Soil landscape controls on biological soil crust distribution, Mojave Desert

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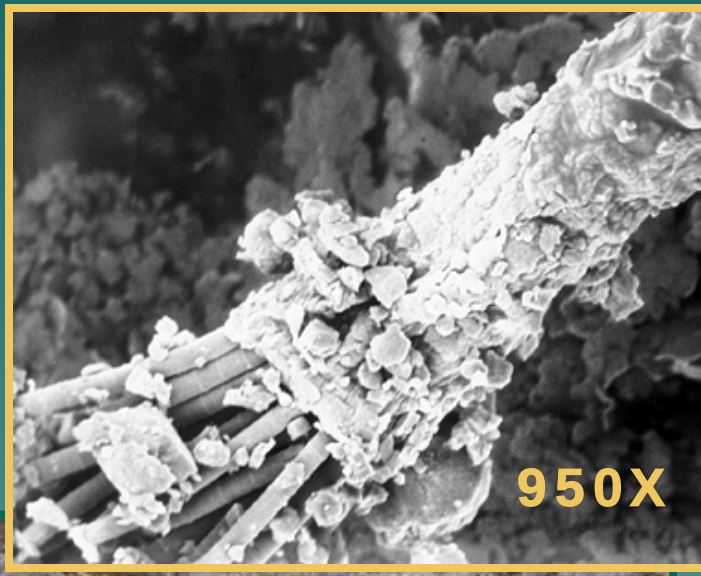
What are biological soil crusts (BSCs)?

- Matrix of:
  - Mosses
  - Lichen
  - Cyanobacteria
- "Desert Skin"
- Cover up to 70% of land

Two Morphologies of BSCs

1. Cyanobacteria Crusts

- **1st** crusts, stabilize soil
- Thread-like cyanobacteria
- Cyanobacteria "move"



Two Morphologies of BSCs in the Mojave Desert:

2. Pinnacled Crusts

- **2nd** crusts to form, on stable soil
- Mosses, lichen, and cyanobacteria

Why are BSCs important?

Ecosystem Engineers

- Stabilize soil
  - Prevent erosion
  - Prevent dust emissions

Why are BSCs important?

- Fix C & N
- Add OM
- Control water

Prevent Desertification

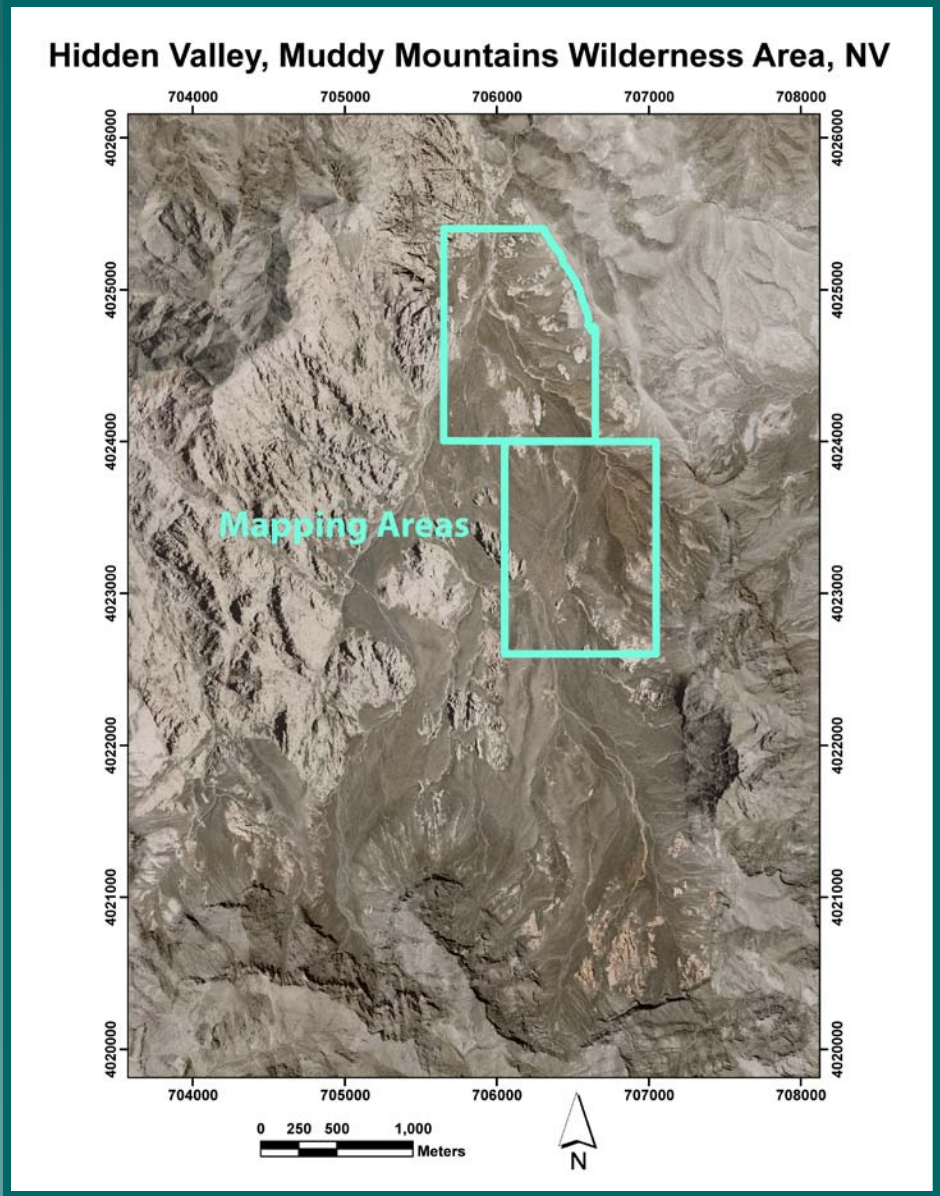
Project Objectives

- Investigate the relationships among geomorphology, soils, and BSCs
- Understand feedback mechanisms controlling co-evolution

Project Outcomes

- Predict BSC growth - land management & restoration
- Role of BSCs in pedogenesis & landscape evolution

