Vesicular horizons of the western United States: Hydropedology and recovery from disturbance

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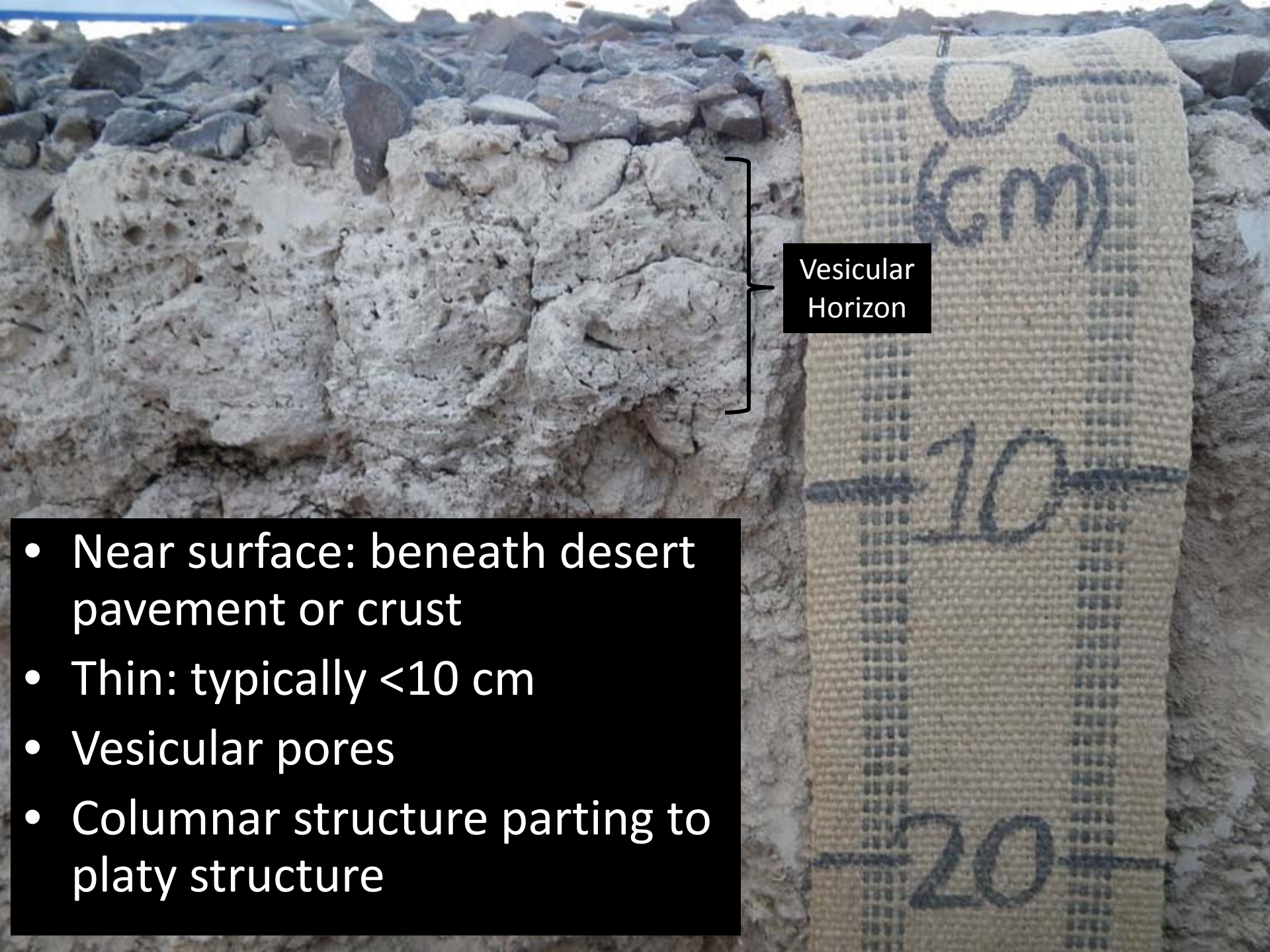
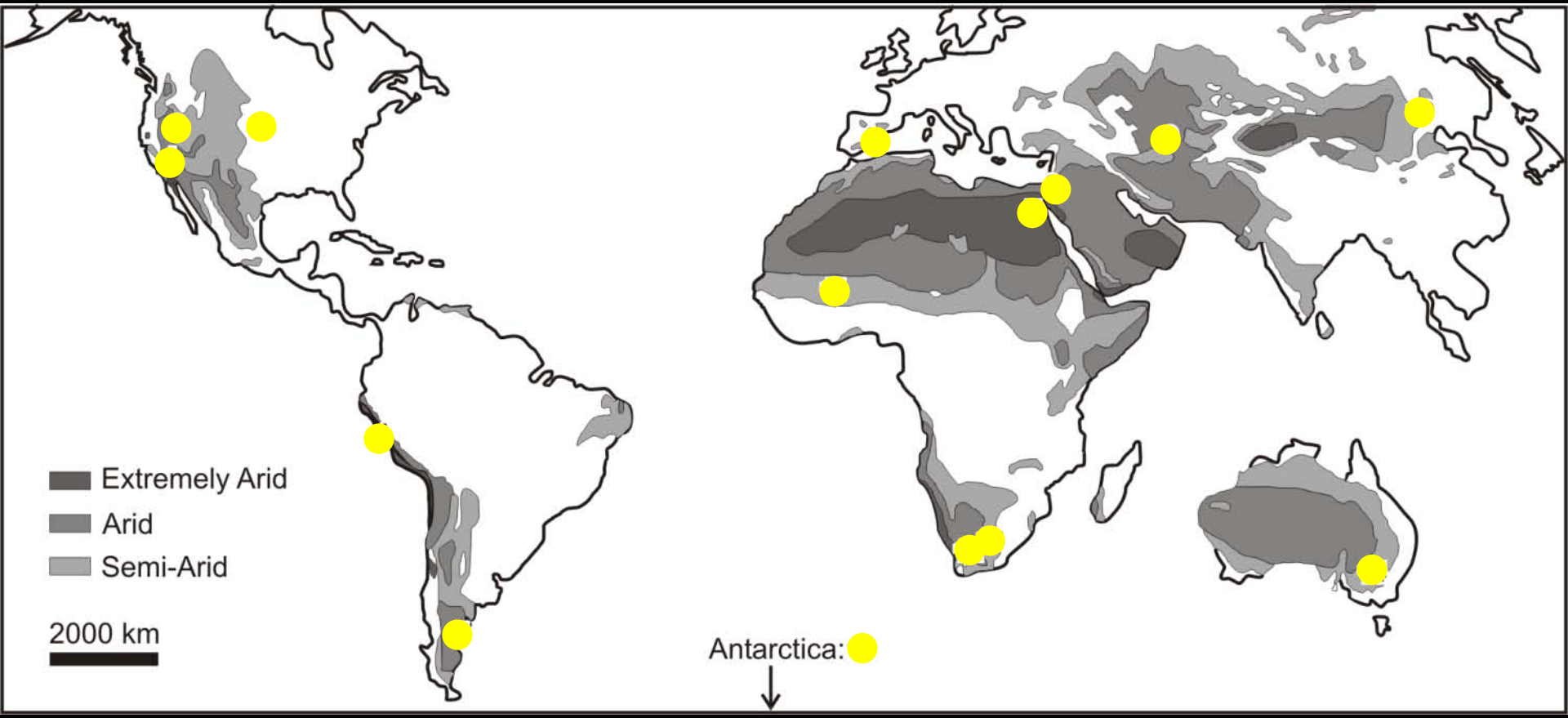
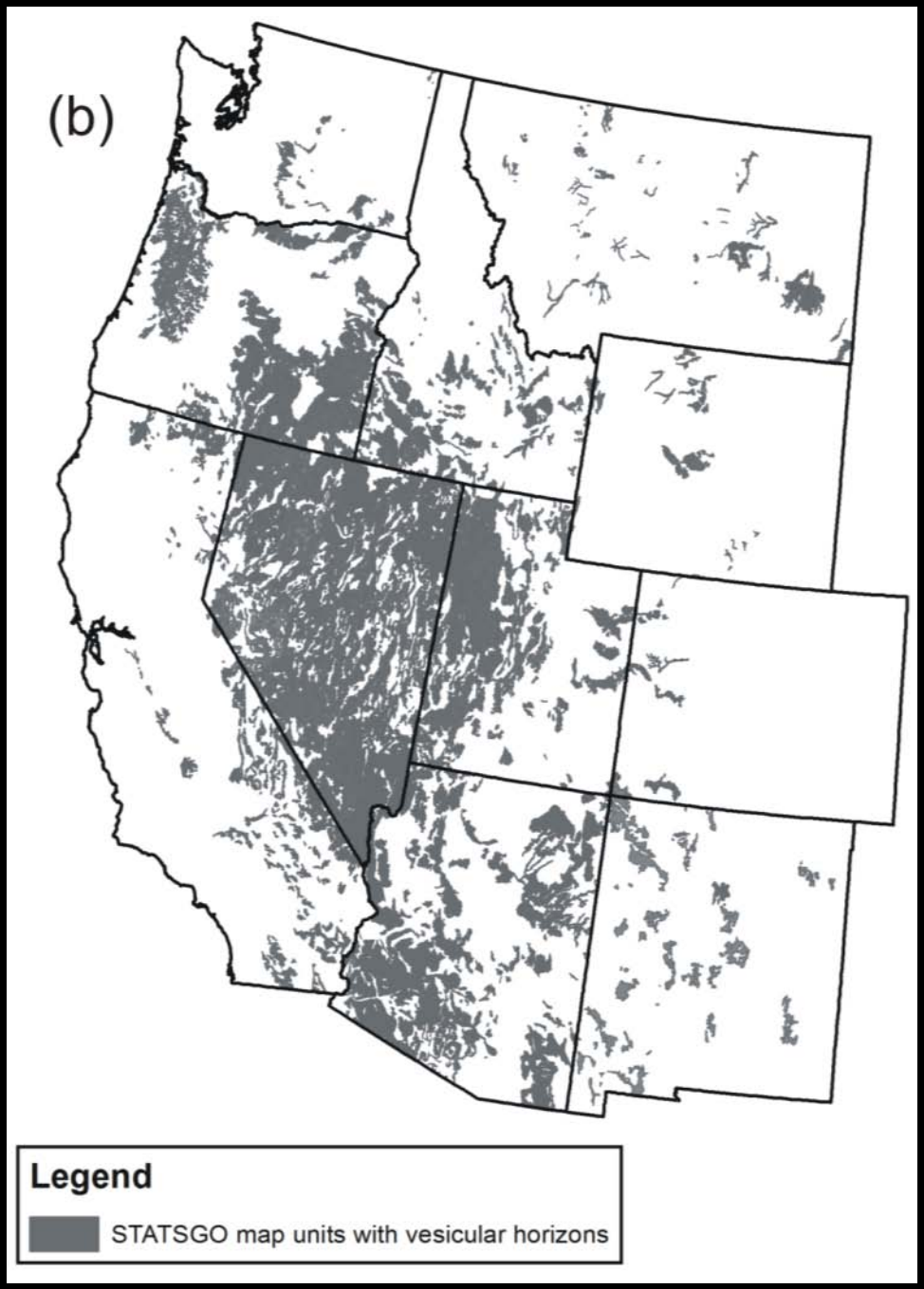


