Snow Avalanches Genesis and Avalanche Classification

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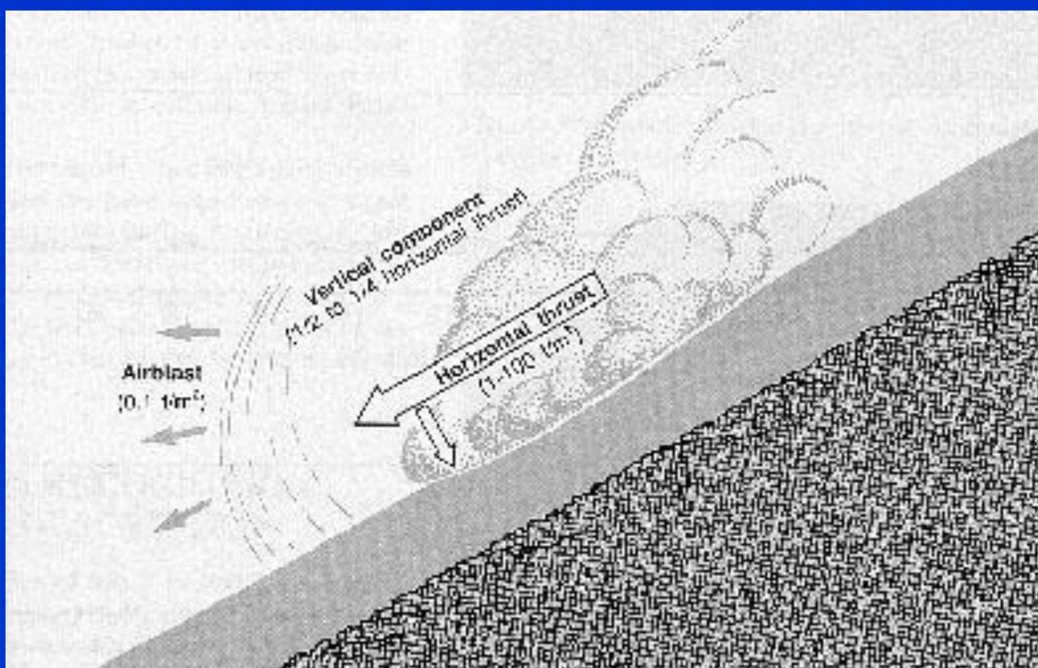
Genesis of Avalanches

Avalanches

- Sudden downward motion of snow mass
- May contain rocks, soil, ice, trees etc.
- Exerts pressure up to 50 ton m^{-2}



Genesis of Avalanches

Ingredients of Avalanche

Terrain

- Slope
- Exposure w.r.t Sun
- Ground Cover

Snow

- Critical Snow Height
- Snowpack Characteristics

Weather

- Western Disturbances
- Wind Flow Influences
- Radiation Interaction with Snow cover

