Early Grain-Coat Formation in Chaco Dune Field, New Mexico: Insight into Formation Mechanisms, Distribution, and Implications for Predictive Modeling to Assist in Deep Play Identification*

W. L. Esch[1], J. M. Ajdukiewicz[2], and A. C. Reynolds[3]

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[1]New Play Concepts, ExxonMobil Upstream Research Company, Houston, TX. (william.l.esch@exxonmobil.com)
[2]Formation Evaluation, ExxonMobil Exploration Company, Houston, TX.
[3]Department of Geosciences, University of Arizona, Tucson, AZ.

Abstract

Clay grain-coats preserve favorable reservoir quality in deeply buried eolian sandstones by inhibiting quartz cement. Reported mechanisms for clay-coat formation include:

1. Translocation of airfall/rainout dust into eolian sands.

2. Inheritance of coated sand grains from ephemeral fluvial systems.

Sparse information exists regarding where the coating processes are most effective, the distribution of clay-coated sands in fluvial-eolian environments, and survivability of coats during eolian transport. Such limited knowledge makes pre-drill predictions of coated grains difficult. Consequently, we are conducting field studies in modern eolian environments focused on the genetics and distribution of clay-coated sands. This work will form the basis for predicting the presence, continuity, and composition of clay grain-coats in ancient eolian strata that are potential reservoir targets.

The Chaco dune field, northwest New Mexico, was selected as one of several investigation sites. A transect from the Chaco River to the northeast was sampled that includes sand sheets, barchanoid dunes, parabolic dunes, ephemeral fluvial channels, and Cretaceous age bedrock. Consistent with literature, clay-coated grains are found in Chaco River sediments. These fluvially coated grains appear to be transported by wind into the adjacent dune field from the river bed and lose their coats by abrasion. Clay coats are subsequently regenerated in nascent soils by translocation of dust into vegetation-stabilized dunes and sand sheets.

Climate is a key control on vegetation which promotes stabilization of the sands and coat regeneration. Climate cyclicity also is important. Conditions must periodically be dry enough to allow eolian transport, but wet enough at intervening times for stabilization and translocation. The results are being incorporated into a probabilistic predictive model.

Early grain-coat formation in Chaco dune field, New Mexico: insight into formation mechanisms, distribution, and implications for predictive modeling to assist in deep play identification

W. L. Esch, J. M. Ajdukiewicz, and A. C. Reynolds

Contributions by:

Pam Houser (SEM Analysis)

Bill Reese (XRD Analysis)

Glen Van Gaalen (Thin Section and XRD Sample Preparation)

John Leiphart (Thin Section Preparation)

Bob Brovey (Satellite Imagery)

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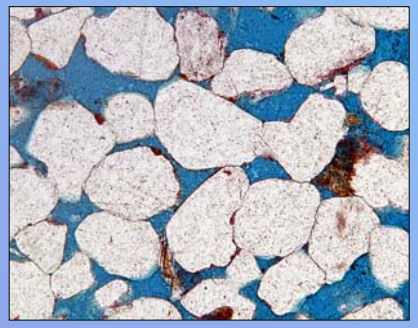
Note: Field work on the Navajo Nation was conducted under a permit from the Navajo Nation Minerals Department, and persons wishing to conduct geologic investigations on the Navajo Nation must first apply for, and receive, a permit from the Navajo Nation Minerals Department, P.O. Box 1910, Window Rock, Arizona 86515, telephone # (928) 871-6587.

Project Motivation, Goal, and Challenges

New Play Concepts

Motivation for research:

- Grain-coating clays impart favorable RQ to eolian sandstones by inhibiting quartz cement.

clay coats   no clay coats

Main Goal:

- Develop process-based forward model(s) for prediction of eolian grain-coats.

Challenge:

- Understand the genesis and distribution of clay coats.

Clay coatings in eolian sands … how do they form?

