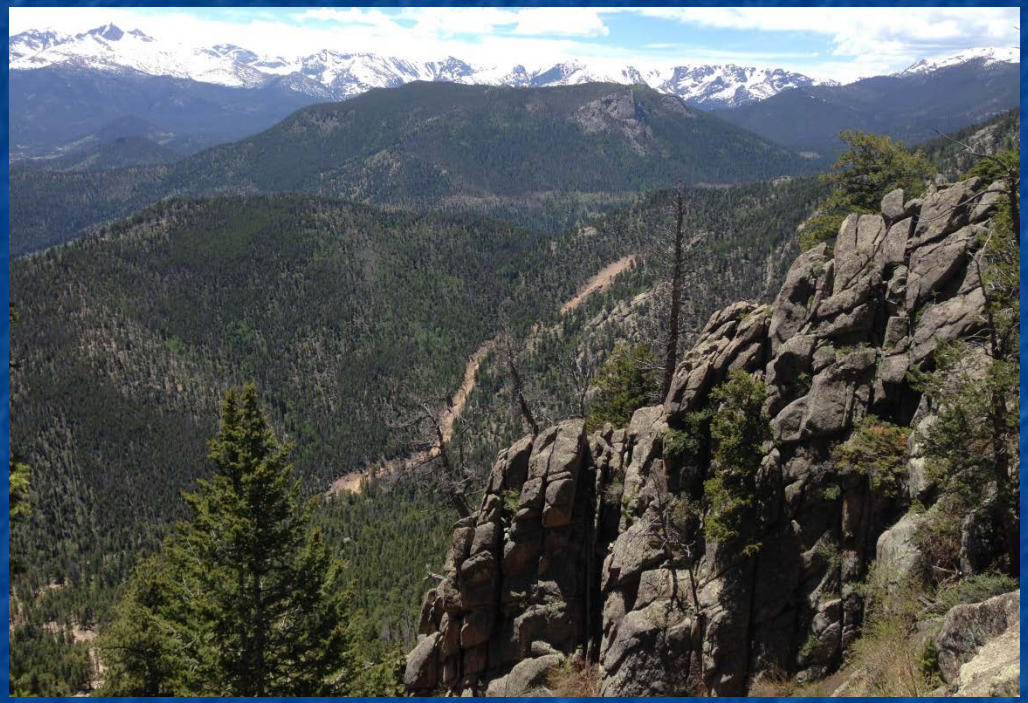
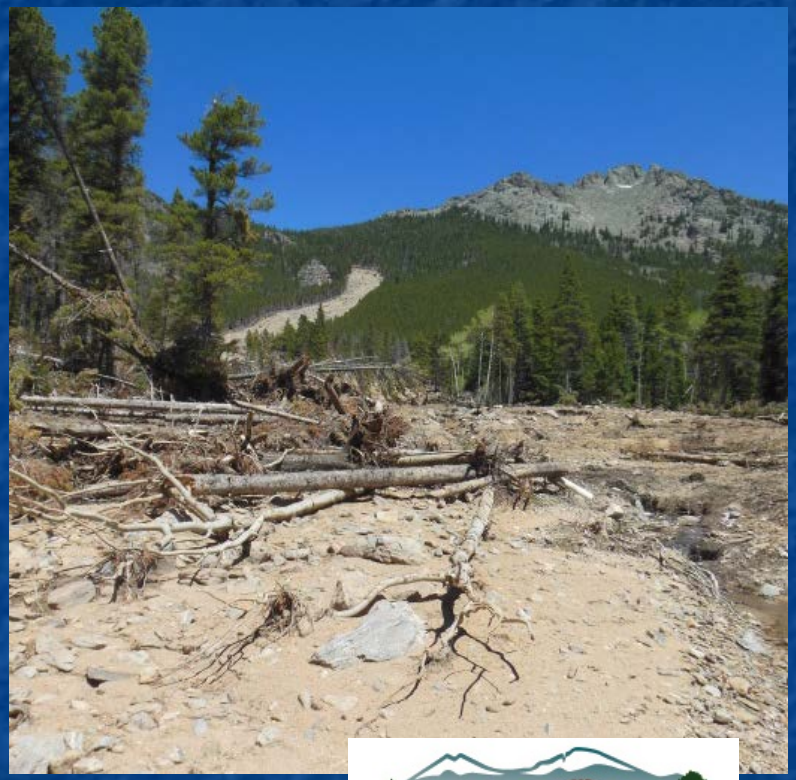
What are those Scars on the Hillsides? Debris Flow Occurrence in Rocky

Centennial Science behind the Scenery





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with special thanks to Paul McLaughlin, Eric Bilderback, Nick Santiago and Clare Lukens, and Rocky Mountain National Park and NPS for funding

Colorado State University
Warner College of Natural Resources

Outline

- Getting to Know Debris Flows
  - Causes and controls
- Why Interested in Debris Flows?
- Debris Flow Landforms
- Occurrence in Rocky
  - Big Horn site
- Preliminary Findings
- Questions

