THE SCUPLTURAL POTENTIAL OF SNOW
AS A DESIGN ELEMENT

BY

CARLA L.W. KEAST

A Practicum submitted to the Faculty of Graduate Studies of the Universtiy of Manitoba in partial fulfillment of the requirements for the degree of

MASTER OF LANDSCAPE ARCHITECTURE

ISBN 0-315-77852-0

THE SCULPTURAL POTENTIAL OF SNOW AS A DESIGN ELEMENT

BY

CARLA L.W. KEAST

A practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF LANDSCAPE ARCHITECTURE

ABSTRACT

The intent of this study was to explore the sculptural qualities of snow and snowdrifts in order to illustrate the design opportunity they present to landscape architects.

The report is divided into two parts.

The first part is a compilation of what is known about snow and snowdrifting: the characteristics of snow; the factors governing snowdrift formation; the snowdrift patterns that are created by specific obstacles. The information in this section is both of a general nature as well as specific to certain situations. It is presented in a format which can easily be utilized by landscape architects.

The second part of this report is an exploration of the sculptural qualities of snow and snowdrifting: the interaction of light, shadow, texture, and form. It proposes that these qualities give life, magic, rhythm, and humor to the snow-clad winter environment, and that these qualities can and should be incorporated into landscape design.

Both sections include suggestions for exploring and playing with the characteristics and qualities of snow and snowdrifts in order to create effects which could contribute to landscape design in a winter environment.

ACKNOWLEDGEMENTS

I would like to thank the members of my practicum committee, Professor Charlie Thomsen (chairperson), Professor Rory Fonseca, and Professor John Welch. Their enthusiasm and guidance has helped make my research most enjoyable.

I would also like to thank Dr. William Pruitt and Mr. Ron Tabler for taking the time to discuss snow, and for opening their personal libraries to me. As well I would like to thank my friends and family - their questions and observations have taught me much.

A special thanks to Michele and Chuck Ammeter for so generously sharing their snowdrifts, photo collection, and warm home.

And a very very special thank-you to my husband Joe, and to my parents for their encouragement, patience and support.

Lastly, I would like to thank the Canada Mortgage and Housing Corporation for their financial assistance in support of this study.

TABLE OF CONTENTS:

introduction

SNOWDRIFTS HAPPEN

Snowdrifts happen. Every winter in Manitoba, and everywhere north of 45, snowdrifts happen.[1]

They grow in fields, across ravines, through shelterbelts, up the sides of garages. They transform the landscape. They sculpt it and resculpt it. They flow, dip, and swirl across it. They are fluid and ever moving. They dance. They rest. They laugh. And then they're gone. See figures 1-6.

Snowdrifts are elusive. They arrive one day uncalled for. They stay yet continually change on a whim of light, or shadow, or wind or sun. See figures 7-8. They are elusive. Yet they are, to an extent, predictable.

When wind, snow and obstacles meet, drifts happen.

This then gives designers a choice. We can plan for a drift to happen; allowing it the space it requires, while taking advantage of special viewing angles and play opportunities. Or we can ignore it, and let the client wage a long costly, yet futile attempt to remove it from the road, the parking lot, the doorway...

Because planned for or not, snowdrifts happen.

Figure 1
Sunset (5:00 - 6:00 p.m.)
Starbuck, Manitoba
February 11/92
-23.4° C. Wind S at 11 km./hr.

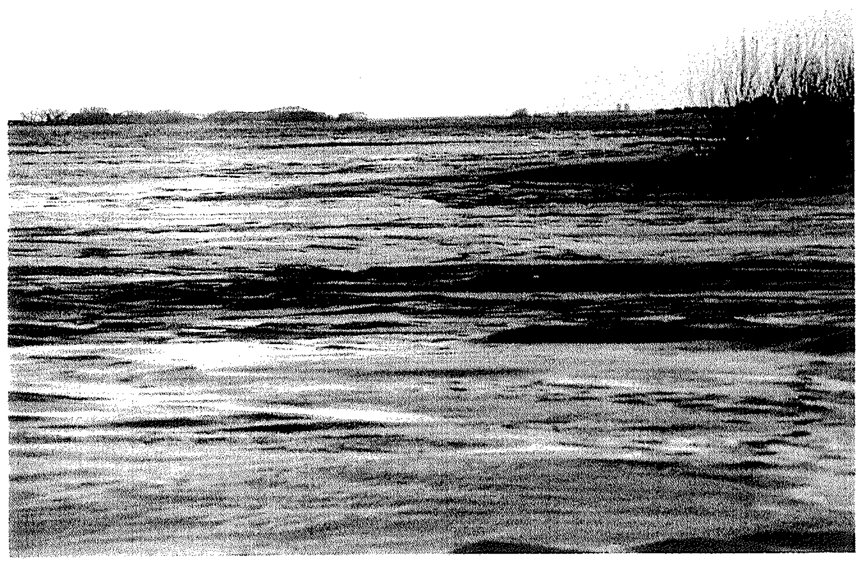


Figure 2
Snow Whitecap
Delta, Manitoba
February 23/91
-17.2° C. Wind N at 7 km./hr.

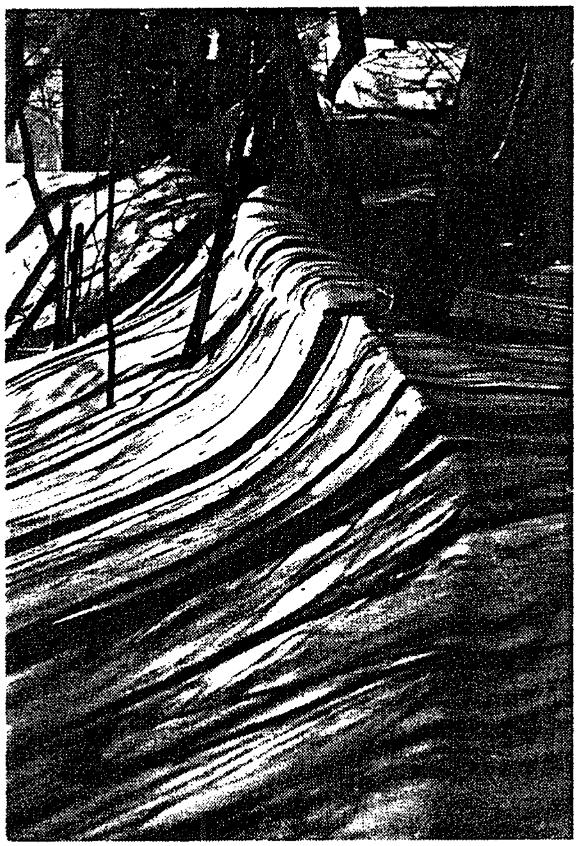


Figure 3
Playing by the Barn
Starbuck, Manitoba
February 11/92, Post sunrise (9:00 - 9:30 am)
-29° C. Wind W at 4 km./hr.

Figure 4
Wave Winter
Ile-des-Chenes, Manitoba
January 19/92, 2:00 p.m.
-17.2° C. Wind N at 13 km./hr.

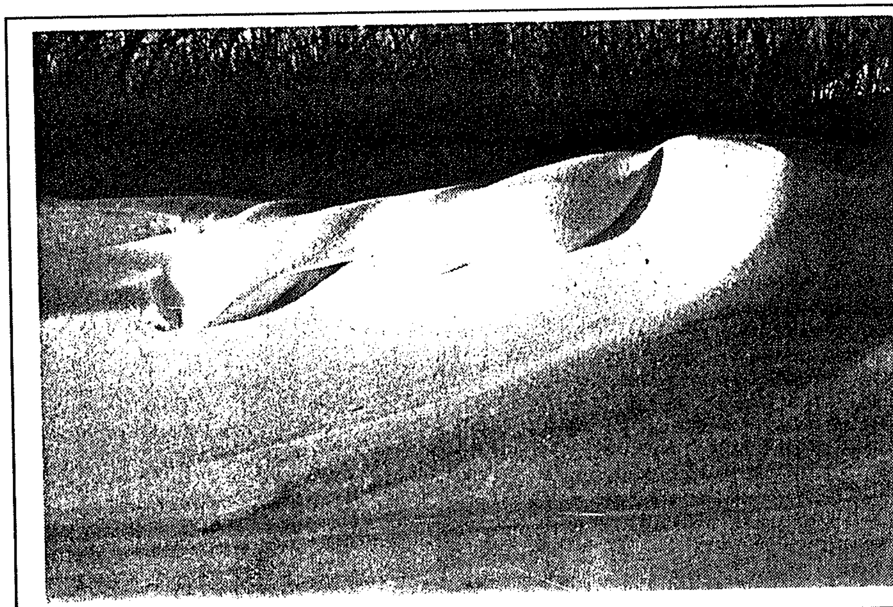


Figure 5
Winter Beachnik
Delta, Manitoba
February 13/91, 2:00 p.m.
-17° C. Wind N at 6 km./hr.

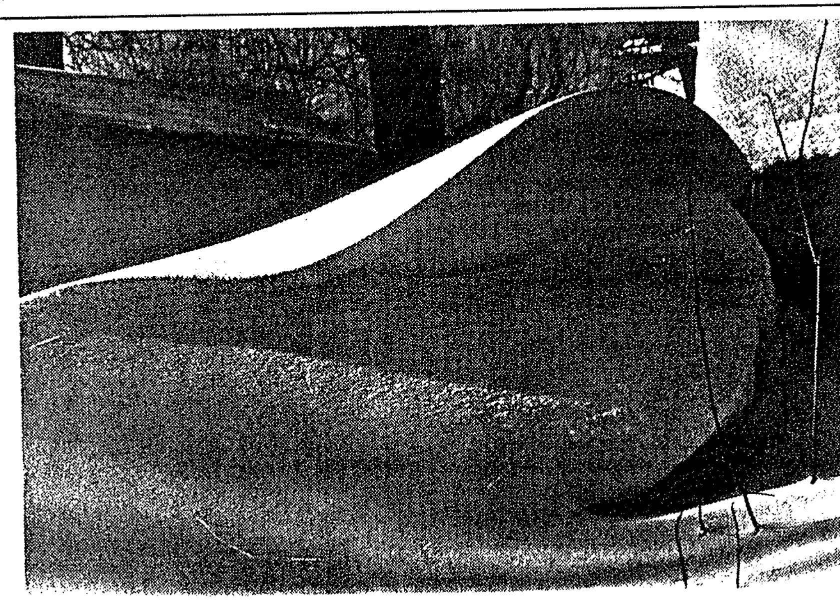
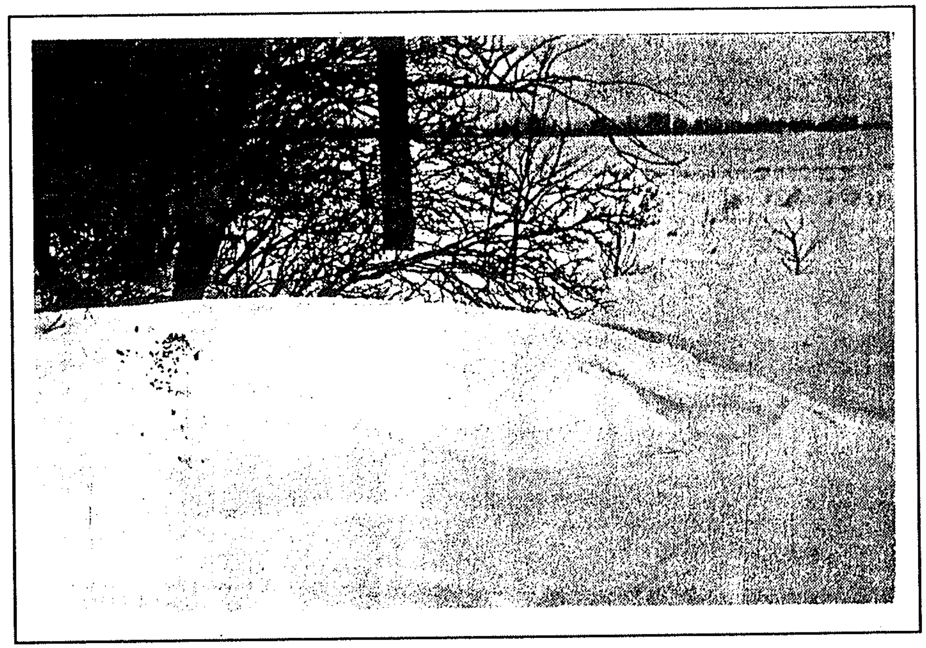


Figure 6
Undulating Edge
Delta, Manitoba
March 21/92, 3:00 p.m.
-17° C. Wind N at 7 km./hr.

Figure 7
Playing with Perception: Under Clouds
Ile-des-Chenes, Manitoba
January 19/92, 11:00 a.m.
-17° C. Wind N at 15 km./hr.



What I am suggesting then, is for designers to account and plan for snowdrifts during the initial stages of design. I am further suggesting that snowdrifts be used as a design element. They add texture, form, color light, shadow, rhythm, even humor to the landscape.

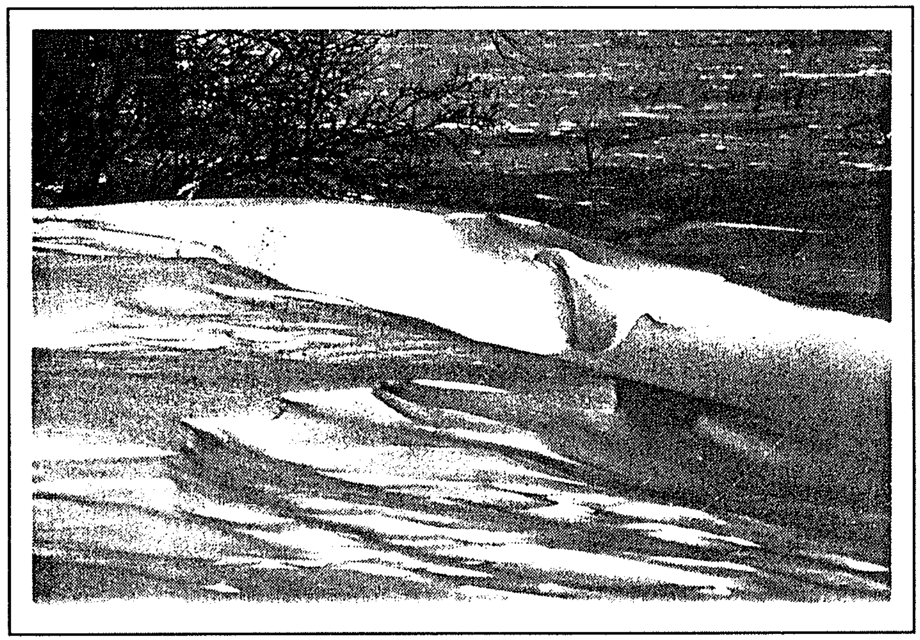
While denial of winter is part of the reason why snowdrifts are not currently considered a design element, lack of accessible information is also responsible.

Snowdrifting is a complex and not well understood process. Drifting information tends to be geared for moisture retention in agricultural practices and for alievating "problematic snowdrifting".[2] Occasionally, the sculptural effects of snowdrifts is mentioned, but only in passing - a suggestion of a possibility.

This report is an exploration of that possibility. It is an illustration of some of the qualities of snow which offer potential for landscape design. It is also a summary of the known "facts" about snow and snowdrifting.

I have tried to present the information in a way which is useful for landscape architects. As well, I have included several suggestions for expanding, exploring, and playing with what is known about snowdrifting. Hopefully this report will inspire northern designers to begin to incorporate and to celebrate snow and winter in their work.

Figure 8
Playing with Perception: In the Sun
Ile-des-Chenes, Manitoba
January 19/92, 2:00 - 2:30 pm
-17° C. Wind N at 13 km./hr.



WHAT IS SNOW?

"When Man was still very young he had already become aware that certain elemental forces dominated the world womb. Embedded on the shores of their warm sea, the Greeks defined these as Fire and Earth and Air and Water. But at first the Greeks sphere was small and circumscribed and the Greeks did not recognize the fifth elemental.

About 330 B.C., a peripatetic Greek mathematician named Pytheas made a fantastic voyage northward to Iceland and on into the Greenland Sea. Here he encountered the fifth elemental in all of its white and frigid majesty, and when he returned to the warm blue Mediterranean, he described what he had seen as best he could. His fellow countrymen concluded he must be a liar since even their vivid imaginations could not conceive of the splendor and power inherent in the white substance that sometimes lightly cloaked the mountain homes of their high-dwelling Gods.

Their failure to recognize the immense power of snow was not entirely their fault. We who are the Greeks' inheritors have much the same trouble comprehending its essential magnitude."[3]

What have we learned about snow in 3000 years ?

Farmers know that it helps replenish the water table, and that it can reduce soil erosion.[4] Zoologists know that it is the difference between life and death for many animals. It shelters and insulates animals such as the shrew, vole, lemming[5] and ptarmigan.[6] It leads others, such as the human hunter to food.[7] Botanists know that snowdrifts can extend the life of some kinds of trees and shrubs by several years.[8] Ecologists recognize its role in creating openings in spruce forests, thus allowing willow and alders to grow - moose habitat.[9] Anthropologists know that indigenous peoples of the north used it to construct dwellings.[10] Architects know that it can collapse the roof of a building,[11] that it blocks entrances and air vents,[12] and that it will even bury an entire settlement.[13] Engineers know that a properly located snow fence can prevent snowdrifts from obstructing highways and railroads.[14] Landscape architects know that shelterbelts do the same thing.[15] They also know that snow melting around subtle undulating contours creates rhythmic abstract landscape patterns and compositions.[16] See figure 9.

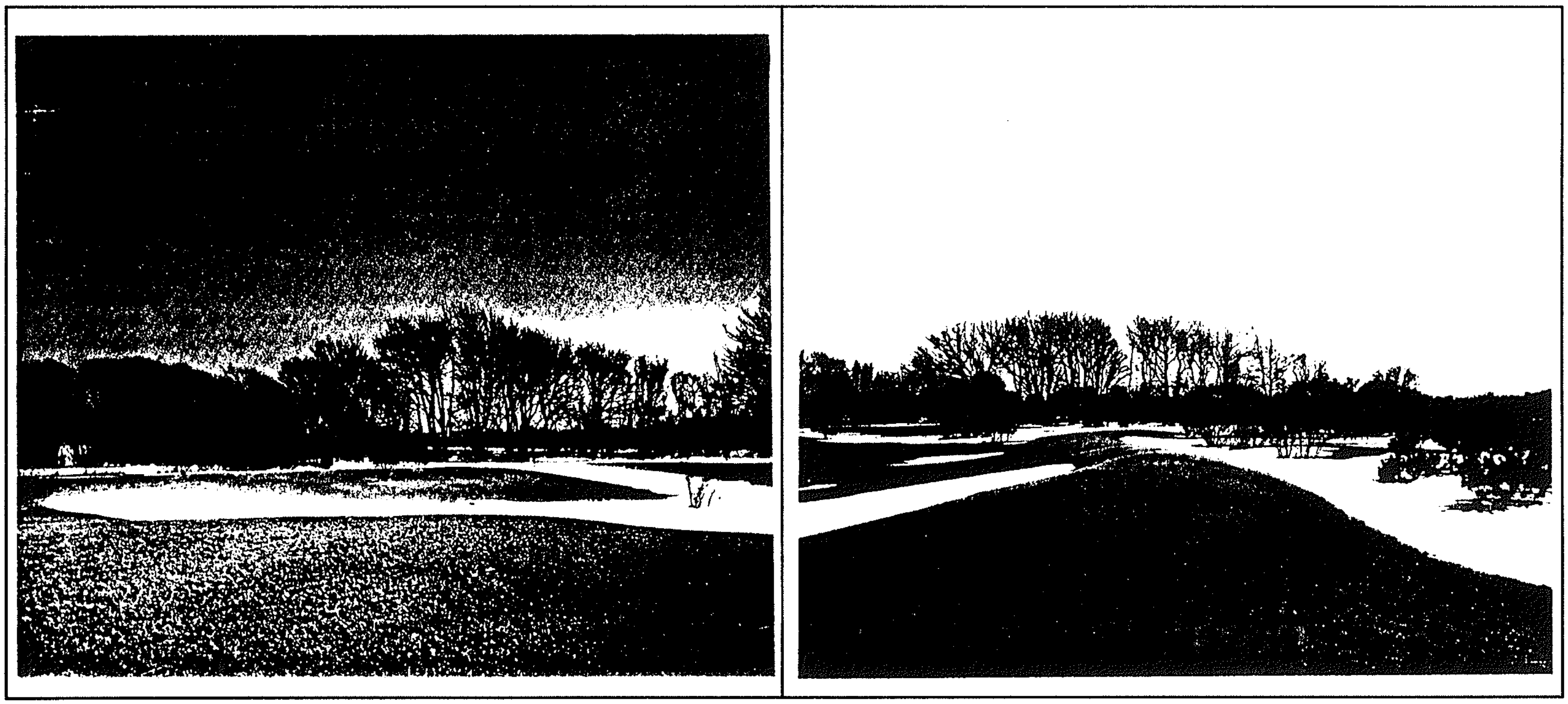
Figure 9
Abstract Patterns and Compositions
A.E,Bye. Art into Landscape, Landscape into Art. Arizona: PDA Publishers Corporation, 1983, Figures 1.10-1.11.

Farley Mowat knows that:

"It is the fragility of Christmas dreams sintering through azure darkness to the accompaniment of the sound of sleigh bells.

It is the bleak reality of a stalled car and spinning wheels impinging on the neat time schedule of our self-importance.

It is the invitation that glows



ephemeral on a woman's lashes on a winter night.

It is the resignation of suburban housewives as they skin wet snowsuits from runny-nosed progeny.

It is the sweet gloss memory in the failing eyes of the old as they recall the white days of childhood.

It is the banality of a TV advertisement pimping CocaCola on a snowbank at Sun Valley.

It is the gentility of utter silence in the muffled heart of a snow-clad forest.

It is the brittle wind-rush of skis; and the bellicose chatter of snowmobiles...

Snow, which on our planet is a phoenix continually born again from its own dissolution, is also a galactic and immortal presence...

When the first star voyager arcs into deep space...(s)now will be the last of the elementals in his distant eye. Snow may provide the first shining glimpse of our world to inbound aliens..."[17]

It is that elusive. And that special.

WHO GETS SNOW?

Not everyone gets snow. Only those regions where temperatures fall below freezing, and where there is sufficient moisture receive snow. This generally includes the temperate zones, as well as the mountain tops of the tropical zones.[18] Snow visits many places occasionally, but only a few can count on it year after year. See figure 10.

Manitoba is a region that can count on having snow every winter. See figure 11. For five to six months of the year, Manitoba's temperatures are below freezing.[19] It snows on about half of those days.[20] During the course of one season, snowfall may accumulate to a depth of 60 cm, or it may accumulate to a depth of 2.5 m.[21] Regardless of the amount, there will be snow. Manitobans can count on it.

Figure 10

Who Gets Snow?

M. de Quervain. "Snow and avalanches," in Forces of Nature. Ed. Sir Vivian Fuchs New York: Holt, Rinehart and Wilston, 1977, p. 84.

Map of North America showing number of days per year with snow, ranging from one or less in California to over nine months in the Canadian Arctic. (From F. Wilhelm 1975 after S. S. Visher 1954).

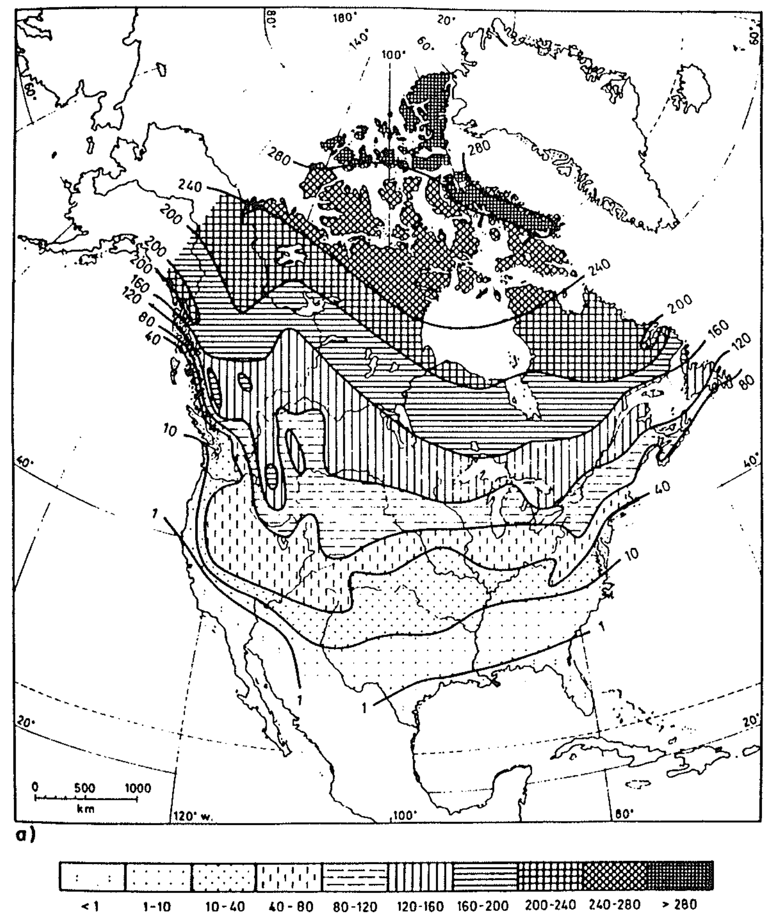


Figure 11
"Nov. 9—Make Way— An Army track vehicle assists a city emergency crew as Winnipeg digs out of its worst snowstorm in 20 years. The storm, that began Friday afternoon, dumped 35 centimetres of snow on parts of southwestern Manitoba."
Winnipeg Free Press, November 9, 1986.

THE PROBLEM WITH SNOW

We may be able to count on there being snow every winter, but that doesn't mean we like it.

As Farley Mowat illustrates,

> "Somewhere, on this day, the snow is falling...
>
> It may be settling in great flakes on a calm night over a vast city; spinning cones of distorted vision in the headlights of creeping cars... (A)dult men and women wait impatiently, for if it does not stop soon the snow will smother the intricate designs that have been ordained for the next day's pattern of existence.
>
> Or the snow may be slanting swiftly down across a cluster of tents huddled below a rock ridge on the arctic tundra... Inside the tents men and women smile. Tomorrow the snow may be deep enough and hard enough so that the tents can be abandoned and the welcome domes of snowhouses can rise again to turn winter into a time of gaiety, of songs, of leisure and lovemaking."[22]

What a remarkable difference in perception and attitude! The people of the arctic tundra have incorporated snow into their lives. For the city people, snow is an inconvenience.

An inconvenience, a nuisance, a problem, an ongoing war. We city people dread it, fight it, endure it; but perhaps worst of all, we deny it. "Winnipeggers, in fact, go out of their way to deny the very existence of winter."[23]

We wear spring and autumn clothing during the winter.[24] Picture books describe Canada in a multitude of color, texture, form and rhythm - but in the absence of winter. "History and popular mythology are almost devoid of winter references."[25] Its rare appearances are associated with bleak, barren, harsh, uncompromising, nothingness, and death.

> "It lay thickly drifted on the crooked crosses and head stones, on the spears of the little gate, on the barren thorns. His soul swooned slowly as he heard the snow falling faintly through the universe and faintly falling, like the descent of their last end, upon all the living and the dead."[26]

Some of the indigenous peoples of the north have dozens of words to describe all of the varieties of snow, some have over a hundred.[27] Winnipeggers have three: "snow", "more snow", and "blowing snow".[28]

Denial is costly. We consume vast amounts of energy to heat our buildings, warm our parking lots, and drive our vehicles from heated garage to heated garage. We pay millions of tax dollars year after year to have snow salted, sanded, plowed, loaded, and hauled off of our streets and out of our cities. (In the past five years the City of Winnipeg has spent an average of 12 million dollars per year on snow removal.[29]) It depletes our energy reserves, it depletes our money reserves. And in doing so, contributes to air pollution, ozone depletion, water table depletion, flooding and soil erosion.

Denial is costly. We pay for in lives[30], and we pay for it in social ills such as depression[31] and alienation.[32]

Denial has given us tall buildings that direct the wind down on us[33] while robbing our sunshine,[34] glassed in malls that alienate us from nature,[35] wide streets that focus and accelerate the wind[36] and treacherous sidewalks of ice, slush, and plowed snow.[37] No wonder we dread it. Unfortunately, it is a "somewhat self-inflicted winter problem, one could subtly add."[38]

Denial is not only a Winnipeg attitude. So widespread is the problem, that a group called the Livable Winter Cities Association has been formed. This group seeks to address the unique opportunities and problems associated with living in a winter environment. It asks the question "Why do northern cities look the same as southern ones"? It challenges our denial of winter and suggests that accepting the climatic realities inherent in winter, will empower us to develop efficient, comfortable, healthy cities.

The approach is simple: "increase in the enjoyment of winter's positive aspects, and protection from the negative ones."[39]

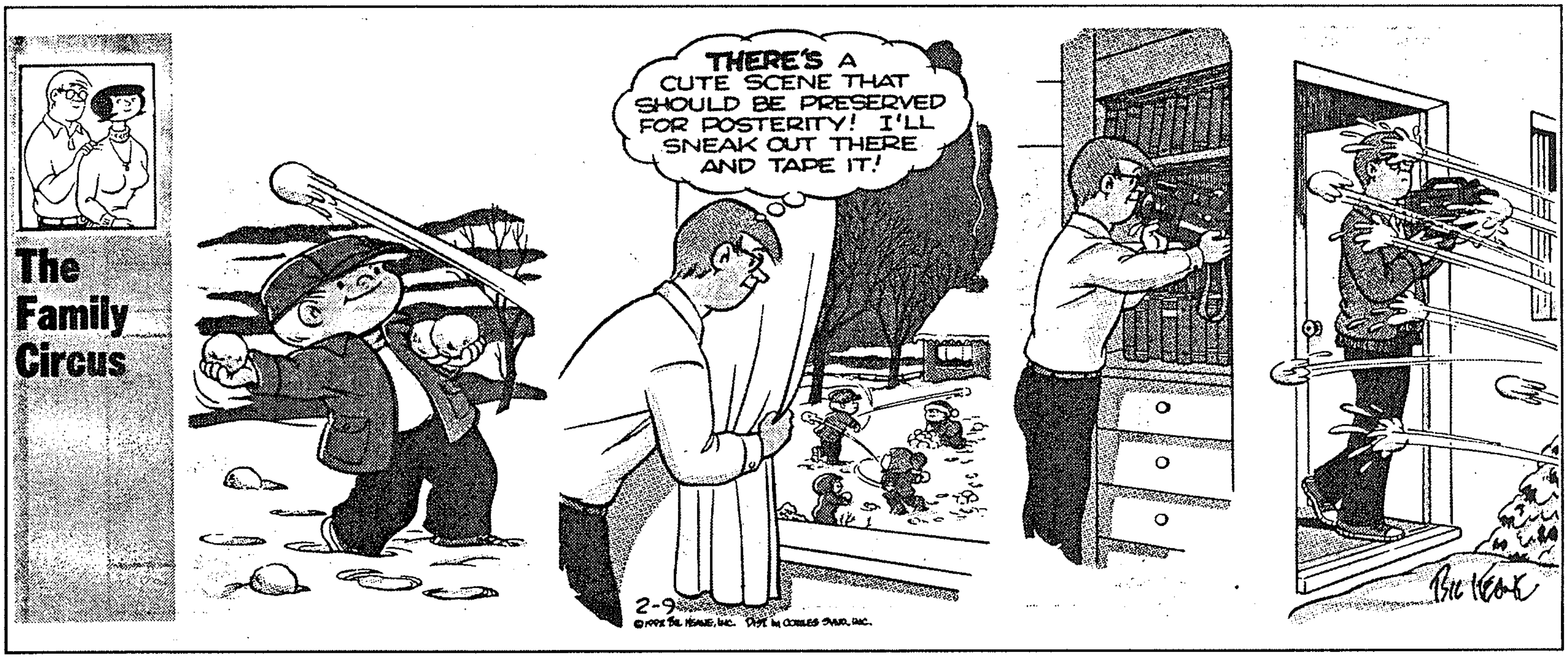
Draw up a list of winter's positive and negative aspects. Snow obviously belongs in the "protection from the negative" column. Or does it?

"The diffuse light reflected by snow lightens shadows and creates landscapes and townscapes of unique beauty which can be enjoyed by looking out of a window."[40]

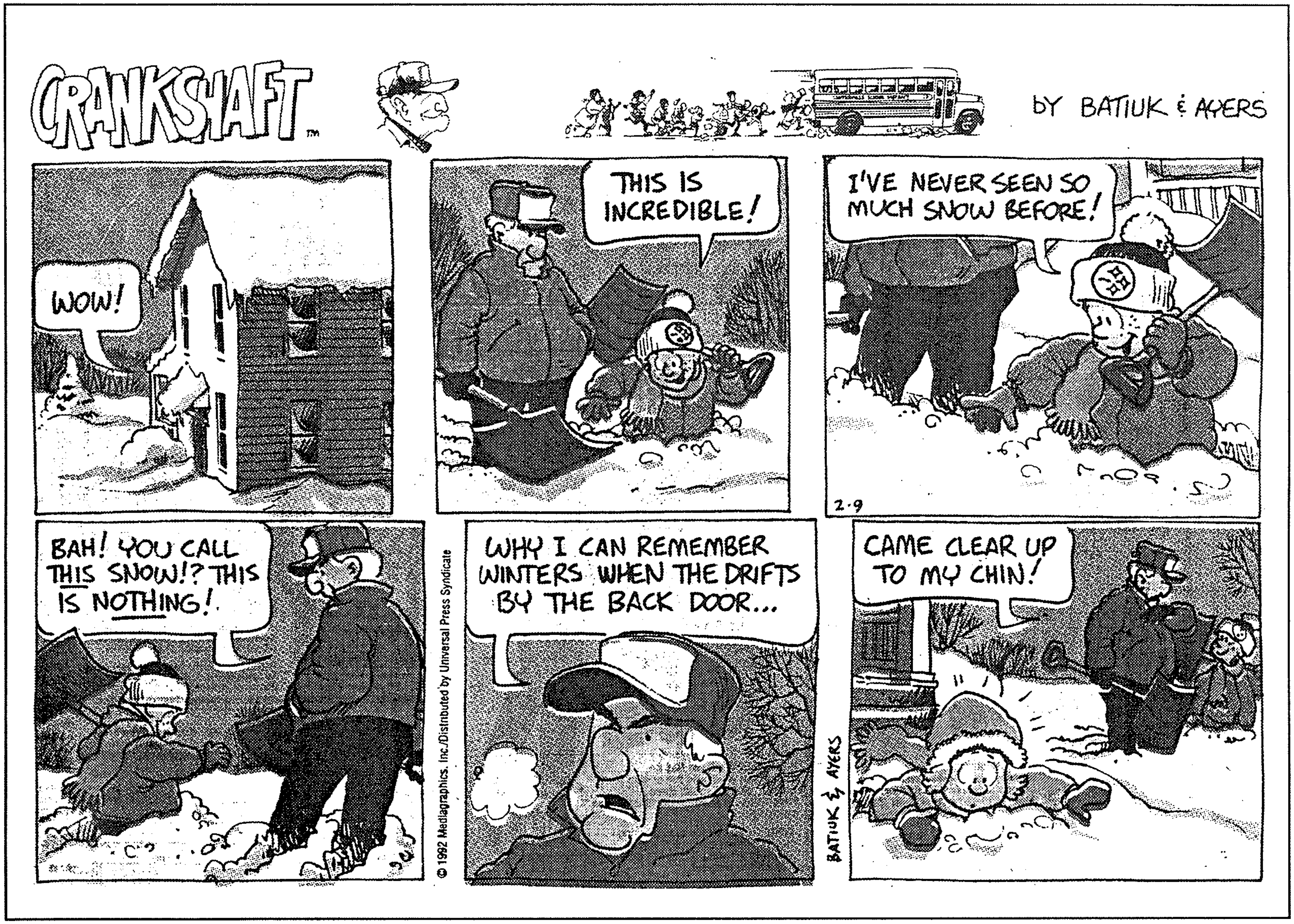
"The magic of snow and ice generates a variety of natural play opportunities, which allow children to use their creativity and imagination."[41] And adults too.

"Snow piled high at the side of the road is a mountain to be climbed or molded into the endless forms conjured by the imagination... There is a new found freedom... The snow transforms whole neighborhoods into adventure playgrounds."[42]

The Family Circus
Winnipeg Free Press
February 8, 1992



Crankshaft, Winnipeg Free Press, February 8, 1992



"First snow is one of the most magical moments of the year for me."[43]

"For those who suffer from night blindness, tunnel vision, a cataract, or some other visual impairment (and I have most of them), the snow serves us very well.

When there's snow on the ground I can walk safely to the bus station at night, or even to the Miner's Home Hotel, and stagger back. The snow provides a clear division between garden fences and sidewalks. It provides contrast on steps, and it acts as a reflector for street lights.... Snow provides a measure of security and liberty for me."[44]

"The beauty of snow and of rime frost in trees or on the ground, the sweeps and spirals of wind-blown snow, the reflection of lights from the white ground and roofs, the springtime run of icy water in gutters - all these and more are part of the aesthetic of the outdoor north, and should be part of city planning".[45]

Snow it would seem, belongs in both columns. We do need protection from it, but it is also a positive aspect of winter, something to be enjoyed.

THE WONDER OF SNOW

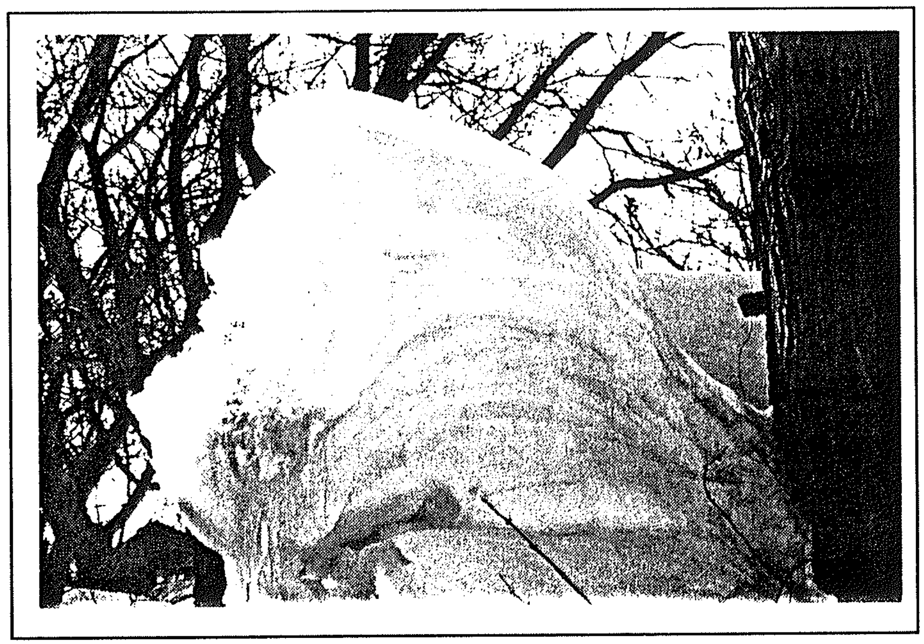
Snow is a contradiction. It is white and it is all colors. It is cold, yet it is warm. It is a mass that can be sometimes walked over, and sometimes walked through. It can be blown away, and thrown away, but it does not go away until it melts. A bit of it will melt in your hand, a lot of it can freeze your hand. It is mystical, magical, and elusive. It is a gift to celebrate and enjoy.

Let's begin with a myth. This is the snow myth - the explanation for why snow is. Such a myth doesn't actually exist (not in my readings anyway), but there should be one, so here it is:

the snow myth

The gods invented winter because the animals of the north needed a time of rest. Unlike the animals of the south, the animals of the north did not rest in the hot midday heat. So the gods invented a season of rest and called it winter. They made the days short and the nights long, and they made it cold, to make sure the animals slept long and well. And then they remembered the insomniacs, and took pity. To give them light to see by, they made snow. And they gave it to the wind and said "Blow this into shapes which will give hope and joy to those who cannot sleep." And so the wind sculpts snow into waves and whitecaps and beaches and sand dunes and fields of flax...

Delta, Manitoba
March 21/92, 3:00 p.m.
-2.2°C. Wind W at 6 km./hr.



REFERENCES:

[1]Royal Architectural Institute of Canada and the American Institute of Architects, Winter Cities, (Edmonton, Alberta, February 20-23, 1986), p.ii.

[2]A note on the phrase "problematic snowdrifting": These two words have been paired up so frequently in the literature, that the word "snowdifting" itself has begun to imply problematic. Snowdrifts however are simply snowdrifts. Drifts that develop over roads, across sidewalks, against doorways, etc., etc. are the result of poor planning and poor design, not problematic snowdrifts. Snowdrifts are simply snowdrifts.

[3]Farley Mowat, The Snow Walker, (Toronto: McClelland and Stewart, 1975), pp. 10-11.

[4]J.H. Stoeckeler, "Shelterbelt Influence on Great Plains Field Environment and Crops: A Guide for Determining Design and Orientation," Production Research Report No. 62. (U.S. Department of Agriculture, Agriculture Research Service, October 1962), p. 4.

[5]William O. Pruitt, Jr. "Life in the Snow", Manitoba Nature (Winter 1973): 8.

[6]William O. Pruitt, "Some ecological aspects of snow," Proceedings of the 1966 Helsinki Symposium on Ecology of the Subarctic Regions, UNESCO series Ecology and Conservation 1 (1970): 95.

[7]Farley Mowat, p. 16.

[8]Mr. Garry Leiberman, Systems Co-ordinator, City of Winnipeg, Operations Department, Central Administration Branch, August, 1992.

[9]J.H. Stoeckeler and E.J. Dortignac, "Snowdrifts as a Factor in Growth and Longevity of Shelterbelts in the Great Plains," Ecology 22. 2 (April 1941): 117, 124.

[10]Mines, Resources, Environmental Management, Winter Weather and Wild Ungulates: A Literature Review with Special Reference to Manitoba, Development and Extension Service, Resource Projects, Report No. 10, p. 24.

[11]Enrico Guidoni, Primitive Architecture Trans. Robert Erich Wolf (New York: Rizzoli International Publications, Inc., 1975), pp. 25, 28.

[12]Peter A. Irwin and Colin J. Williams, "Snowdrift Models," The Northern Engineer, 17. 3 (1985): 4.

[13]Morrison, Hershfield, Theakston & Rowan Ltd., Consulting Engineers, Wind and Snow Control Studies (Guelph, Ontario: Theakston & Rowan Ltd., [1970?]), pp.1-34.

[14]Interview with John Welch, Professor of Environmental Studies, Faculty of Architecture, University of Manitoba, Winnipeg, January, 1992.

[15]R.D. Tabler, "Snow Fence Technology: State of the Art," First International Conference on Snow Engineering (Santa Barbara, California, July 1988), p. 297.

[16]G.O. Robinnette, ed., Plants, People and Environmental Quality (Washington: U.S. Dept. of the Interior, National Park Services, 1972), p.91.

[17]A.E,Bye, Art into Landscape Landscape into Art (Arizona: PDA Publishers Corporation, 1983), pp.1-12.

[18]Farley Mowat, pp. 11-12.

[19]M. de Quervain, "Snow and avalanches," in Forces of Nature, ed. Sir Vivian Fuchs (New York: Holt, Rinehart and Winston, 1977), p. 83.

[20]Winter Weather and Wild Ungulates, p. 9.

[21]John Welch, "The Effects of Sun, Wind and Snow on Urban Design," The Winter City, Canadian Housing Design Council and University of Manitoba, Continuing Education, Winter, 1982, p. 29.

[22]Winter Weather and Wild Ungulates, pp. 11-12.

[23]Farley Mowat, p. 18.

24Leonard W. Vopnfjord, "The Planner's Role," The Winter City, Canadian Housing Design Council and University of Manitoba, Continuing Education, Winter, 1982, p. 12.

[25]Vopnfjord, p. 12.

[26]Winter Cities, p. 3.

[27]James Joyce, "The Dead," in Dubliners, (New York: Random House, 1954), p.288.

[28]Farley Mowat, p. 17.

[29]Local radio and television weather forcasts.

[30]Vladimir Matus, "Let the Sunshine In!" Winter Cities 8. 2 (August 1990): 48.

[31]Michael Hough et. al., Winter Cities Design Manual (Sault Ste. Marie: Hough Stansbury Woodland Limited, 1991), p. 20.

[32]Hough, p. 6.

[33]Hough, p. 5.

[34]Jan Gehl, "Hot Time in the Cold Town," Winter Cities 8.2 (August 1990): 28.

[35]Hough, p. 20.

[36]Hough, p. 5.

[37]Hough, p. 44.

[38]Gehl, p. 28.

[39]Hans Blumenfeld, "Get the Devil Out by Detail," Winter Cities 8.2 (August 1990): 59.

[40]Blumenfeld, p. 59.

[41]Hough, p. 83.

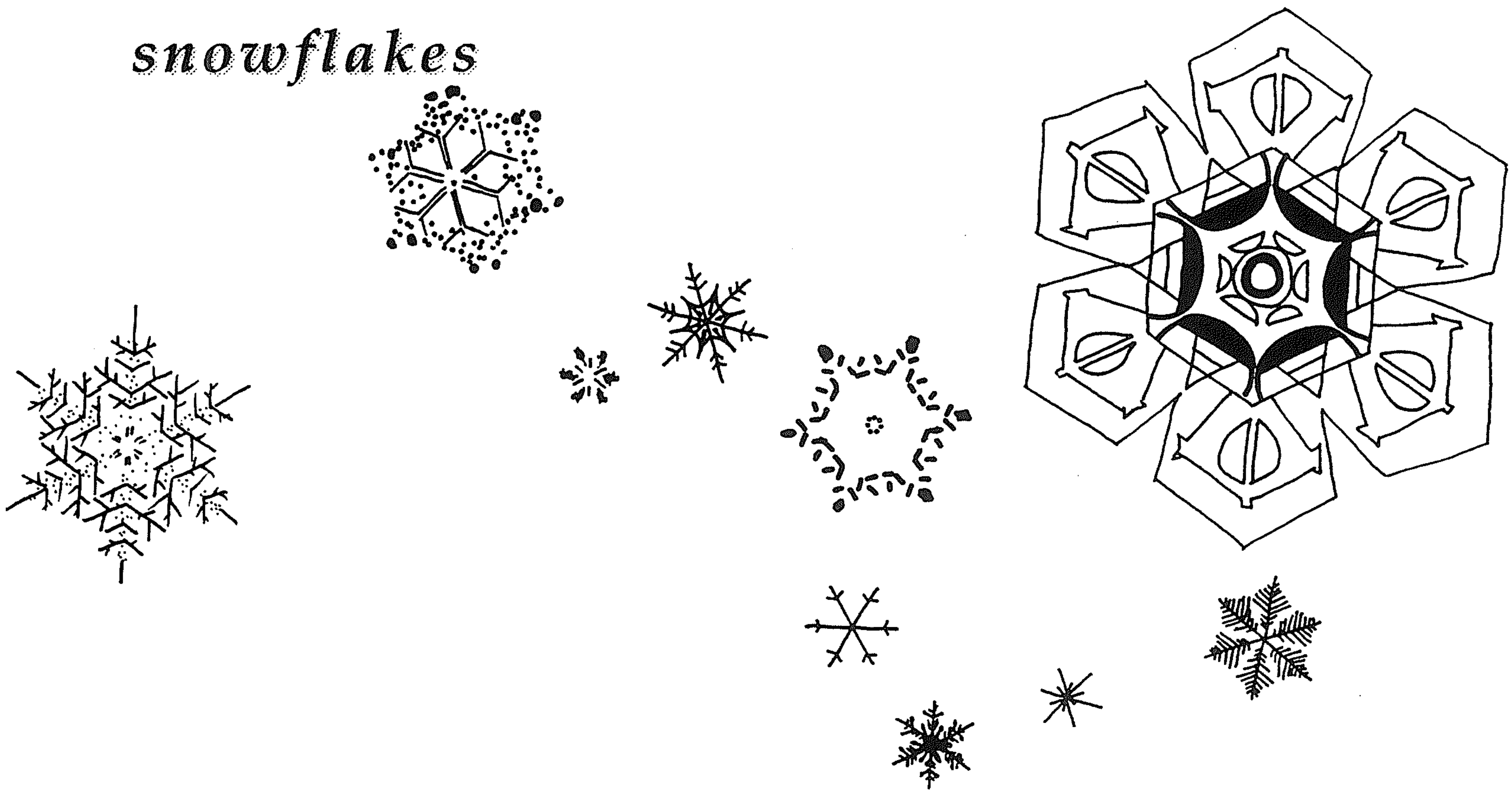
[42]C.H. Thomsen and A. Borowiecka, Winter and Play: Design Guidelines for Winter Play Environments of the Canadian Prairie (Ottawa: Canada, Mortgage and Housing Corporation, 1980), p.1-1.

[43]Julie Misener, in The New Morningside Papers, ed. Peter Gzowski (Toronto: McClelland and Stewart, 1987), p. 389.

[44]John, R. Hunt, in The New Morningside Papers, pp. 394-395.

[45]Ralph Erskine, "Architecture and Town Planning in the North," The Polar Record 14. 89 (1968): 170-171.

snowflakes



FORM

No two snowflakes are the same. We know this to be true because the paper snowflakes we made in grade school art class were all different - even the really beautiful ones that we tried to make copies of. We know it to be true because once we stood outside catching and examining falling snowflakes in our woolen mitts. Sure enough, each one was different from the one before, and the one before that... Big shiny plates, tiny spindly arms, spikes, feathers, flowers, ferns, stars, swords, arrows, armor... All different, all unique, and all exquisitely detailed.

But what else could a collection of crystals be? For this is what a snowflake is: a collection of *ice or snow crystals.*

Snow crystals as well as snow flakes are infinitely varied. However, because water tends to crystalize in 60° angles when it freezes, there is some general similarity in form.[1,2] Based on this, snow crystals have been classified into as few as three groups[3] and as many as eighty[4]. See figure 12. Rarely however, do snow crystals fall neatly into one category with obvious delineations between them. Their form is the result of the action and sequence of many factors during their development - a journey that is unique to each snow crystal.[5] What they have in common though, is the 60° angle, and thus triangles and hexagons (two and three dimensional) are the basic themes.[6,7,8,9,10,11] See figure 13.

A crystal's form, size, detailing, as well as growth rate depends on the ambient temperature and humidity - the weather.[12]

The specific *crystal form* is determined by the surrounding temperature. As figure 14 shows, temperatures at the freezing point and just below it tend to produce hexagonal plates. As temperatures get colder, the form changes to prisms, then to hexagonal plates, then star-shaped crystals, then hexagonal plates, and finally at very cold temperatures (below -25°C) prisms are formed.[13]

It would seem then that all snowflakes within any given snow fall would be all of the same general form. In fact, a variety of forms are usually present in a snowfall.[14] As well, while the particles of any snowlike substance falling from the sky tend to be referred to as snowflakes, this is not always the case. Both individual snow crystals as well as snowflakes form snowfall. At

Figure 12

Snow Crystal Classification

C. Magono and C. Lee. "Meteorological Classification of Natural Snow Crystals," Journal of Faculty of Science, Hokkaido University, Ser. VII, Vol. 2, p. 321; reprinted in D.M. Gray and D.H. Male (eds.), <u>Handbook of Snow: Principles, Processes, Mangaement, and Use.</u> Toronto Ont.: Pergamon Press, 1981, pp. 140-141.

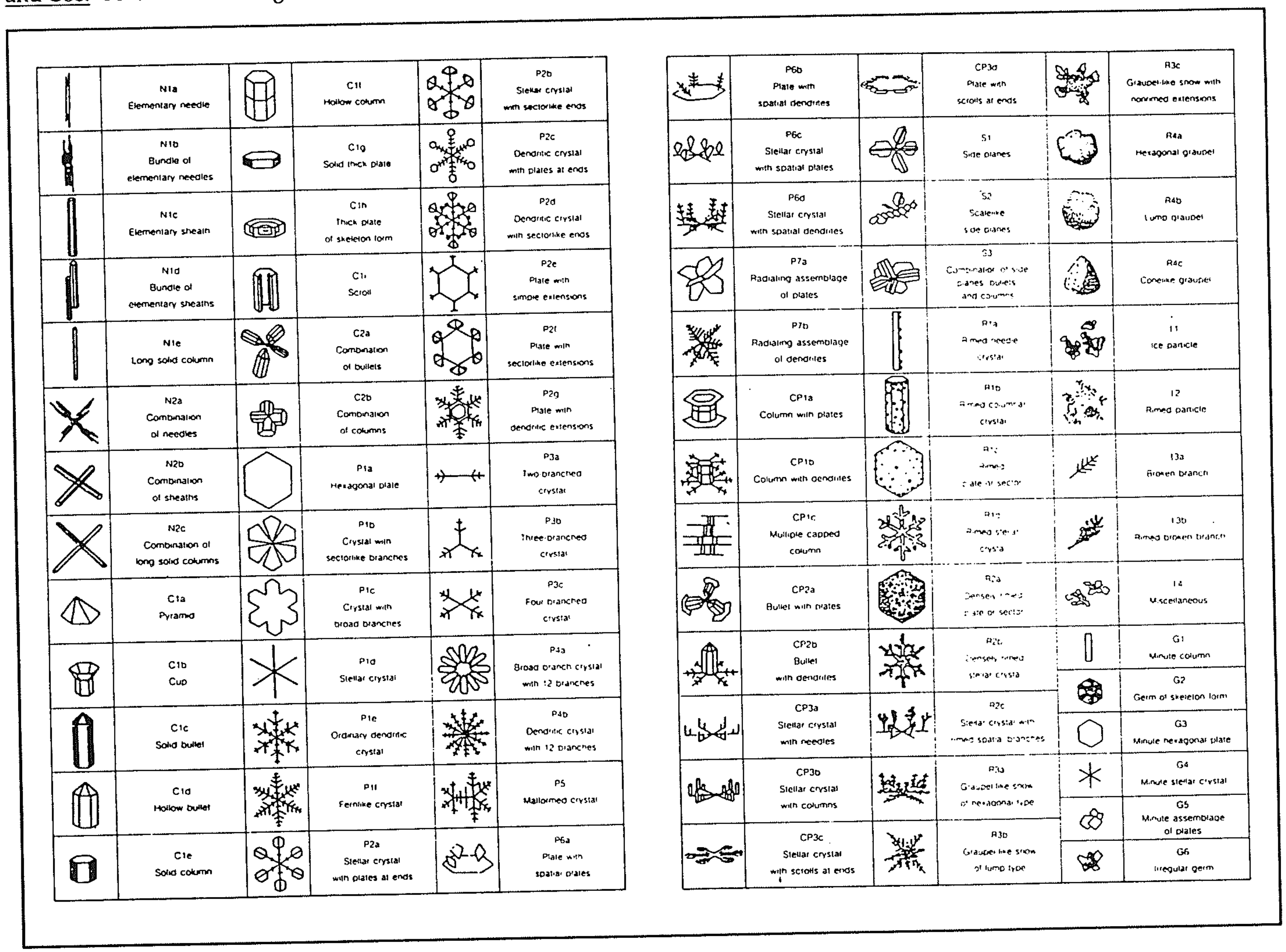


Figure 13

Snowflakes: Variations on Triangles and Hexagons.

W.A. Bentley and W.J. Humphreys. Snow Crystals. New York: McGraw-Hill Book Co. Inc., 1931, pp. 145, 203, 45, 91, 184.