- Near surface: beneath desert pavement or crust
- Thin: typically <10 cm
- Vesicular pores
- Columnar structure parting to platy structure

Occur in arid/semiarid lands around the world



Turk and Graham, *in press*

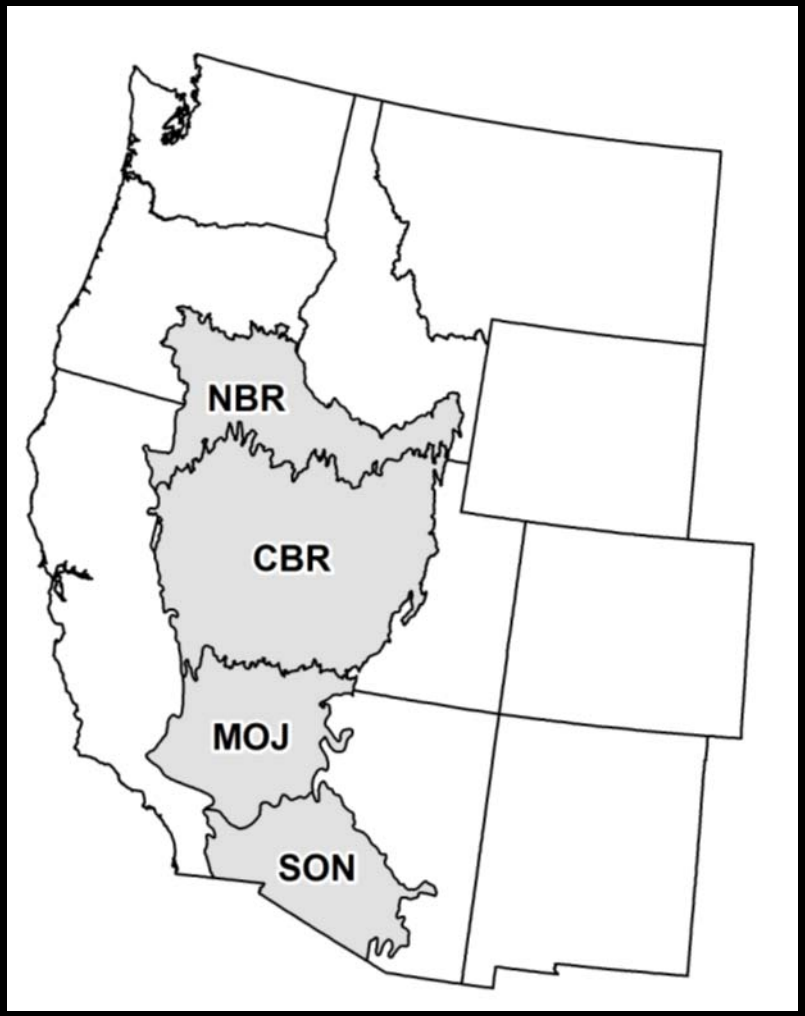


Turk and Graham, *in press*

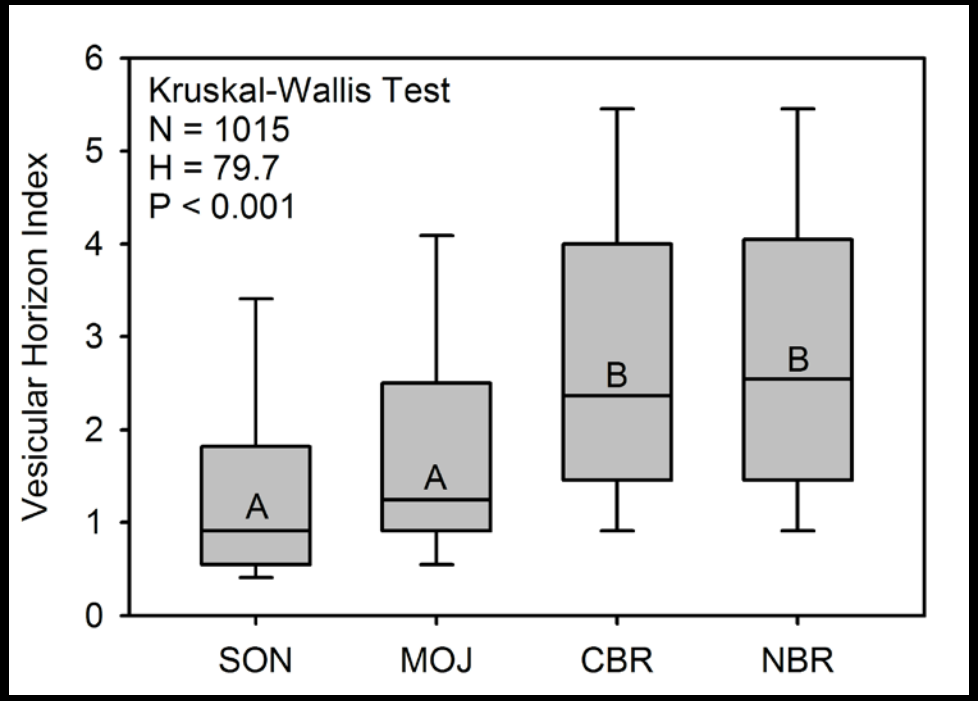
In western U.S.:

- 1092 soil series have vesicular horizons
- These soil series cover **157,000 km^2**