Getting to Know Debris Flows

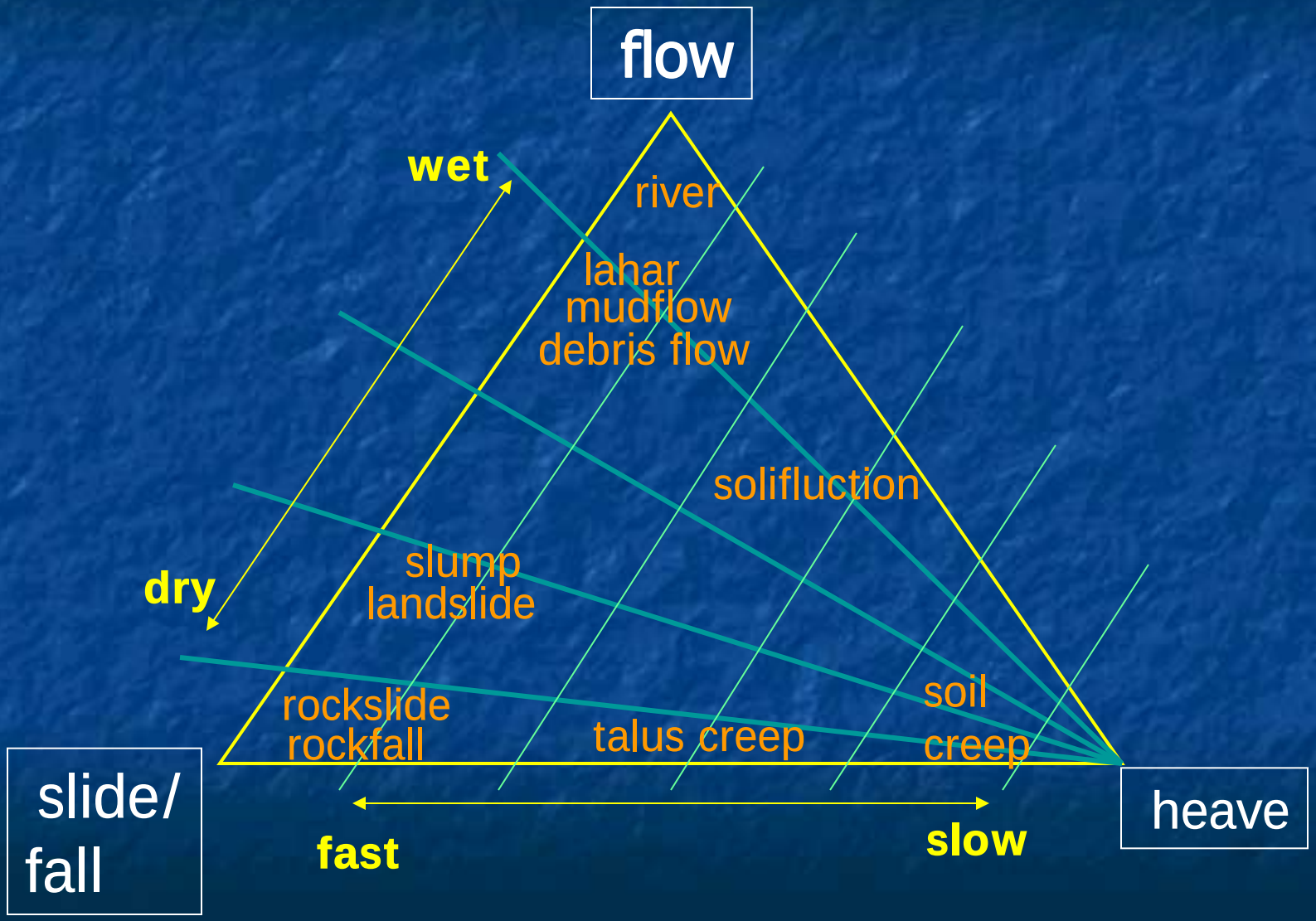
Rockfall

Debris flow

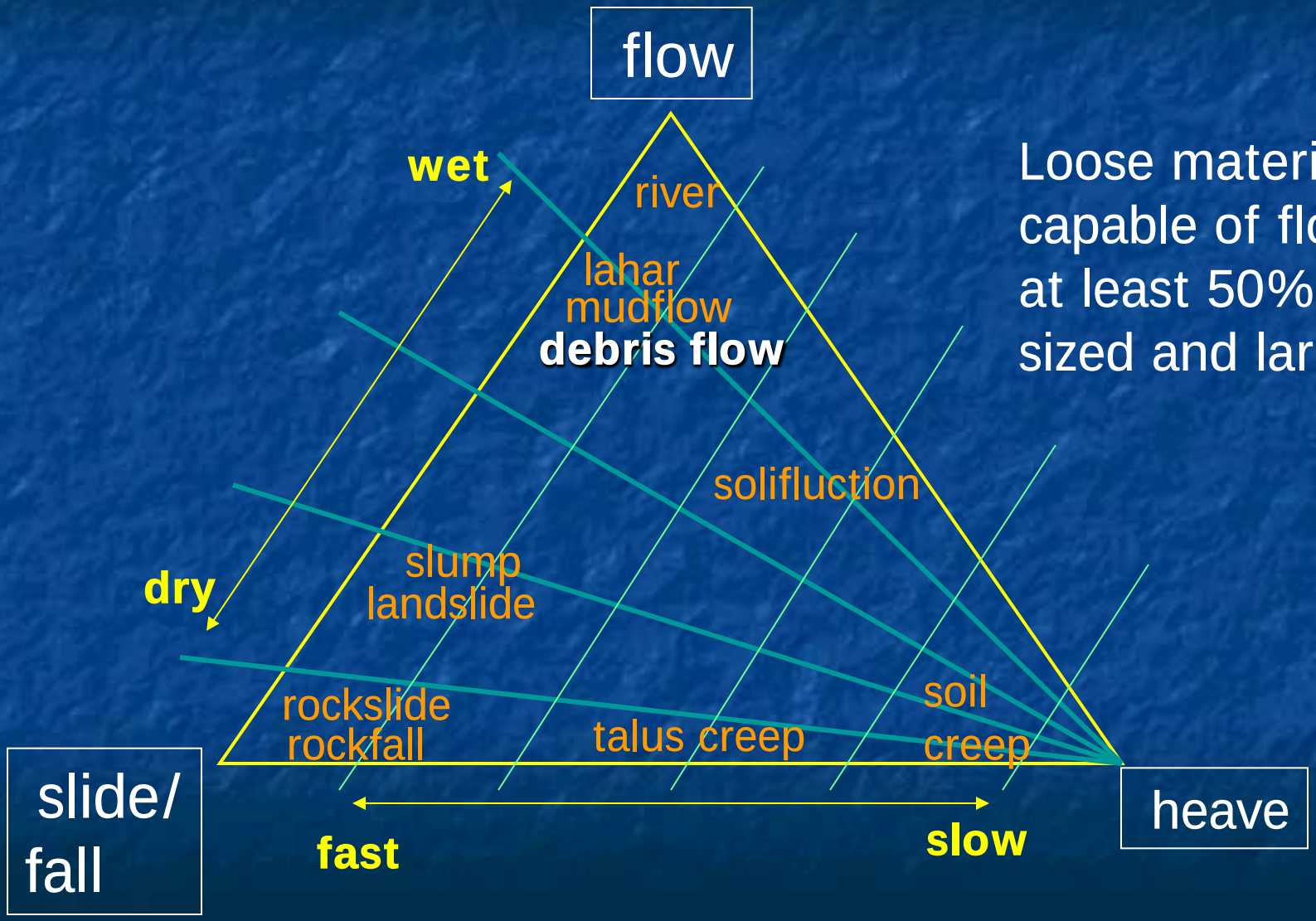
Soil creep

Mass Movements – gravitationally caused downslope transport of rock, soil, sediment, debris, snow, or ice; debris flows a type of mass movement.

