Snow Avalanches

what is an avalanche?

- a falling mass of snow and/or ice
- a mass-wasting process
  - analogous to debris flows or mudslides
- a natural hazard

ski area avalanche management

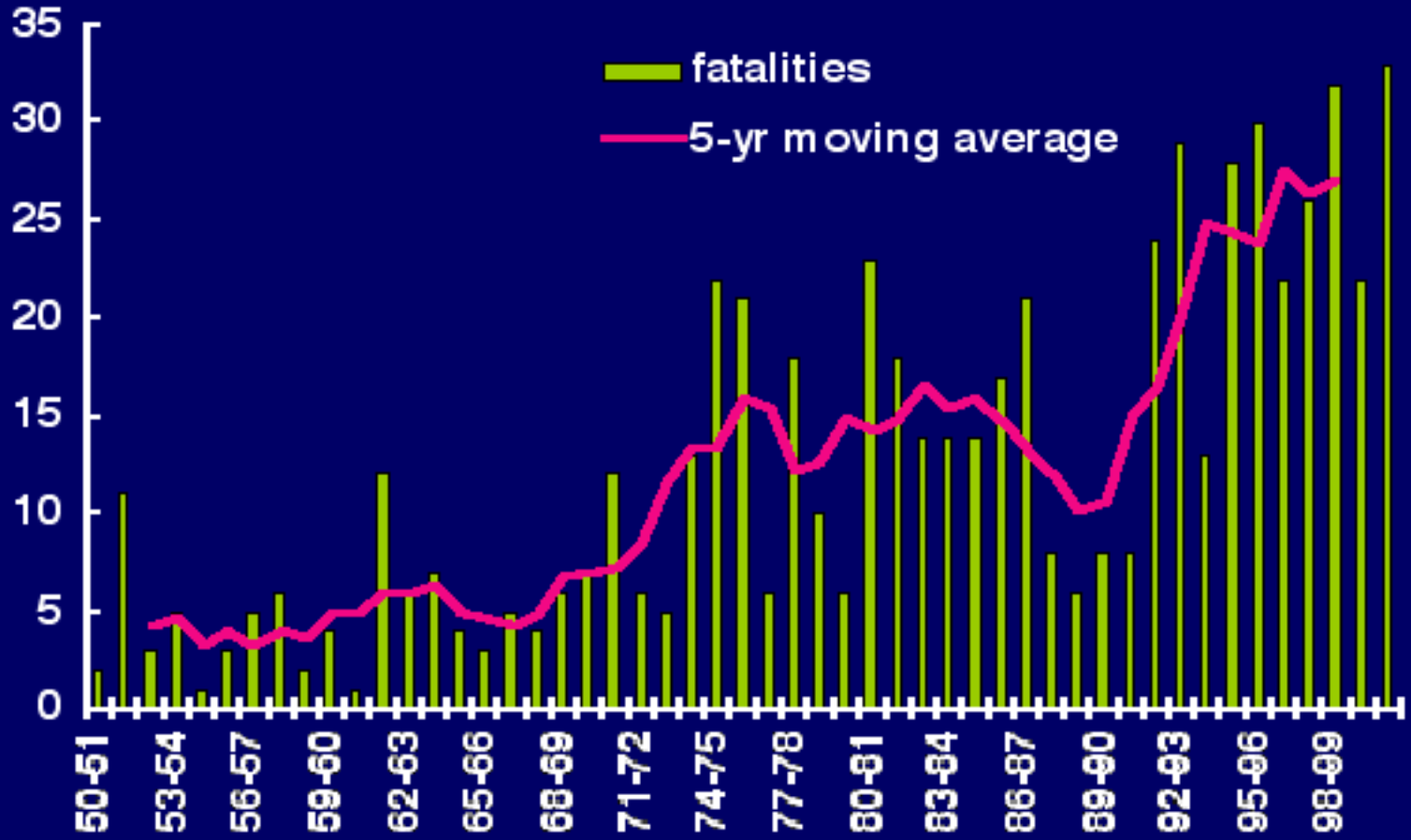
- snow compaction
  - skier traffic
  - boot packing
- intentional avalanche release
  - explosives
  - ski cutting
- cornice management

Westwide Avalanche Network

backcountry recreation

- no active control
  - who gets caught ?
  - education
    - be your own snow expert