Study Area

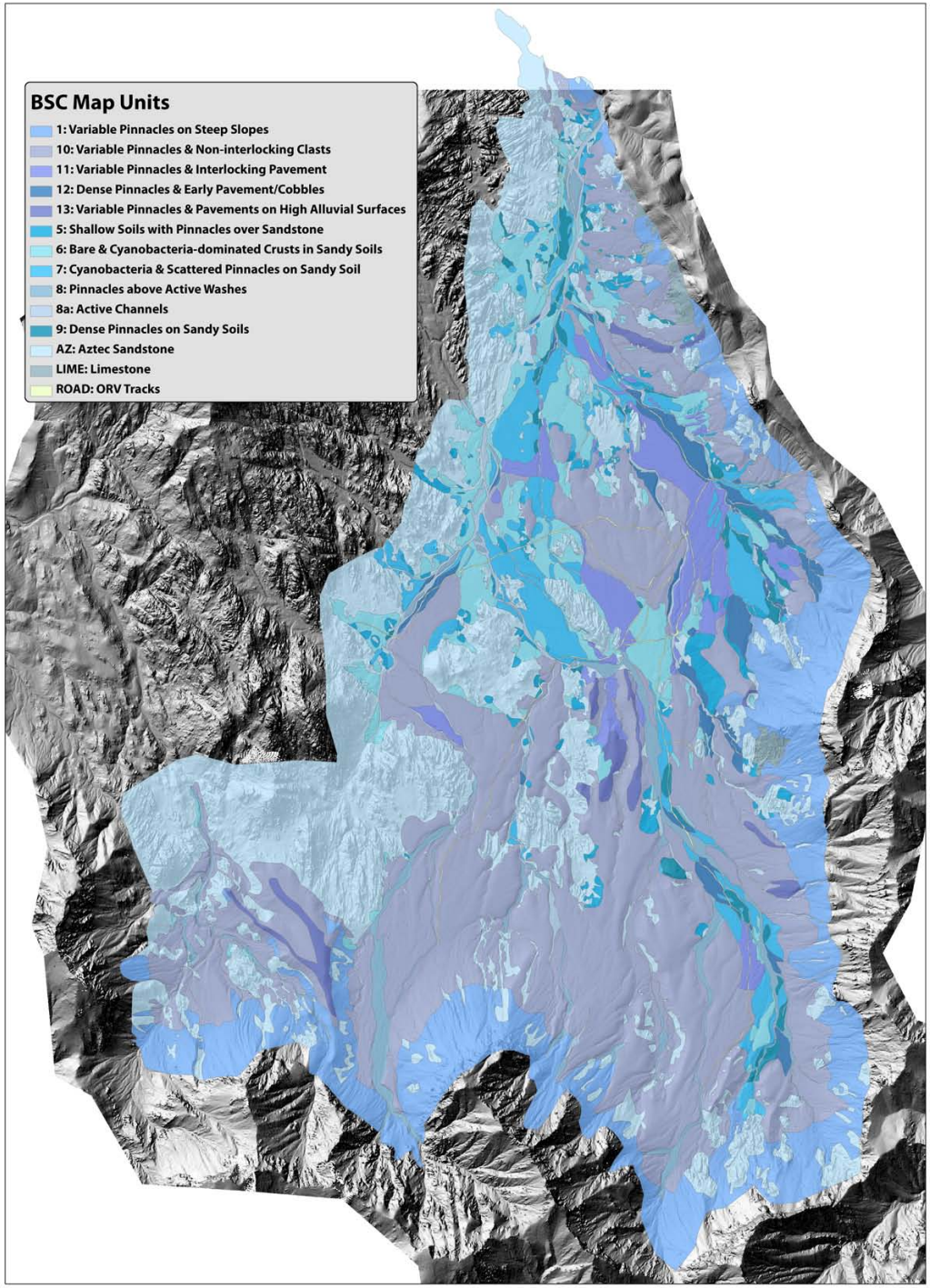


- Pristine Valley
- Limestone & sandstone
- Thermic, Aridic

Methods

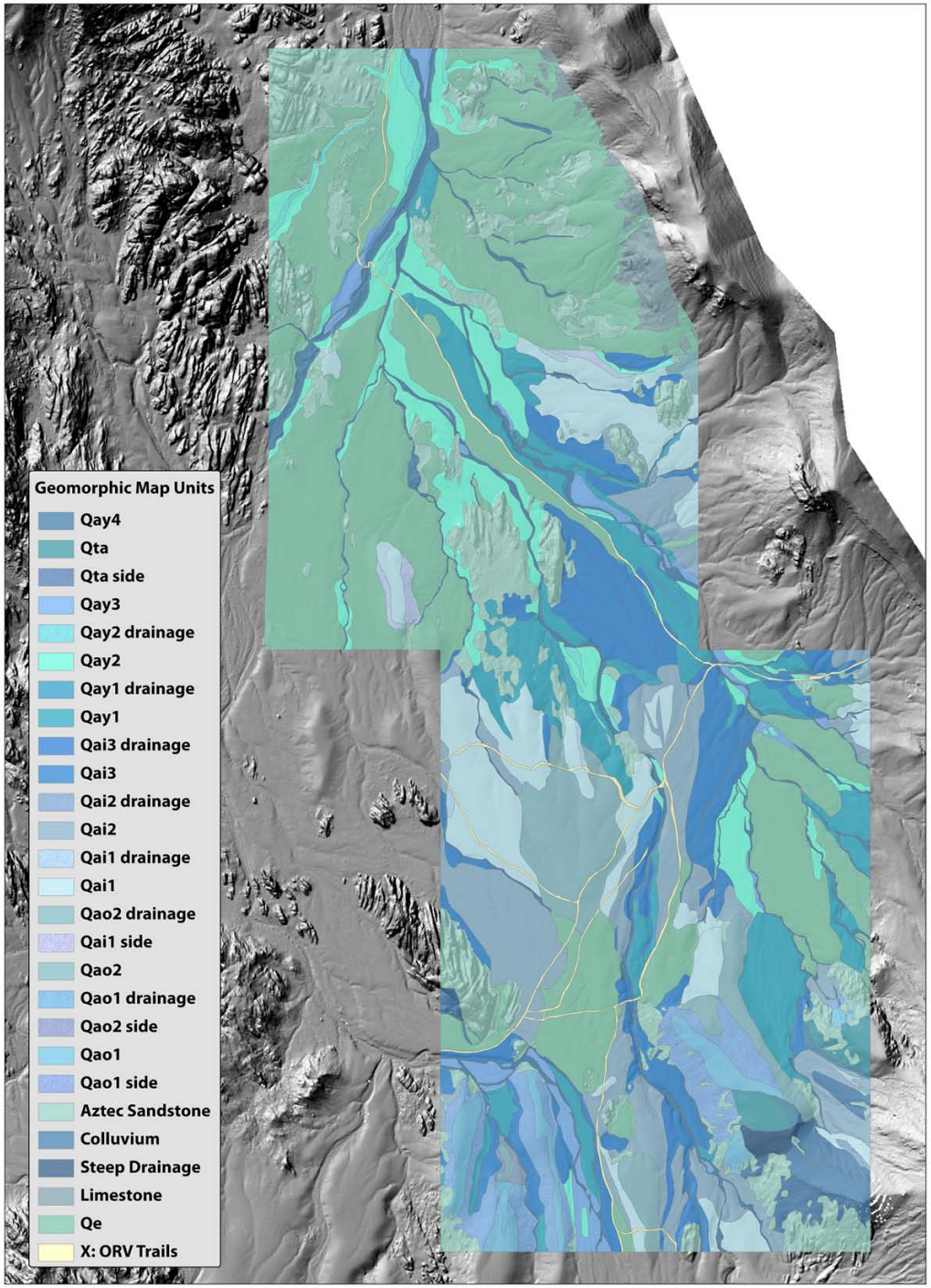
BSC Mapping

- BSC Composition
- Surface Morphology
- 10 Map Units



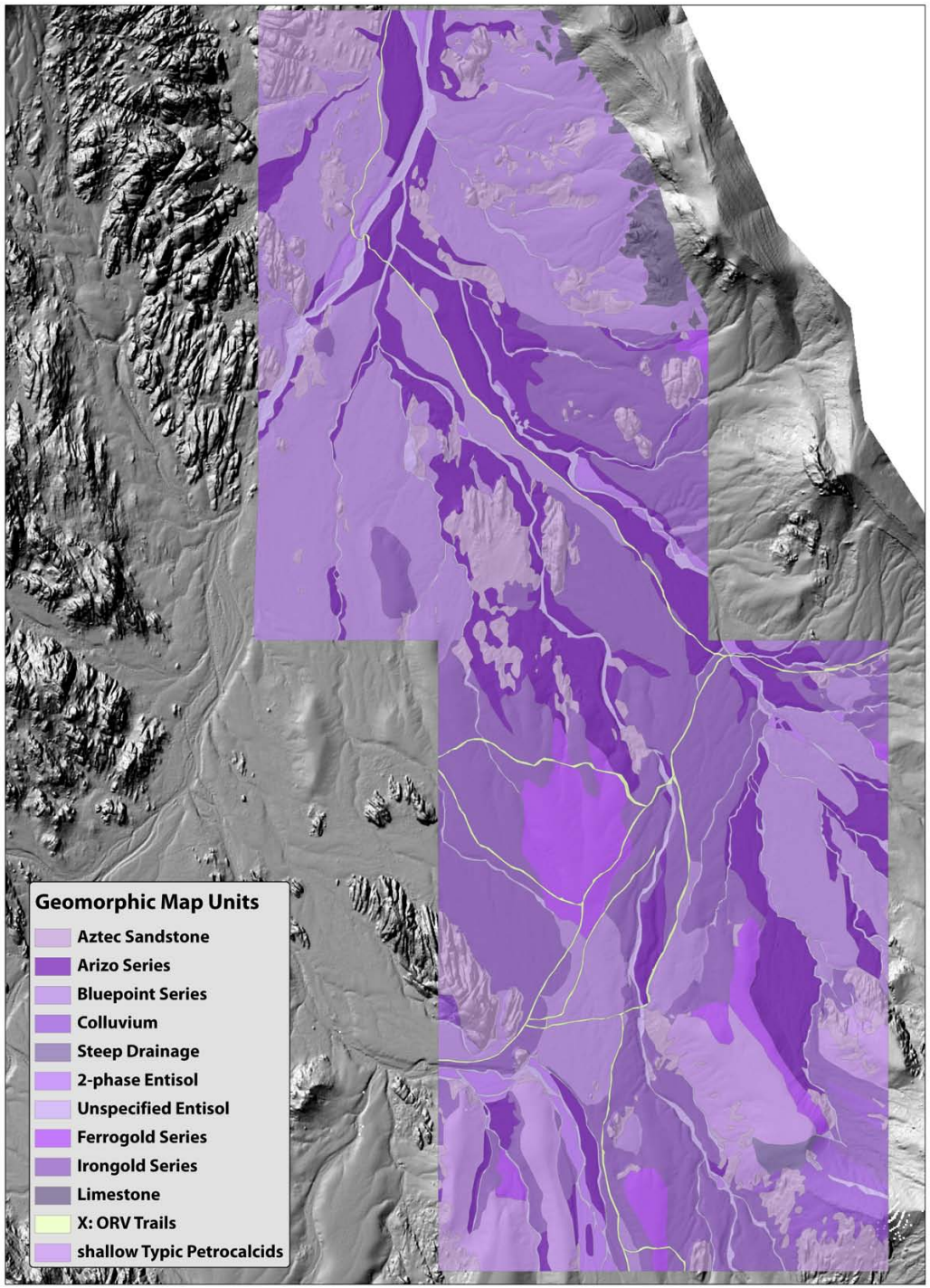
Geomorphic Mapping

- 11 Surfaces
- Alluvium & Sand Sheets
- Late Miocene (earliest Pleistocene?)
- Recent Holocene



Soil Mapping

- Correlated 4 Official Soil Series
- 3 uncorrelated units



Characterization

36 Plots (Soils/BSCs)
14 Soil Profiles

- BSCs
- Vascular Plants
- Surface Clasts
- Soil Cover
- Topography
- Sampled/Analyzed Soils
- Soil Profile Descriptions

Analyses

- GIS Overlays
