Appendix F
ICSI Classification for Seasonal Snow on the Ground

Morphological Classification					Process-Oriented Classification		Additional Information on Physical and Strength		
Basic Classification	Code	Subclass	Abbrev	Shape	Place of Formation	Classification	Physical Process	Dependence on Most Important Parameters	Common Effect on Strength
Precipitation Particles +	1		PP		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 approximately cylindrical			Growth at high supersaturation at –3°C 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		

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Decomposing and fragmented precipitation particles	2		DF						
	a	Partly decomposed precipitation particles	dc	Partly rounded particles, characteristic shapes of precipitation particles still recognizable	Recently deposited layer	Initial rounding and separation	Decrease of surface area to reduce surface free energy at low temperature gradients	Speed of decomposition decreases with decreasing snow temperatures and decreasing temperature gradients	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		RG		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 equilibrium form	Grain-to-grain vapor diffusion due to low to medium temperature gradients; mean excess vapor density 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 an increasing temperature gradient	De-sintering could decrease strength

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Faceted crystals □	4		FC		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; <0.5 mm 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 crystals with recent rounding of facets		Transitional form as temperature gradient decreases	Faceted grains are rounding due to decrease in temperature gradient		

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Cup-shaped crystals: Depth hoar ∧	5		DH		Dry snow				
	a	Cup crystal ∧ ▲	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 recrystallized; high recrystallization rate for long period and 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		WG		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 polycrystalline grain; may be seen either wet or refrozen		Melt-freeze polycrystals	Wet snow at low water content, melt-freeze cycles form polycrystals when water in veins freezes	Particle size increases with number of melt-freeze cycles; radiation penetration 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

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	c	Slush	sl	Separated 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		SH						
⋁	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 vapor toward the snow surface; snow surface cooled to below ambient 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
	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		

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Ice masses	8		IM						
	a	Ice layer	il	Horizontal ice layer	Buried layers in snow becoming melted and refrozen	Ice layer from refreezing of draining meltwater; usually some degree of permeability	Rain or meltwater from the surface percolates into cold snow where it refreezes; water may be preferentially held by fine-grain 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 once snow is completely wetted
	b	Ice column	ic	Vertical ice body	Within layers	Ice column from refreezing of draining meltwater	Water within flow fingers freezes due to heat conduction into surrounding 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 impermeable and very cold (e.g. permafrost)	Weak slush layer may form on top
Surface deposits and crust	9		CR						
	a	Rime	rm	Soft rime: irregular deposit; Hard rime: small supercooled water droplets frozen in place	Surface	Surface rime	Accretion of 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 ice surface layer	Surface	Frozen rain water at snow surface	Result from freezing rain on snow; forms a surface glaze	Droplets have to be supercooled but coalesce before freezing	Thin breakable crust

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	c	Sun crust, firnspiegel	sc	Thin, transparent glaze or surface film	Surface	Refrozen meltwater at snow surface	Refrozen surface layer partially melted by solar radiation; shortwave absorption in the glaze is decreased; cooling of the glaze by longwave 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 (longwave cooling), air temperatures below freezing and strong irradiation (not to be confused with melt-freeze crust); melting can occur below the crust in clean snow	Thin, often breakable crust
	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

Note: Canadian modifications are employed for the crust symbol, surface deposit and for the rain crust symbols. Upper case and lower case abbreviations are used to distinguish between the basic classifications and the subclass.

Refer to Colbeck and others, 1990 for further explanation of shapes, place of formation, process-oriented classifications, physical process, and common effects on strength.