Classification of Mass Movement Processes



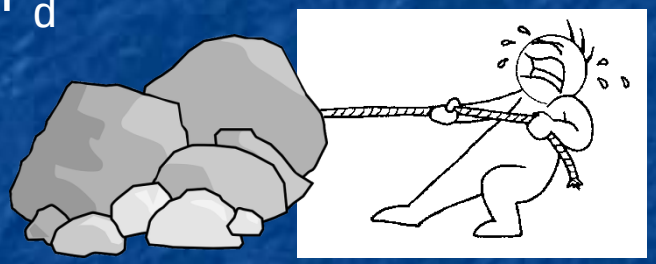
Classification of Mass Movement Processes



Loose material, capable of flowing; at least 50% is sand-sized and larger

Causes and Controls

$F_R > F_d$



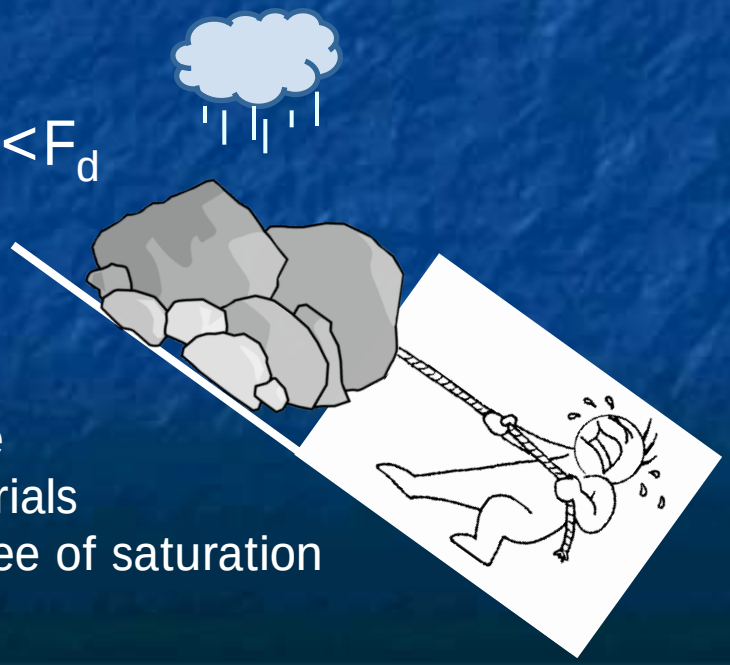
Resisting forces (F_R)

properties that resist the stresses generated by gravitational force

↓

Shear strength

$F_R < F_d$



Driving forces (F_d)

conditions that enhance the stresses generated by gravitational force

↓

Shear stress

Slope
Materials
Degree of saturation

Conditions for Initiation:

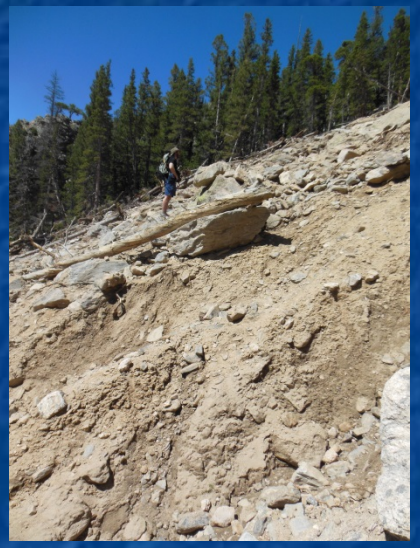
Steep slope

Large volume unconsolidated material

Abundant precipitation

Large uncertainty

- stochastic process



Threshold problem

Slope Failure

Slope Stability

Why Interested in Debris Flows?

- A dangerous natural hazard
  - On average, <u>most costly</u> natural hazard
    - >$670 million after 2013 floods and debris flows (Coe et al., 2014)
  - Improve hazard prediction and mitigation
- Critical role in the rock cycle
  - 1st step in transportation of sediment
- Critical role in evolution of landscapes
  - Hillslope delivery of sediment to streams
    - 2013 introduced 1000s of years of sediment (Anderson et al., 2015)