- ANOVA (Parametric & Non-Parametric)
- MRPP (Multi-Response Permutation Procedure)
- Correlation Coefficients (Parametric & Non-Parametric)

Results

GIS OVERLAYS

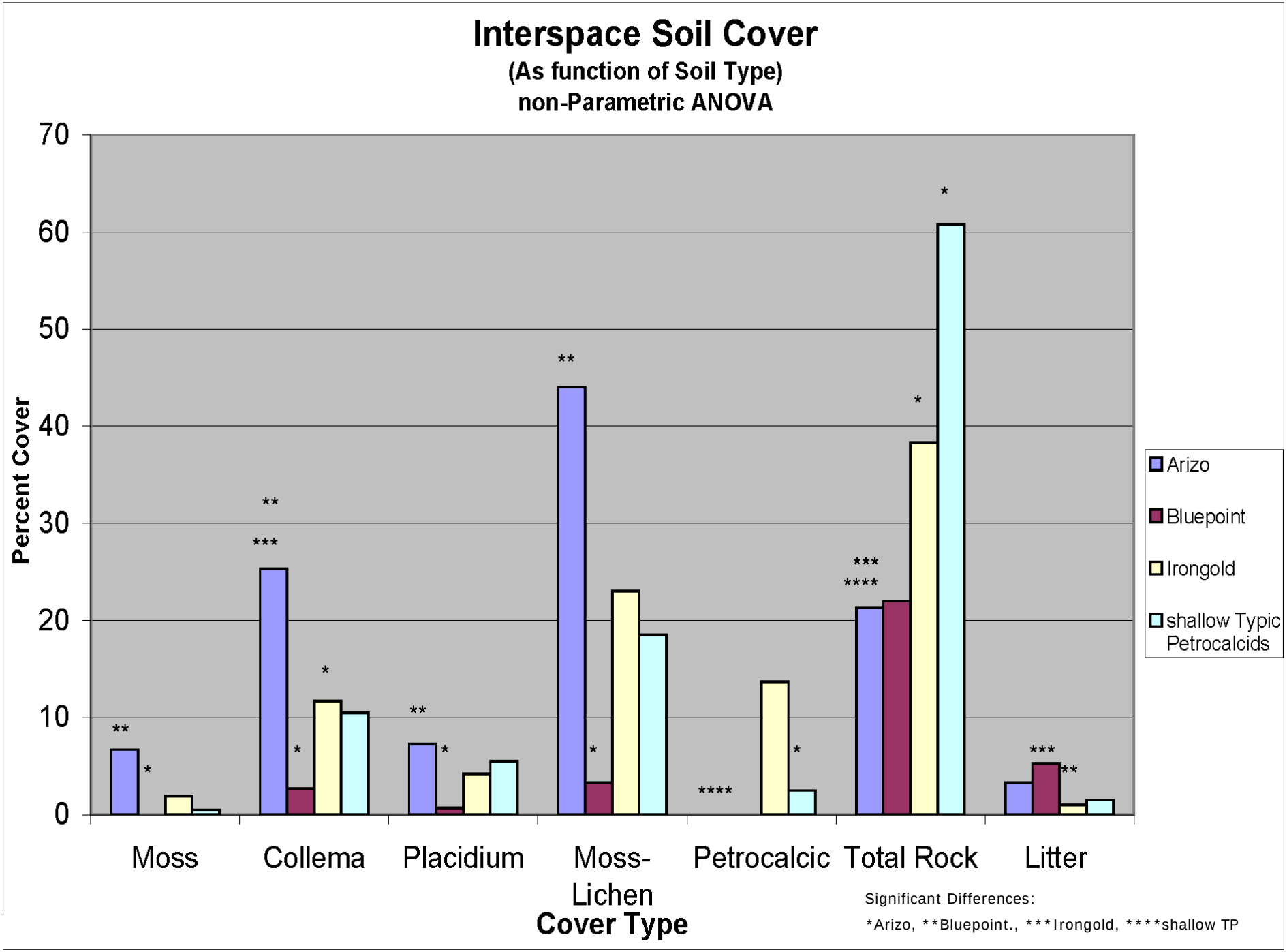
Crust Cover	**Dominant Soil** (% Overlap)	**Dominant Geomorphic Surface** (% Overlap)
Cyanobacteria Crust BSC Map Unit 6	Bluepoint (66%) *Deep sand sheets*	Qe (66%) *Deep sand sheets*
Moss-Lichen Crust BSC Map Units 9 & 12	Arizo (57-59%) *Mid-Holocene Alluvium*	Qay1 & Qay2 (57-59%) *Mid-Holocene Alluvium*
Pavement Surfaces BSC Map Units 10, 11 & 13	Irongold, Ferrogold, & Shallow TP (63-87%) *Alluvium (> Mid-Holocene)*	Qai3 and Older (63-87%) *Alluvium (> Mid-Holocene)*

