The International Classification for Seasonal Snow on the Ground

Prepared by:

Working Group on Snow Classification:

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Issued by:

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FOREWORD

In 1985 the International Commission on Snow and Ice established a Working Group on Snow Classification to update the old system for classifying snow on the ground. This group sought input from many people from various countries, and after several years of discussions about the different needs, it was able to put together a system that has widespread support.

After this long and difficult period of synthesizing ideas from different countries and users, we are fortunate to have the publication of this document made possible by the World Data Center A for Glaciology and CRREL. On behalf of ICSI, I would especially like to thank Dr. S. Colbeck, the Chairman of the Working Group, who has put much effort in the organization of the ICSI system's updating and made possible its publication through CRREL, as well as the members of his Working Group: Dr. E. Akitaya, Dr. R. Armstrong, Dr. H. Gubler, Dr. J. Lafeuille, Dr. K. Lied, Dr. D. McClung and Dr. E. Morris for their valuable contributions to this very important work.

V.M. Kotlyakov
President, ICSI

ACKNOWLEDGMENTS

It is probably not possible to provide a classification system that would truly satisfy all levels of users in all countries, but after several years of work, we have developed a system that we feel is a major step forward. We hope that we have addressed the needs of most users and that they will find the system useful. I thank those who encouraged the pursuit of a system that is based on morphology but includes the dominant physical processes as we understand them.

Among the members of the Working Group, Dr. H. Gubler should be recognized for completing the first draft of this report, and I thank the other members for comments on the many subsequent iterations. The names and addresses of the Working Group members are included so that they can act as sources of information. Many people outside of the Working Group also contributed in both moral support and suggestions. These included Dr. J. Montagne and Dr. S. Custer, who should have been members of the original Group. The staff at the Swiss Federal Institute for Snow and Avalanche Research took a deep interest in the project and contributed in many ways. Many other people helped with useful suggestions for improvements or comments on how the new system would affect their ongoing observations. Eric Brun translated the dictionary into French, and Stig Jonason translated it into Swedish.

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Samuel C. Colbeck,
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INTRODUCTION

In 1954 the International Commission of Snow and Ice issued a classification for snow on the ground (Technical Memorandum No. 31, Associate Committee on Soil and Snow Mechanics, National Research Council, Ottawa, Canada). This work has been widely used as a standard for describing the most important features of seasonal snow covers and is often cited in publications where a common description is needed. Other systems have been developed and used more recently, in part because of the increase in knowledge about the formation of snow-cover crystals and the changing nature of the way observations are made. The practice was markedly different in different countries, and some consolidation and updating were badly needed before a widely acceptable system could be published.

A new committee was formed in 1985 to update the existing international classification by including results of recent research and adapting the guidelines to several more or less parallel systems in use today in different countries. Special consideration was given to meeting the requirements of the various user groups working with seasonal snow: snow avalanche safety, snow hydrology, seasonal snow-cover remote sensing, snow mechanics, and research in snow physics including snow metamorphism.

An important feature of the classification is that it has been set up as the basic framework, which can be expanded or contracted to suit the needs of any particular group ranging from scientists to skiers. It has also been arranged so that many of the observations can be made either with the aid of simple instruments or by visual methods. Since the two methods are basically parallel, measurements and visual observations can be combined to produce the degree of precision required for any particular type of work.

The morphological classification of grain shapes has been supplemented with a process-oriented classification that includes some remarks on the physical processes involved. In many discussions it has become clear that users can be divided into two groups, one group classifying with only morphological criteria and a second group always using more process-oriented reasoning for snow characterization. Attempts have been made to set up a more structured, tree-like, exclusively morphological classification, but so far they have clearly failed. Futhermore, these seem not to be accepted by the majority of users. The request to include parameters available from automatic texture analyses could not be accepted because of the lack of a standard, unambiguous set of parameter definitions.

The material has been arranged into two sections and several appendices. Alphanumeric and graphical symbols are defined to allow for easy characterizations of snow types. The alphanumeric symbols of the snow grain classification are different from those of the 1954 classification. Some graphic symbols have been added to adapt the classification for practical use. There are two parallel alphanumeric symbols. The first simply divides the classification into *a,b,c,...* while the other uses letters from the English words, e.g., *dh* for depth hoar. Either of these two systems may be used since they are equivalent.

Solid precipitation, in the sense of freshly deposited snow particles, has been included in Section I on deposited snow. For the classification of falling snow, internationally recognized systems can be used when more detail is needed.

Section I is based on the fundamental features that determine the physical characteristics of a mass of snow and distinguish one type from another. It includes freshly fallen snow as well as surface deposits such as hoar and rime. Section II deals with other measurements that characterize the snow cover, including its surface features. The appendices include a list of symbols (A), a summary of definitions of terms (B), a multilinguistic dictionary of terms (C), an example of a graphic representation of a snow cover profile (D), and photographs to help practitioners classify snow (E).

I. FEATURES OF DEPOSITED SNOW

A snow cover is generally composed of layers of different types of snow, each of which is more or less homogeneous within its own boundaries. This section deals with the classification of the snow in any one layer. Inhomogeneity invariably occurs on a large scale and can occur within layers for reasons such as flow fingers, wind, or the disturbance caused by snow falling from trees. These features can be taken into account by classifying grain types within the disturbed areas separately and by making an additional description of the extent and shape of the disturbance. Three types of ice bodies that commonly occur in snow covers are also described: horizontal layers, vertical channels and basal ice.

Table 1. Primary physical characteristics of deposited snow.

Feature	*Units*	*Symbol*
Density	kg/m^3	ρ
Grain shape	(see Table 2)	F
Grain size, greatest extension	mm	E
Liquid water content	% by volume (Table 4)	θ
Impurities	% by weight	J
Strength (compressive, tensile, shear)	Pa	Σ
Hardness index	depends on instrument	R
Snow temperature	°C	T

Snow is very porous and sometimes contains liquid water. In the general case, therefore, snow can be regarded as a mixture of ice, air and water. The ice is in the form of crystals and grains that are usually bonded together to form a texture that possesses some degree of strength. The physical characteristics of a mass of snow, like those of many other materials, depend on its texture, its temperature and the relative proportions of its constituents. The primary distinctions between types of deposited snow are based on physical characteristics. The proposed standards are given in Table 1. The terms used in this table are defined in Appendix B.

Density — General symbol: ρ

Density is mass per unit volume. Mass is normally determined by weighing snow of a known volume. Sometimes total density and dry or ice density are measured separately.

Grain shape (form) — General symbol: F

In Table 2 (included as a foldout in the back of this report) the morphological classification of grains is supplemented by a process-oriented classification, including remarks on the most important physical processes involved. This side-by-side representation of the two classification types should help various user groups arrive at a more reliable classification and an easier physical interpretation of their observations.

For the grain shape classification, numbers *1–9* are used for the basic grain types, and letters *a*, *b*,... are used for the corresponding subclassifications. An alternate set of letters is given (e.g., *dh* or *mf*) for those who want symbols that suggest the corresponding English description. The two sets, however, are equivalent. If one has to deal with mixtures of grain types, proportions of the various types may be expressed as the number of tenths, e.g., *8F2aE0.5* and *2F1cE1.0*, where the first number is the fraction, *Fxx* indicates the shape and *Exx* indicates the size. The graphic symbols for the different types of a mixture can either be separated by commas or, if a metamorphic transition between the different types can be identified, arrows indicating the direction of transition.

Additional attributes can be used to refine the description of the grains. Examples of these attributes are grouped below and may be seen in Appendix E, which contains the photographs:

- General appearance: solid, hollow, broken, abraded, partly melted, rounded, angular;
- Grain surface: rounded facets, stepped or striated, rimed;
- Grain interconnections: bonded, unbonded, bond size, clustered, coordination number (number of bonds per grain), oriented texture, arranged in columns.