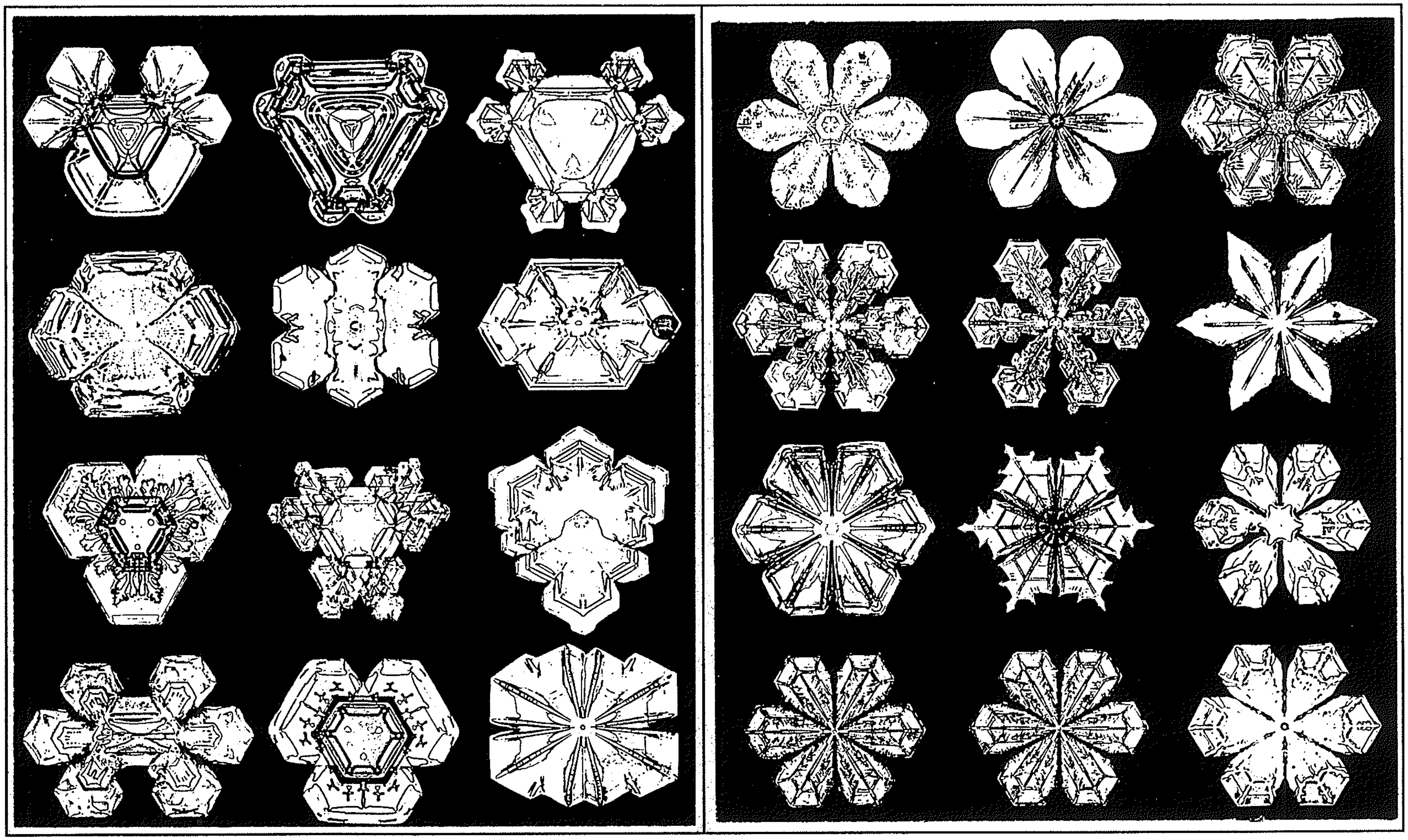


Figure 13 (con't)
Snowflakes: Variations on Triangles and Hexagons.
W.A. Bentley and W.J. Humphreys. Snow Crystals. New York: McGraw-Hill Book Co. Inc., 1931), pp. 145, 203, 45, 91, 184.

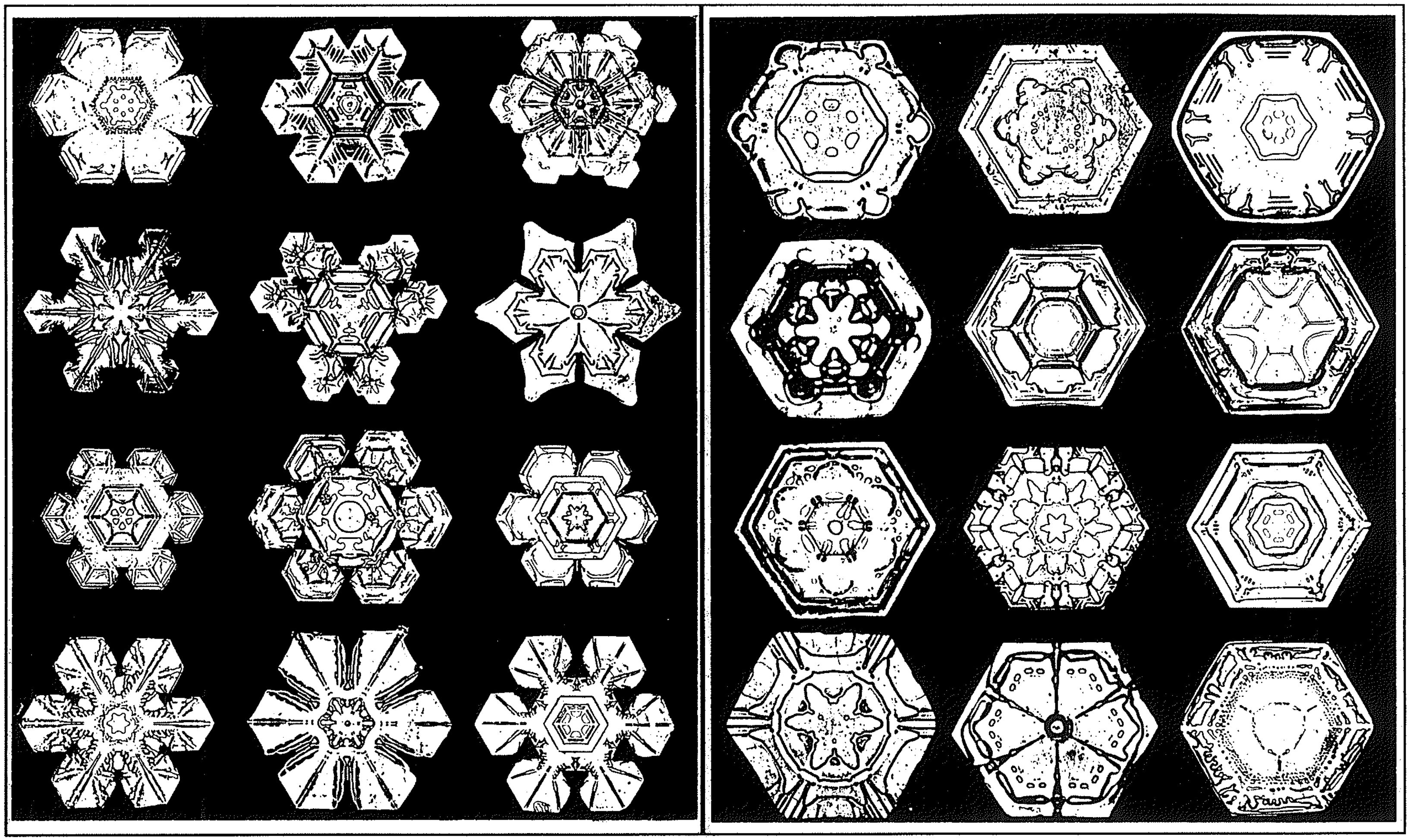
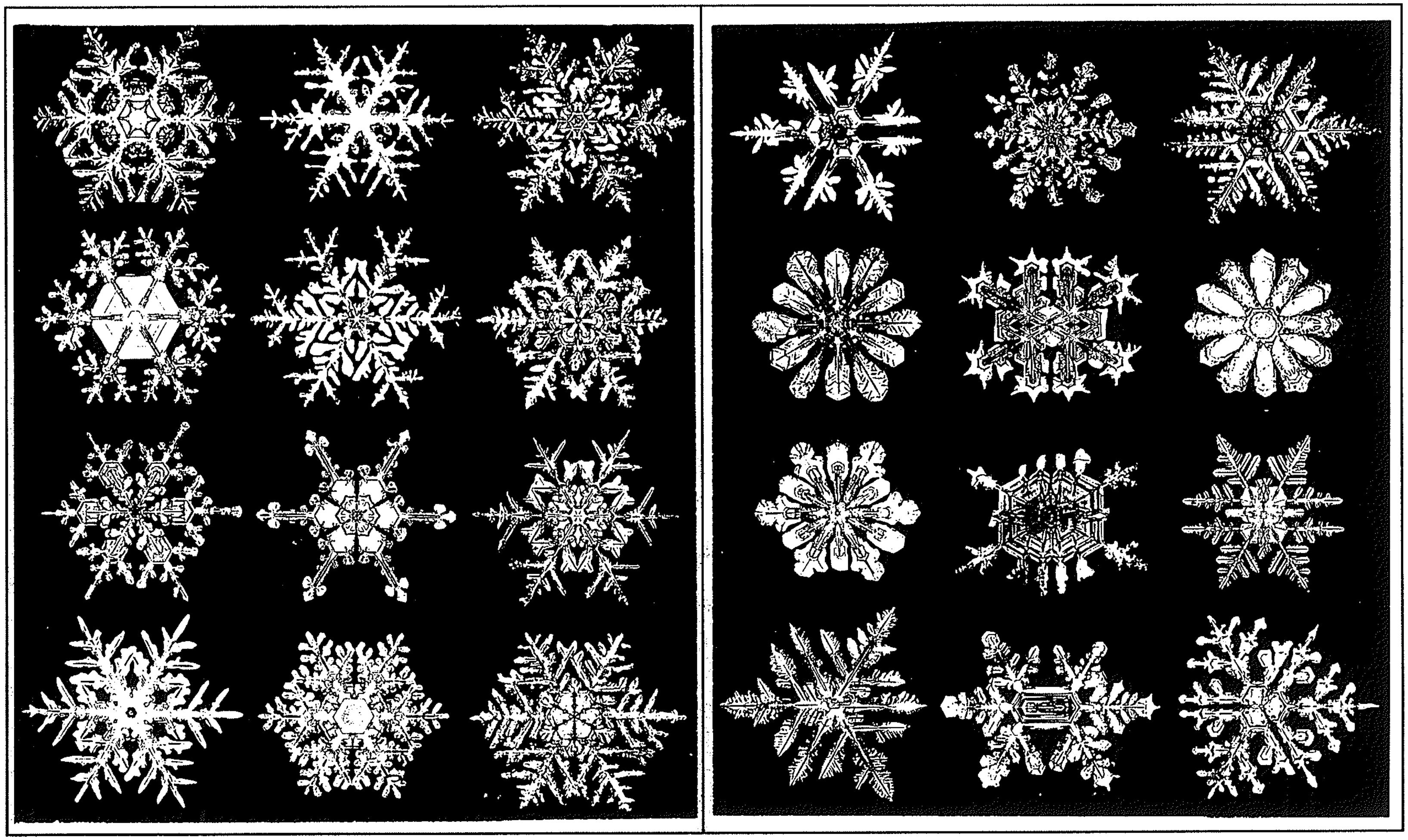


Figure 13 (con't)
Snowflakes: Variations on Triangles and Hexagons.
W.A. Bentley and W.J. Humphreys. Snow Crystals. New York: McGraw-Hill Book Co. Inc., 1931), pp. 145, 203, 45, 91, 184.



warmer temperatures, snowflakes fall; at colder temperatures snow crystals fall.[15]

The *size of a crystal* also depends on the temperature. Generally warmer temperatures produce larger crystals.[16]

The *rate of crystal growth and the amount of detail* depends on the humidity.[17] As the surrounding moisture increases, crystals grow faster and their forms become more exaggerated and embellished. Needles become longer, plates grow larger and thinner, and star-shaped crystals develop many layers of branching and sub-branching.[18]

INCEPTION AND DEVELOPMENT

The delicacy of a snowflake is the antithesis of its inception and development.

Snow crystals depend not only on the weather, but also on the presence of something to crystallize to - a piece of earth dust for instance, or perhaps even meteorite debris.[19]

At the base of the cloud, known as the water condensation level, water vapor condenses

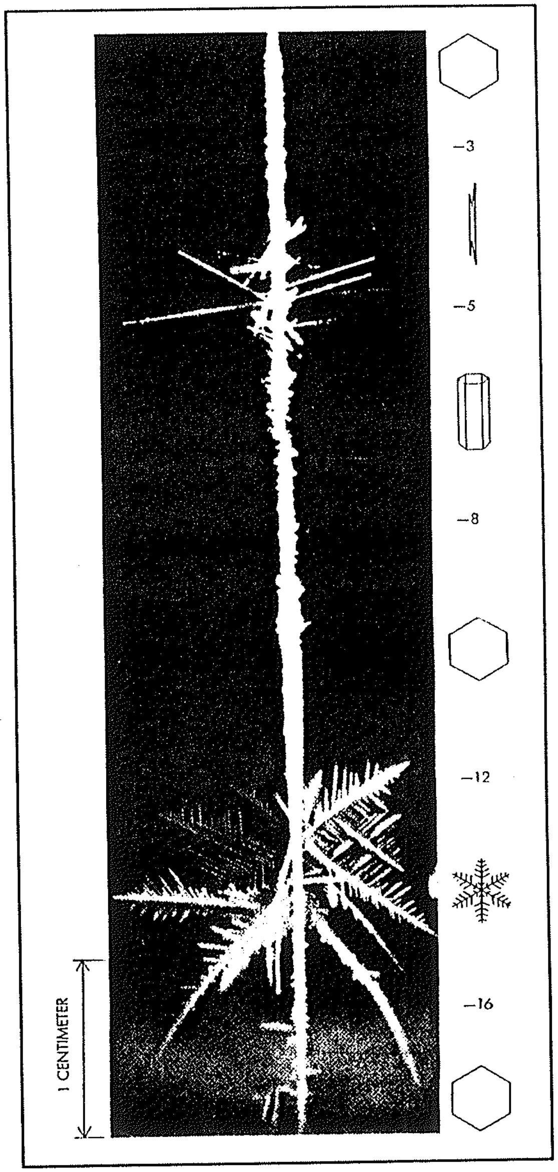


Figure 14
"Gamut of Ice Crystal Shapes grows on a filament suspended in a diffusion chamber with controlled temperaure gradient. Crystals take characteristic forms at various temperatures as indicated along the right edge of the photograph. Reading from the top, the symbols represent: the hexagonal plates, needles (which are defective prisms), hollow prismatic columns, hexagonal plates, branced star-shaped crystals (or dendrites), and hexagonal plates. At temperatures lower than 25 degrees below zero C. prisms appear again."
B.J. Mason. "The Growth of Snow Crystals," Scientific American Vol. 204 . No. 1, January 1961, p.128.

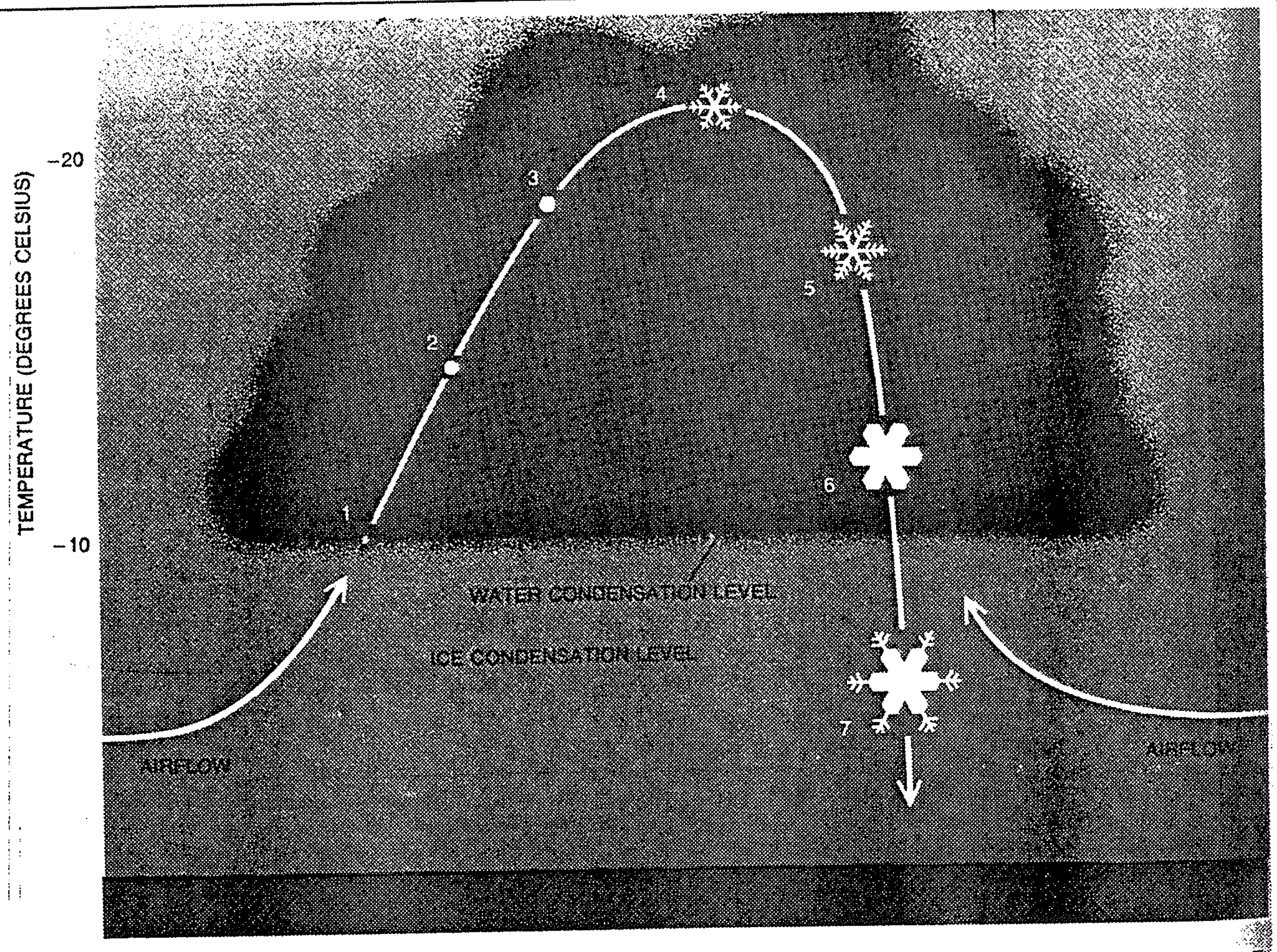
onto a piece of debris. This dust and water combination rise up through the cloud, stealing vapor from other water vapor droplets as it goes. It eventually freezes, thus establishing the primary snow crystal form. But even in a frozen state, it continues to steal from others and in doing so grows larger. The primary crystal grows larger and new crystals are added to the primary one. Eventually it reaches a point where it is so heavy that it begins to fall.[20] See figure 15.

As the crystal collection falls, it not only continues stealing vapor from water droplets as it passes by them, but sometimes gathers such speed that the water droplets are unable to move out of the way. The snowflake smashes into them, and absorbs them into the crystal collection (this process is called riming), and in doing so, accelerates both its growth and speed.[21] Snow crystals can undergo riming to such an extent that they become a big blob of ice; their original form totally obscured. Snow crystals in this state are called *graupel*.[22] See figure 16.

There is the chance of course, of the snowflake itself shattering during a collision. When this happens, the fragments set out on their own unique journeys of robbery and high speed chases.[23]

It seems that pure chaos governs crystal formation. To a certain extent this is true. Crystal development and destruction is completely dependent on the supply of neighboring water vapor and the fierceness of travelling crystals - which may change on a whim of the weather. In fact, crystal development "can follow almost any course".[24] However, growth is always very ordered. New crystals orient themselves in a way which is complementary to and harmonious with the configuration of the primary crystal.[25]

Figure 15
Charles and Nancy Knight. "Snow Crystals," <u>Scientific American</u> Vol. 228. No. 1, January 1973, p .102.



SNOW CRYSTAL GROWS within a cloud that has been formed by convection: warm, moist air rising through a layer of cold, dry air. A droplet of water condenses (*1*) at the base of the cloud at the water-condensation level. It grows (*2*) as it rises in an updraft and eventually freezes (*3*) into an ice crystal. Water-vapor molecules in the cloud attach themselves to the lattice of the crystal, creating the branches of the familiar snow dendrite (*4*). The crystal is now falling (*5*) and starts to rime (*6*), or collide with relatively large water droplets. It falls out of the cloud altogether and continues to grow from vapor (*7*) until it drops below the ice-condensation level on its way to the ground. The growth of the snow crystal can follow almost any course of events. Temperatures shown are arbitrary.

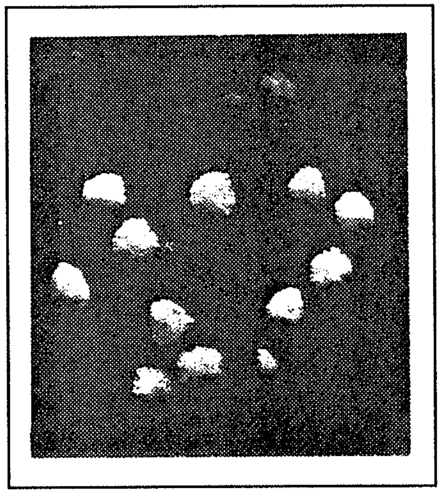


Figure 16
Graupel
W.A. Bentley and W.J. Humphreys. <u>Snow Crystals</u>. New York: McGraw-Hill Book Co. Inc., 1931, Figure 5, p. 223.

AGING

Snow is inherently unstable. Snowflakes continually change during their formation, and continue to do so after they reach the ground. In fact snowcover is in a state of perpetual change for as long as it remains as snow.[26,27,28]

When a snowflake falls to the ground it encounters different weather conditions from what was in the cloud.[29] As well, it is subject to new stresses such as gravity and wind pressures.[30]

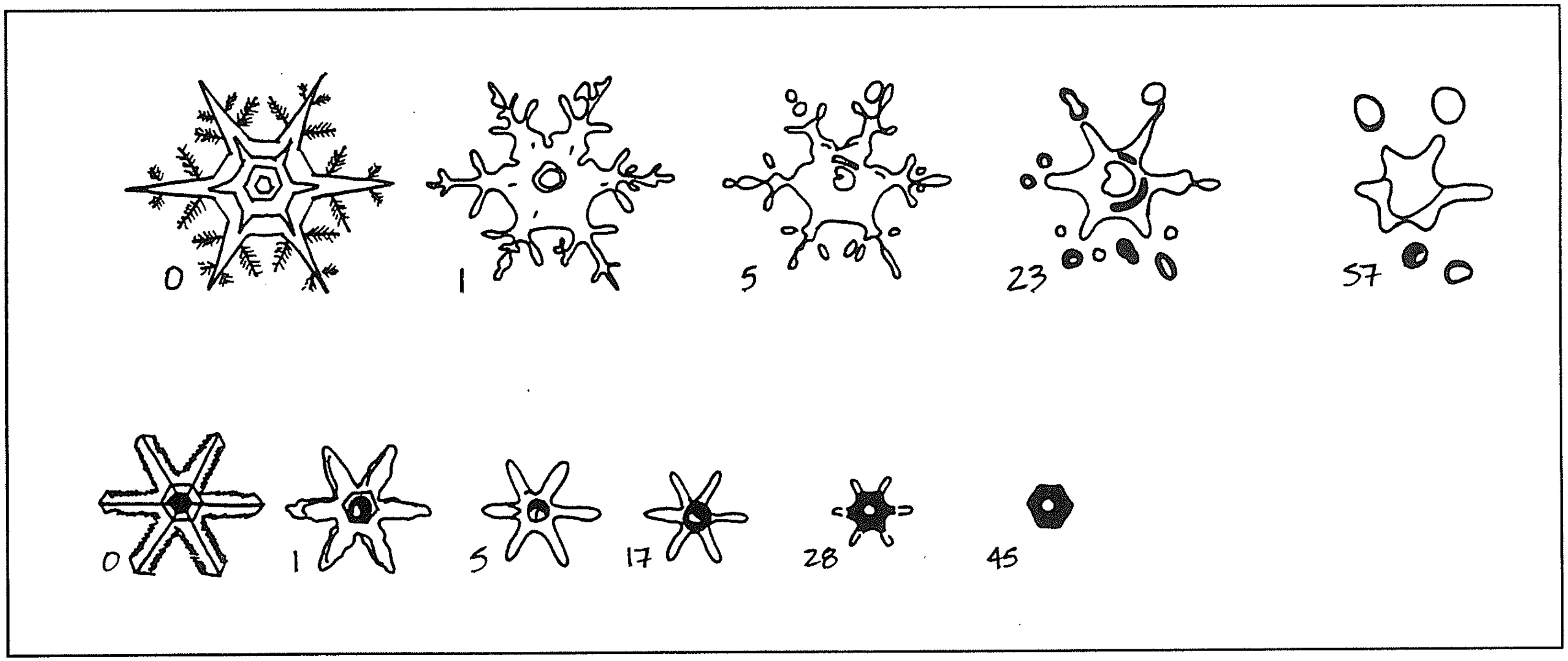
The tendency is for all crystals to reform themselves into symmetrical hexagonal prisms. How quickly this happens depends on the temperature.[31]

In stable temperatures the general snowflake form is conserved, but the fine detailing tends to erode away. See figure 17. Drastic alterations in form occur when the temperature changes. In warm temperatures, the crystals tend to assume simple forms with rounded edges. In colder temperatures, the crystals continue to evolve into simpler forms, yet develop sharp edges.[32]

Figure 17

"Metamorphorism of a snow crystal in a closed atmosphere. Temperature below -2.5o C. Numbers indicate age in days."

Henri Bader, "Mineralogical and Structural Characterization of Snow and of its Metamorphism," in Snow and its Metamorphism. U.S. Army, Corps of Engineers, Snow, Ice and Permafrost, Research Establishment, Translation 14, (January 1954), pp. 4,5.



REFERENCES:

[1]Doug Sadler, Winter: A Natural History, (Peterborough: Broadview Press, 1990), p. 15.

[2]Harold Hanen, "*A Tribute to the Snowflake*: Canada's Neglected Winter Flower," Livable Winter Newsletter, Vol. 5. No. 1, (February 1987): 11.

[3]B.J. Mason, "The Growth of Snow Crystals," Scientific American Vol. 204 . No. 1, (January 1961): 120.

[4]C. Magono and C. Lee, "Meteorological Classification of Natural Snow Crystals," Journal of Faculty of Science, Hokkaido University, Ser. VII, Vol. 2, p. 321; reprinted in D.M. Gray and D.H. Male (eds.), Handbook of Snow: Principles, Processes, Mangaement, and Use, (Toronto Ont.: Pergamon Press, 1981), pp. 140-141.

[5]Charles and Nancy Knight, "Snow Crystals," Scientific American Vol. 228. No. 1, (January 1973): 100.

[6]W.A. Bentley and W.J. Humphreys, Snow Crystals, (New York: McGraw-Hill Book Co. Inc., 1931), pp. 5-7.

[7]Hanen, p. 11.

[8]Knight and Knight, pp. 100, 101, 104-106.

[9]Mason, pp. 120-121, 129.

[10]G.D. Rikhter, Snow Cover, Its Formation and Properties, (Moscow: Publishing House of the Academy of Science, 1954), p. 3.

[11]Vincent J. Schaefer, "Treasures of the Snow," The Conservationist, (December-January 1960-1961), pp. 2-3.

[12]Rikhter, p. 4.

[13]Mason, p. 128.

[14]Rikhter, p. 3.

[15]Sadler, p.17.

[16]Rikhter, p. 4.

[17]Mason, p. 129.

[18]Knight and Knight, p. 103.

[19]Mason, p. 122.

[20]Knight and Knight, pp.100-105.

[21]Knight and Knight, p. 105.

[22]Knight and Knight, p. 105.

[23]Knight and Knight, p. 104.

[24]Knight and Knight, p. 100.

[25]Knight and Knight, p. 105.

[26]Henri Bader, "Mineralogical and Structural Characterization of Snow and of its Metamorphism," in Snow and its Metamorphism, U.S. Army, Corps of Engineers, Snow, Ice and Permafrost, Research Establishment, Translation 14, (January 1954), pp. 5-20.

[27]Henri Bader, The Physics and Mechanics of Snow as a Material, U.S. Army Cold Regions Research and Engineering Laboratory, Cold Regions Science and Engineering, Part 11: Physical Science, Section B (July 1962), pp. 1-18.

[28]Rikhter, pp. 1-39.

[29]Bader, Snow and its Metamorphism, p. 12.

[30]Rikhter, p 6.

[31]Henri Bader, Snow as a Material, p. 5.

[32]Bader, Snow as a Material, p. 5.

s s
n
s
o s n
s w s
snowcover s n
o
s n
n o
o
w
n n
o
o
n w o
o w
w
w w
w

Michael D. Welch.
Egret. California: Press Here, 1989

LAYERS AND LAYERS

Falling snowflakes collect in layers which are collectively called snow or snow cover.[1] See figure 18. Snow is a simple substance made up of crystals, water vapor, and air.[2] On the other hand, it is extremely complex.

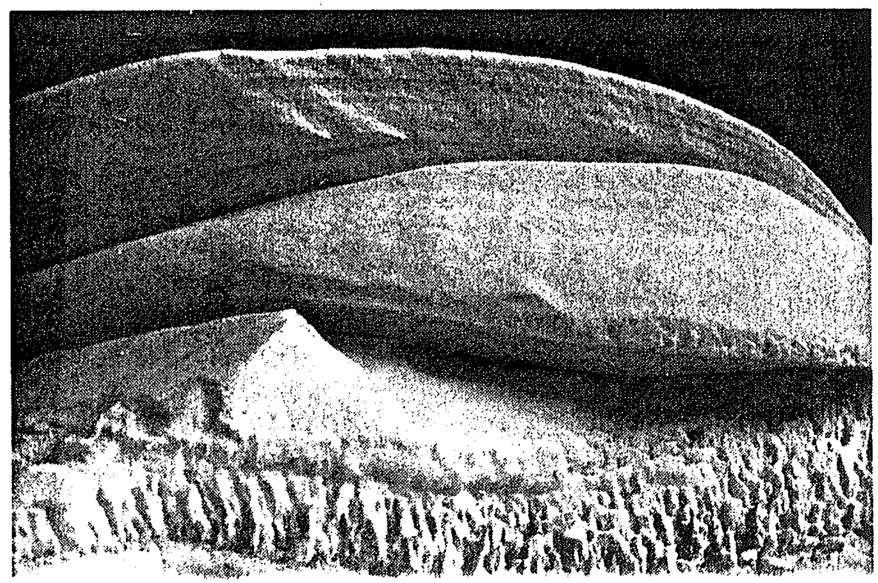
The texture, density, strength, color and many other characteristics of snow depend on the snowflake form.[3] Changes to snow occurs when new crystals develop (a result of bonding and recrystallization) and when old crystals are destroyed (a result of packing, and thawing).[4,5,6]

Figure 18
Layers and Layers
Starbuck, Manitoba
February 11/92
Sunset (5:00 - 6:00 p.m.)
-23° C. Wind S at 11km./hr.

CRYSTAL TRANSFORMATIONS

Bonding

Snow begins changing almost as soon as it reaches the ground. Initially snowflakes simply fall beside and on top of one another and form a very loose type of snow cover in which snow-flakes are not bonded together. Responding to changes in temperature and moisture, newly fallen snow almost immediately begins forming new bonds and new alliances with neighboring



crystals.[7,8]

The crystals of one snowflake bond to the crystals of neighboring snowflakes. In this way snowcover acquires strength.[9]

The rate of bonding is moisture dependent. In dry conditions bonding is slow; in moist conditions bonding is fast. Strong snowcover is made up of large snowflakes which have many bonds with neighboring snowflakes.[10]

Recrystallization

Temperature and moisture gradients within the snowcover results in "the growth of some crystals at the expense of others"[11] The result is fewer crystals. However they are very large and very granular. Snow which has undergone recrystallization is very dense (though not strong) and is loose, powdery, and has a very course texture. Recrystallization commonly occurs immediately above the soil surface.[12,13] See figure 19.

Figure 19
Granular Crystals Adjacent to Soil Surface

Packing

Snow that has fallen in the absence of wind tends to form a very loose layer. The snowflakes simply fall beside and on top of one another and form a very weak type of snow cover in which snowflakes are not bonded together. However, packing begins almost immediately. The texture and strength of snowcover then changes accordingly.[14]

Packing is the result of a force which causes the crystals to break. Forces which cause packing are gravity, moisture, and wind. Like all snow processes packing is dependent on the temperature. While packing occurs continually, it is much faster during warmer temperatures.[15]

Packing of dry snow occurs as a result of gravity alone. Weight from new layers of snow causes bonds within and between crystals in the lower layers to break. The broken crystals slide into the empty spaces between the crystals where they rebond. Thus the entire process creates a denser type of snowcover. See figure 20.

Depth of sampling, cm	Density (Jan. 27, 1902)	Depth of sampling, cm	Density (Jan. 27, 1902)
0-5	0.06	25-30	0.24
5-10	0.12	30-35	0.24
10-15	0.17	35-40	0.28
20-25	0.20		

Figure 20
Density of Snowcover at Various Depths
G.D. Rikhter. Snow Cover, Its Formation and Properties. Moscow: Publishing House of the Academy of Science, 1954, p. 6.

Packing of wet snow during thawing occurs as a result of gravity and moisture. Bonding accelerates when water is present. In warm temperatures, snow crystals reshape into plates, thus loosing branches, corners, and other protrusions and elaborations. The plates are able to lie much closer together, and because bonding occurs rapidly at warmer temperatures, large crystal composites are formed. The weight of these crystals causes more settling, resulting in a dense snow pack.[16]

Wind also causes packing of snow cover. The wind breaks off snowflakes and crystals from the surface, pushes and smashes them over the surface, which causes more crystals to break away, and then eventually drops the fragments.

These fragments tend to fall into and fill up the air spaces between the crystals in the snowcover. The fragments and the existing crystals from new bonds. The resulting layer, called a *wind slab*, is dense, strong, and fine grained.[17,18] The process is similar to packing of dry snow from gravity except that movement is horizontal rather than vertical, and is much more dramatic.

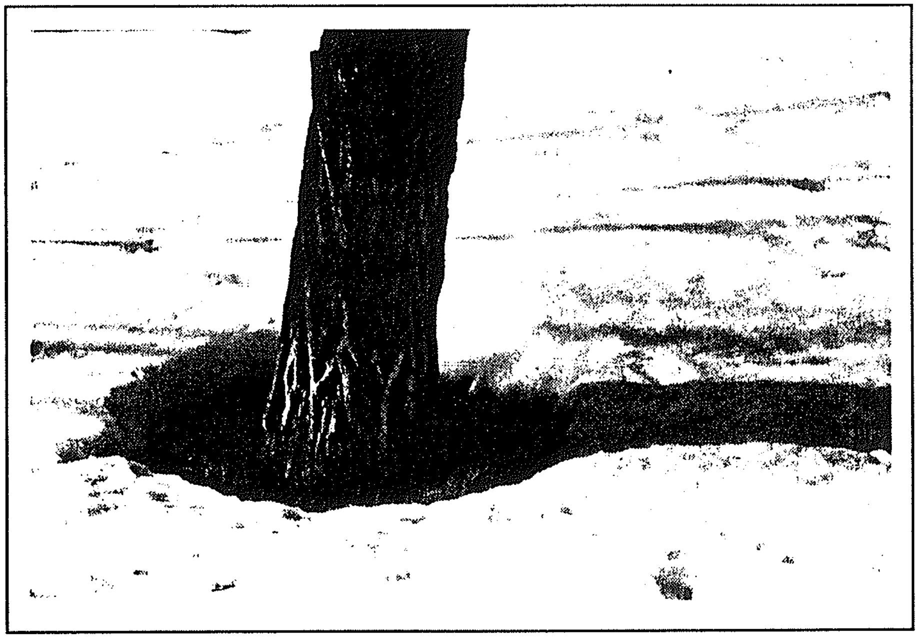
Thawing

Thawing is snow's response to heat. Sources of heat include the sun, air masses, rain, moisture, and soil.[19]

One common type of thawing which occurs to a certain extent all winter long is the result of the sun's heat. Dark objects such as tree trunks, grass, dirt absorb heat and melt the snow adjacent to it. Small hollows or craters appear around these objects. This is where the ground is first seen in the spring time.[20] See figure 21.

Emphasizing this could make for an interesting spring sculpture. For instance, dark colored objects could be arranged so as to cause the snow to melt away and expose bright patches of color in early spring (or during a midwinter thaw). It would be a symphony of color welcoming the spring.

Figure 21
Snow melt Around Dark Objects
Winnipeg, Manitoba
March 6/92, 3:00 p.m.
-2° C. Wind W at 6 km./hr.



Thawing can also occur when the air temperatures rise above freezing. Snow most susceptible to thawing from warm air is the clean unblemished white kind. It melts and sinks below the dirtier snow - the footprints, the debris, the darkened ruts - the initially lower parts. The result of this type of melting creates an interesting inversion as the higher undisturbed areas slowly melt and sink below the lower crushed areas.[21]

When the top layer of snow begins to melt and then freezes, or when wet snowfall or rain falls on existing snow and then freezes, a *snow crust* is formed.[22] Snow crusts tend to be very dense and very strong. Crusts have various textures and densities depending on the conditions that formed them.[23] See figure 22.

While they form at the surface of the snowcover, they may be subsequently covered over by new snow and eventually become one of the middle layers of the snow cover.[24]

Melting Snow
Delta, Manitoba
March 21/92, 3:00 p.m.
-2° C. Wind W at 6 km./hr.

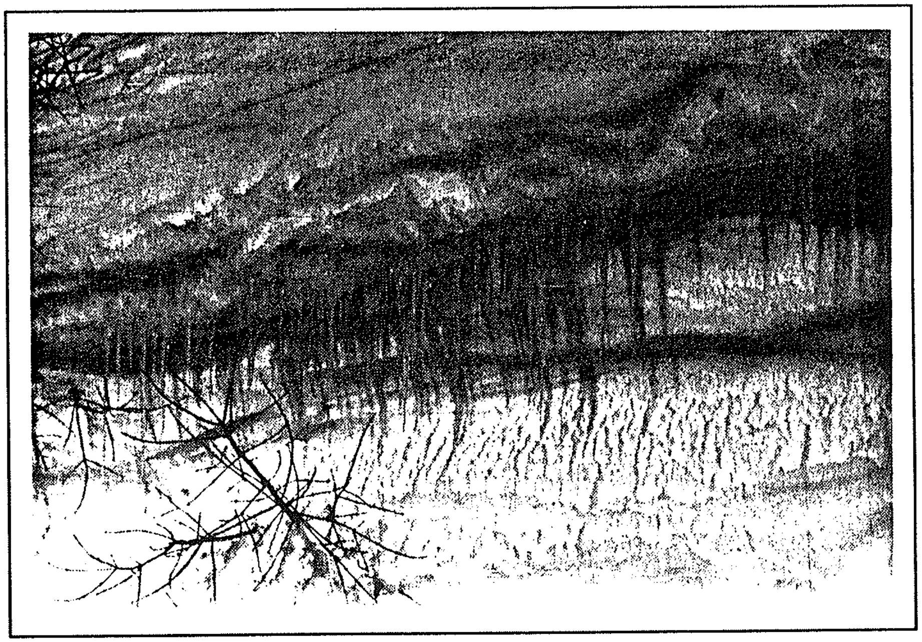


Figure 22
Snow Crust Characteristics
G.D. Rikhter. Snow Cover, Its Formation and Properties. Moscow: Publishing House of the Academy of Science, 1954, p. 11.

Type of Ice or Snow Crust	Description	Conditions of Formation	Passability
Sun crust	Thin, opaque, white and matted ice crust, binding the surface of the snow; a few millimeters in thickness, consisting of fused grains.	Forms on clear, frosty days, due to the fusing of the surface layers of snow by the sun's rays, most frequently in the early spring.	Easily broken through by skis, but constitutes no obstacle to passage. Slipperiness only slight.
Coat crust	Very thin layer of clear ice, lying on top of hard snow, but separated from it by an air space. Very brittle.	Forms in calm, clear weather with sharp diurnal fluctuations in temperature.	Splendid surface for skis. Makes the snow slippery beneath the skis and yet does not permit sideslip on turns.
Perforated crust	Sun crust, dotted with small perforations. Very brittle and breakable.	Results from the evaporation of snow under the rays of the sun.	Good skiing surface.
Grooved snow (flaky snow)	Surface of snow covered by ice flakes, separated by furrows. The flakes lie at an incline with their raised side facing the sun (southward).	Occurs in spring, as the snow thaws.	The direction of the flakes may serve to indicate one's direction. Good ski surface.
Rain crust	Thin, transparent, ice crust, often with flakes of ice on its surface.	Forms on snow surface as a result of precipitation of rain thereon.	Very slippery, and when thick enough, constitutes an obstacle to movement on skis. Dangerous for horse transport, as the ice crust wounds the hooves which break through into the loose snow beneath.
Temperature crust	Thick white crust of tiny ice crystals.	Results from freezing of snow which had thawed in warm spell. Possibly, the formation of this crust results from the sublimation of water vapor from the deep layers of the snow cover.	Will usually support a skier, but renders motion slow and difficult due to excessive slipperiness. Also dangerous for cavalry. Slows wheeled transport.
Wind crust	Thin layer of dense snow (up to 3.0 cm), only slightly slippery. Matted white.	Wind-packed snow.	Good for movement of ski troops. Poor for cavalry and wheeled transport.
Wind grooves	Looks like grooved snow, but the grooves follow the direction of the wind. Hollows may be seen on the windward side beneath the crust.	Results from blizzards breaking the surface of the crust.	Little slipperiness. Not an obstacle to movement on skis.
Wind board	Thicker layer of wind crust (over 3.0 cm), greatly varied in thickness and density in accordance with exposure to winds. Usually covers drifts and forms cornices over ledges.	Snow on windward slopes driven and packed by the wind during blizzards.	Very dense surface capable of sustaining infantry and sledges on ski-type runners.

TYPES OF SNOW

Obviously, all snow is not the same. Researchers have proposed various snow classification systems which describe different kinds of snow based on its mechanical and physical properties. However, no one scheme has been generally adopted.[25] See figure 23 for an example of one such classification system. The northern native peoples made it easy on themselves. Rather than trying to describe different types of snow, they simply gave different kinds of snow different names. See figure 24.

SNOW CHARACTERISTICS

Density

Density is a measure of how much water is contained in a specific volume of snow. More tightly packed snowflakes and crystals yield more water than loosely packed ones of the same volume. Snowcover which contains mostly tightly packed snowflakes and crystals is therefore more dense.[26]

Density is determined by the snowflakes present in the snowcover and by the weather and by gravity. Density is greater when temperatures are warm, when the snow has been subjected to wind, and when the snow is old.[27]

Once snow has fallen, it tends to become more and more dense due to ongoing factors such as aging, gravity, and wind. Density increases very quickly in warmer temperatures and during thaws, while relatively slowly at colder temperatures.[28]

Generally, the more dense that snow is, the stronger it is;[29] which means that you won't fall through it when you walk on it, and that it will stay plastered against a fence or building or other vertical element instead of sliding down.[30] An exception to this is at temperatures near 0°C; although density is very high, strength is very low.[31]

Figure 23

Classification of Snow

G.D. Rikhter. Snow Cover, Its Formation and Properties. Moscow: Publishing House of the Academy of Science, 1954, pp. 56-59.

Category	Type	Variety	Condition of Formation and description	Density	Physical and mechanical properties according to A. Goff and G. Otten			
					Test density	Adhesion within strata kg/m^2	Tensile strength kg/m^2	Coefficient of friction within stratum
Freshly fallen (new, young) snow, retaining in part or in whole the original crystalline form it had when it fell.	Fresh dry snow		Loose snow deposited by snowfalls in calm weather. Considerable variety, depending upon form of flakes and weather conditions during fall. Highly mobile, capable of being drifted about at wind velocities of 3.5 to 4 m/second. Not only men on foot but even skiers sink into it. Forms crumbly snowballs if one attempts to mold it. Hardly sticks to skis. No obstacle to transport if it is not thick.	0.01 - 0.2	0.1 - 0.13	0 - 50	0	
		Fluff (powder)	Falls during dead calms and at temperatures close to 0°C. Consists of star-shaped flakes with undamaged points and of clods. Very loose and sticky. Bright white in color. Often sparkles. Exceptionally sticky. A major factor in camouflage. The pedestrian, the skier, and all types of transport sink in easily and leave a deep track, readily visible.	0.03 - 0.06				
		Needle (wild)	A variety of fluff snow, but precipitated at very low temperatures (below −15°C) and consists of very fine needles. Exceptionally loose and mobile.	0.01 - 0.03				
		Powder (sand)	Falls only at low temperatures and consists of tiny, hard crystals in a variety of forms (flakes, prisms, needles). Exceedingly low degree of slipperiness. Skis will not move over it when the thermometer falls lower than −20°C, due to friction.					
		Mealy (flour)	Falls at temperatures close to 0°C, and consists of opaque white grains of snow or ice. Less mobile and crumbly.	0.05 - 0.07				

Figure 23 (cont'd)

Classification of Snow

G.D. Rikhter. Snow Cover, Its Formation and Properties. Moscow: Publishing House of the Academy of Science, 1954, p. 56-59.

		Hoar frost snow	Formed by precipitation of fog on cold, snowy surface. Consists of branched crystals, fused together, but loose. Very fragile, hardly slippery at all, and of little mobility.					
	Freshly fallen, wet snow		Forms at temperatures near 0°C, of large, moist clods of flakes that have stuck together. Slippery and very sticky, adhering to skis and runners.	0.1 - 0.3				
Packed (old) snow, which has partly lost its original structure, chiefly due to settling (without crystallization)			Packing of newly fallen snow results both from settling caused by its own weight and by rising temperature (without recrystallization), and from the effects of the wind. While the flakes have changed considerably in shape, they retain their original crystalline structure. When packed or old snow has developed out of wet snow, its structure is hardly definable, and it constitutes a uniform snowy mass. Old snow will sustain the weight of a skier and, when it reaches density 0.35, that of a man on foot. It provides favorable conditions for sleigh transport. Strong snowdrifting windstorms may pack it to such a density that a layer only 15 to 20 cm thick can stop a train.	0.2 - 0.6	0.15 - 0.32	75 - 175	0 - 275	0 - 45
	Settled dry snow		Snow packed by the force of gravity but retaining its original crystal structure. For the most part loose and crumbly. When dug, it pours off the shovel. Balls molded of it have very slight solidity. It is very slippery and therefore an excellent medium for ski and sleigh transport. It will not sustain a man on foot.	0.2 - 0.3				
	Settled wet snow		Snow which has become packed as a result of rising temperatures, warm damp winds, and rain. The delicate branches of the snowflakes melt and the snow is transformed into a uniform mass without structure. Capable of being molded into good snowballs and may form large snow	0.3 - 0.4				

Figure 23 (cont'd)

Classification of Snow

G.D. Rikhter. Snow Cover, Its Formation and Properties. Moscow: Publishing House of the Academy of Science, 1954, p. 56-59.

Category	Type	Variety	Condition of Formation and description	Density	Physical and mechanical properties according to A. Goff and G. Otten			
					Test density	Adhesion within strata kg/m²	Tensile strength kg/m²	Coefficient of friction within stratum
			rollers. When dug, the shovel picks it up in large chunks. Capable of use for building structures of snow without the addition of water. Very good for ski and sleigh transport. Will sustain the weight of a man on foot.					
	Storm (wind) snow		Composed of snow drifted by the wind and redeposited snow. Consists exclusively of tiny fragments of crystals. Density subject to wide variation in accordance with wind velocity. Sometimes forms only a surface layer, called "wind crust" or "wind slab." Grains very small; color pure white. Supports a pedestrian with ease, and sometimes a horse and sleigh, which will leave no track if it is dense enough. When dug, fractures into large sharp-cornered and sharp-edged chunks. Lends itself readily to cutting of bricks and large blocks, and is therefore the best building material for snow structures. Sometimes pick and crowbar must be used to break it up. At temperatures lower than —5°C, it will sustain unit loads of 0.5 - 3.0 kg/cm².	0.4 - 0.6				
Old snow (recrystallized, firn)			Snow which has entirely lost its original structure and the flakes of which have lost their crystalline shape. Under sublimation it recrystallizes into grains (firn), large or small in size.					
Old snow (recrystallized,	Young		Pure white, fine-grained, dense, and compact. Breaks into pieces at the	0.03 - 0.06	0.32-0.48	850-4,700	500 - 1,500	0.39 - 0.50

Figure 23 (cont'd)

Classification of Snow

G.D. Rikhter. Snow Cover, Its Formation and Properties. Moscow: Publishing House of the Academy of Science, 1954, p. 56-59.

firn). The snowflakes in the snow cover have entirely lost their original shapes. Consists of crystals of ice.			blow of a shovel. Consists of small grains (not over 1.0 mm in diameter) lacking definite shape. Readily permeable to air and water. Sun and warmth in springtime make it soft and loose at the surface. Very slippery. The very best for skiing.					
	Old (firn)		Blue-gray, sometimes brown-tinted snow, consisting of large semi-transparent grains of snow and ice larger than 1.0 mm in diameter. Formed through sublimation of young firn snow. Fairly dense, but crumbles into grains at the blow of a shovel. Readily permeable to water and air. Often spongy at the surface and crumbled into rounded grains below, it renders transport over its surface exceedingly difficult and may be compared, in this respect, to dry and free-flowing sand.	0.4 - 0.7	0.32-0.48	1,000-3,600	350 - 850	0.39 - 0.55
	Quicksand snow (depth hoar)		Usually forms in the lower strata of the snow cover or over interlayers of ice in the snow. Consists of large transparent crystals of ice, usually in the form of sharp-edged rectangular laminae up to 10 or 15 mm in length and 5.0 mm in width. Often, however, their shape is that of incompletely developed triangular laminae with corners forming 60° angles. Dull streaks are frequently seen on the surfaces of the crystals. The crystals lie loosely with large gaps between them and are remarkable for their negligible cohesion, high mobility, and ready flow. This snow creates great difficulties for all types of mechanized transport. Both the wheels of automobiles and the tracks of tractors skid in this granular snow. It is particularly dangerous in mountains and on steep slopes, as it forms a sliding surface for the layers of snow above it in slides and avalanches.	0.3-0.4				

Figure 24
"Specialized Snow Terms of Some Northern Peoples (from Pruitt,1960)"
W.O. Pruitt, "Some Ecological Aspects of Snow," Proceedings of the 1966 Helsinki Symposium on "Ecology of the Subarctic Regions," UNESCO Series "Ecology and Conservation," No. 1, (Paris, 1970), p. 92.

English	Kobuk Valley Eskimo (Alaska)	Dindye (Fort Yukon, Alaska)	Chipewyan (northern Saskatchewan)
Snow	anniu	ža	sil(ch)
Snow that collects on trees	qalí	dé-ža	de-chén-kay-síl(ch)
Snow on the ground	apí	non-kót-za	sil(ch)-de-trán
Depth hoar	pukak	žai-ya	yath(k)óna
Wind-beaten snow	upsik	seth(ch)	sil(ch)-t(ch)rán-al
Fluffy taiga Snow		theh-ní-zee	yath-they-yé-ree-lay
Smoky snow or drifting snow	siqóq	za-he-áh-tree	nil(ch)-see-ni-(k)oth
Smooth snow surface of very fine particles	salumá roaq		
Rough snow surface of large particles	natatgónaq		
Sun crust	siqoqtoaq	ža-es-(čh)a	na-hó-t(ch)ran
Drift	kimoaqruk	za-ké-an-é-hae	yath-neé-zus
Space formed between drift and obstruction causing it	aŋamaŋa		
Sharply etched wind-eroded snow surface *(zastrugi* or *skavler)*	kaioglaq		
Irregular surface caused by differential erosion of hard and soft layers	tumarinyiq		
Bowl-shaped depression in snow around base of	qámaniq	(zh)e-quín-zee	day-chen-yath-dó-dee
Snow deep enough to need snow-shoes		det-thlo(k)	yath-thay-t(r)án-ai(ch)há
Spot blown bare of snow		si(ch)	oh-béh
Area of deep snow that persists perhaps all summer		za-kay-tak-kok	yath-thay-(án)

Permeability

Depending on the snow type, snow can either be permeable to air or not. Loose, porous snow cover is permeable, whereas snow crusts are not. Air moves quickest within a layer, rather than between layers. And it moves fastest through small grained snow.[32]

Permeability is important for survival. Animals such as reindeer rely on the permeability of snow in order to smell reindeer moss through it.[33] As well, the survival of people who have been buried alive in an avalanche for several hours and sometimes several days[34] is partially due to having a supply of fresh air which is the result of permeability.

Thermal Conductivity

Snow cover is a very good heat insulator. Loose snow, with lots of air is even better. Thermal conductivity depends on the snow density and snow moisture. Loose snow (which has lots of air trapped in it) is the best insulator; dry snow is a better insulator than wet.[35]

Snow is in fact such an exceedingly good heat insulator that unfrozen soil that has been snowed on remains unfrozen even if air temperatures dip below freezing. The warm air adjacent to the soil remains trapped there by the snow, thus preventing the soil from freezing. Good thermal resistance means that there is a considerable lapse between changes in air temperature and the time it takes for the snow temperature to 'catch up'. In fact the soil freezes only when air temperatures remain below freezing for extended periods.[36]

Once snow cover is established, temperature gradients tend to occur within it. The temperature of the bottom layers, adjacent to the soil tends to be stable while the temperature in the top layers tends to fluctuate according to the above snow air temperatures. During the course of a day, the bottom layers fluctuate about 0.16°C while temperatures in the top 25 cm can fluctuate between 2°C and 30°C. However, 2°C shifts are the most common.[37]

The good thermal resistance of snow can be advantageous. For instance when snow covered soil does freeze, frost depth is minimal, whereas bare soil tends to freeze very deep.[38] Farmers are therefore able to work fields that were snow covered sooner than bare ones. Earthworks which are to proceed during the winter can be planned so as to take advantage of deep or shallow freezing of the soil.[39]

Eskimo, Inuit, and Northern Indians traditionally built temporary and seasonal dwellings which were designed to take advantage of the insulating qualities of snow. The snow structures took advantage not only of the insulation provided by the snow itself, but also of the heat trapped in the underlying soil. Snow provided an oasis from often extremely cold temperatures. Temperatures within an igloo can range from -12° to 15°C (10° to 59°F), while outside temperatures may be as low as -40°C (-40°F).[40,41] See figure 25.

Thus the snow provides shelter and protection from the cold and wind, provides a readily available heat source (warm soil), and then prevents heat from escaping from the pocket of air in the snow shelter.

Reflectivity

Snow cover is one of the most reflective naturally occurring materials. See figure 1. Reflectivity is related to the purity , the age, and the moisture levels of the snow. Snow with very little debris, such as that which occurs in the Arctic is exceptionally reflective. New snow, as well as dry snow tends to be relatively free of debris and is therefore more reflective than old snow. For comparison:

soil	10 - 30% of the sun's rays are reflected
dry grass	19%
green grass	26%
old snow	30 - 50%
sea ice	40 - 60%
new snow	70 -90%[42]

Snow's reflective quality is due to its snow crystals. Though snowflakes fall in no particular order, there is always a certain percentage of the crystals whose plane lie in the same orientation to the sun. These crystals reflect the sun in unison. As the crystals age, their edges become less sharp and less clear, and therefore less reflective.[43]

Figure 25
Normee Ekoomiak. Arctic Memories Toronto: N.C. Press Ltd., Plate 1.

ᐃᒡᓗ ᐃᓗᐊᓂ

ᓄᑕᕋᐅᓯᖕᖑᕐᓗᖓ ᐃᒡᓗᒥᓯᖕᒍᐊᓚᐅᕋᑦᑕ, ᐅᑭᐅᖑᑎᓕᓗᒍ ᐊᒻᒪᓗ ᐅᑭᐅᖑᙱᓕᖕᖑᑦ ᑐᐱᕐᒥᓚᐅᕋᑦᑕ. ᐃᒡᓗᓕᐅᕐᐸᒃᑐᑦ ᐃᒻᒍᐊᕐᑐᓕᐅᕐᓗᑎᒃ ᐊᐅᓯᒥᑦ. ᐅᑭᐅᖅᑕᖅᑐᒥ ᓯᕿᓐᓂᖅ ᐅᑭᐅᒃᑯᑦ. ᐃᓐᓇᕐᓇᕐᓗᓂ ᐊᒻᒪᓗ ᑖᕐᓗᓂ. ᓯᕿᓂᖅ ᑕᓕᕐᑎᑕᕐᑦ ᑭᓯᐊᓂ ᐅᐱᕐᖑᖕᒍᓴᖕᖑᑦ, ᕼᐅᒪᓯᓯᐊᓕᕐᓗᓂ ᐅᓐᓄᒃᑯᓗᐃᓐᓇᖅ ᐅᑭᐅᖑᔪᖕᖑᑦ ᐊᓂᒐᔪᒃᐸᕐᓂᓗᑕ ᑭᓯᐊᓂ ᐱᓂᓚᕐᑐᒍᑦ ᕿᑎᒃᐸᓗᑕ ᐃᒡᓗ ᐃᓗᐊᓂ. ᐅᕙ ᐊᑖᑕ ᓴᓇᖕᒋᐊᕐᑐᖅ ᐅᔭᕋᕐᒥᒃ ᓴᓇᖕᒍᐊᕐᐱᖕᒥ ᓂᐅᕕᕐᑕᐅᕆᐊᕐᓴᓂᖕᖑ. ᐅᕙ ᐊᓈᓇ ᒥᕐᓱᕐᑐᖅ ᓇᕐᓯᐅᑉ ᐊᒥᖕᖑᓂᒃ ᑐᐱᓕᐅᕐᒪᕐᓗᓂ. ᐅᖅᑰᓯᕐᓂᕐᓂ ᑕᐃᒃᑲᖕ ᑕᕐᓇ ᑐᐱᖅ. ᐃᒡᓗ ᐃᓗᐊᓂ ᕿᓪᓕᖅ ᓂᐅᒃᑯᖅᑐᖅ ᐱᖕᖑᓂᖅ. ᑖᓇᓂ ᑕᐃᒃᑯᐊ ᕿᓪᓕᖅ ᐊᒻᒪᓗ ᐅᖅᐱᒃᑖᒃᐸᓗᑕ ᓇᕐᓯᒥᑦ. ᓯᓂᒃᓯᓐᓇᑕ. ᕿᓪᓕᖅ ᖃᒥᑦᑕᐅᒃᑲᓗᓂ ᐃᒡᓗ ᐅᖁᐃᓕᐊᓕᕐᐸᒃᑐᖅ, ᕿᐱᖕᒋᑕᓗᑦ ᑐᒃᑐᑦ ᐊᒥᖕᖑᓂᑦ ᑕᒃᐱᐊ ᐅᓂᒡᒍᐃᑦ ᓄᑕᕋᑦ ᐅᖁᓂᖕᑳᕐᒥᑦ ᐃᓂᖃᕐᑦ ᓯᖃᐃᕐᓚ ᐊᖓᔪᖃᕐᒥᖕᓂᑦ ᐊᑯᓐᓂᖕᖑᓂᓯᖕᖑᒪᑕ.