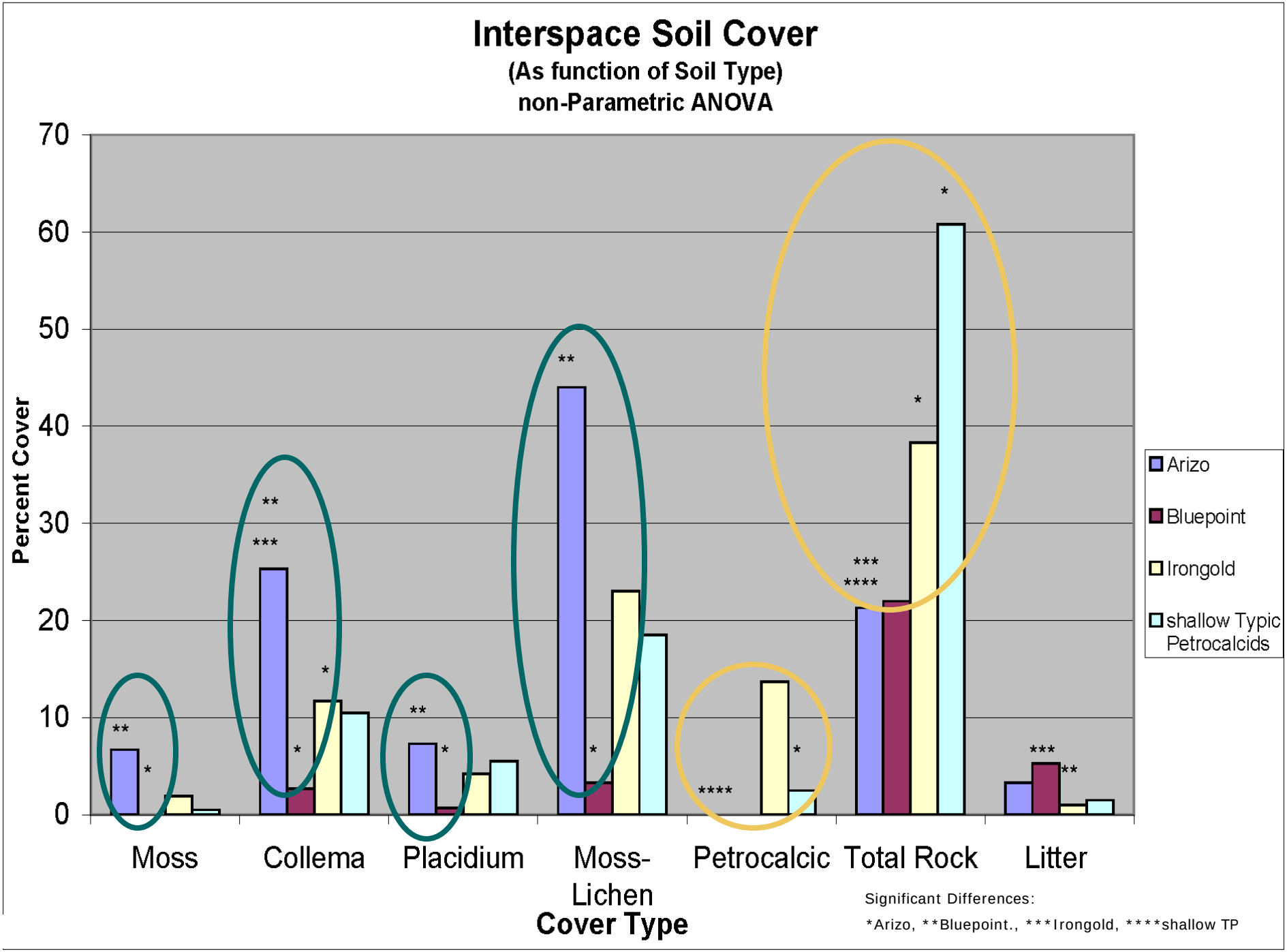
MRPP

Significance of Map Units

Mapping Units	MRPP Association Values	MRPP Significance
BSC Map Units	A=0.52	p=0.00000000
Soil Map Units	A=0.29	p=0.00000875
Geomorphic Map Units	A=0.35	p=0.00000657

A>0.3 are high values for ecological data sets (McCune and Grace, 2002)


Interspace Soil Cover
(As function of Soil Type)
non-Parametric ANOVA
Percent Cover
70
60
50
40
30
20
10
0
Moss
Collema
Placidium
Moss-Lichen
Petrocalcic
Total Rock
Litter
Cover Type
Arizo
Bluepoint
Irongold
shallow Typic Petrocalcids
Significant Differences:
*Arizo, **Bluepoint., ***Irongold, ****shallow TP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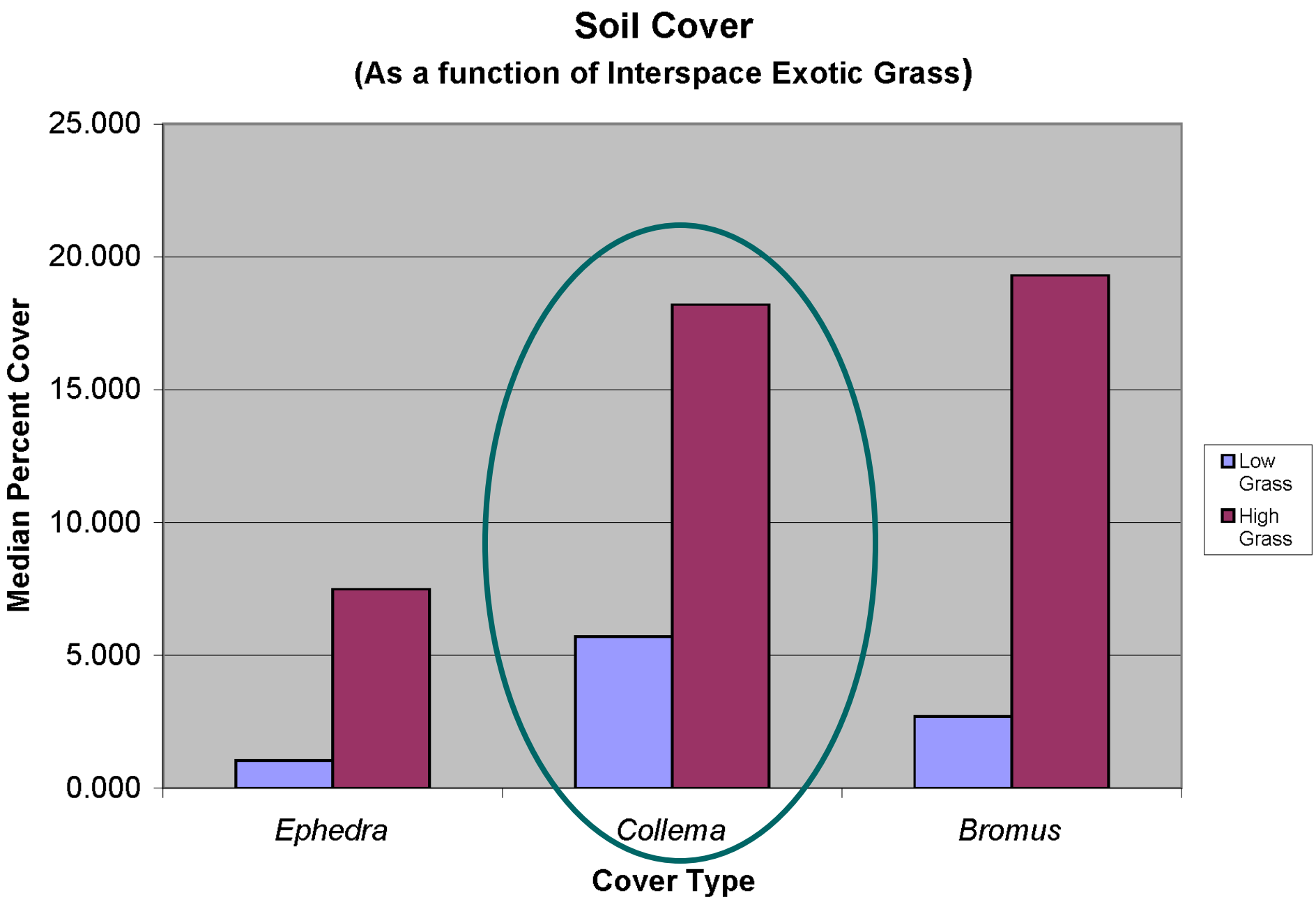
Total Rock
Litter
Cover Type
Arizo
Bluepoint
Irongold
shallow Typic Petrocalcids
Significant Differences:
*Arizo, **Bluepoint., ***Irongold, ****shallow TP