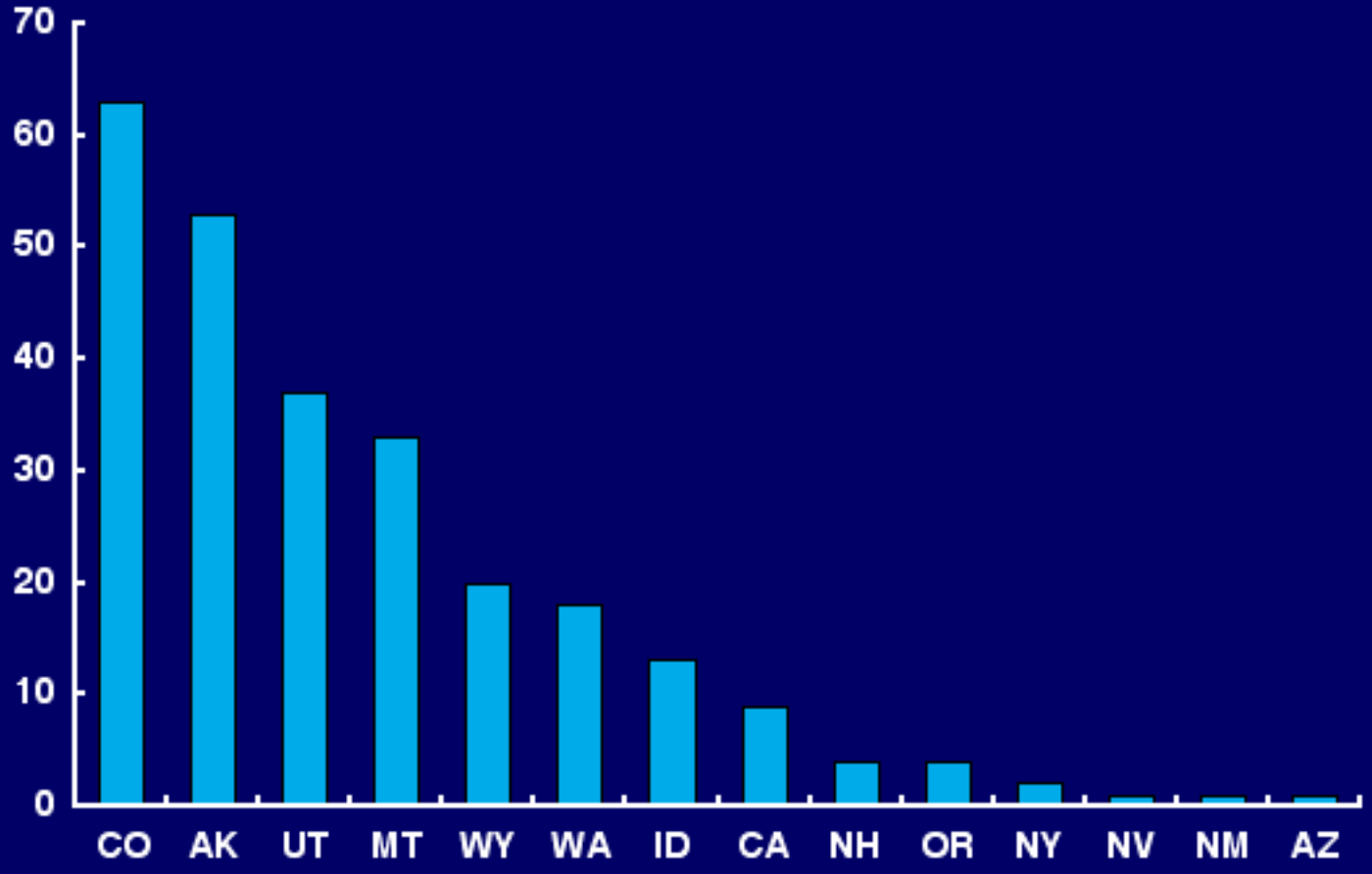
US Avalanche Fatalities By Winter



Colorado Avalanche Information Center

1950/51 to 2000/01

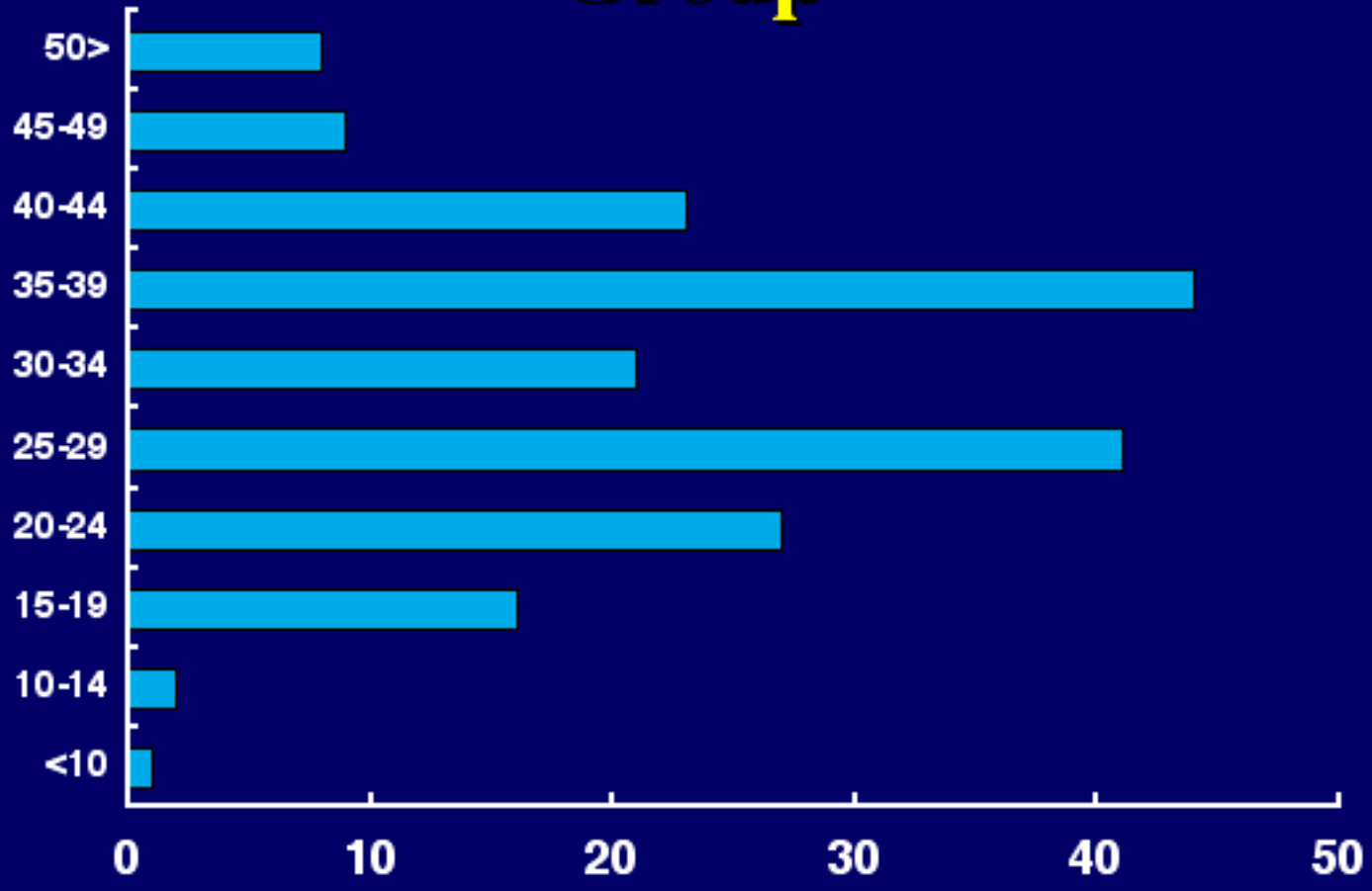
US Avalanche Fatalities By State



Colorado Avalanche Information Center

1991/92 to 2000/01

US Avalanche Fatalities By Age Group



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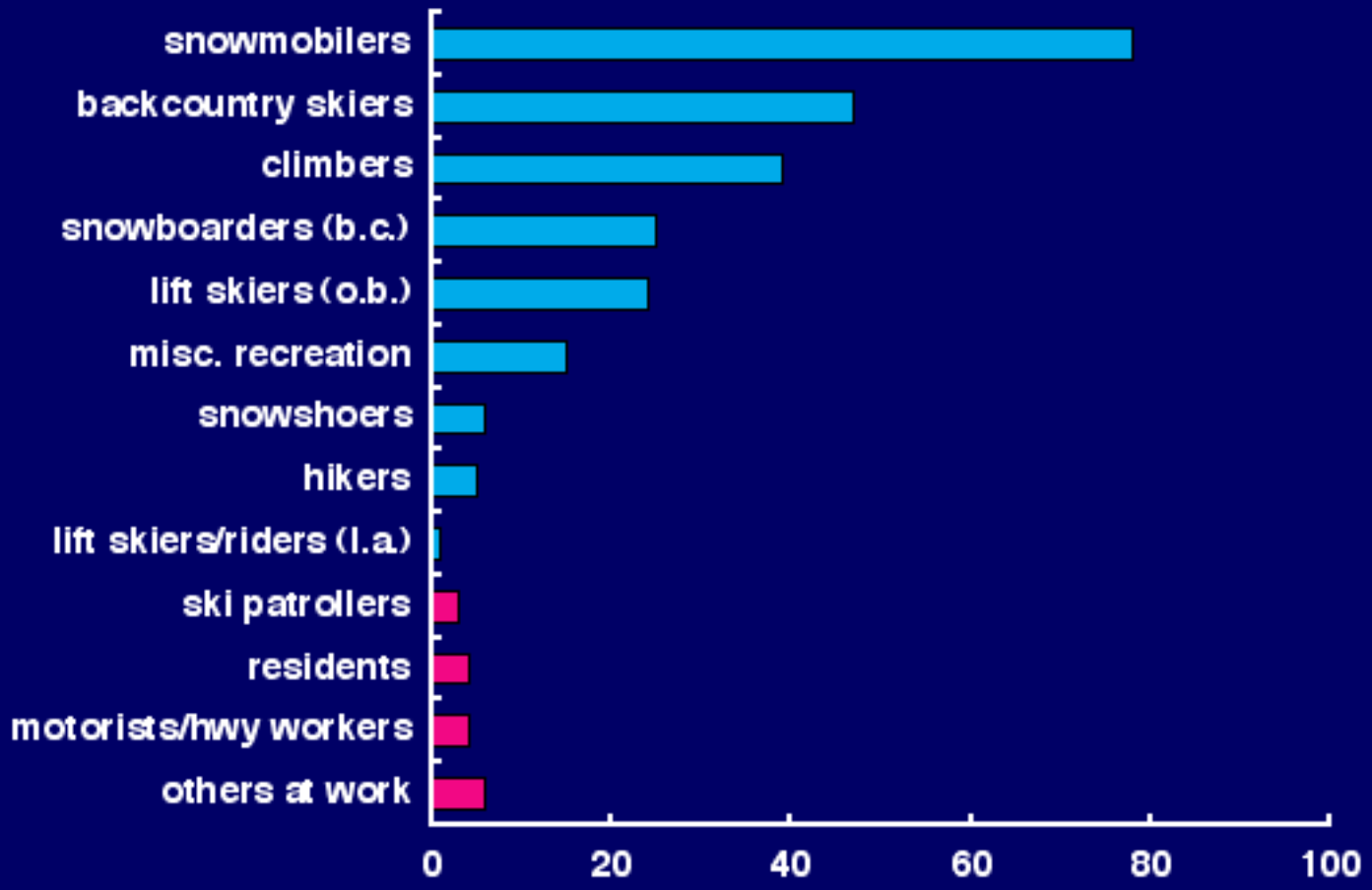
1991/92 to 2000/01

US Avalanche Fatalities By Activity



Colorado Avalanche Information Center

1991/92 to 2000/01

Why these changes? Recent trends:

- explosion in backcountry use
- technological advances
  - ski gear
  - snowmobile power and design
- "Extreme" hype

- availability of avalanche education

Gallatin National Forest Avalanche Center

avalanche hazard to communities

- primarily a European issue
  - higher alpine population density
- resort development in US

types of avalanches

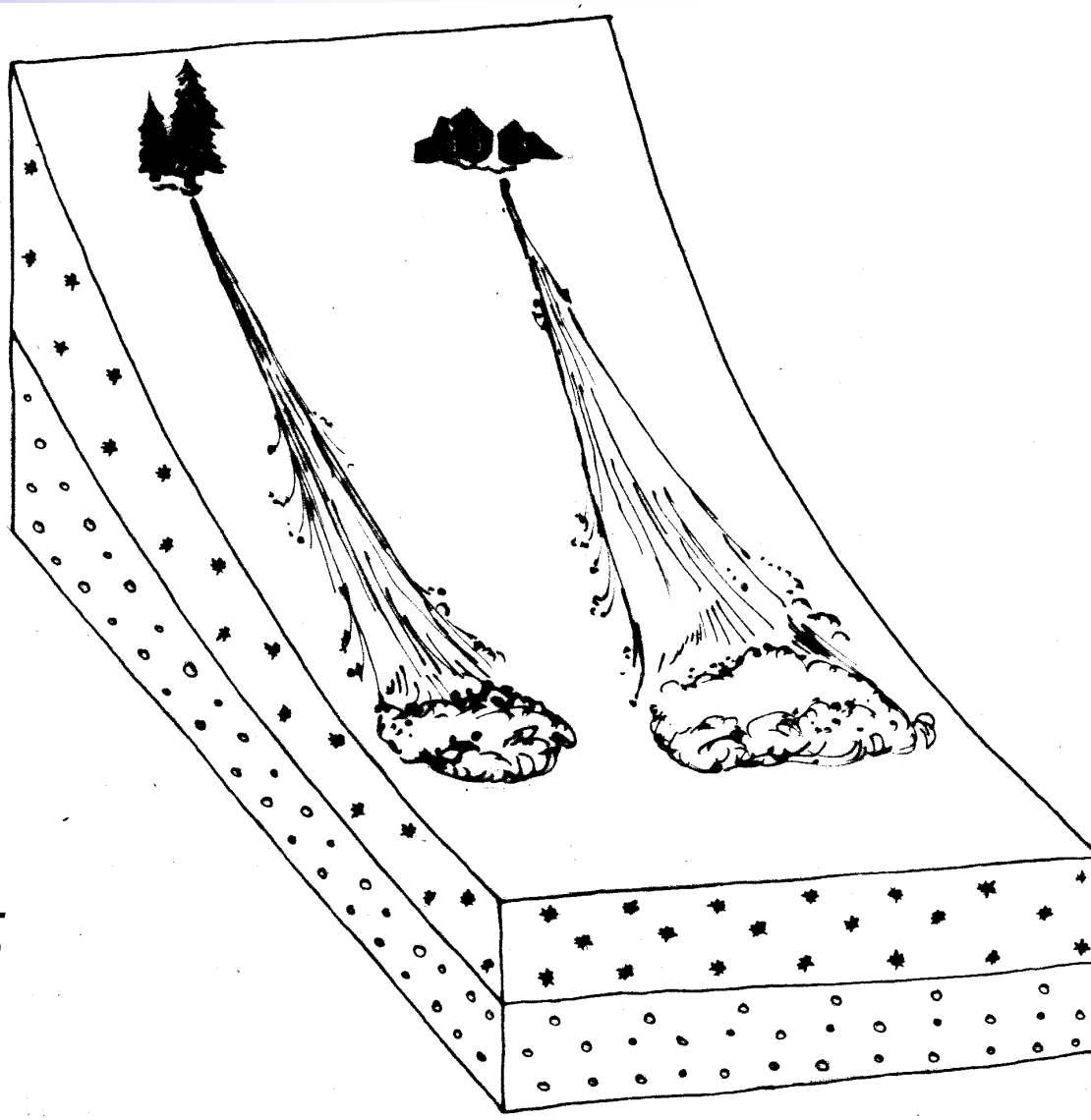
- loose snow (point release)
- slab
  - soft slab
  - hard slab
- distinction based on snow cohesiveness
- can be wet or dry snow

Loose-snow avalanches (sluffs)

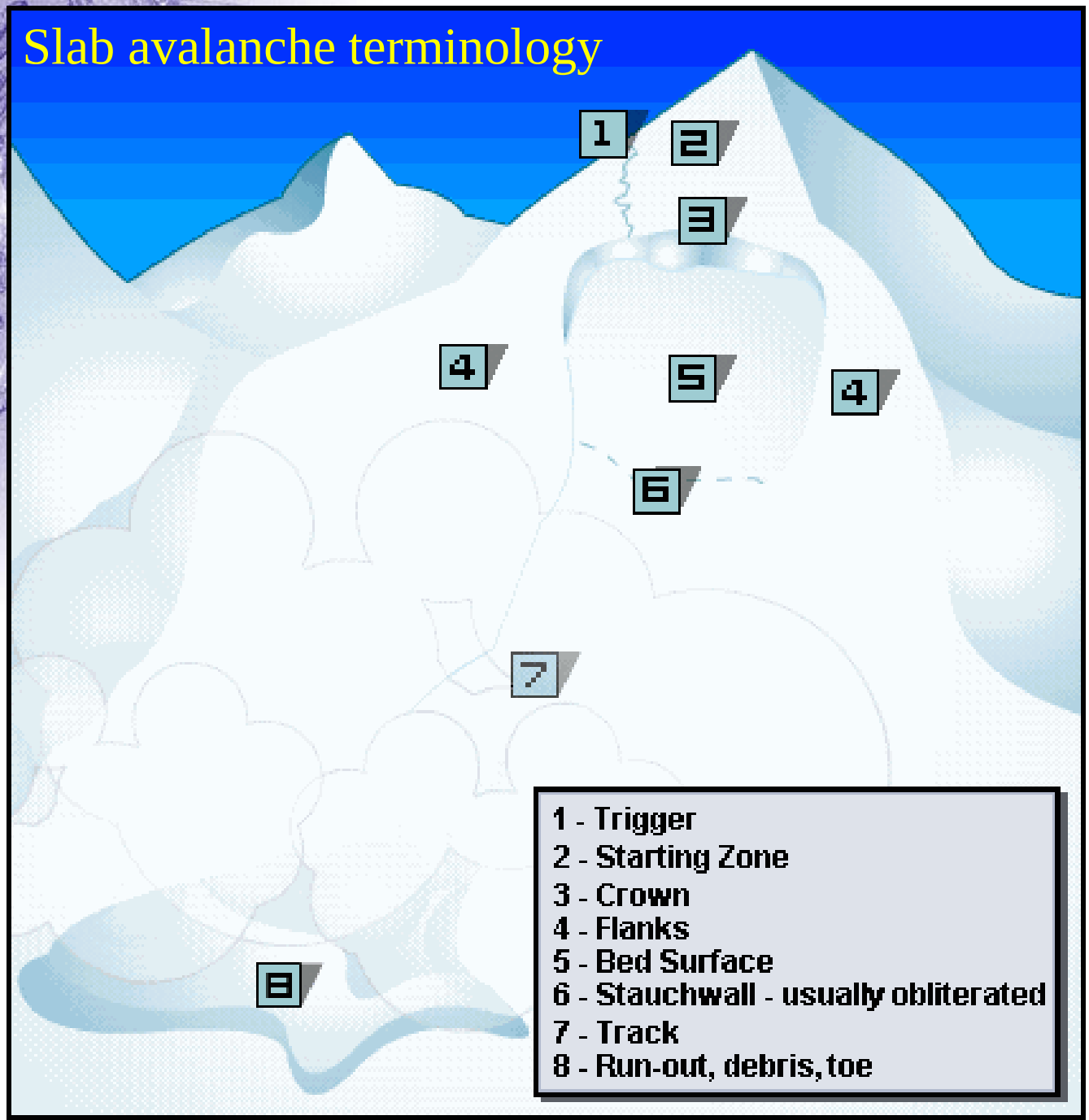
- usually small and relatively harmless
- occur most frequently in newly fallen snow on steep slopes
- have little internal cohesion
- light fluffy snow + gentle winds
- Point release

