 cm 1	10 18	1.72	3.64	67	28	5								35.5	3	3	3
62-70 cm	11.52	2 086	28.62	62	32	6								25 5	3	4	3.5
Pit #79									1	1	W	61	B	25.5	3	4	3.5
5-13 cm 1	13.46	1.589	11.49	78	14	8								25.5	3	4	3.5
47-55 cm	12.15	1.843	25.19	71	22	7								32.5	3	4	3.5
Pit #80									1	100	W	60	B	32.5	3	4	3.5
12-20 cm	17.9	1.347	15.06	67	29	4								32.5	3	4	3.5
52-60 cm	10 01	1.984	54.95	68	26	6								36	4	4	4
Pit #92 Cam							S	2	3	1.5	W	95	T	16	5	1	3
10-15 cm	8 591	2.49	35.65	80	13	7								16	5	1	3
40-43 cm	8 911	1 135	31 36	80	11	9								16	5	1	3
70-78 cm	8 69	1.296	1.17	92	5	3								28.5	4	1	2.5

Pit #93 Cam							S	2	1	5	W	74	T	28.5	4	1	2.5
6-14 cm 1	13.12	1.769	32.63	68	18	14								28.5	4	1	2.5
66-74 cm	10.65	1.84	18.23	75	20	5								26	4	2	3
Pit #94 Cam							S	2	1	5	W	74	T	26	4	2	3
5-13 cm 1	12.36	1.496	13.66	69	19	12								26	4	2	3
bottom 2	8.094	3.543	55.88	79	19	2								31.5	3	2	2.5
Pit #95 Cam							S	2	1	1.5	W	85	T	31.5	3	2	2.5
7-15 cm 1	14.02	1.337	0.74	59	34	7								31.5	3	2	2.5
bottom 2	8.053	2.695	56.8	78	19	3								32	2	2	2
Pit #96 Cam							S	2	3	100	W	75	T	32	2	2	2
12-20 cm	11.83	1.806	9.94	72	20	8								32	2	2	2
47-55 cm	12.85	1.684	2	61	30	9								32	2	2	2
bottom 3	13.65	1.223	19.97	71	24	5								24.33	2	3	2.5
Pit #97							S	2	3	20	W	84	B	24.33	2	3	2.5
6-14 cm 1	29.87	0.88	10.02	88	11	1								24.33	2	3	2.5
24-32 cm	10.79	1.5	10.64	83	14	3								24.33	2	3	2.5
71-79 cm	11.56	1.833	4.27	56	39	5								23	2	3	2.5
Pit #98							S	2	1	15	W	72	B	23	2	3	2.5
9-18 cm 1	9.483	1.581	11.11	85	12	3								23	2	3	2.5
46-53 cm	8.671	1.805	3.47	69	22	9								19	1	4	2.5
Pit #99							S	2	1	10	W	64+	B	19	1	4	2.5
10-18 cm	16.03	1.517	24.83	87	11	2								19	1	4	2.5
43-51 cm	13.31	1.615	9.71	75	17	8								19.5	1	4	2.5
Pit #100							S	2	1	5	W	49+	B	19.5	1	4	2.5
top 1 of	18.41	1.312	3.01	81	17	2								19.5	1	4	2.5
bottom 2	11.59		6.97	80	14	6											

Appendix #2 Pit and Sample Descriptions

July 3
Pit #1 lower Met Station
SAMPLES: top 1-8 cm, 12-17 cm, 40-47 cm and 65-70 cm
GENERAL DESCRIPTION:
roots to 45 cm, surface mostly gravelly rocky material with fine matrix, 25% veg cover with dryas, salix, cerastium, melandrium, sax.opp., oxyria, papover, potentila, a l d 70 cm

July 5

Pit #2 Sandy Plateau
SAMPLES: 5-13 cm and 40-48 cm
GENERAL DESCRIPTION:
roots to 9 cm, surface fairly large boulders(10+m) to the N, 7% veg cover sax.opp papover, 2deg N facing slope, a.l.d. approx 64 cm hard to tell b of larger rocks at bottom of the pit

Pit #3
SAMPLES: 4-13 cm and 35-40 cm
GENERAL DESCRIPTION:
STRIPED area, roots to 45 cm, surface covered with small pebbles, 12% veg cover sax opp., salix, papover, oxyria, melandrium, a.l.d. 52 cm