Soil Cover
(As a function of Interspace Exotic Grass)
Median Percent Cover
25.000
20.000
15.000
10.000
5.000
0.000
Ephedra
Collema
Bromus
Cover Type
Low Grass
High Grass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5.000
0.000
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Collema
Bromus
Cover Type
Low Grass
High Grass

Soil-Geomorphology & BSCs

Cyanobacteria Crusts

- Active sand sheets
- Sandy particle size control section
- Low dust capture
- "Bluepoint"

Soil-Geomorphology & BSCs

Pavement-Dominated Surfaces

- Smooth, high rock cover
- Pleistocene+
- Loamy or Loamy-skeletal
- "Irongold" "Ferrogold" "shallow Typic Petrocalcids"

Soil-Geomorphology & BSCs

Moss-Lichen Crusts

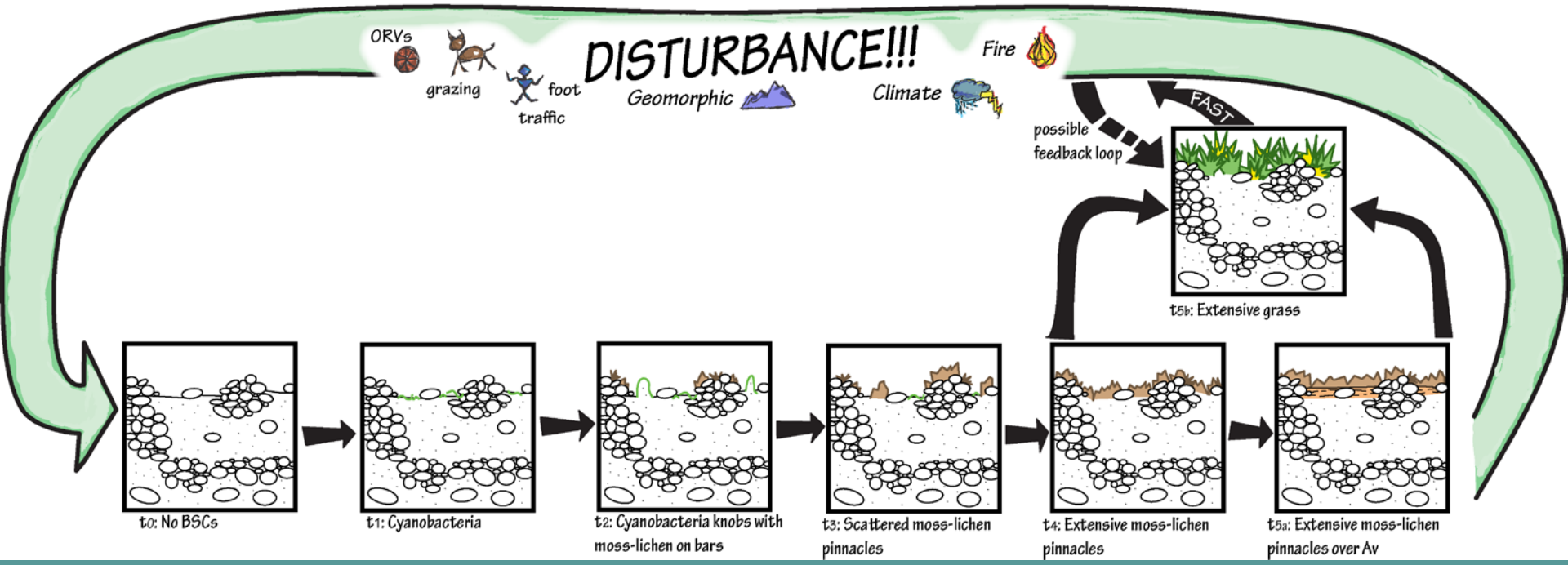
- Rough, stable surfaces
- High dust capture
- Mid-Holocene
- Sandy-skeletal
- Thin Av
- “Arizo”