Grain size **General symbol: *E***

The grain size of a more or less homogeneous mass of snow is the average size of its characteristic grains. If there is an obvious mixture of different grain types and sizes, the different classes may be characterized individually. The size of a grain or particle is its greatest extension measured in millimeters. Other definitions are possible depending on the application but have to be clearly stated. A simple method suitable for field measurements is to place a sample of the grains on a plate that has been ruled in millimeters. The average size is then estimated by comparing the size of the grains with the spacing of the lines on the plate. This estimate may differ from those obtained by sieving or stereology. Some users will need to specify the range or distribution of sizes.

The grain size of deposited snow is expressed in millimeters or alternatively by using the terms in Table 3. A grain size of 1 mm is classified as *E1.0*.

Table 3. Grain size.

Term	*Size (mm)*
Very fine	< 0.2
Fine	0.2–0.5
Medium	0.5–1.0
Coarse	1.0–2.0
Very coarse	2.0–5.0
Extreme	> 5.0

Liquid water content **General symbol: θ**

Measurements of liquid water content or wetness are expressed as a percentage by volume, which usually requires a separate measurement of density. Several methods are in use today for field measurements to determine liquid water content: hot (melting) and cold (freezing) calorimetry, dilution and dielectric measurements. A general classification of liquid water content is given in Table 4.

Liquid water is only mobile if the irreducible water content is exceeded. The irreducible water content is about 3% by volume and depends significantly on snow texture, grain size and grain shape. This is the water that can be held by surface forces against the pull of gravity.

Impurities **General symbol: *J***

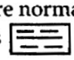
This subsection has been included in the classification to cover those cases in which the kind and amount of an impurity have an influence on the physical characteristics of the snow. In these cases the kind of impurity should be fully described and its amount given as a percentage by weight. Common impurities are dust, sand, organic material and solubles. Very low amounts of impurities do not strongly influence the physical properties of snow but are of hydrological and environmental interest. These are normally given in parts per million by weight (e.g. acids). The graphic symbol for impurities is 

Table 4. Liquid water content.

Term	*Remarks*	*Approximate Range of θ*	*Graphic Symbol*
Dry	Usually T is below 0°C, but dry snow can occur at any temperature up to 0°C. Disaggregated snow grains have little tendency to adhere to each other when pressed together, as in making a snowball.	0%	[ ]
Moist	T = 0°C. The water is not visible even at 10 × magnification. When lightly crushed, the snow has a distinct tendency to stick together.	< 3 %	[|]
Wet	T = 0°C. The water can be recognized at 10 × magnification by its meniscus between adjacent snow grains, but water cannot be pressed out by moderately squeezing the snow in the hands. (Pendular regime)	3–8 %	[||]
Very Wet	T = 0°C. The water can be pressed out by moderately squeezing the snow in the hands, but there is an appreciable amount of air confined within the pores. (Funicular regime)	8–15 %	[|||]
Slush	T = 0°C. The snow is flooded with water and contains a relatively small amount of air	> 15 %	[||||]

Snow strength **General symbol: Σ**

Snow strength depends on the stress state (compressive, tensile or shear), stress rate, strain and strain rate. In addition, strength depends on the sample volume because snow is imhomogeneous. To make measurements meaningful, all of these parameters must be considered. Moreover, strength types such as ductile, brittle fracture or maximum strength at low strain rates must be given.

Strain is dimensionless. The units are s^{-1} for strain rate, Pa for stress and Pa-s for stress rate.

Snow hardness **General symbol: *R***

Hardness measurements are subjective and produce an index value that depends on the instrument; therefore, the device has to be specified. A widely accepted instrument is the Swiss Rammsonde (cone tip angle: 60°; base diameter: 40 mm; weight: 10 N/m; ram weight: 10 N). Hardness is measured in newtons. It may be classified as shown in Table 5, which includes both the Rammsonde and the commonly used hand test. With the hand test, objects of different areas are gently pushed into the snow with a penetration force of about 50 N, which is easily executed with the hand.

Table 5. Hardness of deposited snow.

Term	*Swiss Rammsonde (N)*	*Order of magnitude strength (Pa)*	*Hand test*	*Symbol*	*Graphic symbol*
Very low	0–20	0–10^3	fist	R1	
Low	20–150	10^3–10^4	4 fingers	R2	/
Medium	150–500	10^4–10^5	1 finger	R3	X
High	500–1000	10^5–10^6	pencil	R4	//
Very high	> 1000	> 10^6	knife blade	R5	✳
Ice				R6	▬

Snow temperature **General symbol: *T***

The temperature of snow should be given in °C. Sometimes it is desirable to record other related temperatures; the suggested symbols for the more common ones are

Temperature	*T*
1.5-m air temperature	*Ta*
Temperature of snow surface	*Ts*
Ground temperature	*Tg*
Snow profile temperature at height H (m)	
above the ground	*TH0.5*
or below the surface	*TH–0.5*

Layer thickness **General symbol: *L***

The layer thickness is usually of primary interest, although in the case of lenses the lateral dimension is also important. The diameter and spacing of columnar features is essential for their description. For convenience, the use of centimeters is allowed as an exception to the SI system of units for measurements such as thickness and depth.

II. ADDITIONAL MEASUREMENTS OF DEPOSITED SNOW

A cross section of a snow cover can be described by classifying the snow in each layer, including the surface of the snow cover, as outlined in Section I. Some of the important measurements are listed in Table 6. The locations of the boundaries of the layers relative to the snow/ground interface should also be given. The location is generally established by its vertical distance from the surface of the ground, but when only the upper part of the snow cover is of interest or where it is difficult to use the ground as the reference, the snow surface may be taken as the reference. This should be indicated by using negative coordinate values.

The symbols *H*, *HS* and *HN* should be used for all vertical measurements, regardless of whether they are taken at a place where the snow surface is horizontal or inclined. Vertical measurements are sometimes preferred even when the snow lies on a slope. If, however, the measurements are perpendicular to an inclined snow surface, this fact should be indicated by using the corresponding symbols *D*, *DS* and *DN*.

Table 6. Snow cover measurements.

Term	*Dimension*	*Symbol*
Vertical coordinate (measured from the ground)	cm	*H*
Total depth of snow cover	cm	*HS*
Depth of daily new snowfall	cm	*HN*
Measurements corresponding to those above but taken perpendicular to an inclined snow cover	cm	*D* *DS* *DN*
Inclination of snow layer or ground	deg	ψ
Aspect of snow-covered slope	deg	*AS*
Surface roughness		*S*
Penetrability of snow surface layers		*P*
Water equivalent of snow cover	mm	*HSW*
Water equivalent of snow layer	mm	*HW*
Water equivalent of new snow layer	mm	*HNW*
Ratio of snow covered area to total area	tenths	*Q*
Age of snow deposit	hours, days or years	*A*

Surface roughness **General symbol: *S***

This subsection does not refer to roughness due to the granular nature of snow but to the roughness of a snow surface caused by wind, rain, uneven evaporation or uneven melting. The average depth of the irregularities, measured in millimeters, can be combined with the relevant symbol, for example, *Sc15*. The wavelength and compass direction may also be of interest. The roughness types are given in Table 7.

Table 7. Surface roughness.

Term	*Symbol*	*Graphic symbol*
Smooth	*Sa*	——
Wavy	*Sb*	
Concave furrows	*Sc*	
Convex furrows	*Sd*	
Random furrows	*Se*	

Load-bearing capacity of the snow surface **General symbol: *P***

Occasionally an approximate indication is required of the ability of a snow cover to support a certain load satisfactorily. The depth of penetration in millimeters of some suitable object, such as a ski or a foot, may be employed for this purpose. The following symbols are suggested:

Depth of ski track (skier supported on one ski)	*PS*
Depth of footprint (person standing on one foot)	*PP*
Penetration depth of a Swiss Rammsonde (first element by its own weight)	*PR*

Water equivalent **General symbol: *HW***

The water equivalent is the height of water if a snow cover is completely melted, measured in millimeters, on a corresponding horizontal surface area.