In the Iglu

"Iglu" means house. When I was small, we used to live in a snow house in the winter and in a tent the rest of the year. During the long winter up North, there is little sun and it is always dark. We stay inside and do our work and play. Here the father is carving a soapstone sculpture for sale at the co-op. The mother is sewing together seal skins to cover a tent. When it starts to get warm, the snow house will melt. We will build a tent to live in, and we will move with it from place to place when we hunt for food. Inside the iglu there is an oil lamp on three legs. It is for light and for heat. But when we go to sleep, we put out the lamp, and then it gets cold, so we must all sleep together to keep warm. The kids sleep in the middle, between their parents.

An interesting result of the reflection from the snow is that both days and nights tend to be brighter.[44] See figure 26. One wonders just how much shorter December 21 would seem without snow?

Too much light can be a bad thing though. The reflected sun light can bounce off the snow and up into the eye, causing a temporary, though painful condition called "snow blindness". This happens most often to people who are outside looking out over broad expanses of highly reflective snow. Snow blindness can be avoided by

Figure 26
"Night Snow at Kambara"
by Hiroshige
Richard Lane. . Images from the Floating World: The Japanese Print. New York: G.P. Putman's Son's, 1978, p. 177.

using sunglasses.[45]

Color

Snow is white of course - obviously. Pick it up in your mitt and look closely. It is white. Unless of course it's yellow, in which case... It's also yellowy grey when it's old, and undergone many thaws and collected lots of dust.[46] But other than that, snow is white. Except when it's blue, or violet, or gold, or orange, or green, or red...[47,48] See figure 27.

In fact, snow can be any color. Like a chameleon, snow can temporarily take on the color of its surroundings. Snow does this by reflecting nearby colors, and does so at many scales.[49]

The sun dusts great expanses of snow with pink, mauve and peach each morning and evening as it rises and sets. See figures 1, 28, 29. During a bright sunny day, the snow can be as blue as the sky. See figure 161. And indeed it should be, since it is the sky that is being reflected in the snow.

On a much smaller scale, the color of any object can be reflected in the snow adjacent to it. See figures 30, 31.

Coloring snow by arranging brightly colored elements is an interesting design opportunity. Color could be used to subtly enhance or reinforce a particular mood. Color could also be used to animate a place. Reflecting warm colors might be particularly welcome in February, when the sun tends to be quite bright and the winter quite long.

Translucence

Sunlight can easily penetrate snow cover. Studies have shown that twenty percent of the light striking the surface of snow will penetrate to a depth of 10 cm.[50,51] See figure 32.

This quality has enormous potential for outdoor winter art. What wonderful statements and effects are possible by combining snow sculpture and light? By combining snow, ice and light?

Figure 27
"Skiing Behind the Hayrack"
William Kereluk. A Prairie Boy's Winter. Montreal: Tundra Books of Montreal, 1973, plate 9.

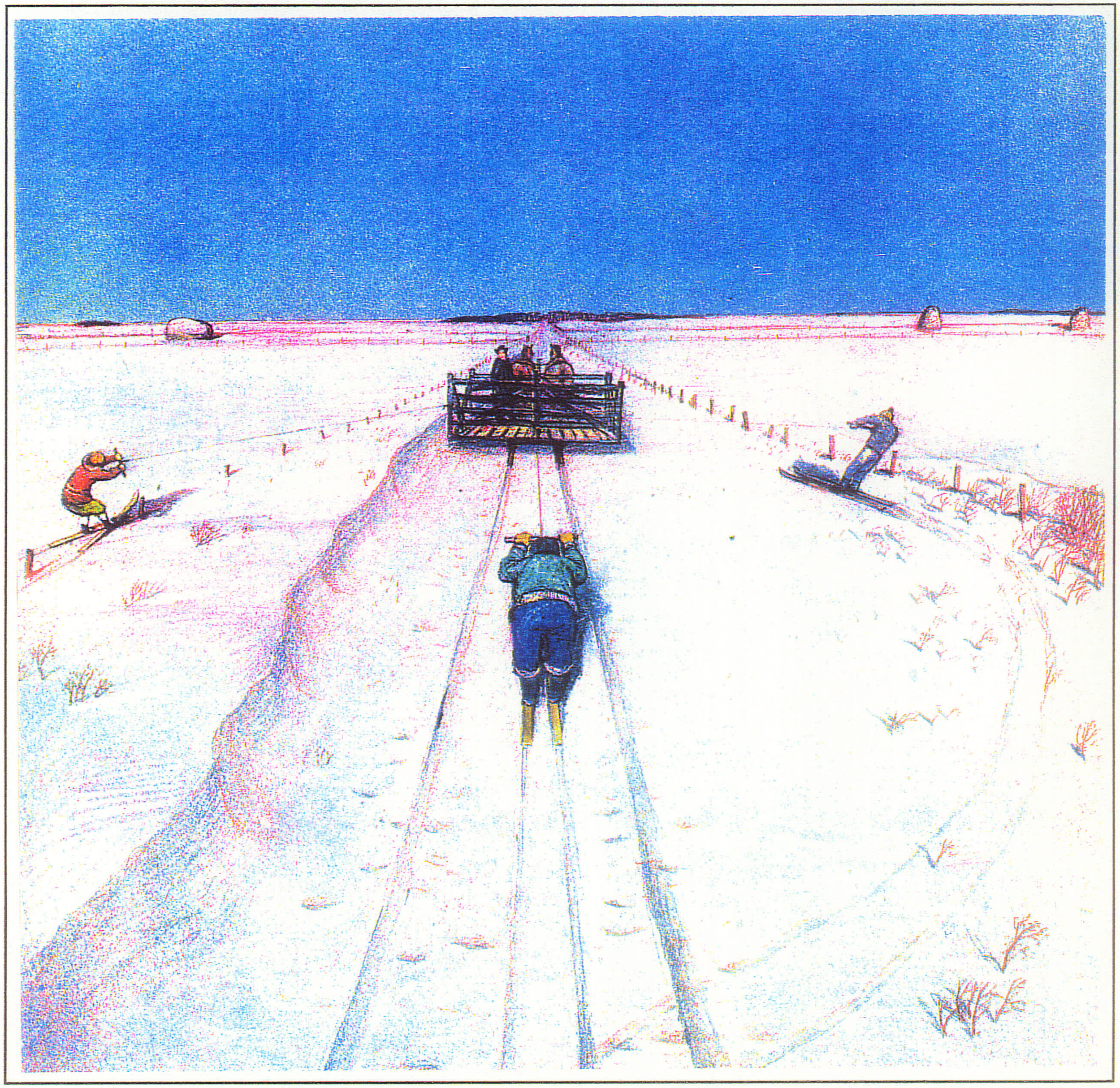


Figure 28
Sunrise at Starbuck
Starbuck, Manitoba
February 11/92
-29° C. Wind W at 4 km./hr.

Figure 29
Sunset at Ile-des-Chenes
Ile-des-Chenes, Manitoba
January 19/92, 3:00 p.m.
-17° C. Wind N at 13 km./hr.

Figure 30
Red Colored Snow
Ile-des-Chenes, Manitoba
January 19/92, 3:00 p.m.
-17° C. Wind N at 13 km./hr.

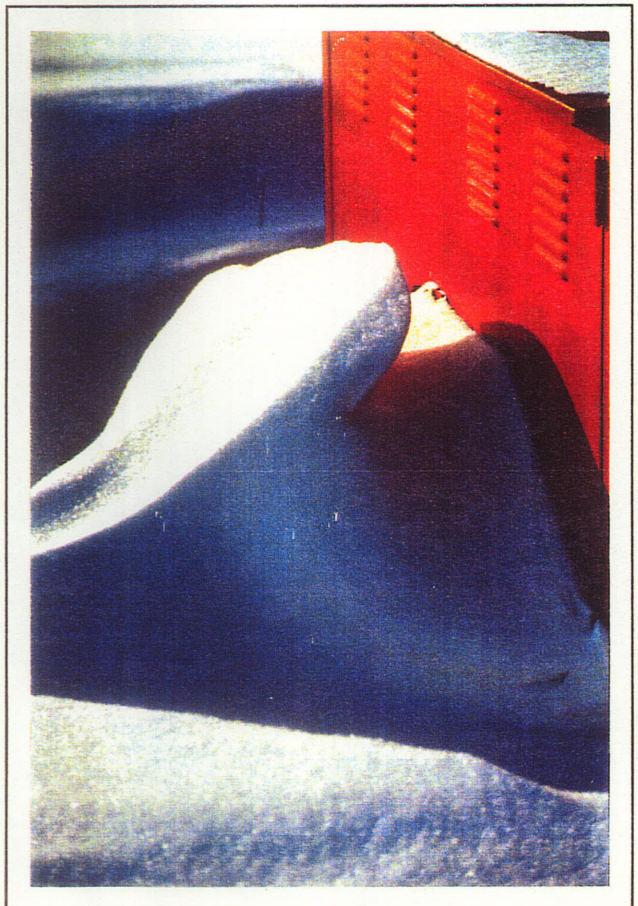
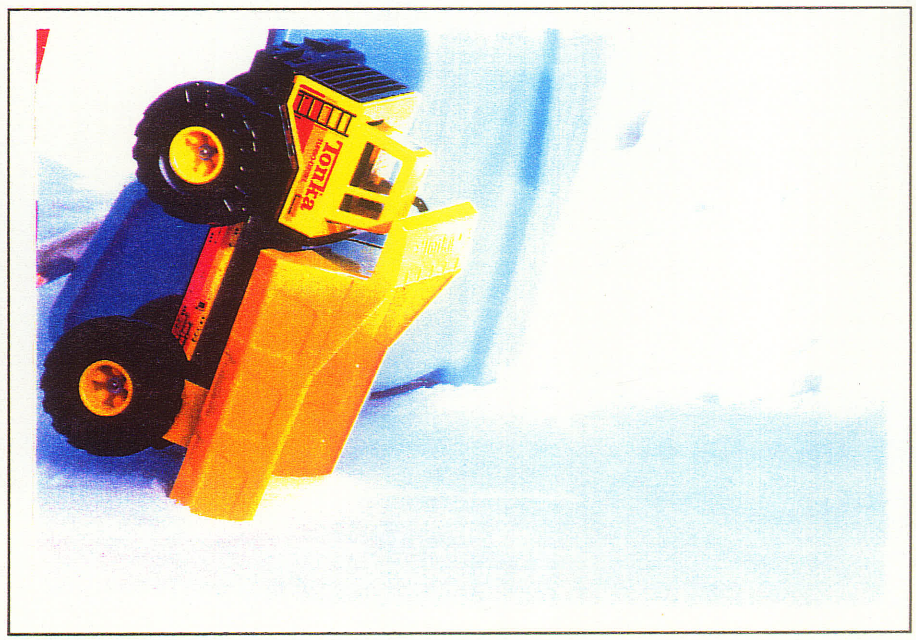


Figure 31
Colored Snow from Brightly Colored Object
Winnipeg, Manitoba
February 29/92, 3:00 p.m.
4.5° C. Wind W at 17 km./hr.



Snow-Cover, Thickness in cm	% of radiant energy which passed through it, relative to total reaching surface
0	100
8	90
10	20
15	5.5
20	3.2
30	1.7
40	1.2
45	1.0
60	0.7

Figure 32
"Translucence of Snow"
G.D. Rikhter. Snow Cover, Its Formation and Properties. Moscow: Publishing House of the Academy of Science, 1954, p. 26.

Plasticity

Does any other material or element surpass the plasticity of snow? It melts, it freezes. It re-melts, it re-freezes. It can be molded into a multitude of forms from simple snow balls to humans to boats to...

It can be painted, chopped, melted, iced. Things can be embedded into it or onto it. Hollows can be burrowed into it; towers erected from it. An amiable material, snow responds well to tools such as a gloved hand, a shovel, a pick, a bucket of water, a paint brush...

Plasticity
Winnipeg, Manitoba
February 7/92, 3:00 p.m.
-13° C. Wind NW at 17 km./hr.

Snow Sounds

> "Winter has its own brand of sounds too. The whiteness seems to intensify talking, laughing, shouting. They are different sounds than in the summer. Sometimes they are carried on top of the howling wind, sometimes in the footsteps in the snow at night. Sometimes they are so clear and crisp, they are like slivers of diamond ice being propelled through the air and lost somewhere in the sky."[52]

Most of us have heard the snow protesting as we dig our heels into it. And most of us have also noticed that as it gets colder and colder out, the protests become more and more high pitched. Those protests are in fact the sounds of breaking ice crystals.[53]

In warmer temperatures, the crystals have lots of air spaces between them, are less fragile, and upon breaking, are slow to recrystallize. Sounds, therefore, tend to be soft and muffled. At colder temperatures the crystals are closer together, very fragile, and tend to recrystallize very quickly. There are therefore more crystals to break and they break very easily. In this condition, sounds tend to be squeaky, crunchy and sharp.[54] In clear weather, the squeaky sounds produced by sledge runners can be heard for miles around.[55]

As snow ages, it doesn't always do so quietly. Large snow crusts settling can cause noises that sound like distant explosions. As well, large snow chunks falling from trees produce a distinctive bang on impact.[56]

> "O, how the wood was silent!
> Save when the boughs let fall
> Their snow upon the speckled drift;
> No other noise at all."[57]

Weathering

In the Arctic, the bases of cliffs are polished to a smooth gloss. The polisher is in fact blowing snow. As a result of either ice crystals, which become very hard at temperatures below 15°C, or the wind born sand that travels with blowing snow, polishing occurs.[58]

This could have some very interesting applications for outdoor artists and landscape architects. In a receptive medium, a snow polished surface could become a visual record of storms - an evolving sculpture.

Electricity

Electrical conductivity of snowcover changes with moisture levels. Dry snow is a poor electrical conductor; wet snow is a good conductor.[59]

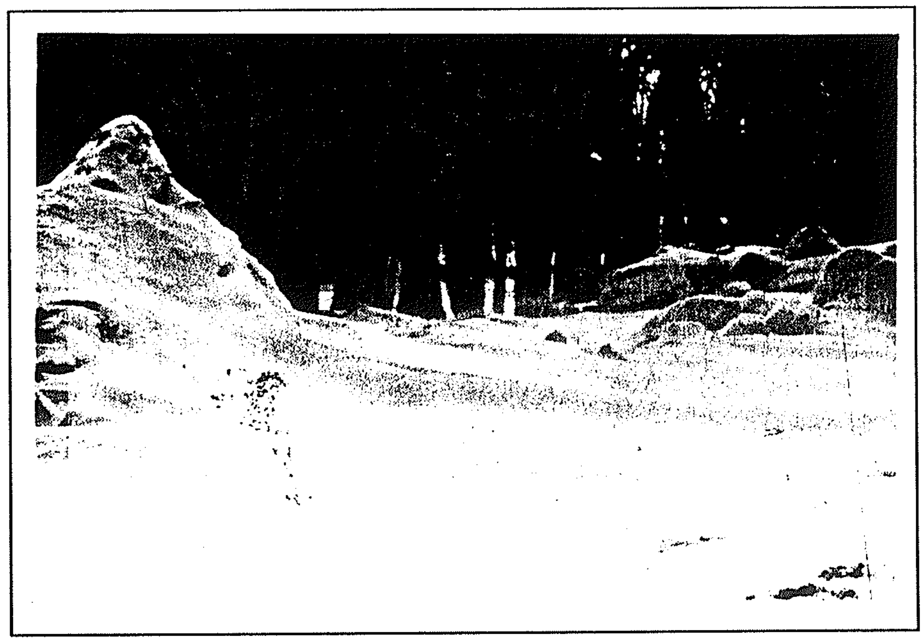
An interesting electrical phenomenon associated with snowstorms occurs in mountainous areas. In an attempt to release high levels of electrical charging that develop at mountain tops, miniature lightning storms occur. Lightning takes the form of electrical streams called St. Elmo's Fire. Snowflakes which fall during these storms are mostly graupel.[60]

REFERENCES:

[1]Rikhter, p. 1.
[2]Bader, The Physics and Mechanics of Snow as a Material, p. 1.
[3]Rikhter, p. 4.
[4]Bader, The Physics and Mechanics of Snow as a Material, pp. 6-9.
[5]Rikhter, pp. 1-20.
[6]Pruitt, "Some Ecological Aspects of Snow," 85-86.
[7]Bader, Snow and Its Metamorphism, p. 12.
[8]Rikhter, p. 4.
[9]Bader, p. 6.
[10]Bader, p. 6.
[11]Rikhter, p. 9.
[12]Rikhter, p. 9.
[13]W.O. Pruitt, "Some Ecological Aspects of Snow," p. 85.
[14]Rikhter, p. 6.
[15]Rikhter, p. 6.
[16]Rikhter, p. 6.
[17]Rikhter, p. 6.
[18]Bader, Snow and Its Metamorphism, p. 17.
[19]Rikhter, p. 33.
[20]Rikhter, p. 34.
[21]Rikhter, p. 34.
[22]Rikhter, p. 10.
[23]Rikhter, p. 11.
[24]Rikhter, p. 10.
[25]Bader, Snow and Its Metamorphism, p.17.
[26]Rikhter, p. 7.
[27]Rikhter, pp.7-8.
[28]Rikhter, p. 8.
[29]Rikhter, p. 10.
[30]Rikhter, pp. 9-10.
[31]Rikhter, p. 10.
[32]Rikhter, p. 27.
[33]Rikhter, p. 27.

[34]Bader, Snow and Its Metamorphism, p. xiii.
[35]Rikhter, p. 21.
[36]Rikhter, p. 22.
[37]Rikhter, p. 22.
[38]Rikhter, p. 22.
[39]Rikhter, p. 22.
[40]Robert W.Elsner and William O. Pruitt, Jr., "Some Structural and Thermal Characteristics of Snow Shelters," reprinted from "Arctic," Journal of the Arctic Institute of North America, Vol. 12, No. 1, pp. 20-21.
[41]Guidoni, pp. 28, 191.
[42]Rikhter, p. 23.
[43]Rikhter, p. 24.
[44]Rikhter, p. 24.
[45]Rikhter, p. 24.
[46]Rikhter, p. 25.
[47]Sadler, p. 21.
[48]William Kereluk, A Prairie Boy's Winter, (Montreal: Tundra Books of Montreal, 1973), plate 9.
[49]Sadler, p. 21.
[50]Rikhter, p. 26.
[51]Rikhter, p. 26.
[52]Alexandra Borowiecka, Winter and Playgrounds (Winnipeg: Unpublished Thesis, University of Manitoba, Faculty of Architecture, Master of Landscape Architecture, 1980), p.3.
[53]V.A. Arabadzhi and K.I. Rudik, The Squeak of Snow. Trans. E.R. Hope. Directorate of Scientific Information Services DRB Canada (January 1966), p. 1.
[54]Arabadzhi and Rudik, pp. 1-2.
[55]Rikhter, p. 31.
[56]Rikhter, p. 31.
[57]Francis Joseph Sherman, "In Exile", source unknown.
[58]Rikhter, p. 33.
[59]Rikhter, p. 31.
[60]Schaefer p. 3.

blowing snow



Blowing Snow
Winnipeg, Manitoba
March 15/92, 3:00 p.m.
-2° C. Wind S at 37 km./hr.

THRESHOLD VELOCITY

Drifting snow acts in a way which is very similar to drifting sand[1] Snow crystals however, unlike sand grains can weather, erode, and break,[2] which adds a further, very interesting dimension to the snow drifting process.

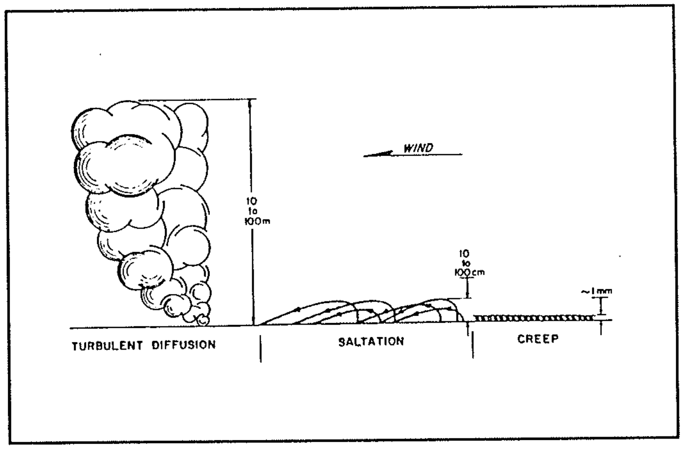
Drifting snow comes from two sources: falling snow and existing already fallen snow. Both falling snow as well as snow that has just recently fallen are much more susceptible to drifting than older, packed or settled snow. While wind packed snow tends to have a very dense strong surface which is able to withstand considerable force, nothing is exempt from the effects of the wind for long. Very high winds will break up even densely packed snow and cause drifting.[3,4,5]

Drifting occurs when certain minimum wind speeds are present. Wind speeds of between 3 and 10 m/sec (10 and 35 km/hr) are all that is necessary for loose freshly fallen snow to begin drifting.[6,7,8] Wet snow and old wind packed snow, the least susceptible, and can require wind speeds of up to and even greater than 30 m/sec (108 km/hr) for drifting to occur.[9,10]

There is a definite relationship between wind speed and the amount of snow that is blown. The faster the wind, the more snow it carries and blows.[11]

Snow crystals and crystal particles are driven by the wind in three different ways: *suspension, saltation* and *surface creep*. See figure 33. The specific mode of transport that a particle takes depends on its density.[12]

Figure 33
"The three modes of transport for blown snow"
Malcolm Mellor. "Blowing Snow," Cold Regions Science and Engineering Part III, Section A3c. Hanover, New Hampshire: Cold Regions Research & Engineering Laboratory, November 1965, p. 5.



Small, light particles become suspended in the air stream and flow with the wind above the ground. This mode of transport is called *suspension*.[13,14,15] In severe polar storms, the suspension layer can extend up to and beyond 100 m[16] and is the primary cause of drift formation around tall structures.

Larger, heavier particles also get picked up by the wind and then, being too heavy to be suspended, get dropped. These particles hop across the snow surface, crashing into and loosening other particles along the way. This mode of transport is called *saltation* and is the 10cm to 20cm thick layer that whirls around one's boots on windy days. Saltation is the most common form of drifting and is the largest contributor to drift formation.[17,18,19,20]

Very large heavy particles can be pushed around, but not actually picked up by the wind. These particles are pushed directly across the snow surface and serve to further chip away at the snow crystals along the way. This mode of transport is called *surface creep*[21,22,23] and is important in the formation of *sastrugi* and *snow ripples*.[24] See figures 93, 95.

SNOWSTORMS

Snowfall accompanied by a wind can produce a snowstorm. There are two types of snowstorms: *low snowstorms* and *high snowstorms*.[25,26]

In *low snowstorms*, the source of the blowing snow is previously fallen snow. Drifting occurs adjacent to the ground and is only a few cm thick.[27,28]

In *high snowstorms*, the source of the blowing snow is both falling snow, as well as existing previously fallen snow.[29,30] High snowstorms accompanied high wind speeds (20 - 40 m/sec., 70 - 145 km/hr,)[31] are called blizzards. Travelling in a high snowstorm can be extremely difficult. See figure 34. Being engulfed in blowing snow is extremely disorienting. People often lose their sense of direction as well as their ability to think clearly. In some cases people have had hallucinations and severe perceptual difficulties. One skier for instance, had the feeling that he was going uphill backwards.[32]

Figure 34

"Nov. 8 — STUCK —Winnipeg motorists struggle to get their vehicles out of knee-high snow drifts Saturday as southern Manitoba is hit by one of the worst blizzrds in 20 years."
Winnipeg Free Press, November 8, 1986.

B.C.
Winnipeg Free Press, February 22, 1992.

SUBLIMATION

Snow, as well as ice, can evaporate without actually melting.[33] In this process, called *sublimation*, water goes from a frozen state, entirely bypasses the liquid state, and becomes a gas. Ice disappearing from the car windshield is an example of sublimation.

During drifting, a considerable number of snow particles disappear as a result of sublimation. However new particles are constantly added to the amount of blowing snow (for as long as the wind blows). The resulting snowdrift patterns and sizes are not visually affected by sublimation unless the upwind supply of snow becomes exhausted.[34]

REFERENCES:

[1]Rikhter, p. 14.

[2]R.J.Kind, "Snow Drifting," Handbook of Snow : Principles, Processes, Managements, and Use. Eds. D.M. Gray and D.H. Male. (Toronto: Pergamon Press, 1981), p. 338.

[3]Ronald D. Tabler, J. W. Pomeroy, and B. W. Santana, "Drifting Snow," Cold Regions Hydrology and Hydraulics, (New York: American Society of Civil Engineers, 1990), p. 109.

[4]Rikhter, p. 12.

[5]Malcolm Mellor, "Blowing Snow," Cold Regions Science and Engineering Part III, Section A3c, (Hanover, New Hampshire: Cold Regions Research & Engineering Laboratory, November 1965), p. 24.

[6]Mellor, p. 1.

[7]Rikhter, p. 12.

[8]Tabler et. al., "Drifting Snow," p. 99.

[9]Mellor, p. 1.

[10]Kind, pp. 343, 345.

[11]R.W. Verge and G.P. Williams, "Drift Control," Handbook of Snow, p. 631.

[12]Mellor, p. 5.

[13]H. Pugh and W. Price, "Snow Drifting and the Use of Snow Fences," The Polar Record, Vol. 7. No. 47, (January 1954), pp. 5-6.

[14]Verge and Williams, p. 631.

[15]Kind, p. 338.

[16]Mellor, p. 6.

[17]Pugh and Price, pp. 5-6.

[18]Verge and Williams, p. 631.

[19]Kind, pp. 338, 347.

[20]Mellor, p. 6.

[21]Pugh and Price, pp. 5-6.

[22]Verge and Williams, p. 631.

[23]Kind, p. 338.

[24]Mellor, p. 5.

[25]Rikhter, pp. 12-13.

[26]M. de Guervain, p. 85.
[27]Rikhter, pp. 12-13.
[28]M. de Guervain, p. 85.
[29]Rikhter, pp. 12-13.
[30]M. de Guervain, p. 85.
[31]Rikhter, pp. 12-13.
[32]M. de Guervain, p. 85.
[33]Ronald D. Tabler, Snow Control Course Notes (Niwot, Colorado: Tabler & Associates, 1990), p. 11.
[34]Kind, p. 353.

snowdrift formation

DEPOSITION

The wind deposits snow whenever its velocity is decreased. Any kind of an obstruction is sufficient to slow down the wind, which then drops many of the snow particles it has been carrying.[1,2] Changes in topography, as well as buildings, trees, shrubs, telephone poles, fences, field stubble, vehicles, existing snow drifts, and polar ice caps will all cause snow deposition.[3,4] See figures 35 - 42.

Like geological strata, drifted snow is laid down in layers. Some layers are composed of large granular particles (laid down by strong winds), other of very fine grained particles (laid down by mild winds).[5,6]

The way that snow is deposited is not random, but in fact quite orderly. Snow is always deposited in such a way as to "reduce the aerodynamic drag of the surface".[7] As such, snow is first deposited in areas where the wind speed is lowest.[8] In fact snowdrift forms reflect their associated wind reduction patterns.[9,10] In general terms, similar obstacles produce similar drift forms and patterns. The "shape and size of a drift depends on the shape and size of the obstacle and its orientation to the wind direction".[11]

Figure 35
Where Drifts Occur
Winnipeg, Manitoba
February 5/92, 10:00 a.m.
-6.5° C. Wind SSE at 13 km./hr.

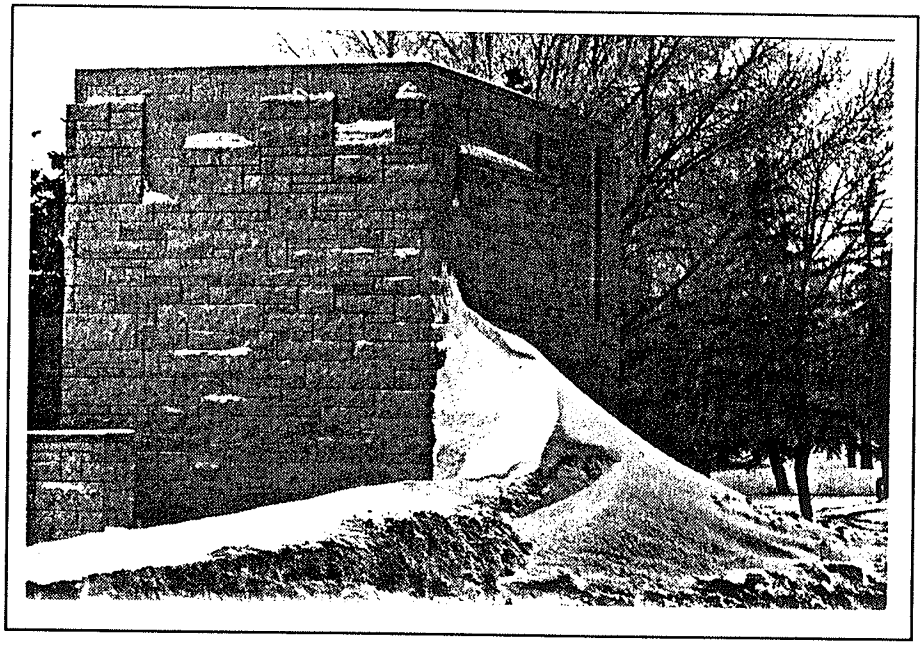


Figure 36
Where Drifts Occur
Delta, Manitoba
February 23/91, 1:30 a.m.
-17° C. Wind N at 9 km./hr.

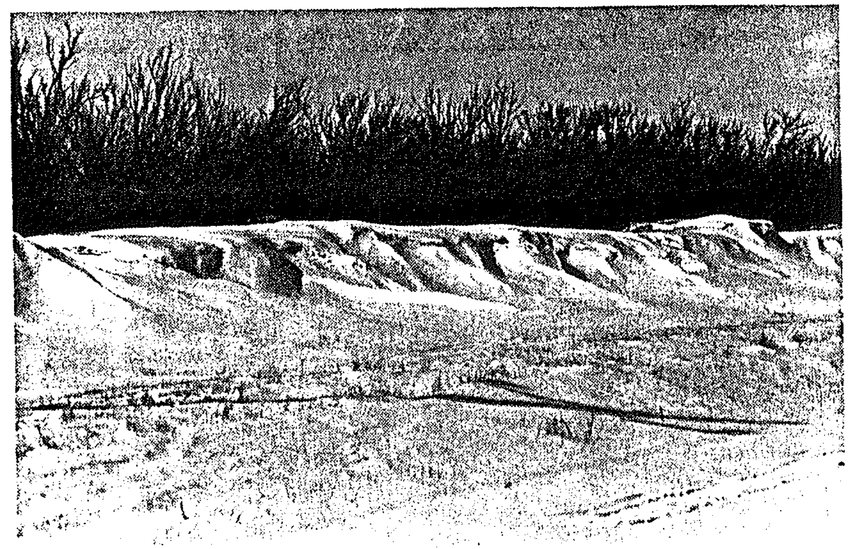


Figure 37
Where Drifts Occur
Portage la Prairie, Manitoba
February 23/91, 1:30 p.m..
-17° C. Wind N at 9 km./hr.

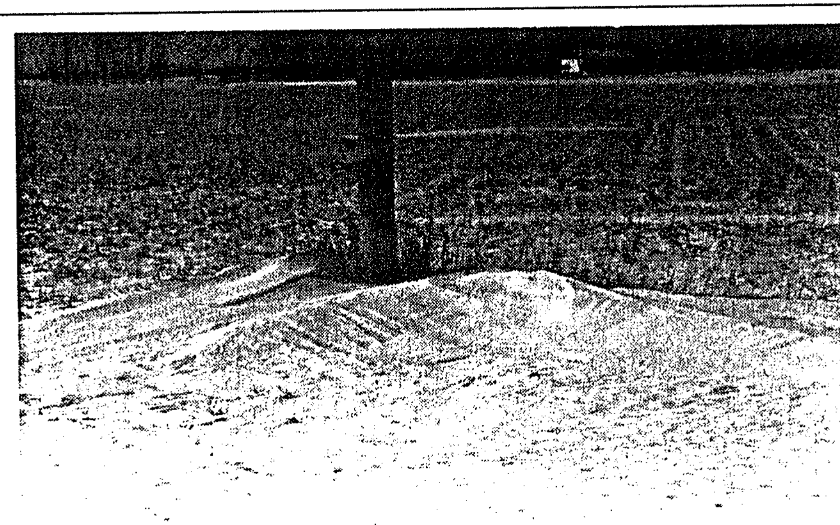


Figure 38
Where Drifts Occur
Portage la Prairie, Manitoba
February 23/91, 1:30 p.m.
-17° C. Wind N at 9 km./hr.

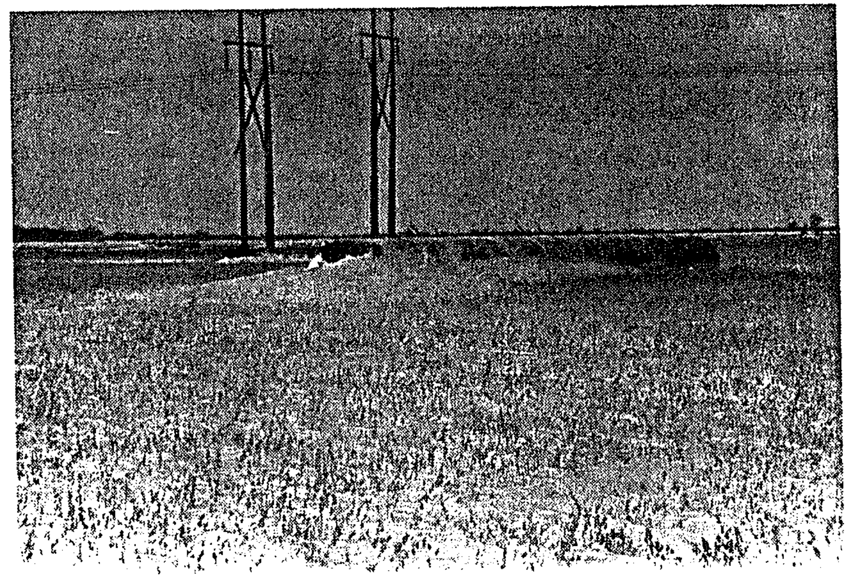


Figure 39
Where Drifts Occur
Winnipeg, Manitoba
January 23/92, 10:30 a.m.
-20° C. Wind NW at 22 km./hr.

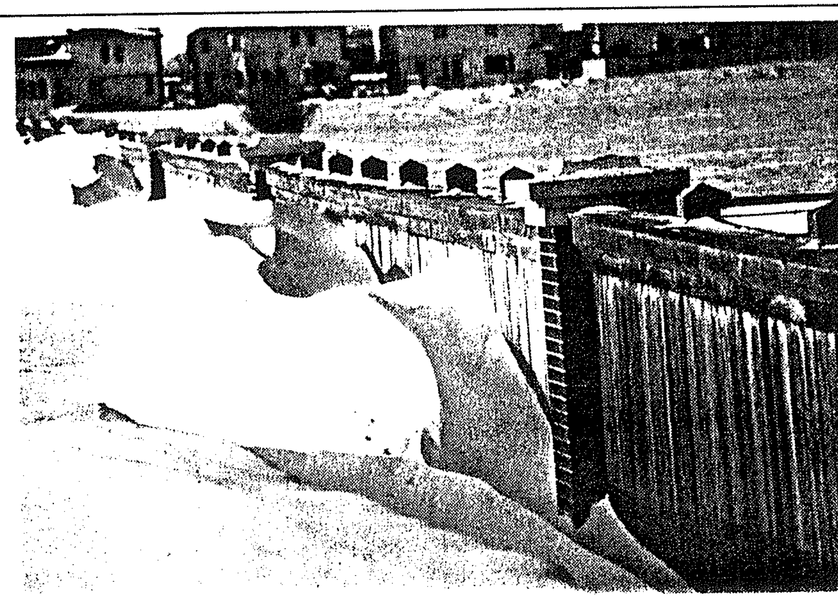


Figure 40
Where Drifts Occur
Winnipeg, Manitoba
January 23/92, 10:00 a.m.
-20° C. Wind NW at 22 km./hr.

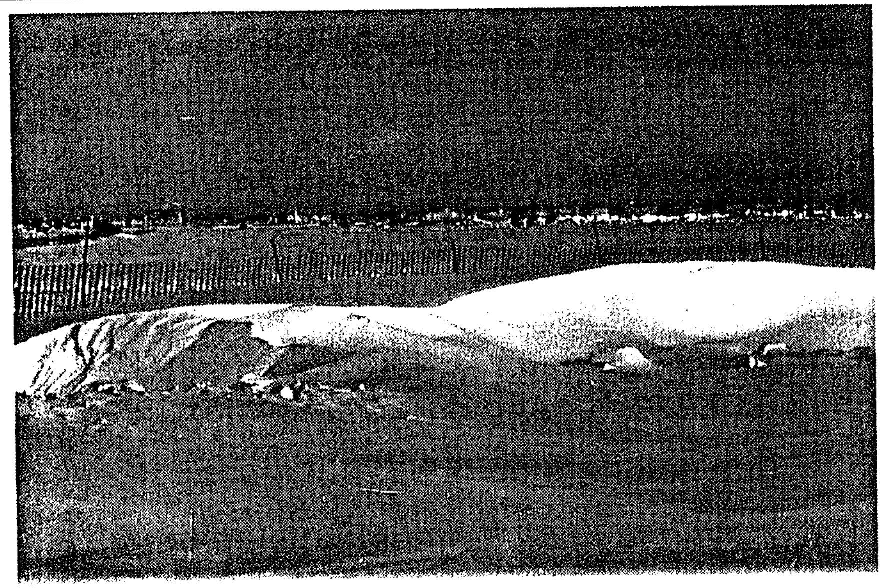


Figure 41
Where Drifts Occur
Winnipeg, Manitoba
January 16/92, 8:30 a.m.
-13° C. Wind S at 6 km./hr.

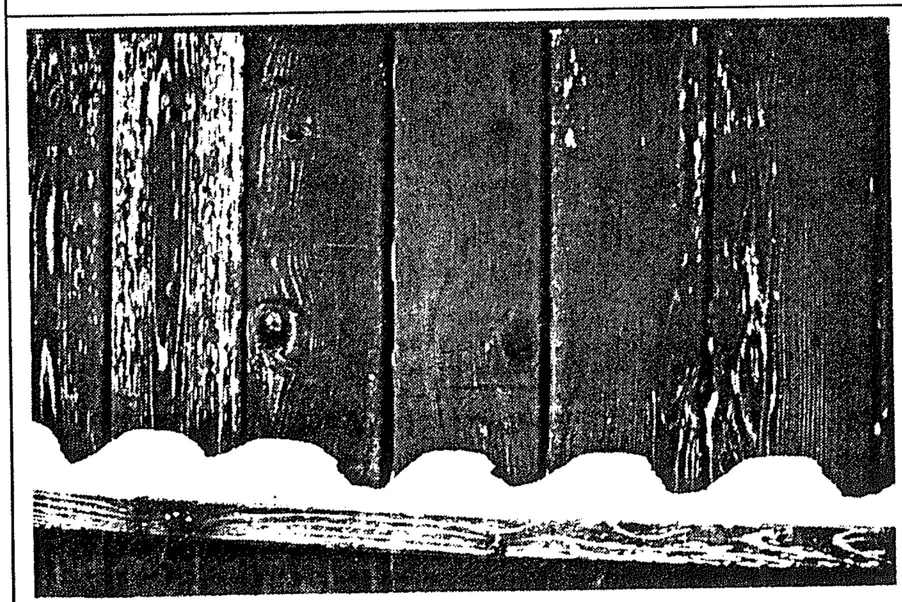
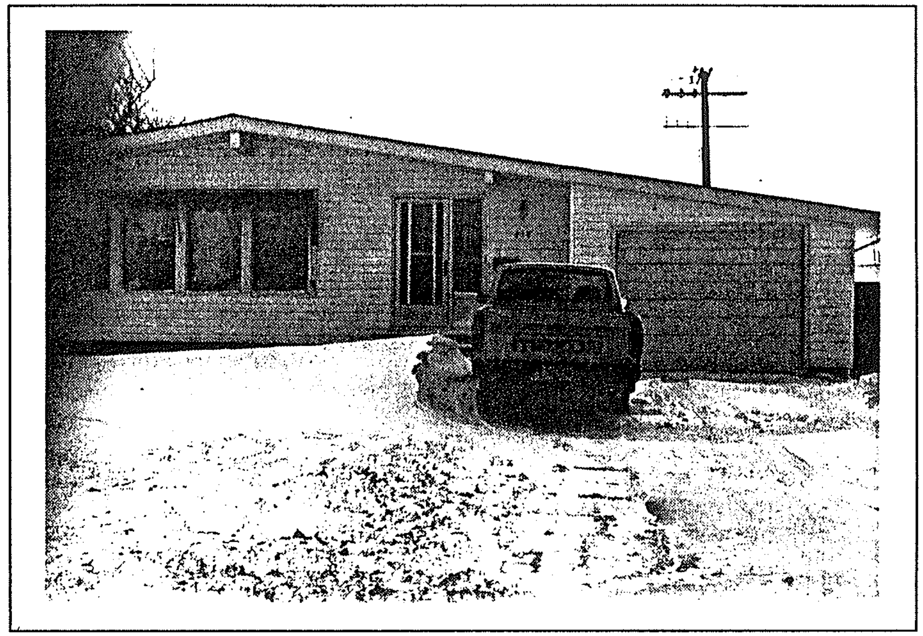


Figure 42
Where Drifts Occur
Winnipeg, Manitoba
November 3/91, 9:00 a.m.
-14° C. Wind NW at 33 km./hr.



Furthermore, as long as the obstacles are not considerably altered or moved, similar drifts will develop in similar locations year after year. (Provided prevailing winds are the same from year to year.) The exact size and form will vary depending on the amount of snow, wind speed, temperature etc. The important thing however, is that snow drift formation is predictable. See figures 43 - 53.

Generally, solid obstacles produce areas of greatly reduced wind speed, as well as areas of greatly accelerated wind speed. Drifts formed by solid obstacles tend to be short and deep and tend to form on both sides of the obstacle.

Porous obstacles produce areas of moderately reduced winds, as well as areas of moderately accelerated wind speed. A small drift tends to develop on the windward side of the obstacle, while a large drift develops on the leewards side. As well, drifts formed by porous obstacles tend to be longer and less deep than those formed by solid obstacles. As the porosity of an obstacle increases, the drift becomes progressively longer and shallower.

Thus wind speed determines the size, structure, and texture of a drift, while its form and location depends on the nature of the obstruction and on the orientation of that obstruction to the wind.[12,13]

Figure 43
Similar Drifts Develop in Similar Locations Year After Year
Delta, Manitoba
February 23/91, 2:00 p.m.
-17° C. Wind N at 6 km./hr.

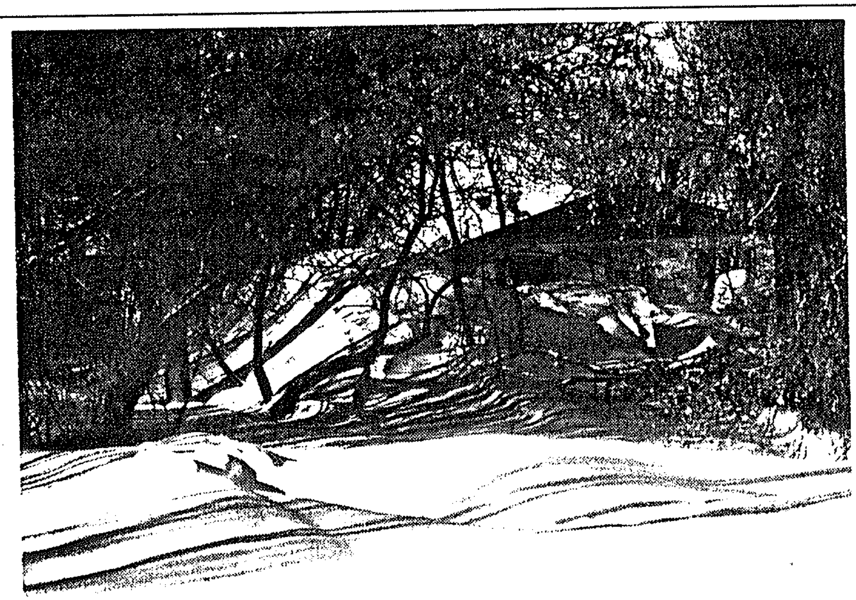


Figure 44
Similar Drifts Develop in Similar Locations Year After Year
Delta, Manitoba
March 21/92, 2:00 p.m.
-17° C. Wind N at 6 km./hr.

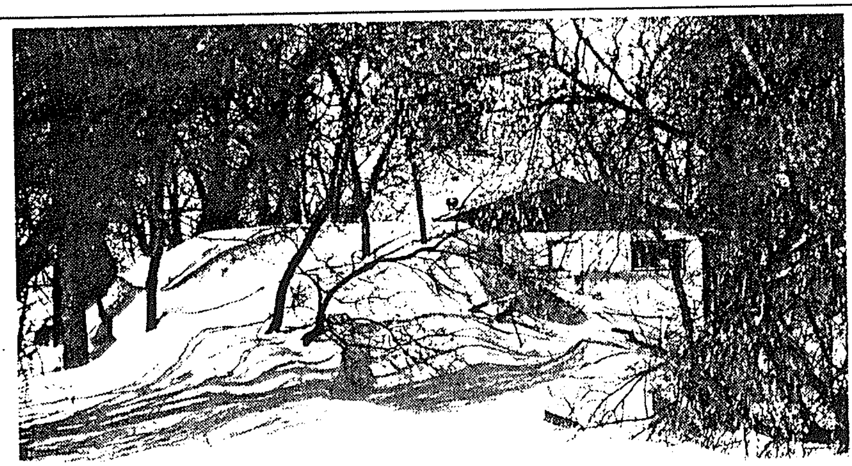


Figure 45
Similar Drifts Develop in Similar
Locations Year After Year
Delta, Manitoba
February 23/91, 2:00 p.m.
-17° C. Wind N at 9 km./hr.

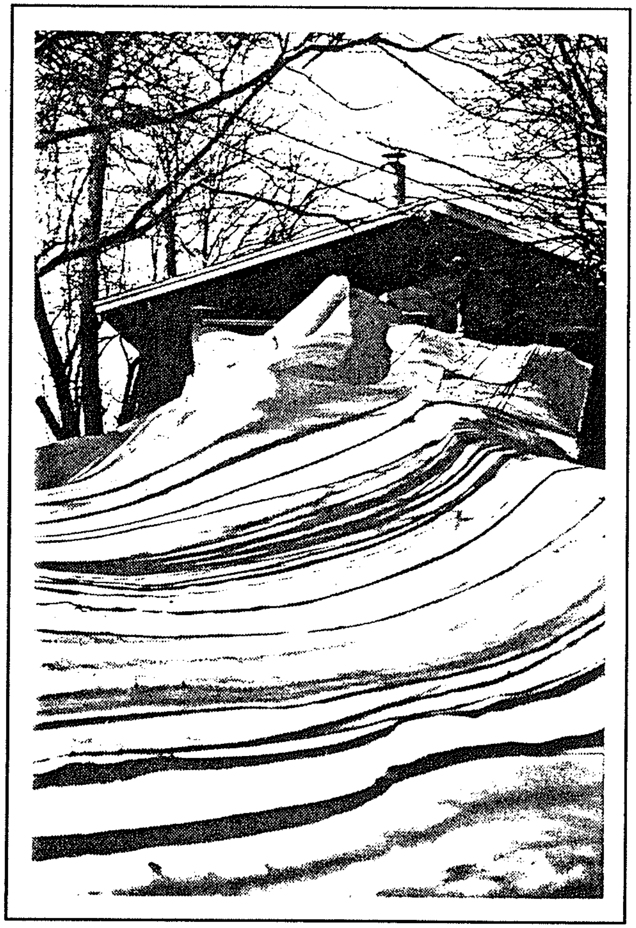
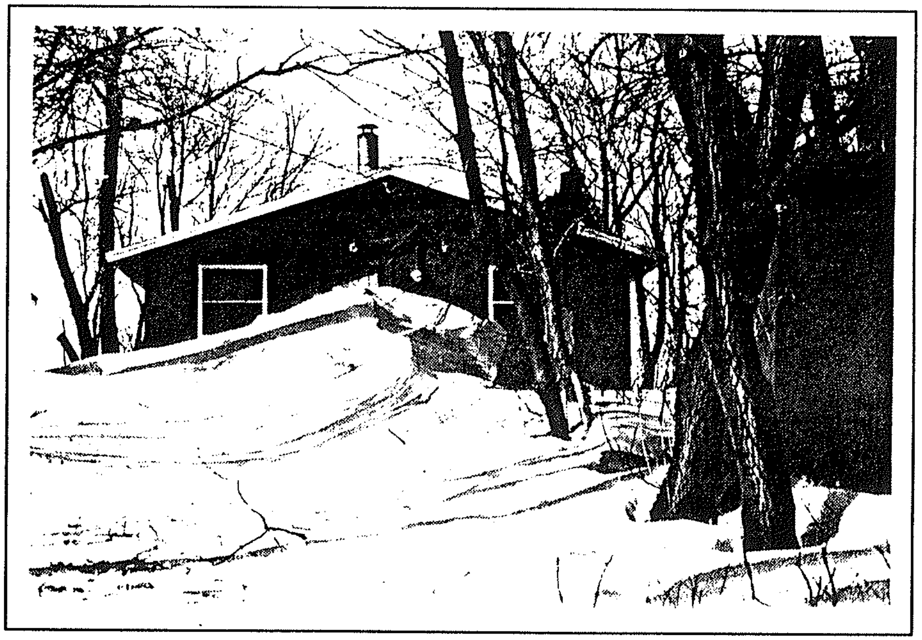


Figure 46
Similar Drifts Develop in Similar
Locations Year After Year
Delta, Manitoba
March 21/92, 2:00 p.m.
-3° C. Wind WSW at 7 km./hr.



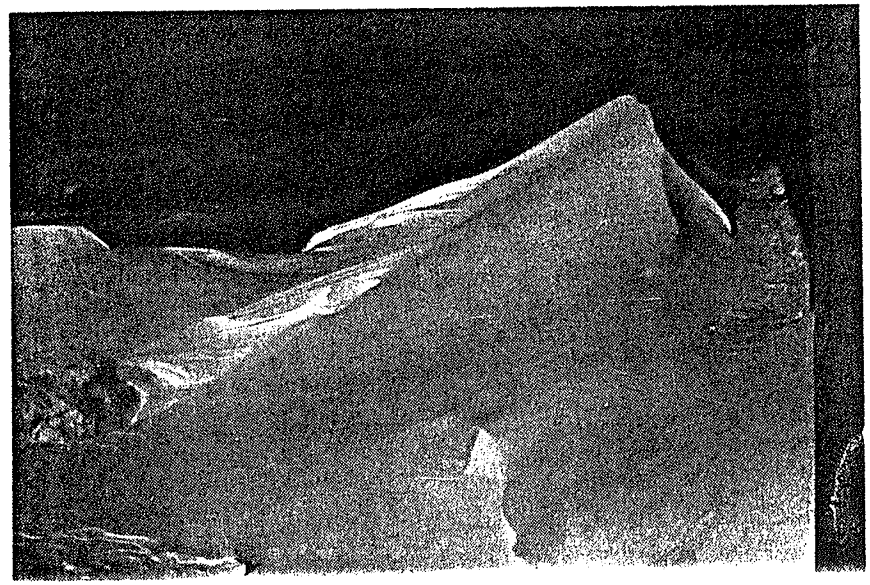


Figure 47
Similar Drifts Develop in Similar Locations Year After Year
Starbuck, Manitoba
Spring 1989
Photo by Mich'ele Ammeter

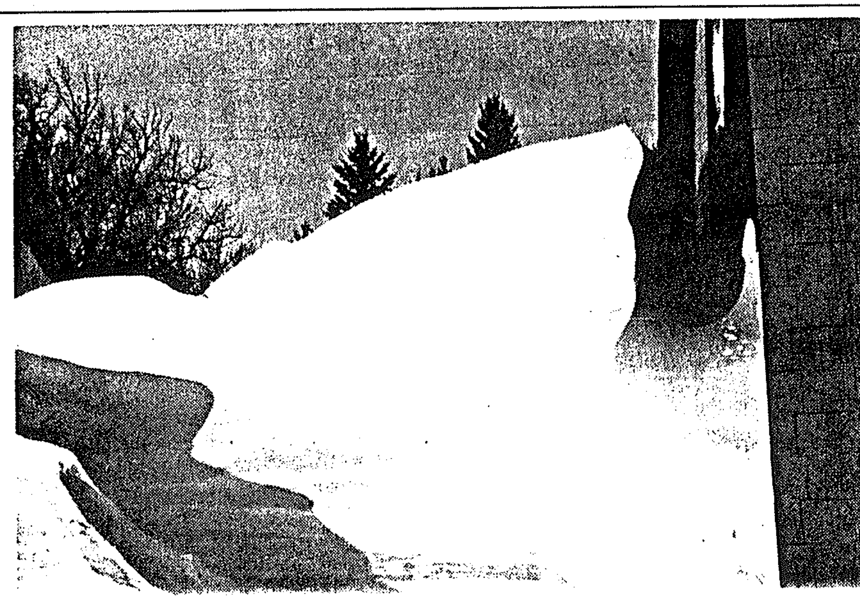


Figure 48
Similar Drifts Develop in Similar Locations Year After Year
Starbuck, Manitoba
February 11/92

Figure 49
Similar Drifts Develop in Similar Locations Year After Year
Starbuck, Manitoba
March 1989
Photo by Mich'ele Ammeter

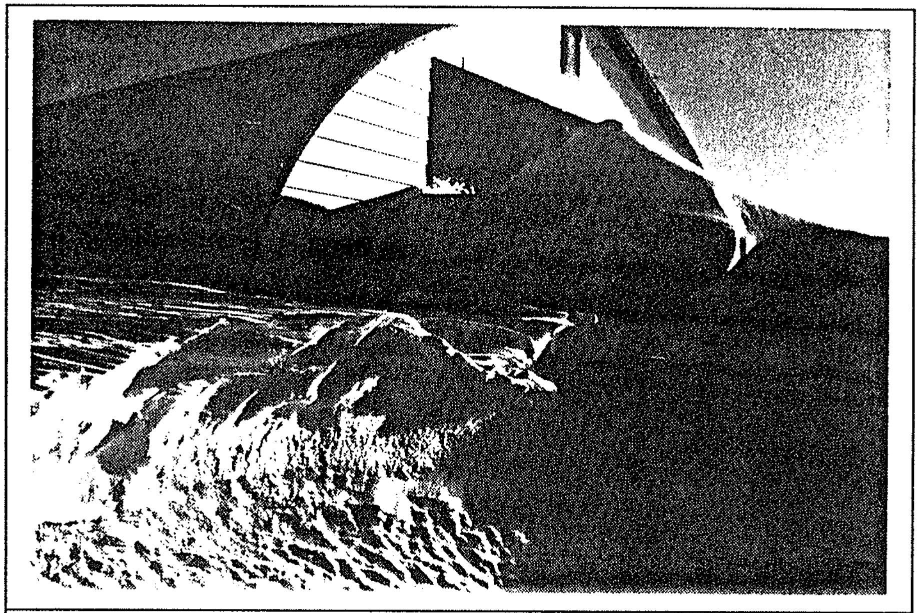


Figure 50
Similar Drifts Develop in Similar Locations Year After Year
Starbuck, Manitoba
February 11/92, 2:00 p.m.
-17° C. Wind N at 6 km./hr.