Pit #4
SAMPLES: 4-13 cm and 31-40 cm
GENERAL DESCRIPTION:
STRIPED area, roots to 41 cm, 90% veg cover carex, salix, draba, sax.opp., dryas, polygonac, a.l.d. 41 cm, pit is wet

Pit #5
SAMPLES: 3-10 cm and 32-40 cm
GENERAL DESCRIPTION:
frostboils/lobes, roots to 44 cm, fine matrix cover, 65% veg cover of which 40%salix, moss, carex, dryas, beneath surface are rocks 10-15 cm big to a depth of 10-15 cm, a.l.d. 44 cm

July 8

Pit #6 "Caribou Antler Pit"
SAMPLES: 5-13 cm and 25-33
GENERAL DESCRIPTION:
rocky/stony area quit dry, roots to 30 cm, fine silty/clay matrix, 60% veg. cover cassiope, salix, sax.opp., papover, sax.c., oxyria, wet a.l.d. variable 18 cm under moss to 30 cm elsewhere under different surface

Pit #7
SAMPLES: 5-13 cm and 34-38 cm
GENERAL DESCRIPTION:
meadow wet swampy flat area with no drainage patterns, 2 layers evident 0-33 cm sandy/silty mixture with rocks at the bottom, 34-38 cm black organic layer, roots to 38 cm, 35% veg cover salix, some papover, oxyria, dryas, grass, a.l.d. 48 cm

July 9
Pit #8 Lake Ridge
SAMPLES: 8-13 cm and 50-58 cm
GENERAL DESCRIPTION:
stony gravel ridge top, 2 layers, roots to 52 cm,15% veg.cover, dryas,salix, grass, sax.c., a.l.d. 65 cm

Pit # 9
SAMPLES: 0-10 cm and 60-65 cm
GENERAL DESCRIPTION:
stony gravel ridge similar to the above pit but the surface has a higher portion of the finer matrix, roots to 60 cm, veg. cover 10% grass, melandrium, sax.opp. dryas, salix, a.l.d. 100 cm

Pit # 10 Mud Boil
SAMPLES: 6-14 cm and 36-44 cm
GENERAL DESCRIPTION:
mud boil with clay matrix, root s to 20 cm, veg cover 5 %, a.l.d 53 cm

Pit # 11
SAMPLES: 5-13 cm and 8-16 cm
GENERAL DESCRIPTION:
sample one from the centre of the polygon and the second from the depression, polygon; roots to 25 cm, veg.cover 35%, a.l.d 25 cm depression; roots to bottom 18-31 cm, 80% veg.cover, a.l.d 18-31 cm

Pit # 12 Pond Pit
SAMPLES: 5-13 cm and 30-38 cm
GENERAL DESCRIPTION:
pond wet anaerobic area?? roots to bottom , veg.cover 100%, a.l.d. 44 cm

July 23

Pit # 13 The Overflowing Pit
SAMPLES: 4-12 cm and bottom
GENERAL DESCRIPTION:
very wet marshy area, roots to the bottom, 2 layers 100% veg.cover, a.l.d. 40 cm

Pit # 14 The Red Sands
SAMPLES: 9-17 cm and 85-93 cm
GENERAL DESCRIPTION:
red sandy material mixed in with parent material bottom of pit collapsed due to the water, roots to 47 cm, 30%veg. cover, a.l.d. 92 cm

Pit # 15 Red Moss Pit
SAMPLES: 8-16 cm and 46-54 cm
GENERAL DESCRIPTION:
Sandy intermixed area on a slope mixed in with the parent material, 65%veg. cover, a.l d.64 cm

Pit # 16 Glacier Tripod Photo
SAMPLES: 2-10 cm and black band 15 cm
GENERAL DESCRIPTION:
on top of the ridge that the preceding 4 samples were taken from, 5-10% veg cover a l.d 25 cm

Pit # 17 Old Glacier Pit
SAMPLES: 0-8 cm, white sand, and brown sand
GENERAL DESCRIPTION:
shallow pocket of sand 3 layers easily differentiated by colour, 5% veg. cover a.l.d 27 cm but it was to the bottom of the sand pocket and not to the permafrost as it was not discernable because of the environment