Omernik's Ecoregions



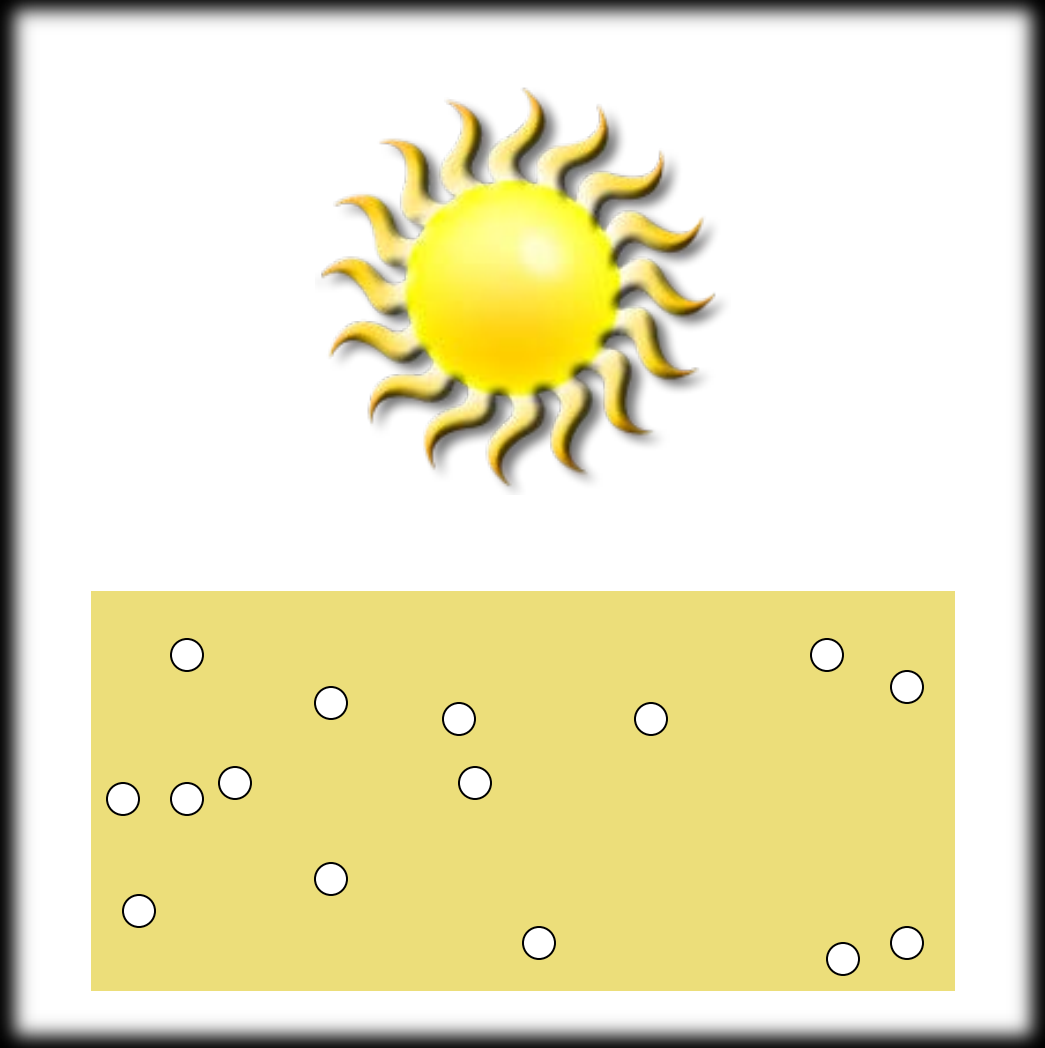
Vesicular horizon expression



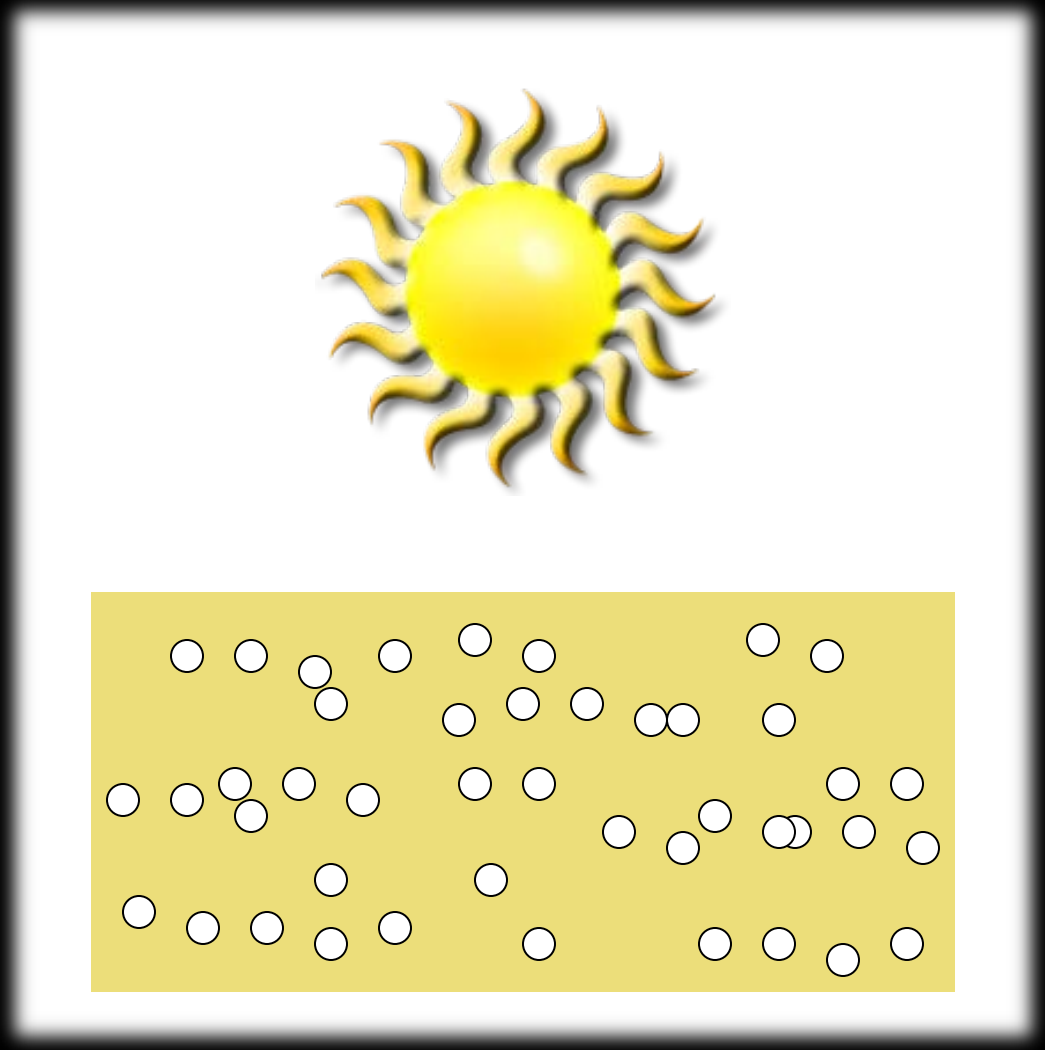
Turk and Graham, *in press*

Vesicular pore formation by air entrapment

Vesicular pore formation by air entrapment



Vesicular pore formation by air entrapment



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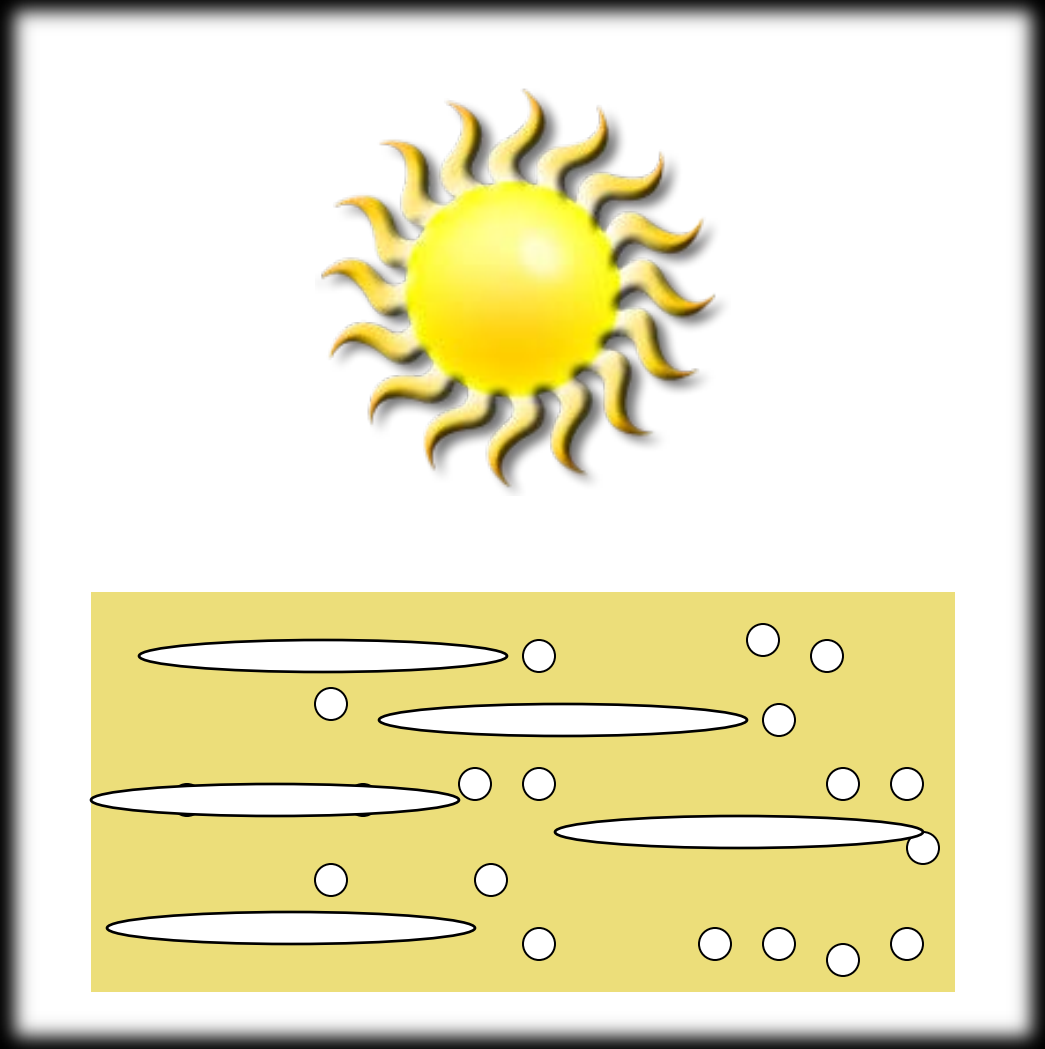
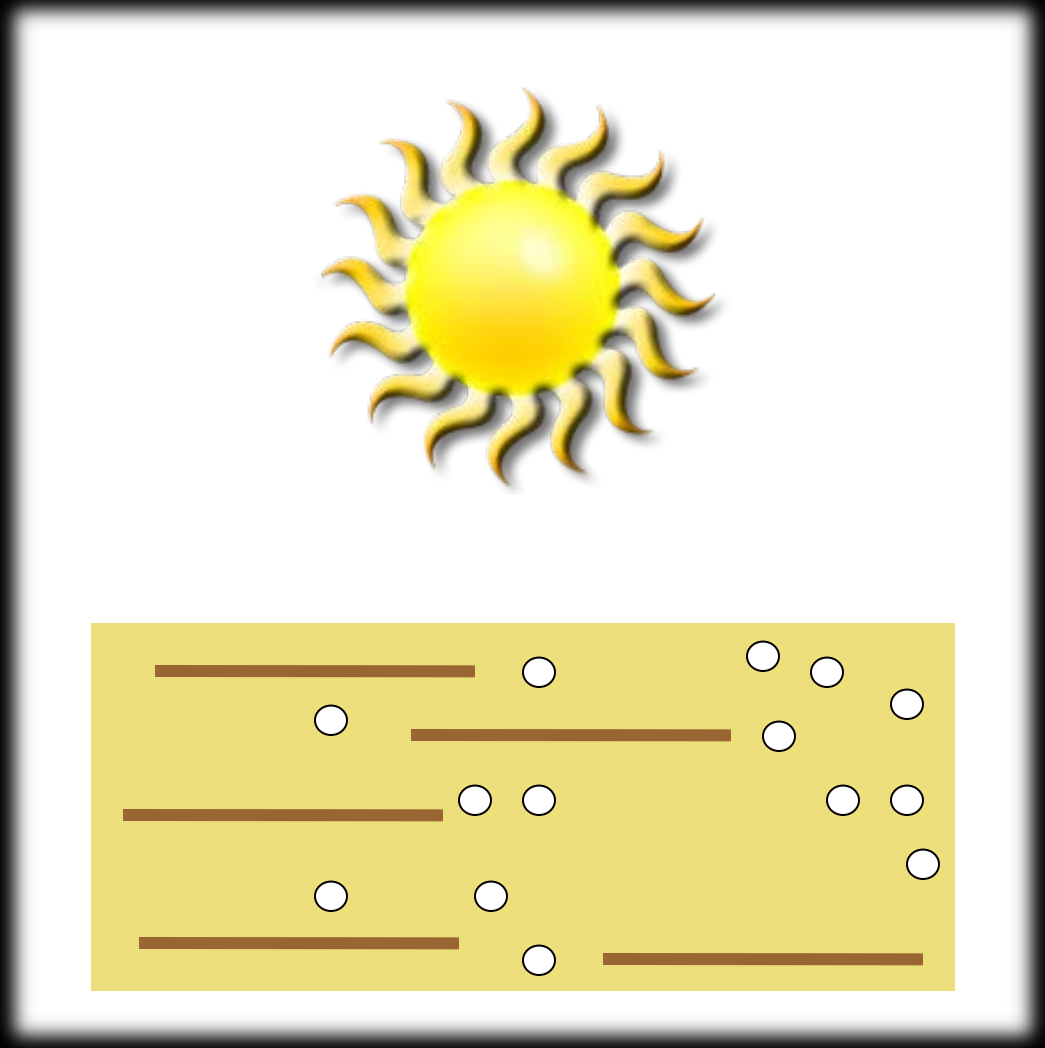