Loose Snow Avalanche

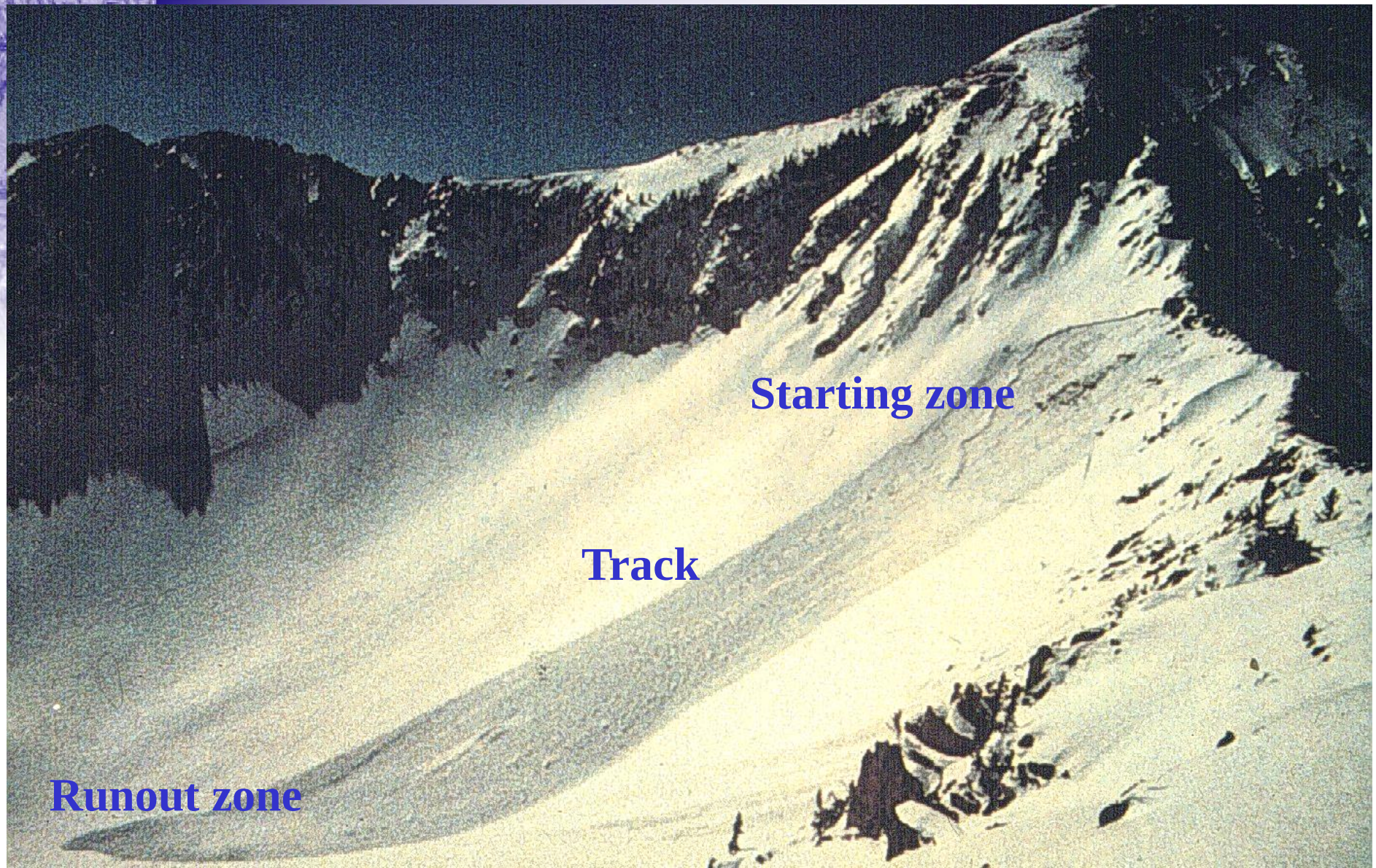
- Tear drop shape
- Unconsolidated
- Wet or Dry
- Often only surface snow
  - Point release
  - Sluff
- Easier to predict



Slab avalanche terminology



slab avalanche terminology



slab avalanche terminology

- crown face
- bed surface
- flanks
- stauchwall

Slab avalanches

- originate in all types of snow
- snow breaks away with enough internal cohesion to act as a single unit
- destructive

Avalanche formation factors

- terrain
- weather
- snowpack
- humans

- good news: the snowpack is stable the majority of the time

terrain

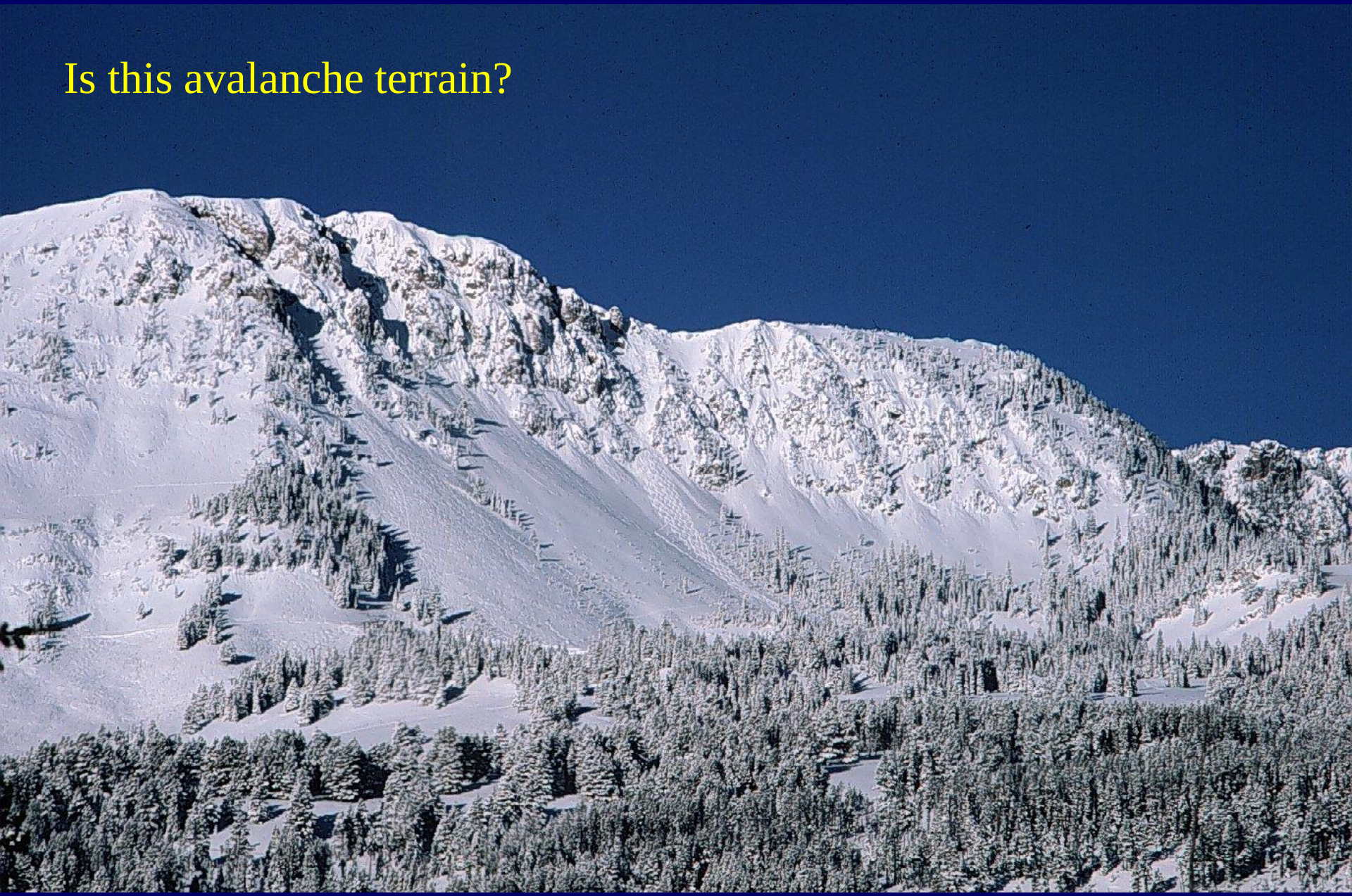
- Is the terrain capable of producing an avalanche?

terrain

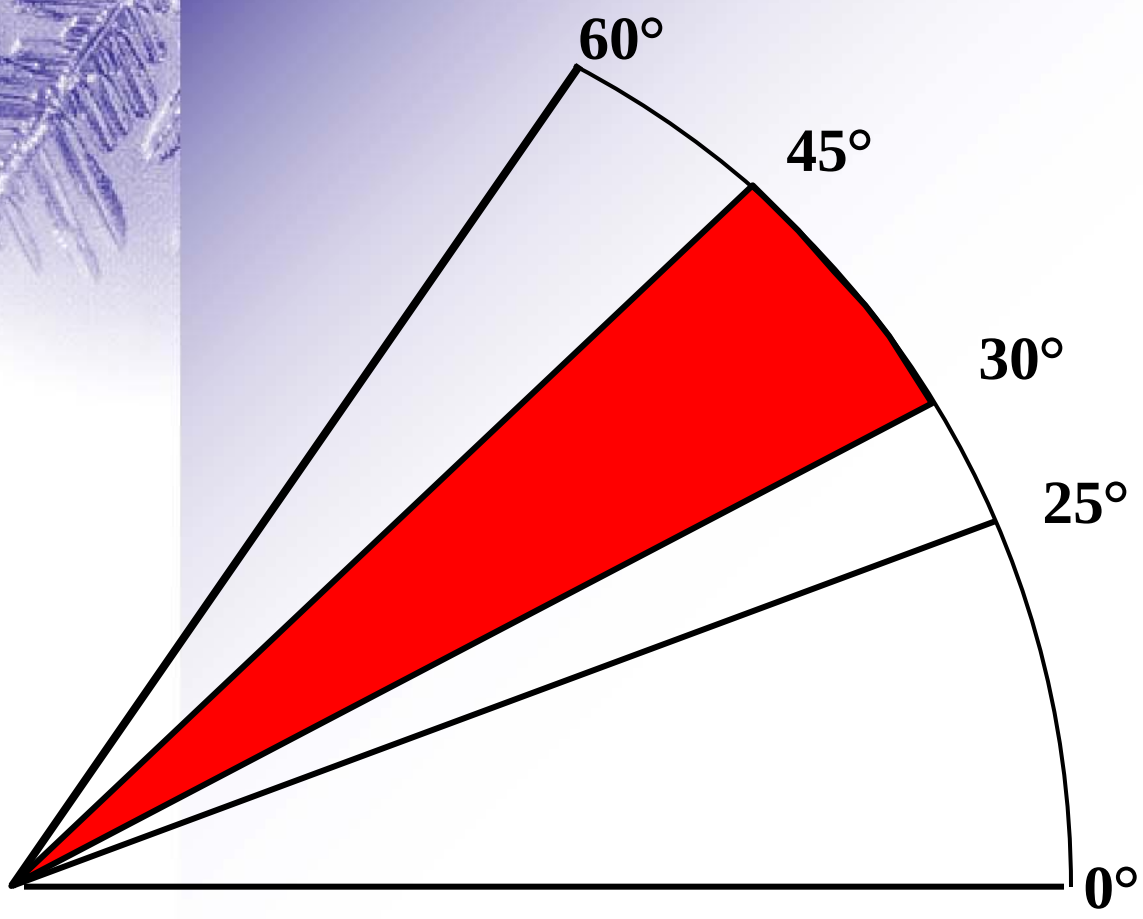
Factors to consider:

- slope angle
- slope size and consequences
- slope shape
- vegetation and trees
- runout
- aspect with respect to wind
- elevation

Is this avalanche terrain?