July 24

Pit # 18 Sandy Oasis
SAMPLES: 5-13 cm
GENERAL DESCRIPTION:
small deposit of sand which is vegetated, water flowing from and through the rocks above appear to have deposited the sand, roots to bottom of pit, 15%veg. cover, a.l d. 27 cm same problems as above

Pit # 19 Sandy Oasis #2
SAMPLES: 7-15 cm
GENERAL DESCRIPTION:
same description as last pit different location but the rest is pretty much the same, a l d. 23 cm

Pit # 20 Collapsible Pit
SAMPLES: dep 11-19, str 5-13 bot of stripe 68-76
GENERAL DESCRIPTION:
striped area with small depression stripe 7%veg.cover 50% rock cover, dep 25% with moss, a.l.d. 76 cm

Pit # 21 Alpine Elevated Fuel Drum
SAMPLES: 2-10 cm, 24-32 cm, and 70-78 cm
GENERAL DESCRIPTION:
very sandy surface with 80% rock cover 3 layers evident, 5 % veg. cover, a.l.d. 78 cm

Pit # 22 Alpine Elevated Paul's Cairn
SAMPLES: gold 22-30, red 22-30 cm, and 68-76 cm
GENERAL DESCRIPTION:
sandy surface with 85% rock cover roots to 30 cm less than 1% veg.cover a.l.d. 78 cm

July 26

Pit # 23 Glacier Slope Pit
SAMPLES: 3-11 cm and 17 cm
GENERAL DESCRIPTION:
sandy matrix with fairly coarse pebbles, on slope just to the S of the glaciers snout, <1% veg. cover, a.l.d. 25 cm but rocks at the bottom not to the permafrost table

Pit # 24 Vista Cairn Pit
SAMPLES: 5-13 cm and 57-65 cm
GENERAL DESCRIPTION:
At the top of the slope mentioned above at a higher elevaticn, no plant cover, a.l.d. 67 cm

Pit # 25 Yellow Bedrock Pit
SAMPLES: 0-8 cm, 17-25 cm, and 32-40 cm, and bedrock sample
GENERAL DESCRIPTION:
on the dinosaur knees, yellow platy, easily shattered rock material, 3 layers evident, 2% veg. cover, a.l.d. 44 cm

Pit # 26 Brown Sugar Pit
SAMPLES: 5-13 cm and 80-88 cm
GENERAL DESCRIPTION:
gravel sandy ridge near lower met station, 50% surface rock cover, <1%veg.cover, a.l.d.97 cm

Pit # 27 Western Pit
SAMPLES: 5-13 cm and 37-45 cm
GENERAL DESCRIPTION:
polygon centre, roots to 33 cm, 50% veg cover, a.l.d. 52 cm

Pit # 28 Western Depression Pit
SAMPLES: 5-13 cm and 37-45
GENERAL DESCRIPTION:
in the depression of the above polygon, roots to 30 cm, 80% veg. cover, a.l.d. 45 cm

Pit # 29 Coal Pit
SAMPLES: 1-8 cm, 20-28 cm, 46-54 cm, and 56-64 cm
GENERAL DESCRIPTION:
on the hill coming from the west to the east towards the lower met station, 0% veg. cover, a.l.d. 64 cm

Pit # 30 Striped Pit
SAMPLES: 6-14 cm, and 60-68 cm
GENERAL DESCRIPTION:
flat plateau are with stripes that are delineated by vegetation, depression 90%veg. cover stripe, 1% veg cover, a.l.d. 68 cm

Pit # 31 Cassiope Pit
SAMPLES: 7-15 cm and 65-73 cm
GENERAL DESCRIPTION:
ridge area in the lower portion but east of the met station, surface mottled with veg free and vegetated areas and large rocks, 2 layers evident, roots to 37 cm, veg. cover 85%, a.l.d. 77 cm

July 29

Pit # 32 Hill Transect Cairn #7 top
SAMPLES: 5-13 cm and 40-48 cm
GENERAL DESCRIPTION:
top of a rocky ridge surface cover mostly rock with some veg, fine sand matrix, 2% veg.cover, a.l.d 80 cm

Pit # 33 Cairn #6
SAMPLES: 5-13 cm and 88-96 cm
GENERAL DESCRIPTION:
red rock with orange coloured sand matrix mostly covered with rock, roots to 23 cm, 5% veg. cover, a.l.d. 100 cm