New Play Concepts

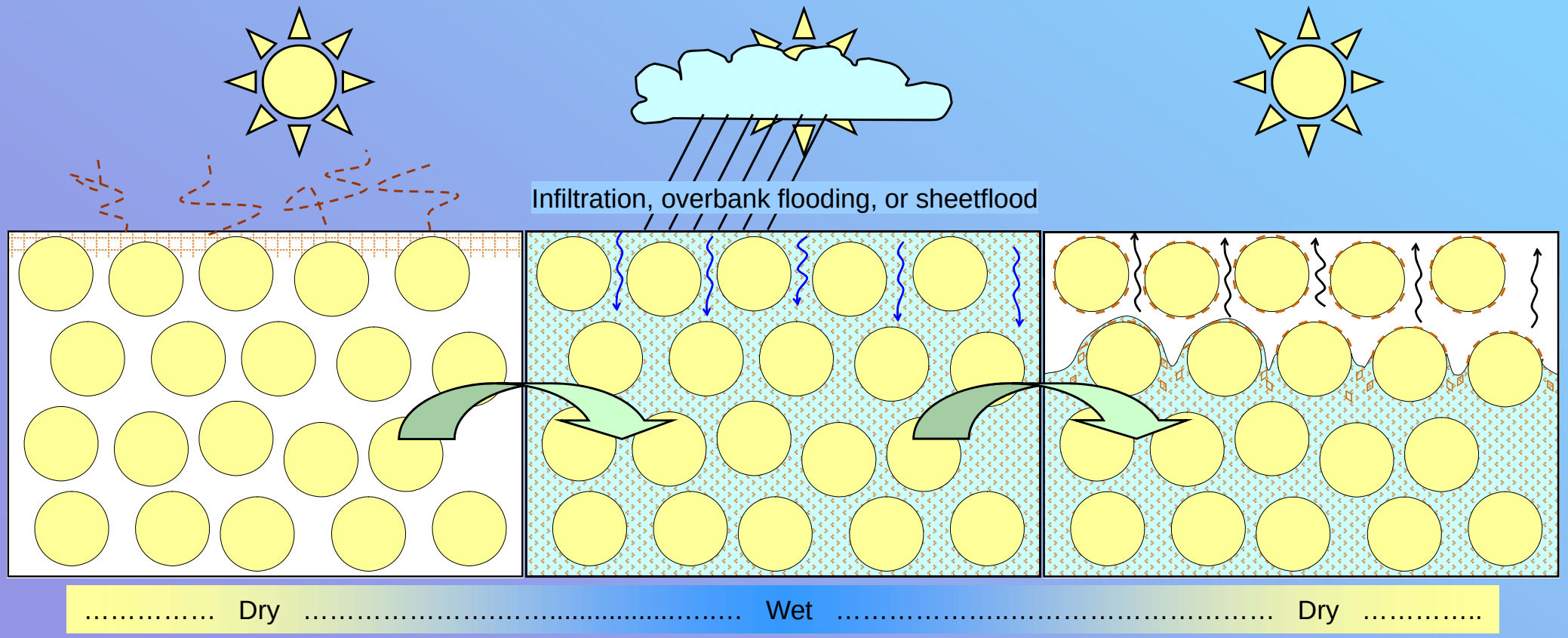
Clay coats form by translocation of clay and clay-sized particles in vadose zone

(Translocation concepts and fluvial model after Crone, 1975; eolian model after Ahlbrant and Fryberger, 1980; and Ehrman, 1987).

Eolian: Dust settling …… rain-out / translocation …….. infiltration and coating

Fluvial: +/- Dust settling …….. overbank flooding by clay-laden water …… infiltration and coating

Alluvial: +/- Dust settling …….. sheetflood by clay-laden water …… infiltration and coating