Genesis of Avalanches

Different Zones of Avalanche

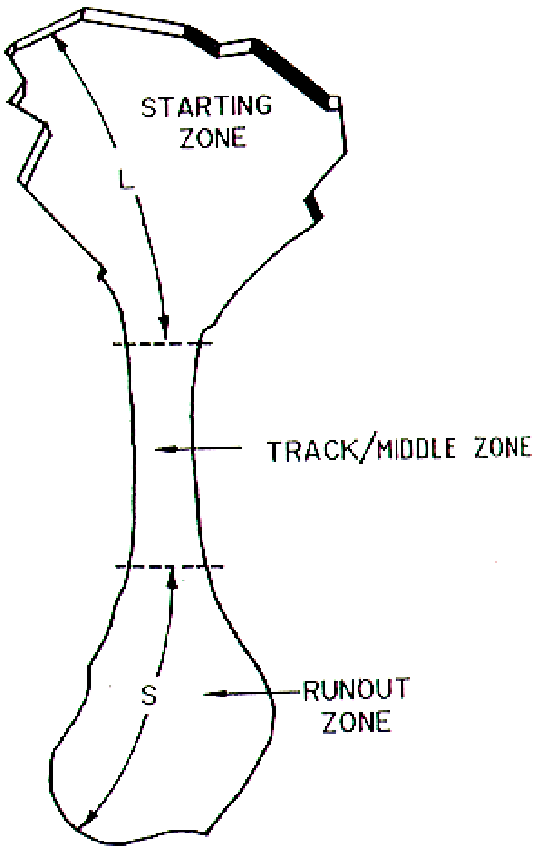


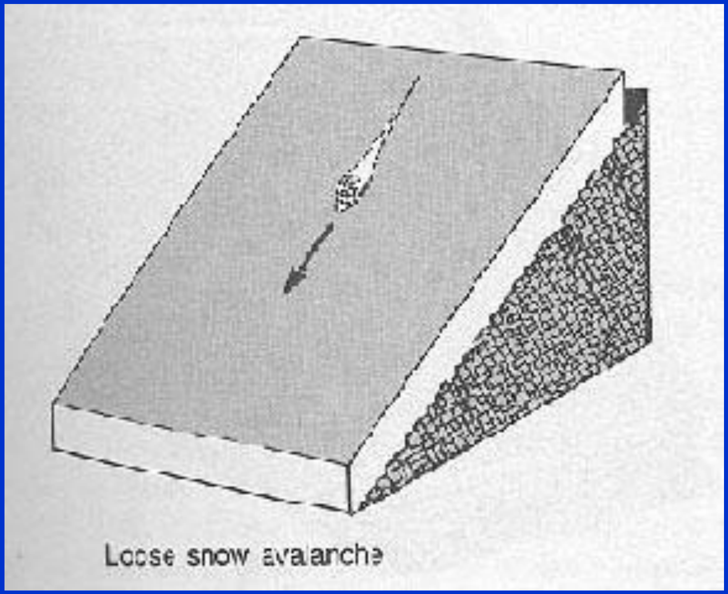
Plate 5. Avalanche zones.

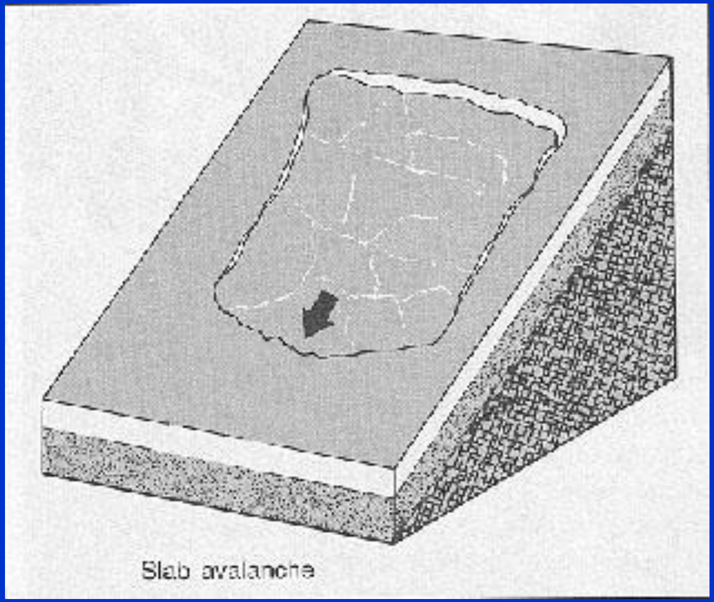
Genesis of Avalanches

<u>Broad Classification of Avalanches</u>

Avalanches

Loose snow Avalanches	Slab Avalanches
* Start at or near the surface	* Initiates by a failure at depth
* Involves surface or near surface snow	* Involves blocks of snow
* spread outs in triangular form	* Approximates a rectangular shape