Pit # 34 Cairn #5
SAMPLES: surface, 7-15 cm and 64-72 cm
GENERAL DESCRIPTION:
Fairly well vegetated area with a thick moss cover, 2 layers evident, 60% veg.cover with moss, a.l.d. 78 cm

Pit # 35 Cairn #4
SAMPLES: 4-12 cm and 68-74 cm
GENERAL DESCRIPTION:
similar to the last pit 1st step up from the felsimere field and the rest of the cairns, compact clay matrix, 3-5% veg. cover, a.l.d. 87 cm

Pit # 36 Cairn #3
SAMPLES: 5-13 cm and 59-66 cm, 71 -70 cm
GENERAL DESCRIPTION:
loosely patterned ground 35% of surface is rock, 2 layers evident, 40%veg. cover, a.l.d. 84 cm

July 30

Pit # 37 Peat Mound Centre
SAMPLES: 5-13 cm
GENERAL DESCRIPTION:
centre of a peat mound, very wet swampy region, centre has collapsed, 35% veg. cover, 95% with moss and lichen, a.l.d. 24 cm

Pit # 38 Peat Mound Edge
SAMPLES: 5-13 cm
GENERAL DESCRIPTION:
same description as the last one with a change occurring in that the sample was taken from the edge of the polygon, a.l.d. 32 cm, P.S. would be approximately the same depth as the centre had it not collapsed

Pit # 39 Cairn #2
SAMPLES: 5-13 cm, 9-17 cm and 47-64 cm
GENERAL DESCRIPTION:
cover similar to Cairn #3, dug in the depression and under the vegetated area, 3 layers evident, 60% veg. cover 100% including moss and lichen, a.l.d. 64 cm

Pit # 40 Cairn #1 (bottom of hill transect)
SAMPLES: 6-14 cm and 24-32 cm
GENERAL DESCRIPTION:
wet sedge moss type meadow pit, 100%veg cover mostly grasses, 2 layers evident, a.l.d. 32 cm

NEXT FEW PITS ARE FROM THE LARGE WELL FORMED POLYGONS

Pit # 41 Polygon #1 Dep
SAMPLES: 4-12 cm and 36-44 cm
GENERAL DESCRIPTION:
pit to the most northern point, hummocks on the surface, roots to 35 cm, 45% veg.cover 65% with the moss, a.l.d. 44 cm

Pit # 42 Polygon #1 Surface
SAMPLES: 4-12 cm and 36-44 cm
GENERAL DESCRIPTION:
same polygon, same cover, roots to 44 cm, a.l.d. 44 cm

Pit # 43 Polygon #2 Surface
SAMPLES: 7-15 cm and 57-65 cm
GENERAL DESCRIPTION:
polygon surface quite flat with a few small lobes, 25-30%surface rock, 25%veg cover, a.l d 65 cm

Pit # 44 Polygon #2 Dep
SAMPLES: 7-15 cm and 21-29 cm
GENERAL DESCRIPTION:
same polygon, many very small hummocks, 50% veg. cover, a.l.d 29-41 cm

Pit # 45 Polygon #3 Surface
SAMPLES: 3-11 cm and 47-55 cm
GENERAL DESCRIPTION:
little vegetation, surface is dry dusty clay material, few rocks on the surface, roots to 45 cm, 5% veg.cover, a.l.d 55 cm

Pit # 46 Polygon #3 Dep
SAMPLES: 5-13 cm and 32-40 cm
GENERAL DESCRIPTION:
same polygon, fewer rocks on surface, more hummocks, roots to 35 cm, a.l.d. 40 cm

Pit # 47 Polygon #4 Surface
SAMPLES: 7-15 cm 62-70 cm and shale sample
GENERAL DESCRIPTION:
dry crusty surface, a lot of fossilized rocks at the surface which,1% veg. cover, a.l.d. 70 cm

Pit # 48 Polygon #4 Dep
SAMPLES: 6-14 cm and 29-37 cm
GENERAL DESCRIPTION:
hummocky surface with moss, roots to 37 cm, veg. cover 5%, a.l.d. 37 cm

August 2

The following samples were all taken from separate transects around the pond which is located to the west of the camp. The samples with the larger letter were taken from the farthest point on the transect from the lake. The samples that end with an A are samples collected immediately beside the pond surface.