Italian Alps

Erosional Landforms

chute

channelized so causes stream incision

Twin Sisters
Sept. 2013

unchannelized

scarp

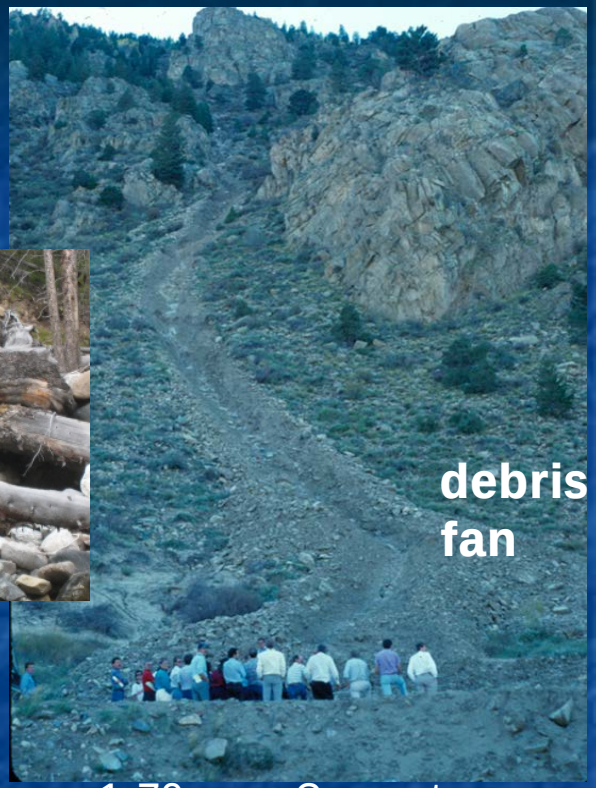
starts as colluvial hollow

Depositional Landforms

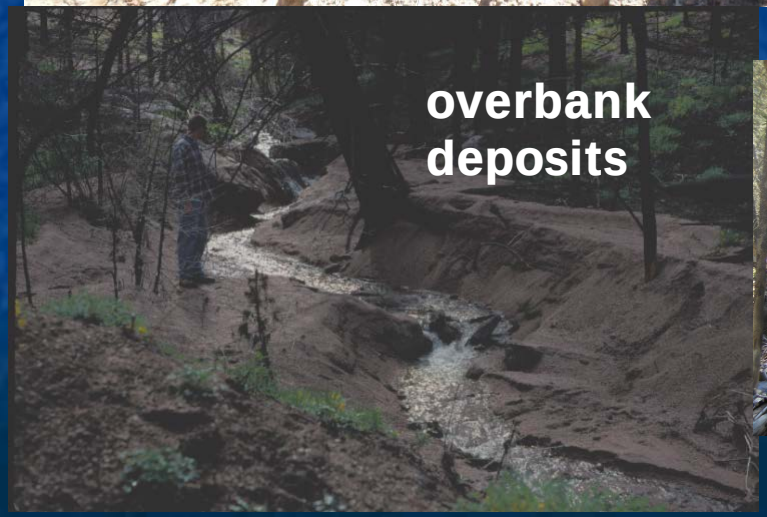
Big Horn site

log jam

Lulu Creek



1-70 near Georgetown



Buffalo Creek, fire/ floods 1996

Lulu Creek

Colorado River (Grimsley, 2012)

Debris Flows in Action

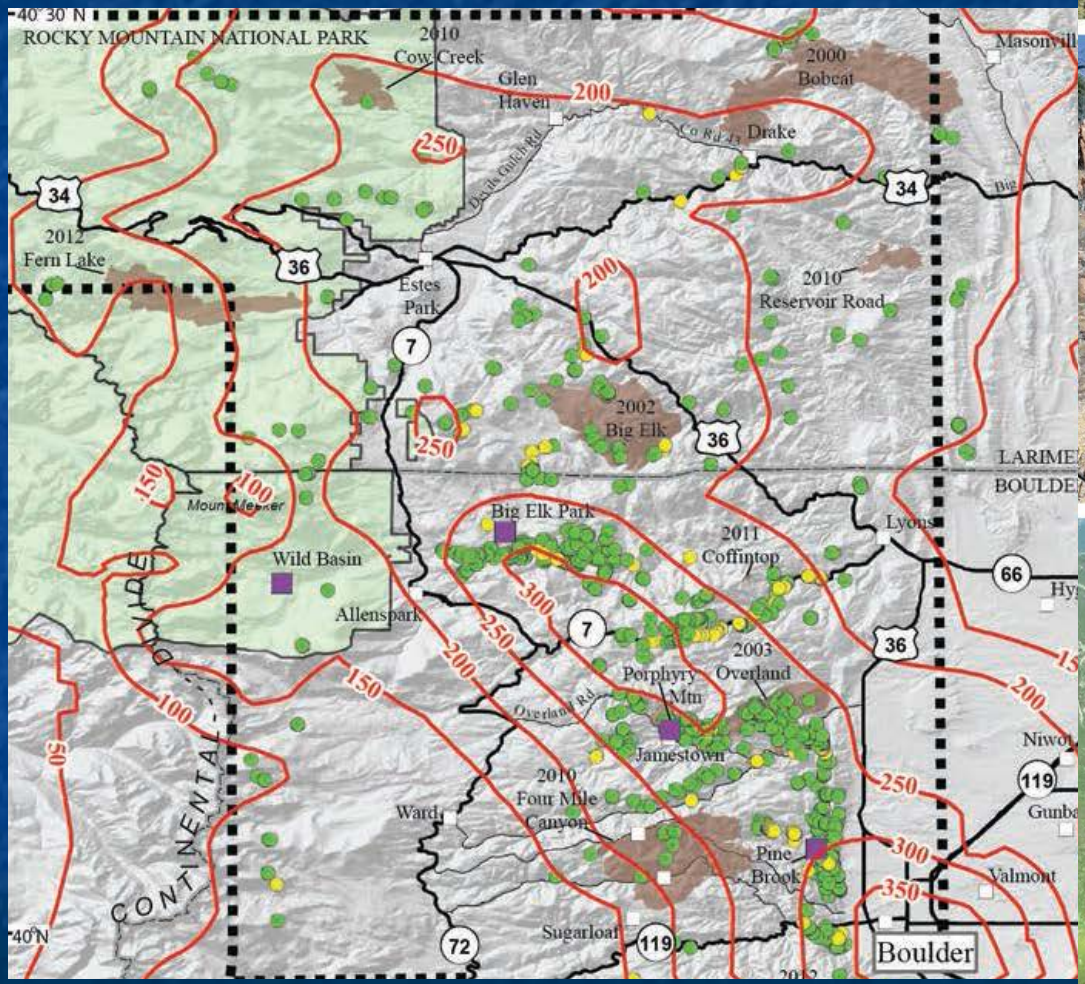
https://www.youtube.com/watch?v=8mKC3eID074