Genesis of Avalanches

Examples of Loose snow avalanches

Genesis of Avalanches

An example of slab avalanches

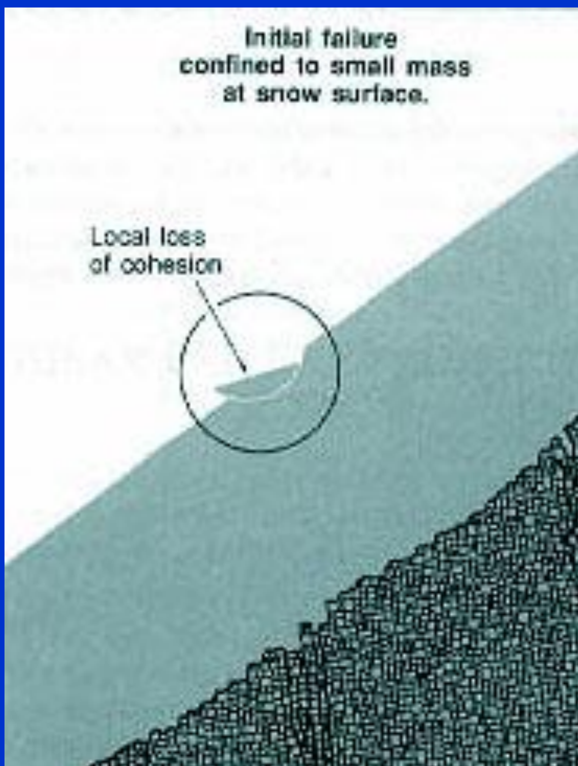
Genesis of Avalanches

Loose Snow Avalanche Formation

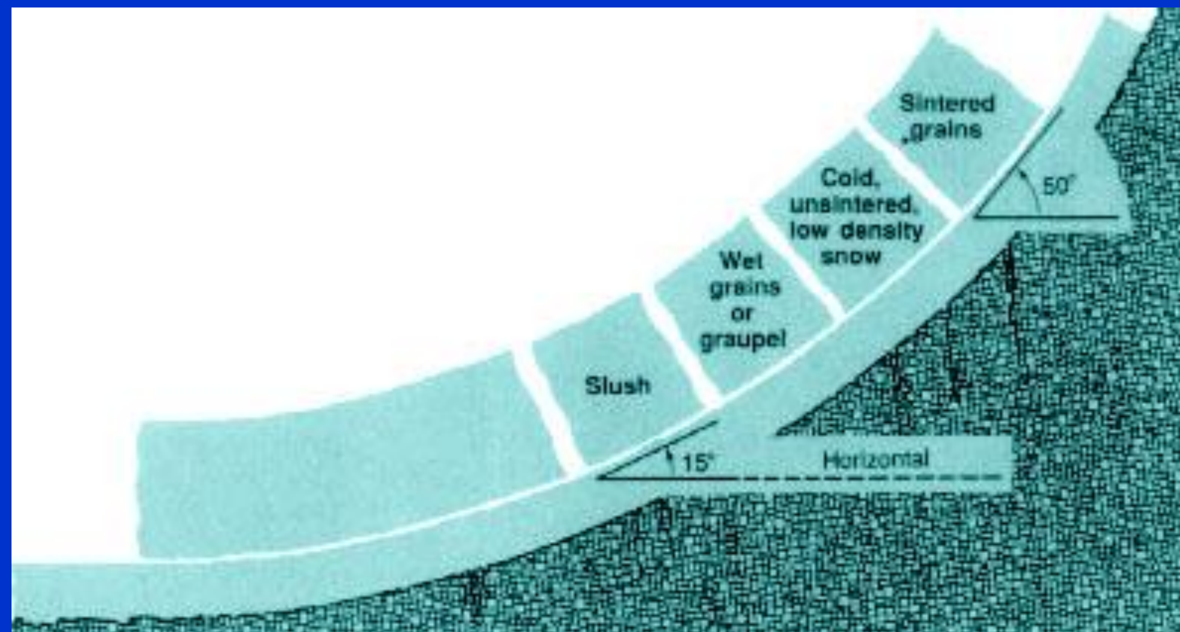
- **When slope angle exceeds the *angle of repose* (or *static friction angle*) necessary to cause motion.**
- **Angle of repose depends on grain geometry, temperature, cohesiveness, and water content.**
- **Natural LSA are triggered by a local loss of cohesion due to meta-morphism or the effect of sun or rain**
- **Often the initiation is near rock outcrops, which cause local high temperatures**
- **Dry LSA commonly form under cold, relatively windless condition**
  (Cold temp retards bond formation)
- **Dry LSA can release a day or two after a storm stops in cold weather**
  (Initial metamorphism may decrease cohesion)

Genesis of Avalanches

Loose Snow Avalanche Formation



Mechanism of loose snow avalanche failure

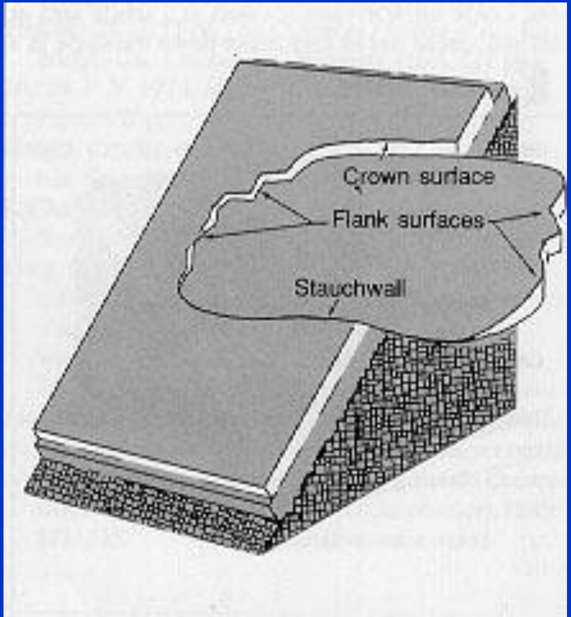


Schematic of angle of repose as a function of snow type

Genesis of Avalanches

Snow Slab Nomenclature and Fracture Geometry

- **Snow slab:** A cohesive layer of snow with a thinner, weaker layer beneath it
- **Bed Surface:** Surface over which the slab slides; Can be the ground
- **Crown :** The breakaway wall of the top periphery of the slab
  - Usually at the right angle to the bed surface
  - It is formed by tension fracture through the depth of the slab from bottom to top



- **Flanks :** Left and right sides of the slab, formed by shear fractures, tension fractures or a combination of both.
- **Stauchwall:** Lowest downslope fracture surface, appears just before the slab moves downhill.