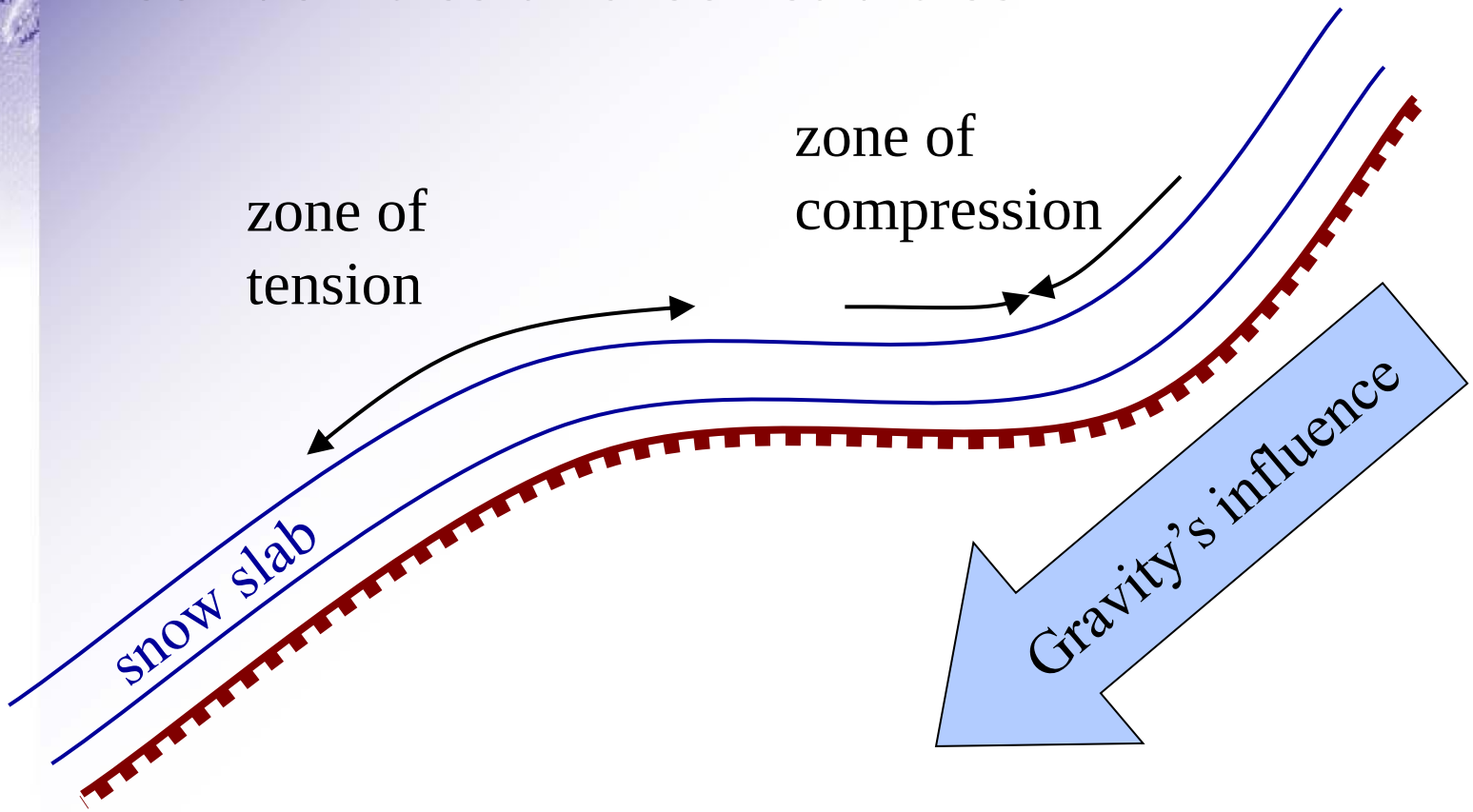
slope angle



- NOTE: referring to the *steepest* part of the slope

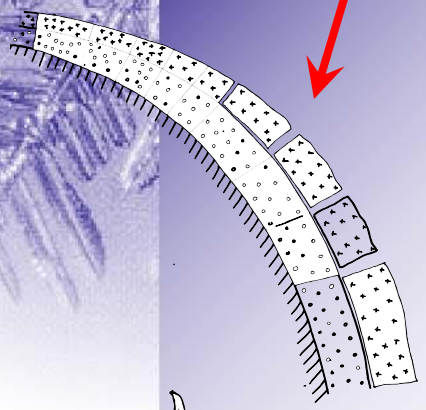
slope shape

- convexities and concavities

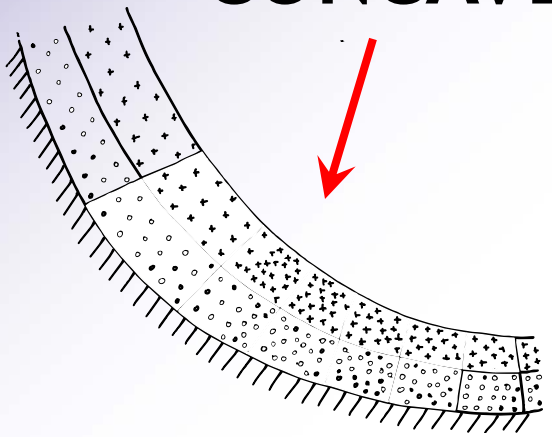


Trigger Points

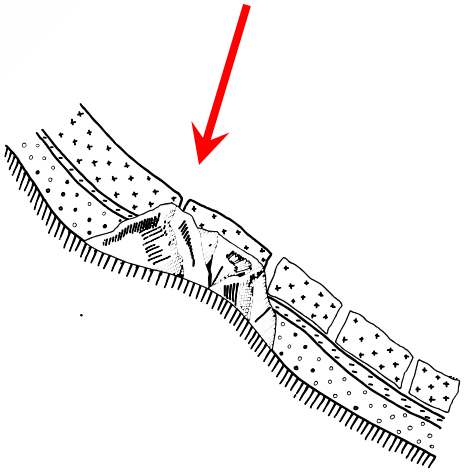
CONVEX



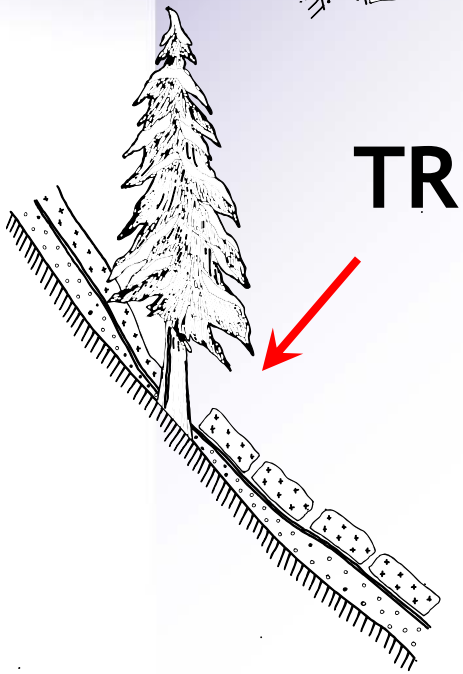
CONCAVE



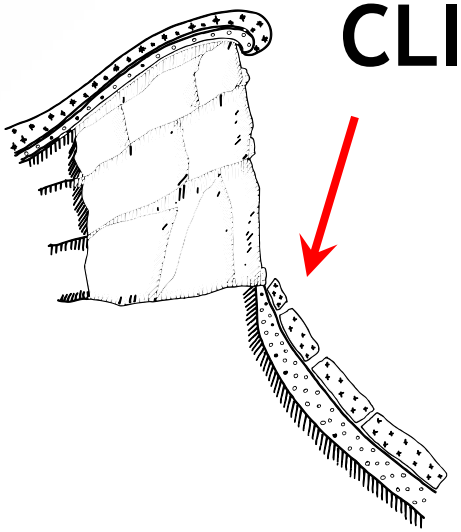
ROCK



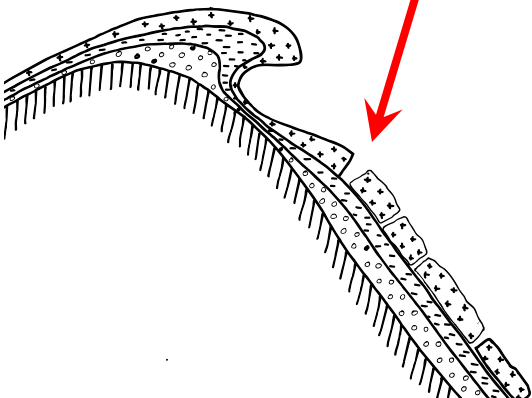
TREE

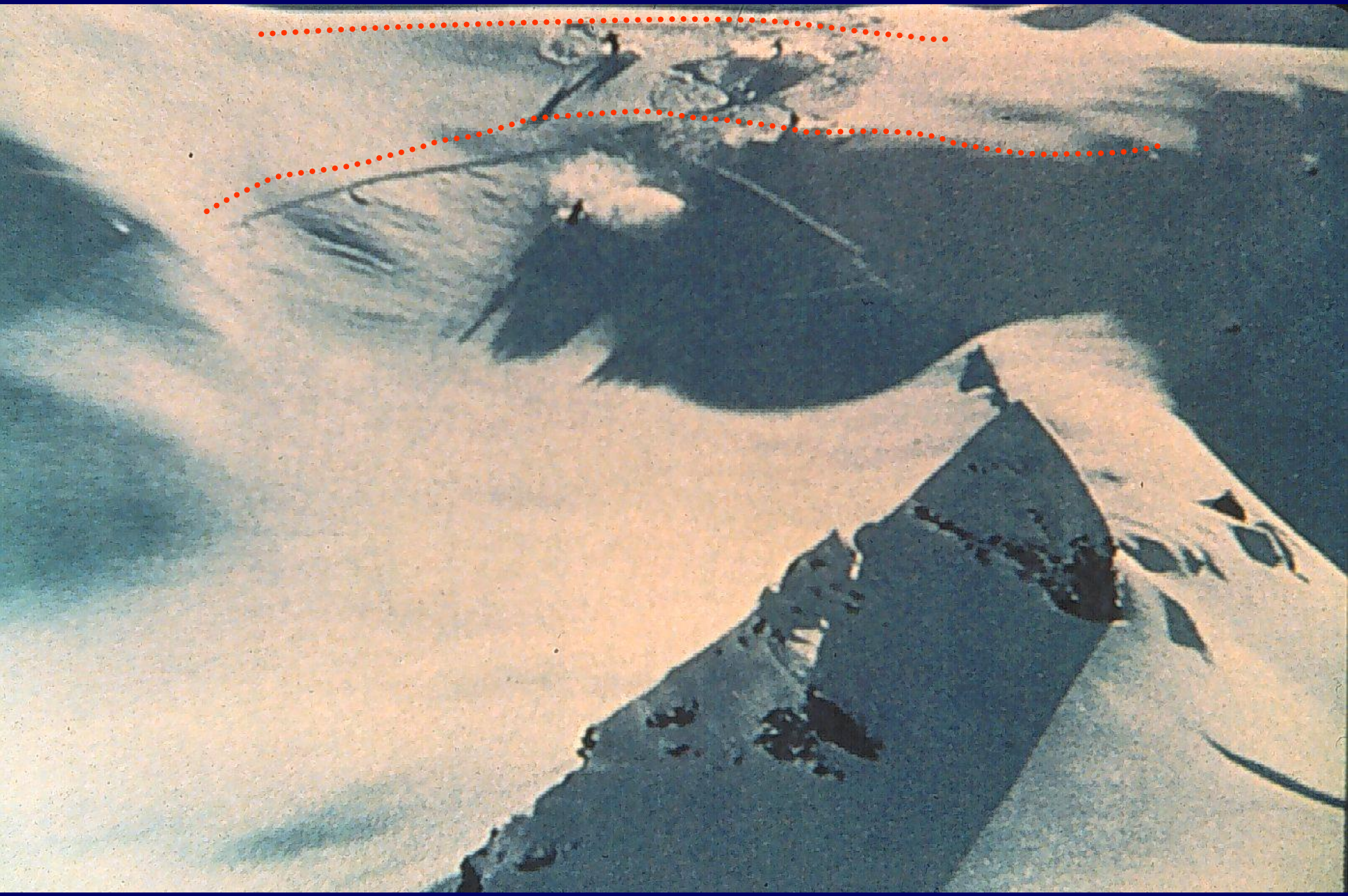


CLIFF



PILLOW



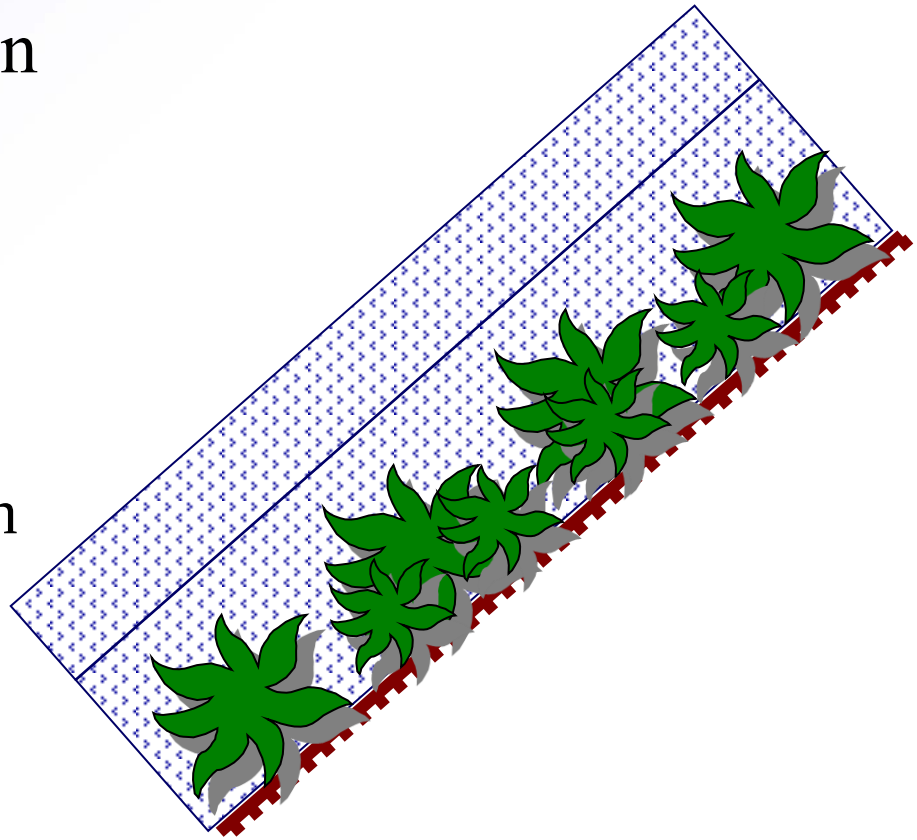


vegetation and trees

- indicators of avalanche activity
  - tree “flagging”
  - secondary growth

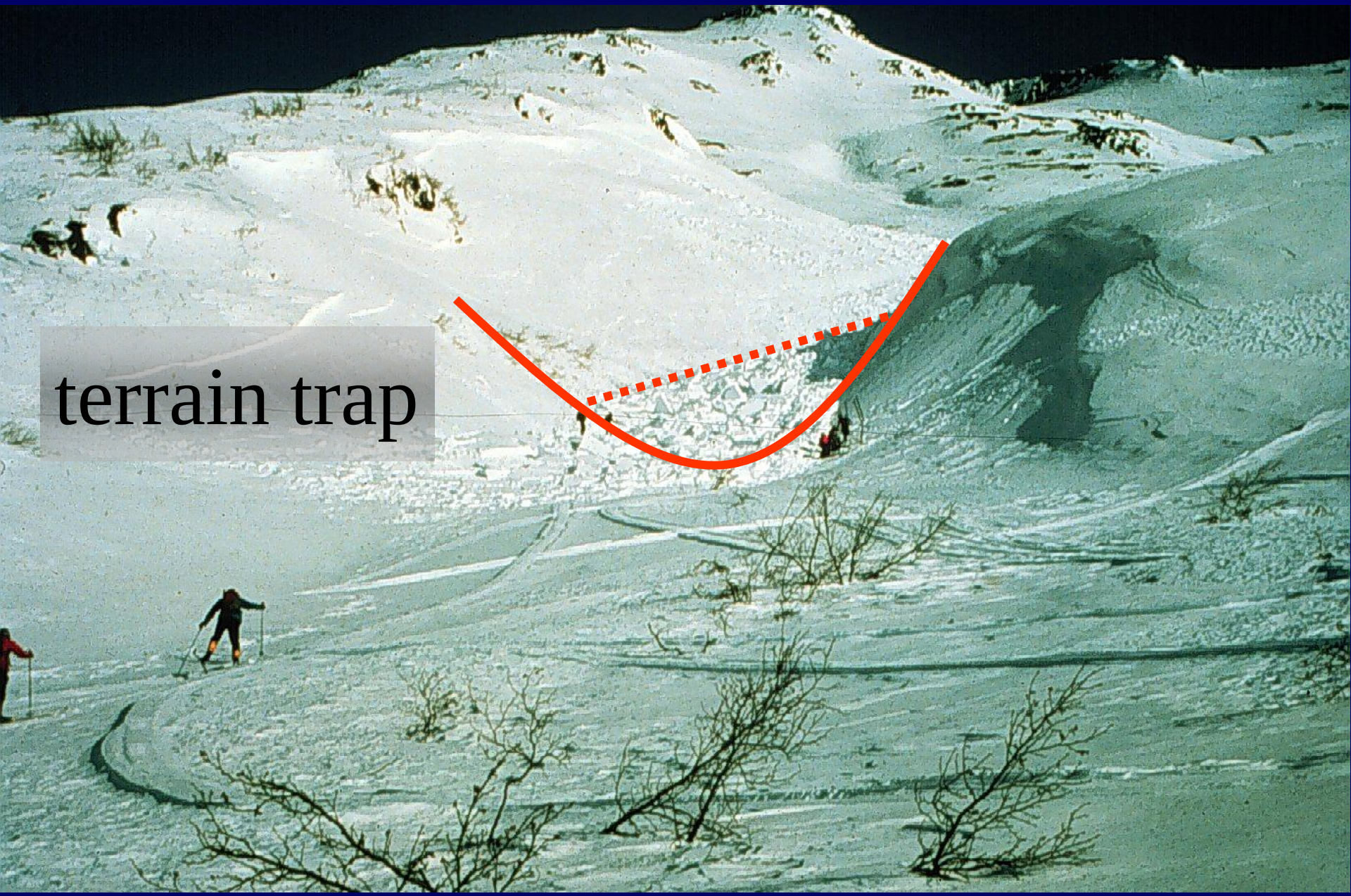
vegetation and trees

- trees can anchor snow…but: depends on amount of trees