Pit # 49 Pond T1A
SAMPLES: 4-12 cm and pond bottom
GENERAL DESCRIPTION:
mud boil dry surface water flowing into pit, little vegetation, a.l.d. 30 cm stopped because of water flowing into pit

Pit # 50 Pond T1H
SAMPLES: 4-12 cm and 28-36 cm
GENERAL DESCRIPTION:
between 2 sandy/rocky outcrops, roots to 35 cm, 80%veg. cover 100% including black and white goo, a.l.d. 35 cm

Pit # 51 Pond T2F
SAMPLES: 4-10 cm and 60-70 cm
GENERAL DESCRIPTION:
patterned ground poorly defined polygon, 60-70% of surface are rocks, roots to 40 cm, <1% veg. cover, a.l.d 77 cm

Pit # 52 Pond T2A
SAMPLES: surface
GENERAL DESCRIPTION:
striped area, depressions, holding water, rocky surface 35% of the cover, 20%veg. cover, a.l.d. 50 cm but not to permafrost stopped because there were more larger rocks showing up the further down you went

Pit # 53 Pond T3A
SAMPLES: surface and 58-66 cm
GENERAL DESCRIPTION:
similar to T2A, no standing water and surface is a bit more mucky, 2 layers evident, 5% veg. cover, a.l.d. 66 cm

Pit # 54 Pond T3F
SAMPLES: 5-13 cm and 49-57 cm
GENERAL DESCRIPTION:
similar to T2F 35-40% of the surface is rock, rocky boils/patterned ground, 30%veg. cover, a.l.d. 63 cm

Pit # 55 Pond T4F
SAMPLES. 5-13 cm and 92-100 cm
GENERAL DESCRIPTION:
orangy brown sandy surface with a few pebbles and rocks, roots to 60 cm, 10% veg cover, a.l.d. 102 cm

Pit # 56 Pond T4A
SAMPLES: surface
GENERAL DESCRIPTION:
stripe depression, 100% veg. cover, a.l.d. unknown because of the wetness impossible digging

Pit # 57 Pond T5A
SAMPLES: 4-12 cm
GENERAL DESCRIPTION:
surface similar to T4A, dug in the depression, 40% veg. cover, a.l d. unknown

Pit # 58 Pond T5E
SAMPLES: 4-12 cm and 62-70 cm
GENERAL DESCRIPTION:
sort of striped surface depressions, 45-50% surface rock, dug under the stripe, 2 layers evident, 100% veg. cover, stripes <1%, a.l.d. 80 cm

Pit # 59 Pond T6G
SAMPLES: 5-13 cm and 47-55 cm
GENERAL DESCRIPTION:
striped/patterned ground, 25-30% surface is rock, roots to 45 cm, depressions 80% veg cover, dug under 20% veg. cover, a.l.d. 55 cm

Pit # 60 Pond T6A
SAMPLES: 5-13 cm
GENERAL DESCRIPTION:
similar to the other pits near the water, looks as though the area has been completely under water at other times, small delta, little vegetation, a.l.d. 35 cm

Pit # 61 Pond T7A
SAMPLES: 14-22 cm
GENERAL DESCRIPTION:
surface completely moss covered, roots to bottom, 100% veg. cover, a l d 24 cm

Pit # 62 Pond T8A
SAMPLES: 4-12 cm, 19-27 cm, and 36-43 cm
GENERAL DESCRIPTION:
mud shelf possibly a result of ice shove on the bank, 3 layers, 100% veg cover,a l d 43

August 3

Pit # 63 Pond T9H
SAMPLES: 5-13 cm and 39-47 cm
GENERAL DESCRIPTION:
small pools of standing water, small hummocks, roots to 51 cm, 75% veg. cover, 100% including moss and lichen, a.l.d 51 cm

Pit # 64 Pond T9A
SAMPLES: 14-21 cm
GENERAL DESCRIPTION:
shelf near the lake with small hummocks, roots to 26 cm, 100%veg. cover mostly moss and lichen, a.l d. 26 cm

Pit # 65 Pond T8F
SAMPLES. 7-15 cm and 32-40 cm
GENERAL DESCRIPTION:
very wet with algae growing in puddles, hummocky, dug in depression, roots to 40 cm, 100% veg. cover, a.l.d. 40 cm

Pit # 66 Pond T7F
SAMPLES: 5-13 cm and 72-80
GENERAL DESCRIPTION:
small rocky outcrop/ridge above mossy area, rocks 50% of the surface, 10% veg. surface, a.l.d. 80 cm