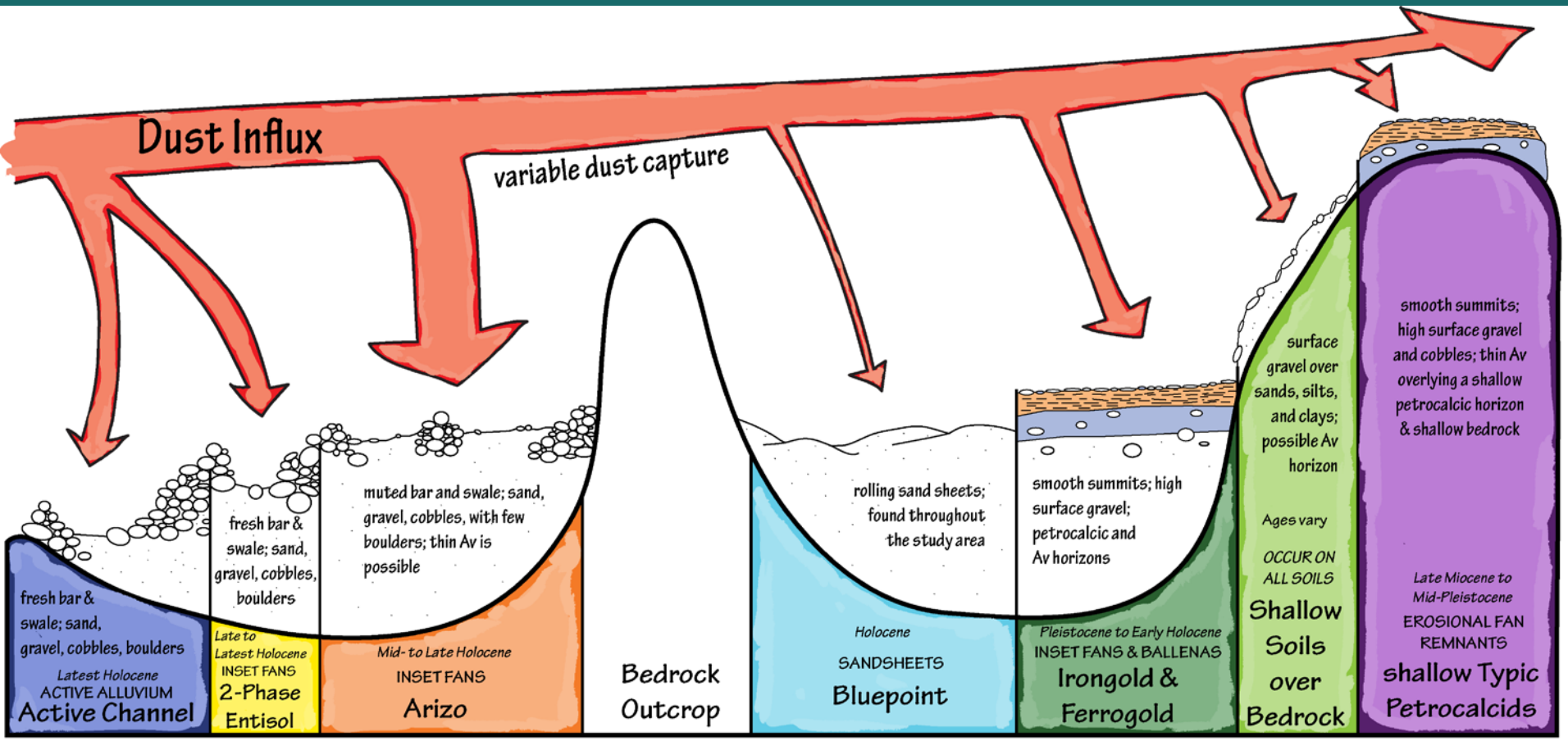
Dust Accretion

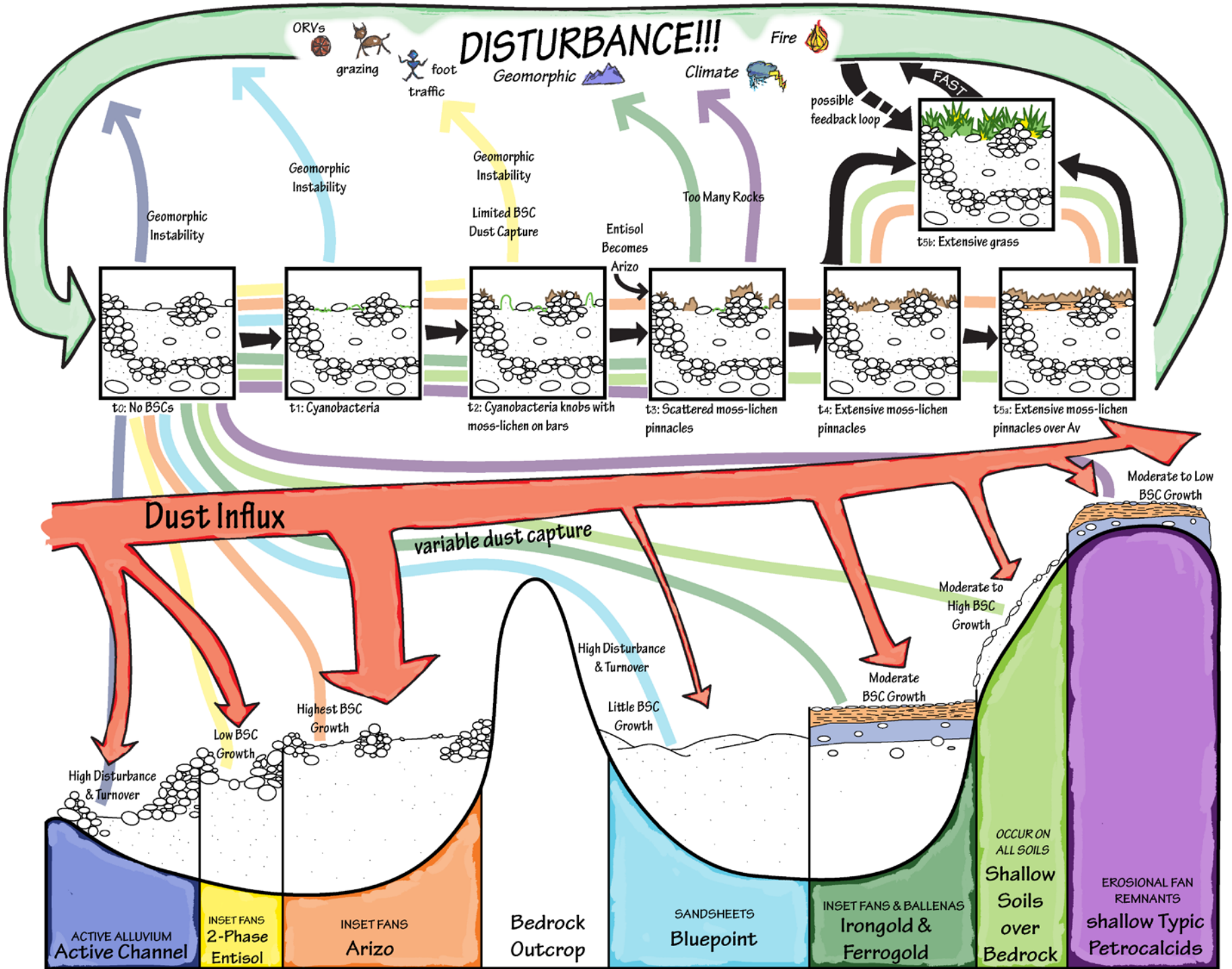
- Greatest on roughest surfaces
- Water, Nutrients, Surface Area