Genesis of Avalanches

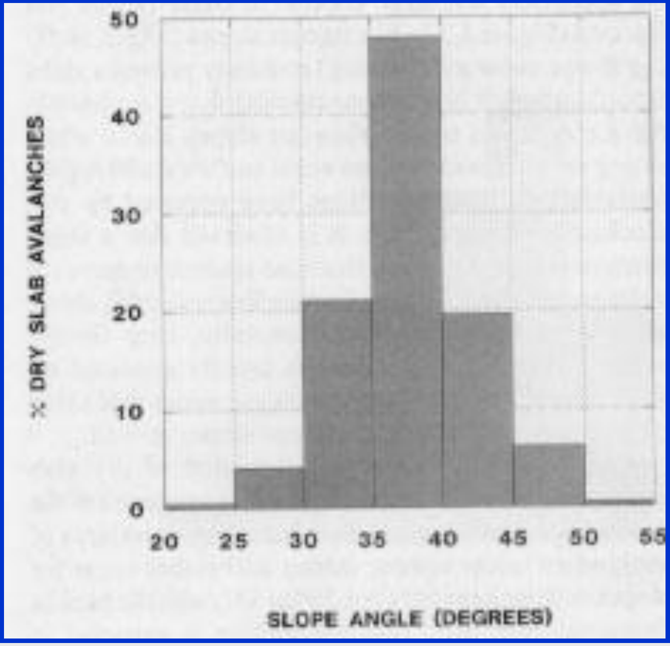
Characteristics of Dry Slab Avalanches

Characteristics of slab features measured at fracture line provide important information that can affect decisions about travel in avalanche terrain-

- **Slope Angle:**

* Normal range for slab formation: 25^{o} to 55^{o}.

* Instability increases with increasing slope angle.



Slope angle dependence from fracture line studies

Genesis of Avalanches

Dry Slab Avalanche Formation

- **Difference b/w *failure* and *fracture* -**

  * *Failure* in a dry slab avalanche occurs when the downslope component of the weight of the slab approaches the shear strength in the weak layer.
  * It is possible to have *failure* in a material such as snow without *fracture*.
  * At *failure*, a sample of snow has absorbed the maximum load that it can bear
  * *Fracture* means, catastrophic *failure* of the material and this is a prerequisite for slab avalanche release.
  * *Fracture* takes place only if snow is sheared at a critical rate (about 1mm/min)

- **Two requirements must be met before a shear fracture propagates-**

  (i) The shear stress must approach the shear strength in the weak layer
  (ii) The rate of deformation in the weak layer must be enough to provoke fracture

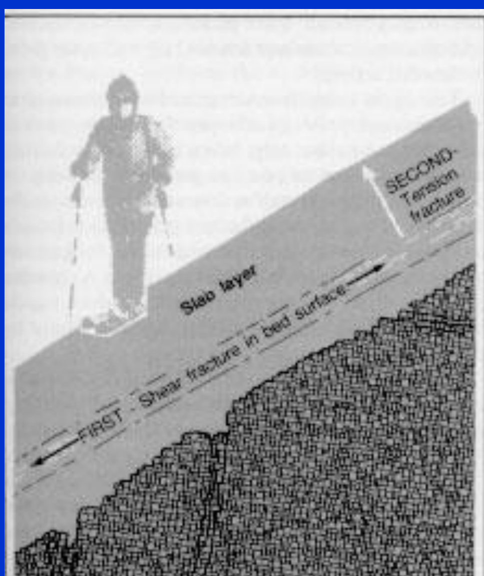
Genesis of Avalanches

<u>Dry Slab Avalanche Formation</u>

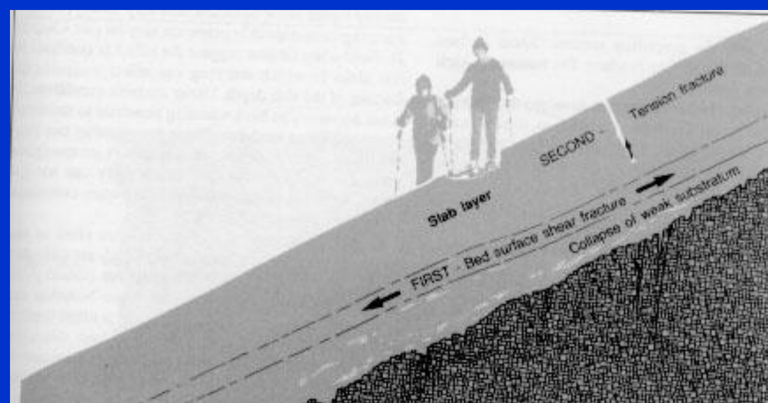
- First condition only ⇒ Instability prevails

Both conditions ⇒ dry slab avalanche can start

Intermediate condition - a serious threat to travelers in snow-covered terrain



Possible fracture sequence for dry slab initiation



Initial failure accompanied by collapse of a substratum. Shear fracture produces a tension fracture at the crown

Initial shear fracture produces a crown tension fracture near a skier

Genesis of Avalanches

<u>Dry Slab Avalanche Formation</u>

- Most common triggers for natural dry snow slab avalanches-
    - New snowfall
    - Blowing snow
    - Rain
    - Falling cornice
    - Vibration by earthquake

Genesis of Avalanches

<u>Wet Slab Avalanche Formation</u>

- Three principal mechanisms -

  (1) Loading by new precipitation (rain)
  (2) Change in strength of buried weak layer due to water
  (3) Water lubrication of a sliding surface

- When water reaches a weak layer, the strength of the layer will be reduced.