Aspect **General symbol: *AS***

The compass direction of the fall line of the snow-covered slope should be given by two digits, e.g. 09 for East, 18 for South, 27 for West or 36 for North.

APPENDIX A. LIST OF SYMBOLS

Symbol	*Description*	*Units*
A	Age of snow deposit	h, d, y
AS	Aspect of snow-covered slope	deg
D	Slope-perpendicular coordinate	cm, m
DN	Slope-perpendicular new snow thickness	cm, m
DS	Slope-perpendicular snow thickness	cm, m
E	Grain size	mm
F	Grain shape	
F1a..F9e	Grain shape classification	
H	Vertical coordinate above ground	cm, m
HN	Depth of new snowfall (daily)	cm, m
HNW	Water equivalent of new snow layer	mm
HS	Total depth of snow cover	cm, m
HSW	Water equivalent of snow cover	mm
HW	Water equivalent of layer	mm
J	Impurities	%, ppm (both by weight)
L	Layer thickness	mm, cm, m
P	Penetrability	mm
PP	Depth of foot print	mm
PR	Penetration depth of Swiss rammsonde	mm
PS	Penetration depth of ski track	mm
Q	Snow-covered area	tenths
R	Hardness index	N
R1..R6	Hardness classification	
S	Roughness of snow surface	mm
Sa..Se	Surface roughness classification	
T	Temperature of snow	°C
Ta	Air temperature	°C
Tg	Ground temperature	°C
TH..	Snow profile temperature at height H (m) (i.e. *TH0.5* is the snow temperature 0.5 m above the ground)	°C
Ts	Temperature of snow surface	°C
ψ	Inclination	deg
ε	Strain	
θ	Liquid water content	% (by volume)
ρ	Density	kg/m^3
σ	Stress	Pa
Σ	Strength	Pa

APPENDIX B. DEFINITIONS

Abraded	Mechanically rounded by interaction with other particles in the saltation layer
Aspect	The exposure of the terrain as indicated by compass direction of the fall line
Calorimetry	A method for determining the amount of heat needed to either freeze the liquid water content or melt the ice portion of the snow; used to determine the liquid water content
Crust	A hard, usually thin layer consisting of either one or a few grains in thickness or consisting of uniform, well-bonded material
Crystal	A solid whose atoms or molecules have a regularly repeated arrangement that may be outwardly expressed by plane faces
Density	Mass per unit volume
Dielectric devices	Instruments that use the dielectric properties of snow to determine the liquid water content through capacitance and density measurements
Dilution method	Method for determining the liquid water content of snow based on the reduction in concentration when the snow is added to an aqueous solution
Equilibrium form	The shape (usually rounded) resulting from no or slow growth
Facet	A crystal face or flat surface of a crystal; external manifestation of internal order
Firnspiegel	The thin, clear sheet of ice that forms over snow by absorption of sunlight on clear, cold days; gives bright, specular reflection of sun
Flow fingers	Vertical channels with percolating water
Funicular regime	The condition of high liquid water content in which liquid exists in continuous paths; grain-to-grain bonds are weak
Grain bond	The interconnection between grains, usually neck-like and narrow
Grain, particle	The smallest characteristic subunit of snow texture recognizable with a hand lens (e.g. 10 ×); it can consist of one or more crystals of ice
Hardness	The resistance to penetration of an object into snow
Ice	Ice crystals frozen together, with isolated pores and a density greater than about 830 kg/m^3
Ice layer	Snow grains that have been frozen together to form a hard mass, which may still be permeable
Irreducible liquid content	The liquid content held by capillarity against the pull of gravity
Kinetic growth form	Faceted shapes that result from rapid growth
Layer	A stratum of snow that is different in at least one respect from the strata above and below
Liquid water	All water in the liquid state; sometimes called free water
Morphological classification	A classification of the shape of the individual grains

Pendular regime	The condition of low liquid-water content where air exists in continuous paths; grain-to-grain bonds give strength
Penetrability	The depth of penetration of an object into the snow cover
Solid precipitation	The various kinds of solid water particles that develop in the atmosphere and fall earthward, for example, snow crystals or ice pellets, including freshly deposited particles that have not undergone perceptible transformation after being deposited on the ground; when clear morphological differences exist between falling and deposited particles, the term applies to precipitation while it remains air-borne
Process-oriented classification	A classification with respect to the most important physical processes responsible for a given grain shape
Sintering	The process of bond formation in snow
Size	The largest dimension of a grain or particle, measured in millimeters
Specific surface area	The surface area per unit mass of a bulk sample of snow
Striation	Easily recognizable growth steps across facets or crystal surfaces
Slush	Snow that is soaked with water and has very little strength
State of snow	Snow as characterized by such properties as liquid water content, temperature, impurities and hardness
Structure	Stratification or layering of snow, usually seen in snow pits
Suncrust	A hard, thin layer with refrozen crystals from surface melting
Surface roughness	The average shape and depth of the irregularities at a snow surface
Texture	The intergranular relationship; the size, shape and arrangement of grains as seen with a hand lens
Type of snow	Snow characterized by its texture and density

APPENDIX C: MULTILINGUAL LIST OF TERMS

English	*German*	*French*	*Swedish*	*Russian*
abraded	abgeschliffen	abrasé	avslipad	корродированный
air	Luft	air	luft	воздух, воздушный
airborne	in der Luft schwebend	dans l'air	luftburen	с воздуха (наблюдения)
alphanumeric	alphanumerisch	alphanumérique	alfanumerisk	аналогоцифровой
atom	Atom	atome	atom	атом
avalanche safety	Lawinensicherheit	securité contre les avalanches	lavinsäkerhet	лавинная защищенность, безопасность
bond size	Bindungsdurchmesser	taille des ponts	bindningsstorlek	размер контакта, связи
bonded	gebunden	soudés	bunden	связанный
brittle	spröd	fragile	spröd	хрупкий, ломкий
broken	zerbrochen	brisé	bruten	сломанный, разрушенный
classification	Klassifikation	classification	klassificering	классификация
clustered	in Gruppen	en grappes	samlad	аггрегированный
coarse	grob	gros	grov	грубый, необработанный; крупнозернистый
column	Saule	colonne	pelare	колонка; столбик (снежинка)
compressive	unter Druck	en compression	kompressiv	сжимающий
concave furrows	konkave Furchen	sillons concaves	konkava fåror	вогнутые формы микрорельефа (бороздки)
convex furrows	konvexe Furchen	sillons convexes	konvexa fåror	выпуклые формы микрорельефа
coordination number	Koordinationszahl	nombre de coordination	koordinationstal	координационное число
crust	Kruste	croûte	skorpa, skare	корка
crystal	Kristall	cristal	kristall	кристалл, кристаллический
cup	Becher	gobelet	bägare	кубок, бокал
decompose	spalten, zerfallen	décomposer	sönderdela	распадаться
degree	Grad	degrée	grad	степень, градус
density	Dichte	densité	densitet	плотность
depth hoar	Tiefenreif	givre de profondeur	rinnsnö	глубинная изморзь
droplet	Tropfen	gouttelette	liten droppe	капля
dry	trocken	sec/sèche	torr	сухой
ductile	duktil	ductile	tänjbar	пластичный, вязкий
evaporation	Verdampfen	évaporation	avdunstning	испарение
facet	Facette	facette	fasett	грань
faceted	facettiert	à facette	fasetterad	гранный, ограненный