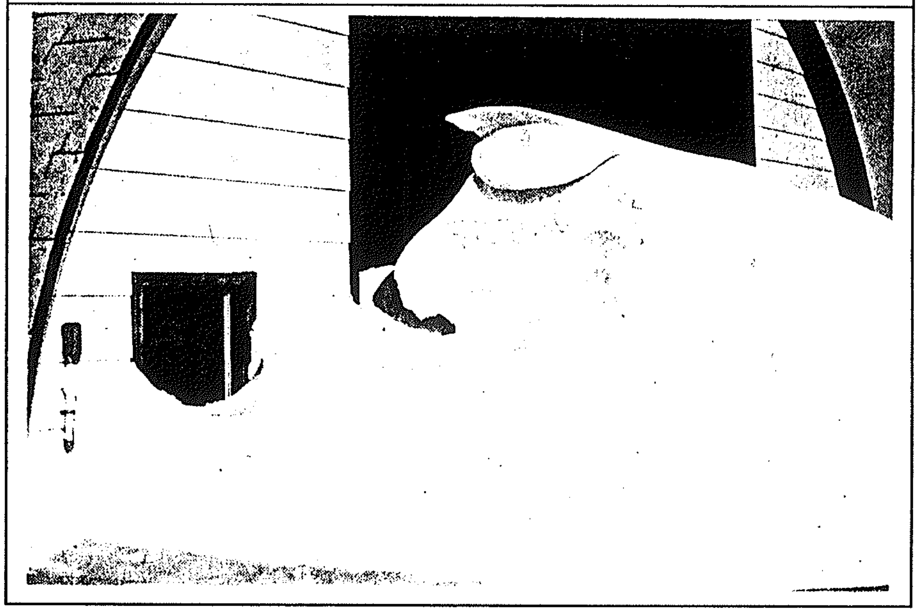


Figure 51
Similar Drifts Develop in Similar Locations Year After Year
Delta, Manitoba
March 21/92, 2:00 p.m.
-2° C. Wind W at 6 km./hr.

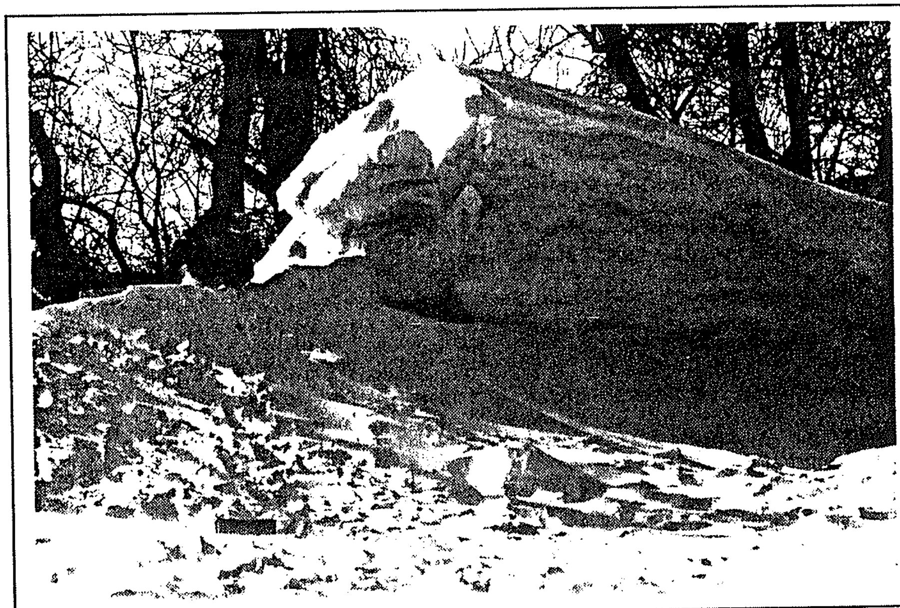


Figure 52
Similar Drifts Develop in Similar Locations Year After Year. Compare to Figure 129.
Delta, Manitoba
March 21/92, 3:00 p.m.
-2° C. Wind W at 6 km./hr.

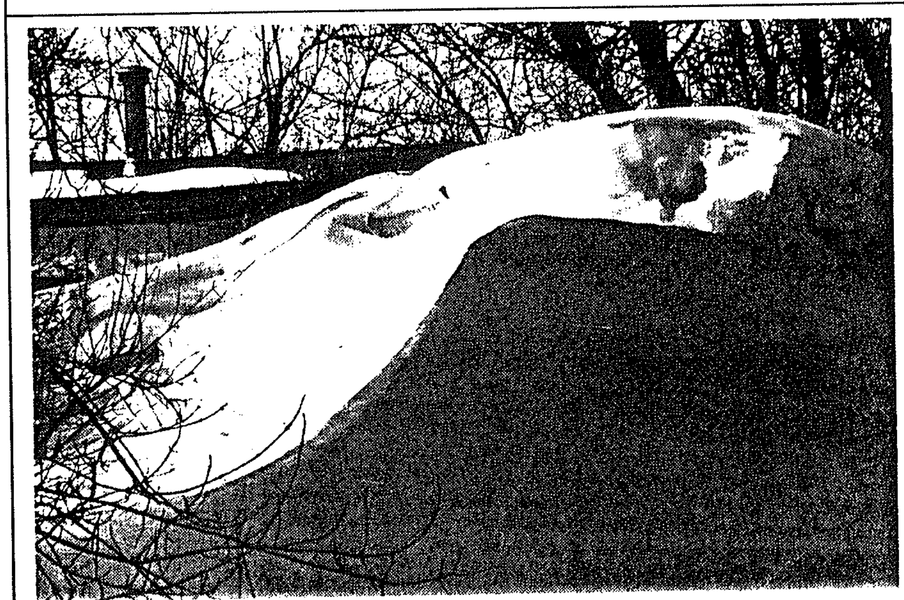
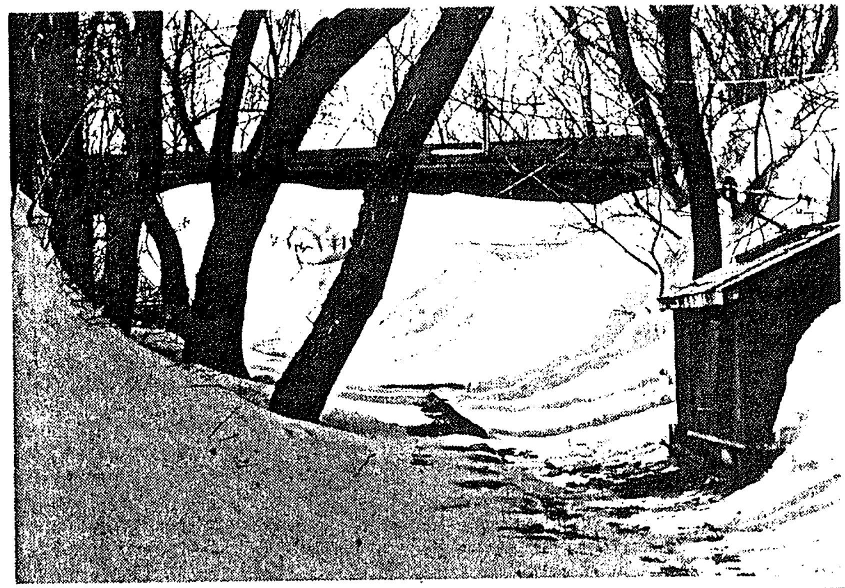


Figure 53
Similar Drifts Develop in Similar Locations Year After Year. Compare to figure 54.
Delta, Manitoba
March 21/92, 3:00 p.m.
-2° C. Wind W at 6 km./hr.



EROSION

As previously mentioned (see page 64), obstacles disrupt the normally smooth flow of the wind, creating areas of both lower and higher wind speeds. When the wind speed accelerates, all or most of the snow is swept away from that particular area. This is called *scouring*.[14,15,16] See figures 54, 55.

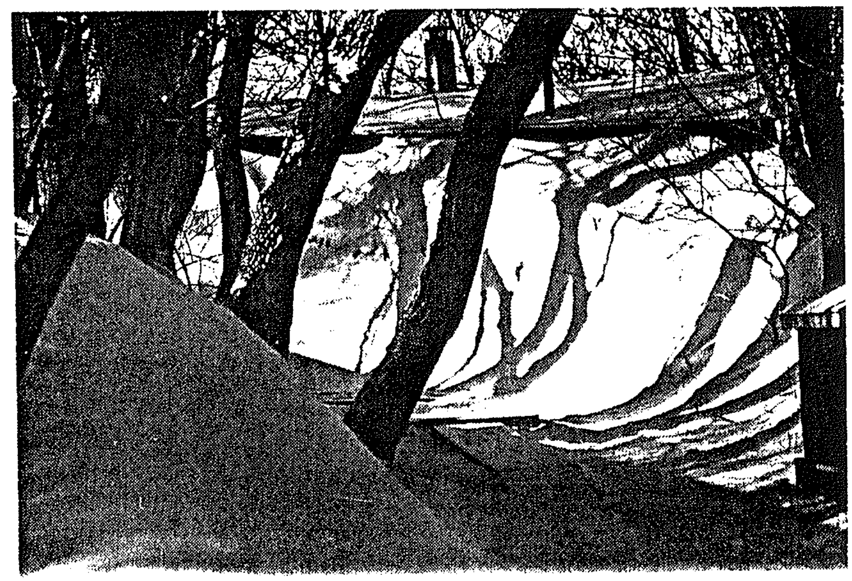


Figure 54
Scouring
Delta, Manitoba
February 23/91, 2:30 p.m.
-17° C. Wind N at 6 km./hr.

REFERENCES:

[1]Mellor, p. 22.
[2]Tabler et al., "Drifting Snow," p. 109.
[3]Mellor, pp. 24, 30-31.
[4]Kind, p. 34.
[5]Mellor, p. 23.
[6]Pugh and Price, p. 6.
[7]Tabler et al., "Drifting Snow," p. 9.
[8]Mellor, pp. 30-31.
[9]Ralph A Read, "Tree Windbreaks for the Central Great Plains," U.S. Department of Agriculture Handbook No. 250. U.S. Dept. of Agriculture (February 1964), p. 7.
[10]Hough, p. 41.
[11]Verge and Williams, p. 631.
[12]Rikhter, pp. 14-18.
[13]Pugh and Price, p. 6.
[14]Kind, pp. 353-354.
[15]Mellor, p. 30.
[16]Tabler et. al., "Drifting Snow," p. 109.

Figure 55
Scouring
Portage la Prairie, Manitoba
February 23/91, 1:30 p.m.
-17° C. Wind N at 9 km./hr.

snowdrift patterns

Drift Patterns
Portage la Prairie, Manitoba
February 23/91, 1:30 p.m.
-17° C. Wind N at 9 km./hr.

PATTERNS

The deposition and erosion of snow produces various patterns in the landscape. Deposition and erosion work together as well as independently.[1] The resulting patterns vary from large dramatic drifts to small subtle rippling effects. See figures 56, 57.

Figure 56
Large Dramatic Drift
Delta, Manitoba
February 23/91, 2:30 p.m.
-17° C. Wind N at 6 km./hr.

Figure 57
Scouring
Starbuck, Manitoba
February 11/92, 3:30 p.m.
-21° C. Wind S at 4 km./hr.

DRIFTS THAT ARE CREATED BY OBSTACLES

The height of the obstacle is one of the primary determinants of a snowdrift's form, size and location. This is true for all kinds of obstacles. As such, the height of the obstacle is referred to as H. All other measures are then based on magnitudes of H (2H, 3H, 4H etc.)[2]

Vegetation

> "When you plant a tree, you also plant a drift."[3]

Almost all kinds of vegetation create snowdrifts. Snow collects behind, in front of, and sometimes directly on top of plants. Vegetation produces the greatest variety of snowdrift forms.

Drifts can add interest and complement to the form of a plant. Or they can transform the plant that created the drift. They add line, texture, contrast, and emphasis. A small shrub gathers up a pillow of snow and transforms itself into a pin cushion. The spruce tree is introduced with a long supple rhythmic bow. Waves and whitecaps crash through rows of trees and shrubs.

See figures 58 - 61.

Figure 58
Pincushion Shrub
Ile-des-Chenes, Manitoba
January 19/92, 2:30 p.m.
-17° C. Wind N at 13 km./hr.

Figure 60
Winter Whitecap
Delta, Manitoba
February 23/91, 2:30 p.m.
-17° C. Wind N at 6 km./hr.

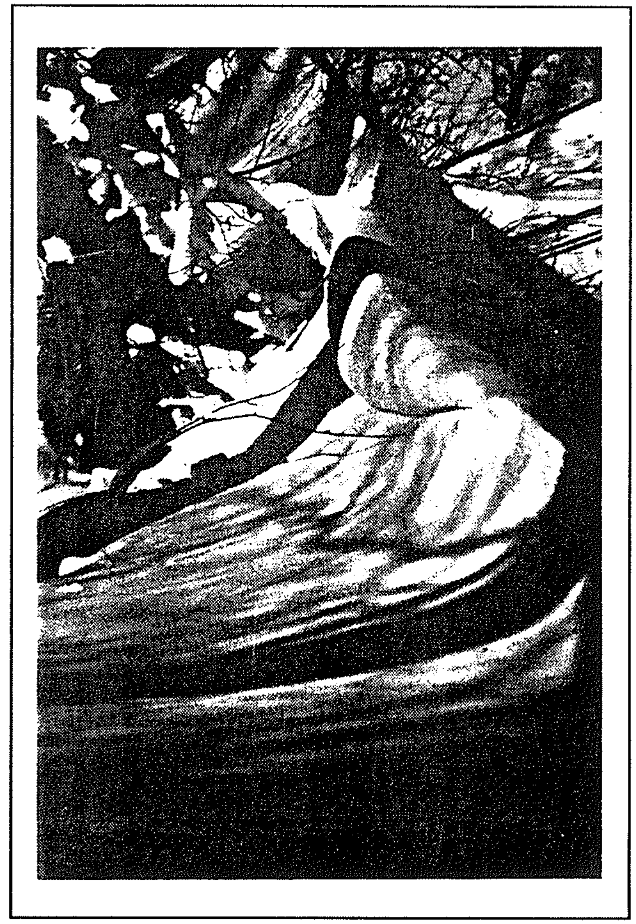


Figure 59
Rythmic Bow
Ile-des-Chenes, Manitoba
January 19/92, 12:30 p.m.
-17° C. Wind N at 15 km./hr.

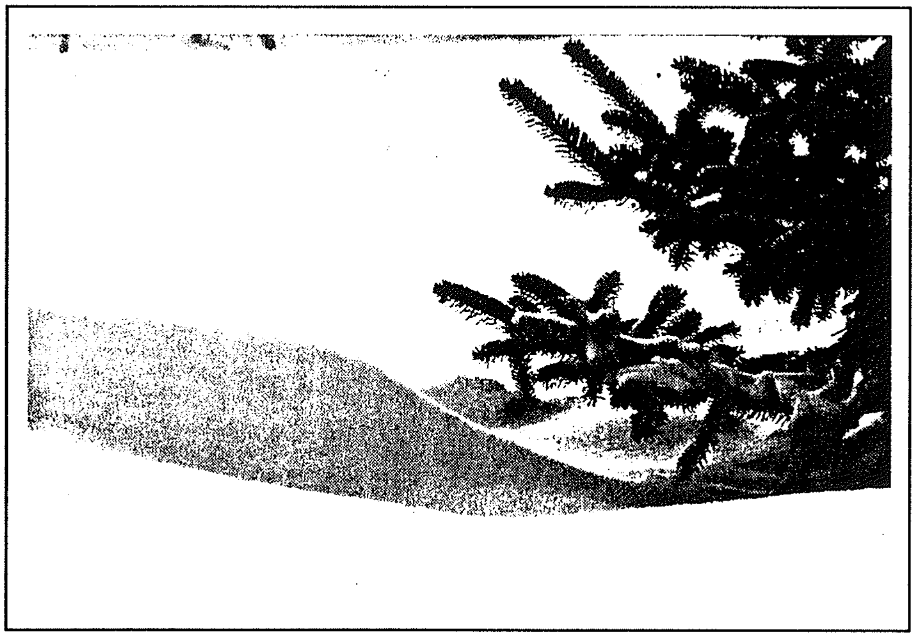


Figure 61
Winter Breaker
Starbuck, Manitoba
February 11/91, 9:30 a.m.
-29° C. Wind W at 4 km./hr.

Until recently, it was a common agricultural practice to plant shrubs and trees in rows in order to reduce soil erosion and to encourage snow drifting.[4] Shrubs and trees planted for this use are called *windrows* or *shelterbelts*. Species composition, the spacing between plants in the row, and the number of rows all effect the density,[5] and therefore the form, size, and location of the snowdrift. The orientation of the entire shelterbelt to the prevailing wind also effects drift form, size, and location. Since landscape architects frequently incorporate rows of trees and shrubs into their designs, snowdrifts that are created by shelterbelts are important to consider. Figures 62 - 64 illustrate the general snowdrift forms which are created by shelterbelts of various densities.

Stoeckeler has done considerable research into the resultant drift forms that are created by specific species. See figure 65.

Figure 62

General Drift Form Created by Shelterbelts: Short Deep Drifts. Adapted From:

J.M. Caborn. Shelterbelts and Windbreaks. London: Faber and Faber, 1965, p. 194.

R.B. Campbell and R. B. Grau. Evergreen Windbreaks for Iowa Farmsteads. Iowa State College, Agriculatural Experiment Station- Agricultural Extension Service, Cooperative, May 1948, Bulletin P88, p. 925.

Roger du Toit. "Livable Winter Cities" Livable Winter Newsletter. Vol. 3, No. 6, December 1985, p. 9.

Ralph A. Read. "Tree Windbreaks for the Central Great Plains" U.S. Department of Agriculture Handbook No. 250. U.S. Dept. of Agriculture, February 1964, pp. 5, 7.

G. O. Robinnette, ed. Plants, People and Environmental Quality Washington: U.S. Dept. of the Interior, National Park Services, 1972, p. 91.

Jack Royle. "Frank Theakston's thirty-year search for the secrets of the wind, snow and sun" Winter Cities News. Vol. 6, No. 1, p. 6.

J. H. Stoeckeler. "Shelterbelt Influence on Great Plains Field Environment and Crops: A Guide for Determining Design and Orientation." Production Research Report No. 62. U.S. Department of Agriculture, Agriculture Research Service, October 1962, pp. 4-7.

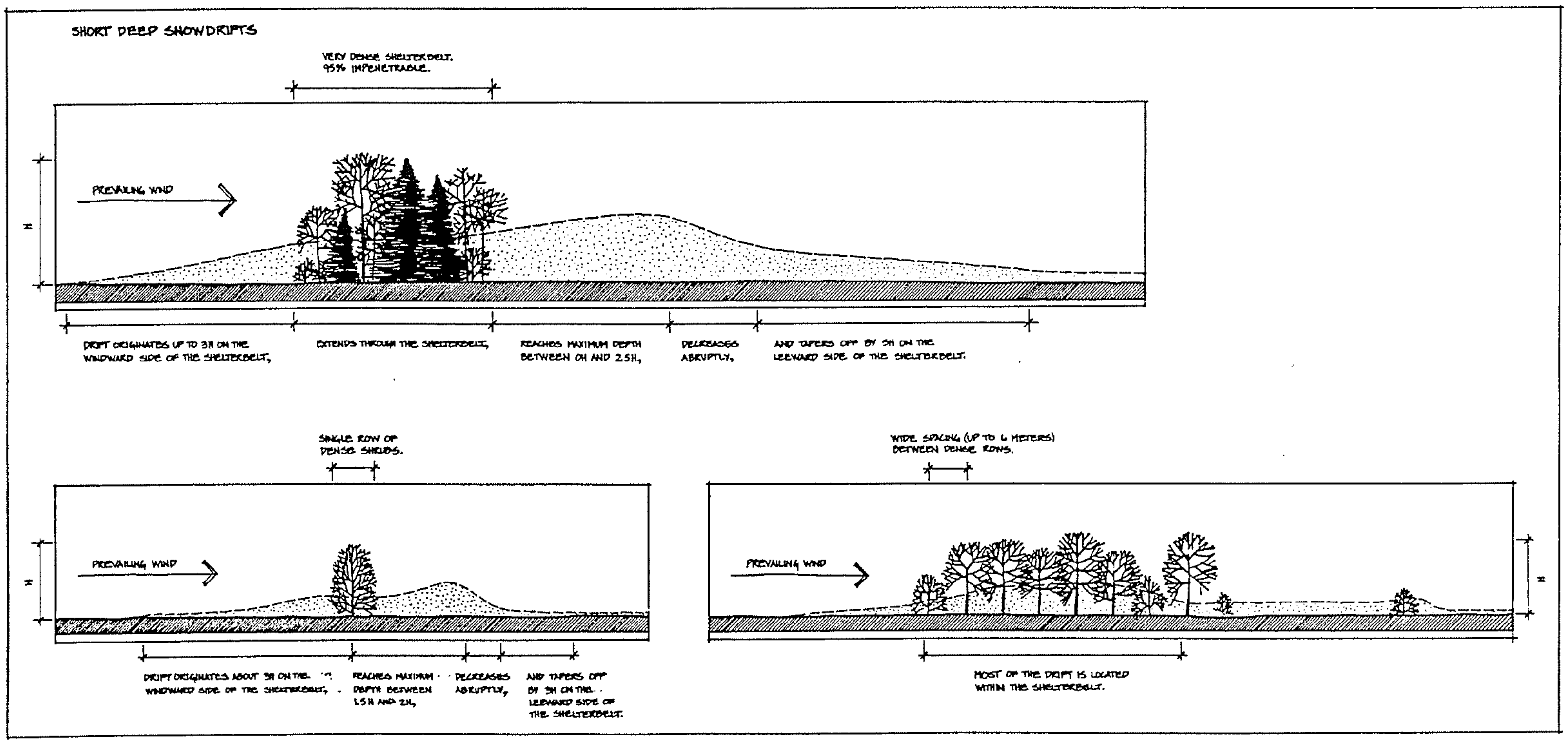


Figure 63

General Drift Form Created by Shelterbelts: Moderate Length Drifts

Adapted From:

J.M. Caborn. Shelterbelts and Windbreaks. London: Faber and Faber, 1965, p. 194.

Roger du Toit. "Livable Winter Cities" Livable Winter Newsletter. Vol. 3, No. 6, December 1985, p. 9.

Ralph A. Read. "Tree Windbreaks for the Central Great Plains" U.S. Department of Agriculture Handbook No. 250. U.S. Dept. of Agriculture, February 1964, p. 7.

G. O. Robinnette, ed. Plants, People and Environmental Quality Washington: U.S. Dept. of the Interior, National Park Services, 1972, p. 91.

J. H. Stoeckeler. "Shelterbelt Influence on Great Plains Field Environment and Crops: A Guide for Determining Design and Orientation." Production Research Report No. 62. U.S. Department of Agriculture, Agriculture Research Service, October 1962, pp. 4-7.

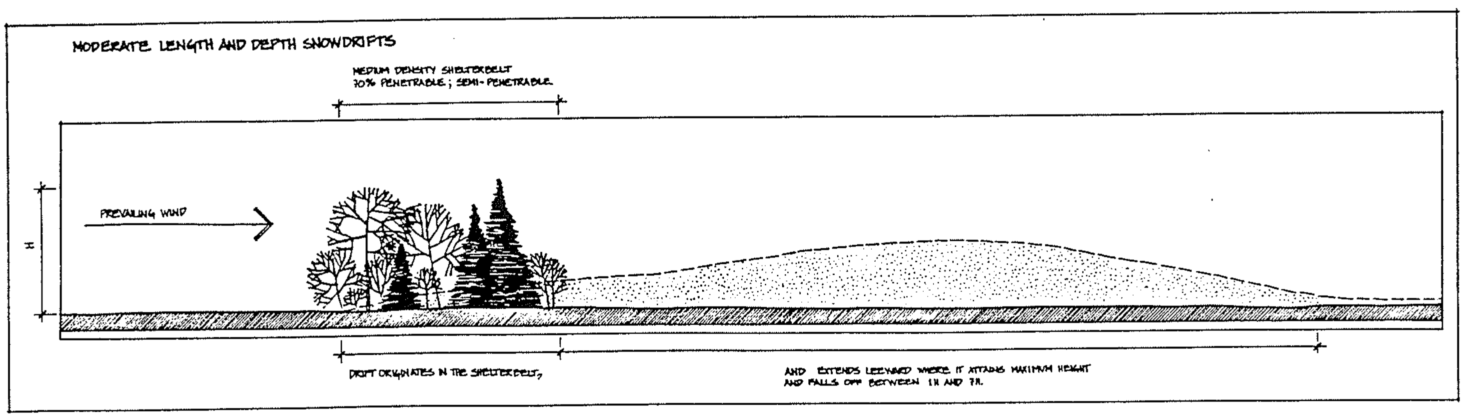


Figure 64

General Drift Form Created by Shelterbelts: Long Shallow Drifts

Adapted From:

J.M. Caborn. Shelterbelts and Windbreaks. London: Faber and Faber, 1965, p. 194.

Roger du Toit. "Livable Winter Cities" Livable Winter Newsletter. Vol. 3, No. 6, December 1985, p. 9.

Ralph A. Read. "Tree Windbreaks for the Central Great Plains" U.S. Department of Agriculture Handbook No. 250. U.S. Dept. of Agriculture, February 1964, p. 7.

G. O. Robinnette, ed. Plants, People and Environmental Quality Washington: U.S. Dept. of the Interior, National Park Services, 1972, p. 91.

J. H. Stoeckeler. "Shelterbelt Influence on Great Plains Field Environment and Crops: A Guide for Determining Design and Orientation." Production Research Report No. 62. U.S. Department of Agriculture, Agriculture Research Service, October 1962, pp. 4-7.

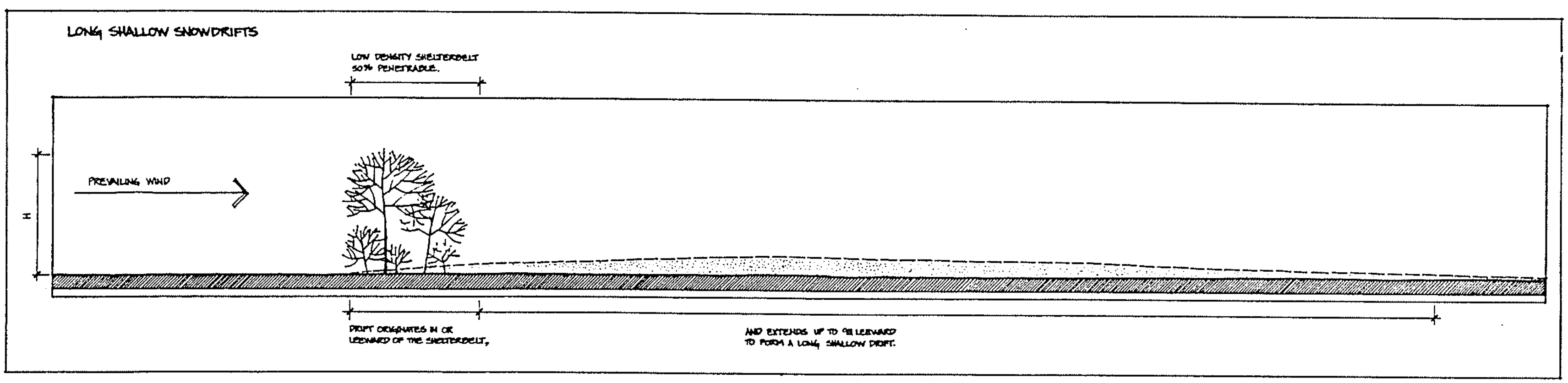
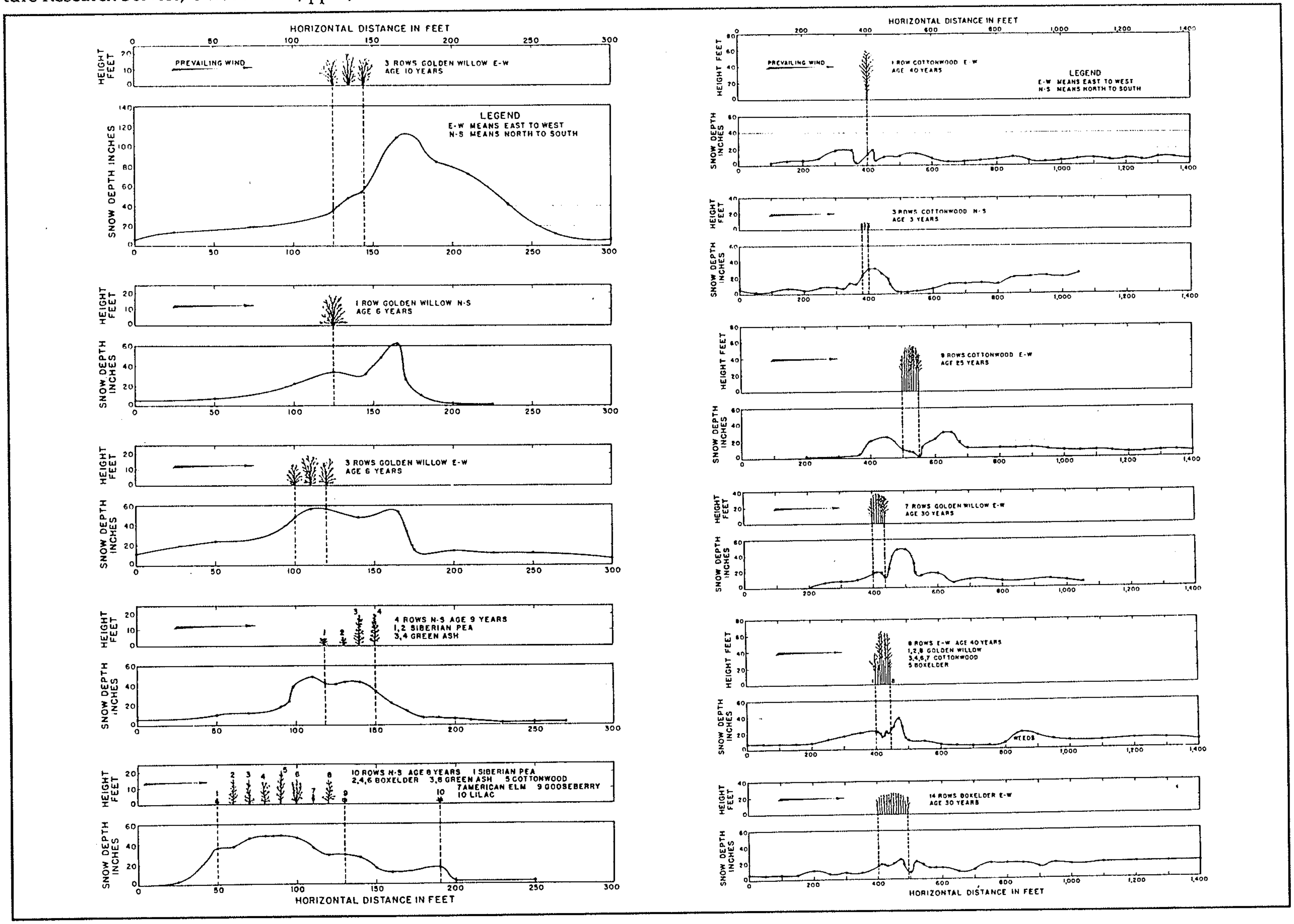


Figure 65, Drift Forms Created by Specific Kinds of Trees and Shrubs. J. H. Stoeckeler. "Shelterbelt Influence on Great Plains Field Environment and Crops: A Guide for Determining Design and Orientation." Production Research Report No. 62. U.S. Department of Agriculture, Agriculture Research Service, October 1962, pp. 5, 6.



Simply copying these configurations is rather restricting for landscape design. As well, the possibility of reproducing an exact drift form is questionable, given the multitude of factors which contribute to a snowdrift's form in any specific location.[6]

According to Heisler and DeWalle "visual porosity is a useful guide to windbreak effectiveness for natural barriers..."[7] This combined with the general drift form that results from various shelterbelt densities is perhaps more useful for landscape designers. For instance, thinking in terms of "very dense row of shrubs" and "deep short drift adjacent to the shrubs" enables the designer to work in terms of masses, which is much more amenable to landscape design.

Other items pertaining to snowdrift design using shelterbelts include:

Spacing between the rows of trees or shrubs can vary between 3 m and 6 m without changing the resulting drift form.[8] See figure 66.

A single row of trees or shrubs is likely to develop gaps as trees inevitably die. Gaps left by dead plants create areas of scouring.[9] See figure 67. The intended drift form will be considerably altered.

Some shelterbelts are oriented in such as way as to direct the wind flow rather than reduce it. This type of shelterbelt is called a *wind channel*, and while it does not create drifts itself, it can be extremely important to drift formation. A wind channel intercepts the wind flow and redirects it. This creates an area behind the shelterbelt where snowdrifts tend not to develop. Areas along the shelterbelt as well as at the end of it receive the full force of the redirected wind. There is an opportunity for snowdrifts to develop in this area.[10] See figure 68. To be effective, the foliage must be dense and extend to the ground.[11]

Figure 66
Varying Row Spacing
Ralph A. Read. "Tree Windbreaks for the Central Great Plains" U.S. Department of Agriculture Handbook No. 250. U.S. Dept. of Agriculture, February 1964, pp. 27, 28.

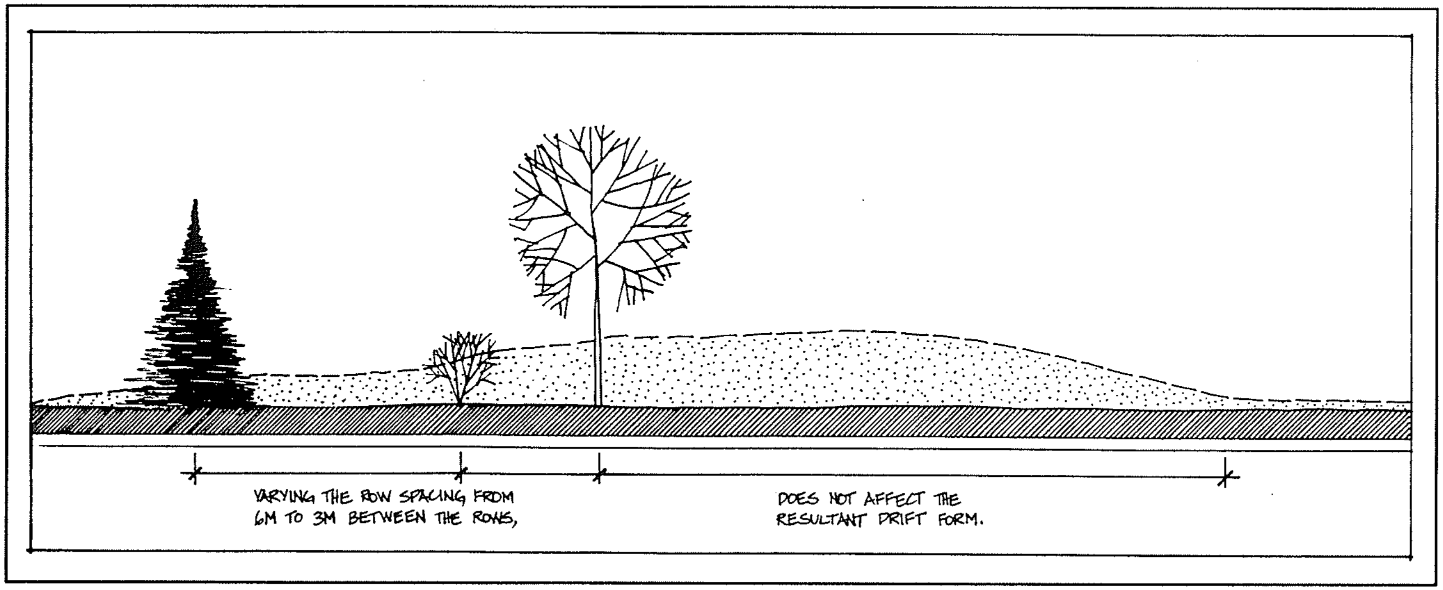
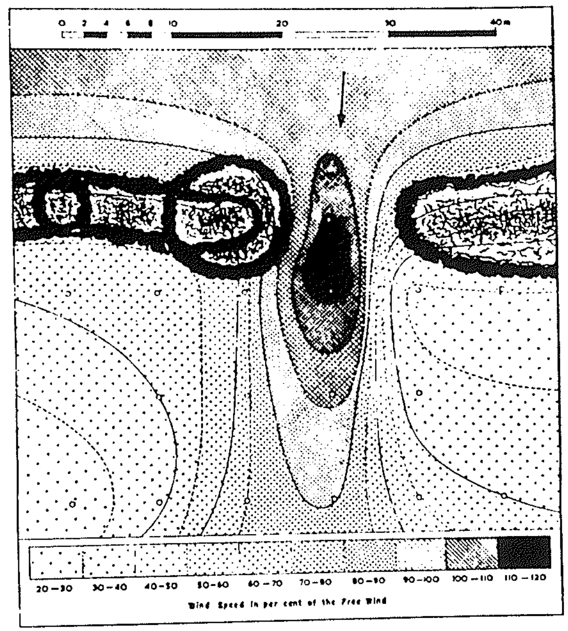
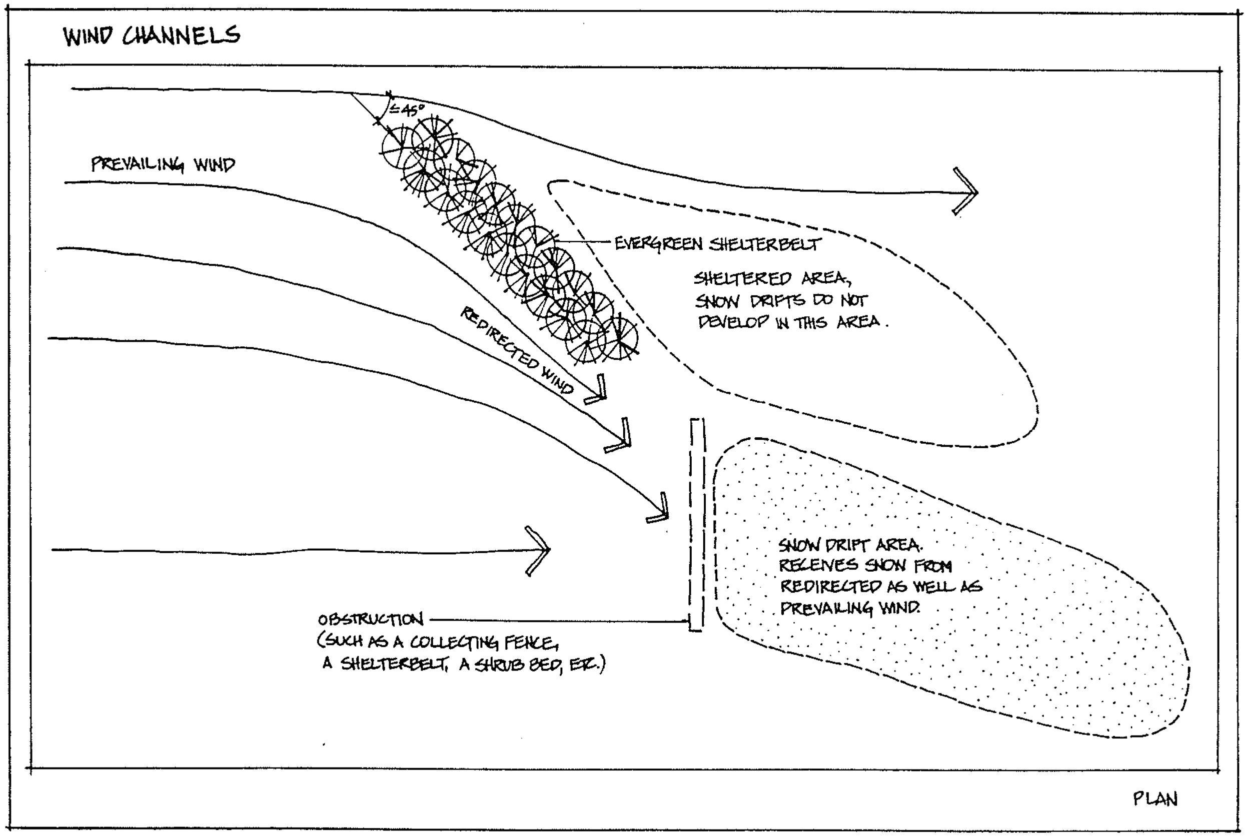


Figure 67
Areas of Increased Wind Velocity as a Result of Gaps in a Shelterbelt
M. Melargno. Wind in Architectural and Environmental Design. Toronto: Van Nostrand Reinhold, 1982, p. 378.



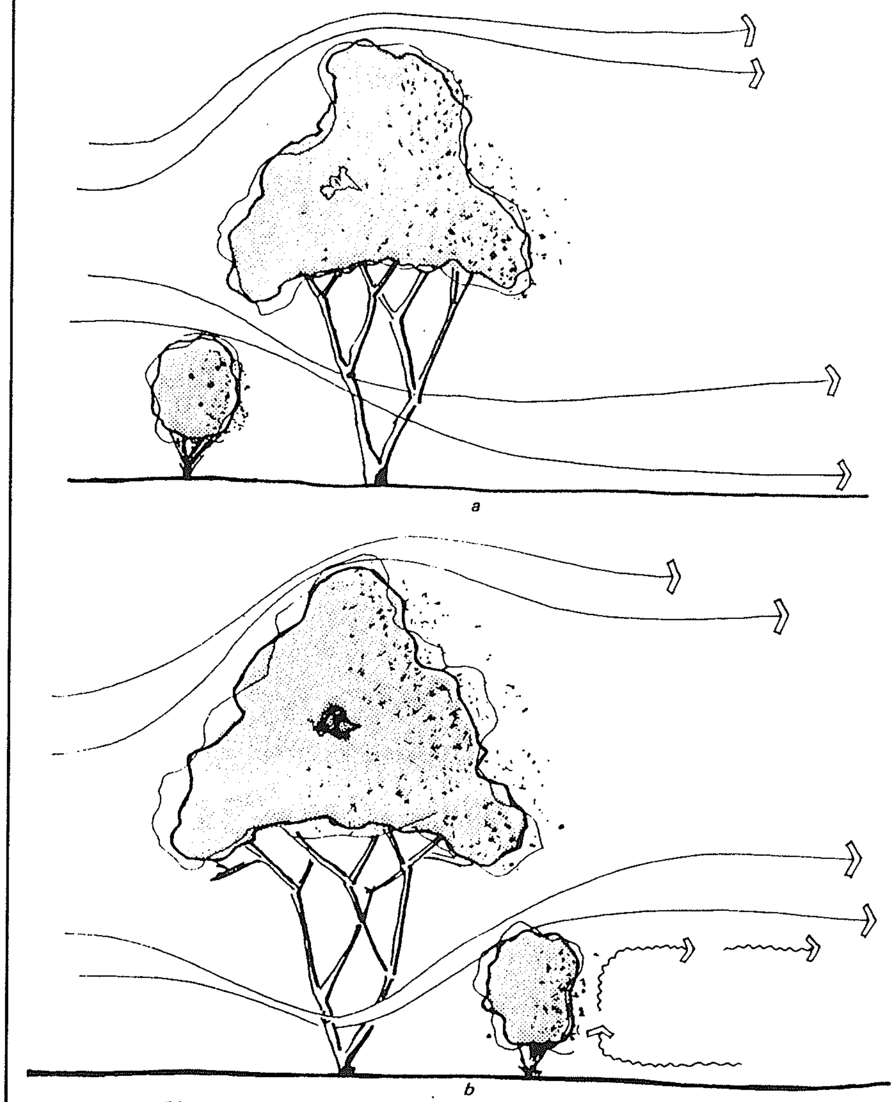
Effects of discontinuities in shelterbelts. An opening in a shelterbelt produces changes in the wind speed in the areas near the opening on the leeward and windward sides. Wind speeds through the opening can reach 120% the speed of the free wind. (After Nägeli, courtesy of J. M. Caborn)

Figure 68
Wind Channel
D.G. Pitt, J. Kissida, and W. Gould, Jr. "How to Design a Windbreak" American Nurseryman. November 15, 1980, pp. 11, 50.



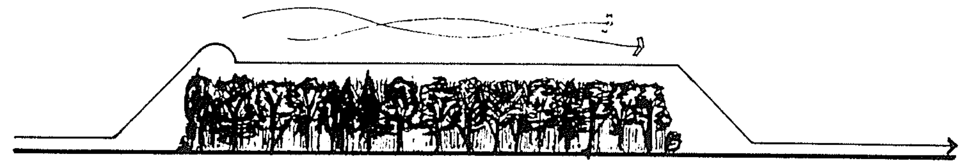
Locating a row a shrubs in front of a row of trees has a very different effect than locating the shrubs behind the row of trees.[12] See figure 69. Data which describes the associated change in drift form is not currently available. Thus if a specific drift is desired which can be achieved by a specific combination of shrubs and trees (figure 36 for instance), it is important to retain the orientation of wind and configuration of shrubs and trees.

Wide shelterbelts (those whose cross-sectional width is wider than 5H) as well as forests, trap most of the snow within their structure.[13,14] See figure 70.

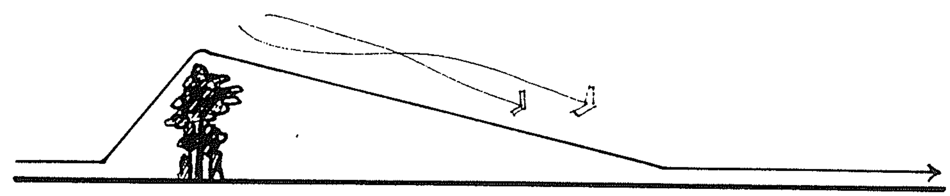


a. The addition of low shrubs in front of trees accelerates the air near the ground. *b*. By placing low shrubs behind trees, the accelerated windflow under the trees is deflected upward, and consequently a sheltered zone is created behind the shrubs.

Figure 69
M. Melargno. Wind in Architectural and Environmental Design. Toronto: Van Nostrand Reinhold, 1982, p. 346.



The depth of the sheltered area on the leeward side of a wide shelterbelt is very small, especially when compared with the depth of the area behind a narrow shelterbelt.



Profile of the sheltered area on the leeward side of a narrow shelterbelt shows the higher efficiency of narrow shelterbelts compared to thick ones.

Figure 70
M. Melargno. Wind in Architectural and Environmental Design. Toronto: Van Nostrand Reinhold, 1982, p. 380.

Plantings need not always be in rows. Theakston has found that coniferous trees located in staggered rows is an effective shelterbelt form.[15] It would seem that if density is the key, then mass plantings would be just as successful in creating drifts as row plantings. See figure 71. In fact, experimenting with alternatives to row planting may produce some wonderful undulating effects. See figure 72.

Very high wind velocities develop at the ends of shelterbelts which creates areas of scouring.[16], See figure 73. The scouring gives the drift rounded ends which extend towards the centre of the snowdrift for about 12H.[17,18]

Figure 71
Mass Plantings

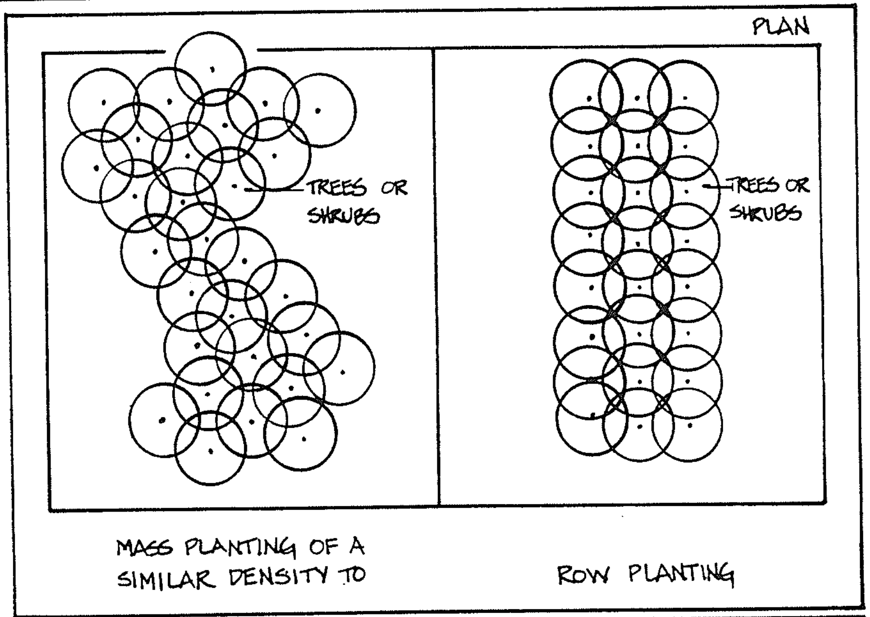


Figure 72
Undulating Effects

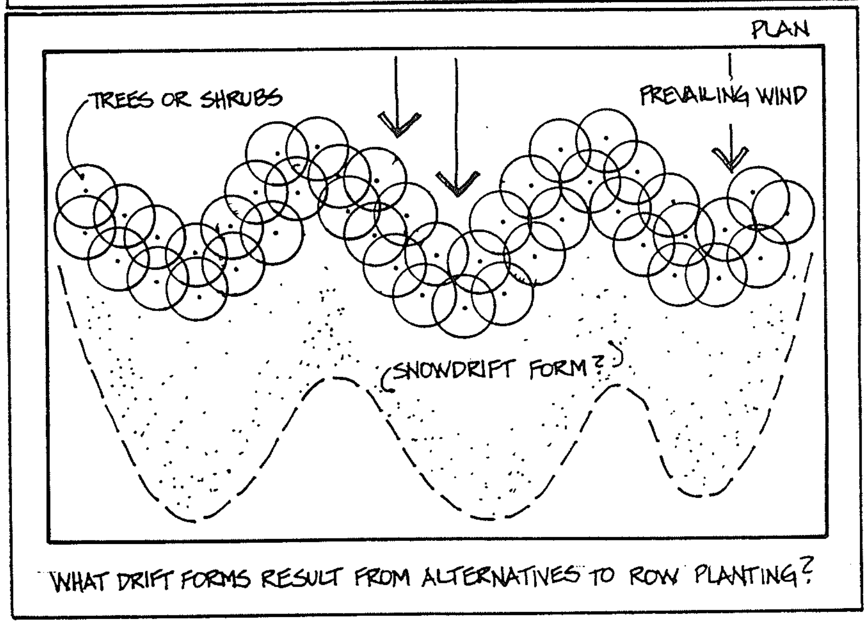
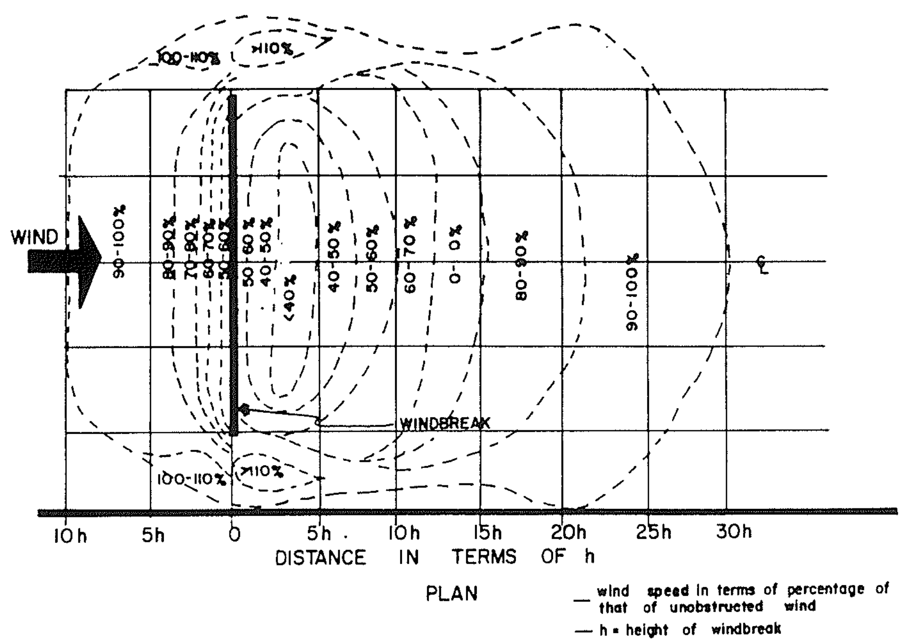


Figure 73
M. Melargno. Wind in Architectural and Environmental Design. Toronto: Van Nostrand Reinhold, 1982, p. 377.

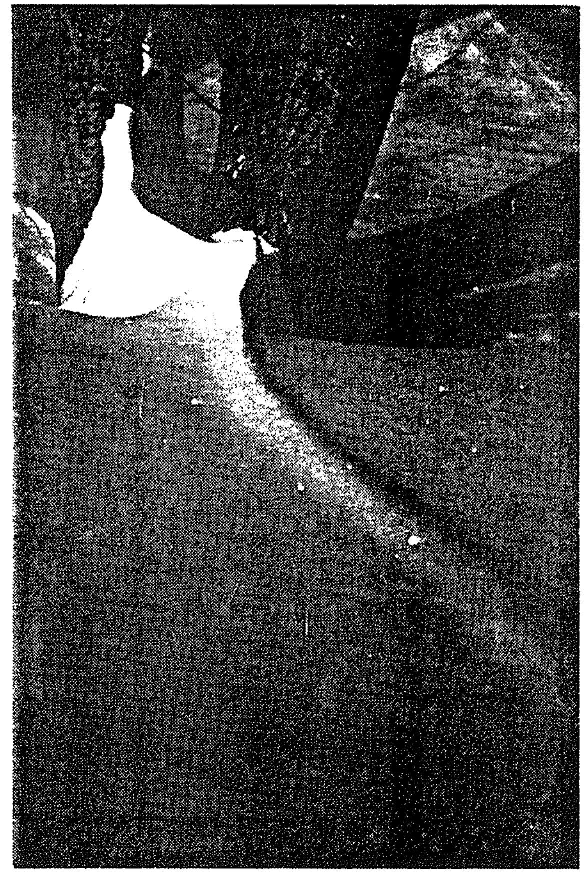


Distribution of the wind velocity around a windbreak whose permeability is defined as "moderately dense." The velocity is expressed as a percentage of the speed of the unobstructed wind. Notice that while the speed is reduced on the leeward and also on the windward side of the windbreak, it increases around the end edges up to 110%.

At the bases of trees, stumps, telephone poles and even grass, a triangular drift often develops on the leeward side. See figure 74. This simple horizontal line is often complementary to the obstacle that produced it. It is also nature's compass (provided prevailing winds are known).[19]

For additional information sources, consult the 'Vegetation References' section of the Appendix.

Figure 74
Nature's Compass
Ile-des-Chenes,
Manitoba
January 19/92,
3:00 p.m.
-17° C. Wind N at
13 km./hr.



Fences and Walls

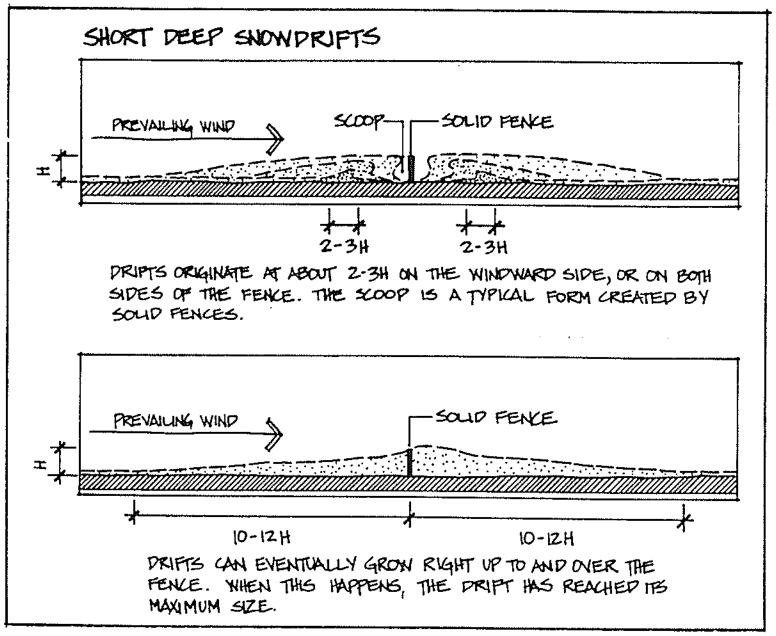
Most fences are oriented in such a way as to reduce the wind velocity, and by design or accident, create snow drifts around them. These fences have been termed *collecting fences*. See figure 39.

The important factor in determining the type of snow drift that develops near a fence, wall, or similar structure, is the density (or porosity) of that structure.[20,21]

Solid fences cause similar short but deep drifts to form on each side of the structure and can eventually become entirely buried in the drift.[22,23,24] See figure 75.

Fences which have openings in them (slat fences for instance) cause longer, more shallow drifts to form. The drift on the windward side tends to be quite short, while the leeward drift can be very long.[25,26] See figure 76.