- When water reaches an impermeable boundary in the snowpack (or the ground), slip of the slab over the boundary may be initiated due to reduction in friction.

- When water is present at a smooth ground surface such as rock or long grass, the friction is reduced and the rate which the snow glides increases.

Genesis of Avalanches

Wet Slab Avalanche Formation

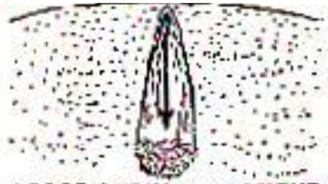
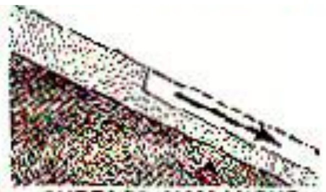
- Two important factor that promote gliding:

  (1) The snow viscosity near the boundary decreases due to increased water content, thereby allowing easier deformation of the snowpack over the ground roughness obstacles, and

  (2) Water reaching the interface may drown out the small roughness features there so that the snow can move over them virtually unimpeded.

Genesis of Avalanches

Types of Avalanches

	CRITERION	ALTERNATIVE CHARACTERISTICS AND NOMENCLATURE	
1	TYPE OF BREAKAWAY	From Single Point  LOOSE-SNOW AVALANCHE	From large area leaving wall  SLAB AVALANCHE
2	POSITION OF SLIDING SURFACE	 FULL DEPTH AVALANCHE	 SURFACE AVALANCHE
3	HUMIDITY OF THE SNOW	Dry DRY-SNOW AVALANCHE	Wet WET-SNOW AVALANCHE
4	FORM OF THE TRACK IN CROSS SECTION	Open Slope  UNCONFINED AVALANCHE	In a Gully  CHANNELLED AVALANCHE
5	FORM OF MOVEMENT	Through the air  AIRBORNE-POWDER AVALANCHE	Along the Ground  FLOWING AVALANCHE

AVALANCHE CLASSIFICATION

Purpose:

- Establish uniform descriptive terms
    - Exchange info: accidents, safety measures, control
- Grouping: Statistical analysis
    - Relationship between avalanches & factors responsible
        * Terrain, weather, snowpack characteristics

AVALANCHE CLASSIFICATION

1. Morphological
- refers to those properties of avalanches that are directly observable and help one to classify the type of avalanche that has taken place.

2. Genetic
- refers to the processes and conditions that cause avalanches or are responsible for their effects.

3. Size
- refers to the mass, path length and impact pressure of avalanche.

AVALANCHE CLASSIFICATION (morphological)

1. Zone of Origin

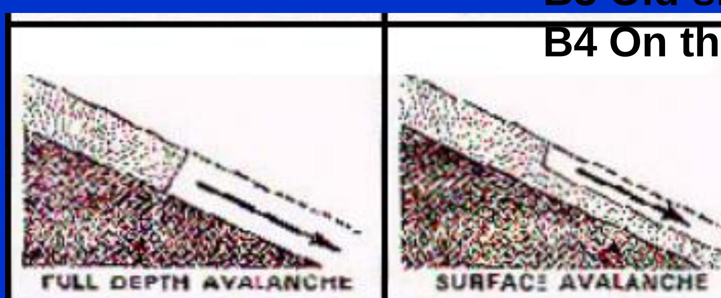
Criterion — **Alternative characteristics Denominations and Code**

A. Manner of starting

A1 starting from a point (loose snow avalanche)
A2 Starting from a line (slab avalanche)

B. Position of sliding surface

B1 Within snow cover (surface-layer avalanche)
B2 New snow fracture
B3 Old snow fracture
B4 On the ground (full-depth Avalanche)

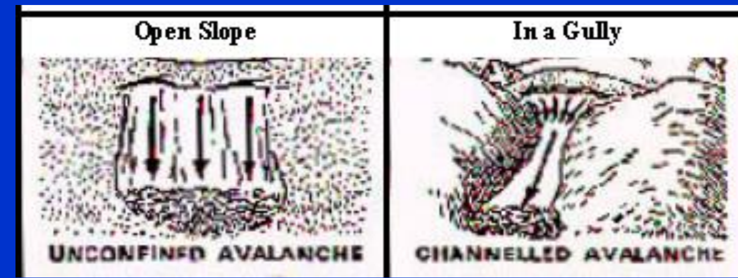


C. Humidity of the snow

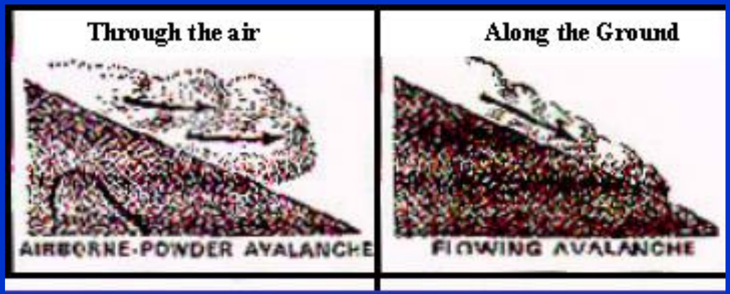
C1 Absent (dry- snow avalanche)
C2 present (wet-snow avalanche)