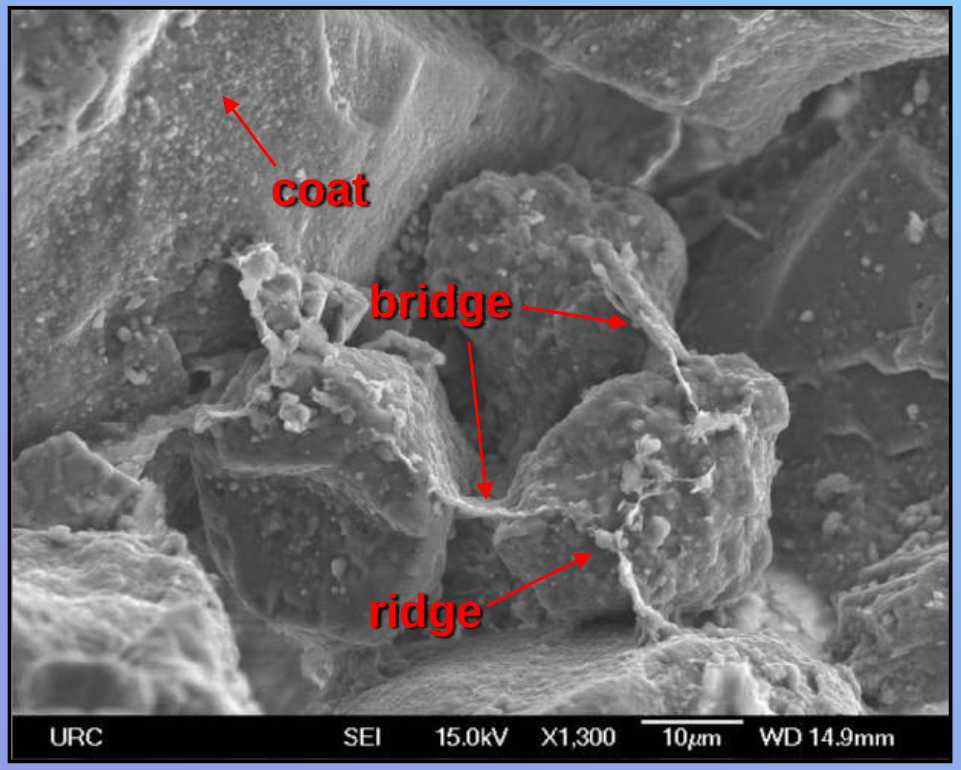


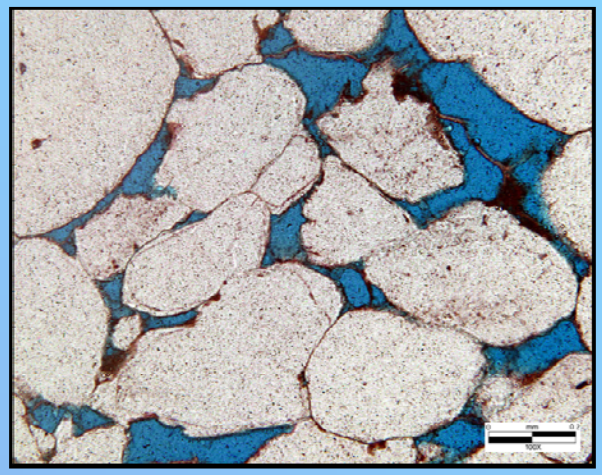
Infiltrated clays; morphologies and interpreted processes