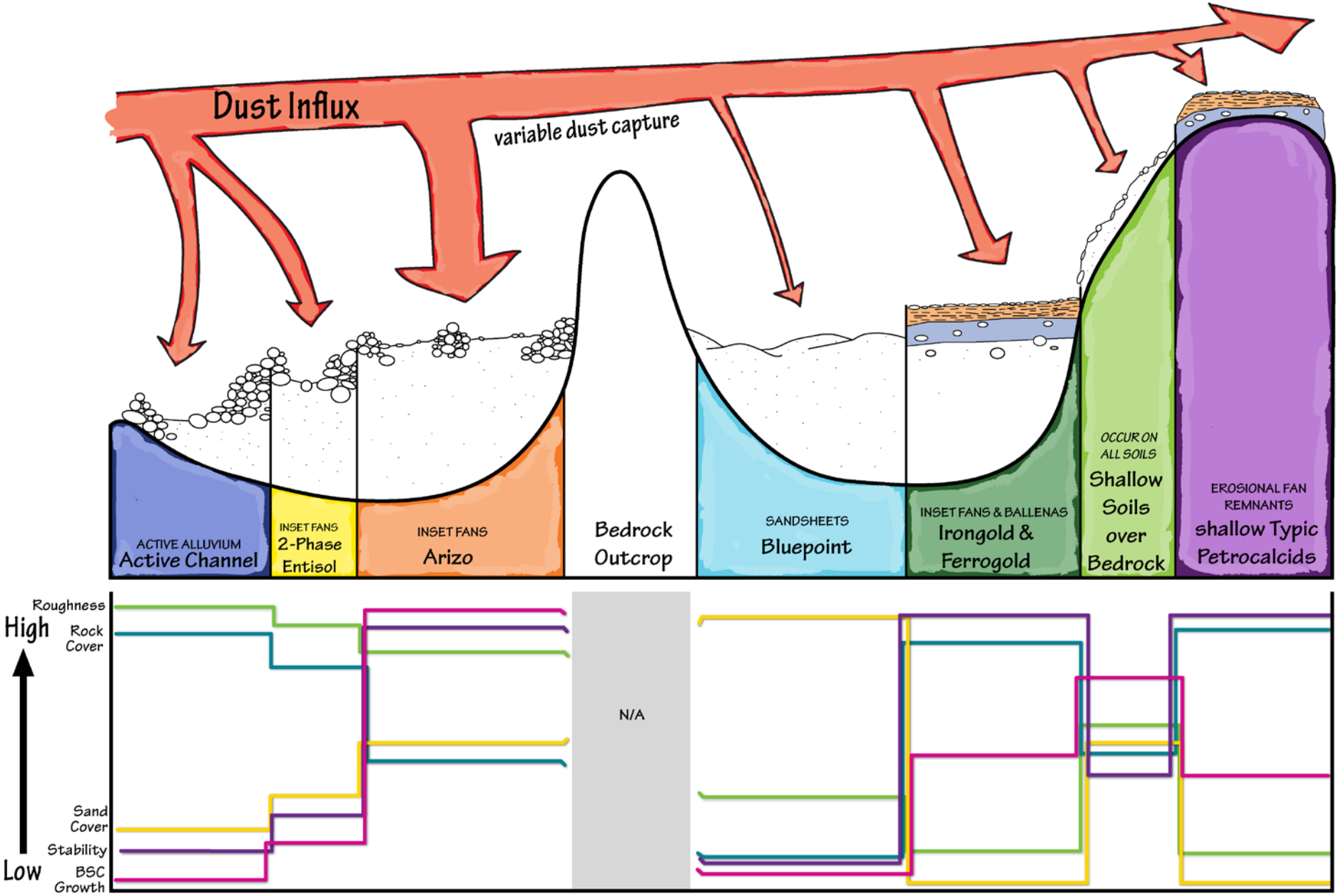
...BSCs also accrete dust

Conceptual Model

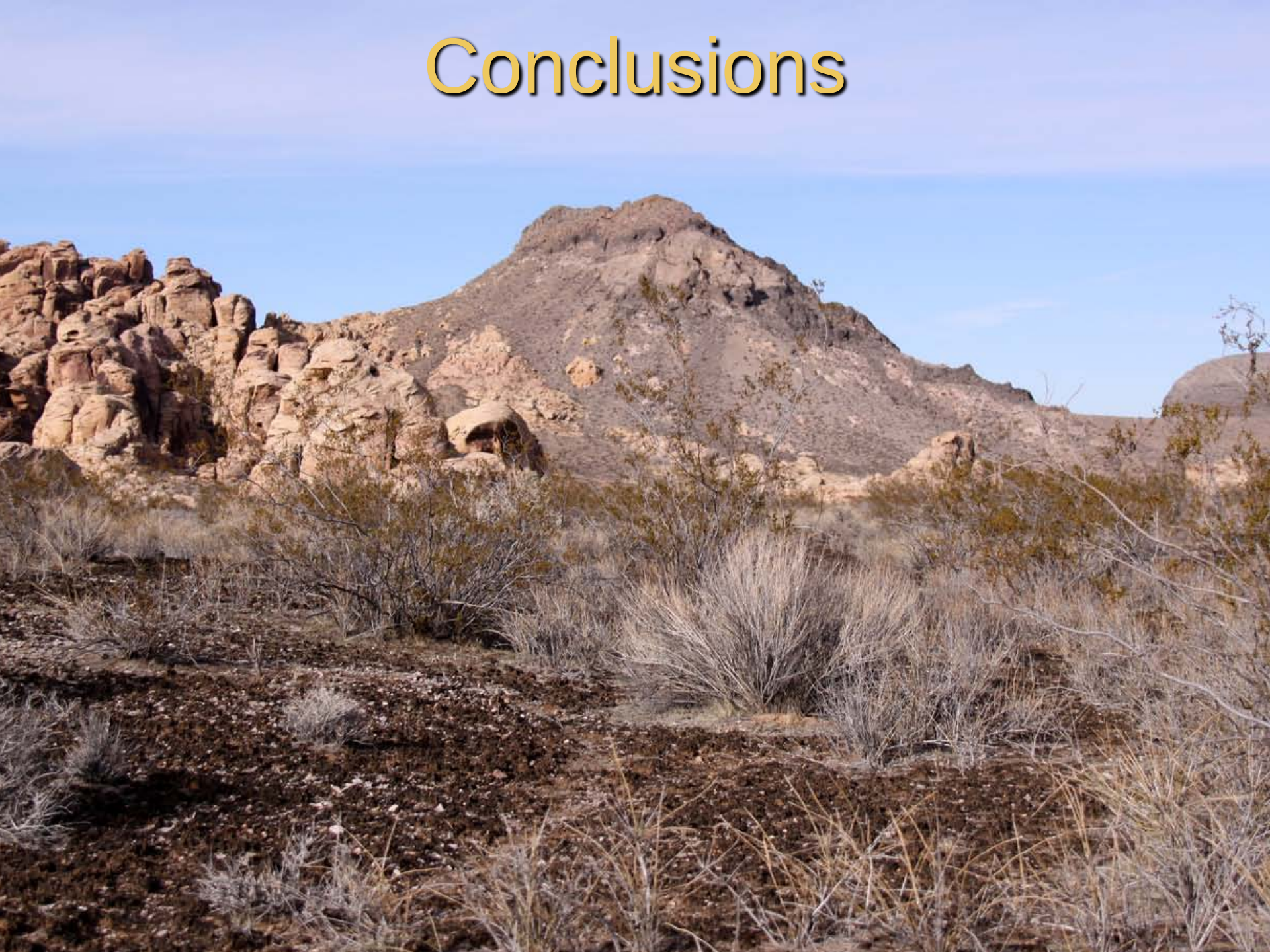

DISTURBANCE!!!
ORVs
grazing
foot
traffic
Geomorphic
Climate
Fire
FAST
possible
feedback loop
t5b: Extensive grass
t0: No BSCs
t1: Cyanobacteria
t2: Cyanobacteria knobs with
moss-lichen on bars
t3: Scattered moss-lichen
pinnacles
t4: Extensive moss-lichen
pinnacles
t5a: Extensive moss-lichen
pinnacles over Av


Dust Influx
variable dust capture
fresh bar & swale; sand, gravel, cobbles, boulders
Latest Holocene
ACTIVE ALLUVIUM
Active Channel
fresh bar & swale; sand, gravel, cobbles, boulders
Late to Latest Holocene
INSET FANS
2-Phase Entisol
muted bar and swale; sand, gravel, cobbles, with few boulders; thin Av is possible
Mid- to Late Holocene
INSET FANS
Arizo
Bedrock Outcrop
rolling sand sheets; found throughout the study area
Holocene
SANDSHEETS
Bluepoint
smooth summits; high surface gravel; petrocalcic and Av horizons
Pleistocene to Early Holocene
INSET FANS & BALLENAS
Irongold & Ferrogold
surface gravel over sands, silts, and clays; possible Av horizon
Ages vary
OCCUR ON ALL SOILS
Shallow Soils over Bedrock
smooth summits; high surface gravel and cobbles; thin Av overlying a shallow petrocalcic horizon & shallow bedrock
Late Miocene to Mid-Pleistocene
EROSIONAL FAN REMNANTS
shallow Typic Petrocalcids


DISTURBANCE!!!
ORVs
grazing
foot traffic
Geomorphic
Climate
Fire
FAST
possible feedback loop
Geomorphic Instability
Geomorphic Instability
Geomorphic Instability
Limited BSC Dust Capture
Entisol Becomes Arizo
Too Many Rocks
t0: No BSCs
t1: Cyanobacteria
t2: Cyanobacteria knobs with moss-lichen on bars
t3: Scattered moss-lichen pinnacles
t4: Extensive moss-lichen pinnacles
t5a: Extensive moss-lichen pinnacles over Av
t5b: Extensive grass
Dust Influx
variable dust capture
Moderate to Low BSC Growth
Moderate to High BSC Growth
Moderate BSC Growth
High Disturbance & Turnover
Little BSC Growth
Highest BSC Growth
Low BSC Growth
High Disturbance & Turnover
ACTIVE ALLUVIUM
Active Channel
INSET FANS
2-Phase Entisol
INSET FANS
Arizo
Bedrock Outcrop
SANDSHEETS
Bluepoint
INSET FANS & BALLENAS
Irongold & Ferrogold
OCCUR ON ALL SOILS
Shallow Soils over Bedrock
EROSIONAL FAN REMNANTS
shallow Typic Petrocalcids


Dust Influx
variable dust capture
ACTIVE ALLUVIUM
Active Channel
INSET FANS
2-Phase
Entisol
INSET FANS
Arizo
Bedrock
Outcrop
SANDSHEETS
Bluepoint
INSET FANS & BALLENAS
Irongold &
Ferrogold
OCCUR ON
ALL SOILS
Shallow
Soils
over
Bedrock
EROSIONAL FAN
REMNANTS
shallow Typic
Petrocalcids
Roughness
High
Rock
Cover
Sand
Cover
Stability
Low
BSC
Growth
N/A

Conclusions



Conclusions

- Soil-geomorphic template (Monger and Bestelmeyer, 2006)
  - Stability/Disturbance
  - Surface roughness
  - Texture
- Moss-lichen crusts
  - Stable, sandy surfaces
  - Sandy-skeletal
  - High surface roughness (dust capture)
  - Arizo Soil Series (Mid-Holocene)
- Ratio of fine sand to rocks vs. geomorphic trajectories
- Integrate into arid landscape models