August 9

The next series of samples were taken from the hill at base camp the 1st series listed i.e. any with a 3 in the title were taken from next to the river, A was taken on the furthest point west and F or H was taken on the furthest eastern point

Pit # 67 Camp T3A
SAMPLES: 5-13 cm and 48-56 cm
GENERAL DESCRIPTION:
dryas hummocks at surface, roots to 40 cm, 80% veg. cover, a.l.d. 59 cm

Pit # 68 Camp T3B
SAMPLES: 5-13 cm and 70-78 cm
GENERAL DESCRIPTION:
dryas cover but much flatter here than the first pit, sandy band much rockier, 75%veg. cover, a.l.d. 78 cm

Pit # 69 Camp T3C
SAMPLES: 14-22 cm and 51-59 cm
GENERAL DESCRIPTION:
near edge of the wetter area, roots to 20 cm, 80% veg. cover, a.l.d 58 cm

Pit # 70 Camp T3D
SAMPLES: 4-12 cm and 43-51 cm
GENERAL DESCRIPTION:
quite swampy marshy wet area, roots to 66 cm, quite smelly, 100% veg. cover, a l.d. 66 cm

Pit # 71 Camp T3E
SAMPLES: 7-15 cm and 60-68 cm
GENERAL DESCRIPTION:
at the base of a rocky stripe, rocks dominate on surface 50%, roots to 30 cm, a.l.d. 73 cm

Pit # 72 Camp T3F
SAMPLES: 10-15 cm and ???
GENERAL DESCRIPTION:
quite steep, rocky area, 100% veg. cover mostly moss, a.l.d. 55 cm

The next series of samples were taken in a transect halfway up the hill.

Pit # 73 Camp T2H
SAMPLES: 10 cm, 25-33 cm, and 60 cm
GENERAL DESCRIPTION:
at the base of the steep cliff, 2 layers, 30-40% veg. cover, 100% including black and white goo, a.l.d. 62 cm

Pit # 74 Camp T2G
SAMPLES: 6-14 cm and 50 cm
GENERAL DESCRIPTION:
rocky surface with black and white goo, 40% veg. cover, a.l.d. 54 cm

Pit # 75 Camp T2F
SAMPLES: 6-14 cm and bottom
GENERAL DESCRIPTION:
sedgy area, smelly, rocks large at the surface, 100% veg cover, a.l.d. 75 cm

Pit # 76 Camp T2E
SAMPLES: 6-14 cm and bottom
GENERAL DESCRIPTION:
in black goo similar to #74, few rocks at surface, 40% veg. cover, a.l.d. 63 cm

Pit # 77 Camp T2D
SAMPLES: 8-16 cm and 45-53 cm
GENERAL DESCRIPTION:
surface mostly dryas tussocks, 60% veg. cover, a.l.d. 53 cm

Pit # 78 Camp T2C
SAMPLES: 6-14 cm, 45-53 cm, and 62-70 cm
GENERAL DESCRIPTION:
bare rocks 25-30% surface cover, 10% veg. cover, a.l.d. 75 cm

Pit # 79 Camp T2B
SAMPLES: 5-13 cm and 47-55 cm
GENERAL DESCRIPTION:
sandy surface, roots to 25 cm, 10% veg. cover, a.l.d. 61 cm

Pit # 80 Camp T2A
SAMPLES: 12-20 cm and 52-60 cm
GENERAL DESCRIPTION:
roots to 35 cm dryas and salix tussocks 100% veg. cover, a.l.d. 60 cm

Pit # 81 Solifluction Lobes Creek
SAMPLES: 4-12 cm and 61-69 cm
GENERAL DESCRIPTION:
top transect of the solifluction lobes, roots to 25 cm, 1% veg. cover, a.l.d. 79 cm

Pit # 82 Solifluction Lobes Creek
SAMPLES: 5-13 cm and 16-24 cm
GENERAL DESCRIPTION:
dug in the depression, rocky surface, 100% veg.cover, a.l.d. 56 cm

Pit # 83 Southern Wet Meadow
SAMPLES: 5-13 cm and 49-57 cm
GENERAL DESCRIPTION:
mucky wet region with the northern aspect flowing into the creek, 100% veg. cover, a.l.d. 60 cm