AVALANCHE CLASSIFICATION (morphological)

2. Zone of Transition

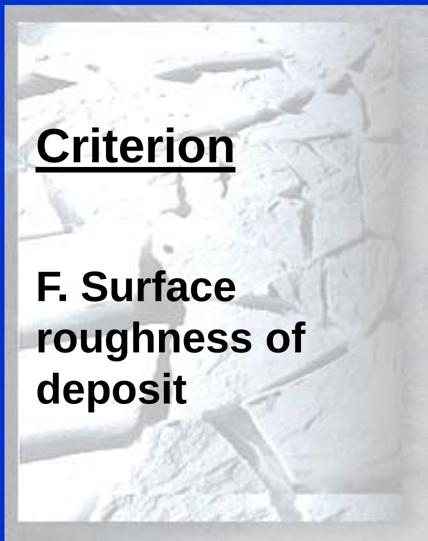


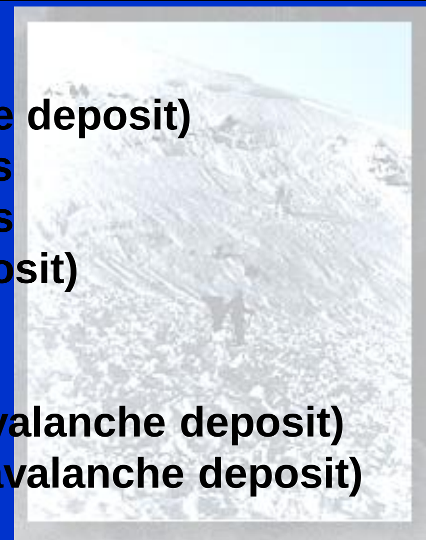
Criterion	Alternative characteristics Denominations and Code
D. Form of path	D1. Path on open slope (unconfined avalanche) D2. Path in gully or channel (channeled Avalanche)
E. Form of Movement	E1. Snow dust cloud (powder avalanche) E2. Flowing along the ground (flow avalanche)



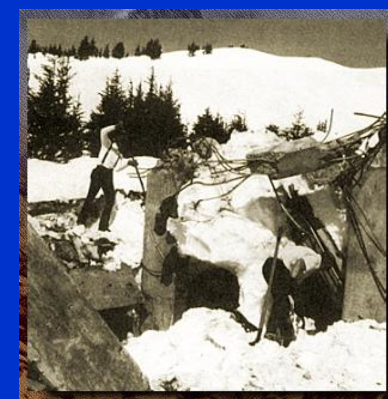
AVALANCHE CLASSIFICATION (morphological)

3. Zone of deposition





Criterion	Alternative characteristics Denominations and Code
F. Surface roughness of deposit	F1. Coarse (coarse deposit) F2. Angular blocks F3. Rounded clods F4. Fine (fine Deposit)
G. Liquid water in snow debris at time of deposition	G1. Absent (dry avalanche deposit) G2. Present (wet avalanche deposit)
H. Contamination of deposit	H1. No apparent contamination (clean avalanche) H2. Contamination present (contaminated Avalanche.) H3. Rock debris, soil H4. Branches, trees H5. Debris of structures

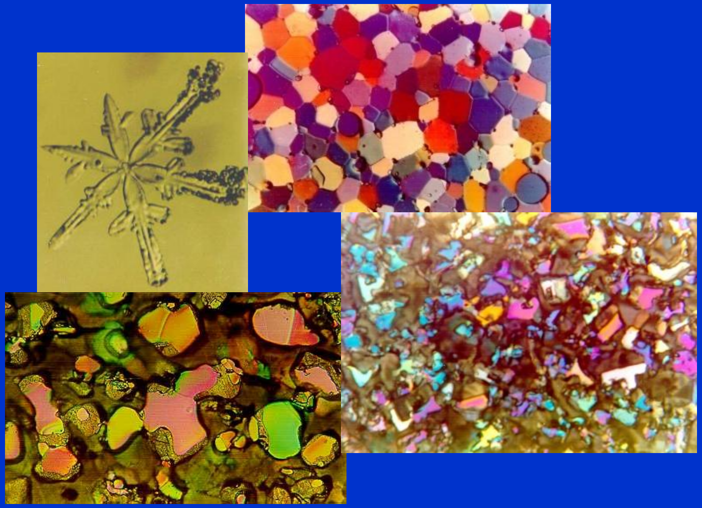


AVALANCHE CLASSIFICATION

(Genetic)

- Conditions responsible for their formation

  * Shape of terrain
  * Weather
  * Properties of snowcover



AVALANCHE CLASSIFICATION

(Genetic)