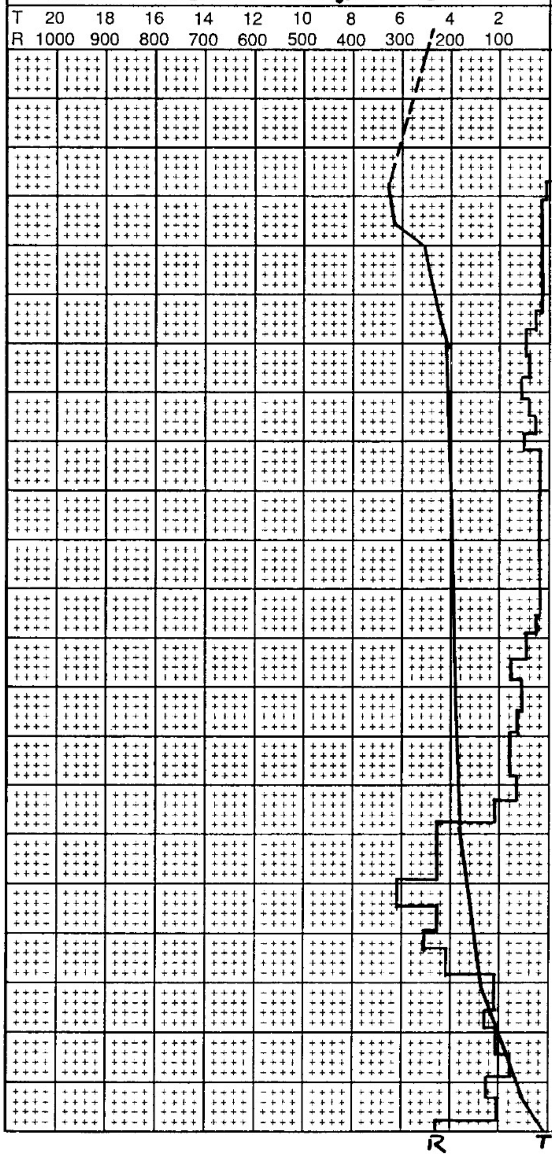
English	German	French	Swedish	Russian
featherlike	federförmig	poudreuse	fjäderformig	перьевидный
fine	fein	fin	fin	мелкий, мелкозернистый
finger	Finger	doigt	finger	палец
fist	Faust	poing	näve	кулак
footprint	Fussabdruck	empreinte	fotavtryck	отпечаток подошвы
fragmented	zerbrochen	fragmenté	fragmenterad	фрагментарный
funicular regime	zusammenhängende Wasserverteilung	régime funiculaire	funikulär regim	струйный (фуникулярный) режим
glazed	blank	vitreux	glaserad	обледенелый
grain shape	Kornform	forme des grains	kornform	форма зерен
grain size	Korngrösse	taille des grains	kornstorlek	размер зерен
graphical	graphisch	graphique	grafisk	графический
graupel	Graupel	neige roulée	snöhagel	снежная крупа
ground	Boden	sol	mark	грунт
hail	Hagel	grêle	hagel	град
hand lens	Handlupe	loupe	lupp	лупа
hand test	Handtest	test manuel	handtest	измерения, сделанные вручную
hardness	Härte	dureté	hårdhet	твердость
hexagonal	sechseckig	hexagonal	hexagonal	гексагональный, шестиугольный
hollow	hohl	creux	ihålig	полый
homogeneous	homogen	homogène	homogen	гомогенный, однородный
horizontal	horizontal	horizontal	horisontell	горизонтальный
ice	Eis	glace	is	лед
ice pellet	Eiskügelchen	sphérule de glace	småhagel	ледяная крупа
impurity	Verunreinigung	impureté	förorening	примесь, включения
inclination	Neigung	inclinaison	lutning	наклон
inclined	geneigt	incliné	lutande	наклонный
instrument	Instrument	instrument	instrument	прибор, инструментальный
intergranular	intergranular	intergranulaire	intergranulär	межзеренный
irregular	unregelmässig	irrégulier	oregelbunden	неправильный, неравномерный
isotropic	isotrop	isotrope	isotrop	изотропный
kinetic growth	geordnetes Kristallwachstum	croissance cinétique	kinetisk tillväxt	кинетический рост
knife blade	Messerklinge	lame de couteau	knivblad	лезвие ножа
laminar	geschichtet	laminaire	laminär	ламинарный
layering	Schichtung	stratigraphie	lagring, skiktning	слоистость

English	German	French	Swedish	Russian
low	gering	bas	låg	низкий
medium	mittel	moyen	intermediär	умеренный, средний
melted	geschmolzen	fondu	smält	талый
melting	schmelzend	fondant	smältande	таяние
mixed forms	gemischte Formen	formes mélangées	blandade former	смешанные формы
mixture	Mischung	mixture	blandningar	смеси
moist	feucht	humide	fuktig	сырой, влажный
needle	Nadel	aiguille	nål	игла
new snow	Neuschnee	neige fraîche	nysnö	свежевыпавший снег
pencil	Bleistift	crayon	penna, blyertspenna	карандаш
pendular regime	unzusammenhängende Wasserverteilung	régime pendulaire	pendulär regim	капиллярный (маятниковый) режим
penetrability	Durchdringbarkeit	pénétrabilité	penetrerbarhet	проницаемость (механическая)
permeability	Durchlässigkeit	perméabilité	permeabilitet	проницаемость
perpendicular	rechtwinklig	perpendiculaire	vinkelrät	перпендикулярный, отвесный
planar	eben	plan	plan	плоский
plate	Platte	plat	platta	пластинка
prismatic	prismatisch	prismatique	prismatisk	призматический
rain	Regen	pluie	regn	дождь
random furrows	unregelmässige Furchen	sillons désordonnés	slumpmässiga fåror	беспорядочный микрорельеф
rime	Reif	givre	dimfrost	иней, изморозь
rimed	bereift	givré	frostbelagd	покрытый инеем
roughness	Rauheit	rugosité	grovhet	шероховатость, неровность
rounded	gerundet	arrondi	avrundad	округлый
seasonal snow cover	Saisonschneedecke	manteau neigeux saisonnier	säsongmässigt snötäcke	сезонный снежный покров
shear	Scherung	cisaillement	skjuvning, skjuva	сдвиг, срез
sixfold	sechszählig	sextuple	sextalig	шестикратный
ski track	Skispur	trace de ski	skidspår	лыжня
slope	Hang	pente	sluttning	склон
slush	Matsch	trempé	slask	талый снег, слякоть, шуга
smooth	glatt	lisse	jämn	гладкий, ровный
snow	Schnee	neige	snö	снег
snow-covered area	schneebedeckte Fläche	surface enneigée	snötäckt område	заснеженная территория
snow deposit	Schneeablagerung	dépôt de neige	snöavlagring	отложенный снег (твердые осадк
snow hydrology	Schnee Hydrologie	hydrologie nivale	snöhydrologi	гидрология снега
snow mechanics	Schneemechanik	mecanique de la neige	snömekanik	механика снега
snow metamorphism	Schneeumwandlung	metamorphisme de la neige	snömetamorfos	метаморфизм снега