Pit # 84 Solifluction Lobes Creek
SAMPLES: 5-13 cm and 67-75 cm
GENERAL DESCRIPTION:
on the surface of the lobe, pit dug in transect #6, same surface cover as, pit 81, roots to 40 cm, a.l.d. 75 cm

Pit # 85 Solifluction Lobes Creek
SAMPLES: 4-12 cm and 45-53 cm
GENERAL DESCRIPTION:
not really a crack between lobes, more situated at the top of a lobe, 100%veg. cover, a.l.d56cm

Pit # 86 Solifluction Lobes Pond
SAMPLES: 6-14 cm and 50-58 cm
GENERAL DESCRIPTION:
depression at the lobes with the westerly aspect facing the pond, 5 cm mat of moss, roots to 30 cm, 100% surface cover, a.l.d. 58 cm

Pit # 87 Solifluction Lobes Pond
SAMPLES: 6-14 cm and 61-69 cm
GENERAL DESCRIPTION:
lobe top, rocks throughout the pit, roots to 35 cm, 2-5% veg. cover, a.l.d. 69 cm

Pit # 88 Solifluction Lobes Pond
SAMPLES: 6-14 cm and 43-51 cm
GENERAL DESCRIPTION:
surface covered with vegetation even though it is a lobe, 90% veg. cover, a.l.d. 51 cm

Pit # 89 Solifluction Lobes Pond
SAMPLES: 10-18 cm and 40-48 cm
GENERAL DESCRIPTION:
depression, organic mat 10 cm thick, 100% veg. cover, a.l.d. 48 cm

Pit # 90 Sax. Ridge Pit
SAMPLES: 0-38 cm, 38-64 cm and 64-76 cm
GENERAL DESCRIPTION:
surface mostly bare rock and soil, poorly formed stripes noticeable mainly because of vegetation, 10-15% veg. cover, a.l.d. 76 cm

Pit # 91 Camp Meadow Pit
SAMPLES: 5-13 cm and 43-51 cm
GENERAL DESCRIPTION:
same as pit #83, southern aspect, 100% veg. cover, a.l.d. 59 cm

Pit # 92 Camp T1A
SAMPLES: 10-15 cm, 40-43 cm and 70-78 cm
GENERAL DESCRIPTION:
very rocky and matrix predominately sand, 1-2% veg. cover, a l.d. 95 cm.

Pit # 93 Camp T1B1
SAMPLES: 6-14 cm and 66-74 cm
GENERAL DESCRIPTION:
hardened clay pan, 5% veg. cover, a.l.d. 74 cm

Pit # 94 Camp T1B2
SAMPLES: 5-13 cm and bottom
GENERAL DESCRIPTION:
cover similar to the last pit, clay surface, mudstone material, gravely mixture at bottom, definite coarsening downward, 5% veg. cover, a.l.d. 74 cm

Pit # 95 Camp T1C
SAMPLES: 7-15 cm and bottom
GENERAL DESCRIPTION:
rocks at surface, similar vegetation to the last pit, coarsening downward, roots to 30 cm, 1-2% veg. cover, a.l.d. 85 cm

Pit # 96 Camp T1D
SAMPLES: 12-20 cm, 47-55 cm and bottom
GENERAL DESCRIPTION:
very wet area, small concave surface, 3 layers, 100% veg. cover, a.l.d. 75 cm

Pit # 97 Camp T1E1
SAMPLES: 6-14 cm, 24-32 cm, and 71-79 cm
GENERAL DESCRIPTION:
black and white goo on the surface, rocky surface, roots to 20 cm where the rocks end, ??% veg. cover, a.l.d. 84 cm

Pit # 98 Camp T1E2
SAMPLES: 9-18 cm and 46-53 cm
GENERAL DESCRIPTION:
surface similar to last one, however pit shows that the area is more homogeneous sand all the way down, roots to 30 cm, a.l.d. 72 cm

Pit # 99 Camp T1F
SAMPLES: 10-18 cm and 43-51 cm
GENERAL DESCRIPTION:
mossy surface with more channelized flow through the rocks, fairly large rocks at surface 30 cm, roots to 25 cm, a.l.d. 64 cm pit collapsed so the depth should be deeper

Pit # 100 Camp T1G
SAMPLES: top and bottom
GENERAL DESCRIPTION:
surface is quite mossy, similar to the last pit, roots to 15 cm, a.l.d. 49 cm stopped digging because it was way to rocky