Figure 75
Drift Form Created by Solid Fences
Adapted from:
H. Pugh and W. Price. "Snow Drifting and the Use of Snow Fences" The Polar Record. Vol. 7, No. 47, January 1954, p. 7.
Ralph A.Read. "Tree Windbreaks for the Central Great Plains" U.S. Department of Agriculture Handbook No. 250. U.S. Dept. of Agriculture, February 1964, p. 7.
Ronald D. Tabler. Snow Control Course Notes. Niwot, Colorado: Tabler & Associates, 1990, p. 17.



Fences with a porosity between forty and fifty percent collect the most snow. A very porous fence tends to create very long and shallow drifts.[27] Interestingly, the width of the slats does not affect the drift in any way. Slat widths of 2.5 cm all the way up to 25 cm can be used.[28] See figure 77.

Figure 76
Drift Form Created by 50% Porous Fences
Ronald D. Tabler. Snow Control Course Notes. Niwot, Colorado: Tabler & Associates, 1990, p. 19.

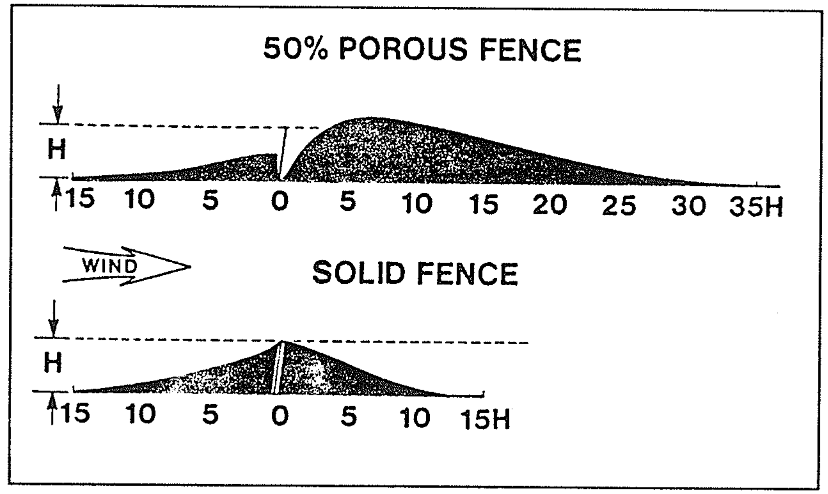
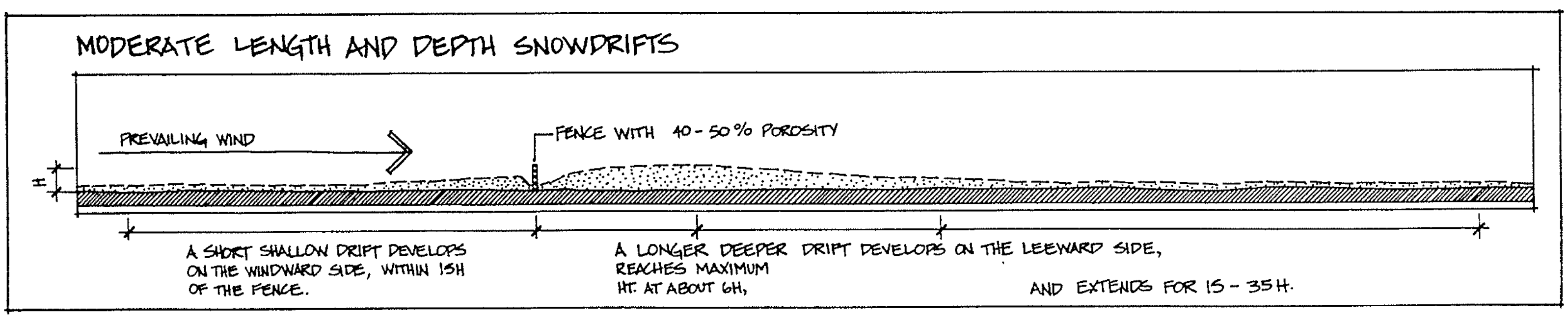


Figure 77
Drift Form Created by 40-50% Porous Fences
Adapted from:
H. Pugh and W. Price. "Snow Drifting and the Use of Snow Fences" The Polar Record. Vol. 7, No. 47, January 1954, p. 9.
Ronald D. Tabler. Snow Control Course Notes. Niwot, Colorado: Tabler & Associates, 1990, p. 15.



A fence which is solid at the top and open at the bottom, creates on open area directly behind the fence, with the drift forming behind that.[29] See figure 78. In this circumstance, the drift will not eventually bury the fence.[30]

At each end of a collecting fence are areas of very high wind speeds. Scouring in these areas gives the drift rounded ends. This has been called *end effect*, and extends towards the centre of the snowdrift for about 12H.[31] See figure 79.

A fence can have the same effect as a wind channel. A fence of this type is called a *leading fence*. See figure 80. Leading fences only work if they are solid and very smooth on the side that will be directing the wind flow.[32]

Figure 78
Drift Form Created by a Solid Fence with a Gap at the Bottom
Adapted from:
H. Pugh and W. Price. "Snow Drifting and the Use of Snow Fences" The Polar Record. Vol. 7, No. 47, January 1954, p. 9.
Ronald D. Tabler. Snow Control Course Notes. Niwot, Colorado: Tabler & Associates, 1990, pp. 16, 18.

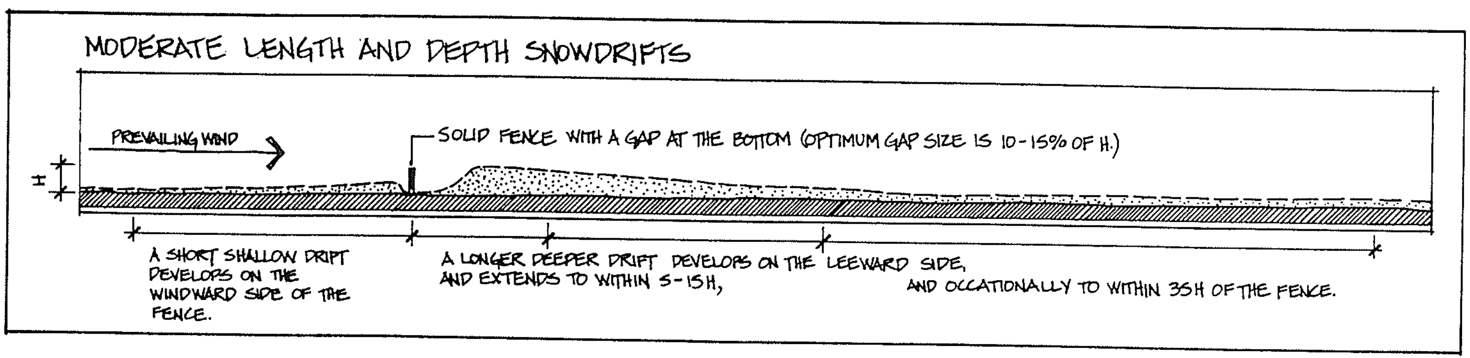


Figure 79
Rounded Ends Created by End Effect Adapted from:
Ronald D. Tabler. Snow Control Course Notes. Niwot, Colorado: Tabler & Associates, 1990, p. 22.

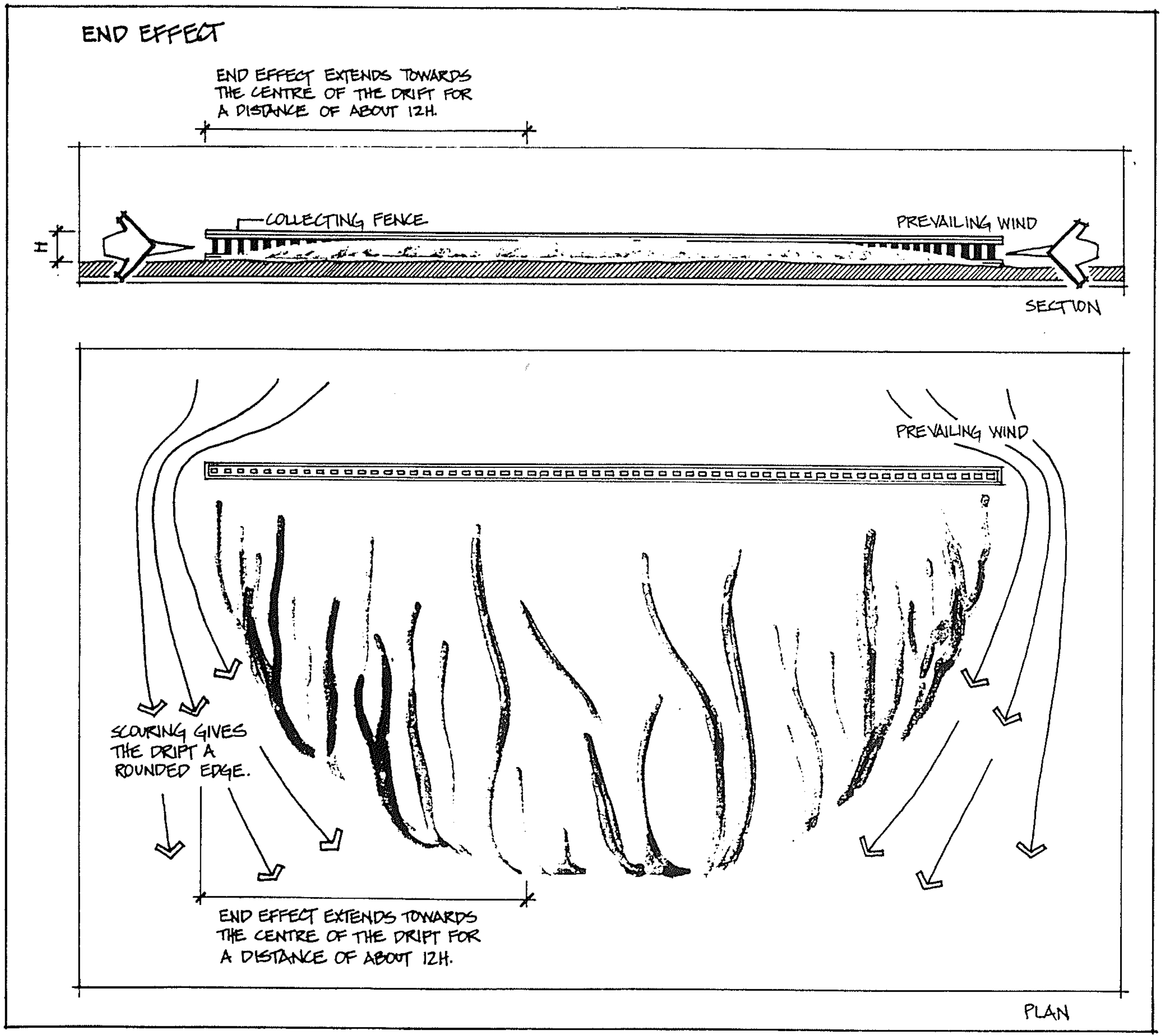
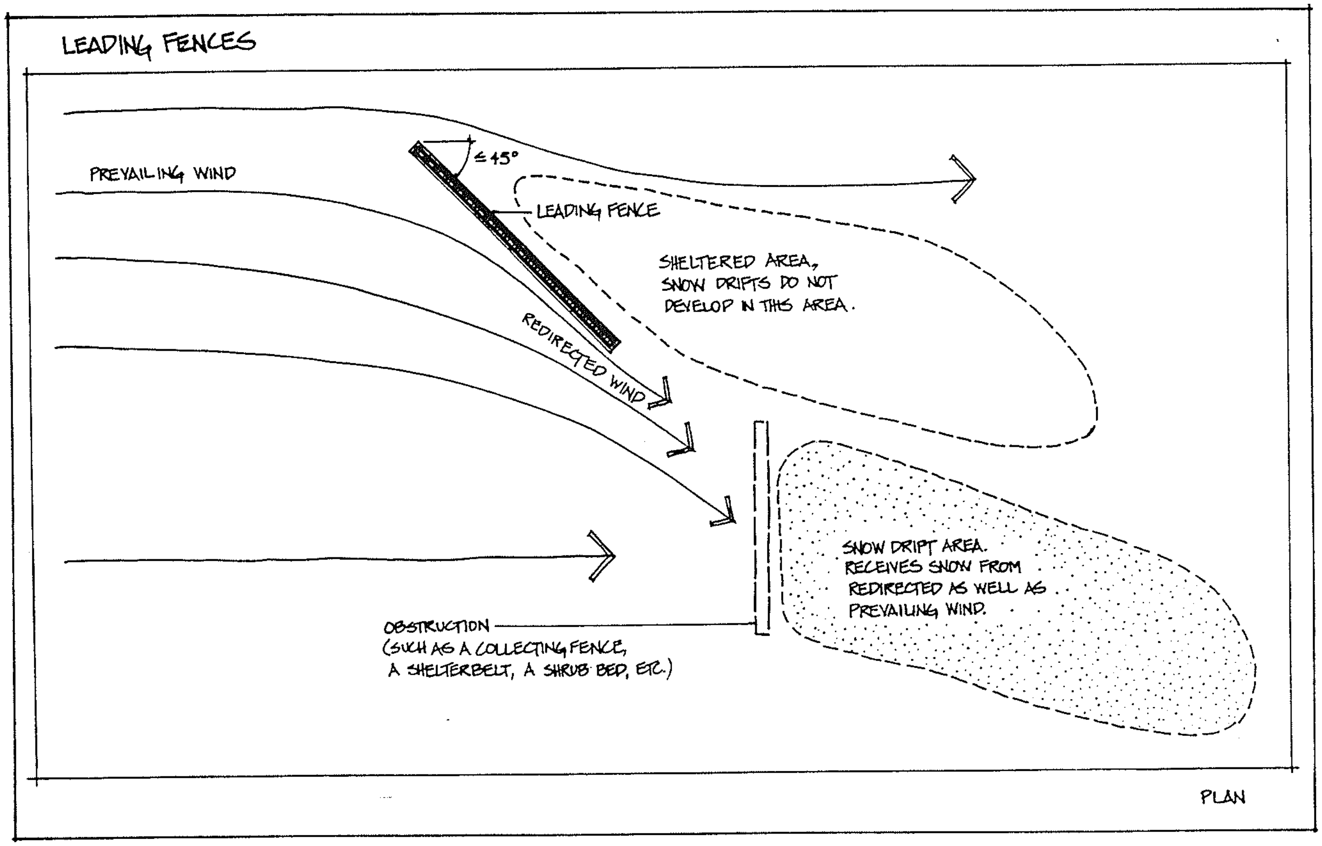


Figure 80
Leading Fences
Adapted from:
Gordon M. Heisler, and David R. DeWalle. "Effects of Windbreak Structure on Wind Flow" International Symposium on Windbreak Technology, Proceedings. Ed. David L. Hintz and James R. Brandle. Lincoln, Nebraska: Great Plains Agricultural Council Publication No. 117, June 23-27, p. 42.
H. Pugh and W. Price. "Snow Drifting and the Use of Snow Fences" The Polar Record. Vol. 7, No. 47, January 1954, p. 7.

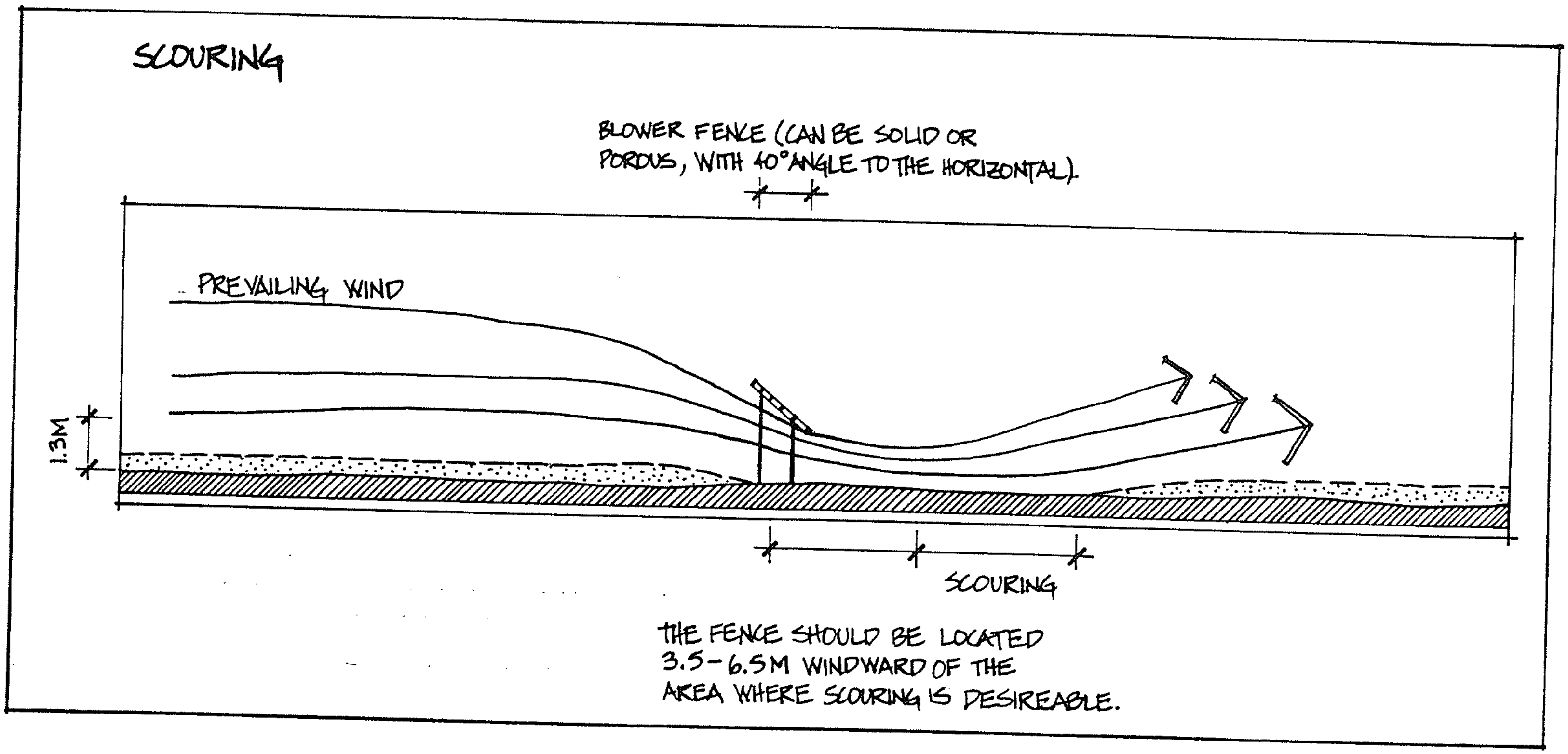


The effect of certain types of fences is to simply give the wind a bit of a push along the way. These types of fences are called *blower fences,* and rather than creating drifts, blower fences create scouring.[33] See figure 81. Blower fences are effective when the prevailing wind is consistently from the same direction. If the wind happens to come from the opposite direction, the opposite effect is achieved: snow collects in the area where scouring is desired.[34]

While the literature and research tends to concentrate on temporary snow fences, landscape architects need not be confined or restricted to these types of fences. For instance, a permanent wall which has a fifty percent porosity will create a similar drift to that created by a temporary snow fence with a fifty percent porosity. The critical factor is porosity, not the fencing material and permanence.

For additional information sources, consult the 'Fence and Wall References' section of the Appendix.

Figure 81
Blower Fences
Adapted from:
H. Pugh and W. Price. "Snow Drifting and the Use of Snow Fences" The Polar Record. Vol. 7, No. 47, January 1954, p. 8.



Topography

Snow collects around all kinds of earth forms and earthworks: berms, ditches, ravines, railway embankments, hills etc. The steepness of the slope, its height, and the orientation to the prevailing wind determine a drift's size and location. [35,36]

Different drifts are created by different slopes. See figure 82.

Generally, snow is blown off the windward slope and top of the berm (hill, embankment, etc.), and collects on the leeward slope. Depressions such as ravines and ditches tend to collect snow and can eventually become entirely covered over.[37] See figure 83.

Depressions which are less than 6 m deep and embankments which are less than 0.6 m high are the most susceptible to drift formation. Depressions which are deeper than 8.5 m and embankments higher than 1 m are the least susceptible to drifting.[38] See figure 84.

In large areas, a series of berms can be used to give an interesting rhythmic effect. Theakston suggests that berms be about 3 m high and be spaced about 10.5 m apart.[39] See figure 85. Varying the berm height and spacing could result in some wonderful rhythmic variations.

For additional information sources, consult the 'Topography References' section of the Appendix.

Figure 82
Different Drift Forms are Created by Different Slopes
Environmental Controls Course Notes, Faculty of Architecture, University of Manitoba, Winnipeg, Winter Session, 1988.

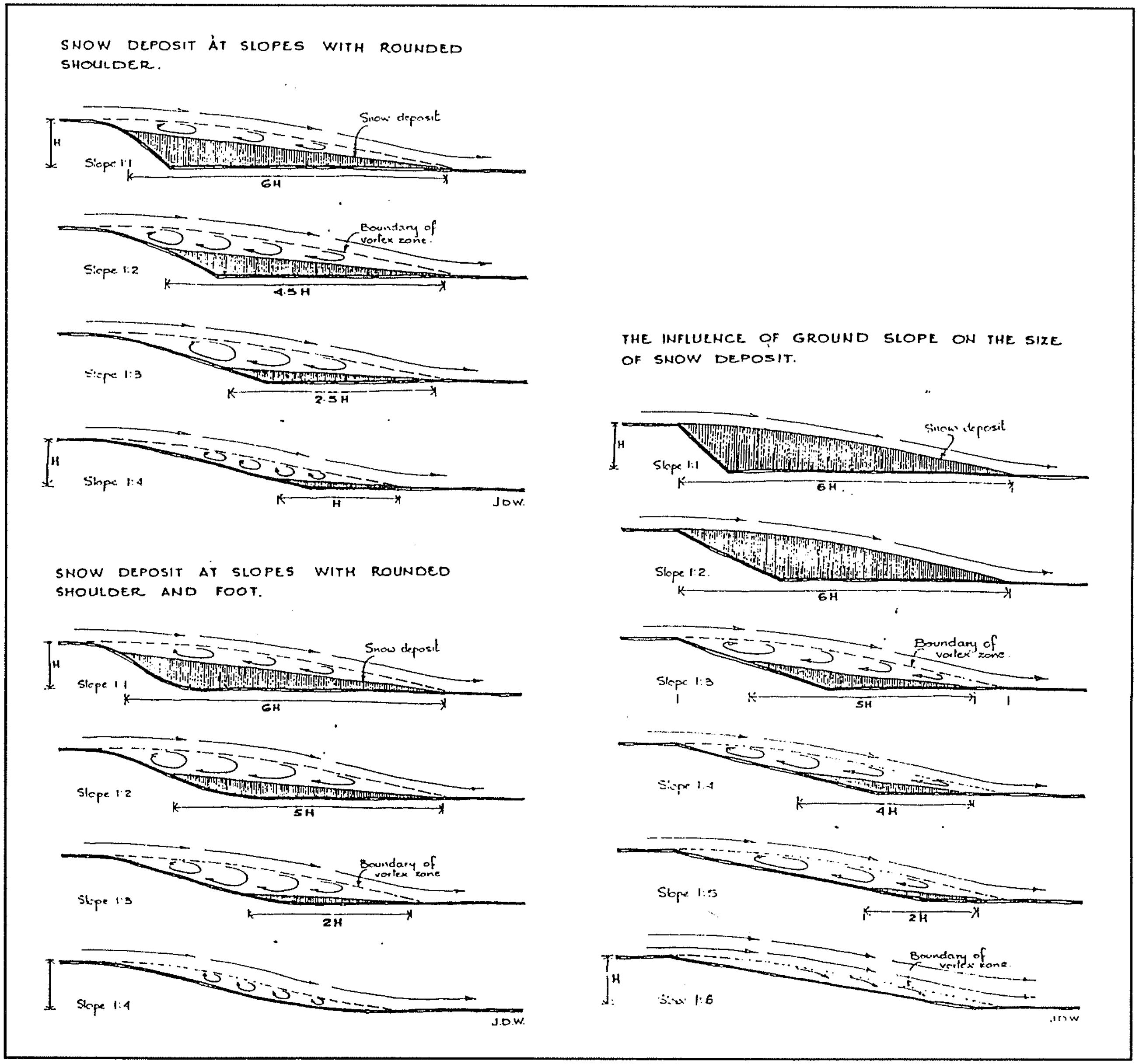


Figure 83
Different Drift Forms are Created by Different Slopes
G.D. Rikhter. Snow Cover, Its Formation and Properties. Moscow: Publishing House of the Academy of Science, 1954, pp. 15-17.

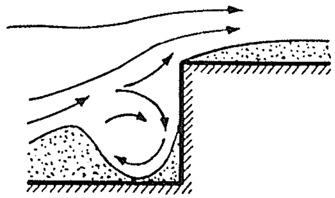


Figure 1. Accumulation of Snow at a Sheer Wall Facing the Wind

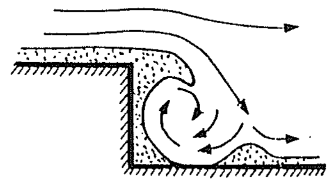


Figure 2. Accumulation of Snow at a Sheer Wall Facing Away from the Wind

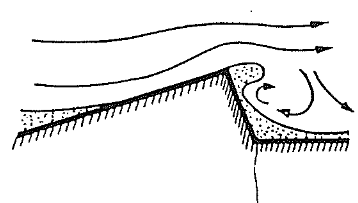


Figure 5. Accumulation of Snow around a Narrow Ridge with Gradual Windward Slope and a Steep Leeward Slope

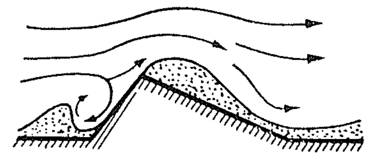


Figure 6. Accumulation of Snow around a Narrow Ridge with a Steep Windward Slope and a Gradual Leeward Slope

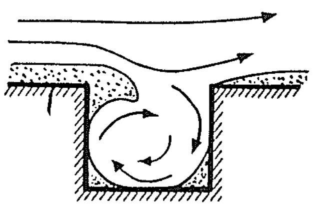


Figure 3. Accumulation of Snow in a Ditch with Sheer Sides

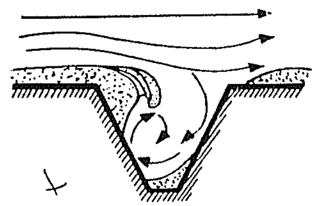


Figure 4. Accumulation of Snow in a Ditch with Sloping Sides

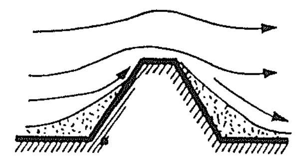


Figure 7. Accumulation of Snow around a Low Ridge of Symmetrical Slope

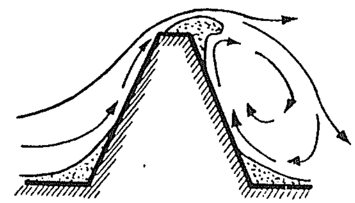


Figure 8. Accumulation of Snow around a High Ridge of Symmetrical Slope

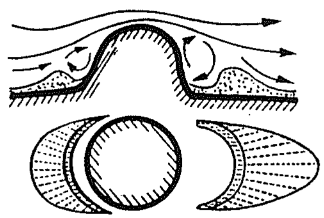
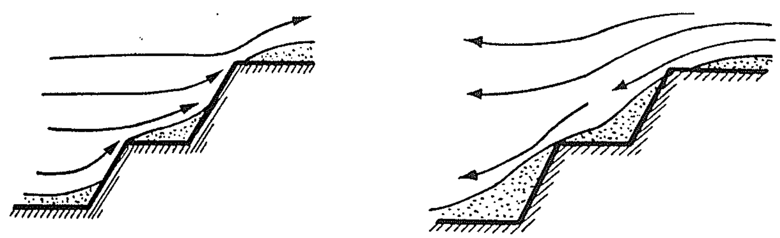


Figure 9. Accumulation of Snow around an Isolated Elevation



Figures 10 and 11. Accumulation of Snow on a Terraced Slope

Figure 84
Depressions and Embankments Most and Least Susceptible to Drift Formation
G.D. Rikhter. Snow Cover, Its Formation and Properties. Moscow: Publishing House of the Academy of Science, 1954, p. 17.

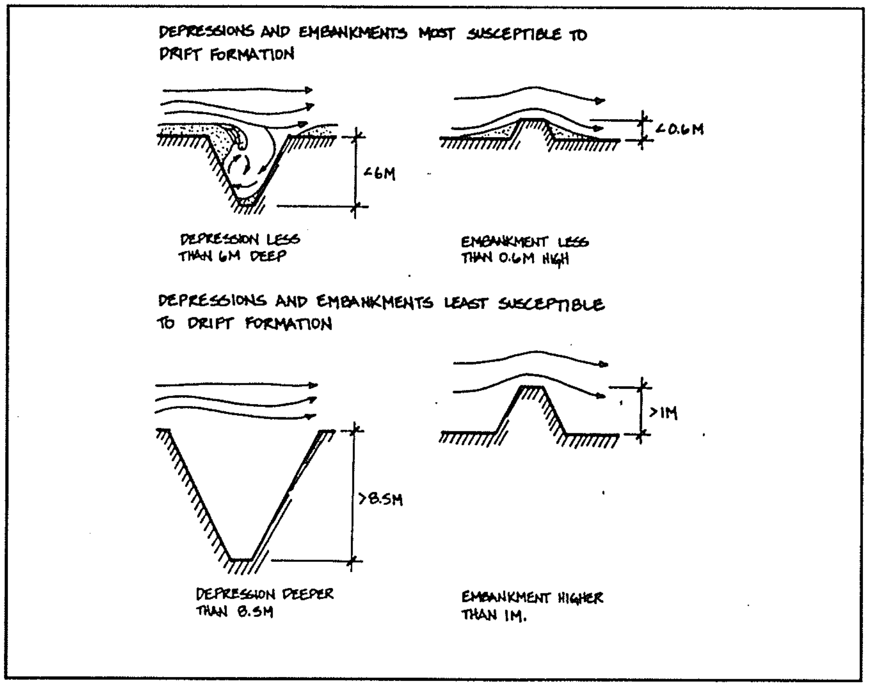
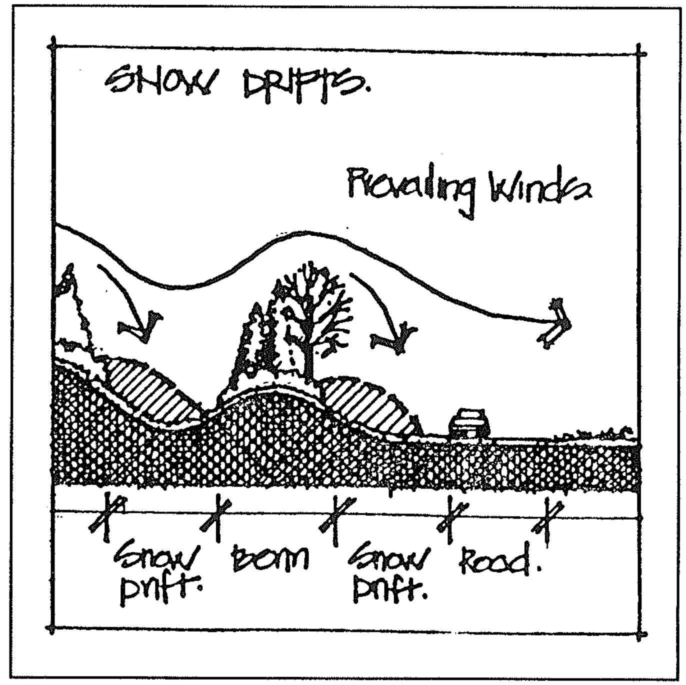


Figure 85
Berm Location to Encourage Drift Formation
Michael Hough et. al. Winter Cities Design Manual. Sault Ste. Marie: Hough Stansbury Woodland Limited, 1991, p. 58.



Combining Vegetation and Topography

A combination of earth berms and shelterbelts have been successfully used to create drifts on the perimeter of a parking lot at Wascana Centre in Regina.[40] See figure 86.

Hough suggests a similar configuration for sidewalks.[41] See figure 87.

While the intent in both of these examples is to keep the parking lot and sidewalk clear of snowdrifts, planning for a drift to develop and allowing it the space to do so is an opportunity for passersby to enjoy the form, shadows, texture, and rhythm of the drift without being inconvenienced by it.

Hough further suggests that "setbacks" be incorporated so as to protect vegetation from the detrimental effects associated with snow clearing, as well as provide space to store the snow.[42] See figure 88. Let's take another step: if we are willing to allow space for piles of plowed up snow, are we also willing to allow that same space for snowdrifts to develop in? Wouldn't we rather surround ourselves with sculpture rather than functional storage containers?

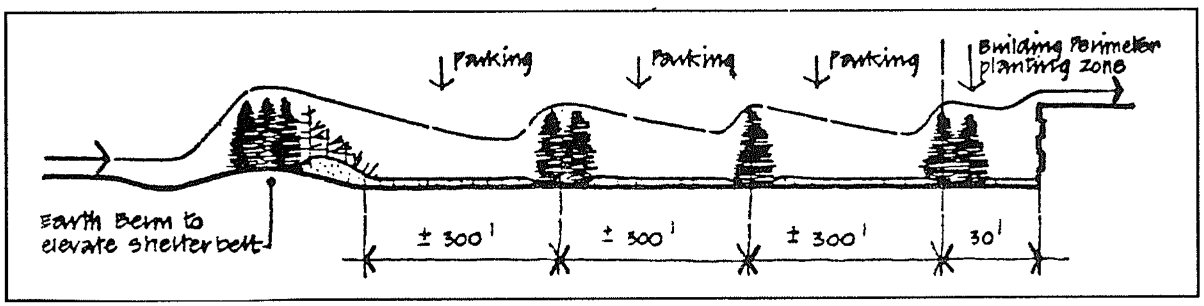


Figure 86
Combining Berms and Shelterbelts to Create Drifts on the Perimeter of a Parking Lot
Roger du Toit. "Livable Winter Cities" Livable Winter Newsletter. Vol. 3, No. 6, December 1985, p. 9.

Figure 87
Combining Berms and Shelterbelts to Create Drifts Beside a Sidewalk
Michael Hough et. al. Winter Cities Design Manual. Sault Ste. Marie: Hough Stansbury Woodland Limited, 1991, p. 41.

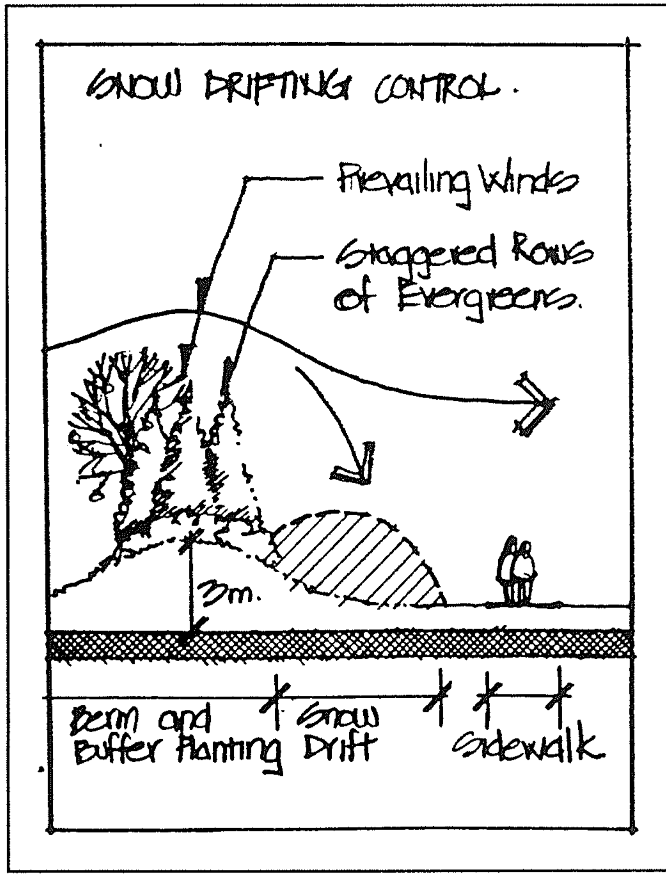
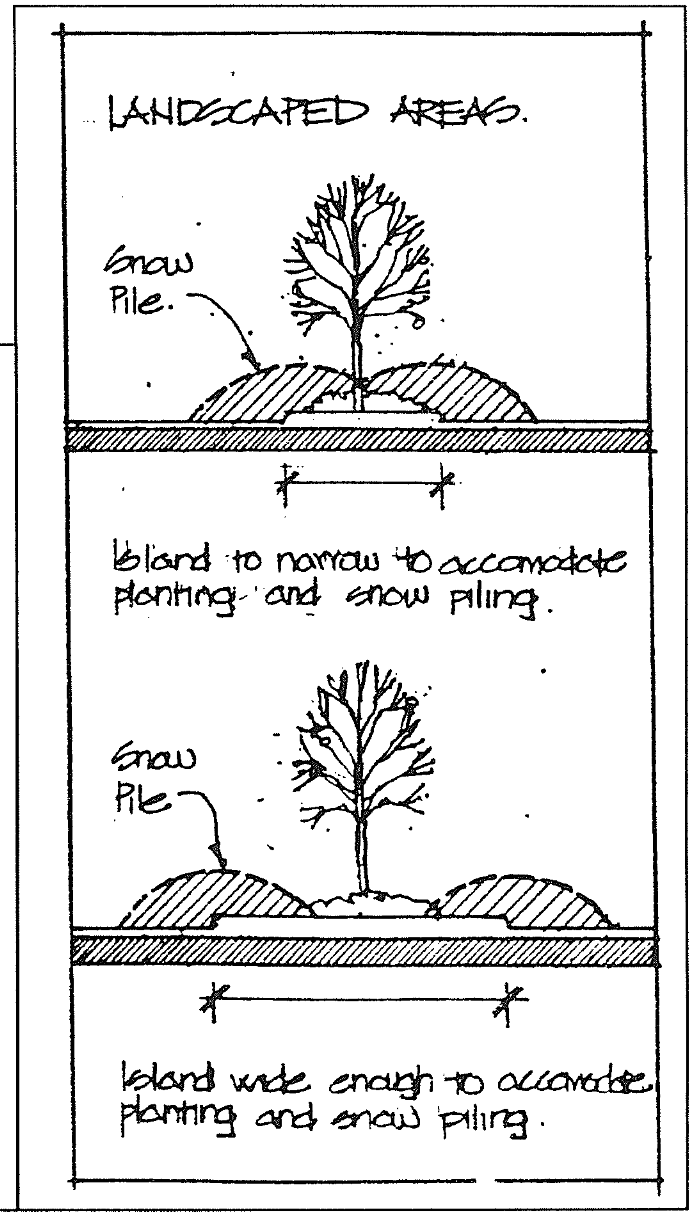


Figure 88
"Setbacks'" to Protect Vegetation and Provide Snow Storage Space
Michael Hough et. al. Winter Cities Design Manual. Sault Ste. Marie: Hough Stansbury Woodland Limited, 1991, p. 42.



Combining Fences and Topography

The drift form that results from fences which are located on relatively shallow slopes (less than 15 percent) is much the same as that which develops on level ground.[43] See figure 89.

The drift formed on the windward side of the fence is most affected by topography. When the fence is located on the windward side or on the top of an embankment, the windward drift is very small. See figure 89. When the fence is located on the leeward side of the embankment, the windward drift is much larger. Fences in this location tend to become buried in the snowdrift.[44,45] See figure 89.

Depressions located on the leeward side of a fence tend to fill in. The resultant drift form is the same as that which develops on level ground.[46] See figure 89. Snowdrifts grow into embankments located on the leeward side of a fence.[47] The drift and embankment together form an interesting undulating pattern. See figure 89.

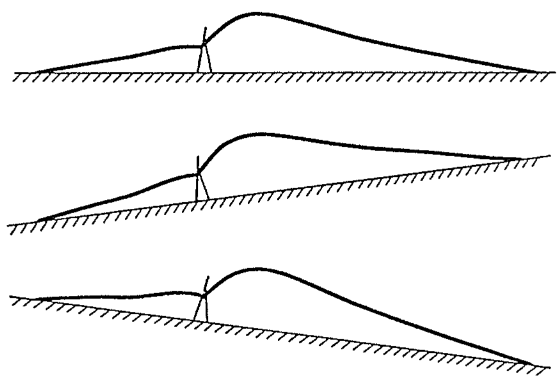
Locating a fence on the top of an embankment creates a much larger leeward drift.[48] See figure 89.

Figure 89
Drift Formation as a Result of Combing Fences and Topography
Ronald D. Tabler. Snow Control Course Notes. Niwot, Colorado: Tabler & Associates, 1990, pp. 23, 24.

5.6 Effect of topography on equilibrium drift shape

6.6.1 Drift shape is affected by the topography both upwind and downwind of a fence.

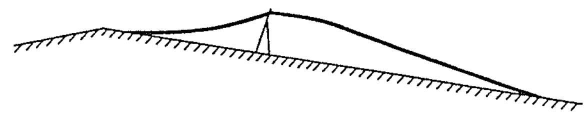
6.6.2 On long, uniform slopes of less than 15%, either upward or downward with respect to the prevailing wind, drift shape will be the same as on level terrain.



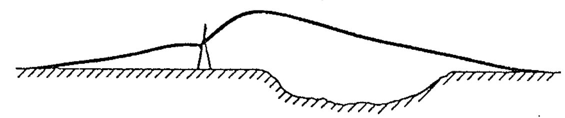
6.6.3 Drifts formed by fences on steep windward-facing slopes, such as fill slopes and embankments, are shaped as though the wind were horizontal rather than parallel to the slope.

6.6.4 The windward drift is very sensitive to topography. Only very small windward drifts form on hillcrests and windward facing slopes steeper than about 10%.

6.6.5 Windward drifts are deeper on slopes that are downward in the direction of the wind, causing a tendency for fences to become buried on slopes steeper than about 10%.



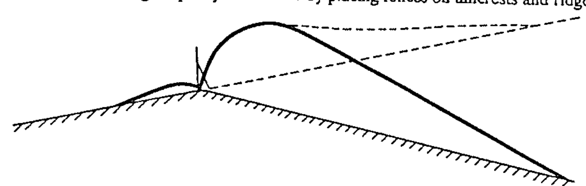
6.6.6 The surface of the equilibrium drift is not affected by topographic irregularities underneath the drift. As a result, depressions such as stream channels can greatly augment snow storage capacity, while mounds or hills reduce storage capacity.



6.6.7 Downward slopes on the lee side of a fence increase storage capacity (tentatively, a 15- 20% increase in capacity for each degree of slope).

6.6.8 Upward slopes in the approach zone increase snow storage capacity by increasing drift depth. As a tentative guide, effective fence height increases about 0.5 feet for each degree of slope, with proportionate increases in storage capacity and equilibrium drift length.

Maximum snow storage capacity is achieved by placing fences on hillcrests and ridgetops.



6.6.9 Upslopes and hills in the exhaust zone generally decrease fence capacity, except as otherwise noted.

6.7 References: Finney (1934); Martinelli (1964); Tabler (1974, 1980a, 1980b, 1985, 1988b, 1989); Tabler and Schmidt (1986); Tabler, Pomeroy, and Santana (1990).

Buildings

Similar building forms create similar drift forms. Generally, a drift which can be large, develops on the leeward side of the building. Scouring clears away most of the snow on the windward side of the building and extends in a horseshoe-like form around the sides of the building. Occasionally, a drift also develops on the windward side.[49,50,51,52]

Drifting and scouring patterns depend on the height of the building and its orientation to the wind, and as well on the length and width of the building and the pitch of the roof.[53] See figures 90 - 91.

For additional information sources, consult the 'Building References' section of the Appendix.

Figure 90
Snowdrift Patterns as a Result of Building Form and Wind Orientation
Richard C. Spears. Appendix A. Preliminary Work Toward Building Form Siting and Orientation in Subarctic Climates. Winnipeg: Centre for Settlement Studies, 1976.

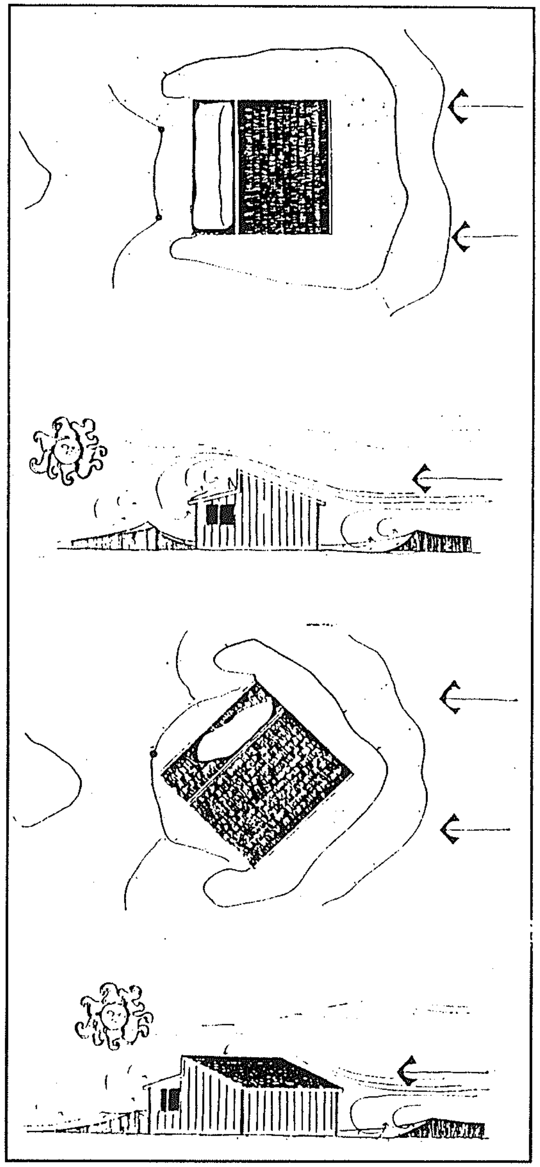


Figure 90 (con't). Snowdrift Patterns as a Result of Building Form and Wind Orientation. Richard C. Spears.

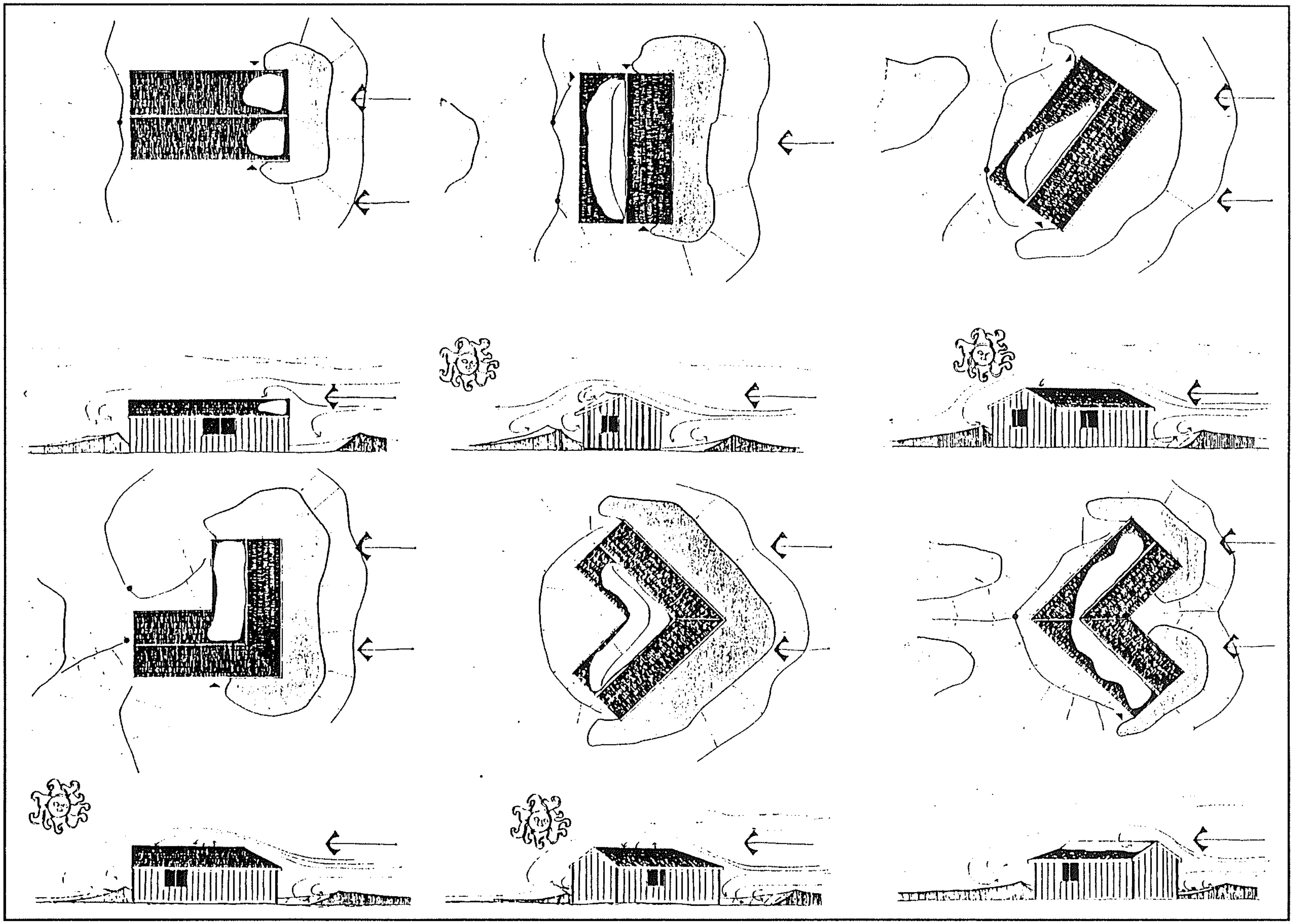


Figure 90 (con't). Snowdrift Patterns as a Result of Building Form and Wind Orientation. Richard C. Spears.

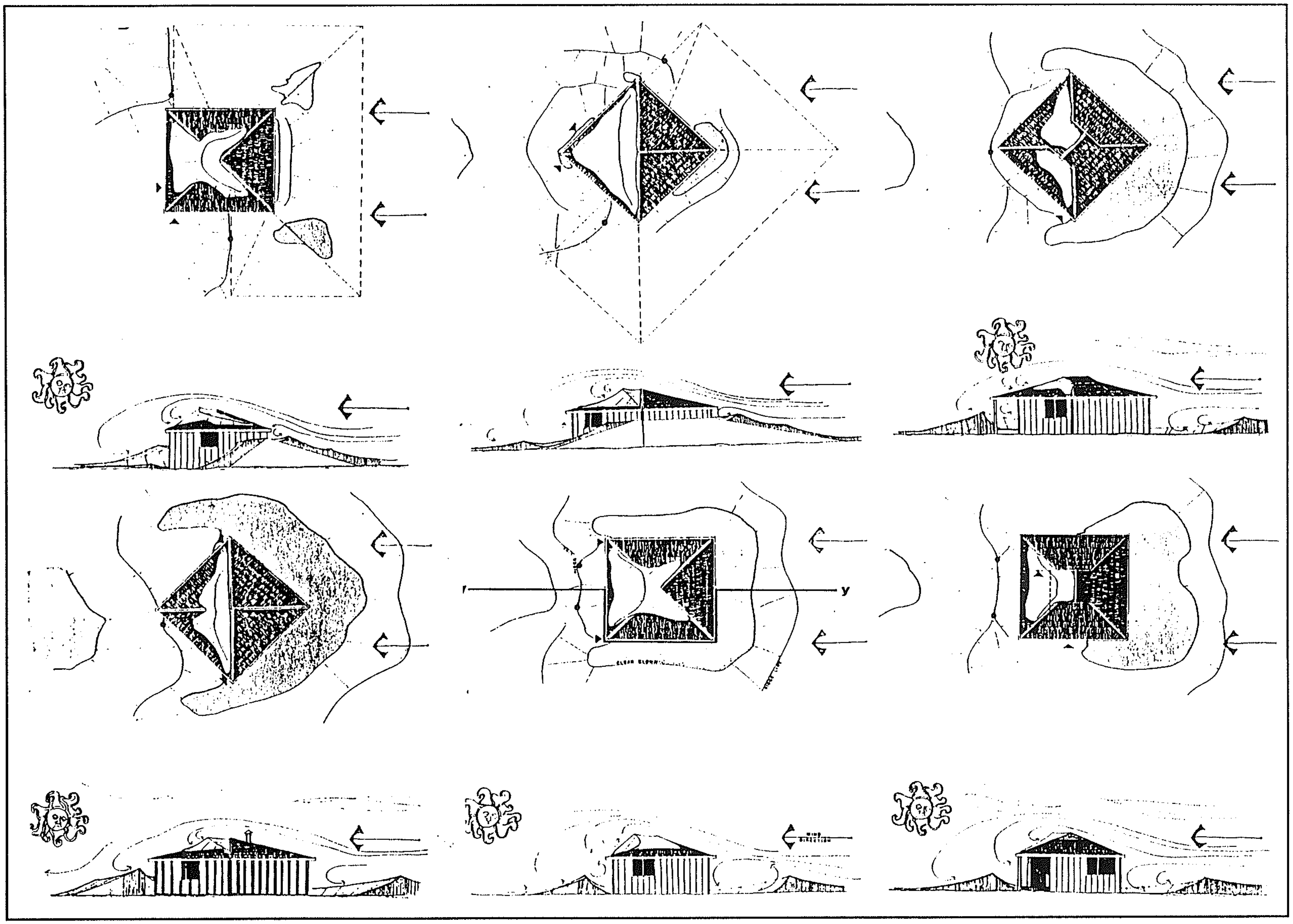
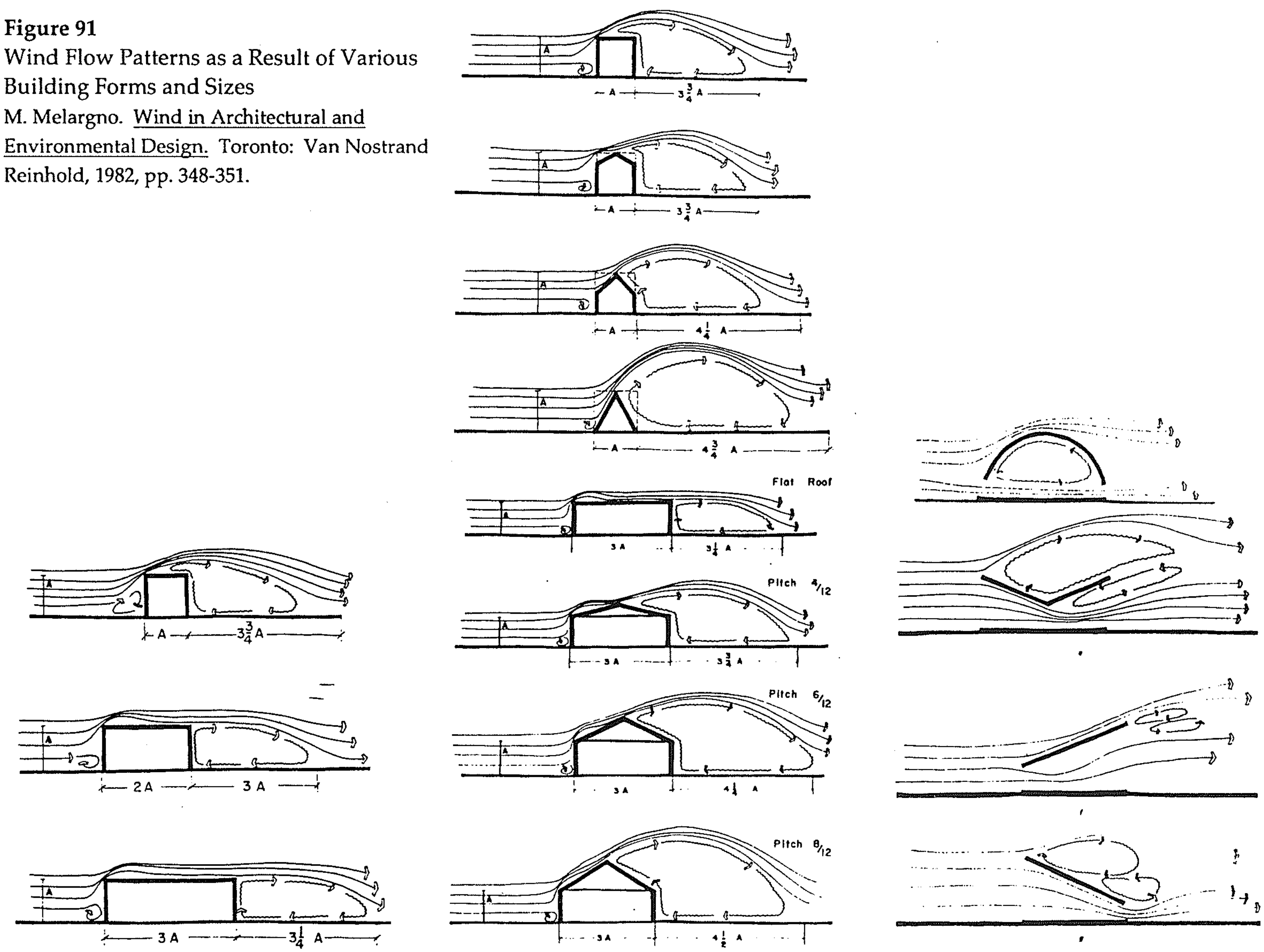


Figure 91
Wind Flow Patterns as a Result of Various Building Forms and Sizes
M. Melargno. Wind in Architectural and Environmental Design. Toronto: Van Nostrand Reinhold, 1982, pp. 348-351.