https://www.youtube.com/watch?v=diRZgza-P9k&feature=youtu.be

Debris Flow Occurrence in Rocky

September 2013 Front Range

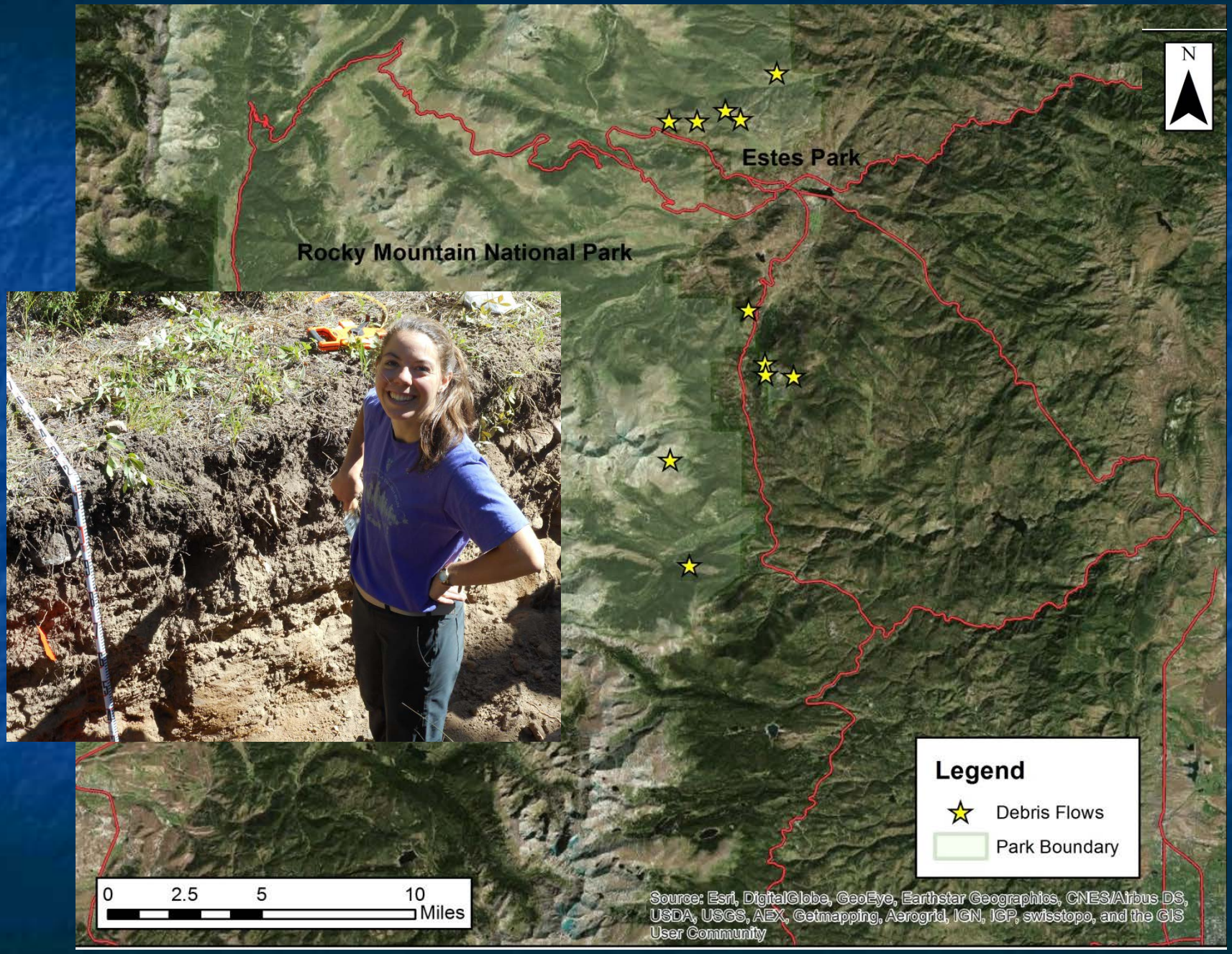
Over 1100 debris flows



From Coe et al., (2014)

- Rainfall, mm 9/10-9/13/13
- Debris flows
- Rock, earth, debris slides

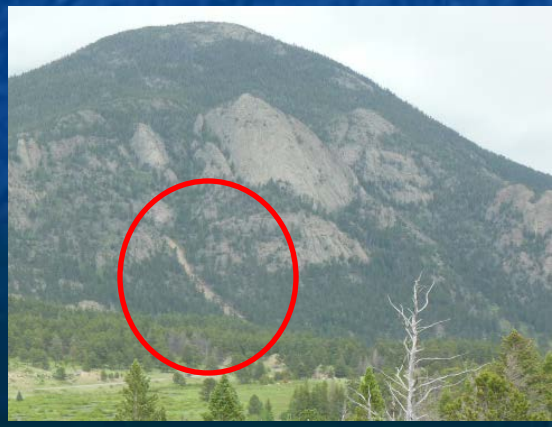
Occurrence in Rocky



Research Hypotheses

- Slope geometry, subsurface bedrock topography and substrate characteristics are dominant site-specific controls on debris flow initiation.
  - Measure characteristics on 2013 debris flows
    - Compare to at least 30 reference sites
- Fire history outweighs slope characteristics in initiating debris flows.