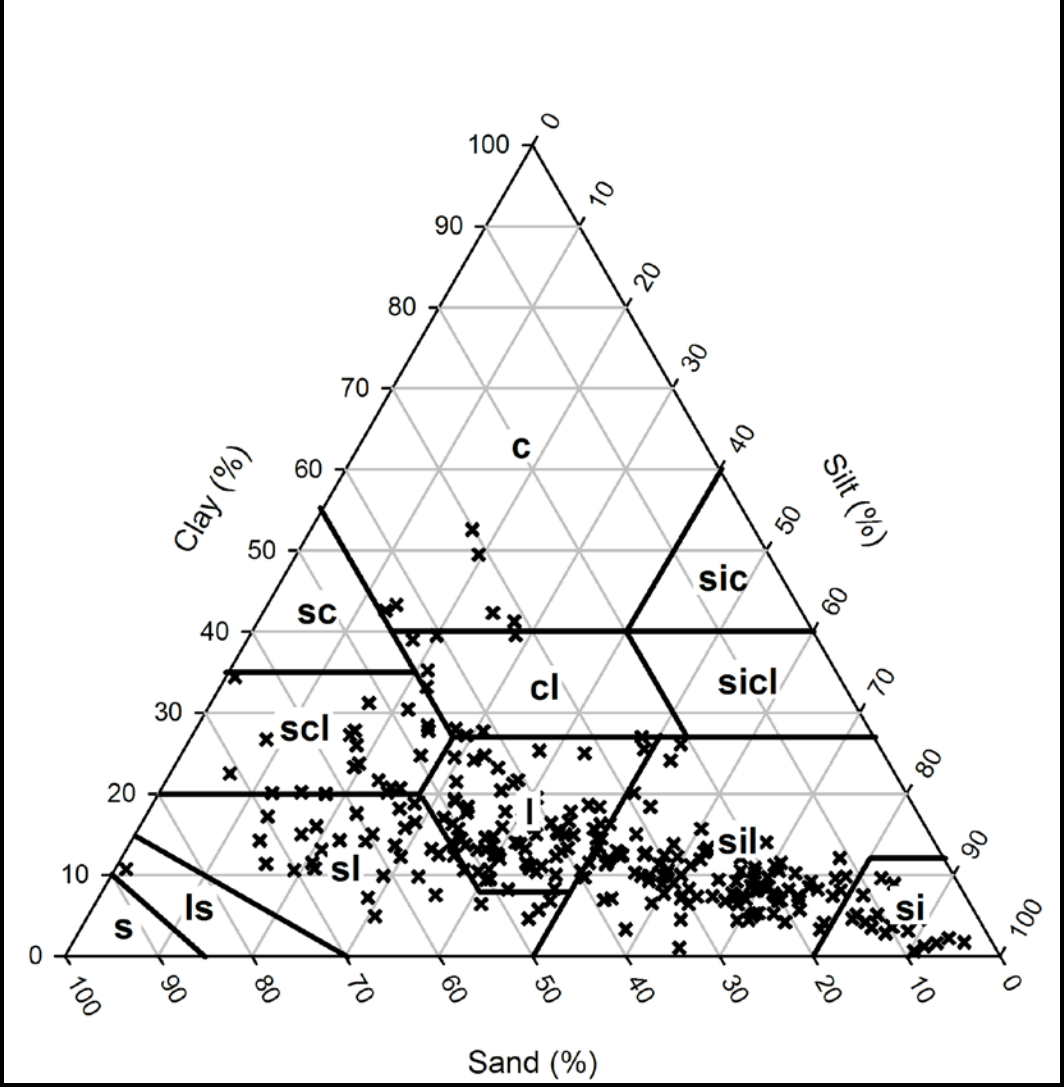
Vesicular pore formation by air entrapment



Conditions for vesicular horizon formation:

1. Silt-enriched surface texture
2. Surface that impedes gas exchange
3. Cyclic wetting and drying

1. Silt-enriched surface texture



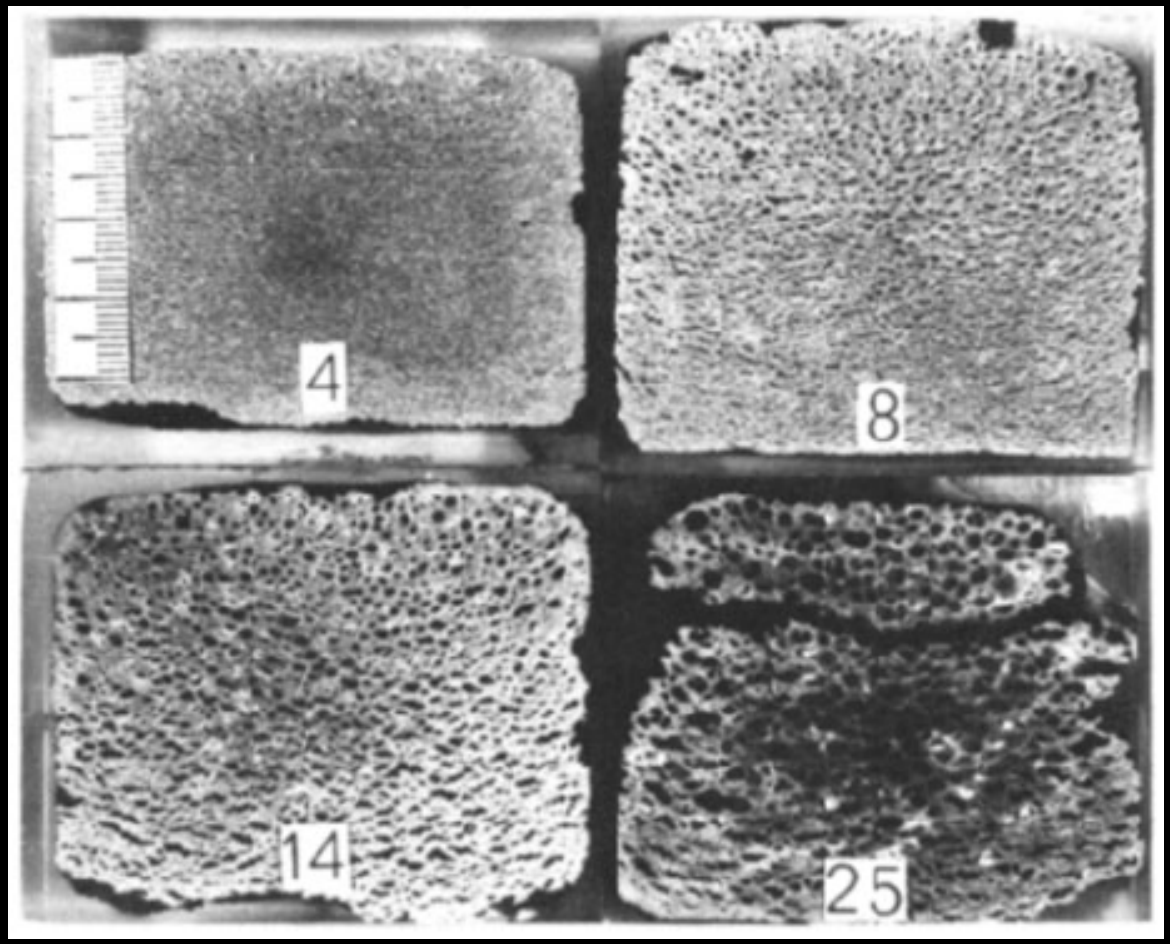
Turk and Graham, *in press*

2. Surface that impedes gas exchange

Desert Pavement

Physical Crust

3. Cyclic wetting and drying

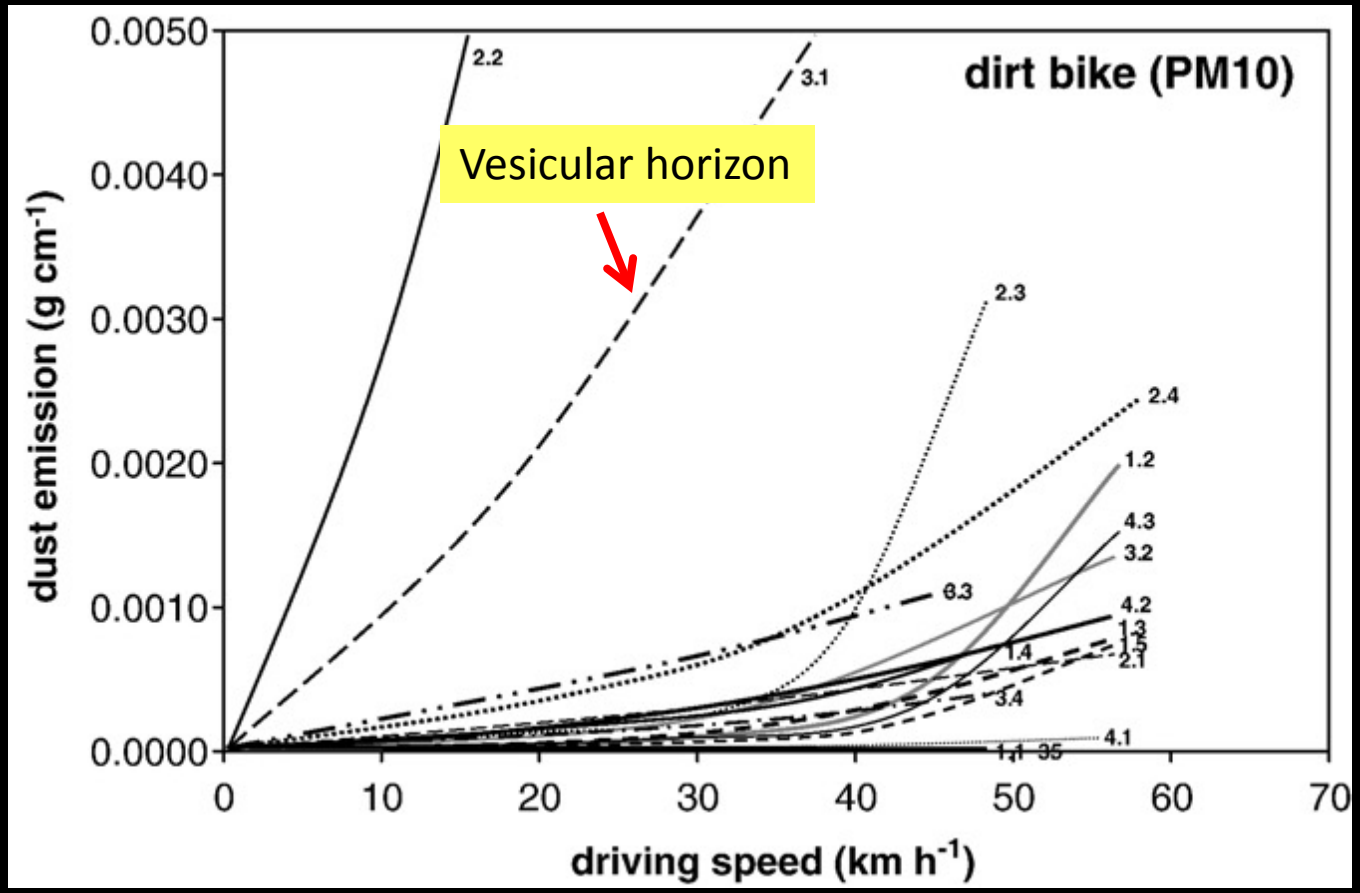


Miller, 1971

Environmental significance:

1. Potential for dust emissions
2. Relation to surface hydrology
3. Role in soil change

1. Potential for dust emissions



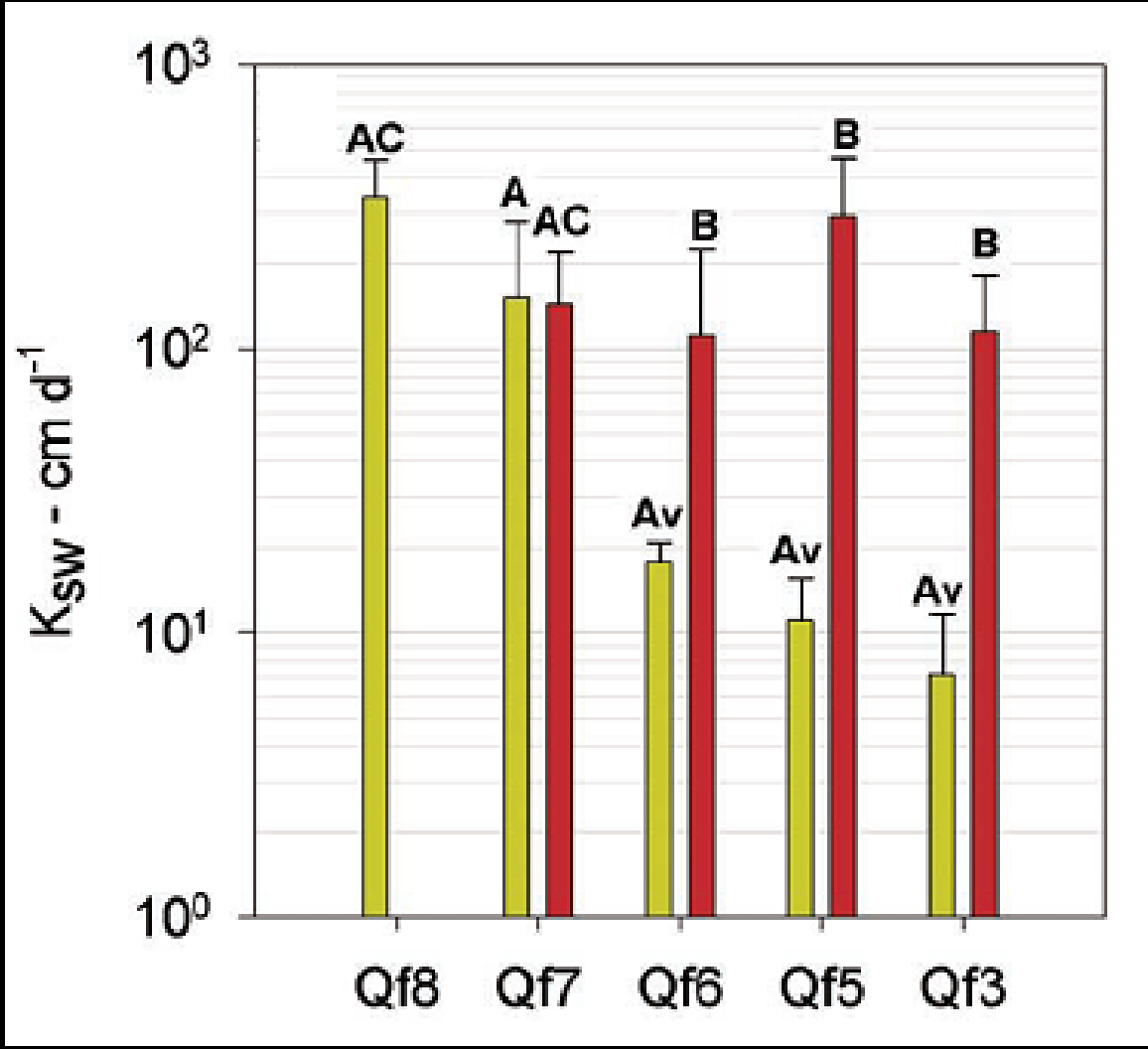
Goossens and Buck, 2009

1. Potential for dust emissions

- Increased disturbance of desert lands: **1.8 million acres** under review for development of solar power facilities (Associated Press, 2010)

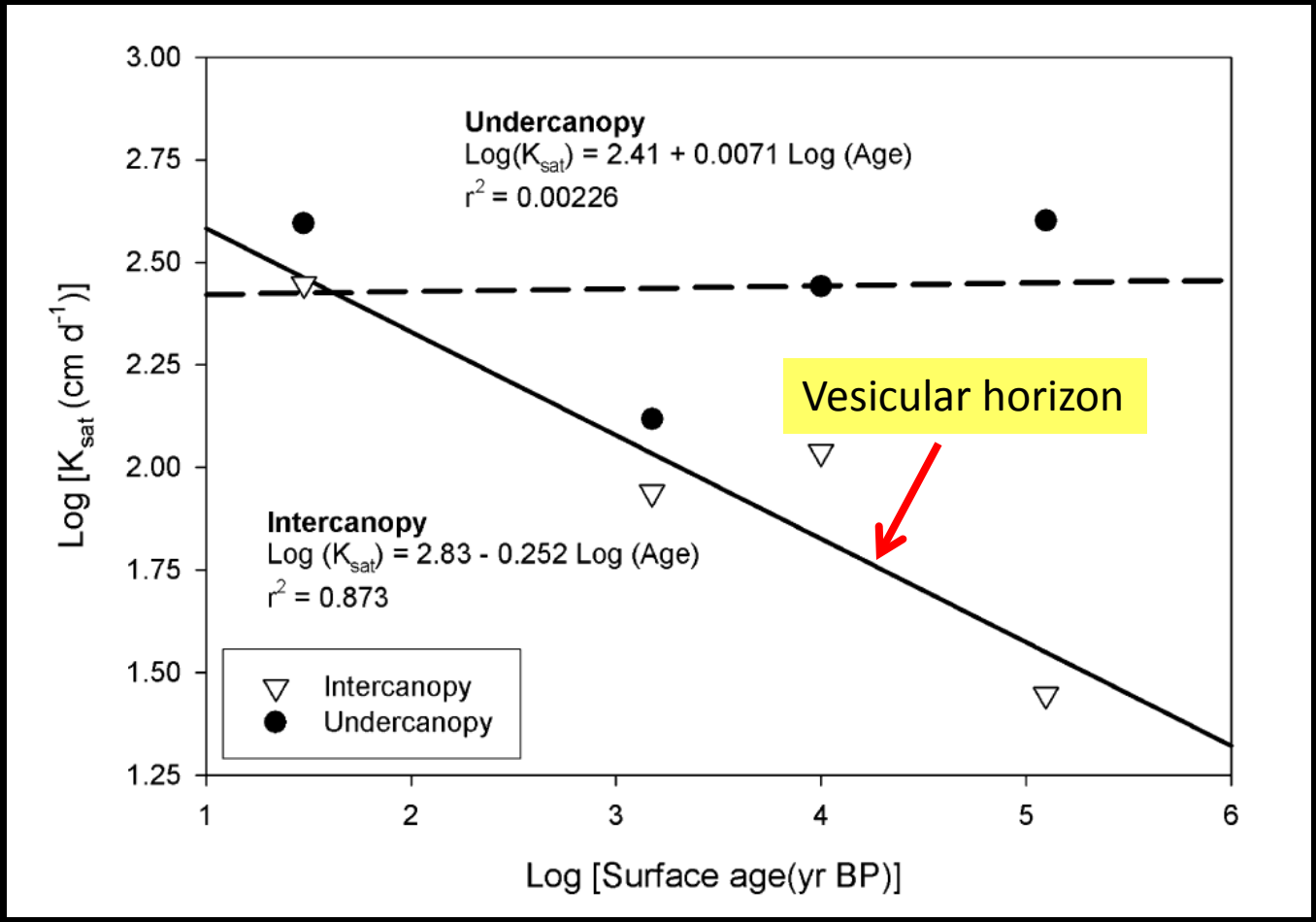
- Far-reaching effects of mobilized dust: Decreased albedo and faster melting of alpine snowpacks (Painter et al., 2010)