FORMS THAT RESULT FROM SURFACE IRREGULARITIES

Large open areas are rarely uniformly smooth. Their "irregularities" give rise to various patterns which are the combined effects of both deposition and erosion. While exact detailing varies, there are general repeating patterns which develop under specific weather conditions.[54]

Dunes tend to form during blizzards. They are large (10-100 m long and 0.5-2 m high), with their long axis flowing with the wind, and have a smooth rounded form.[55] See figure 92.

Sastrugi tend to form during low dry windstorms. They are 1-2 m long and 10-15 cm high, and also orient their long axis to flow with the wind. They have a very sharp sculpted, undulating form.[56] See figure 93.

Figure 92
"Snow dunes deposited on sea ice. This air photo covers an area 3.3 km square. Winds generally from lower left."
Malcolm Mellor. "Blowing Snow" Cold Regions Science and Engineering Part III, Section A3c. Hanover, New Hampshire: Cold Regions Research & Engineering Laboratory, November 1965, fig. 20.

Figure 93
"Sastrugi. A strongly elongated type."
Malcolm Mellor. "Blowing Snow" Cold Regions Science and Engineering Part III, Section A3c. Hanover, New Hampshire: Cold Regions Research & Engineering Laboratory, November 1965, fig. 21(a).

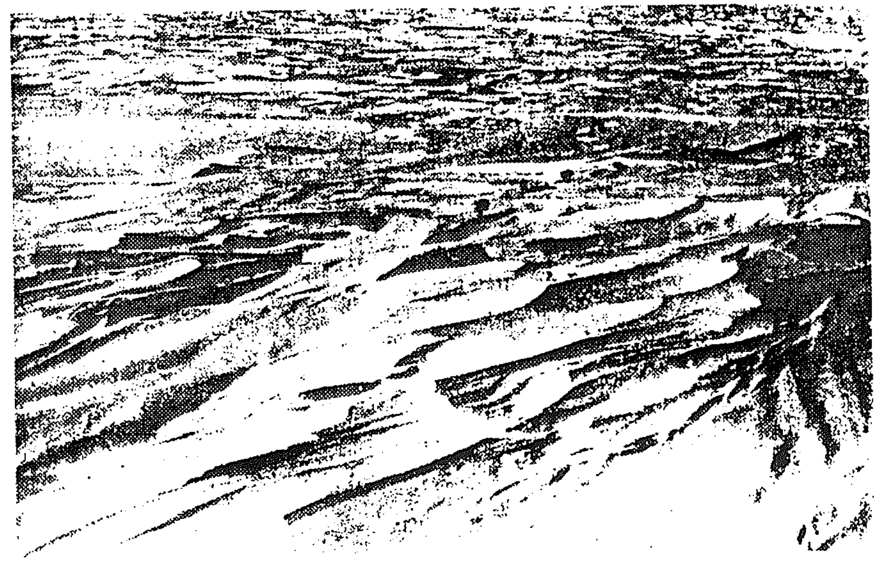
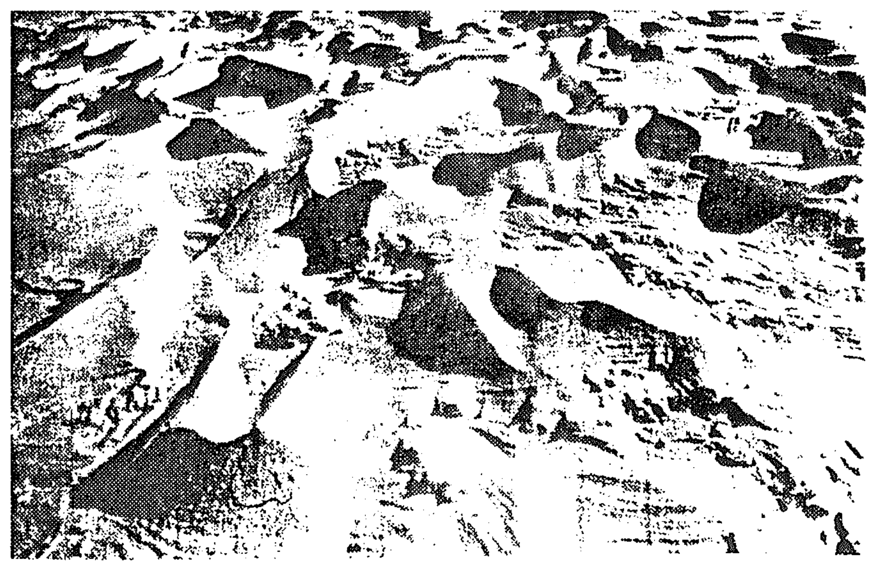


Figure 93 (con't)
"Sastrugi."
Malcolm Mellor. "Blowing Snow" Cold Regions Science and Engineering Part III, Section A3c. Hanover, New Hampshire: Cold Regions Research & Engineering Laboratory, November 1965, fig. 21(c).



Barchans are thought to be a transitional form between sastrugi and waves or ripples. They develop when granular or powdery snow falls on a smooth solid crust They are about 2 m long and form with their long axis against the flow of the wind. From above, barchans look like crescents or giant boomerangs.[57,58] See figure 94.

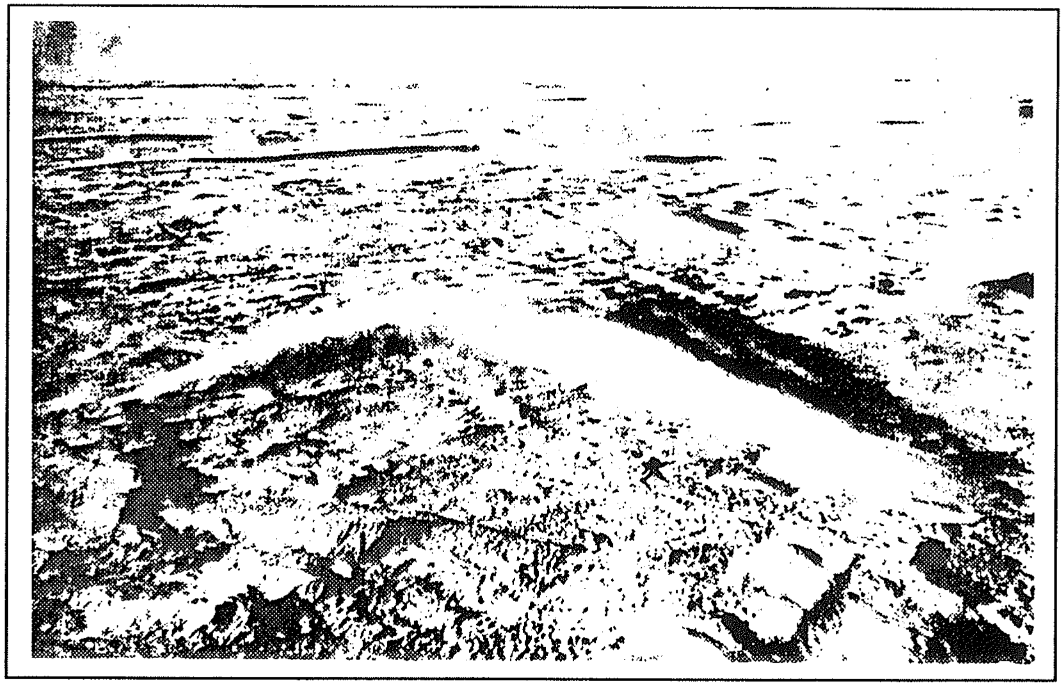


Figure 94
"Snow barchan."
Malcolm Mellor. "Blowing Snow" Cold Regions Science and Engineering Part III, Section A3c. Hanover, New Hampshire: Cold Regions Research & Engineering Laboratory, November 1965, fig. 22.

Waves tend to form in cold, very windy weather. They are 5-10 m long, 10-20 cm high and orient their long axis at right angles to the wind flow.[59]

Ripples are a smaller version of waves. They are 10-40 cm long, 1-2 cm high and tend to form in cold weather when winds are light. Their long axes flow against the wind direction. They have a subtle rounded undulating form[60] which is very similar to fine grained sand. See figures 95, 96.

Figure 95
"Transverse ripples on the snow."
Malcolm Mellor. "Blowing Snow" Cold Regions Science and Engineering Part III, Section A3c. Hanover, New Hampshire: Cold Regions Research & Engineering Laboratory, November 1965, fig. 23.

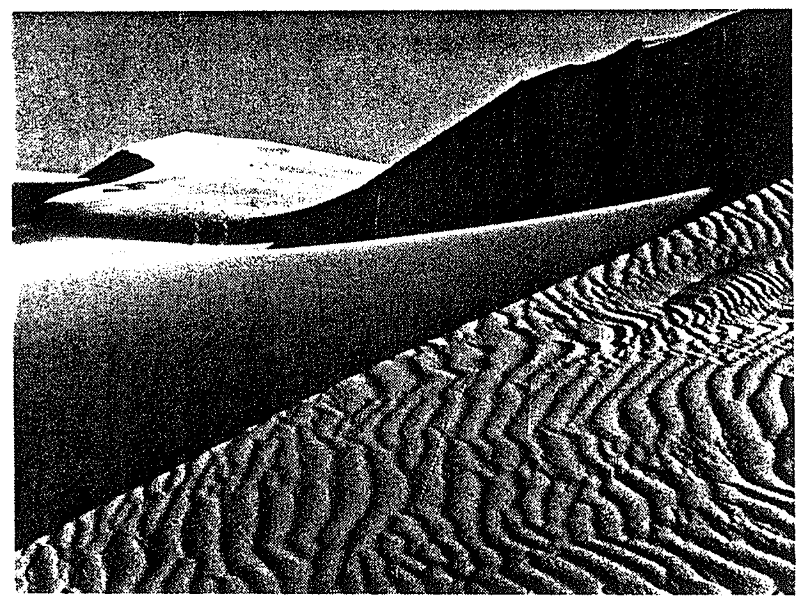


Figure 96
Sand Ripples
photograph by Ansel Adams. Dunes, Oceano, California: Museum Graphics, 1963

REFERENCES:

[1]Mellor, p. 30

[2]It is important to note that all of the following data regarding snowdrifts is based on one obstacle being tested in an open field.

[3]Interview with John Welch, Professor of Environmental Studies, Faculty of Architecture, University of Manitoba, Winnipeg, January, 1992.

[4]"Planning Farm Shelterbelts," Prairie Farm Rehabilitation Administration, (Indian Head, Saskatchewan), p.1.

[5]Read, pp. 27-28.

[6]Rikhter, p. 17.

[7]Gordon M. Heisler and David R. DeWalle, "Effects of Windbreak Structure on Wind Flow," in International Symposium on Windbreak Technology, Proceedings, ed. David L. Hintz and James R. Brandle, (Lincoln, Nebraska: Great Plains Agricultural Council Publication No. 117, June 23-27), p. 42.

[8]Read, pp. 27-28.

[9]Read, p. 15.

[10]Pugh and Price, p. 7.

[11]D.G. Pitt, J. Kissida, and W. Gould, Jr., "How to Design a Windbreak," American Nurseryman, (November 15, 1980) p. 50.

[12]M. Melargno, Wind in Architectural and Environmental Design (Toronto: Van Nostrand Reinhold, 1982), pp. 459-460.

[13]Melargno, p. 380.

[14]Read, p. 4.

[15]Jack Royle, "Frank Theakston's thirty-year search for the secrets of wind, snow and sun," in Winter Cities News, Vol. 6, No. 1, p. 6.

[16]Melargno, pp. 375, 377.

[17]Tabler, Snow Control Course Notes, p. 22.

[18]Melargno, p. 379.

[19]Rikhter, p. 21.

[20]Read, p. 4.

[21]Robinette, Plants, People and Environmental Quality, p. 91.

[22]Tabler, Snow Control Course Notes, p. 18.

[23]Read, p. 4.

[24]Robinette, p. 91.

[25]Read, p. 4.

[26]Robinette, p. 91.

[27]Tabler, Snow Control Course Notes, p. 19.

[28]Pugh and Price, p. 9.

[29]Read, p. 4.

[30]Tabler, Snow Control Course Notes, p. 18.

[31]Tabler, Snow Control Course Notes, p. 22.

[32]Pugh and Price, p. 7.

[33]Pugh and Price, p. 8.

[34]Pugh and Price, p. 8.

[35]Rikhter, pp. 14-15.

[36]Tabler, Snow Control Course Notes, p. 23-24.

[37]Rikhter, p. 15.

[38]Rikhter, p. 17.

[39]Royle, p. 6.

[40]Roger du Toit, "Livable Winter Cities," Livable Winter Newsletter Vol. 3, No. 6, (December 1985), p. 9.

[41]Hough, p.41.

[42]Hough, pp. 42, 58.

[43]Tabler, Snow Control Course Notes, p. 23.

[44]Tabler, Snow Control Course Notes, p. 23.

[45]Tabler, Snow Control Course Notes, p. 23.

[45]Tabler, Snow Control Course Notes, p. 23.

[46]Tabler, Snow Control Course Notes, p. 24.

[47]Tabler, Snow Control Course Notes, p. 24.

[48]Richard C. Spears, Preliminary Work Toward Building Form Siting and Orientation in Subarctic Climates, (Winnipeg: Centre for Settlement Studies, 1976), Appendix A.

[49] Irwin and Williams, p. 7.

[50]Melargno, p. 347.

[51]Vaughan Cornish, "On Snow-waves and Snow-drifts in Canada," The Geographical Journal, Vol. 20. No. 2, (August

1902), pp. 163-164.

[52]Melargno, p. 347.

[53]Mellor, pp. 23-30.

[54]Mellor, pp. 25-26.

[55]Mellor, pp. 25-28.

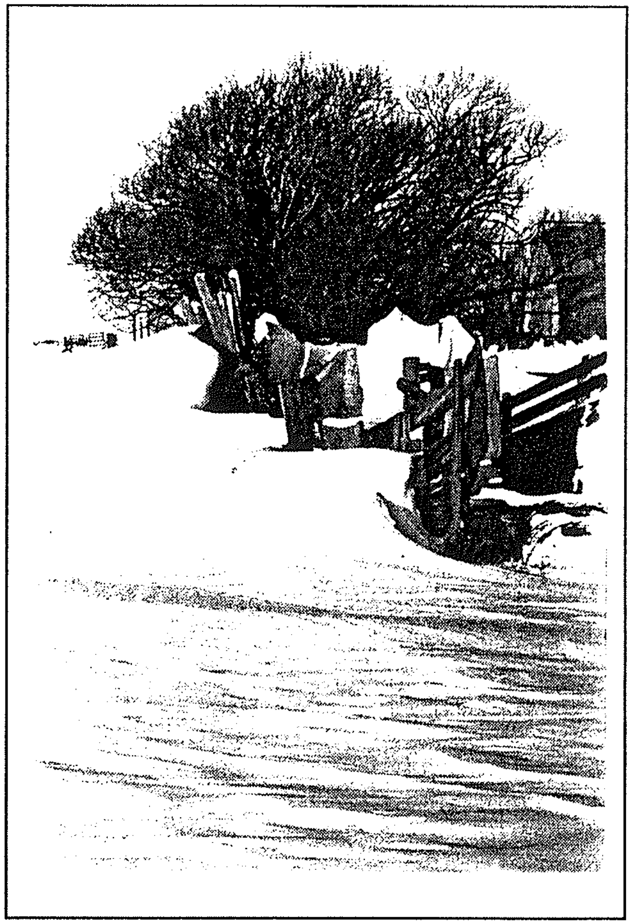
[56]Mellor, pp. 25-26,29.

[57]Rikhter, p. 21.

[58]Mellor, pp. 25-26.

[59]Mellor, pp. 25-26, 29.

the nature of snow and snowdrifts



Starbuck, Manitoba
February 11/92, 12:00 noon
-24° C. Wind NW at 4 km./hr.

THE NATURE OF SNOW AND SNOW-DRIFTS

"The frost patterns were not static but fluid in a way I had never imagined."[1]

"Nature's ice sculptures are living, changing things that are different and fascinating everyday."[2]

"And so the beauty of winter lies in never really quite knowing what will happen."[3]

Snowdrift patterns are predictable. Drifts, however are rarely a uniform featureless mass. While similar objects produce similar drifts, the specific form is unpredictable and infinitely varied in detailing.

This section is about the sculptural potential of snow. It is about the elusive nature of form and texture, about humor, about light, shadow, edge and art. It is about the unquantifiable - the details, the magic, the mystery.

Some of the following examples can be reproduced, some will happen year after year, and some are simply gifts. They all illustrate the possibilities that are associated with snow.

"One morning's frosty forms may evoke for her a seaside memory or the day in childhood when she watched a luna moth unfolding its wings for the very first time. In new mysteries, old mysteries may be recalled and cherished."[4]

RHYTHM

Drifts created by shelterbelts and snow fences tend to have a rhythmic undulating edge. Rhythm exists at many scales, and seems to be associated with scouring. See figures 97 - 101.

Figure 97
Rhythm in a Shelterbelt Drift
Portage la Prairie, Manitoba
February 23/91, 1:00 p.m.
-17° C. Wind N at 6 km./hr.

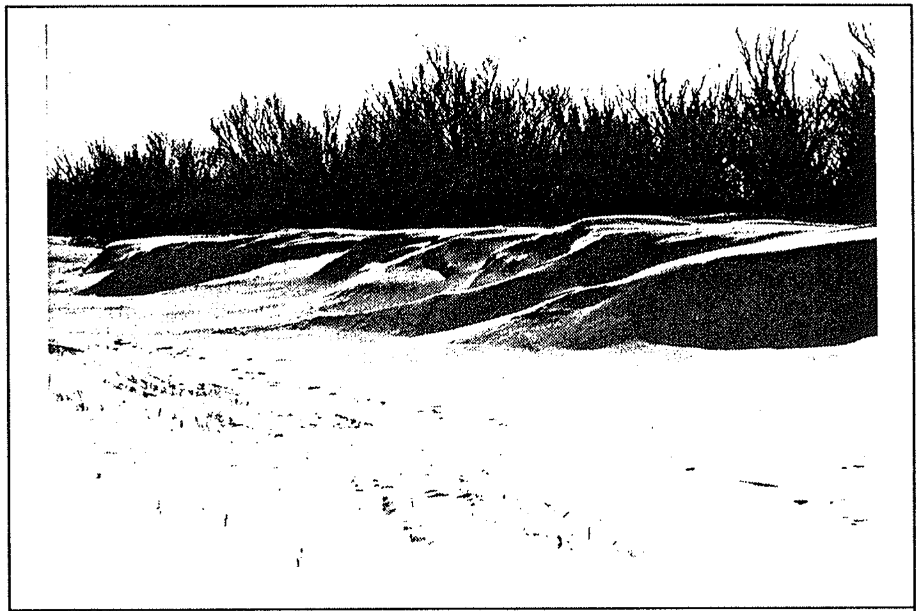
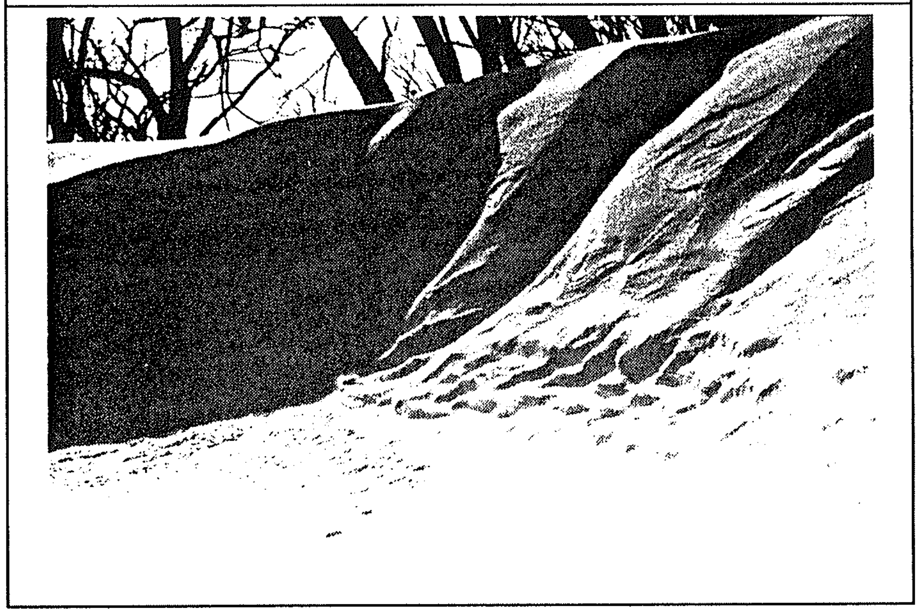


Figure 98
Variations on a Rhythm
Starbuck, Manitoba
February 11/92, 12:00 p.m.
-24° C. Wind N at 4 km./hr.



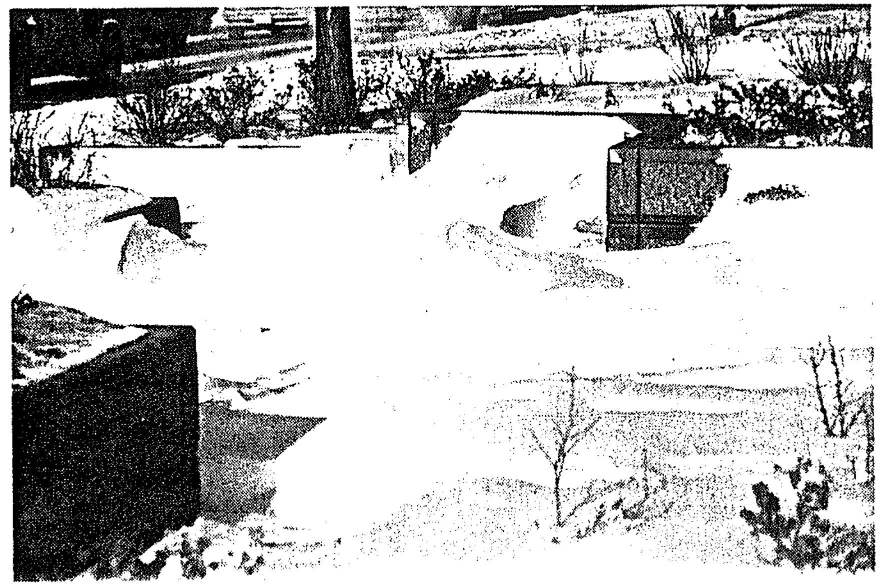


Figure 99
A wonderful swirl winds among and through these planter boxes
Winnipeg, Manitoba
January 23/91, 12:30 p.m.
-19° C. Wind NNW at 20 km./hr.

Figure 100
Plowing or shovelling snow into piles and then allowing the piles to create drifts is a very simple way of establishing rhythm. The size and spacing of the shovelled snow piles can be varied to suit the situation. As well, piles of wood, leaves, soil, gravel, even old cars can be used instead of snow. In this example, piles of snow have been used.
Starbuck, Manitoba
February 11/92, 3:30 p.m.
-21° C. Wind SW at 20 km./hr.

Figure 101
Timber piles located beside a shelterbelt create a dramatic drifting rhythm.
Winnipeg, Manitoba
1991

FOOTPRINTS

Snow is such a tattle tale. It tells of the short cut the paperboy takes through the yard. It tells that the owl is getting slow, that the raccoon is out and about, that the geese are back. Like the neighborhood gossip it keeps us informed about events that we may not have witnessed, but find interesting nonetheless. See figures 102 - 112.

Figure 102
Snow Prints of Snow
Starbuck, Manitoba
Fall, 1991
Photo by Mich'ele Ammeter

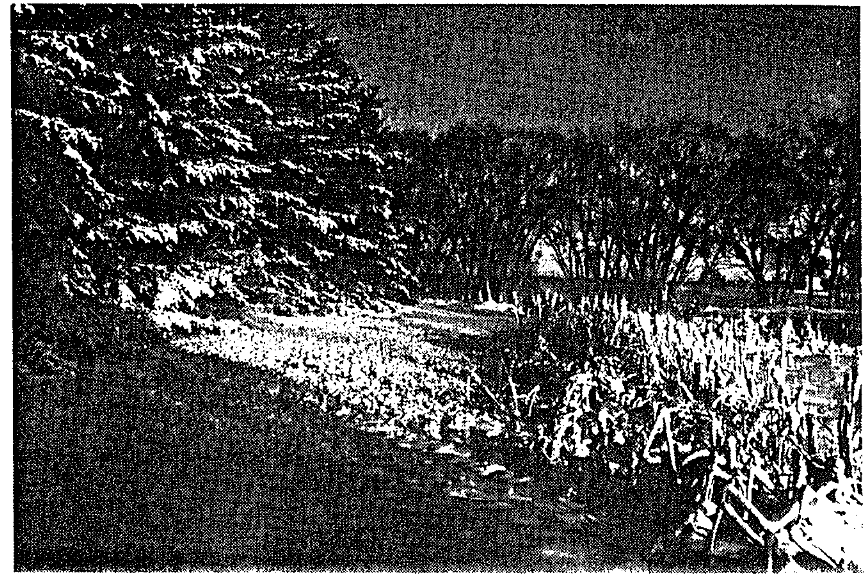


Figure 103
The Cat is Attacked
Starbuck, Manitoba
February 11/92, 12:00 noon

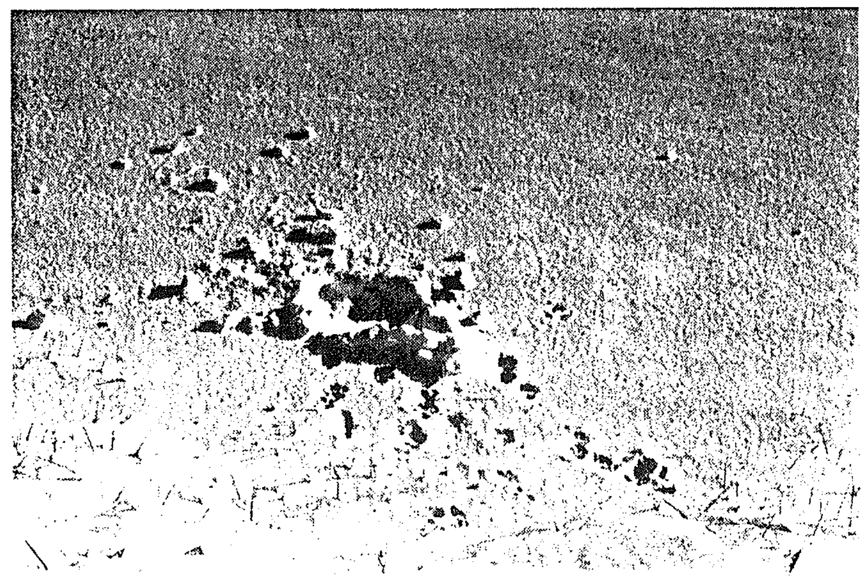


Figure 105
The Paperboy's Shortcut
Winnipeg, Manitoba
January 17/92, 11:30 a.m.

Figure 104
The Cat is Attacked Again
Starbuck, Manitoba
February 11/92, 3:00 p.m.

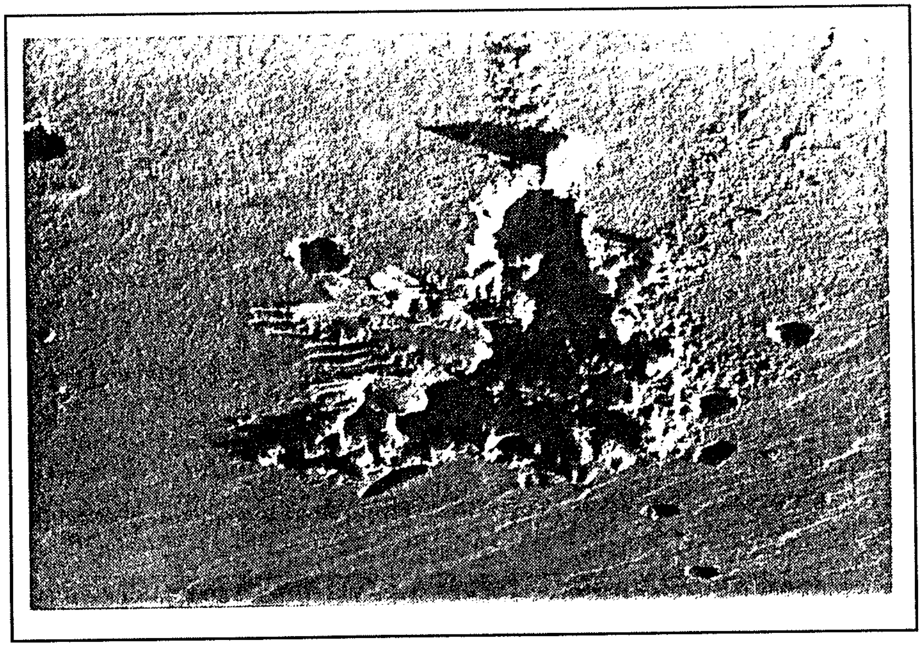


Figure 106
Bum Prints
Winnipeg, Manitoba
January 8/92, 9:30 a.m.

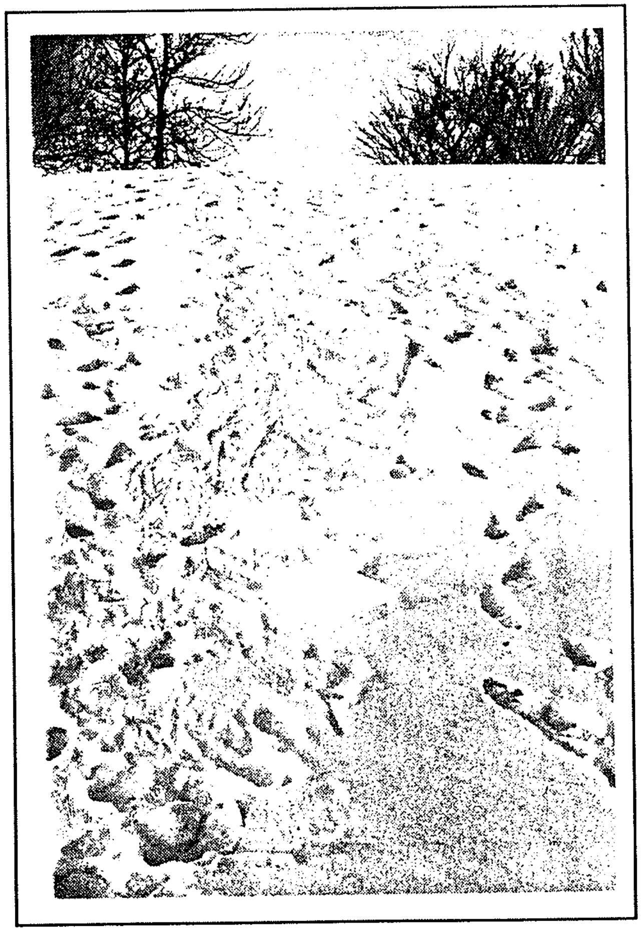


Figure 107
The Squirrel Party
Winnipeg, Manitoba
January 14/92, 12:30 p.m.

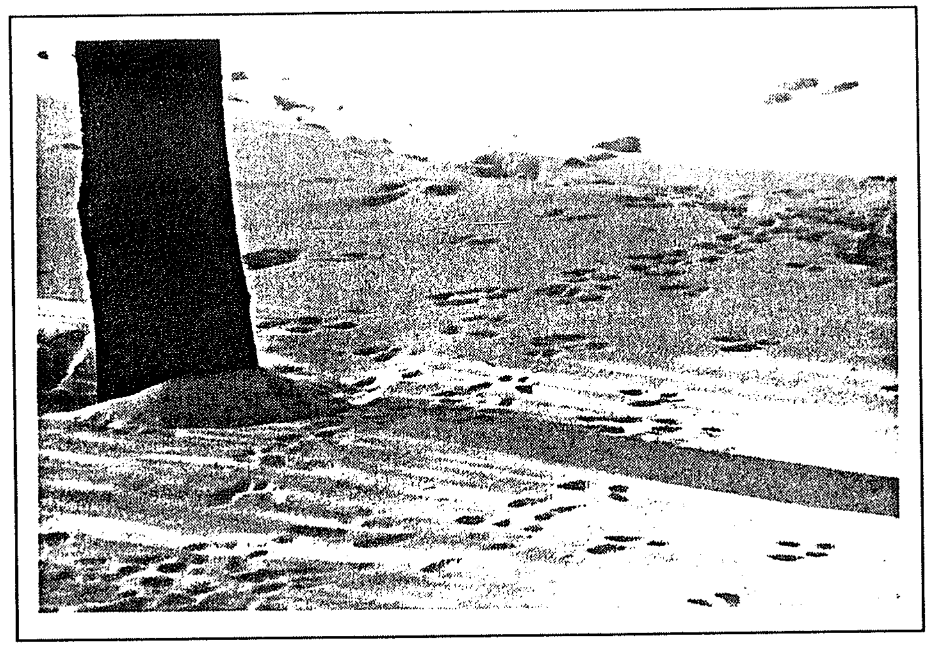


Figure 108
Sasquatch!
Delta, Manitoba
February 23/91

Figure 109
A Bird Walk
Winnipeg, Manitoba
Winter, 1992

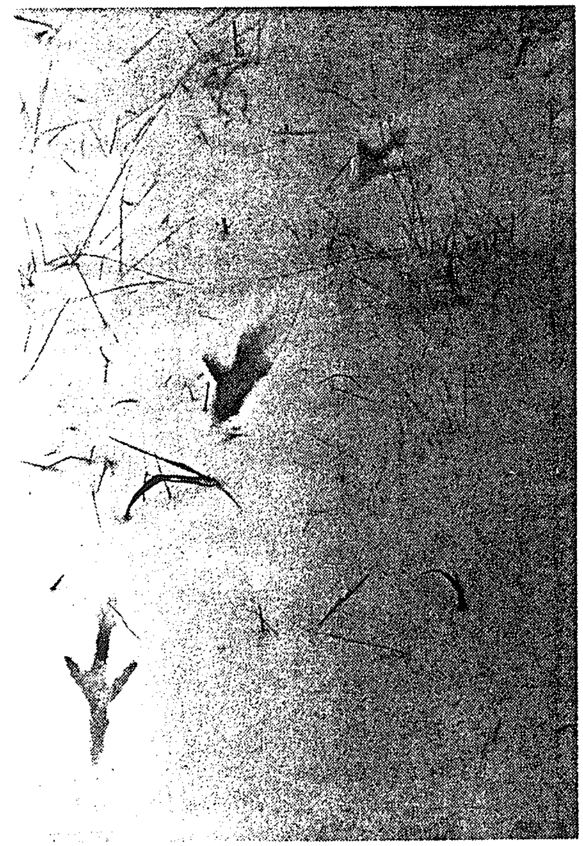


Figure 111
A Raccoon with Dirty Feet?!
Delta, Manitoba
March 21/92, 3:00 p.m.

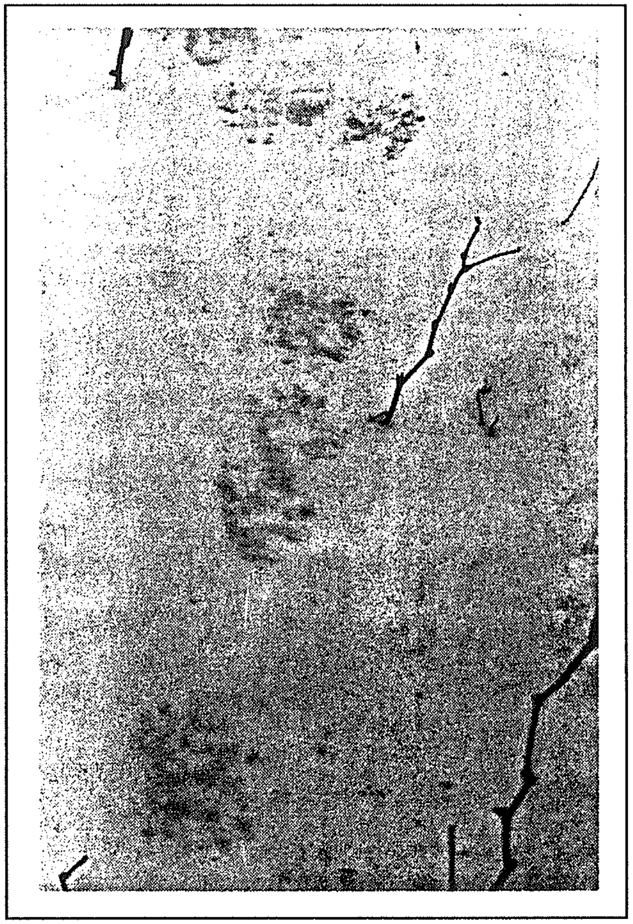


Figure 110
The Geese are Back
Delta, Manitoba
March 21/92, 3:30 p.m.

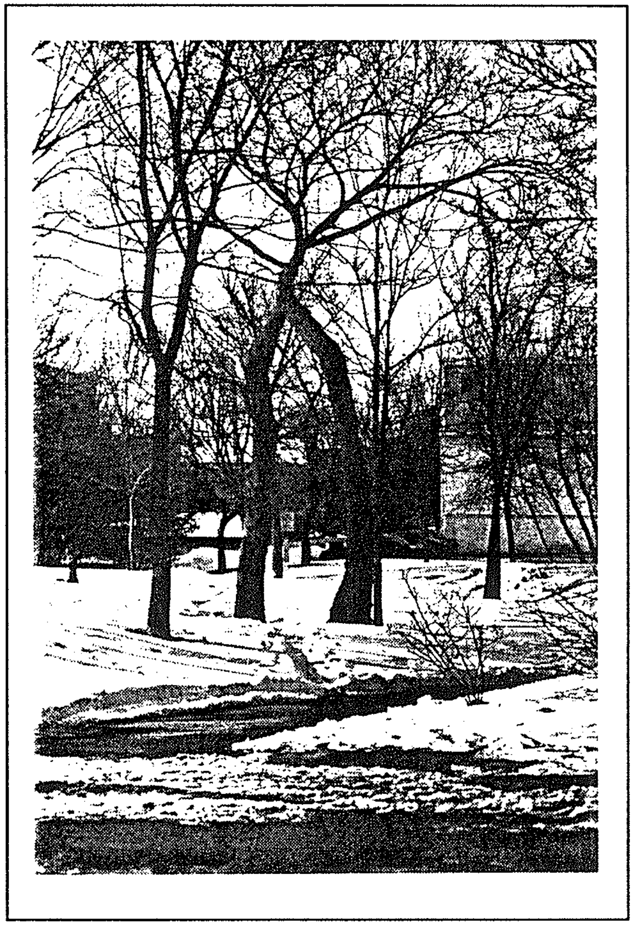


Figure 112
The trail leading to this piece of environmental art is an indication of its sucess.
Winnipeg, Manitoba
March 15/91, 4:00 p.m.

HUMOUR

Humour is probably one of the most elusive qualities of snow, yet given the length of winter, and all of its negative associations, it is perhaps one of the more important ones.

Snow can create humorous forms and set up funny scenes. It is also happy to conspire with other jokers. Many a statue has maintained a philosophical, loving, or stern expression while concealing a snowball behind its back. See figures 113 - 117.

"Sparrows and Camellia in Snow" Hiroshige: Birds and Flowers New York: George Braziller Inc., 1988, plate 11.

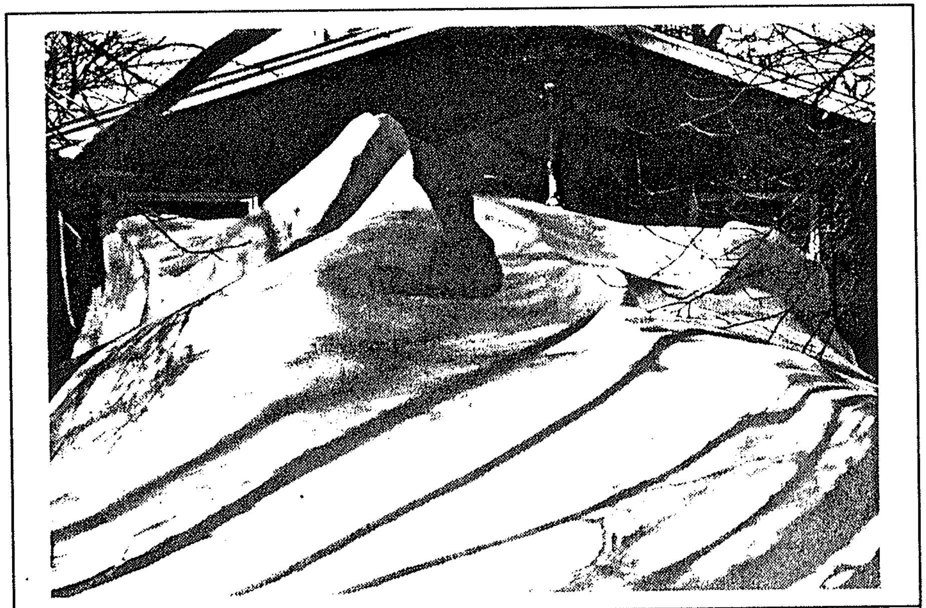


Figure 113
The rest of this cottage's face has emerged to guard against intruders while its owners are away for the winter. And if that's not deterrent enough, it is physically blocking the door.
Delta, Manitoba
February 23/91, 2:00 p.m.
-17° C. Wind N at 6 km./hr.

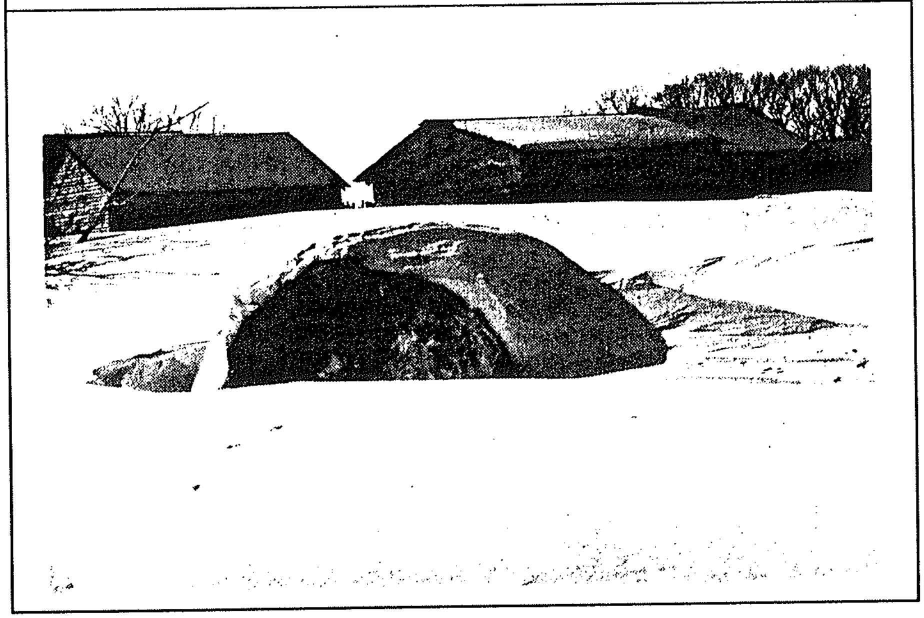


Figure 114
Babushka
Starbuck, Manitoba
February 11/92, 12:00 noon
-24° C. Wind NW at 4 km./hr.

Figure 115
Why Not?
Delta, Manitoba
March 21/92, 2:00 p.m.
-3° C. Wind WSW at 7 km./hr.

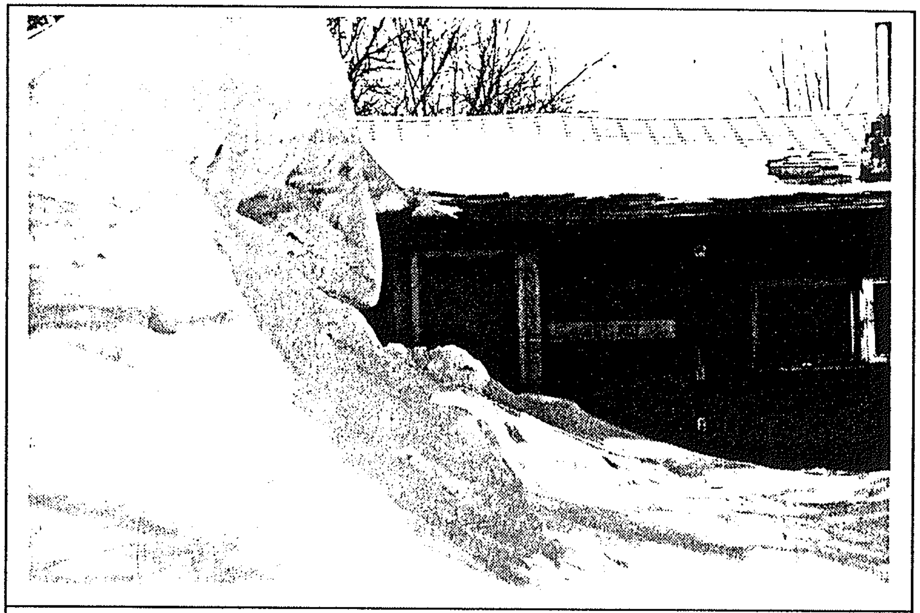
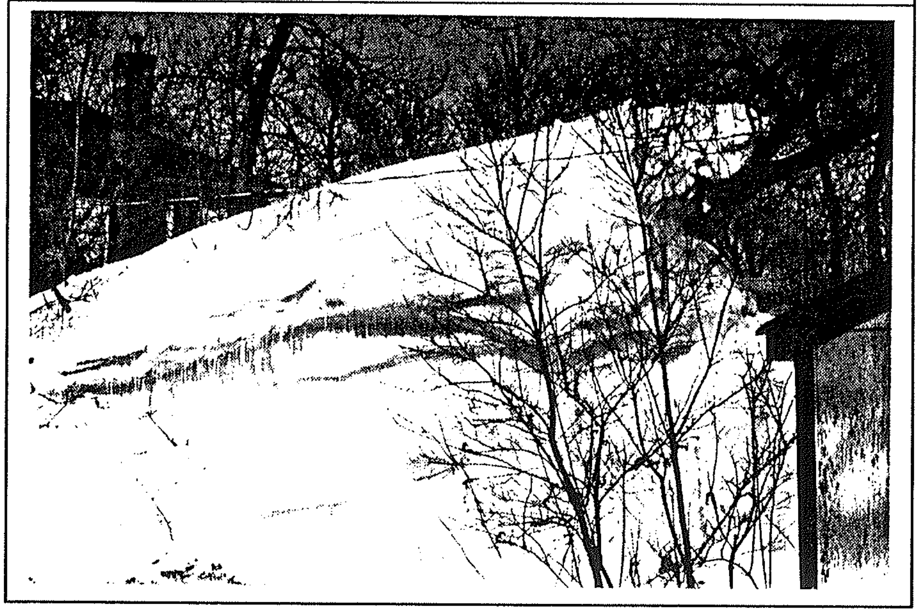


Figure 116
Drift Eats Tree
Delta, Manitoba
March 21/92, 2:30 p.m.
-3° C. Wind WSW at 7 km./hr.



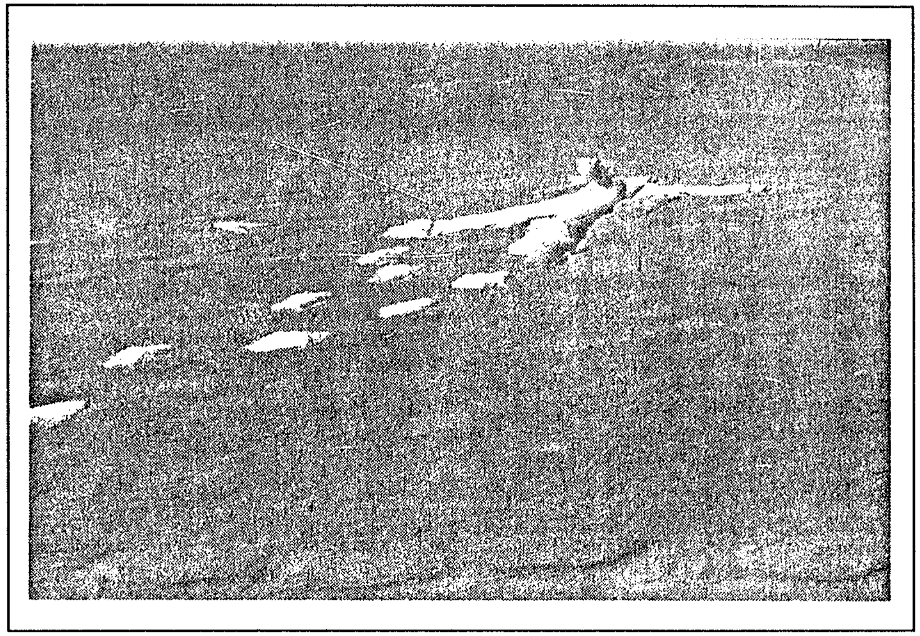


Figure 117
Buried Treasure
Time, day and location are being withheld pending further investigation.

SENSE OF PLACE

Snowdrifts provide an opportunity to further reinforce the feeling of a place. For example, there is a sculpture at the Forks where the sun writes hieroglyphics on stone. It is surrounded by a circle of stone pillars. A snow fence was placed on one side of the site and the drift that formed served to further enhance the mystical, sacred feel of the place.[5] See figures 118, 119.

Or they can be used to add an entirely different feel, thus giving an interesting seasonal duality to a place. For example, L'Heureux designed a fountain to aerate water in a pond - imagine a quiet relatively sedate summer pond with a bit of duckweed, a few flies, a warm breeze, the sun waltzing on the water... During the winter, this same pond had 3 m high towers of ice emerge from it - imagine that! While this example involves the ice, seasonal contrasts in the feel of a place are undoubtedly possible by the manipulation of snow as well.

Figure 118
"The Path of Time" View to the sculpture
The Forks, Winnipeg, Manitoba
January 23/92, 2:00 p.m.
-17° C. Wind NNW at 19 km./hr.
Artist: Marcel Gosselin

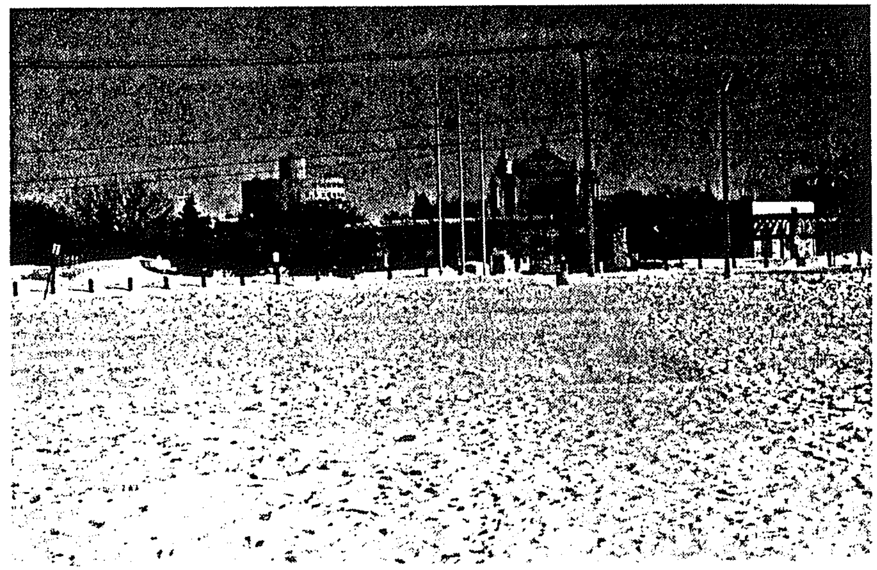
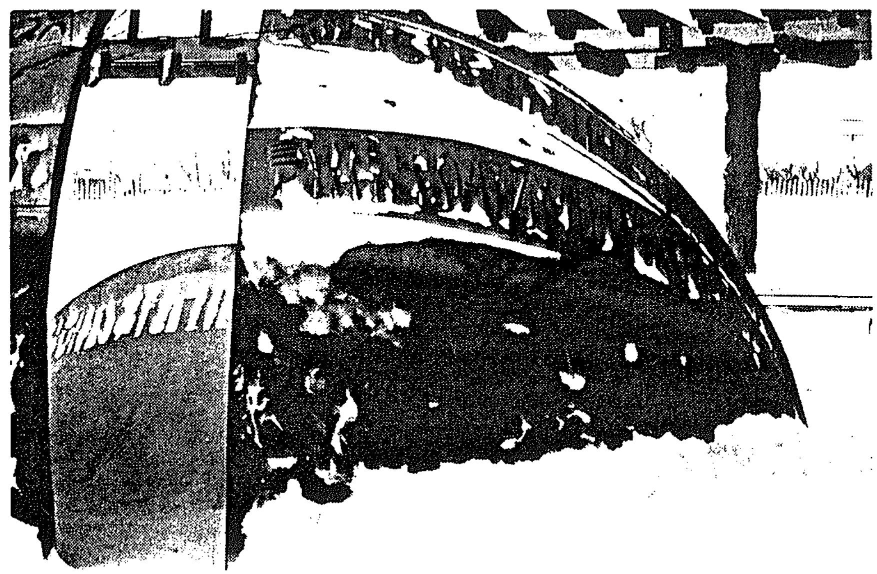


Figure 119
"The Path of Time" View from the Sculpture to the Drift
The Forks, Winnipeg, Manitoba
January 23/92, 2:00 p.m.
-17° C. Wind NNW at 19 km./hr.
Artist: Marcel Gosselin



COMPLEMENT TO ART

Snow can provide a wonderful background medium for displaying outdoor art: no conflicting lines from expansion joints in concrete, no grass to subdue colors, no leaves to obstruct light or views. Snow provides a clean, potentially high contrast background to display art. See figure 120.

Further to this, is it possible to create a piece of art that, like places, can have a seasonal duality? Snowdrifting, or snow collecting could be an intended aspect of the piece, which would add another dimension to the work. See figures 121.

Playing with shadow on snow is also an art form which should be explored. Rhythm can easily be established using shadows on snow. See figure 122. Shadows from a piece of outdoor sculpture which fall over a snowdrift become distorted and abstract patterns in and of themselves. See figure 123.

Figure 120
Snow as a Background for Art
Winnipeg, Manitoba
January 23/92, 10:30 a.m.
-20° C. Wind NW at 22 km./hr.