English	*German*	*French*	*Swedish*	*Russian*
snow physics	Schneephysik	physique de la neige	snöfysik	физика снега
solid	Voll(-körper)	solide	fast kropp	твердый
solid precipitation	fester Niederschlag	précipitation solide	fast nederbord	твердые осадки
spatial	räumlich	spatial	rumslig	пространственный
stellar	Stern	en étoile	stjärnformig	звездчатый
strain	Deformation	déformation	deformation	деформация
strain rate	Deformationsrate	vitesse de déformation	deformationshastighet	скорость деформации
stratification	Schichtung	stratification	stratifiering, skiktning	стратификация
strength	Festigkeit	résistance	hållfasthet	прочность
stress	Spannung	contrainte	spänning	напряжение, давление
stress rate	Spannungsrate	vitesse de mise en contrainte	spänningshastighet	скорость нагружения
striated	stufig, gestreift	strié	räfflad	бороздчатый, покрытый штриховкой
subunit	Untereinheit	sous unité	underenhet	подраздел
sun	Sonne	soleil	sol	солнце
supercooled	unterkühlt	surfondu	underkyld	переохлажденный
surface	Oberfläche	surface	yta	поверхность
surface deposit	Oberflächenablagerung	dépôt en surface	ytavlagring	поверхностное отложение, поверхностные осадки
surface hoar	Oberflächenreif	givre en surface	rimfrost	поверхностная изморозь, иней
Swiss rammsonde	Rammsonde	sonde de battage	stötsond, rammsond	швейцарский пенетрометр, зонд Хефели
temperature	Temperatur	température	temperatur	температура
tensile	unter Zug	sous/de tension	tensil	растяжимый, на растяжение, на разрыв (применительно к прочностным испытаниям)
transformation	Umwandlung	transformation	omvandling	превращение, преобразование
water	Wasser	eau	vatten	вода, водный
wavy	wellig	ondulé	vågig	волнистый
wet	nass	mouillé, humide	våt	влажный
wind	Wind	vent	vind	ветер
with steps	stufig	avec des stries, en escalier	stegformad	поэтапно

APPENDIX D. EXAMPLE OF A DATA SHEET FOR A SNOW COVER PROFILE

SNOW COVER PROFILE	Observer Meister Date 23 Feb 1989 Time 9:00:00	Remarks Wind loaded slope Number 1
Location Totalphorn		Air Temperature -5.0
H.A.S.L. 2500	Co-ordinates 781500/190200	Cloudiness Cu, Ac lens 5/8
Aspect N	Slope 40	Precipitation None
HS 193cm HSW 535mm ρ 177 kg/m³ R 88 N		Wind SE 5m/s

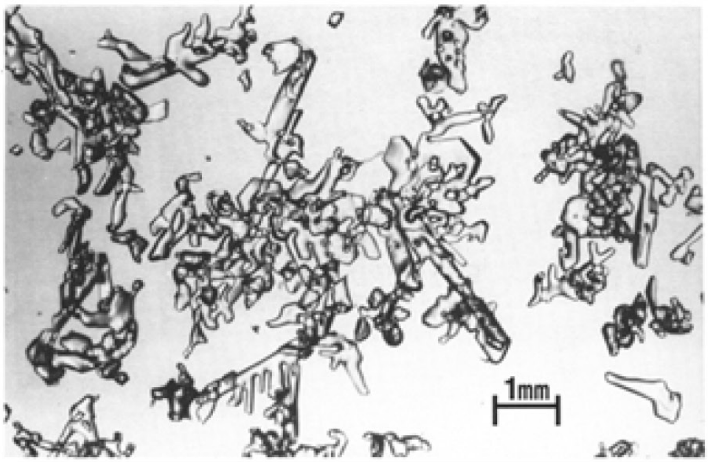


H	θ	F	E	R	HW ρ	Comments
210						
200						
190		/	1-1.5	X		
		/ϕ	1.5	X	28 147	Slide plane
180		•	1-2			
170						
160		●	.5-1	/	39 205	
150						
		V	2-3	/	41 215	slide plane
140						
130		□	1-2		51 268	
120						
110					56 294	
100						
90		□	1-1.5	X		
80						
70						
60					320 326	
50		□	1	//		
40						
30						
20		Λ	1-3	/		
10						

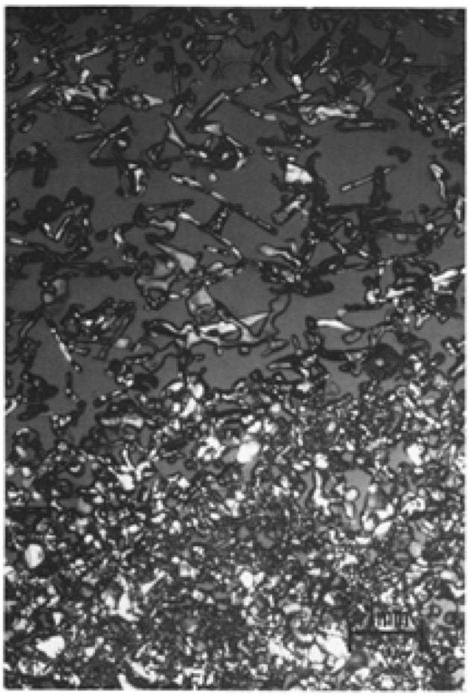
SNOW COVER PROFILE	Observer Date Time	Remarks Number
Location		Air Temperature
H.A.S.L.	Co-ordinates	Cloudiness
Aspect	Slope	Precipitation
HS HSW ρ R		Wind

T 20 R 1000	18 900	16 800	14 700	12 600	10 500	8 400	6 300	4 200	2 100		H	θ	F	E	R	HW ρ	Comments
											210						
											200						
											190						
											180						
											170						
											160						
											150						
											140						
											130						
											120						
											110						
											100						
											90						
											80						
											70						
											60						
											50						
											40						
											30						
											20						
											10						

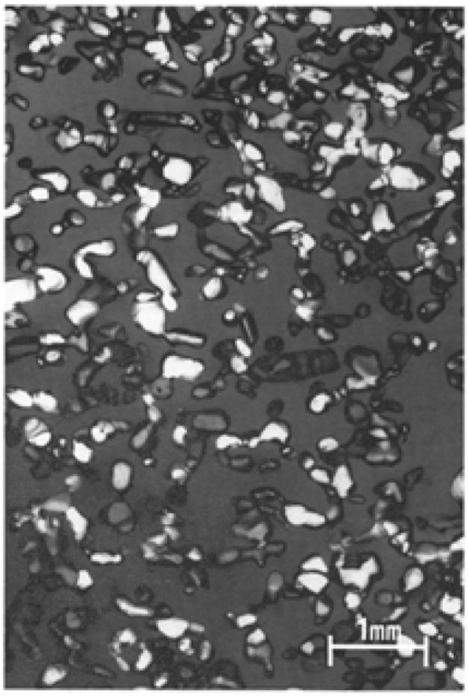
APPENDIX E: PHOTOGRAPHS OF VARIOUS GRAIN SHAPES



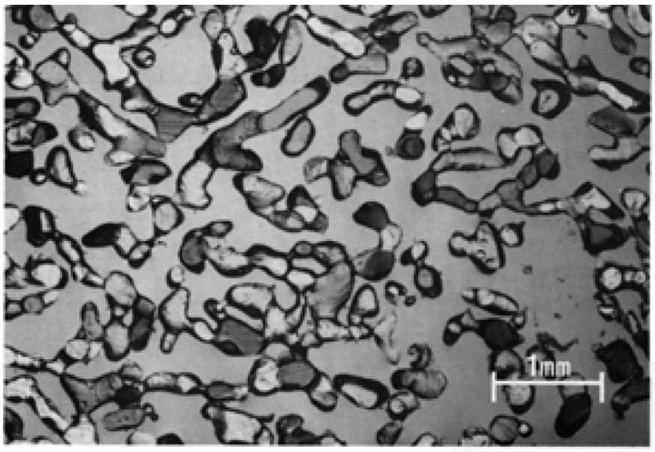
Class 2dc, partly decomposed precipitation particles. Photo by E. Akitaya.



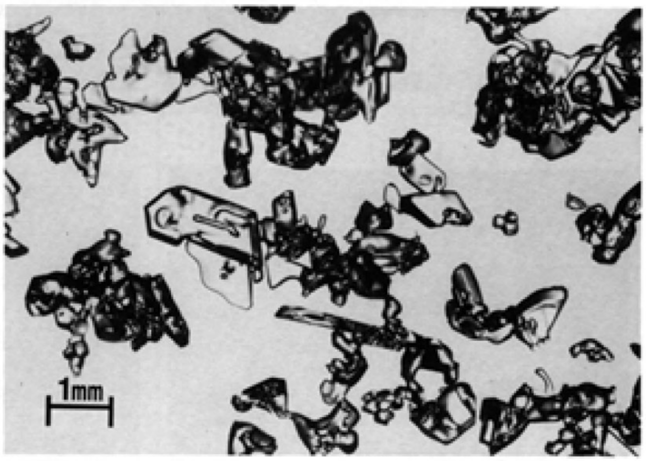
Class 2bk and 9wc, highly broken particles (on top) and wind crust (on bottom). Photo by E. Akitaya.