- ground cover affects:
  - effective snow depth
  - heat transfer ~ snow metamorphism in basal layers



vegetation change

- implications of
  - climate change
  - timber cutting
    - creation of starting zones
  - forest fires
    - removes ground cover, thins trees
  - large avalanche events


terrain trap

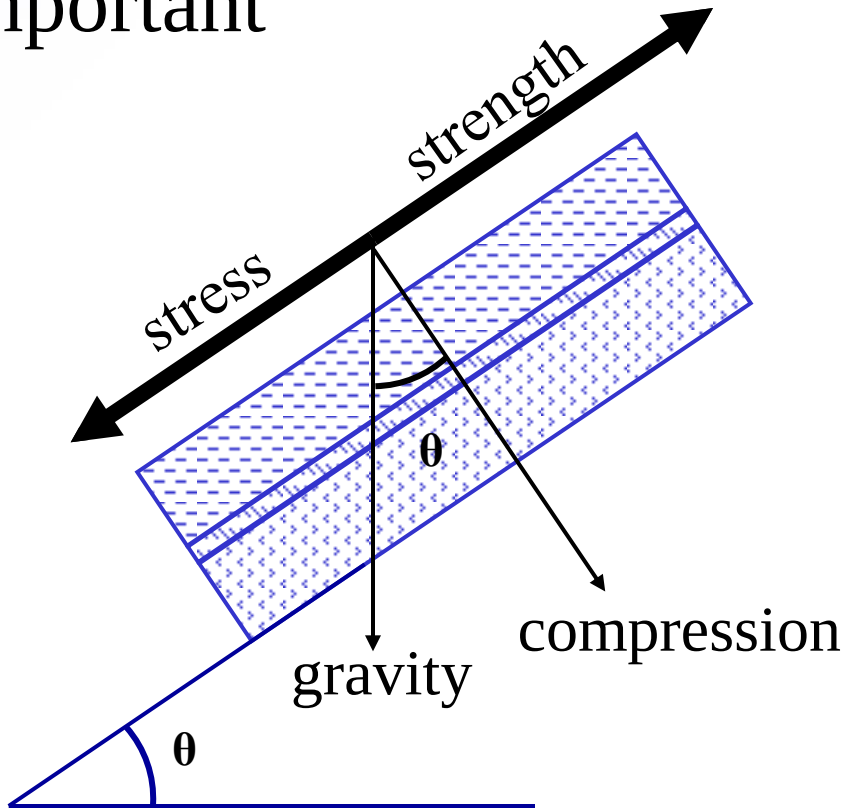
weather

- Is the weather affecting the snow stability?

- Precipitation (snow or rain)
- Wind
- Temperature

precipitation

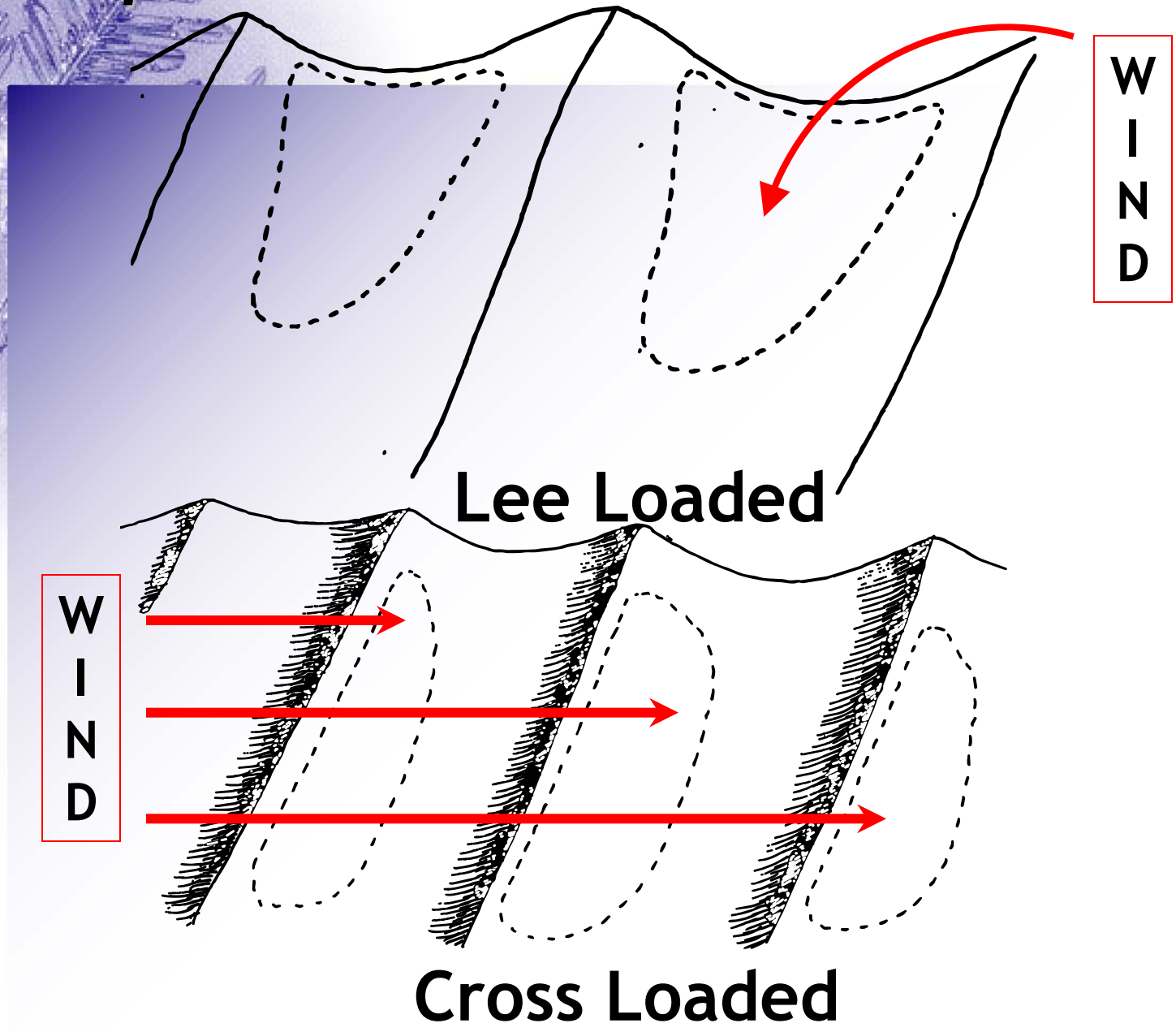
- addition of mass to the snowpack
- rate of addition is important
- stress vs. strength



wind

- snow redistribution
- change in snow density
- cornices

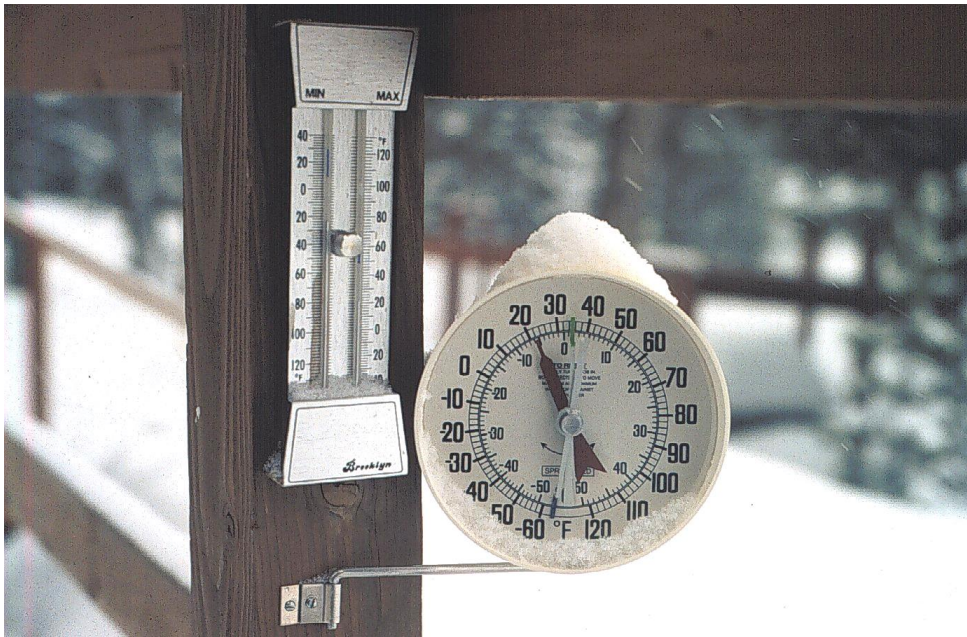
Aspect In Relation To Wind




Which side would you ski on?