New Play Concepts

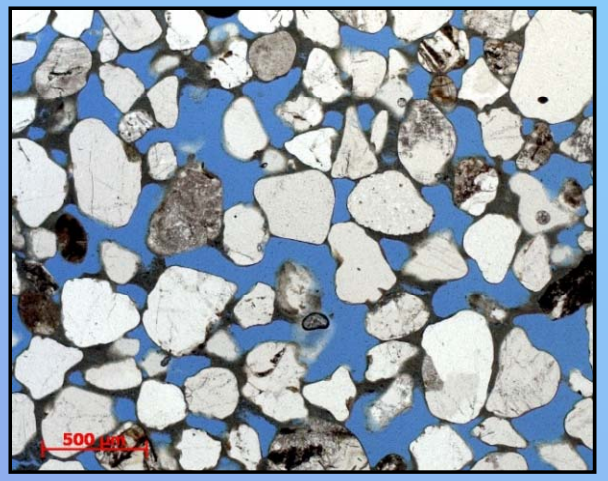
Translocated clay morphologies

Modern





Paleozoic



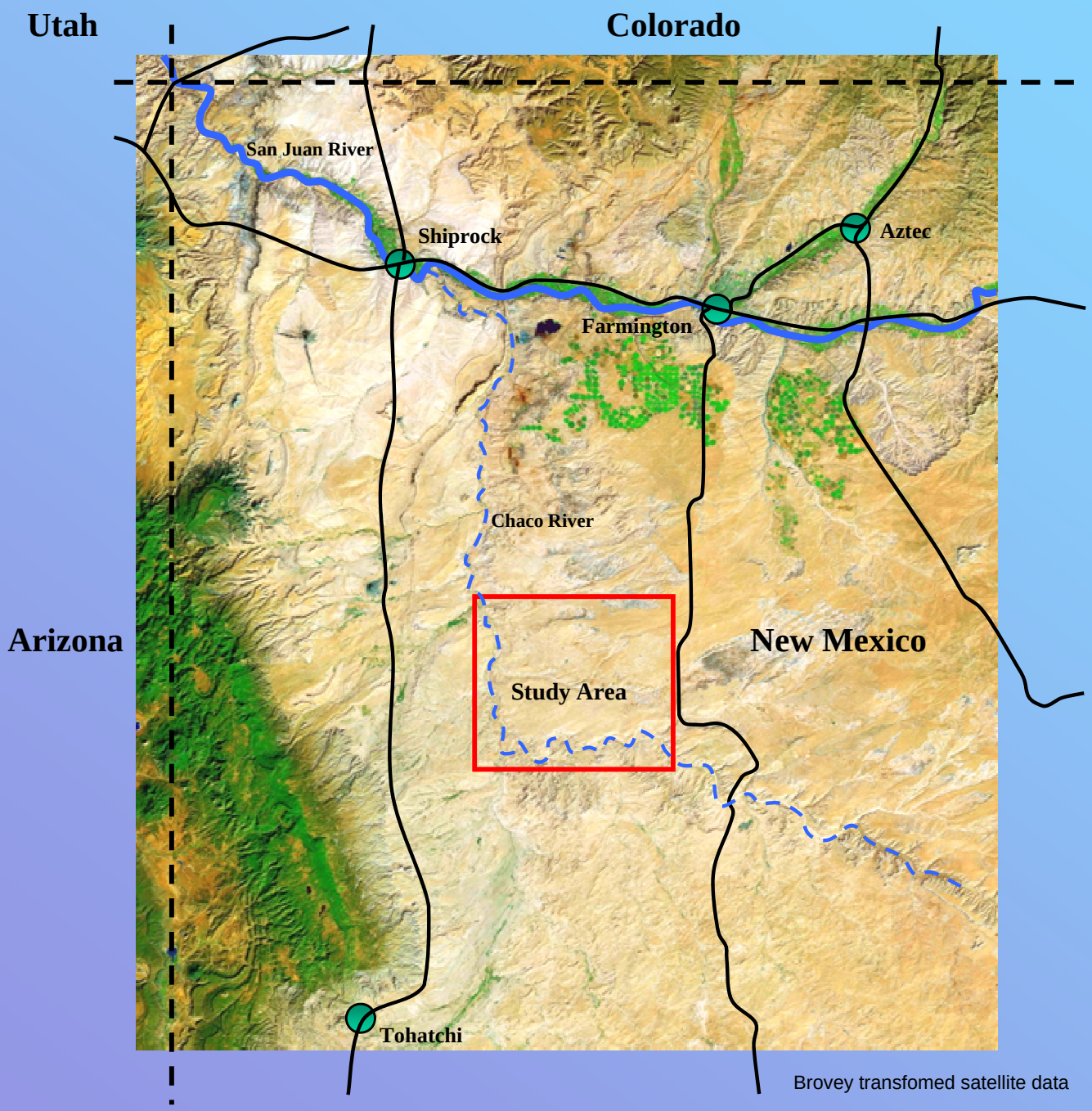
Modern

Criteria for Interpreted Processes from SEM or thin section observations:

- Clay bridges or ridges = current cycle clay translocation (Crone, 1975)
- Partly abraded clay coat without bridges or ridges = no clay translocation, inherited coat