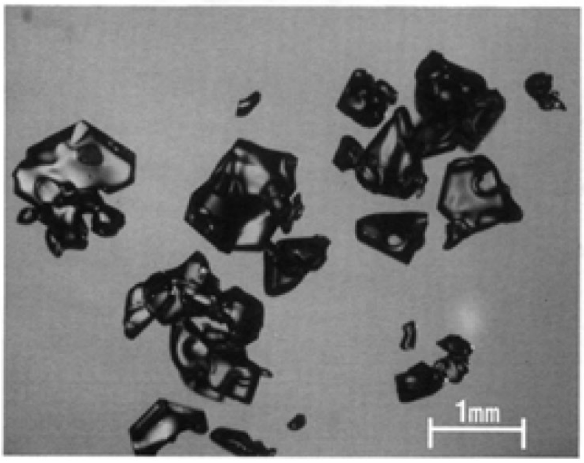
Class 3sr, small rounded particles. Photo by E. Akitaya.



Class 3lr, large rounded particles. Photo by E. Akitaya.

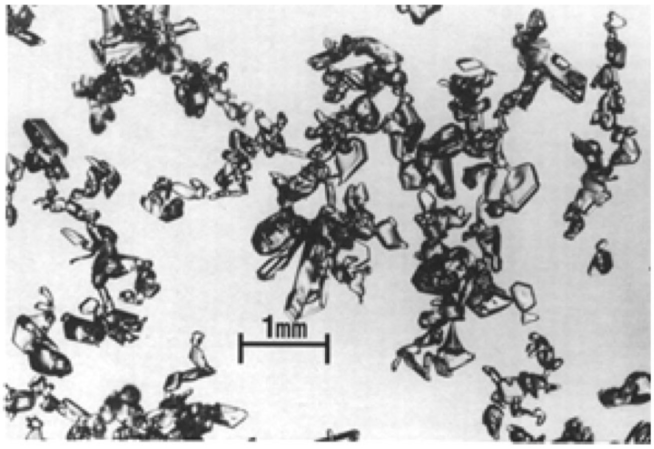


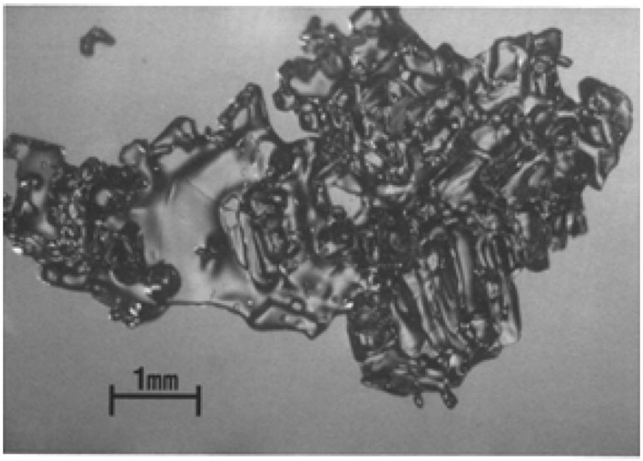
Class 3mx, rounded particles with developing facets. Photo by E. Akitaya.



Class 4fa, solid faceted particles. Photo by E. Akitaya.

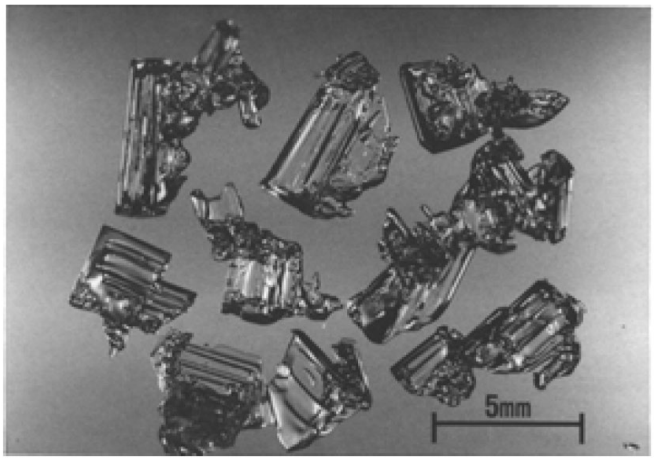
Class 4sf, small faceted particles in surface layer. Photo by E. Akitaya.

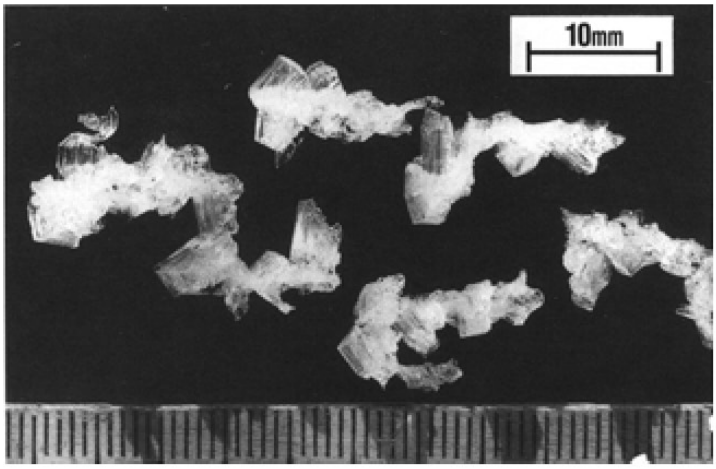




Class 4mx, faceted particles with recent rounding (buried surface hoar, 7sh, in this example). Photo by E. Akitaya.

Class 5cp, cup-shaped, striated crystals. Photo by K. Izumi.

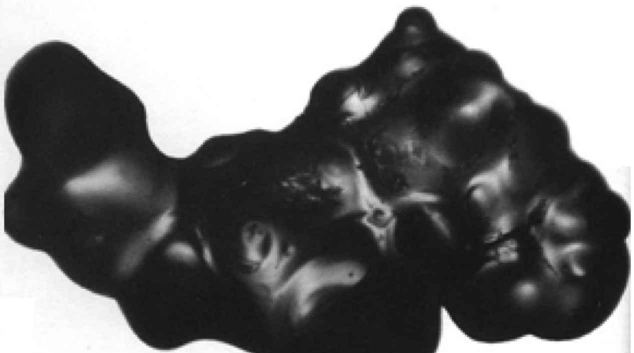




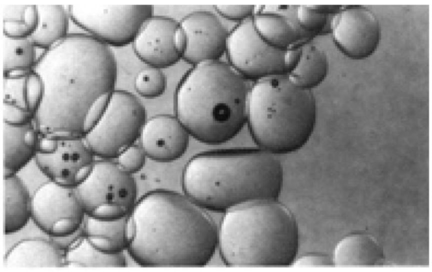
Class 5dh, cup-shaped crystals arranged in columns. Photo by E. Akitaya.

Class 5cl, large columnar crystals. Photo by M. Sturm.

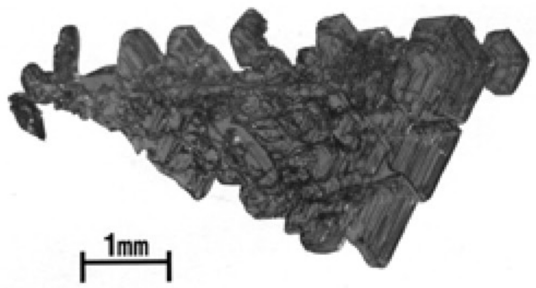
Class 6cl, clustered single crystals at low liquid content. Photo by S. Colbeck.