A. Fixed Framework

CONDITIONS	CHARACTERISTICS
1. Terrain Conditions	
1.1 Relative altitude	Zones of crest, timberline, wind influence
1.2 Inclination of slope	>35^{o} loose; >25^{o} slab; >15^{o} accelerated flow
1.3 Orientation of slope	Relative to sun and wind
1.4 Configuration of terrain	Open, channeled, funnels, ridges, steps, even
1.5 Roughness	Smooth ground, protruding obstacles, vegetation

AVALANCHE CLASSIFICATION

(Genetic)

B. Genetic Variables

CONDITIONS	CHARACTERISTICS
2. Recent weather (Five days back)	
2.1 Snowfall	Type, depth, intensity
2.2 Rain	Promotes wet loose snow avalanche
2.3 Wind(direction, vel, dur)	Enhances local deposit, brittleness;
2.4 Thermal conditions	Temperature, Free water content, sun & temp radiation
3. Old snow conditions (Integrated past weather influences of winter season)	
3.1 Total snow depth	Influences mass of full depth
3.2 Stratification	Sequence of strength, surface & interior of snowcover
4. Triggering condition (Natural/human release)	
4.1 Natural release	Internal influences, non human releases
4.2 Human release	Accidental, Intended

AVALANCHE CLASSIFICATION

(Size)

- Grouped according to their size or destructive force

Size1: Slough; Not injure a human

Size2: Small avalanche; Could injure a human

Size3: Could damage buildings, automobiles, break a few trees

Size4: Could destroy large vehicles,or forests with areas up to 4 ha

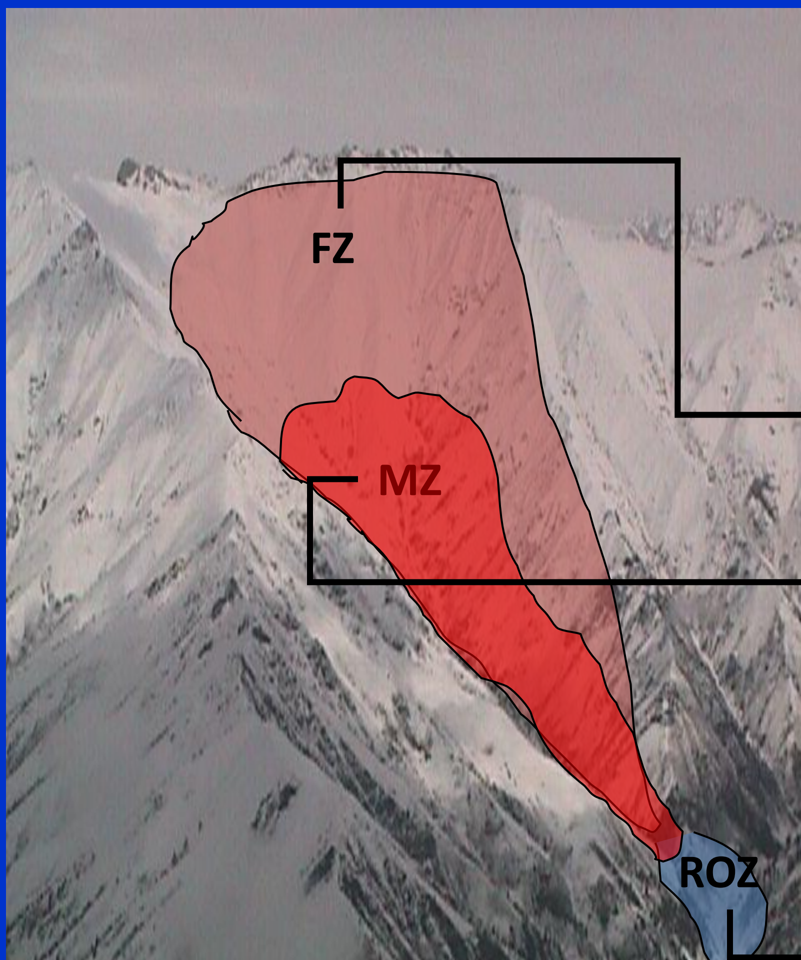
Size5: Unusual, catastrophic events, could damage villages or destroy large forest

Important Terrain Factors

- Mountain Range
- Slope
- Aspect (with respect to sun and wind flow)
- Geometry
- Altitude
- Ground Cover

AVALANCHE TERRAIN

- **Avalanche Area: Location with one or more avalanche paths.**
- **Avalanche path: Fixed locality within which avalanche moves**



- **Unstable snow fails and begins to move**
- **Slope generally > 30 Deg**

- **Connects FZ with ROZ**
- **Slope generally between >15& < 30 Deg**
- **Avalanche attains max. speed**

- **Rapid deceleration**
- **Slope generally between <15 Deg**
- **Debris gets deposited**
- **Avalanche stops**

AVALANCHE TERRAIN

Starting Zone Characteristics

- Slope incline (The most important factor)

60 - 90 Deg: Avalanches rare; snow sloughs frequently in small amounts

30 -60 Deg: Dry loose snow avalanches

45 -55 Deg: Frequent small slab avalanches

35 -45 Deg: Slab avalanches of all sizes

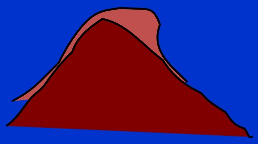
25 - 35 Deg: Infrequent(often large) slab avalanches; wet, loose snow avalanches

10-25 Deg: Infrequent wet snow avalanches and slush flows.