Chaco Dune Field Location

New Play Concepts

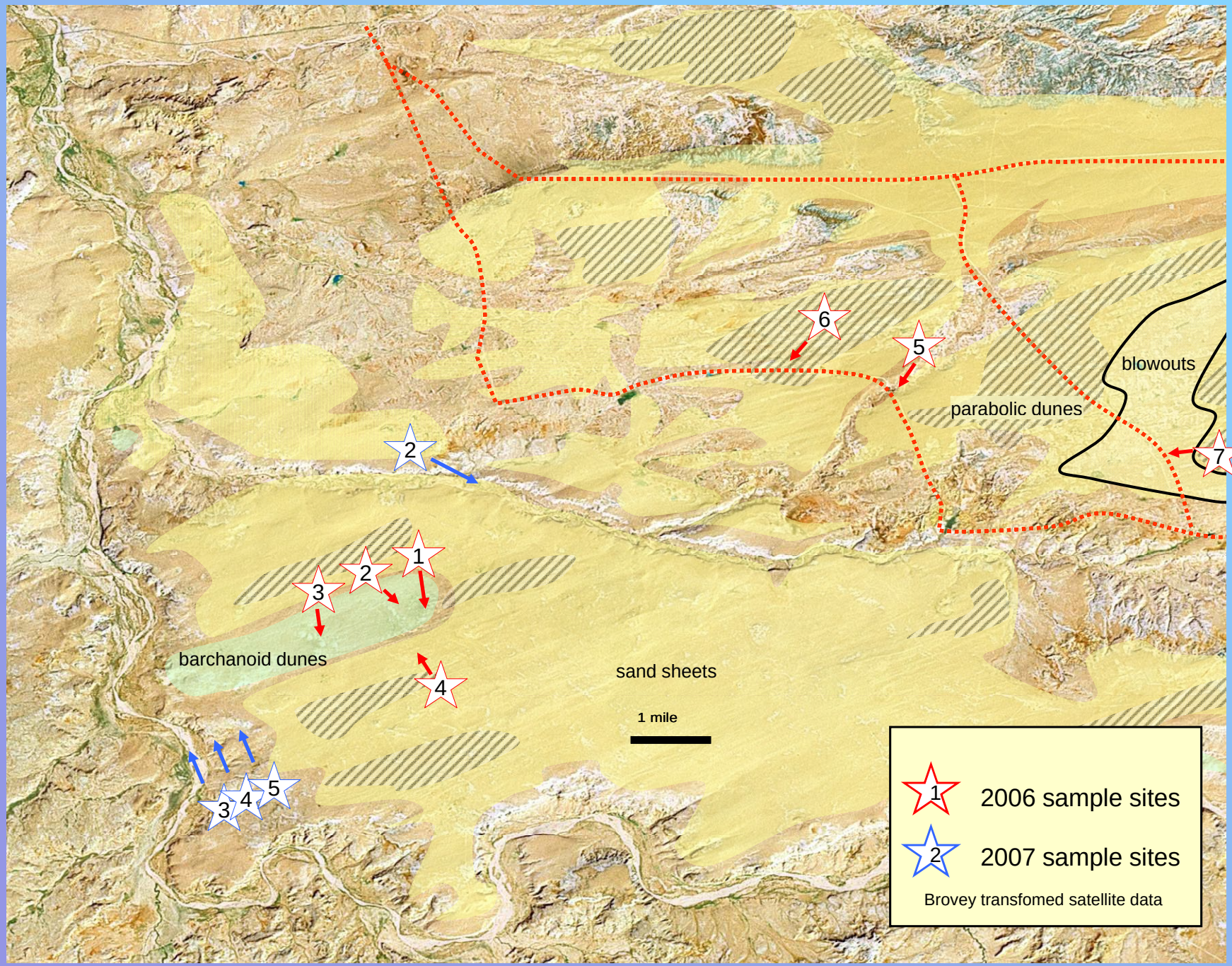


Brovey transfomed satellite data

Chaco Dune Field Sample Sites and Eolian Features

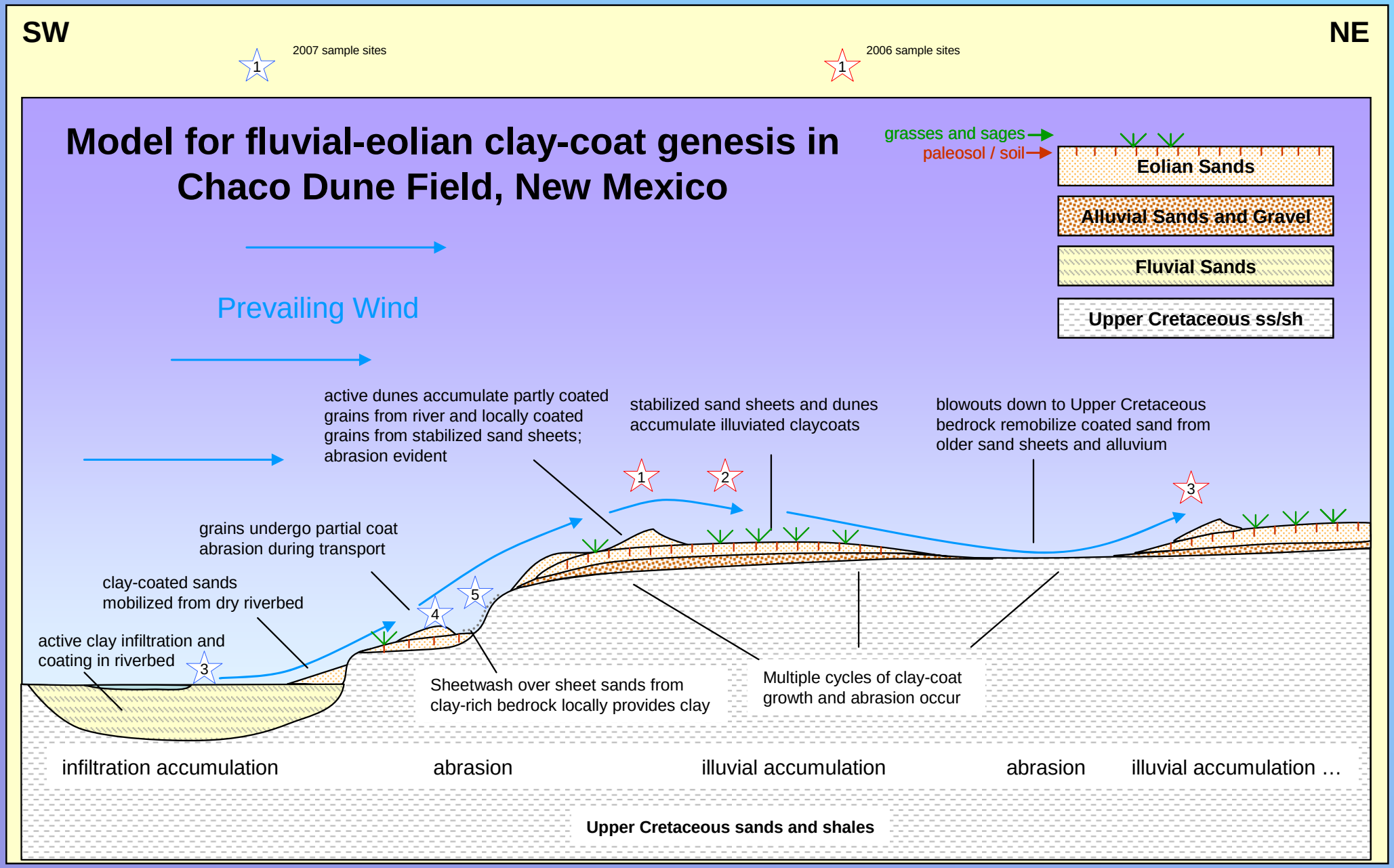
New Play Concepts

Mapped eolian features from Wells, et al. (1990)



Summary Diagram of Genetic Clay-Coat Processes

New Play Concepts



Which translocation process is dominant at Chaco?

New Play Concepts

NE

SW

Eolian: wind mobilizes and transports dust on a widespread basis; rain illuviates settled dust into sands.

dominant

Prevailing southwesterly wind before passage of front

rain

rain

gusty winds

windborne dust

Fluvial: overbank flooding contributes little to clay translocation in eolian sands at Chaco; most eolian sands are located well above the fluvial floodplain on extensive pediments.

Alluvial: sheetflood processes locally translocate clay derived from fine-grained Cretaceous bedrock.