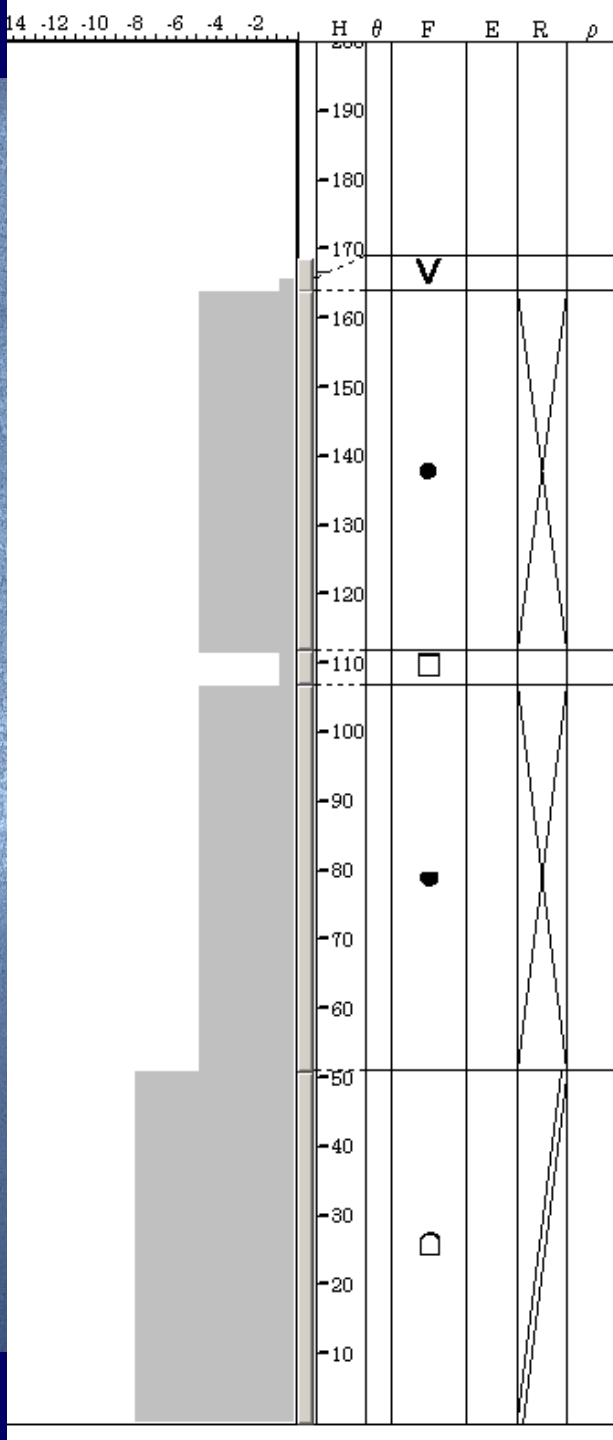
temperature

- changes in temperature can affect snow stability
  - change during storms
  - rapid warming
  - metamorphism effects



snowpack

- “Can the snowpack avalanche?”
  - snow stability evaluation
    - weak layer
    - slab


-14 -12 -10 -8 -6 -4 -2
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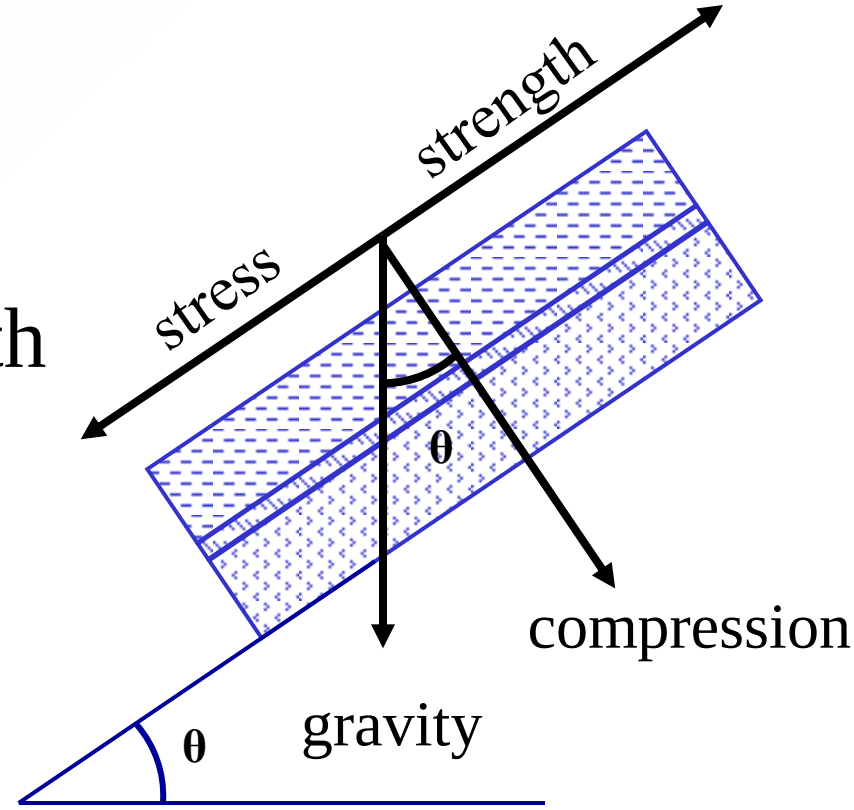
10

stability

- force balance
  - increase stress
  - decrease strength

- stress (τ) vs. strength

  $\tau = m*g*\sin\theta$



stability evaluation

- observe signs of weakness
  - recent avalanching
  - collapsing or “wumpfing”
  - propagating cracks
- evaluate structure of snowpack
  - are weak layers present?
  - is there a slab?
- test the stability of the snowpack
  - stability tests

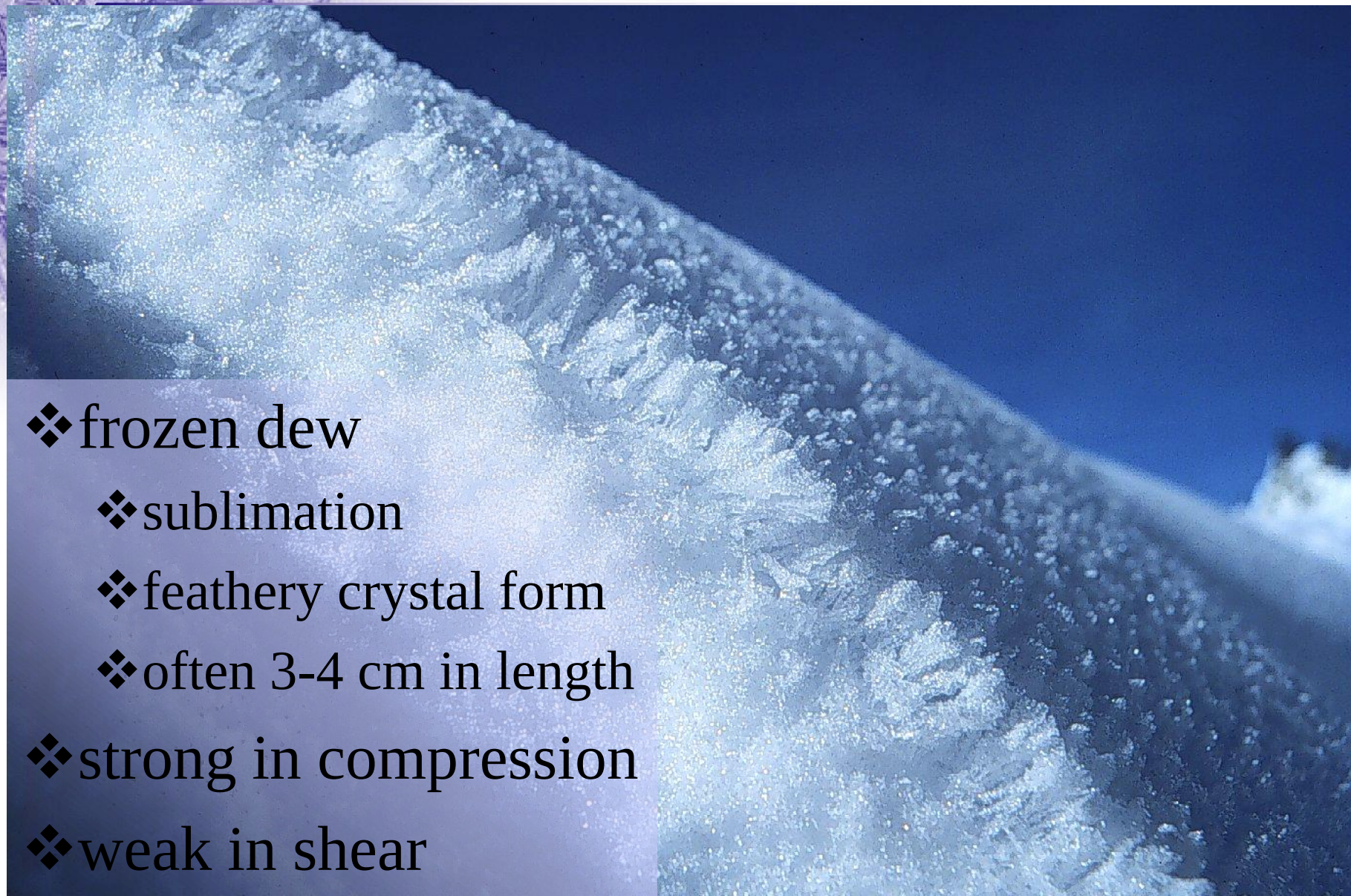
stability tests

- strength/stress balance between slab and weak layer

weak layers

- surface hoar
  - surface deposition
- faceted crystals
  - depth hoar (sugar snow)

surface hoar



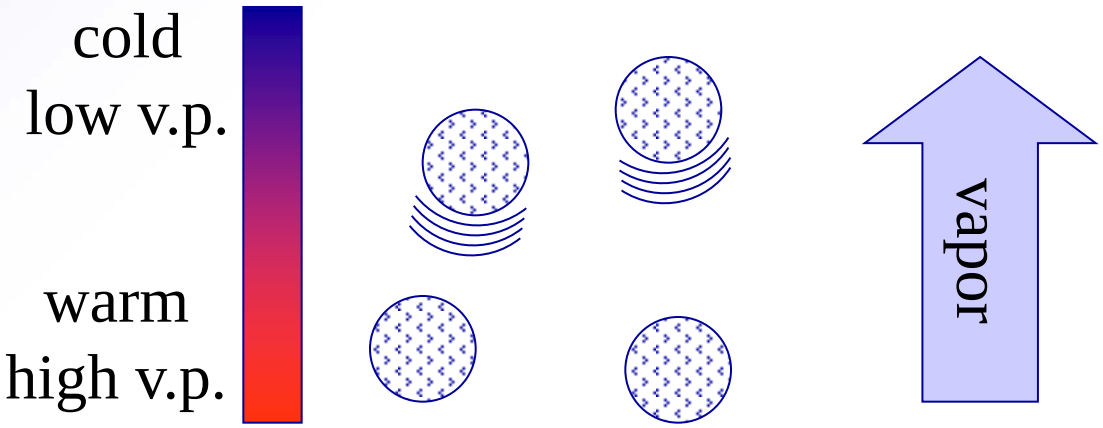
- frozen dew
  - sublimation
  - feathery crystal form
  - often 3-4 cm in length
- strong in compression
- weak in shear