Also:
Assess debris flow chronology at Big Horn site



Occurrence in Rocky

Conceptual Model of Debris Flow Initiation

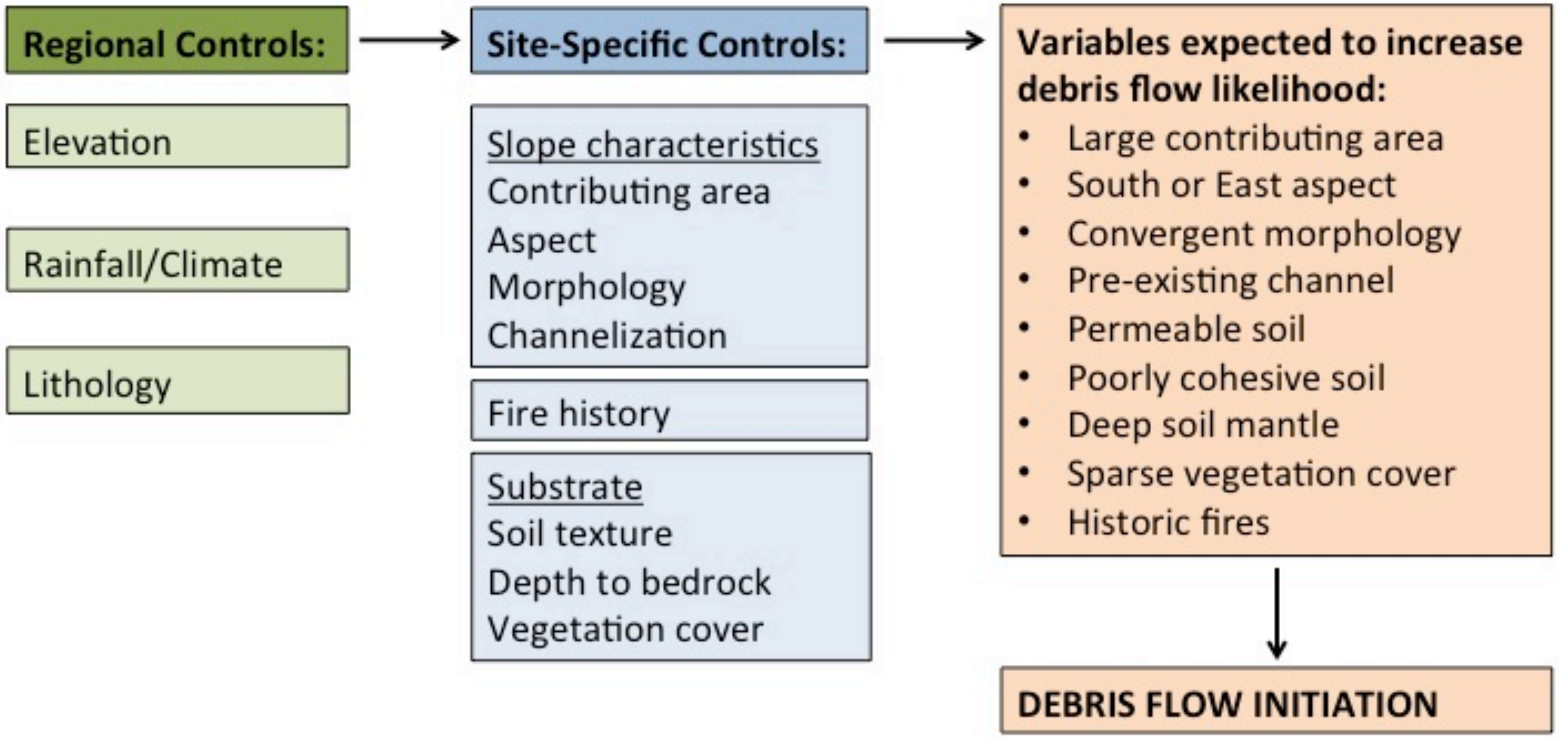


Figure 1. Conceptual model illustrating controls on debris flow initiation. Regional controls are consistent between the study sites. The proposed research will focus on determining the dominant site-specific controls that increase the likelihood of debris flow initiation, including slope characteristics, substrate, and fire history.

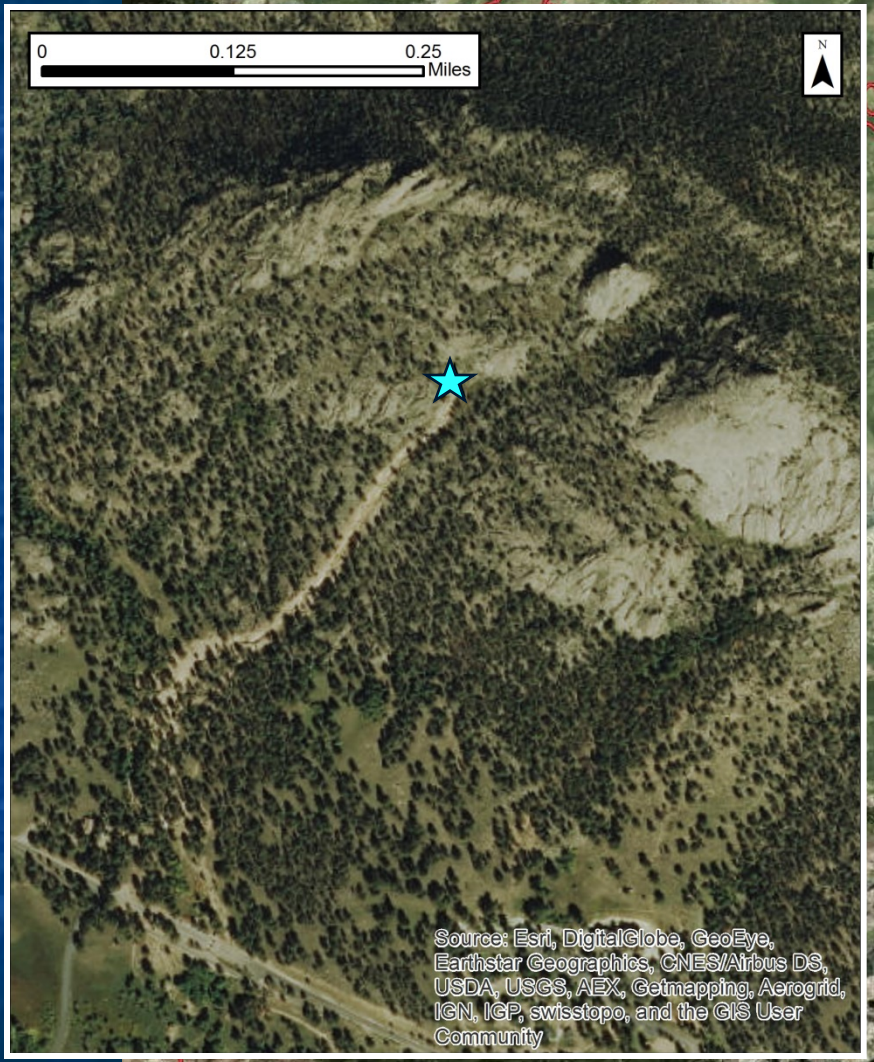
(Patton Research Proposal, 2015)