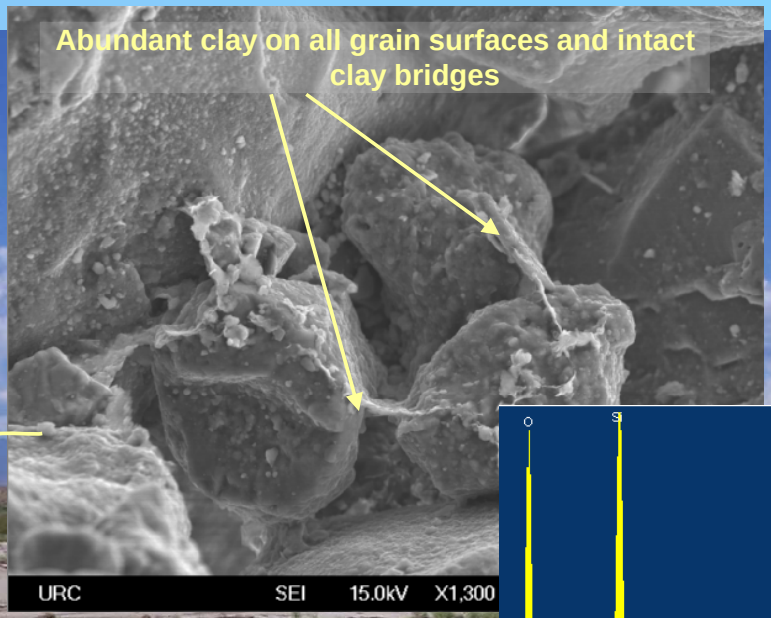
Observations/Interpretations at Chaco site 2007-3

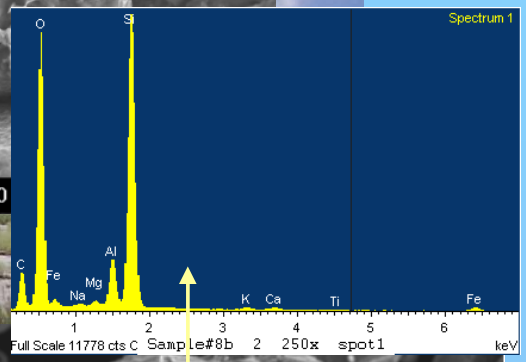
New Play Concepts

Fluvial Sands and Small Dunes

Observations:
- Sands from fluvial channel have abundant coats, bridges and ridges.
- Eolian sands at margin of rive channel have bald high spots and clay in surface depressions.

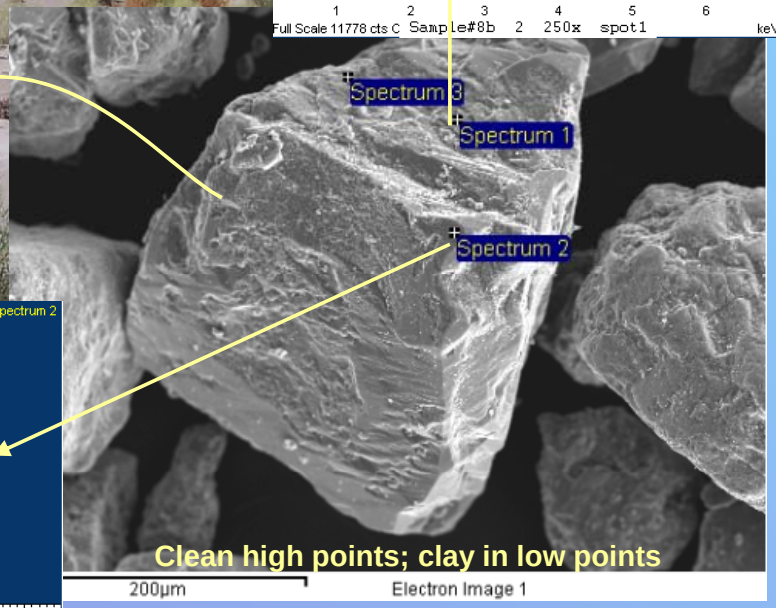
Interpretations:
- Active clay infiltration occurs in Chaco River.
- Eolian transported grains loose ridges and coats from transport abrasion over small distances.