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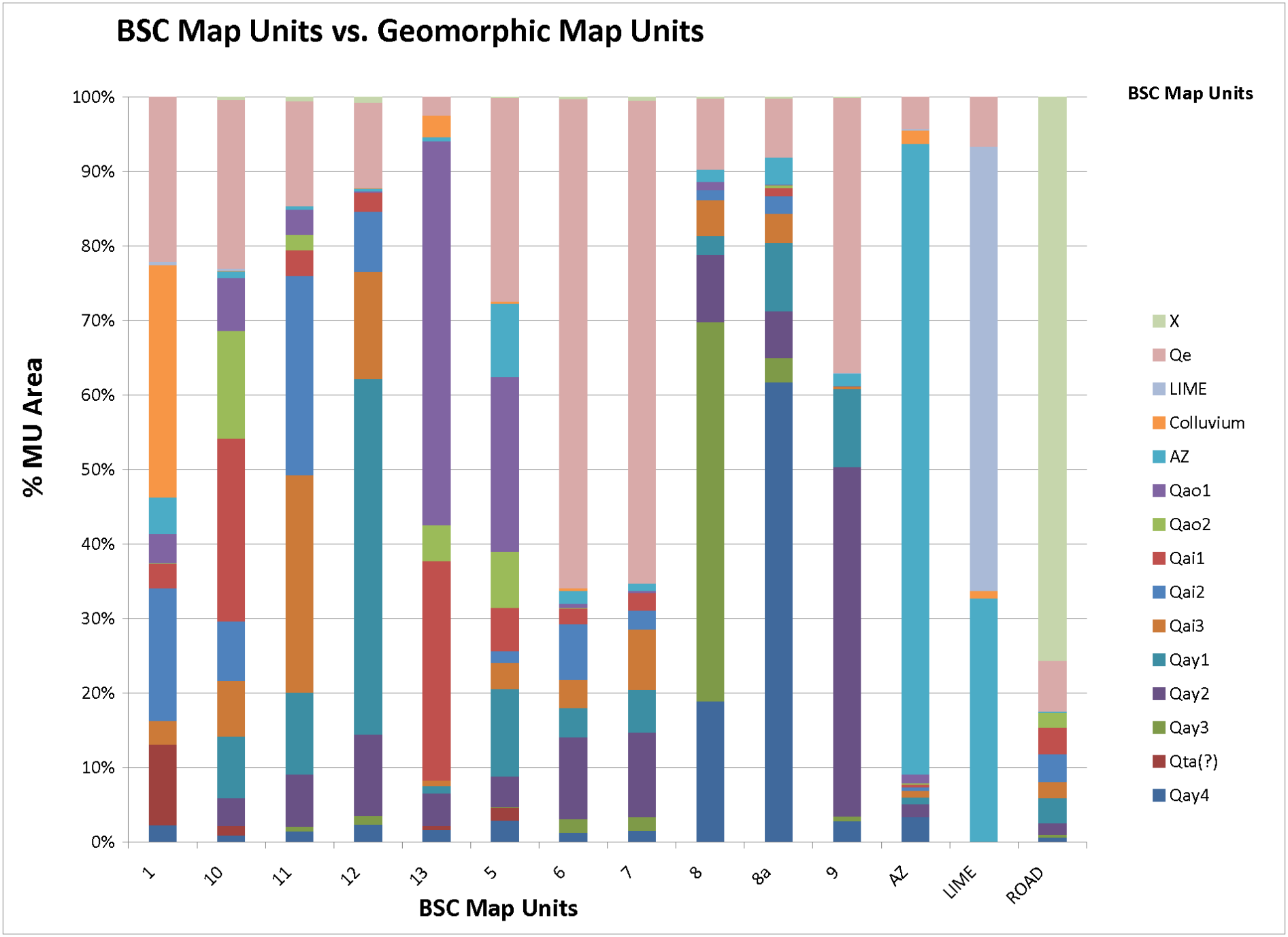
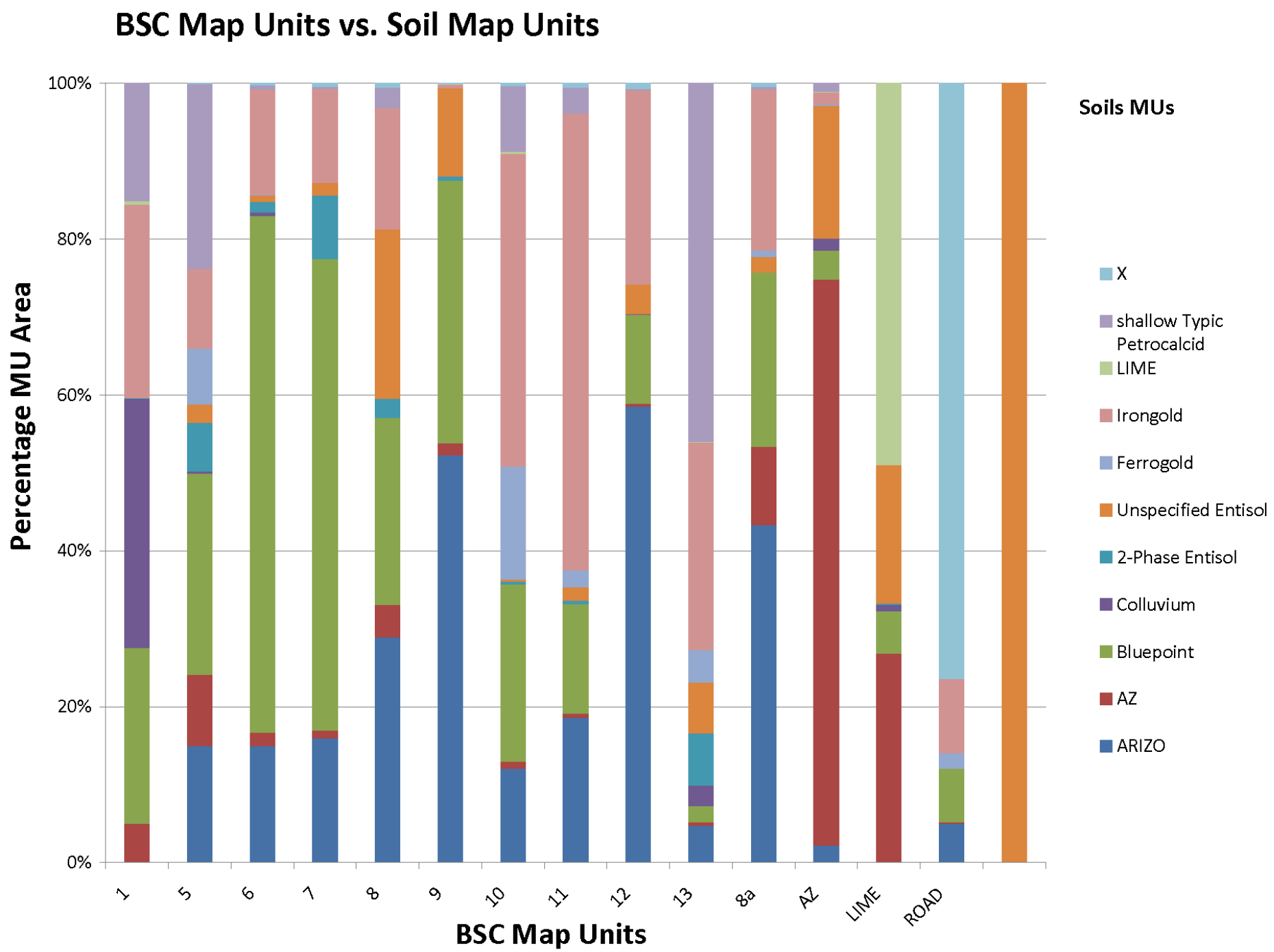
Questions?


BSC Map Units vs. Geomorphic Map Units
% MU Area
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
10
11
12
13
5
6
7
8
8a
9
AZ
LIME
ROAD
BSC Map Units
BSC Map Units
X
Qe
LIME
Colluvium
AZ
Qao1
Qao2
Qai1
Qai2
Qai3
Qay1
Qay2
Qay3
Qta(?)
Qay4


BSC Map Units vs. Soil Map Units
Percentage MU Area
100%
80%
60%
40%
20%
0%
1
5
6
7
8
9
10
11
12
13
8a
AZ
LIME
ROAD
BSC Map Units
Soils MUs
X
shallow Typic Petrocalcid
LIME
Irongold
Ferrogold
Unspecified Entisol
2-Phase Entisol
Colluvium
Bluepoint
AZ
ARIZO

Interspace Characteristics	% Interspace Cover		
	Cyano-bacteria	Moss & Lichen	Total BSCs
% Limestone	-0.49	-0.47	-0.80
% Rock Cover	-0.57	-0.43	-0.83
% Bare	0.38	-0.39	-0.08

SSS

SSS