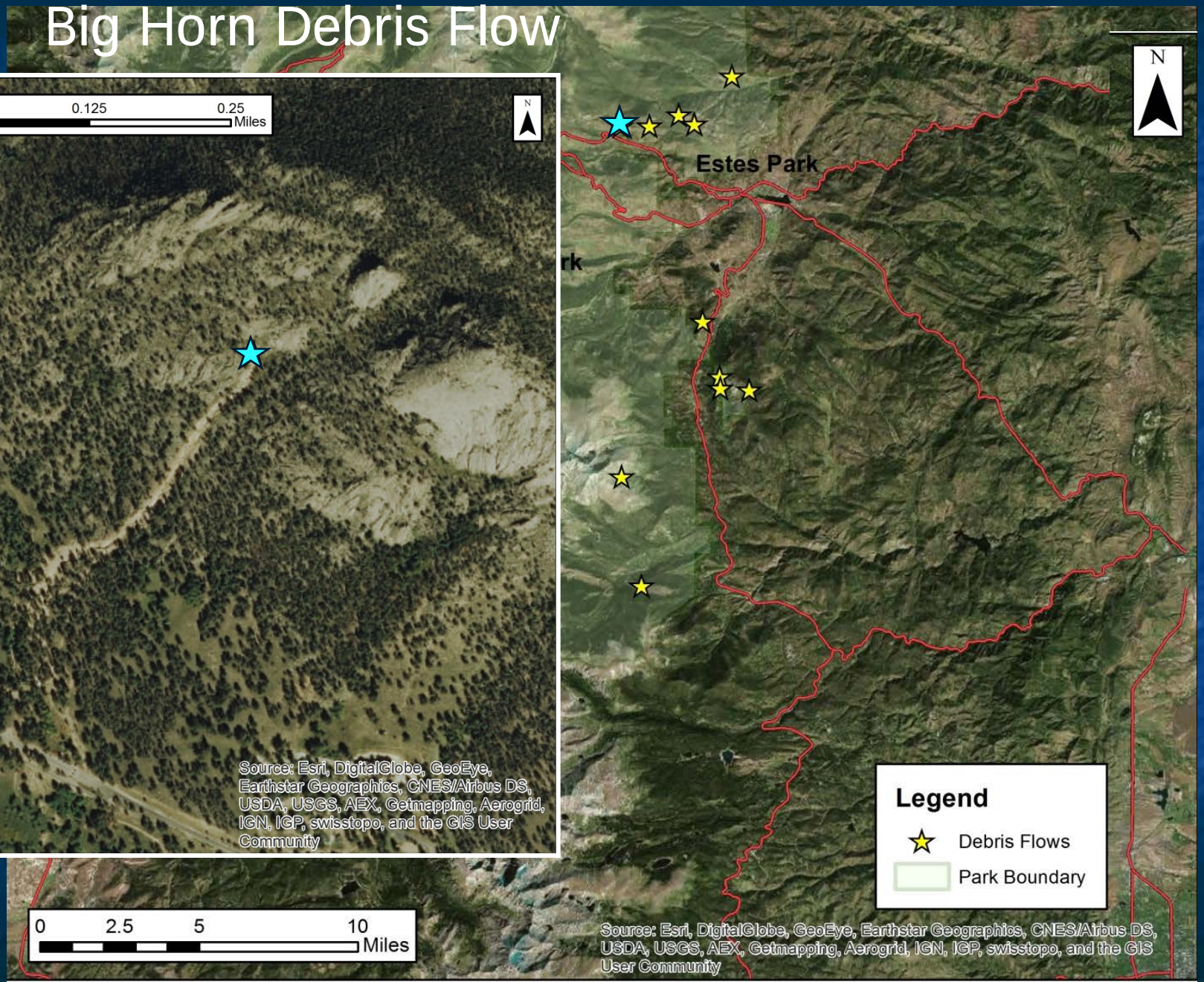
Occurrence in Rocky

- Map debris flow deposits
  - Estimate volumes
  - Delineate zones of erosion and deposition
  - Quantify site specific geomorphic controls
    - Soil texture, soil depth, vegetation cover
- ArcGIS for slope characteristics, failed and reference
  - Contributing area
  - Slope aspect
  - Slope convergence
  - Degree of channelization

Occurrence in Rocky

Big Horn Debris Flow



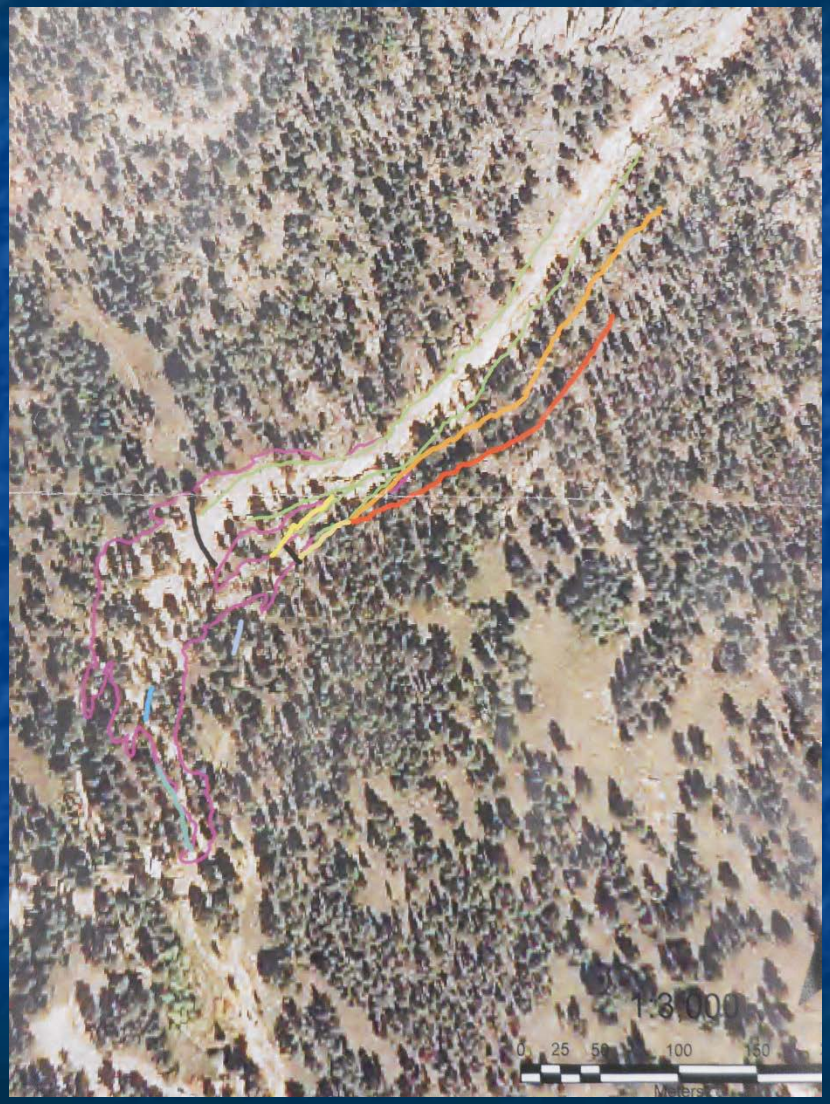


Big Horn Debris Flow

Occurrence in Rocky

- Historic Ranger Station
- Evidence of multiple debris flows
- Develop a debris flow chronology
  - Stratigraphic relationships
  - Scarred trees
  - ^{14}C samples within deposits
  - ^{10}Be of debris flow boulders

Stratigraphic Relationships



(From Eric Bilderback)