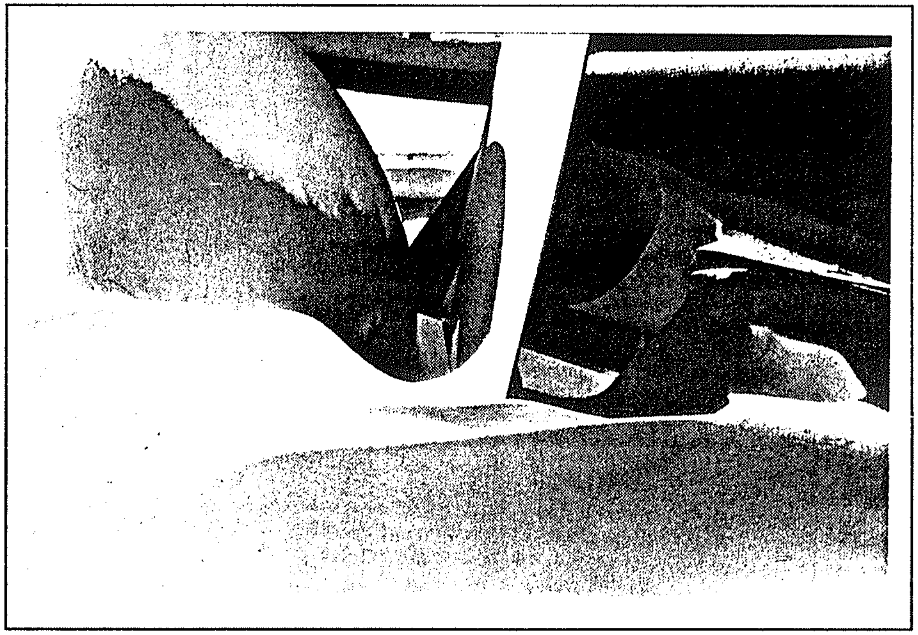


Figure 121
Incorporating Snow into an Outdoor Sculpture

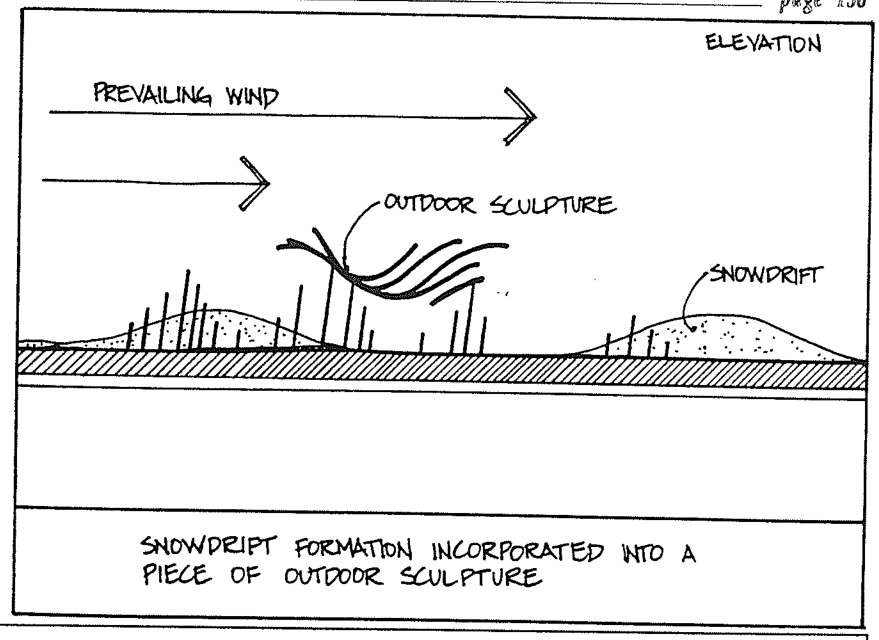


Figure 122
Establishing Rhythm from Shadows on Snow
Winnipeg, Manitoba
Late Winter, 1991

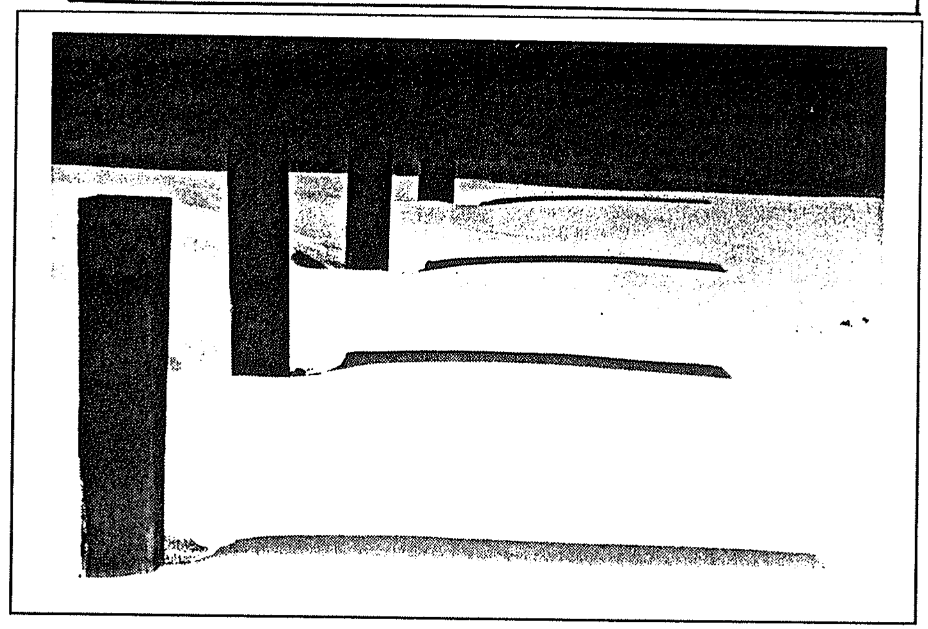
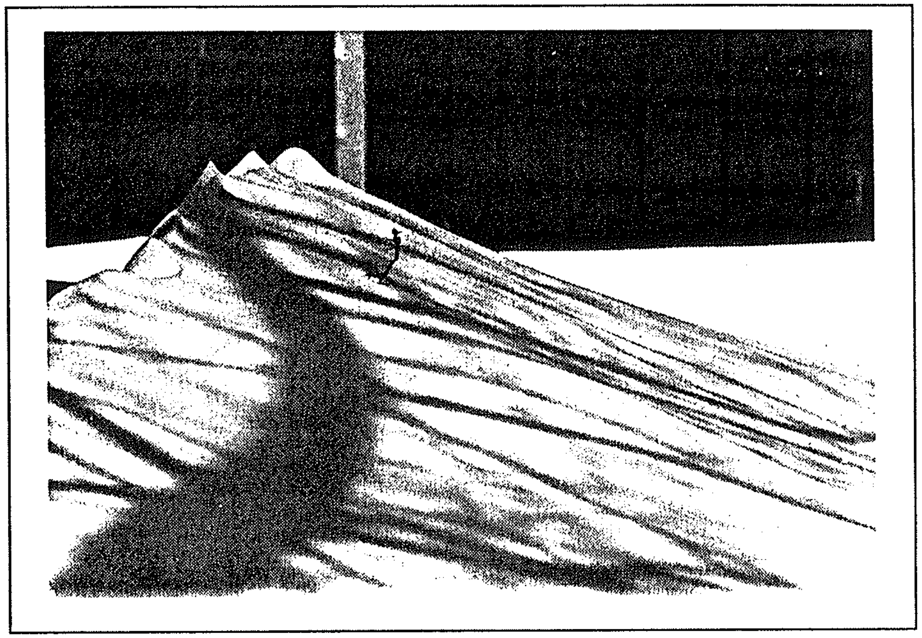


Figure 123
Abstract Patterns from Shadows Falling on a Snowdrift
Winnipeg, Manitoba
Late Winter, 1991



Snow is also a canvas that patterns can be created on. Leaves, rocks, pebbles, or seeds spread over snow form dynamic patterns. See figure 124. Leaves and rocks also create interesting melting patterns. Leaves sink into the snow, creating a pothole effect from which reds, yellows, oranges flow through the snow. See figure 125. Rocks that have been arranged on top of the snow also sink into it during melting. When they reach the ground, they act as heat radiators and melt away the snow adjacent to them, making islands of themselves. See figure 126.

Figure 124
Snow as a Canvas
Audubon Engagement Calendar. New York: MacMillan Publ. Co., 1992.

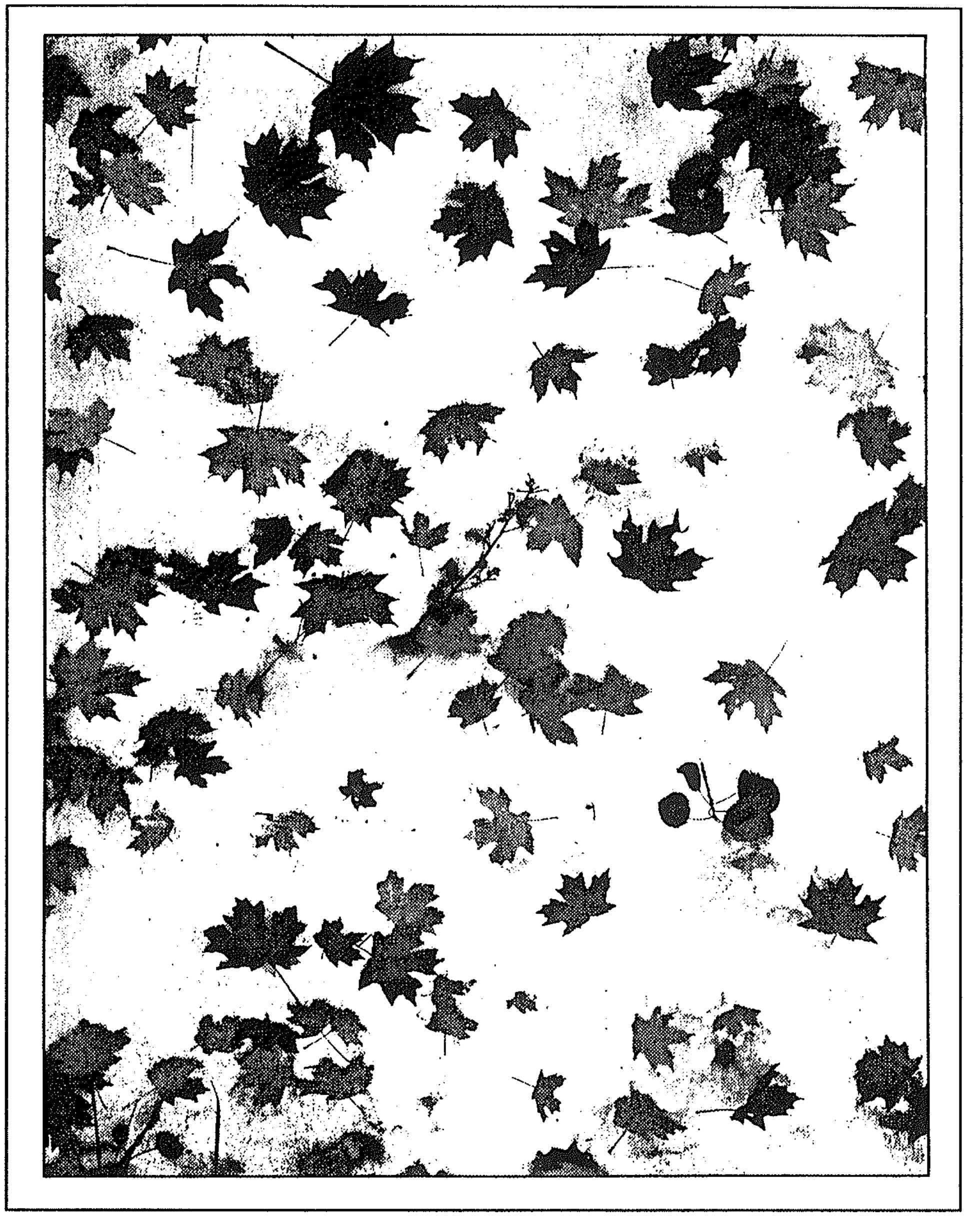


Figure 125
Snow as a Canvas
Winnipeg, Manitoba
February 29/92, 12:00 noon
2° C. Wind S at 28 km./hr.

Figure 126
Snow as a Canvas
Winnipeg, Manitoba
March 15/92, 4:30 p.m.
2° C. Wind S at 28 km./hr.

SNOW ART

"But nowhere in the world
Does snow dryly crackle and crunch
And sparkle underfoot
As in Saskatchewan

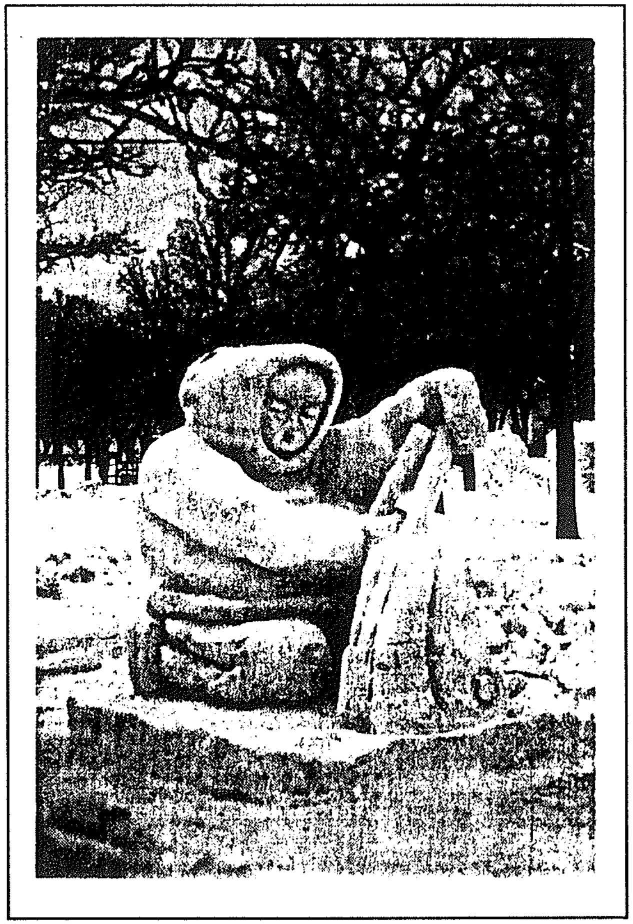
And nowhere in the world
Have I enjoyed making
Angels in the snow
As I have in the hushed
Blue-black, velvety cold
Winter nights in Regina."[6]

We've all made snow angels and snowmen. Some of us may even have sculpted and molded other forms, and perhaps painted them. And if we haven't actually done this ourselves, we've seen the sophisticated and often monumental snow and ice sculptures that are often featured at Winter Festivals. See figure 127.

Beauty surrounds us in the winter. Not just with what we can sculpt snow into, but what snow and wind and sun sculpt snow into.

Melting, freezing, aging, blowing results in an endless variety of forms and textures. Unlike any other material, snow perpetually changes. It changes with the angle of the sun, the wind, the squirrel, the addition of more snow. It is living whim. It transforms safe summer forms into abstract patterns that exaggerate, contort, distort and defy summer's forms.

Figure 127
Festival du Voyageur
Photo by Ted McLachlan



For the sake of convenience this section has been divided into six parts. They are simply six qualities that I have come to enjoy. They are elusive yet among the best qualities of snow (in my mind at least). I have no specific suggestions for integrating these qualities into design. What I've noticed is that it takes a while to really see snow and when you do, there lies a world of texture, pattern, color, rhythm, shadow and light that ebb and flow in abstract patterns.

Light

Light comes from two sources. Light from the sun creates high contrast shadows and develops wonderful form definition and distortion. Occasionally though, light seems to come from within the snow itself. I suspect that this has much to do with the viewing angle. It is a wonderful contradictory effect that could be used to emphasize an important feature. See figures 128 - 131.

Figure 128
Light from Within the Drift
Starbuck, Manitoba
February 11/92, 3:30 p.m.
-21° C. Wind SW at 4 km./hr.

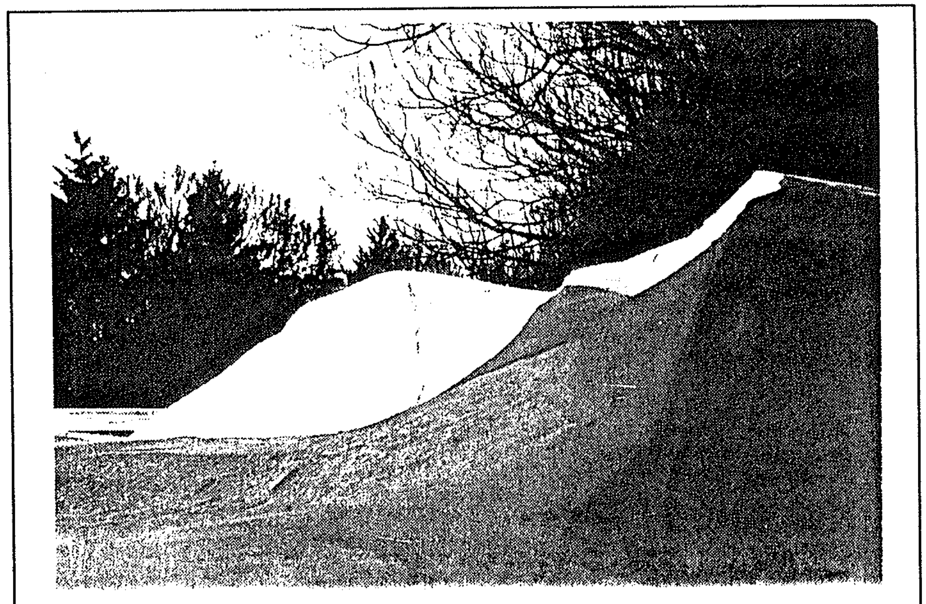


Figure 129
Light from Within the Drift
Delta, Manitoba
February 23/91, 2:30 p.m.
-17° C. Wind N at 6 km./hr.

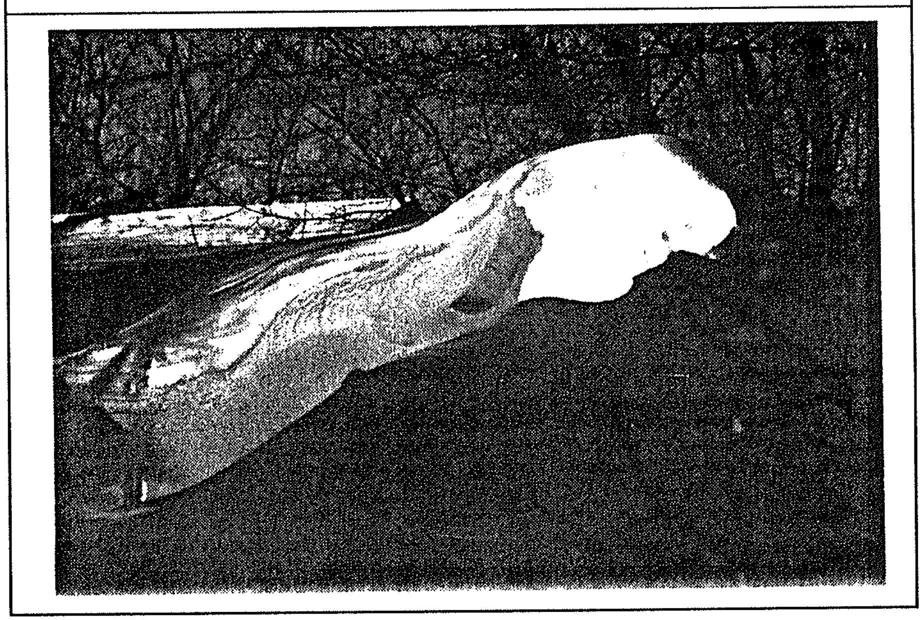


Figure 130
Light from Within the Drift
Delta, Manitoba
February 23/91, 2:00 p.m.
-17° C. Wind N at 7 km./hr.

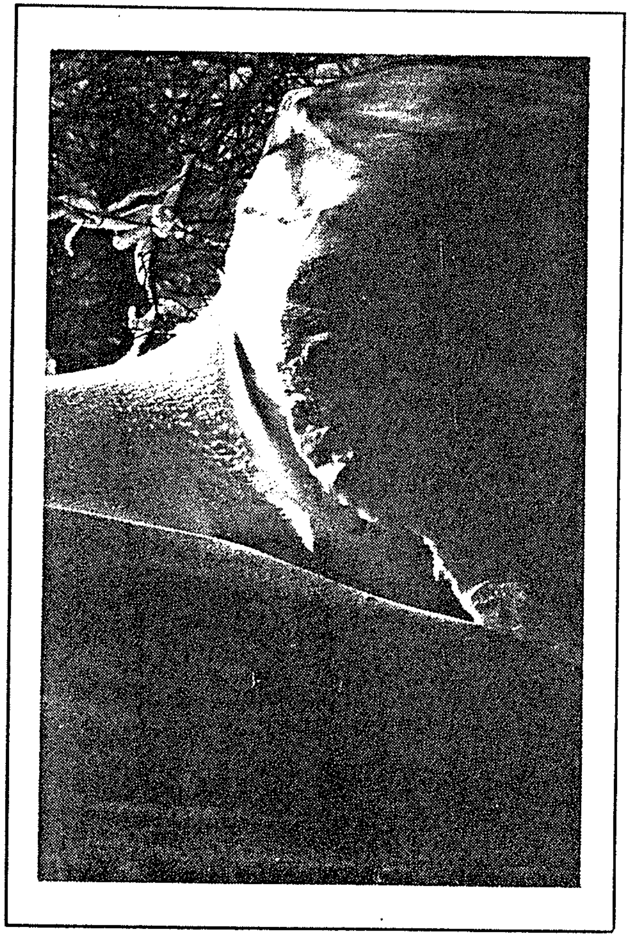
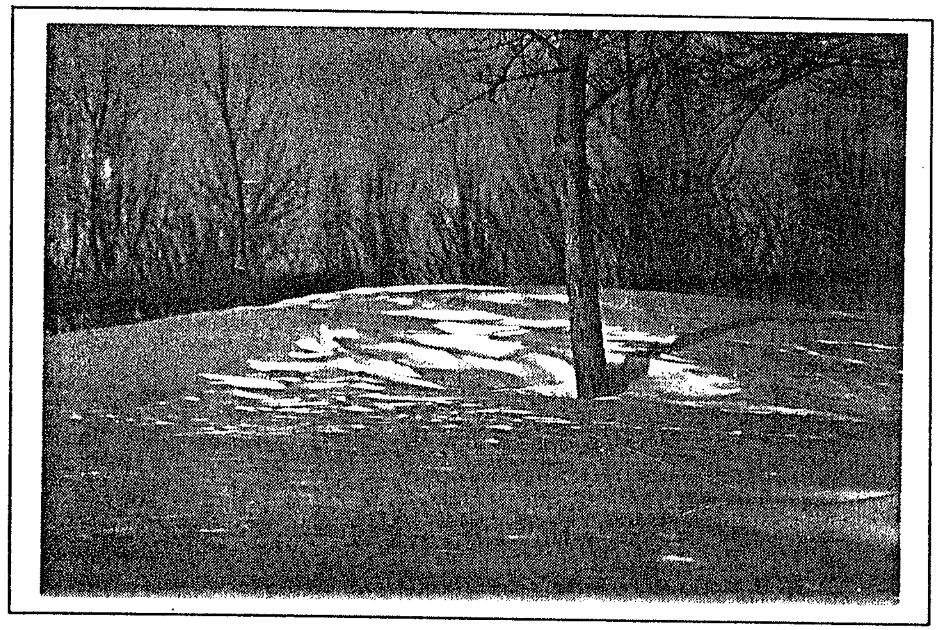


Figure 131
Light from Within the Drift
Ile-des-Chenes, Manitoba
January 19/92, 3:00 p.m.
-17° C. Wind N at 13 km./hr.



Shadows

Shadows from elements and shadows from drifts themselves define the form of a drift. But the drifts distort, exaggerate and create optical illusions with the shadows. See figures 132 - 137.

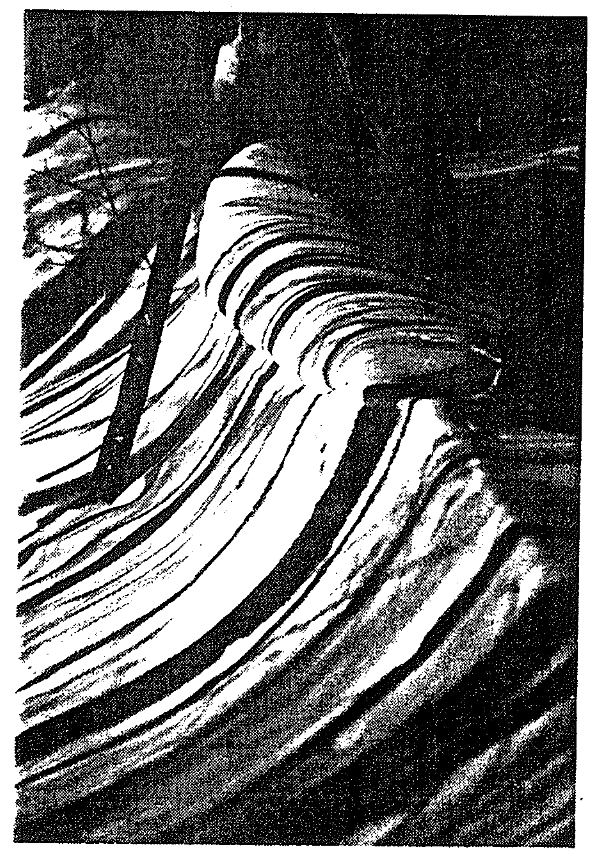


Figure 132
Winter Whitecap
Delta, Manitoba
February 23/91, 3:00 p.m.
-17° C. Wind N at 7 km./hr.

Figure 133
Snow Undulation
Delta, Manitoba
February 23/91, 3:00 p.m.
-17° C. Wind N at 7 km./hr.

Figure 134
Shadows Defining and Distorting Form
Winnipeg, Manitoba
Winter, 1991

Figure 135
Optical Illusion
Delta, Manitoba
February 23/91, 2:00 p.m.
-17° C. Wind N at 6 km./hr.

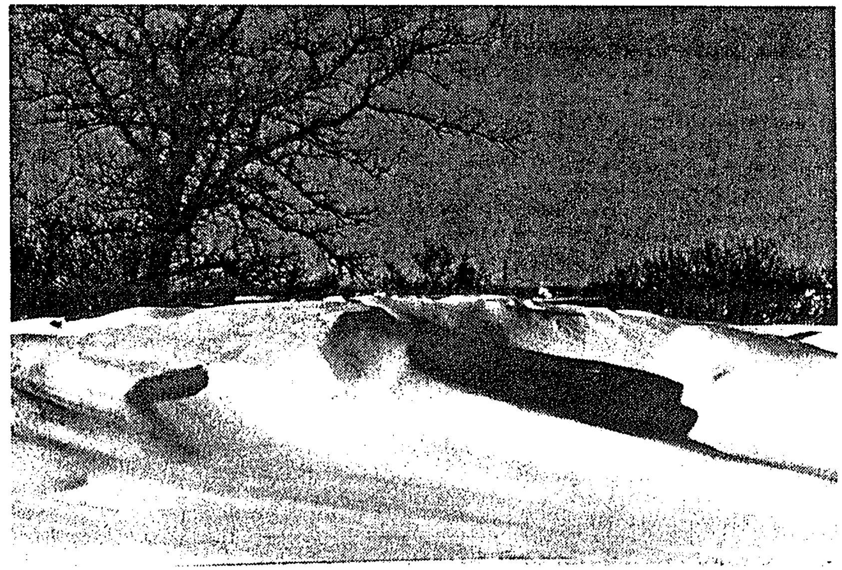


Figure 136
Optical Illusion
Ile-des-Chenes, Manitoba
January 19/92, 3:00 p.m.
-17° C. Wind N at 13 km./hr.

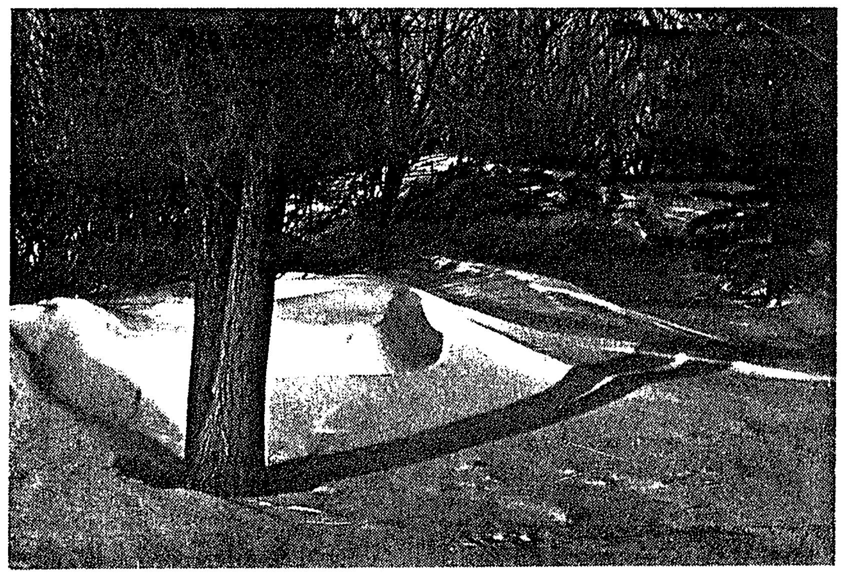
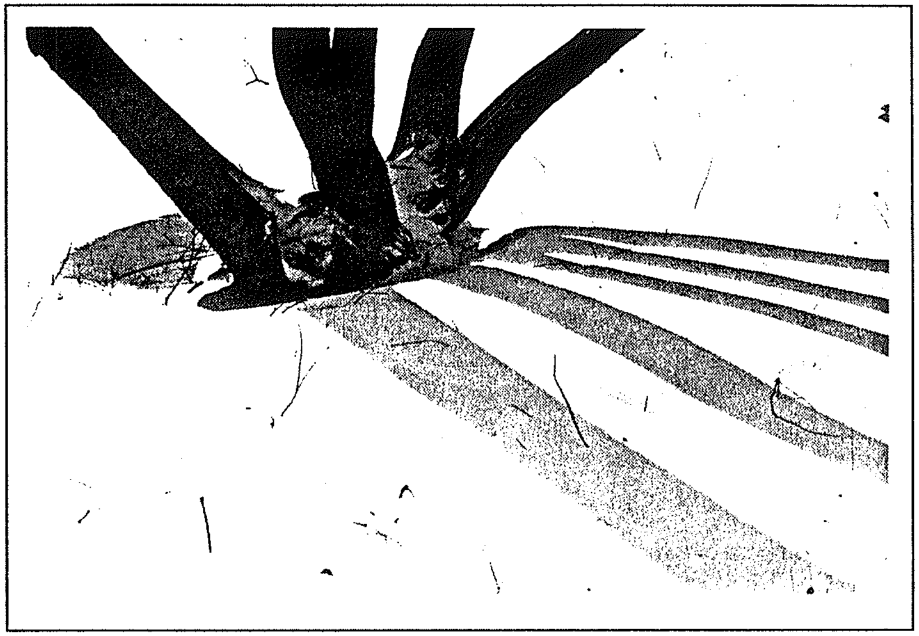


Figure 137
Shadows Defining and Distorting Form
Winnipeg, Manitoba
January 23/92, 12:00 noon
-19° C. Wind NNW at 20 km./hr.



Texture

The effects of cold, wind, warmth, compaction and many other factors produce a variety of textures. Snow can have the sleek translucence of marble, the fluffy nothingness of candy floss, it can look like sand, soap, mica, bedrock or soapstone. It can be gritty, sleek, voluptuous, lean, sharp. See figures 138 - 143.

Figure 138
Snow like Marble
Delta, Manitoba
February 23/91, 2:30 p.m.
-17° C. Wind N at 6 km./hr.

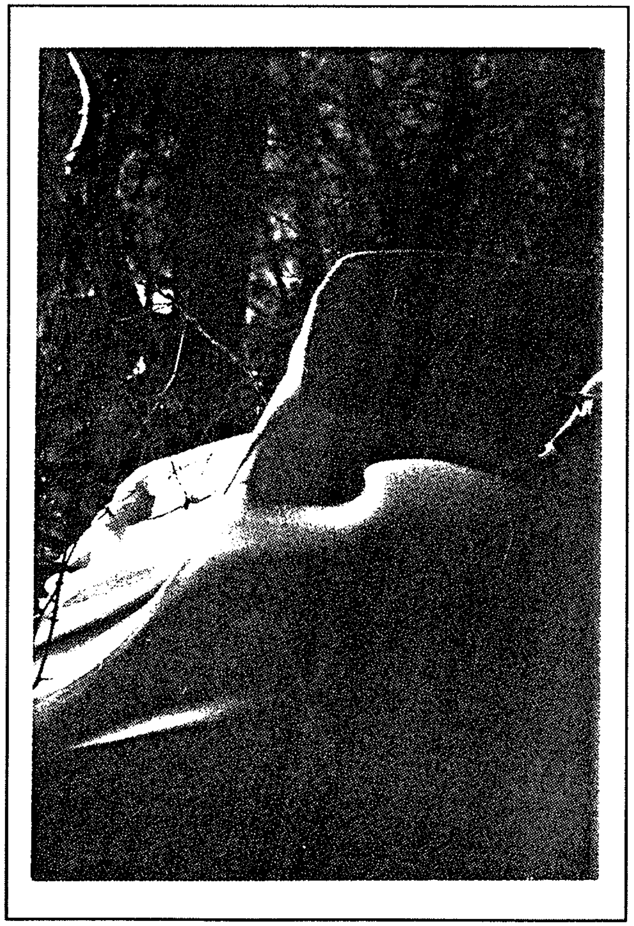


Figure 139
Snow like Sandstone
Winnipeg, Manitoba
Spring 1991

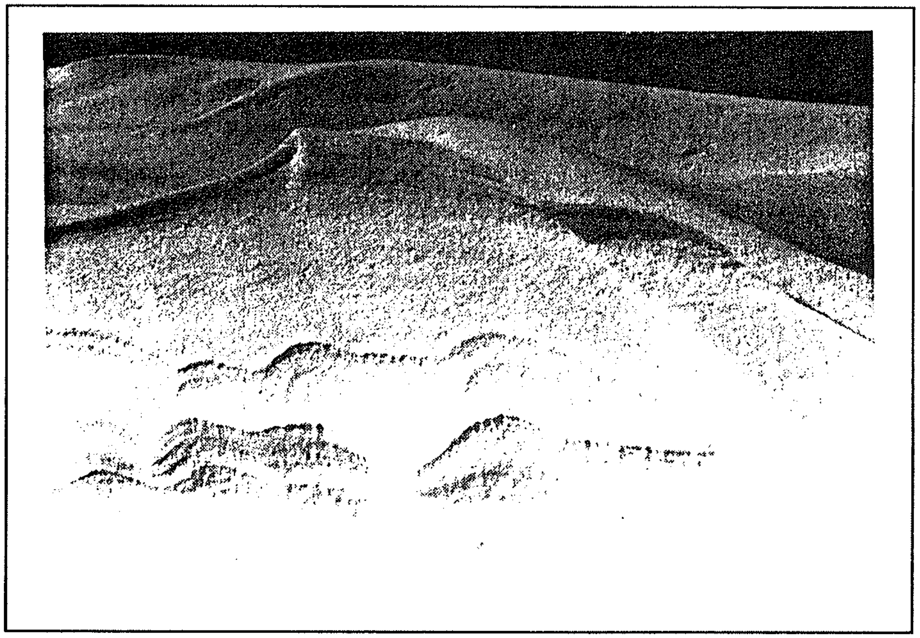


Figure 141
Candy Floss
Starbuck, Manitoba
February 11/92, 9:00 a.m. (post sunrise)
-29° C. Wind W at 4 km./hr.

Figure 140
Snow like Mica
Winnipeg, Manitoba
Spring 1991

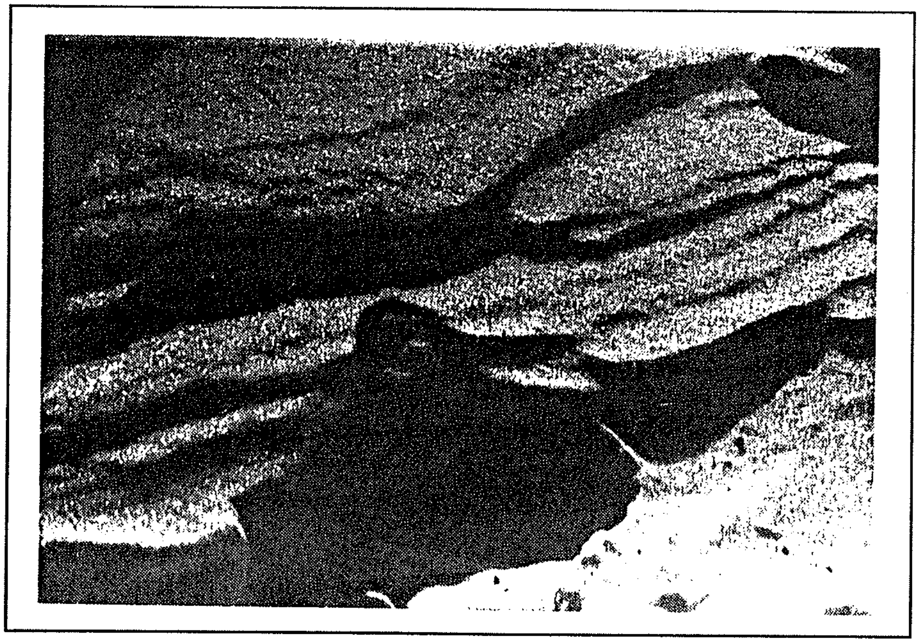


Figure 142
Jagged Texture
Starbuck, Manitoba
February 11/92, 9:00 a.m. (post sunrise)
-29° C. Wind W at 4 km./hr.

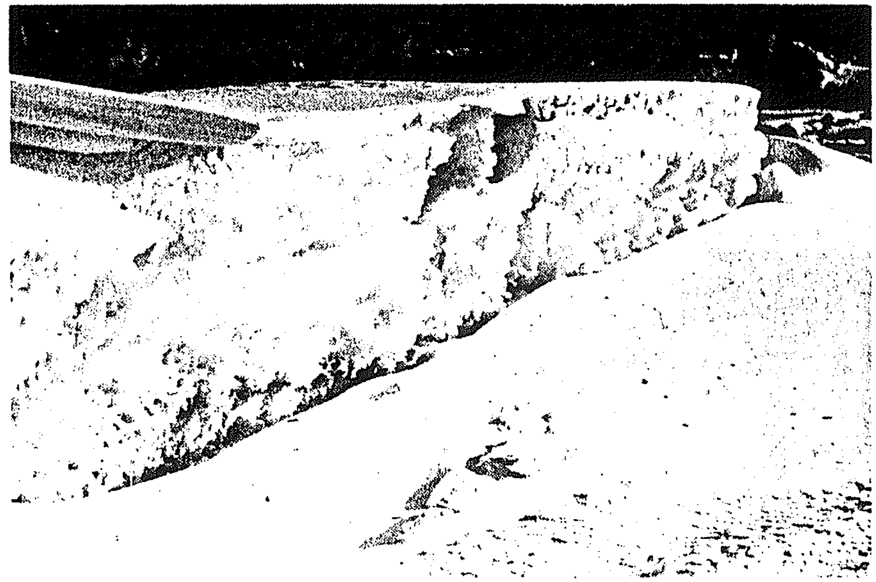
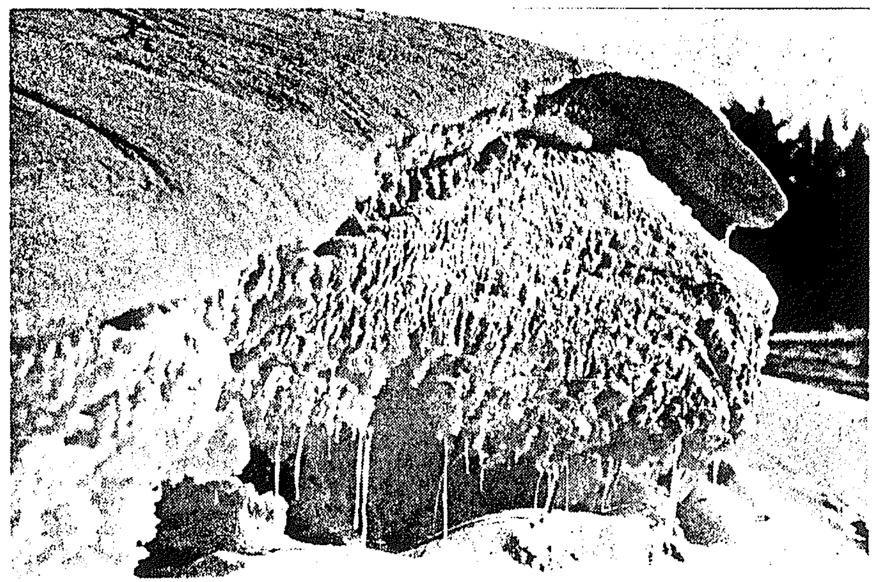


Figure 143
Gritty Texture
Starbuck, Manitoba
February 11/92, 9:00 a.m. (post sunrise)
-29° C. Wind W at 4 km./hr.



Textures Interacting

Snow usually falls in sufficient quantities to cover over existing snow. Occasionally it doesn't. And the interaction of the old and the new snow creates wonderful patterns. See figures 144, 145.

Figure 144
New snow which has partially covered a snow bank that contains old snow, dirt, sand, and ice produces an interesting contrast in color and texture.
Winnipeg, Manitoba
February 5/92, 9:00 a.m.
-6° C. Wind SSE at 17 km./hr.

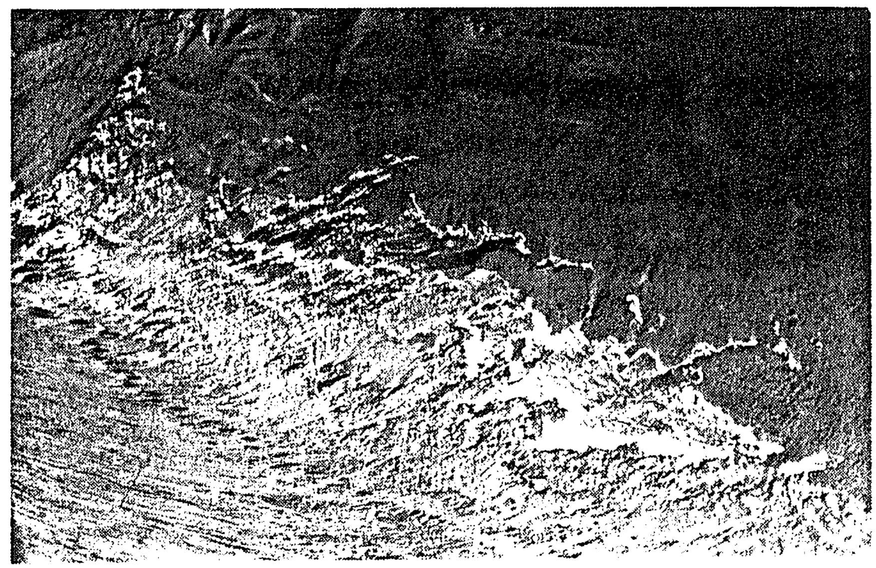


Figure 145
Snow which has been subject to different aging condition will have different characteristics. A really dynamic pattern occurs when the sun comes out to play with wind packed and crusted snow.
Starbuck, Manitoba
February 11/92, 12:00 noon
-24° C. Wind NW at 17 km./hr.

Abstract Forms and Compositions

Drifted snow can develop into exceptionally beautiful forms. The variety of convolutions and contortions are endless. They occur as the details of a larger drift, and as singular elements by themselves. They are large and small, and pop up beside buildings, in fields, along fences. See figures 146 - 150.

Figure 146
Abstract Patterns
Winnipeg, Manitoba
January 23/92, 12:00 noon
-19° C. Wind NNW at 20 km./hr.

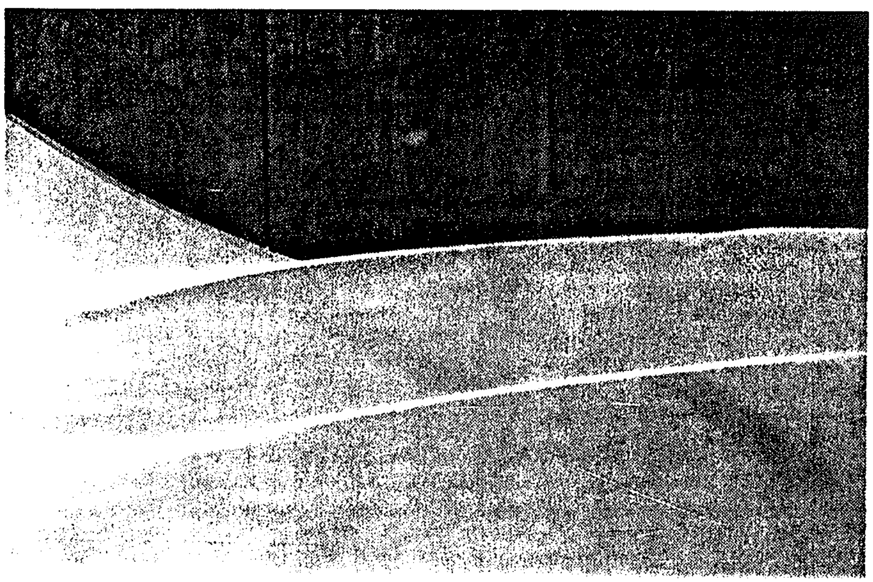


Figure 147
Abstract Formation
Delta, Manitoba
February 23/91, 2:00 p.m.
-17° C. Wind N at 6 km./hr.
Photo by Joe Wiatrowski

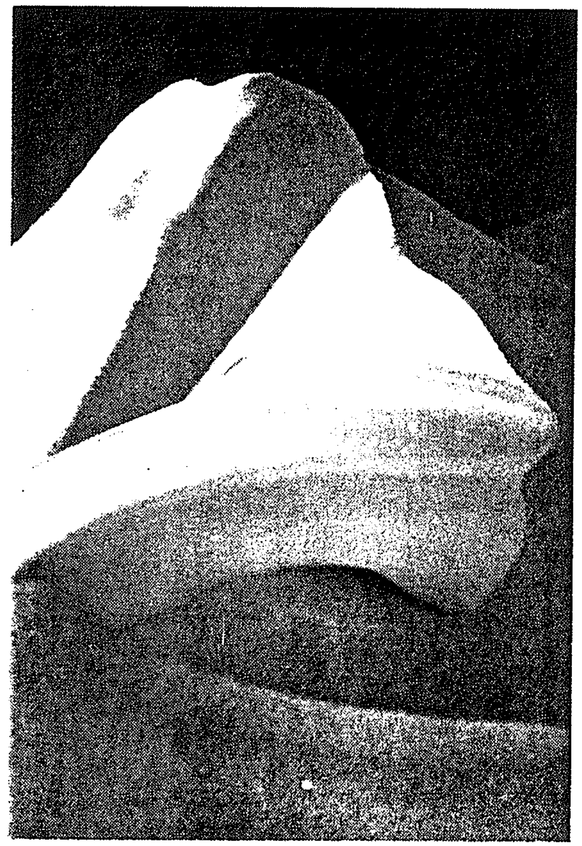
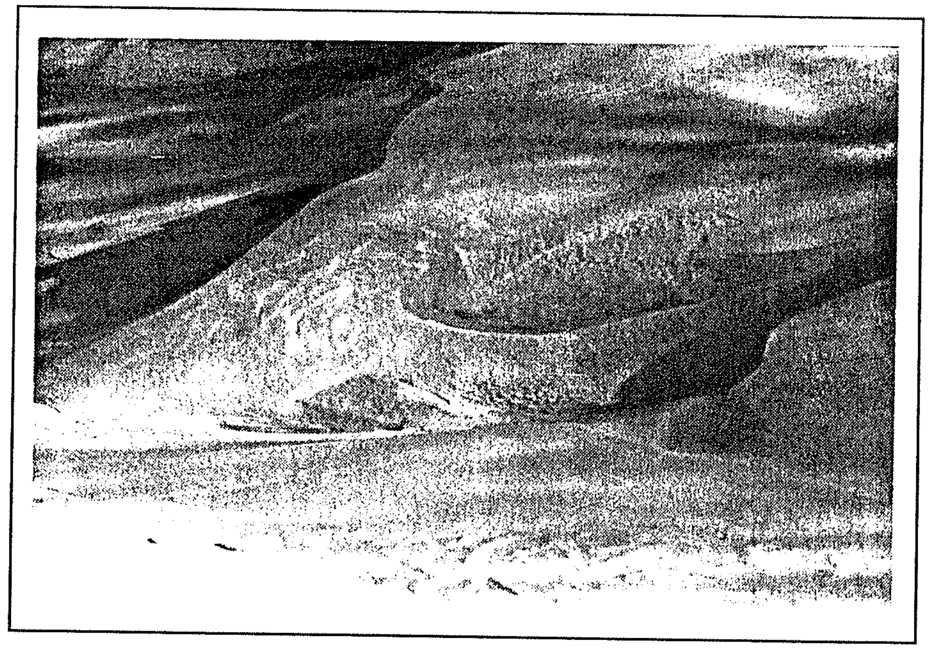


Figure 148
Abstract Formation
Delta, Manitoba
February 23/91, 2:30 p.m.
-17° C. Wind N at 6 km./hr.

Figure 149
Abstract Formation
Starbuck, Manitoba
February 11/92, 12:00 noon
-24° C. Wind NW at 4 km./hr.



The place where drifting and scouring meet, is full of surprises. A definite, often sharp ridge of edge develops. Sometimes it aggressively chews its way forward, sometimes it nonchalantly lulls about, sometimes it throws itself up in a fury. See figures 151 - 154.

Figure 150
Abstract Formation
Ile-des-Chenes, Manitoba
Janury 19/92, 3:30 p.m.
-17° C. Wind N at 13 km./hr.

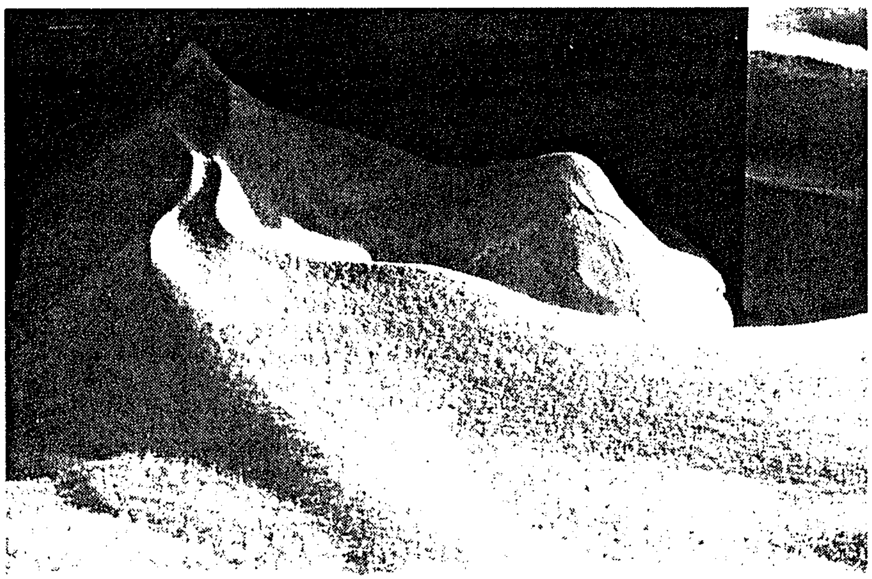


Figure 151
Aggressive Drift
Chews Its Way
Forward
Winnipeg, Manitoba
Spring 1991

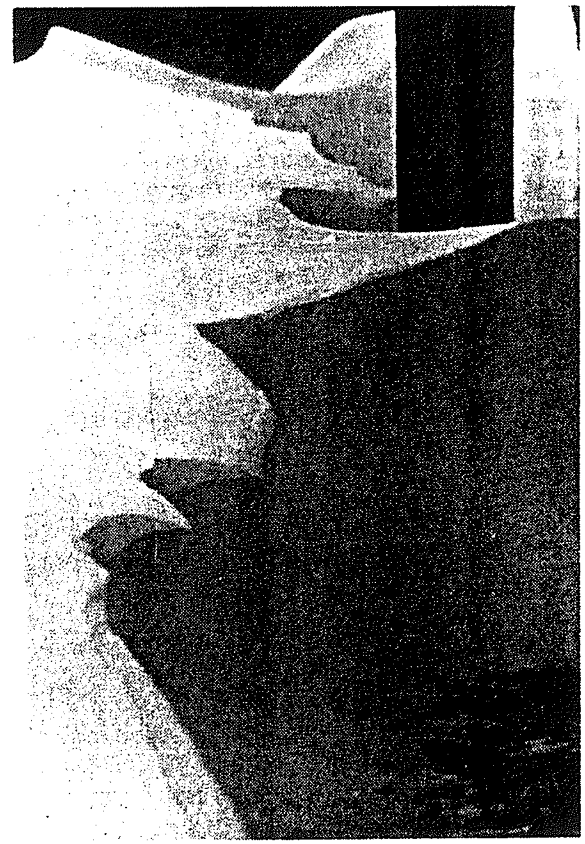


Figure 153
Drift Lulling About
Starbuck, Manitoba
January 11/92, 8:00 a.m.
-7° C. Wind SSE at 24 km./hr.
Photo by Mich'ele Ammeter

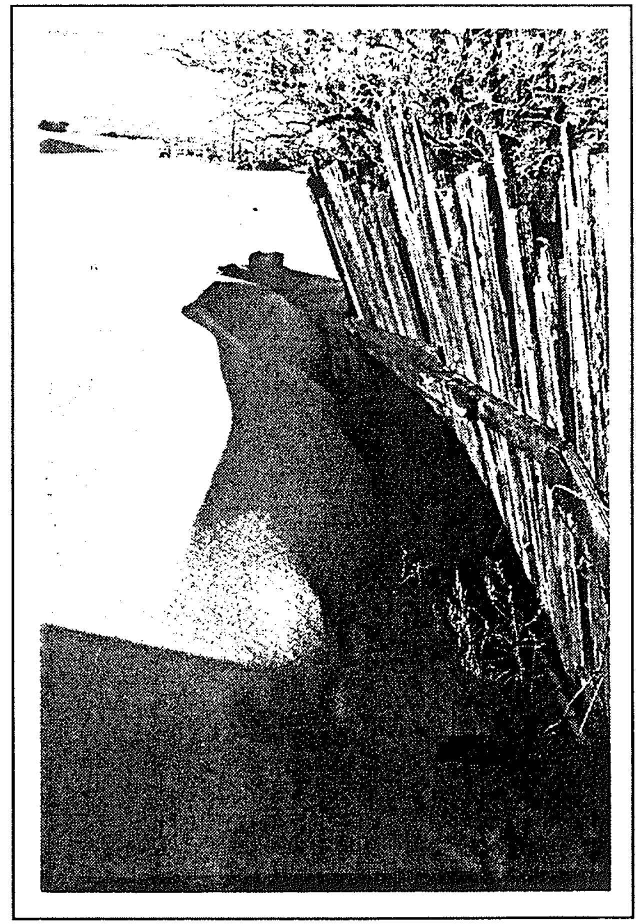
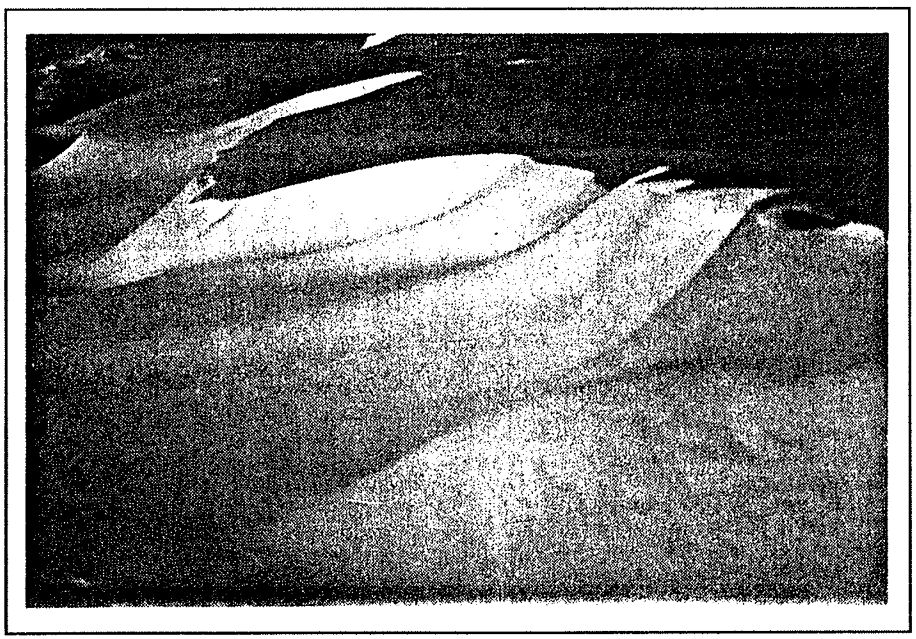


Figure 152
Drift Lulling About
Winnipeg, Manitoba
January 23/92, 10:00 a.m.
-20° C. Wind NW at 22 km./hr.



Seasonal Changes

One of the unique qualities of snow is that it is in a continual state of change. Once established, drifts continue to grow, adding more embellishments and variations. See figures 155 - 159.