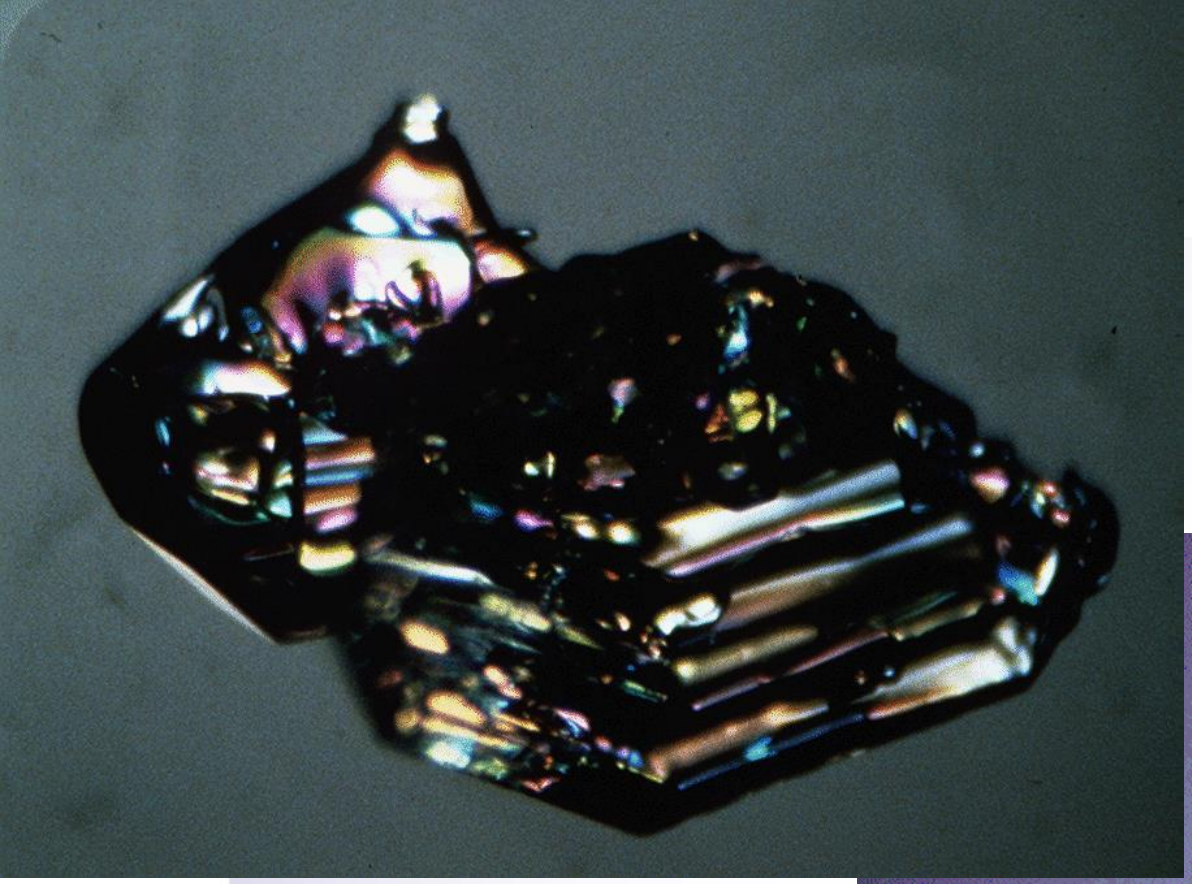
faceted snow

- depth hoar:
  - generally in basal layer
  - sugary consistency
- near-surface facets
  - formed at surface
  - can be found anywhere in the snow column

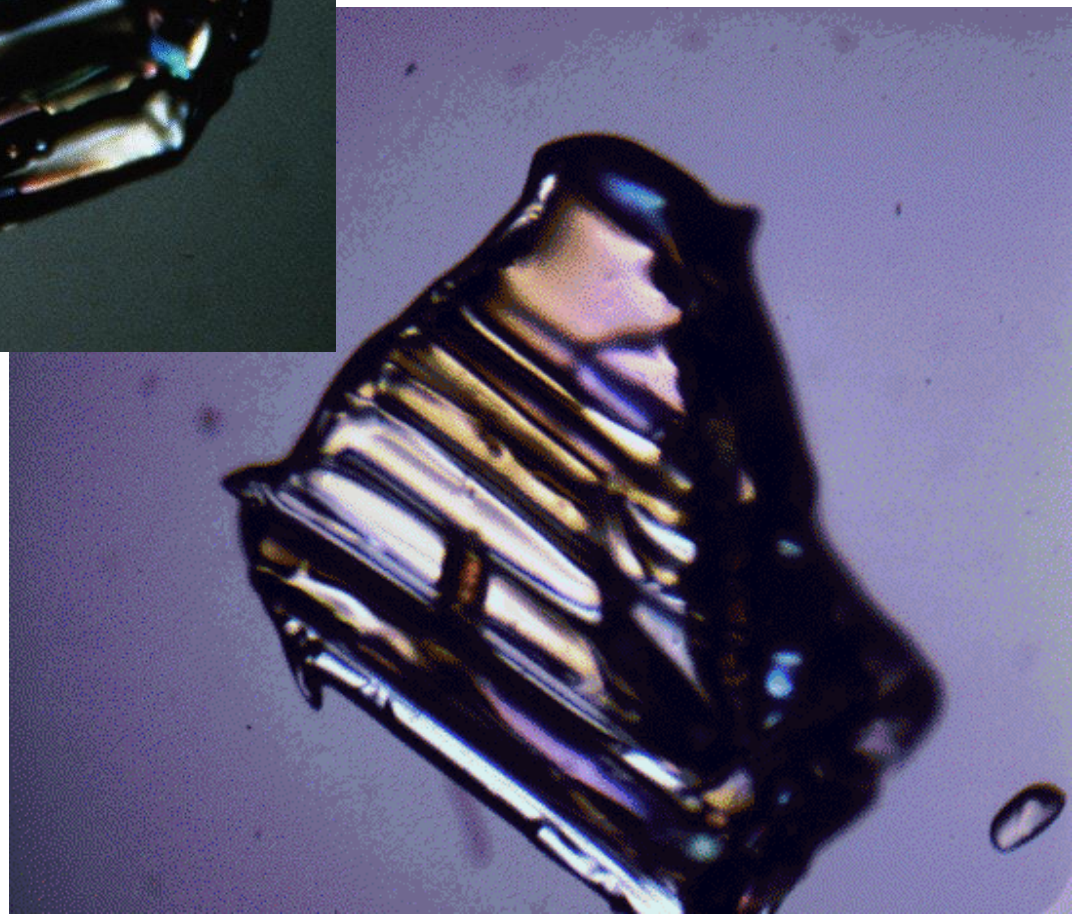
growth of faceted snow

- requires strong temperature gradient
  - typically > 10°C/m
- t.g. induces vapor pressure gradient
  - H_2O vapor moves from high to low v.p.





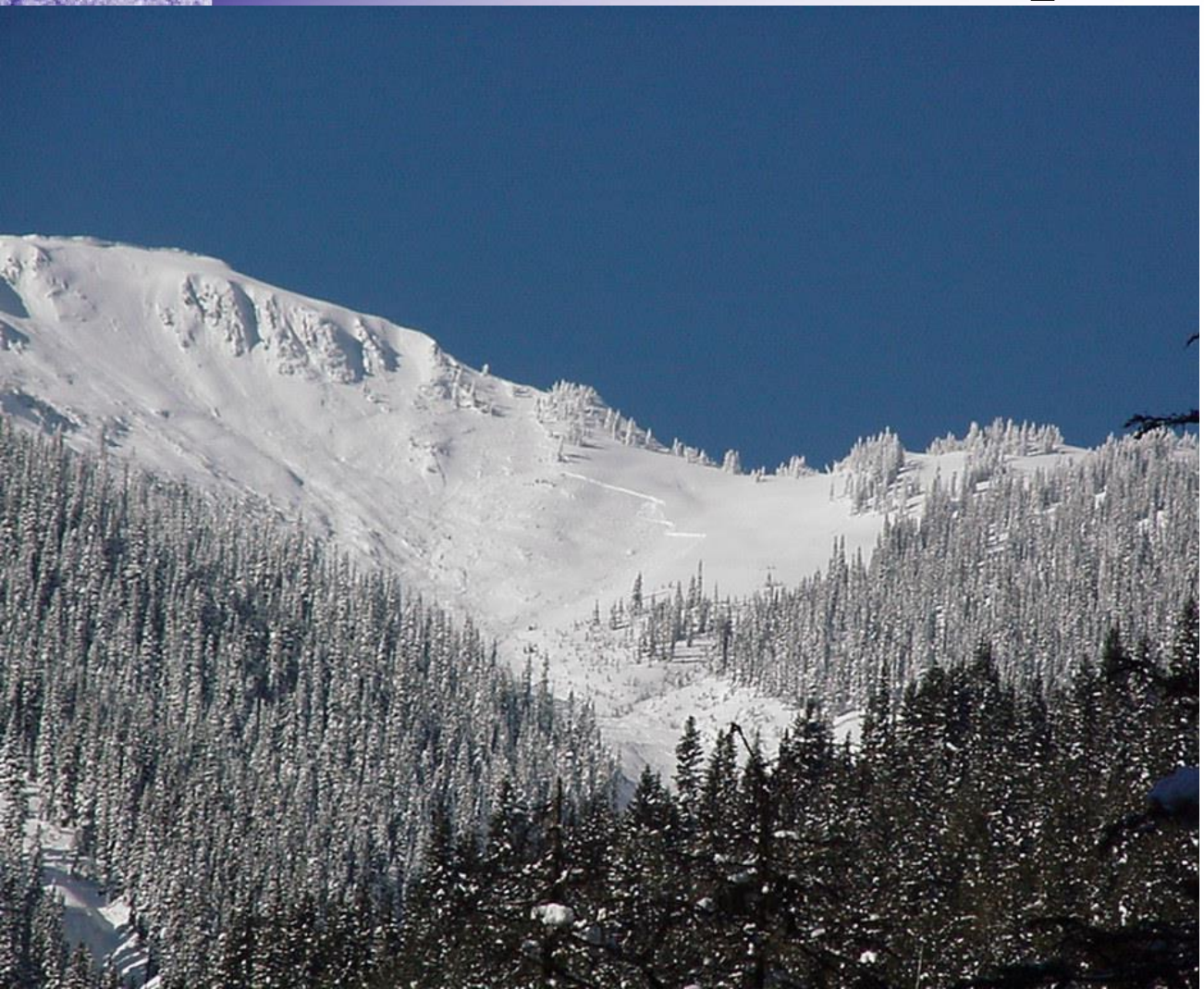
faceted snow



variation in snow properties

- system complexity produces variability
  - over space
  - over time
- snow is thermodynamically active
  - can exist in 3 phases in snowpack
  - sensitive to small environmental changes
  - change can be rapid

spatial variation



- wind
- sun
- temperature
- trees
- …

human factor

- "Can you make an objective assessment of the avalanche danger?"
  - in the vast majority of avalanche accidents, the avalanche was caused by the victim or a member of the victim's party

human factors

- decision making
- routefinding/travel habits
- emotions and logic
- preparedness
- education