AVALANCHE TERRAIN

Starting zone characteristics

Orientation to the wind



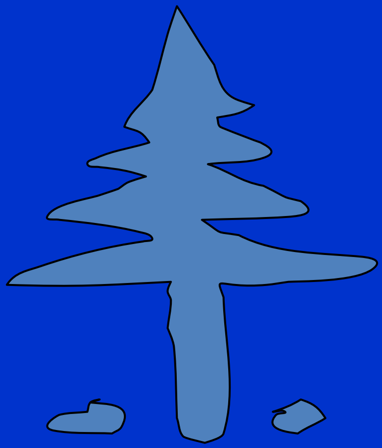
- Slopes that collect drifting snow produce avalanches
- Lee slopes

Orientation to the sun

-Sunny slopes, after initial weakening, stabilize & strengthen

- In late winter and spring sunny slopes can destabilize.
- Shady slopes stabilize slowly, develops weak layers
- On an average sunny slopes produces as many avalanches as shady slopes

AVALANCHE TERRAIN



- **Forest Cover**
  - **- Inhibits large avalanche formation**
  - **- Tree intercepts 10 to 50 percent snowfall**
  - **- Release of lumps and melt water produces irregular structure**
  - **- Tree crowns control incoming/outgoing radiation**
  - **- Tree trunks support snowpack:**
    - ***500 conifers/hectare best for gentle slopes**
    - ***1000 conifers/hectare best for steep slopes**
    - ***Mix species of variable height and age preferable.**
    - ***Scattered trees offer no protection**
    - ***Shrubs have complex affect**

AVALANCHE TERRAIN

Ground Surface

- Rough ground anchors snow pack
- Boulders, stumps, logs etc hold snow to its depth
- Guidelines

    0.3m : Relatively smooth ground cover: fine scree, bedrock, grass

    0.6m : Average terrain: Boulders, small trees, shrubs, irregular surface

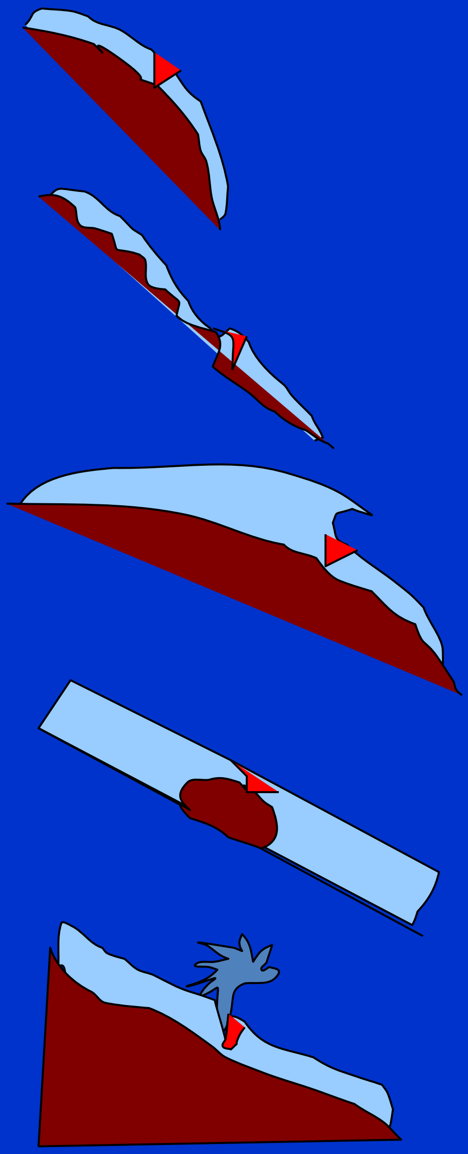
    1.0m : Rough terrain: Large boulders, stumps, logging debris.

- Stabilizing affect reverses after boulders get covered.

- Avalanches frequently from slopes having long grass.

AVALANCHE TERRAIN

- Possible crown locations
  - Convex slope
  - Toe of rock face
  - Beneath cornice
  - Rock outcrop
  - Around trees



AVALANCHE TERRAIN

- **Track characteristics**

  - Open slope: No lateral boundaries

  - Channel slope: Gullies and depressions

Avalanches usually follow fall line

Not always confined to lateral boundaries

Kinetic friction being lower than static friction

: Even lower slopes keep avalanche moving

Angle for continuing motion depends on

: Mechanical properties of flowing snow

: Size of avalanche

: Surface hardness of the path

AVALANCHE TERRAIN

- <u>ROZ characteristics</u>

  - Debris rests
  - Slope angle equals friction angle
  - Avalanches sensitive to small variations in terrain in ROZ
  - Takes unexpected turns
  - Forest cover ineffective in ROZ

THANKS