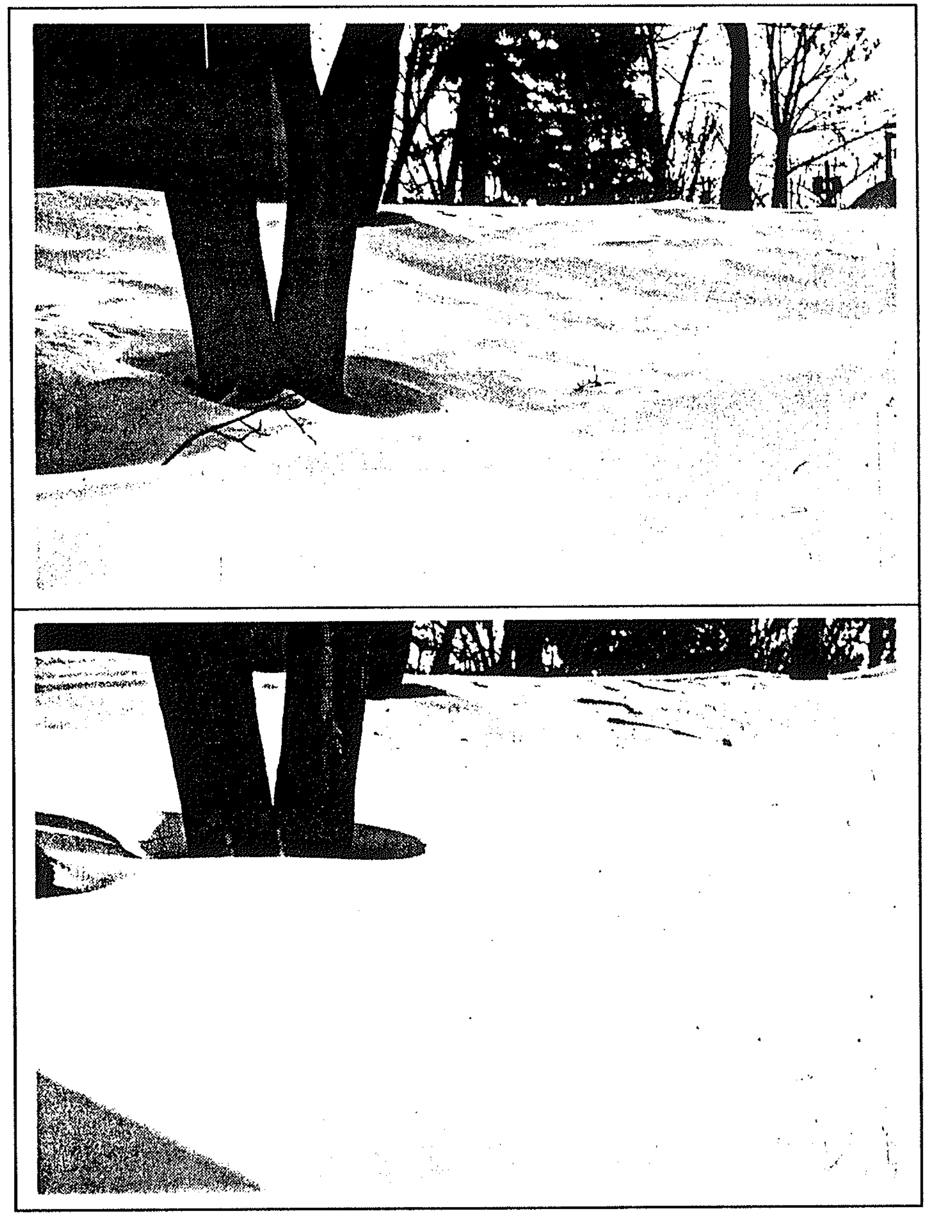
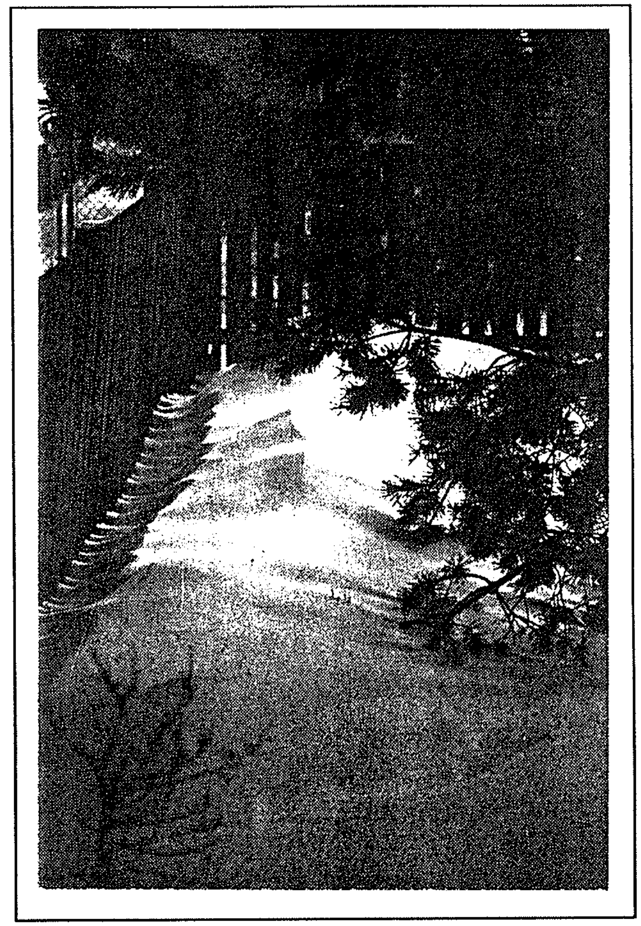


Figure 155
The feel of a place can change not only by incorporating a drift for a special effect, but subtly as the snowcover changes. Notice how the mood of the first photo has an easy relaxed feel to it, while the second one has a more formal controlled feel to it.
Winnipeg, Manitoba
January 15/92, 10:00 a.m.
-30° C. Wind WSW at 11 km./hr.

Janaury 23/92, 12:00 noon
-19° C. Wind NNW at 20 km./hr.

Figure 156
Seasonal Changes
Winnipeg, Manitoba
January 18/92, 8:45 a.m.
-31° C. Wind W at 13 km./hr.

Janaury 23/92, 8:45 noon
-19° C. Wind NNW at 22 km./hr.

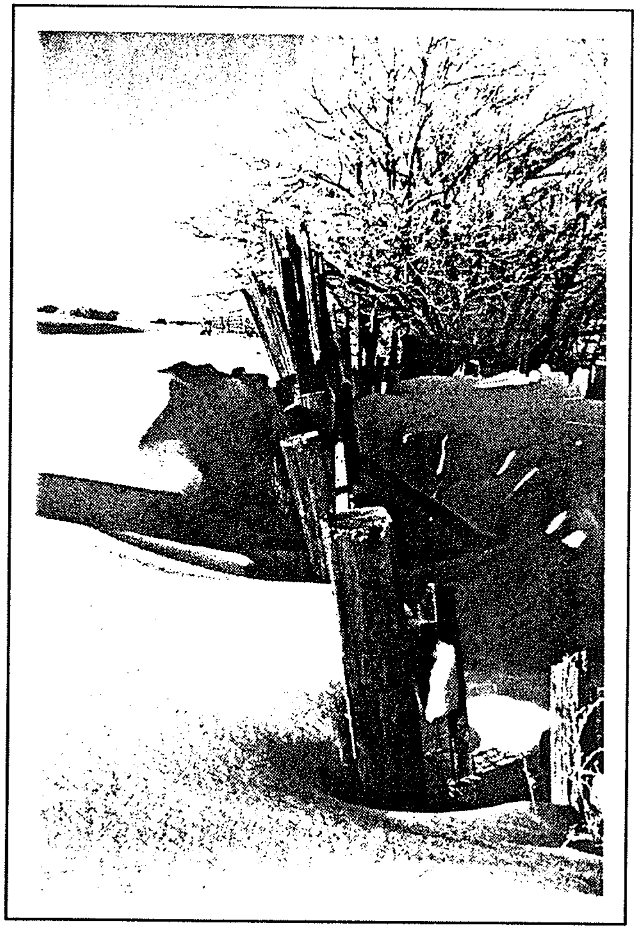


ERRATUM:

Page 157, caption for the second figure should read:

January 23/92, 8:45 a.m.

Figure 157
Seasonal Changes
Starbuck, Manitoba
January 11/92, 8:45 a.m.
-7° C. Wind SSE at 24 km./hr.
Photo by Mich'ele Ammeter



February 11/92, 12:30 p.m.
-24° C. Wind NW at 4 km./hr.

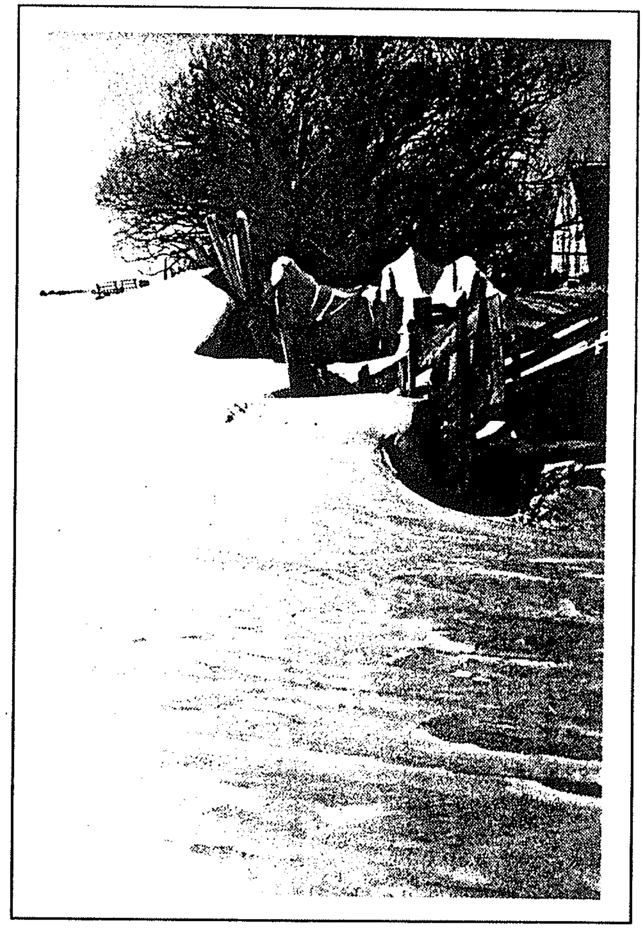
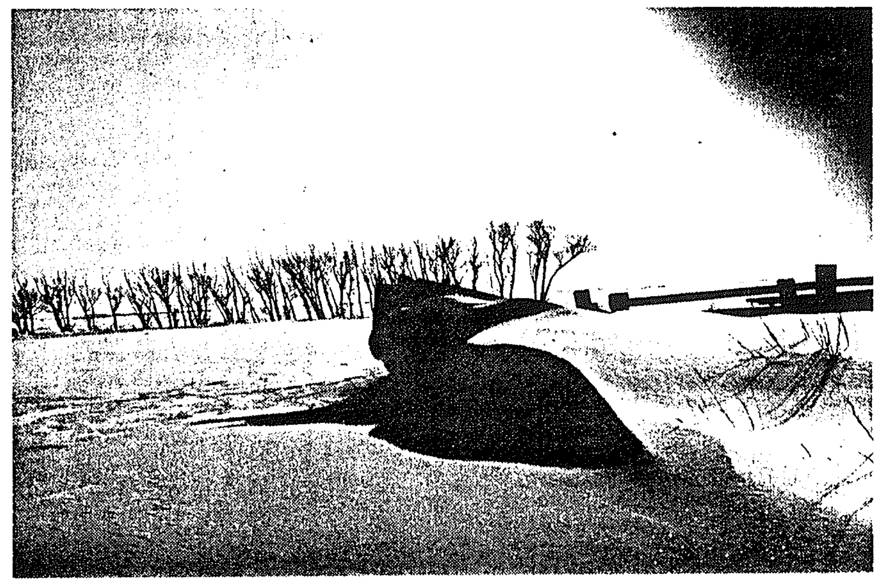
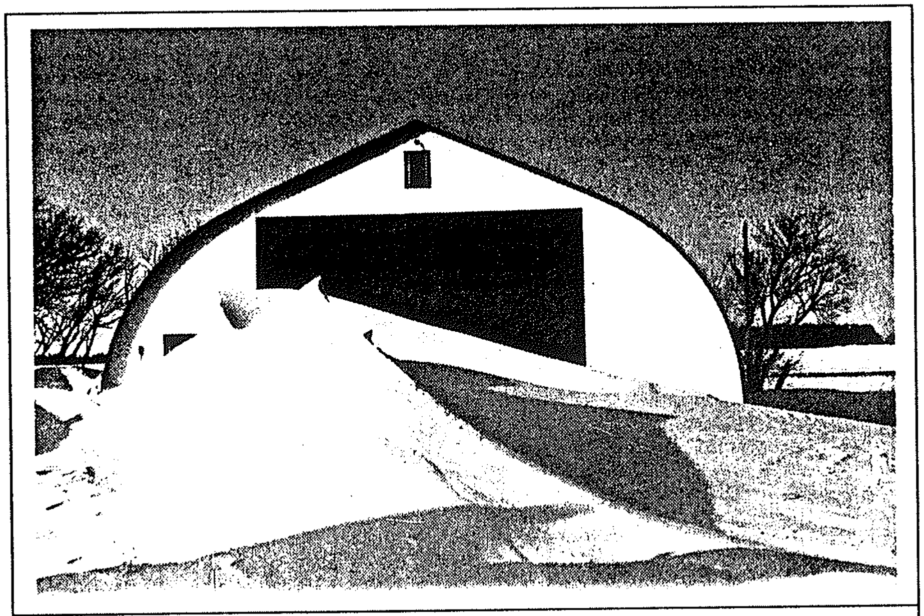


Figure 158
Seasonal Changes
Starbuck, Manitoba
January 11/92, 1:00 p.m.
-4° C. Wind S at 24 km./hr.

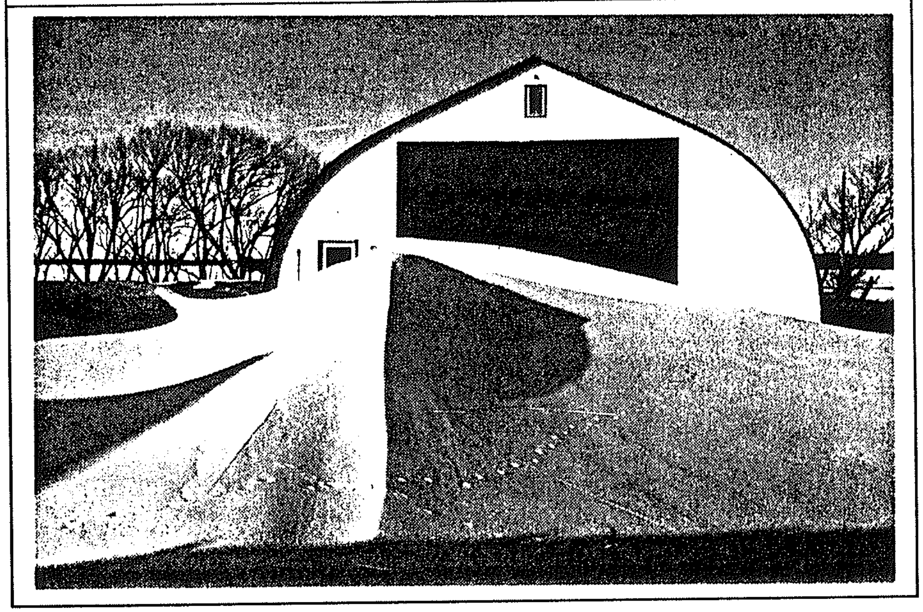


February 11/92, 12:30 p.m.
-24° C. Wind NW at 4 km./hr.

Figure 159
Seasonal Changes
Starbuck, Manitoba
January 11/92, 1:30 p.m.
-4° C. Wind S at 24 km./hr.



February 11/92, 3:30 p.m.
-21° C. Wind SW at 4 km./hr.



Playing with Perception

You just can't pin down the exact shape of a drift. Even on days when the sky is clear, and the wind is at rest, the drifts are restless and moving about. See figures 160 - 163.

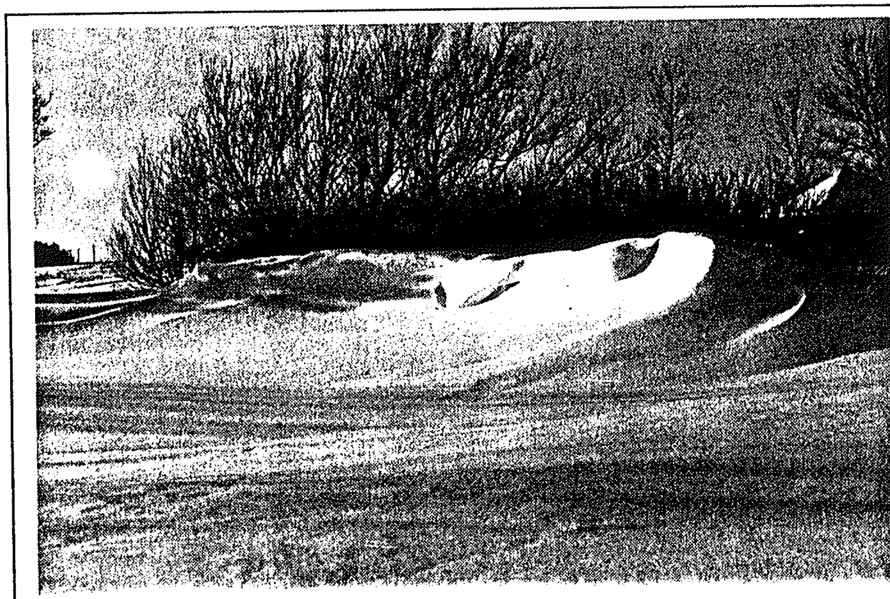
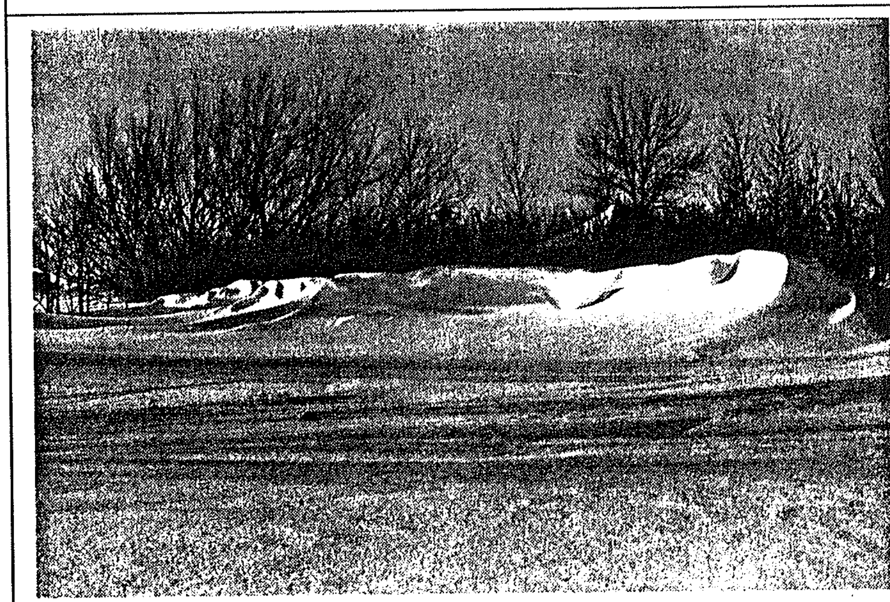


Figure 160
Daily Changes: The following three photographs were taken during a half hour period. Notice how the shapeless mass on the left end of the drift transforms into a finely detailed composition.
Ile-des-Chenes, Manitoba
January 19/92, 3:00 p.m.
-17° C. Wind N at 13 km./hr.



January 19/92, 3:15 p.m.
-17° C. Wind N at 13 km./hr.

January 19/92, 3:30 p.m.
-17° C. Wind N at 13 km./hr.

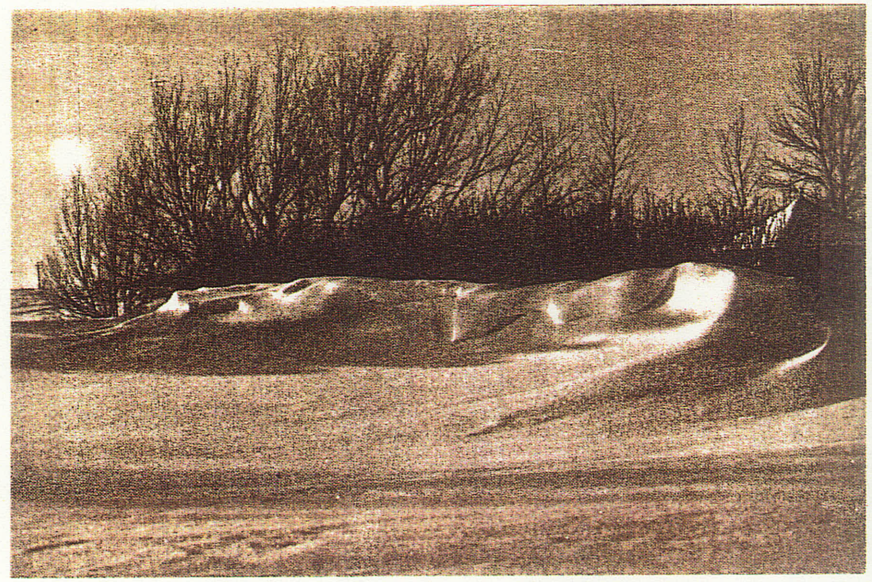


Figure 161
Daily Changes: Like a piece of music, this drift begins with a gentle yet colorful introduction, establishes some primary themes and rhythms, adds accents, emphasis and variation to those themes and rhythms, and then as gently as it began, fades.
Starbuck, Manitoba
February 11/92, 8:30 a.m. (sunrise)
-29° C. Wind W at 4 km./hr.

Next page:

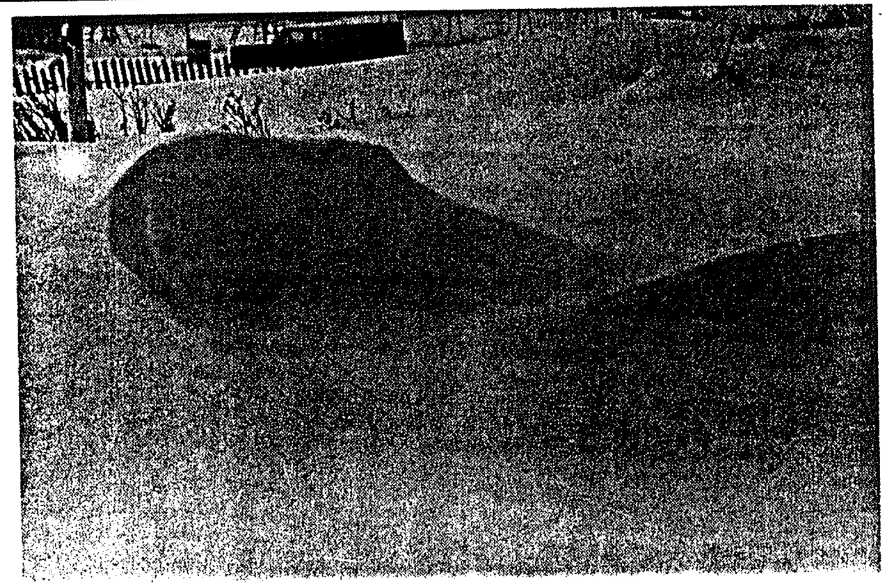
February 11/92, 9:00-9:30 a.m.
(post sunrise)
-29° C. Wind W at 4 km./hr.
(Top left)

February 11/92, 11:30 a.m.
-25° C. Wind NW at 2 km./hr.
(Top right)

February 11/92, 3:00 p.m.
-21° C. Wind SW at 4 km./hr.
(Bottom left)

February 11/92, 5:30 (sunset)
-23° C. Wind S at 11 km./hr.
(Bottom right)

Figure 162
Daily Changes: Drifts also like a good game of peek-a-boo. The first of the following two photographs was taken in the morning under an overcast sky. A couple of hours later the sun came out and so did the drifts. (See also Figures 7, 8.)
Ile-des-Chenes, Manitoba
January 19/92, 12:30 p.m.
-17° C. Wind N at 15 km./hr.



January 19/92, 2:30 p.m.
-17° C. Wind N at 13 km./hr.

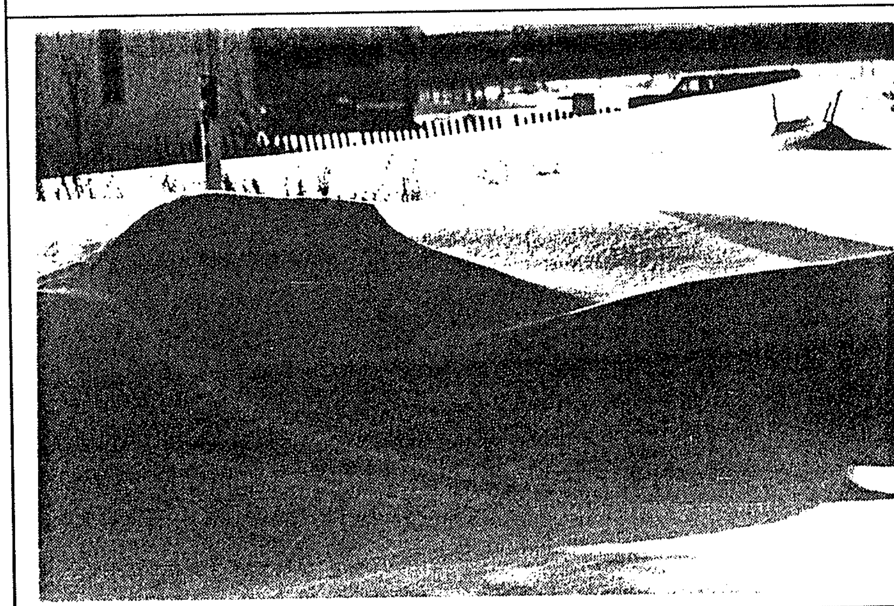
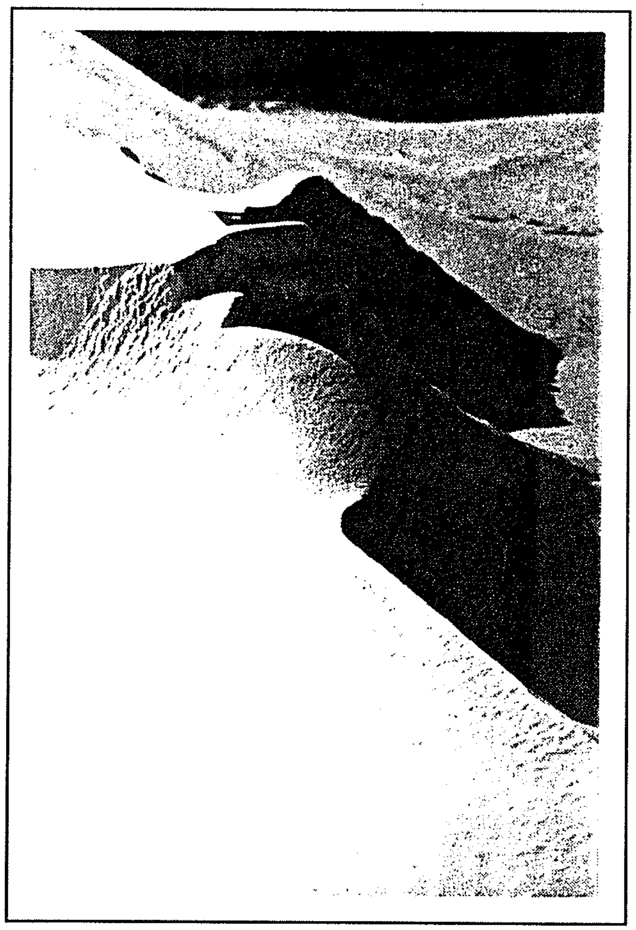
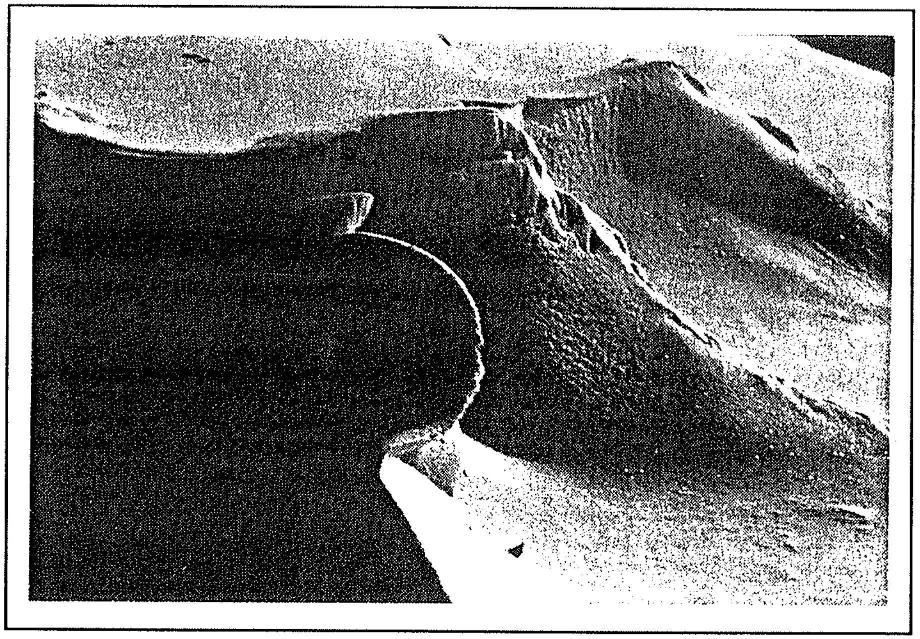


Figure 163
Playing with Perception: The following two photographs become a study in negative and positive space.
Starbuck, Manitoba
February 11/92, 11:30 a.m.
-24° C. Wind NW at 3 km./hr.



February 11/92, 3:30 p.m.
-24° C. Wind SW at 4 km./hr.



REFERENCES:

[1]Lillian Allen, Frost, (Winnipeg: Hyperion Press Limited, 1990), p. 11.

[2]Roger L'Heureux, "Ice - Natures's Superb Manifestation; Obdurate yet fragile - austere yet edible - unspeakably beautiful and unappreciated," in Winter Cities Newsletter, Vol. 5, no. 5, (Oct. 1987), p. 17.

[3]Borowiecka, p. 60.

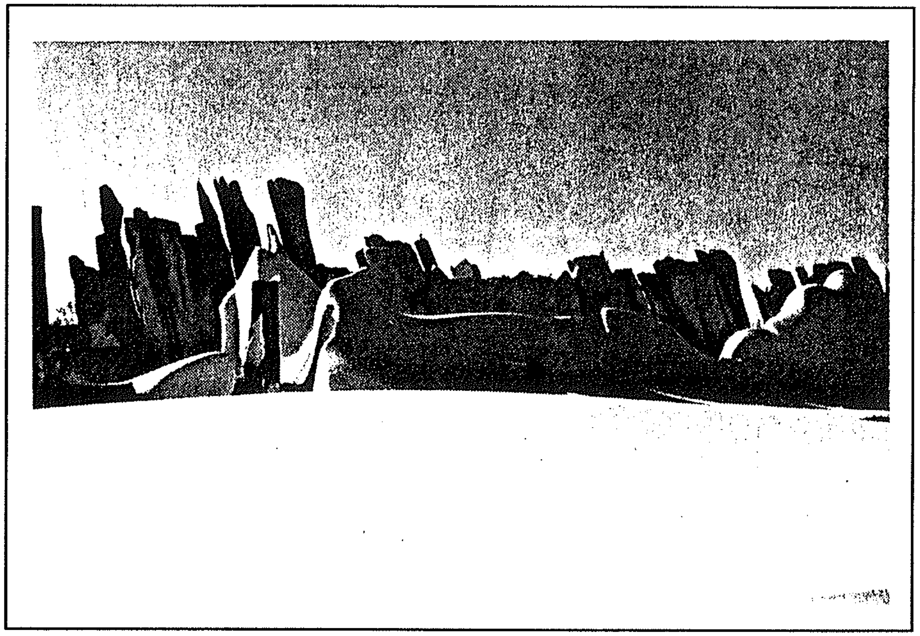
[4]Freeman Patterson, in Frost, by Lillian Allen, (Winnipeg: Hyperion Press Limited, 1990)Frost, p. 7.

[5]The snow fence was put there to retain moisture for the adjacent shrub bed, and to prevent snow drifting over walkway. Source: Marc Maguet of the Forks National Historic Park Service.

[6]Florence E. Brodie, in The New Morningside Papers, p. 385.

conclusion

Starbuck, Manitoba
February 11/92, 12:00 noon
-24° C. Wind NW at 4 km./hr.



CONCLUSION

Snowdrifts happen. Big, bold and beautiful, right where they're least expected - on the front doorstep, across the driveway... But rather than remove them, why not move them, to where their bold, beautiful contours can be enjoyed without them obstructing paths and roads?

Because if a drift grows across the parking lot during this storm , it'll be back the next storm, and the one after that... They are predictable, and in that they offer an opportunity for landscape architects to incorporate them into winter landscape design.

Snow is a unique substance. It is composed of millions of ice crystals which are in a perpetual state of change. They change with the temperature, the wind, with being stepped on, or molded into a snowball. They change with age, with the color of the sky, with the angle of the sun. They can be completely scoured out of an area. And they can collect in large immobile drifts beside hedges, fences, berms and buildings.

But snow is more than merely an unusual substance that can be swept away or collected together - it is a source of beauty. In the world of snow, texture, pattern, color, shadow and light ebb and flow into abstract patterns and rhythms. Incorporating snow into landscape design results in a more visually, as well as physically stimulating winter environment; one in which rhythm, light, shadow, texture, color abound. It is a playground for our children, our eyes, our memories.

There are a couple of ways of incorporating snow into landscape design.

One way is to simply allow space for a snowdrift to develop in and to locate that space in an area where traffic flow and building access will not be impeded. For example, locating a walkway and a row of trees a few meters apart rather than right beside each other, provides a area for drifts to develop in and an opportunity for pedestrians to enjoy those drifts.

The information reviewed in this report can be used as a guide for this type of 'snowdrift design'. While specific situations have been included in the text, the most important things to consider in terms of drift form and location are these:

1. The density of the obstacle creating the drift: solid obstacles create short deep drifts adjacent to the obstacle; less dense (more porous) obstacles create longer more shallow drifts.

2. The orientation of the obstacle to the prevailing wind: leeward drifts tend to be considerably longer and deeper than windward drifts.

In addition to merely replicating 'known' drift forms, simple variations could lead to some interesting effects and drift forms. These include:

*Experimenting with alternatives to traditional linear row planting to create interesting undulating effects.

*Testing different types of fences - both temporary and permanent - rather than depending on traditional snow fences.

*Creating rhythmic snowdrift effects by establishing a series of berms, or by varying the berm height and spacing.

Reasonable expectations should be employed. Drifts aren't particularly cooperative about giving up space, and will simply become problematic drifts if asked to do so. Therefore, enough area should be made available to accommodate the drift.

The variables which govern drift formation increase logarithmetically (at the very least!) as the number of obstacles influencing a drift form increase. Much of the information currently available involves one, or occasionally two obstacles. With the exception of very large open fields, drift formations on most sites are the result of many obstacles, including ones on adjacent sites. Thus the resultant form of a 'designed' drift may not be the exact intended form. This is not reason to be discouraged, but rather another source of surprise.

Another way of incorporating snowdrifts into landscape design is to explore and test the innate unique qualities of snow. Characteristics such as thawing, translucence, weathering effects, color, plasticity, texture, light and shadow effects, and sculptural forms can all serve to complement or to contrast with summer themes. This approach enables designers to explore the design potential of snow, as well as snowdrifts, and in doing so, add another dimension to their work.

Some of the suggestions put forth in this report include:

*Arranging dark colored objects (which absorb the sun's heat and melt the snow adjacent to them) so as to cause the snow around them to melt away and expose bright patches of color. This effect could be particularly striking on a bright February day.

*Playing with the translucence of snow has the potential for wonderful nighttime effects. What statements and effects are possible by combining snow sculpture and light? What are the possibilities when snow and ice and light are combined?

*Snow is a weathering agent. In a receptive medium, a snow polished surface could become a visual record of storms - an evolving sculpture.

*Coloring snow has some exciting possibilities. The reflection of a brightly colored element will color the adjacent snow. In this way, color can be used to contrast or reinforce the mood of a place. Coloring snow with warm colors has some potentially interesting effects.

*Snow is a canvas that patterns can be created on. Leaves, rocks, pebbles, or seeds spread over snow form dynamic patterns. In the spring they also form interesting melting patterns.

*Playing with shadow on snow is an art form which should be explored. Shadows on snow establish rhythm. They also form distorted and abstract patterns in and of themselves.

*Snow has the potential to be incorporated into outdoor art. Snowdrifting or snow collecting could be an intended aspect of the piece, which would add another dimension to the work.

By befriending snow, and utilizing its inherent qualities, landscape architects can add a further dimension to the place they create either by further enhancing the feel of place established by summer themes, or by encouraging a distinct, yet pleasing winter theme.

It is hoped that this report will serve as a beginning - a source of possibilities from which other possibilities will grow. And that in time, northern designers will incorporate and celebrate snow and winter as they currently do with southern exposure and shade trees and water and views... In time, may we come to laugh and dance the rhythm of snow and winter.

"A snow year, a rich year."[1]

REFERENCE:

[1]George Herbert, The Works of George Herbert, (Oxford: Clarendon Press, 1941), p. 324.

appendix

BUILDING REFERENCES:

Alberts, W. "Modeling the Wind in the Town Planning Process." Energy and Buildings. 4, 1982, pp. 71-76.

Cornish, Vaughan. "On Snow-waves and Snow-drifts in Canada." The Geographical Journal. Aug. 1902, Vol. XX, No. 2, pp. 137-175.

Gerry, K. and G. Harvey. "Tower Blocks, Winds and Microclimate." In Energy Saving through Landscape Planning. The Background. Volume 1 of 6. Croydon: Property Services Agency, 1988.

Irwin, P.A. and C.J. Williams. "Snowdrift Models." The Northern Engineer. Fall 1985, Vol. 17, No. 3, pp. 4-11.

Melargno, M. Wind in Architectural and Environmental Design. Toronto: Van Nostrand Reinhold, 1982.

Morrison et al. Wind and Snow Control Studies. Guelph, Ont.: Theakston & Rowan Ltd., [1970?].

Olgyay, V. Design with Climate: Bioclimatic Approach to Architectural Regionalism. Princeton: Princeton University Press, 1963.

Penwarden, A.D. and A.F.E. Wise. Wind Environment Around Buildings. London: Her Majesty's Stationery Office, Dept. of the Environment, Building Research Establishment Report, 1975.

FENCE AND WALL REFERENCES:

Geiger, R. The Climate Near the Ground. Cambridge, Mass,: Harvard University Press, 1959.

Lof, R.J., R.W. Alperi, and C.K. Taft. "Wind Effects on Ski Trails. " Proceedings of the 29th Annual Eastern Snow Conference. Oswego, N.Y.: publ. unknown, 1972, pp. 83-97.

Melargno, M. Wind in Architectural and Environmental Design. Toronto: Van Nostrand Reinhold, 1982.

Perko, Dan. "To catch the snow." Wyoming Wildlife. Wyoming Game and Fish Commission Publication, Jan. 1984, pp. 26-31.

Pugh, H. and W. Price. "Snow Drifting and the Use of Snow Fences." The Polar Record. Jan. 1954, Vol. 7, No. 47, pp. 4-23.

Protz, A. and P. Owen Moen. Farmstead Planning. Family Farm Improvement Branch, Saskatchewan Agriculture / Agriculture Canada, Publication 1674, 1979.

Read, R.A. Tree Windbreaks for the Central Great Plains. U.S. Department of Agriculture, U.S. Dept. of Agriculture Handbook No. 250, Feb. 1964.

Rikhter, G.D. Snow Cover, It's Formation and Properties. Moscow: Publishing House of the Academy of Science, Aug. 1954.

Sommerfeldt, Theron G. "Snow Trapping by Windbreaks." Proceedings of the Regional Saline Seep Control Symposium, 1976, pp. 78-90.

Royle, Jack. "Frank Theakston's Thirty-Year Search for the Secrets of Wind, Snow and sun." Winter Cities Newsletter, Feb. 1988, Vol. 6, No. 1, pp. 5-6.

Tabler R.D., J.W. Pomeroy, and B.W. Santana. "Drifting Snow." Cold Regions Hydrology and Hydraulics: A state of the Practice Report. Edited by W.L. Ryan and R.D. Crissman. New York: American Society of Civil Engineers, 1990, pp. 95-145.

Verge, R.W. and G.P. Williams. "Drift Control" In Handbook of Snow: Principles, Processes, Managements, and Use. D.M. Gray and D.H. Male (eds.). Toronto: Pergamon Press, 1981, pp. 630-647.

TOPOGRAPHY REFERENCES:

Rikhter, G.D. Snow Cover, It's Formation and Properties. Moscow: Publishing House of the Academy of Science, Aug. 1954.

Royle, Jack. "Frank Theakston's Thirty-Year Search for the Secrets of Wind, Snow and sun." Winter Cities Newsletter. Feb. 1988, Vol. 6, No. 1, pp. 5-6.

Verge, R.W. and G.P. Williams. "Drift Control" In Handbook of Snow: Principles, Processes, Managements, and Use. D.M. Gray and D.H. Male (eds.). Toronto: Pergamon Press, 1981, pp. 630-647.

VEGETATION REFERENCES:

Baer, N. and P. Schaefer. "Row spacing: Which windbreak stops snow better - one that is open or one that is tight?" South Dakota Farm and Home Research. 1984, Vol. 35, pp. 17-18.

Butler, Ovid. "The Prairie Shelter Belt." American Forests. 1934, Vol. 40, pp. 395-398, 431.

Campbell, R.B. and R. B. Grau. Evergreen Windbreaks for Iowa Farmsteads. Iowa State College, Agriculatural Experiment Station- Agricultural Extension Service, Cooperative, May 1948, Bulletin P88, pp. 920-929.

Duncan, Don. "Let'er snow and blow." Capper's Farmer. 1953, Vol. 64, No. 4, pp. 83-85.

Melargno, M. Wind in Architectural and Environmental Design. Toronto: Van Nostrand Reinhold, 1982.

Miller, D.R., N.J. Rosenberg and W.T. Bagley. "Wind Reduction by a Highly Remeable Tree Shelterbelt." Agricultural Meteorology. 1975, Vol. 14, No. 3, pp. 321-333.

Olson, H.E. "Landscape Planting for Snowdrift Control." Park Maintenance. March 1963, pp. 17-22, 24, 25, 28.

Perko, Dan. "To catch the snow." Wyoming Wildlife. Wyoming Game and Fish Commission Publication, Jan. 1984, pp. 26-31.

Pitt, D.G., J. Kissida, and W. Gould Jr. "How to Design a Windbreak." American Nurseryman. Nov. 15, 1980, pp. 10, 11, 50.

Prairie Farm Rehabilitation Administration. Planning Farm Shelterbelts. Indian Head, Sask.: PFRA Tree Nursery, T.N. Circ. No. 1, 1984.

Protz, A. and P. Owen Moen. Farmstead Planning. Family Farm Improvement Branch, Saskatchewan Agriculture / Agriculture Canada, Publication 1674, 1979.

Read, R.A. Tree Windbreaks for the Central Great Plains. U.S. Department of Agriculture, U.S. Dept. of Agriculture Handbook No. 250, Feb. 1964.

Rikhter, G.D. Snow Cover, It's Formation and Properties. Moscow: Publishing House of the Academy of Science, Aug. 1954.

Royle, Jack. "Frank Theakston's Thirty-Year Search for the Secrets of Wind, Snow and sun." Winter Cities Newsletter. Feb. 1988, Vol. 6, No. 1, pp. 5-6.

Shaw, D.L. Living Snow Fences: Protection that Just Keeps Growing. Colorado Interagency Living Snow Fence Program, Colorado State University, Fort Collins, CO., Oct., 1991.

Sommerfeldt, Theron G. "Snow Trapping by Windbreaks." Proceedings of the Regional Saline Seep Control Symposium, 1976, pp. 78-90.

Stoeckeler, J.H. and E.J. Dortignac. "Snowdrifts as a Factor in Growth and Longevity of Shelterbelts in the Great Plains." Ecology. Apr. 1941, Vol. 22, No. 2, pp. 117-124.

Stoeckeler, J.H. Shelterbelt Influence on Great Plains Field Environment and Crops: A Guide for Determining Design and Orientation. Production Research Report No. 62. U.S. Dept. of Agriculture, Agriculture Research Service, Oct. 1962.

Tabler, R.D. Snow Control Course Notes. Unpublished, Release 4.0, 1990.

Verge, R.W. and G.P. Williams. "Drift Control" In Handbook of Snow: Principles, Processes, Managements, and Use. D.M. Gray and D.H. Male (eds.). Toronto: Pergamon Press, 1981, pp. 630-647.

Williams, Ross. "Trees that Beat the Blizzard." American Forests. Vol. 55, No. 8, 1949, pp. 26,27,42,43.

Wyman, Donald. Hedges, Screens and Windbreaks. Their Uses, Selection and Care. New York: McGraw-Hill Co. Inc., 1938.

bibliography

BIBLIOGRAPHY:

Allen, Lillian. Frost. Winnipeg: Hyperion Press Limited, 1990.

Arabadzhi, V.A. and K.I. Rudik. The Squeak of Snow. Trans. E.R. Hope. Directorate of Scientific Information Services DRB Canada, January, 1966.

Bader, Henri. "Mineralogical and Structural Metamorphism" Snow and its Metamorphism. U.S. Army, Corps of Engineers, Snow, Ice and Permafrost, Research Establishment, Translation 14. January 1954. pp 5-20.

Bader, Henri. The Physics and Mechanics of Snow as a Material. U.S. Army Cold Regions Research and Engineering Laboratory, Cold Regions Science and Engineering, Part 11: Physical Science, Section B. July 1962. pp 1-18.

Bentley, W.A. and W. J. Humphreys. Snow Crystals. New York: McGraw-Hill Book Co. Inc., 1931.

Blumenfeld, Hans. "Get the Devil Out by Detail" Winter Cities. Vol. 8, No. 2, August 1990. pp 59-61.

Borowiecka, Alexandra. Winter and Playgrounds. Unpublished Thesis, Faculty of Architecture, Master of Landscape Architecture, University of Manitoba, 1980.

Bye, A. E. Art into Landscape, Landscape into Art. Arizona: PDA Publishers Corporation, 1983.

Caborn, J.M. Shelterbelts and Windbreaks. London: Faber and Faber, 1965.

Campbell, R.B. and R.B. Grau. Evergreen Windbreaks for Iowa Farmsteads. Iowa State College, Agricultural Experiment Station - Agricultural Extension Service, Cooperative, May 1948, Bulletin P88, pp. 920-929.

Cornish, Vaughan. "On Snow-waves and Snowdrifts in Canada" The Geographical Journal. Vol. 20, No. 2, August 1902. pp 137-175.

de Quervain, M. "Snow and avalanches" Forces of Nature. Ed. Sir Vivian Fuchs. New York: Holt, Rinehart and Winston, 1977. pp.81-104.

du Toit, Roger. "Livable Winter Cities" Livable Winter Newsletter. Vol. 3, No. 6, December 1985. pp. 8-11.

Elsner, Robert W. and William O. Pruitt, Jr. "Some Structural and Thermal Characteristics of Snow Shelters" reprinted from "Arctic," Journal of the Arctic Institute of North America. Vol. 12, No. 1. pp 20-27.

Environmental Controls Course Notes, Faculty of Architecture, Univeristy of Manitoba, Winnipeg, Winter Session, 1988.

Ekoomiak, Normee. Arctic Memories. Toronto: N.C. Press Ltd.

Erskine, Ralph. "Architecture and Town Planning in the North" The Polar Record. Vol. 14, No. 89, 1968. 165-171.

Gehl, Jan. "Hot Time in the Cold Town" Winter Cities. Vol. 8, No. 2, August 1990. pp 26-30.

Guidoni, Enrico. Primitive Architecture. Trans. Robert Erich Wolf. New York: Rizzoli International Publications, Inc., 1975.

Gzowski, Peter, ed. The New Morningside Papers. Toronto: McClelland and Stewart, 1987.

Hanen, Harold *"A Tribute to the Snowflake:* Canada's Neglected Winter Flower" Livable Winter Newsletter. Vol. 5, No. 1, February 1987. pp 11-12.

Heisler, Gordon M. and David R. DeWalle. "Effects of Windbreak Structure on Wind Flow" International Symposium on Windbreak Technology, Proceedings. Ed. David L. Hintz and James R. Brandle. Lincoln, Nebraska: Great Plains Agricultural Council Publication No. 117, June 23-27.

Herbert, George. The Works of George Herbert. Oxford: Clarendon Press, 1941.

Hiroshige: Birds and Flowers. New York: George Braziller Inc., 1988.

Hough, Michael et. al. Winter Cities Design Manual. Sault Ste. Marie: Hough Stansbury Woodland Limited, 1991.

Irwin, Peter A. and Colin J. Williams. "Snowdrift Models" The Northern Engineer. Vol. 17, No. 3, 1985. pp 4-11.

Joyce, James. "The Dead" Dubliners. New York: Random House, 1954. pp. 224-288.

Kereluk, William. A Prairie Boy's Winter. Montreal: Tundra Books of Montreal, 1973.

Kind, R. J. "Snow Drifting," Handbook of Snow: Principles, Processes, Managements, and Use. Eds. D.M. Gray and D.H. Male. Toronto: Pergamon Press, 1981. pp. 338-359.

Knight, Charles and Nancy Knight. "Snow Crystals" Scientific American. Vol. 228, No. 1, January 1973. pp 100-107.

L'Heureux, Roger. "Ice - Nature's Superb Manifestation; Obdurate yet fragile - austere yet edible - unspeakably beautiful and unappreciated" Winter Cities Newsletter. Vol. 5, No. 5, October 1987. pp. 10-12.

Lane, Richard. Images from the Floating World: The Japanese Print. New York: G.P. Putman's Son's, 1978.

Leiberman, Garry. Systems Coodinator, City of Winnipeg, Operations Department, Central Administration Branch, 1992.

Magono, C. and C. Lee. "Meteorological Classification of Natural Snow Crystals," Journal of Faculty of Science, Hokkaido University, Ser. VII, Vol. 2, p. 321; reprinted in D.M. Gray and D.H. Male (eds.), Handbook of Snow: Principles, Processes, Mangaement, and Use. Toronto Ont.: Pergamon Press, 1981.

Mason, B.J. "The Growth of Snow Crystals" Scientific American. Vol. 204, No. 1, January 1961. pp. 120-31.

Matus, Vladimir "Let the Sunshine In!" Winter Cities. Vol. 8, No. 2, August 1990. pp 48-51.

Melargno, M. Wind in Architectural and Environmental Design. Toronto: Van Nostrand Reinhold, 1982.

Mellor, Malcolm. "Blowing Snow" Cold Regions Science and Engineering Part III, Section A3c. Hanover, New Hampshire: Cold Regions Research & Engineering Laboratory, November 1965.

Mines, Resources, Environmental Management. Winter Weather and Wild Ungulates: A Literature Review with Special Reference to Manitoba. Development and Extension Service, Resource Projects, Report No. 10.

Morrison, Hershfield, Theakston & Rowan Ltd., Consulting Engineers. Wind and Snow Control Studies. Guelph, Ontario: Theakston & Rowan Ltd., 1970? pp 1-34.

Mowat, Farley. The Snow Walker. Toronto: McClelland and Stewart, 1975.

Pitt, D.G., J. Kissida, and W. Gould, Jr. "How to Design a Windbreak" American Nurseryman. November 15, 1980. pp. 10, 11, 50.

"Planning Farm Shelterbelts." Prairie Farm Rehabilitation Administration. Indian Head, Saskatchewan.

Pruitt, Jr., William O. "Life in the Snow" Manitoba Nature. Winter 1973. pp 3-11.

Pruitt, Jr., William O. "Some ecological aspects of snow" Proceedings of the 1966 Helsinki Symposium on Ecology of the Subarctic Regions. UNESCO series Ecology and Conservation. Vol. 1, 1970. pp. 83-99.

Pugh, H. and W. Price. "Snow Drifting and the Use of Snow Fences" The Polar Record. Vol. 7, No. 47, January 1954. pp 4-23.

Read, Ralph A. "Tree Windbreaks for the Central Great Plains" U.S. Department of Agriculture Handbook No. 250. U.S. Dept. of Agriculture, February 1964.

Rikhter, G.D. Snow Cover, Its Formation and Properties. Moscow: Publishing House of the Academy of Science, 1954.

Robinnette, G. O., ed. Plants, People and Environmental Quality Washington: U.S. Dept. of the Interior, National Park Services, 1972.

Royal Architectural Institute of Canada and the American Institute of Architects, Winter Cities. Edmonton, Alberta, February 20-23, 1986.

Royle, Jack. "Frank Theakston's thirty-year search for the secrets of the wind, snow and sun" Winter Cities News. Vol. 6, No. 1. pp. 5-6.

Sadler, Doug. Winter: A Natural History. Peterborough: Broadview Press, 1990.

Schaefer, Vincent J. "Treasures of the Snow" The Conservationist. December-January 1960-1961. pp. 2-3.

Sherman, Francis Joseph. "In Exile." Source unknown.

Spears, Richard C. Appendix A. Preliminary Work Toward Building Form Siting and Orientation in Subarctic Climates. Winnipeg: Centre for Settlement Studies, 1976.

Stoeckeler, J. H. "Shelterbelt Influence on Great Plains Field Environment and Crops: A Guide for Determining Design and Orientation." Production Research Report No. 62. U.S. Department of Agriculture, Agriculture Research Service, October 1962.

Stoeckeler, J. H. and E.J. Dortignac. "Snowdrifts as a Factor in Growth and Longevity of Shelterbelts in the Great Plains" Ecology. Vol. 22, No. 2, April 1941. pp 117-124.

Tabler, Ronald D. J., W. Pomeroy, and B. W. Santana. "Drifting Snow" Cold Regions Hydrology and Hydraulics. New York: American Society of Civil Engineers, 1990. pp 95-145.

Tabler, Ronald D. Snow Control Course Notes. Niwot, Colorado: Tabler & Associates, 1990.

Tabler, Ronald D. "Snow Fence Technology: State of the Art" First International Conference on Snow Engineering. Santa Barbara, California, July 1988.

Thomsen, C. H. and A. Borowiecka. Winter and Play: Design Guidelines for Winter Play Environments of the Canadian Prairie. Ottawa: Canada Mortage and Housing Corporation,1980.

Verge, R.W. and G.P. Williams, "Drift Control," Handbook of Snow. pp. 630-647.

Vopnfjord, Leonard W. "The Planner's Role" The Winter City. Canadian Housing Design Council and University of Manitoba, Continuing Education, Winter, 1982.

Welch, John. "The Effects of Sun, Wind and Snow on Urban Design" The Winter City. Canadian Housing Design Council and University of Manitoba, Continuing Education, Winter, 1982.

Welch, John. Professor of Environmental Studies, Faculty of Architecture, University of Manitoba, Winnipeg. Interview, January, 1992

Welch, Michael, D. Egret. California: Press Here, 1989.

Winnipeg Free Press, November 8, 1986, November 9, 1986, February 8, 1992, February 22, 1992

glossary

GLOSSARY:

barchans - small hard packed crescent shaped snow formations which form with their long axis against the flow of the wind; thought to be a transitional form between sastrugi and waves or ripples; 2m long

blower fence - a solid, smooth fence oriented in such a way as to direct the wind flow in a specific direction

collecting fence - a fence designed to prevent snow from accumulating in a specific area by accelerating and redirecting the wind to that area

density - a measurement of how much water is contained in a specific volume of snow

dunes - large hard packed snow formations which develop during blizzards; they have a smooth rounded form and are oriented with their long axis parallel to the wind; 10-100m long x 0.5-2m high

end effect - the rounded ends of a snowdrift created by very high wind speeds which occur at the ends of collecting fences and dense shelterbelts

graupel - granular snow pellets; also called soft hail

high snowstorms - snowstorms in which drifting and blowing snow occur within a few to several meters of the ground level; the source of drifting and blowing snow is both falling snow and previously fallen snow

ice crystals - see snow crystals

leading fence - a solid, smooth fence oriented in such a way as to direct the wind flow in a specific direction

low snowstorms - snowstorms in which drifting occurs within a few cm of the ground level; the source of drifting snow is previously fallen snow

ripples - small hard packed snow formations which have a subtle rounded undulated form and are oriented with their long axis against the wind flow; 10-40cm long x 1-2 cm high

saltation - the transportation of snow particles by currents of air in such a manner that they move along in a series of short intermittent leaps; the most common mode of transport of blowing snow the the largest source of drifted snow.

sastruga (singular), **sastrugi** (plural) - a wavelike ridge of hard snow usually formed on a level surface by the wind parallel to its direction; 1-2m long x 10-15cm high

scouring - the process by which the wind sweeps away all or most of the snow from a particular area

snow crust - a very dense layer of snow, and occasionally ice which forms on the surface of the snow cover as a result of melting of the surface layer followed by frosts, winds, liquid precipitation, etc.

snow crystals - the solid form assumed by water vapor when subjected to below freezing temperature; infinitely varied in form; may join together to form a collection of crystals called a snowflake; at cold temperatures snowfall consists of individual snow crystals

snowflakes - a collection of snow or ice crystals which have joined together; tend to fall in mild winter weather

sublimation - the process by which a solid is converted to a gaseous state as a result of heat or pressure

surface creep - the transportation of snow particles by currents of air in such a manner that they are moved along the snow surface by the impact of other snow particles in saltation.

suspension - mode of transport of snow particles in which small light particles become suspended in the air stream and flow with the wind above the ground

waves - hard packed snow formations which form with their long axis at right angles to the wind flow; 5-10m long x 10-20cm high

wind channel - a dense shelterbelt oriented in such a way as to direct the wind flow in a specific direction rather than reduce it

windrow - see shelterbelt

wind crust - see wind slab

wind slab - a very dense crust which form son the surface of the snow cover as a result of the packing effects of high winds