2. Relation to surface hydrology



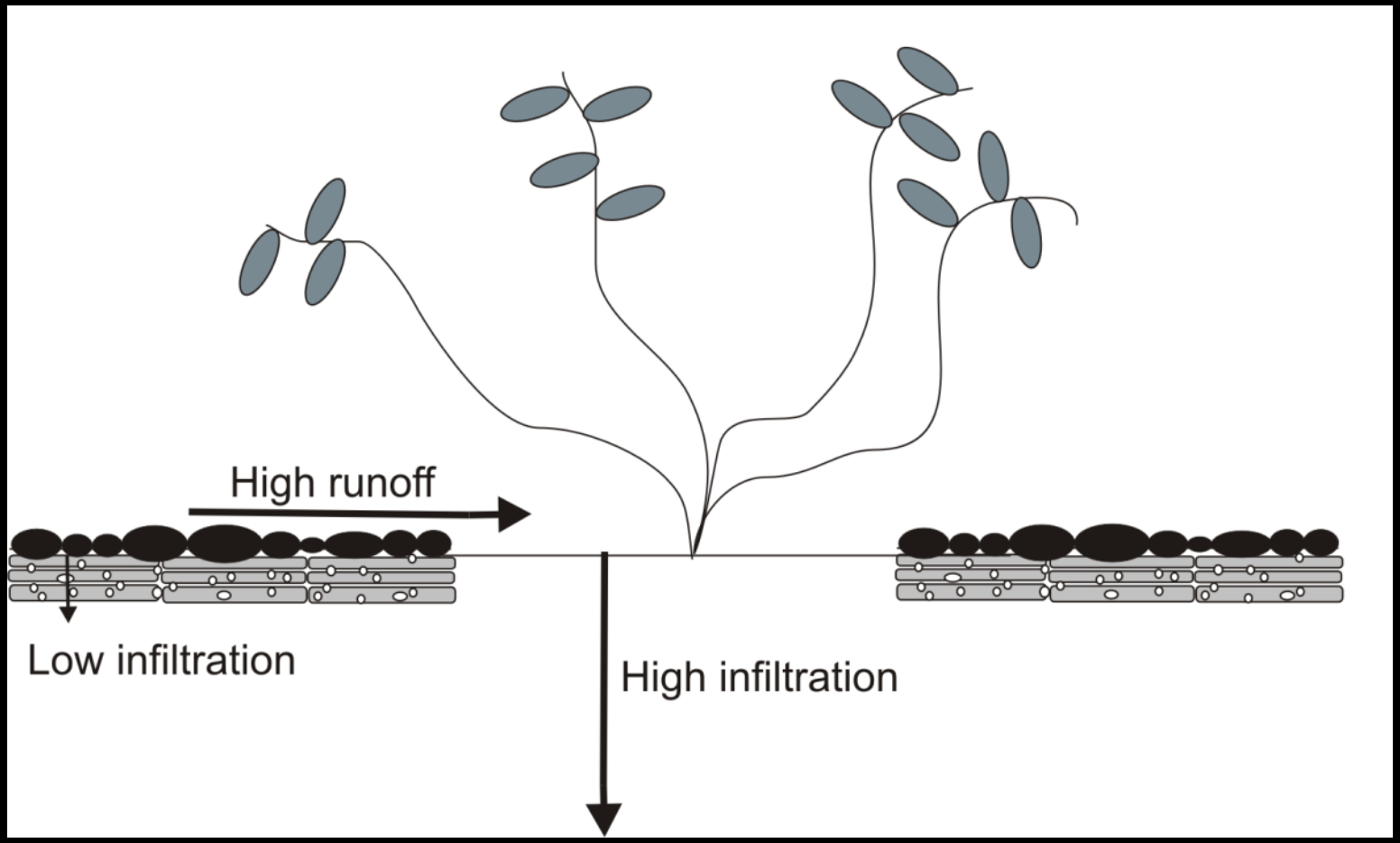
Young et al., 2004

2. Relation to surface hydrology



Shafer et al., 2007

2. Relation to surface hydrology



Vesicular horizons → Increased Runoff → Concentration of water in shrub islands

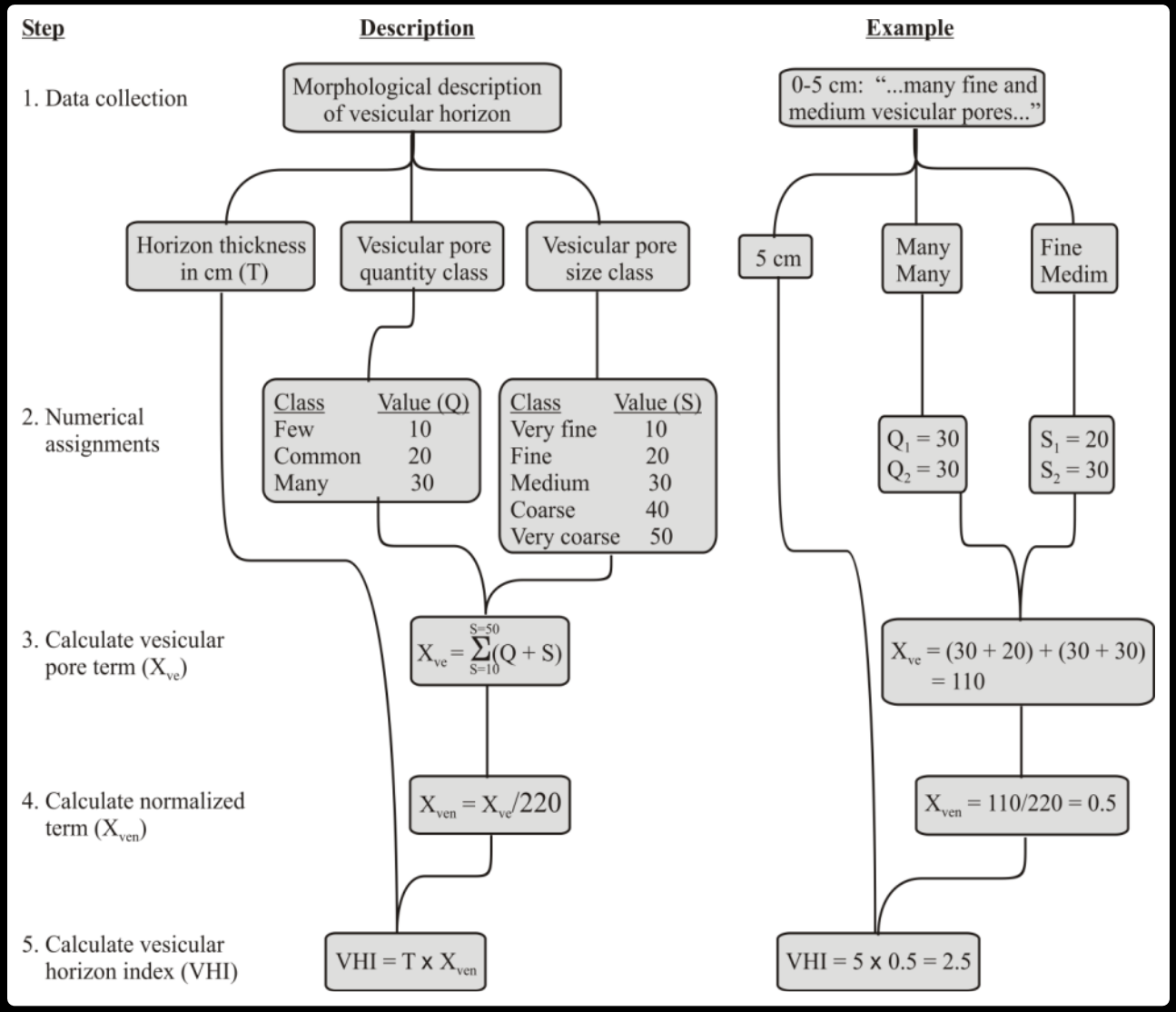
3. Role in soil change: Vesicular horizons as dynamic soil properties

- Can be recreated in the lab over 4-25 wetting and drying cycles (Miller, 1971; Figueira and Stoops, 1981)
- Reformed in disturbed soil material in the field over 4 months (Yonovitz and Drohan, 2009)
- Develop in degraded rangelands in association with shrub invasion (Eckert et al., 1986; Henning and Kellner; 1994)