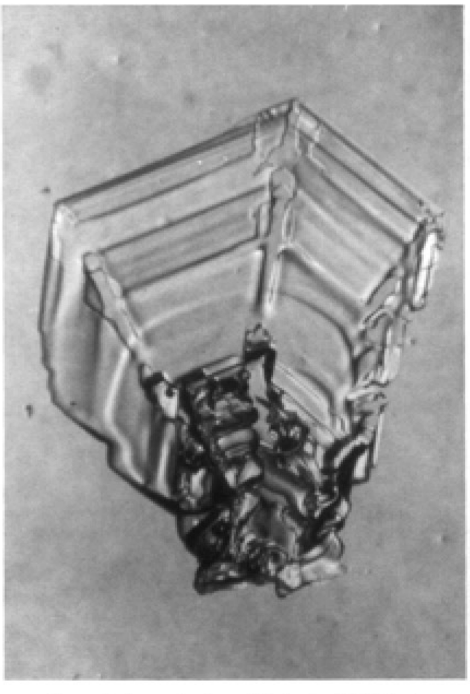
Class 6mf, polycrystalline particle from melt-freeze cycles. Photo by S. Colbeck.



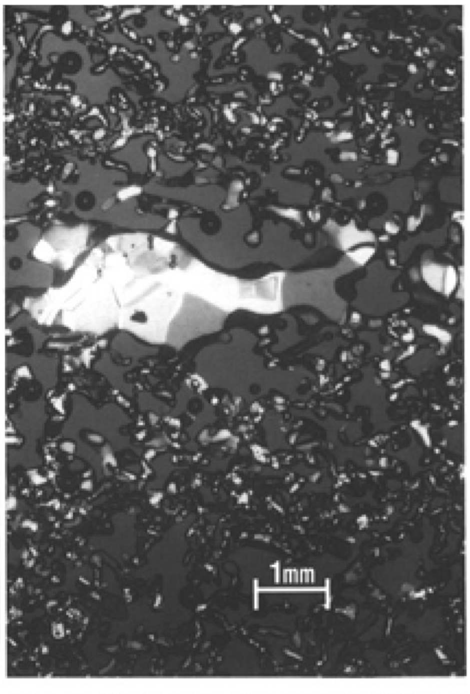
Class 6sl slush. Photo by S. Colbeck.



Class 7sh, surface hoar. Photo by E. Akitaya.

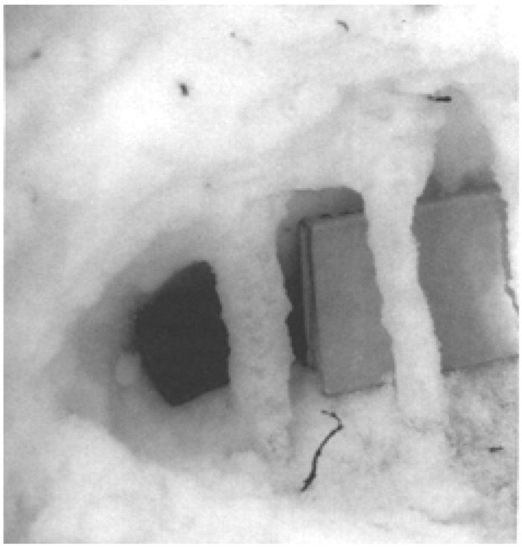


Class 7ch, cavity hoar. Photo by S. Colbeck.

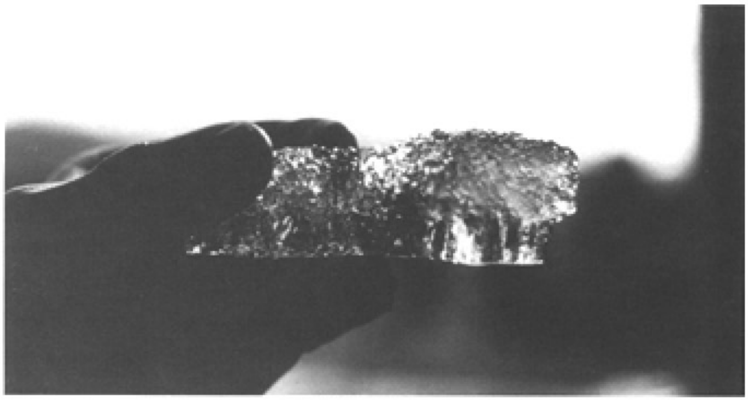


Class 8il, horizontal ice layer (in dry snow, 3sr, in this example). Photo by E. Akitaya.

Class 8ic and 8il, vertical and horizontal bodies. Photo by P. Marsh.



Classiic 8ic, vertical ice bodies. Photo by P. Marsh.



Class 8bi, basal ice layer. Photo by S. Custer.

Class 9sc, sun crust-firn spiegel. Photo by E. Wengi.

TABLE 2 GRAIN SHAPE CLASSIFICATION

MORPHOLOGICAL CLASSIFICATION					PROCESS-ORIENTATED CLASSIFICATION		ADDITIONAL INFORMATION ON PHYSICAL PROCESSES AND STRENGTH		
BASIC CLASSIFICATION	SYMB	SUBCLASS	SYMB	SHAPE	PLACE OF FORMATION	CLASSIFICATION	PHYSICAL PROCESSES	DEPENDENCE ON MOST IMPORTANT PARAMETERS	COMMON EFFECT ON STRENGTH
PRECIPITATION PARTICLES	1				Cloud				
	a	Columns	cl	Short prismatic crystal, solid or hollow			Growth at high supersaturation at -3° to -8°C and below -22°C		
	b	Needles	nd	Needle-like, approx. cylindrical			Growth at high supersaturation at -3° to -5°C		
	c	Plates	pl	Plate-like, mostly hexagonal			Growth at high supersaturation at 0° to -3°C and -8° to -25°C		
	d	Stellars Dendrites	sd	Six-fold star-like, planar or spacial			Growth at high supersaturation at temperatures between -12° to -16°C.		
	e	Irregular crystals	ir	Clusters of very small crystals			Polycrystals growing at varying environmental conditions		
	f	Graupel	gp	Heavily rimed particles			Heavy riming of particles by accretion of supercooled water		
	g	Hail	hl	Laminar internal structure, translucent or milky, glazed surface			Growth by accretion of supercooled water		
	h	Ice pellets	ip	Transparent, mostly small spheroids			Frozen rain		