Map extent of levees

Boulder clusters in berms
Lichen growth and weathering

Stratigraphic Relationships

Debris fan trench, Aug. 12, 2015

Occurrence in Rocky

DF1

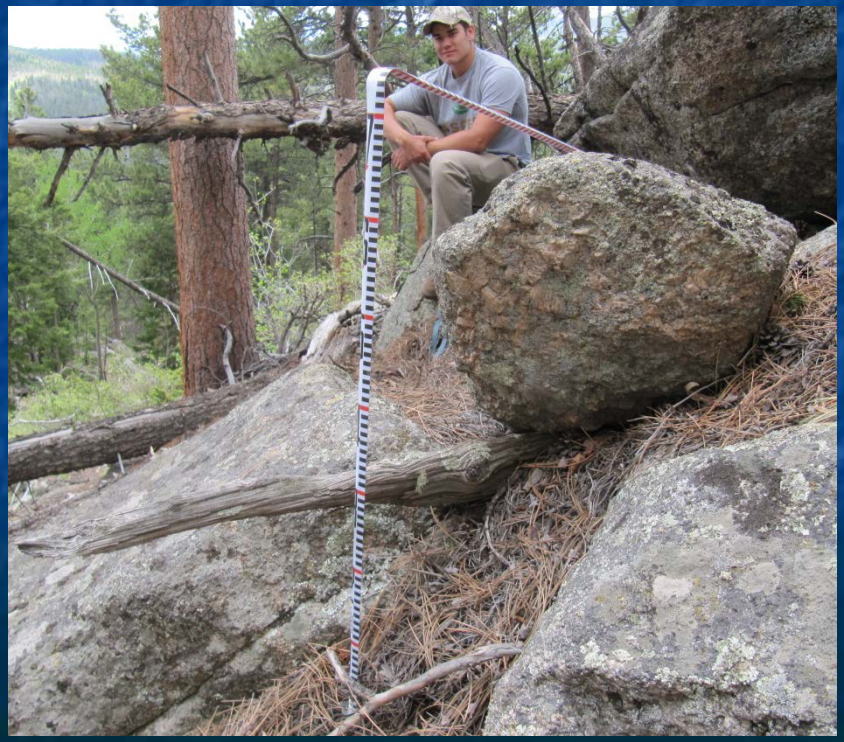
DF2

^{14}C

DF3

Scarred tree and ^{14}C

Occurrence in Rocky



^{10}Be in boulders

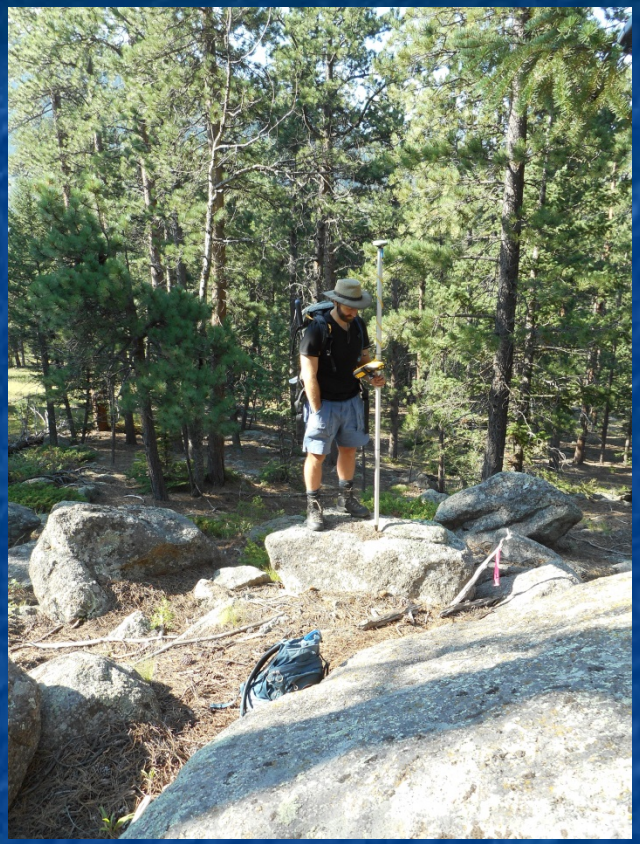
In-situ ^{10}Be cosmogenic radionuclide in quartz

Cosmic rays interact with Earth's surface and produce ^{10}Be

Production of ^{10}Be occurs within few meters of surface

^{10}Be in boulders

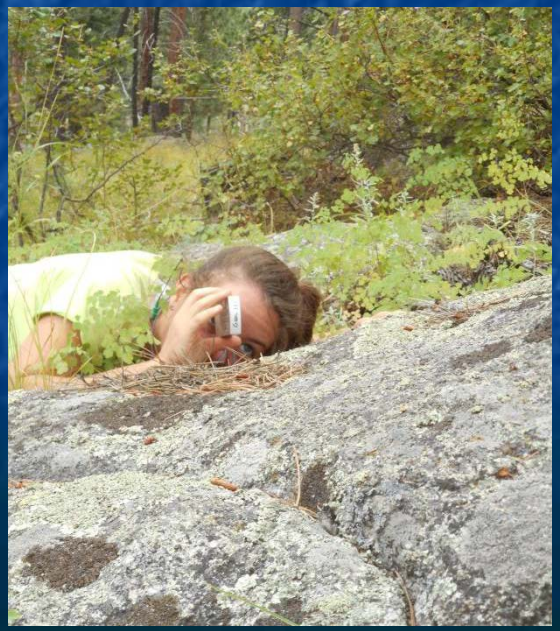
Occurrence in Rocky



Concentration reflects near surface residence time

Expect low ^{10}Be in younger than several 1000 years

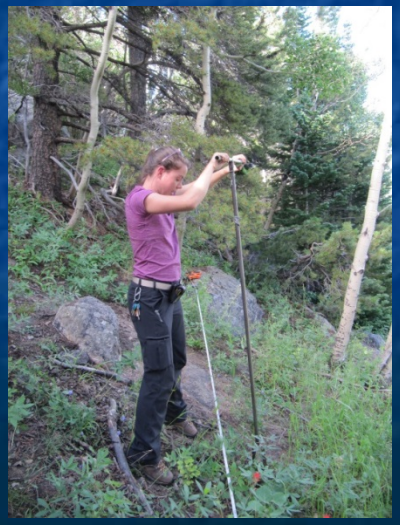
Tricky with inheritance



Preliminary Findings

- Most debris flows originate in colluvial hollows
- Soil texture is sand and coarser, few fines
- Channelized debris flows more common

- Big Horn has evidence of 5-6 different debris flows
- One buried layer dates to 580 yr BP
- Stay tuned!



Questions?

References

Anderson, S., Anderson, S., and Anderson, R., 2015. Exhumation by debris flows in the 2013 Colorado Front Range storm, *Geology*, doi:10.1120/G36507.1

Coe, J., Kean, J., Godt, J., Baum, R., and Jones, E., 2014. New insights into debris flow hazards from an extraordinary event in the Colorado Front Range, *GSA Today*, v. 24, no. 10 doi:10.1130/GSATG214A.1