Year 1: Research Goals

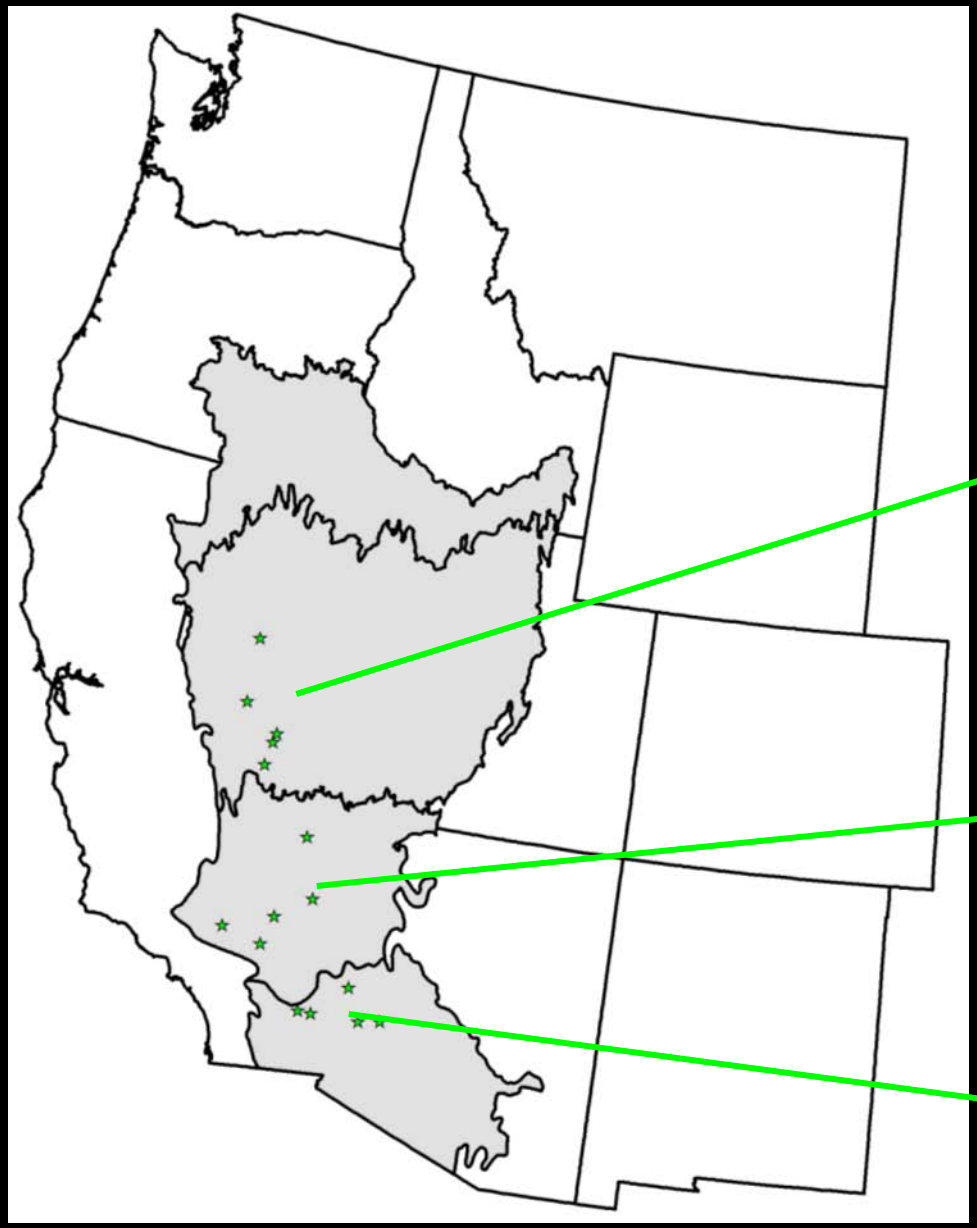
- Characterize vesicular horizon heterogeneity in relation to surface characteristics
- Determine relationship between vesicular horizon morphology and infiltration rate

Vesicular horizon analysis: VHI



Turk and Graham, In Press

Tension disk infiltration



15 Field Sites (3 ecoregions)

Central Basin and Range:
MAP = 14-17 cm
MAT = 10-13°C
Vegetation = *Artemisia spinescens*
Lycium Shockleyi

Mojave Desert:
MAP = 9 cm
MAT = 19°C
Vegetation = *Larrea tridentata*
Ambrosia dumosa

Sonoran Desert:
MAP = 8 cm
MAT = 23°C
Vegetation = *Larrea tridentata*
Ambrosia dumosa

CBR
MOJ
SON

DP

FB
FS

GR

CD

BG

TT

WA

SC

Obj. 1: Vesicular horizon heterogeneity related to land surface units

Prevalent (>90%)

- Desert Pavement
- Flattened Bar
- Flattened Swale
- Tire Tracks

Uncommon (10-50%)

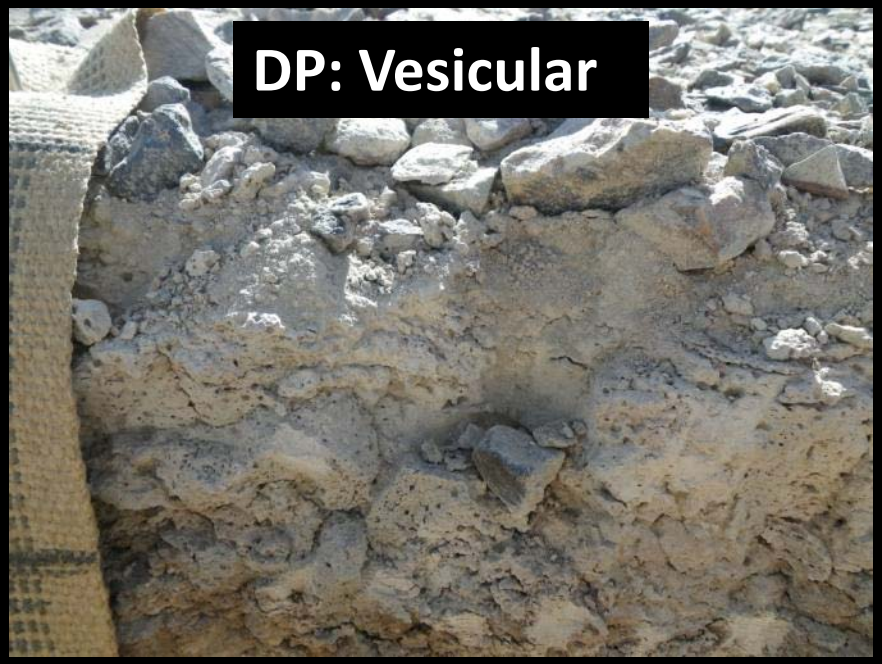
- Coppice Dunes
- Bare Ground
- Scarp

Common (50-90%)

- Gravel

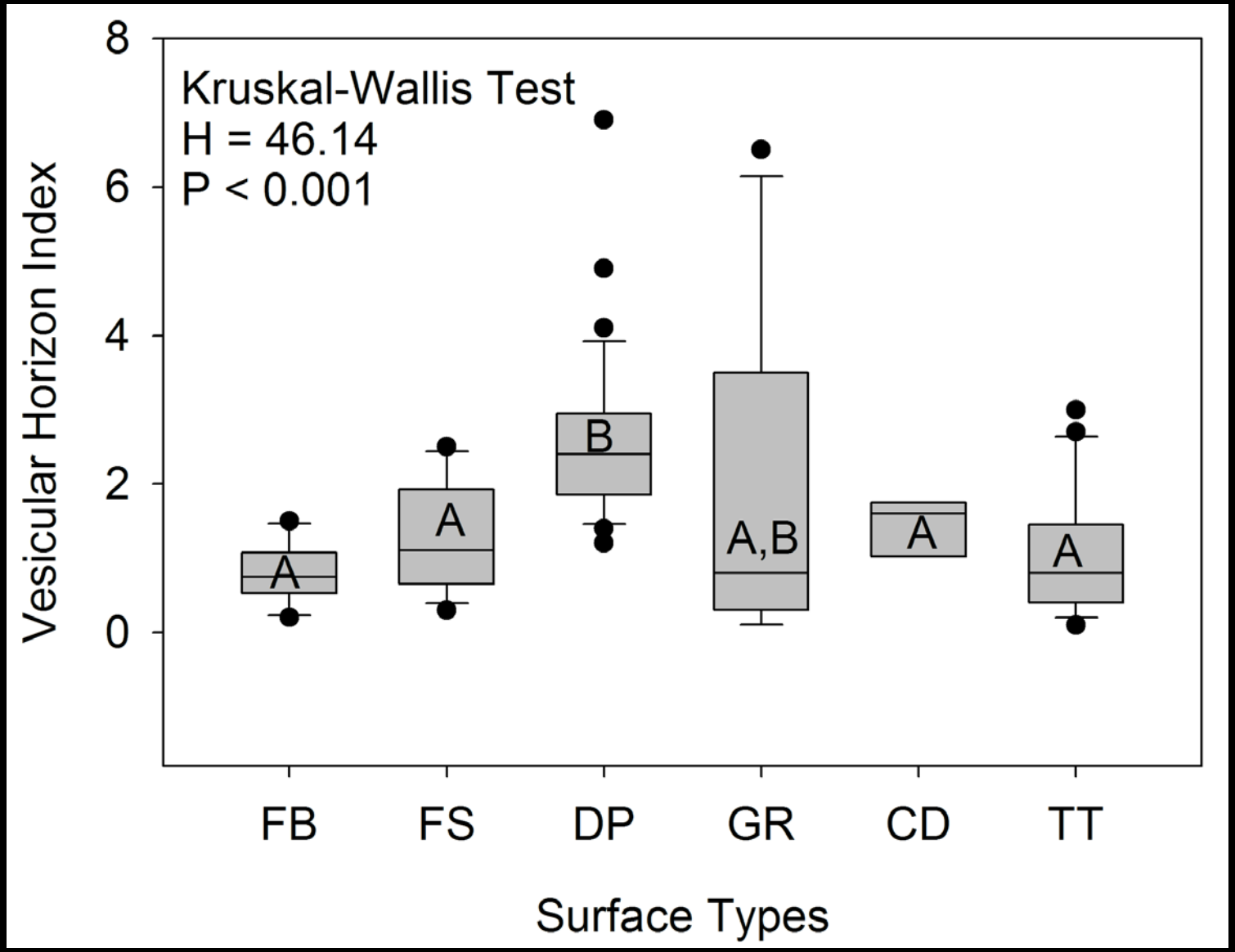
Rare (<10%)