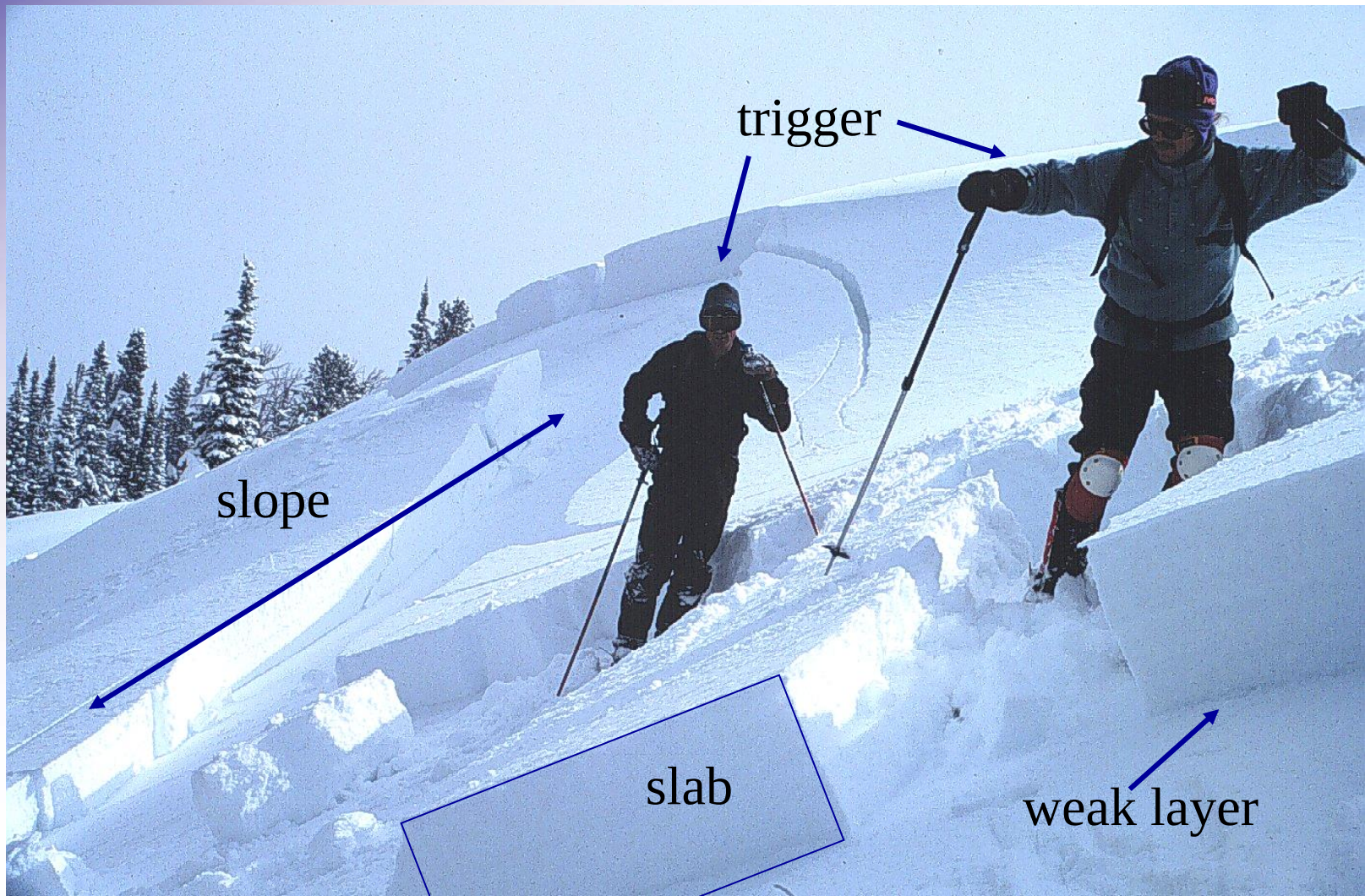
- other concerns:
  - sales product (ski hill)
  - transportation delays
  - real estate location
  - ego

putting it all together

"Any rapid change in the thermal or mechanical state of the snowpack is a precursor to avalanching."

- Ed LaChapelle

slab avalanche ingredients



rescue

- if you are caught in an avalanche, your best hope is your partners
- other options:
  - self-rescue
  - organized rescue
- time of burial is critical

Type of Rescue

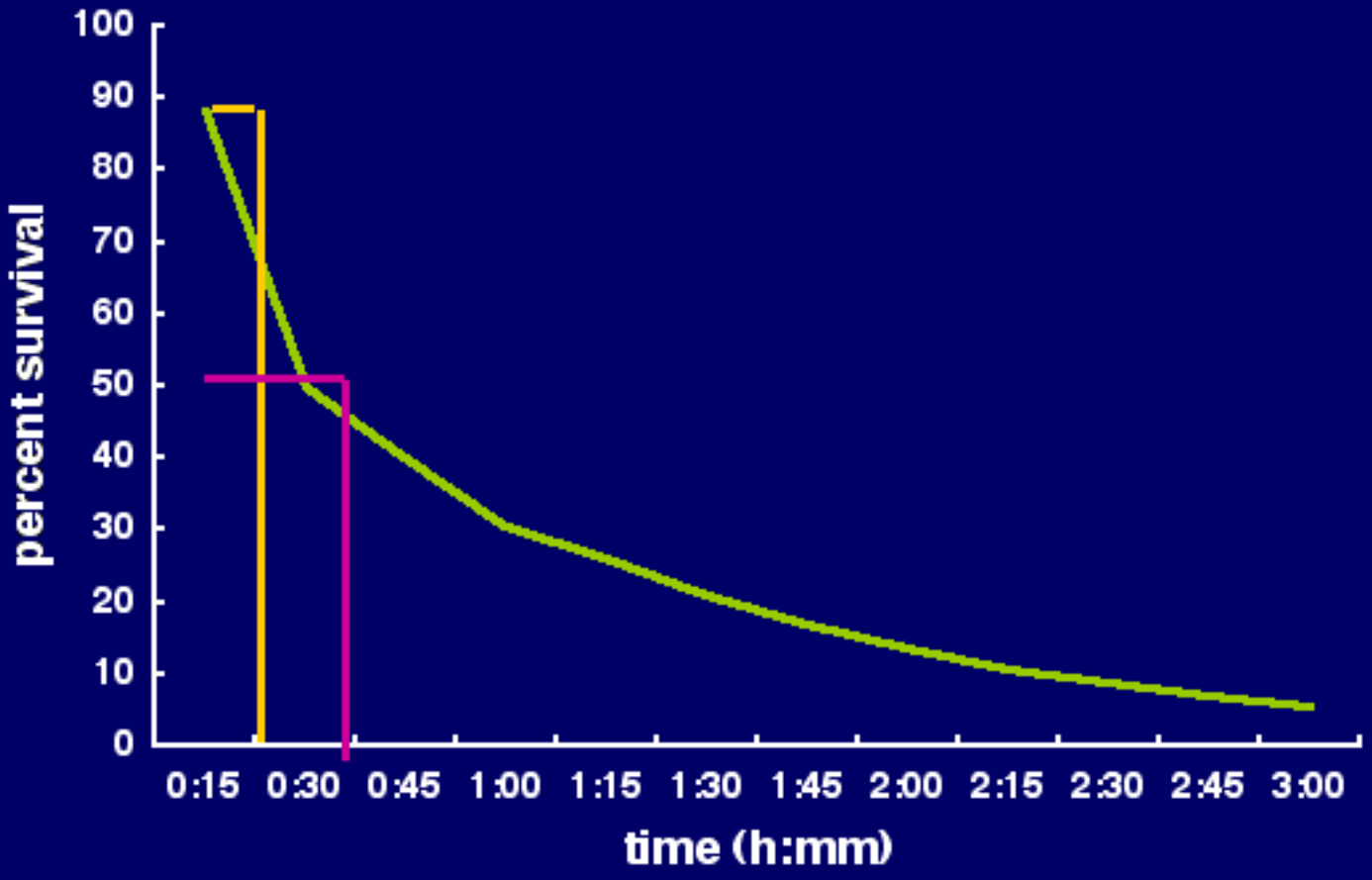
	Self Rescue	Companion Rescue	Organized Rescue
Alive	52 (17%)	204 (65%)	58 (18%)
Dead	——	102 (23%)	336 (77%)

- companion rescue means:
  - safe travel
  - proper gear and training
  - practice

Colorado Avalanche Information Center

1950/51 to 2000/01

Percent Survival vs. Burial Time



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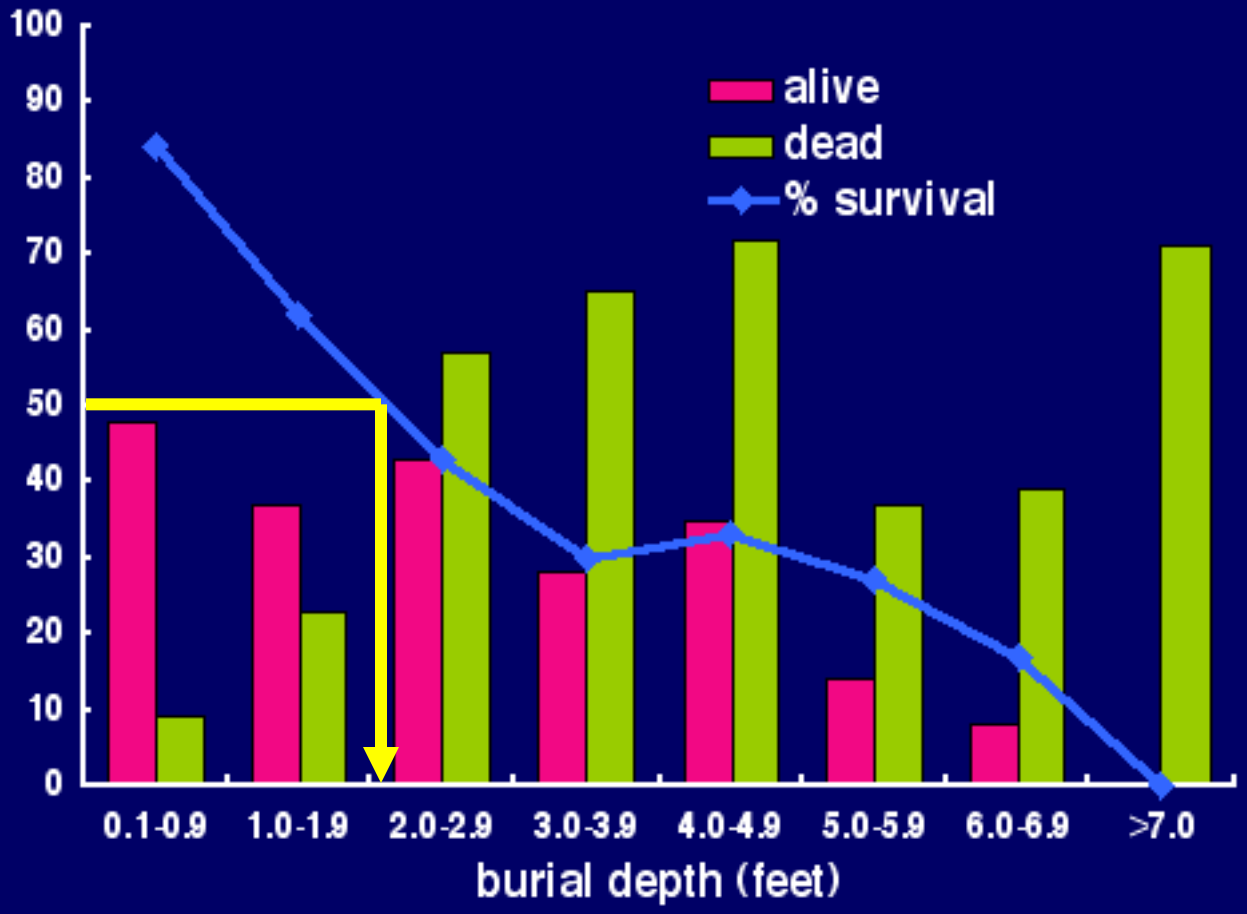
1950/51 to 2000/01

Burial Depth and Survival Probability



Colorado Avalanche Information Center

1950/51 to 2000/01

avalanche forecasting

- US forecast centers
- forecasters use:
  - weather
  - snowpack
  - terrain

…to produce danger ratings

avalanche forecasts

United States Avalanche Danger Descriptors			
Danger Level (& Color)	Avalanche Probability and Avalanche Trigger	Degree and Distribution of Avalanche Danger	Recommended Action in the Backcountry
...WHAT...	...WHY...	...WHERE...	...WHAT TO DO...
LOW (green)	Natural avalanches very unlikely. Human triggered avalanches unlikely.	Generally stable snow. Isolated areas of instability.	Travel is generally safe. Normal caution is advised.
MODERATE (yellow)	Natural avalanches unlikely. Human triggered avalanches possible.	Unstable slabs possible on steep terrain.	Use caution in steeper terrain on certain aspects (defined in accompanying statement).
Considerable (orange)	Natural avalanches possible. Human triggered avalanches probable.	Unstable slabs probable on steep terrain.	Be increasingly cautious in steeper terrain.
HIGH (red)	Natural and human triggered avalanches likely.	Unstable slabs likely on a variety of aspects and slope angles.	Travel in avalanche terrain is not recommended. Safest travel on windward ridges of lower angle slopes without steeper terrain above.
EXTREME (black)	Widespread natural or human triggered avalanches certain.	Extremely unstable slabs certain on most aspects and slope angles. Large, destructive avalanches possible.	Travel in avalanche terrain should be avoided and travel confined to low angle terrain well away from avalanche path run-outs.

further information

- avalanche classes:
  - CAIC
  - Silverton Avalanche School
  - AAA
- forecasts
  - www.avalanche.org
- science
  - US Forest Service National Avalanche Center

A DOZEN MORE TURNS