TABLE 2 (CONT'D). GRAIN SHAPE CLASSIFICATION

DECOMPOSING AND FRAGMENTED PRECIPITATION PARTICLES /	2								
	a	Partly decomposed precip. particles /	dc	Partly rounded particles, characteristic shapes of precip. particles still recognizable	Recently deposited snow	Initial rounding and separation	Decrease of surface area to reduce surface free energy at low temperature gradients	Speed of decomposition decreases with decreasing snow temperature and decreasing temperature gradient	Strength decreases with time; felt-like arrangement of dendrites has modest initial strength
	b	Highly broken particles ⁄ ⁄	bk	Packed, shards or rounded fragments of precipitation particles	Saltation layer	Wind-broken particles; initially fractured then rapid rounding due to small size	Fragmented particles are closely packed by wind; fragmentation followed by rounding and growth	Fragmentation and packing increase with wind speed	Quick sintering results in rapid strength increase
ROUNDED GRAINS (MONOCRYSTALS) ●	3				Dry snow				
	a	Small rounded particles •	sr	Well-rounded; particles of size <0.5 mm often well bonded		Small equilibrium form	Decrease of specific surface area by slow decrease of number of grains and increase of mean grain diameter; equilibrium form may be partly faceted at lower temperatures	Growth rate increases with increasing temperature and temperature gradient; growth slower in high density snow with smaller pores	Strength increases with time, density and decreasing grain size
	b	Large rounded particles ●	lr	Well-rounded particles of size >0.5 mm		Large equilibruim form	Grain-to-grain vapor diffusion due to low to medium temperature gradients; mean excess vapor denstiy remains below critical value for kinetic growth	Same as above	Strength increases with time and density and decreasing grain size
	c	Mixed Forms ●	mx	Rounded particles with few facets which are developing		Transitional form as temperature gradient increases	Growth regime changes if temperature gradient increases above critical value of about 10°C/m	Grains are changing in response to a increasing temperature gradient	Desintering could decrease strength
FACETED CRYSTALS □	4				Dry Snow				
	a	Solid faceted particles □	fa	Solid faceted crystals; usually hexagonal prisms		Solid kinetic growth form	Strong grain-to-grain vapor diffusion driven by large temperature gradient; excess vapor density above critical value for kinetic growth	Growth rate increases with temperature, temperature gradient, and decreasing density; may not occur in high-density snow because of small pores	Strength decreases with increasing growth rate and grain size
	b	Small faceted particles ⧄	sf	Small faceted crystals in surface layer; <0.5mm in size	near surface	Kinetic growth form at early stage of development	May develop directly from 1 or 2a due to large, near-surface temperature gradients	Temperature gradient may periodically change sign but remains at a high absolute value	Low-strength snow
	c	Mixed forms ∩	mx	Faceted particles with recent rounding of facets		Transitional form as temperature gradient decreases	Faceted grains are rounding due to decrease in temperature gradient		

TABLE 2 (CONT'D). GRAIN SHAPE CLASSIFICATION

CUP-SHAPED AND CRYSTALS; DEPTH HOAR Λ	5				Dry Snow				
	a	Cup crystal Λ ▲	cp	Cup-shaped, striated crystal; usually hollow		Hollow or partly solid cup-shaped kinetic growth crystals	Very fast growth at large temperature gradient	Formation increases with increasing vapor flux	Usually fragile but strength increases with density
	b	Columns of depth hoar	dh	Large, cup-shaped striated hollow crystals arranged in columns (<10 mm)		Large cup-shaped kinetic growth forms arranged in columns	Intergranular arrangement in columns; most of the lateral bonds between columns have disappeared during crystal growth	Snow has almost completely recrystalized; high recrystazation rate for long period at low snow density and high external temperature gradient facilitates formation	Very fragile snow
	c	Columnar crystals ≡	cl	Very large, columnar crystals with c-axis horizontal (10-20 mm)		Final growth stage of depth hoar at high temperature gradient in low-density snow	Evolves from earlier stage described above; some bonding occurs and new crystals are initiated	Longer time required than for any other snow crystal	Some strength returns
WET GRAINS ○	6				Wet Snow				
	a	Clustered rounded grains	cl	Clustered rounded crystals held by large ice-to-ice bonds; water in internal veins among three crystals or two-grain boundaries		Grain clusters without melt-freeze cycles	Wet snow at low water content, pendular regime; clusters form to minimize surface free energy.	Meltwater can drain; too much water leads to slush; freezing leads to melt-freeze particles	Ice-to-ice bonds give strength.
	b	Rounded poly-crystals	mf	Individual crystals are frozen into a solid polycrystaline grain; may be seen either wet or refrozen		Melt-freeze polycrystals	Wet snow at low water content; melt-freeze cycles form poly-crystals when water in veins freezes	Particle size increases with number of melt-freeze cycles; radiation pentration over time restores 6a; excess water leads to 6c	High strength in the frozen state; lower strength in the wet state; strength increases with number of melt-freeze cycles
	c	Slush	sl	Separate rounded crystals completely immersed in water		Poorly bonded, rounded single crystals	High liquid content; equilibrium form of ice in water	Water drainage blocked by impermeable layer or ground; high energy input to snow cover by solar radiation, high air temperature or water input	Little strength due to decaying bonds
FEATHERY CRYSTALS ∨	7								
	a	Surface hoar crystals ∨	sh	Striated, usually feathery crystal; aligned; usually flat, sometimes needle-like	Cold snow surface	Kinetic growth form in air	Rapid kinetic growth of crystals at the snow surface by rapid transfer of water vapor toward the snow surface; snow surface cooled below ambient air temperature by radiational cooling	Increasing growth rate with increased cooling of the snow surface below air temperature and increasing relative humidity of the air	Fragile, extremely low shear strength; strength may remain low for extended periods when buried in cold snow

TABLE 2 (CONT'D). GRAIN SHAPE CLASSIFICATION

	b	Cavity hoar	ch	Striated, planar or feathery crystals grown in cavities; random orientation	Cavities in snow; same form might grow in very low density snow with extreme temperature gradient	Kinetic growth form in cavities	Plate or feathery crystals may grow in high-temperature gradient fields in large voids in the snow, e.g., in the vicinity of tree trunks, buried bushes or below sun crusts		
ICE MASSES	8								
	a	Ice layer	il	Horizontal ice layer	Buried layers in snow being melted and refrozen	Icy layer from refreezing of draining meltwater; usually retains some degree of permeability	Rain or meltwater from the surface percolates into cold snow where it refreezes; water may be preferentially held by fine-grained layer such as a buried wind crust	Depends on timing of percolating water and cycles of melting and refreezing; more likely to occur if snow is highly stratified	Ice layers are strong but strength decays onces snow is completely wetted
	b	Ice column	ic	Vertical ice body	Within layers	Icy column from refreezing of draining meltwater	Water within flow fingers freezes due to heat conduction into sourrounding snow at T<0°C	Flow fingers more likely to occur if snow is highly stratified; freezing greater if snow is very cold	
	c	Basal ice	bi	Basal ice layer	Base of snow cover	Ice forms from freezing of ponded meltwater	Water ponds above substrate and freezes by heat conduction into cold substrate	Formation enhanced if substrate is impermeabile and very cold, (e.g., permafrost)	Weak slush layer may form on top
SURFACE DEPOSITS AND CRUSTS	9								
	a	Rime	rm	Soft rime: irregular deposit; Hard rime: small supercooled water droplets frozen in place	Surface	Surface rime	Accretion of small, supercooled fog droplets onto surface grains	Increases with fog density and exposure to wind	Thin breakable crust forms if process continues long enough
	b	Rain crust	rc	Thin, transparent glaze or clear surface layer	Surface	Frozen rain water at snow surface	Results from freezing rain on snow; forms a surface glaze	Droplets have to be supercooled but coalesce before freezing	Thin breakable crust
	c	Sun crust, firn-spiegel	sc	Thin, transparent glaze or surface film	Surface	Refrozen meltwater at snow surface	Refrozen surface layer partially melted by solar radiation; short-wave absorption in the glaze is decreased; cooling of the glaze by long-wave radiation and evaporation; greenhouse effect for the underlying snow; water vapor condenses below the glaze; may develop into smooth, shiny layer of clear ice at surface	Builds during clear weather (long-wave cooling), air temperatures below freezing and strong irradiation (not to be confused with melt-freeze crusts); melting can occur below the crust in clean snow	Thin, often breakable ice crust

TABLE 2 (CONT'D). GRAIN SHAPE CLASSIFICATION

d	Wind crust 	wc	Small, broken or abraded, closely-packed particles; well sintered	Surface	Wind crust	Fragmentation and packing of wind transported snow particles; high number of contact points and small size causes rapid strength increase through sintering	Hardness of crust increases with wind speed, decreasing particle size and moderate temperature	Hard, sometimes breakable crust
e	Melt-freeze crust 	mfc	Crust of recognizable melt-freeze polycrystals	Near surface	Crust of melt-freeze particles	Refrozen layer (e.g. wind crust) which was wetted with water at least once	Particle size and density increases with number of melt-freeze cycles	Hardness increases with number of melt-freeze cycles

Class 9sc, sun crust-firn spiegel. PHOTO BY E. WENGI.