- Washes


DP: Vesicular

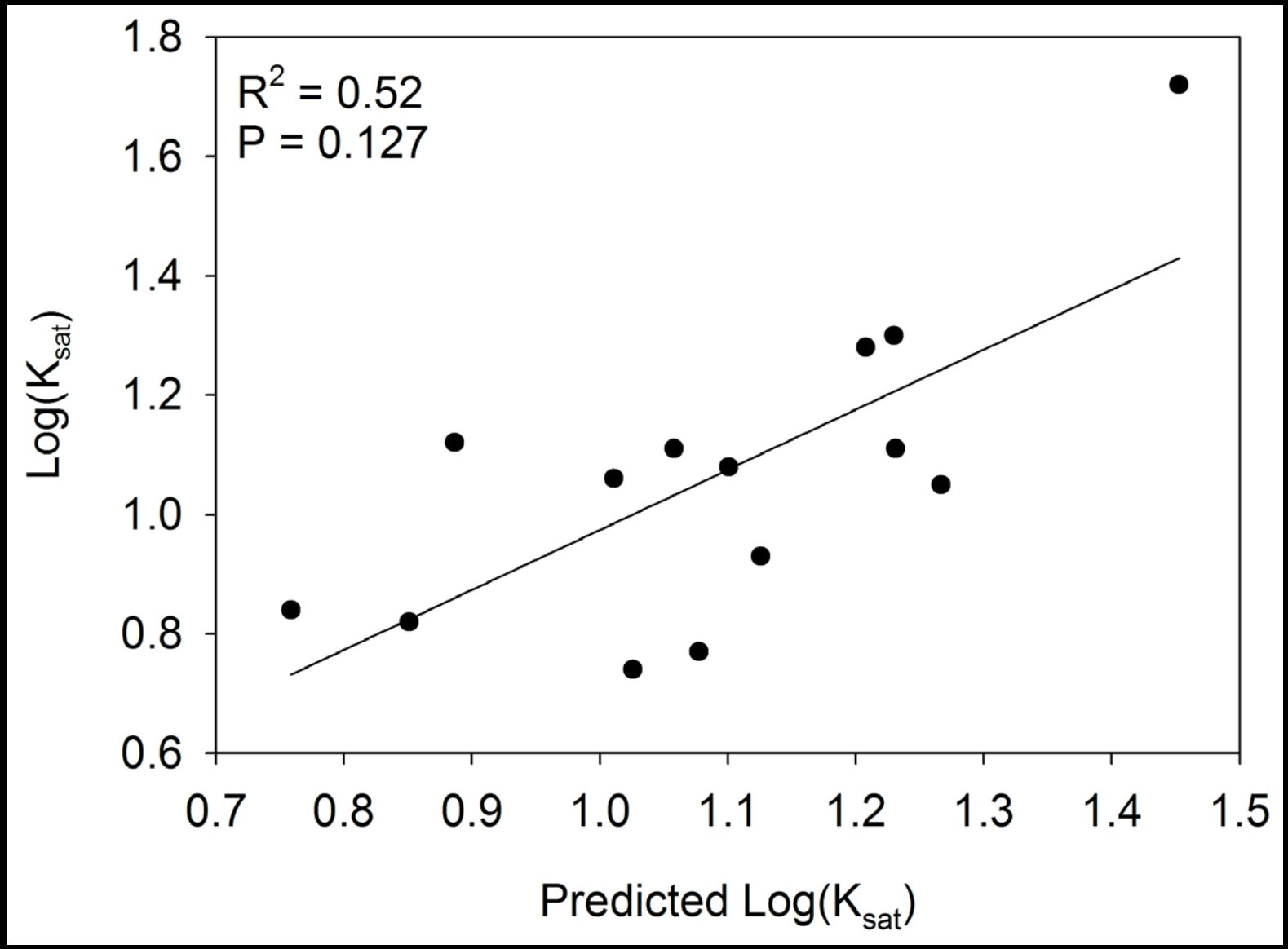
SC: Non-vesicular

CD: Buried vesicular


Kruskal-Wallis Test
H = 46.14
P < 0.001
Vesicular Horizon Index
8
6
4
2
0
A
A
B
A,B
A
A
FB
FS
DP
GR
CD
TT
Surface Types

Obj. 2: Relating infiltration and vesicular horizon properties

Property	**P-Value**	**Relation to infiltration**
%Sand (S)	0.08	Weak positive correlation
Vesicular horizon thickness (T)	0.07	Weak positive correlation
Grade of platy structure (PL)	0.21	Very weak positive correlation
Bulk density (BD)	0.24	Very weak positive correlation



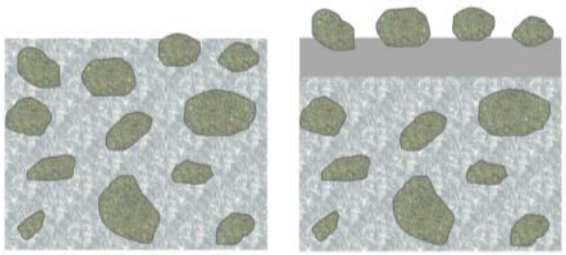
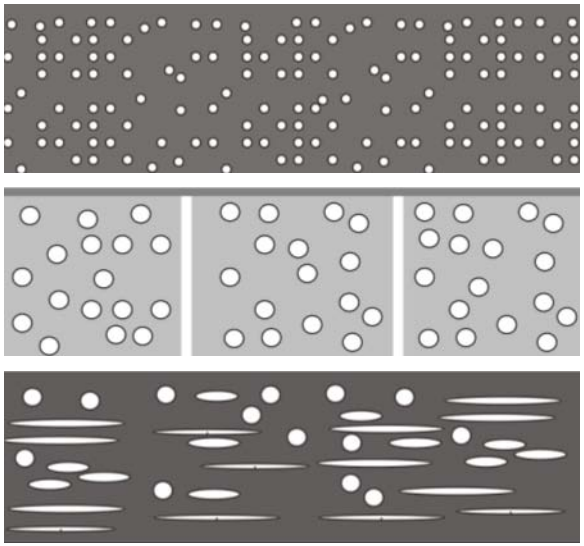
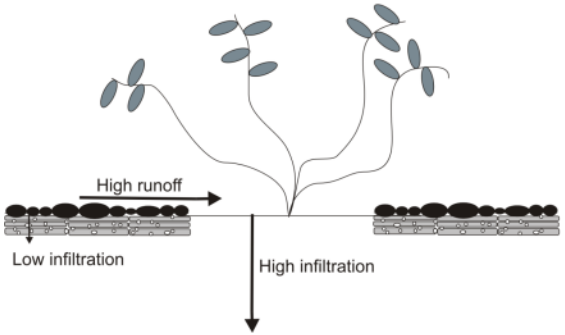
Pred. Log (K_{sat}) = -2.58+.019*(S) + 0.080*(T) + 0.075*(PL) + 1.6*(BD)

Year 2: Research Goals

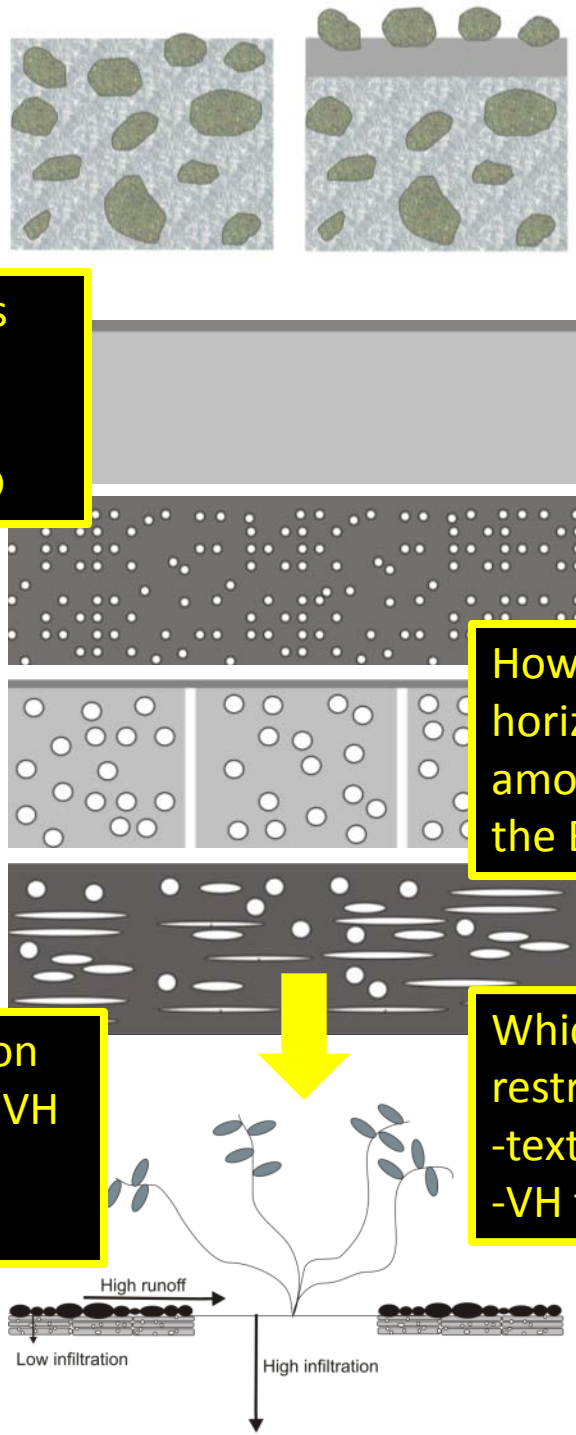
- Determine the influence of vesicular horizon disturbance and recovery on infiltration rates
- Compare vesicular horizon recovery between sites located across three desert ecoregions

Year 1: Measure infiltration → describe initial VH → set up disturbance plots

Year 2: Measure infiltration in disturbance plots → describe reformed VH

Process		Resulting property
Eolian deposition		Silt-rich layer
Surface sealing		Limited gas exchange
Cyclic wetting and drying		Vesicular porosity, platy structure, and polygonal cracking
Restriction of infiltration		Patchy distribution of resources

Process	Resulting property
Eolian deposition	Silt-rich layer
Surfac	Limited gas exchange
Cyclic wetting and drying	Vesicular porosity, platy structure, and cracking
Restrict infiltration	tribution of resources



Which surfaces types have the strongest association with VH?
-DP > FB&FS, TT > CD

How does vesicular horizon formation vary among ecoregions of the B&R province?

How does destruction and reformation of VH influence hydraulic function?

Which VH properties restrict infiltration rate?
-texture
-VH thickness

Acknowledgments

Funding

USDA-NRCS California Cooperative Agreement

USDA-NRCS Soil Survey Research Grant

Field assistance

Myles Davis

Christina Conn

Shahriar Uddin