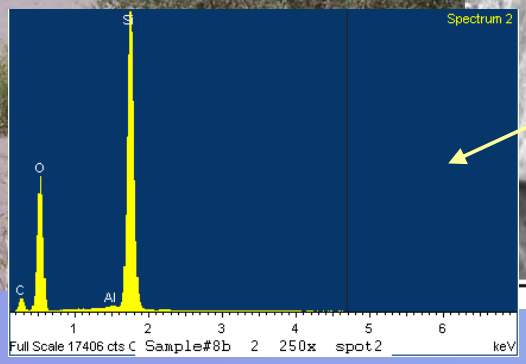


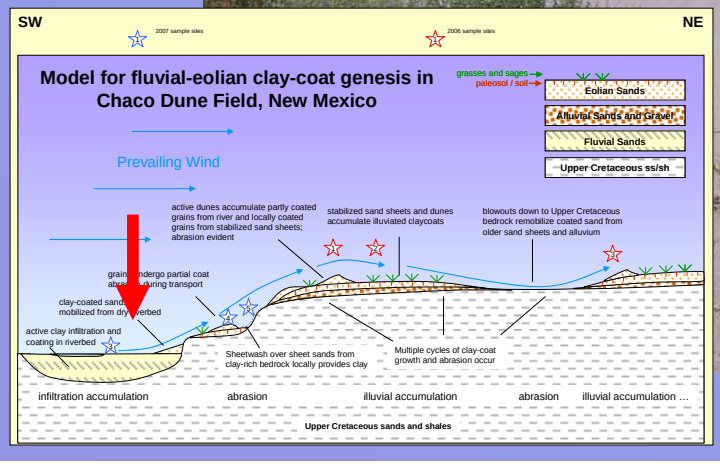


Ephemeral fluvial channel

Small dune at margin of fluvial channel







Observations/Interpretations at Chaco site 2006-1

New Play Concepts

Barchanoid Dunes and Dune Apron

Observations:

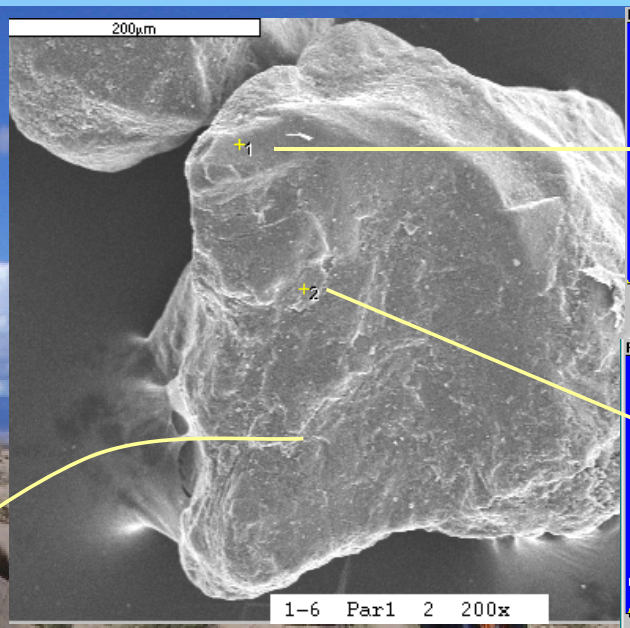
1) Clay ridges or bridges are not present.
2) Grains have bald high areas.
3) Clay coats are present on flats and low areas.

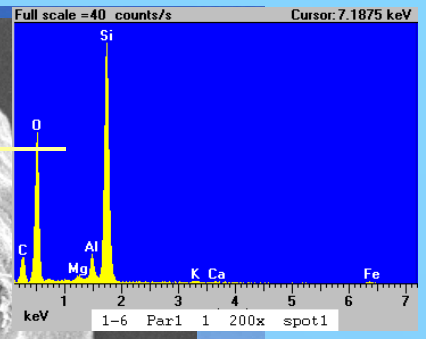
Interpretations:

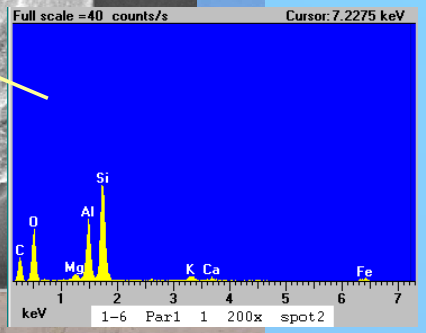
1) Illuviation is not effective in active dunes.
2) Transport abrasion removes preexisting grain coats from high areas on grains.
3) Grain coats are inherited.

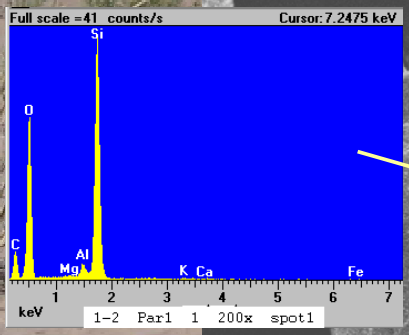
barchanoid dune

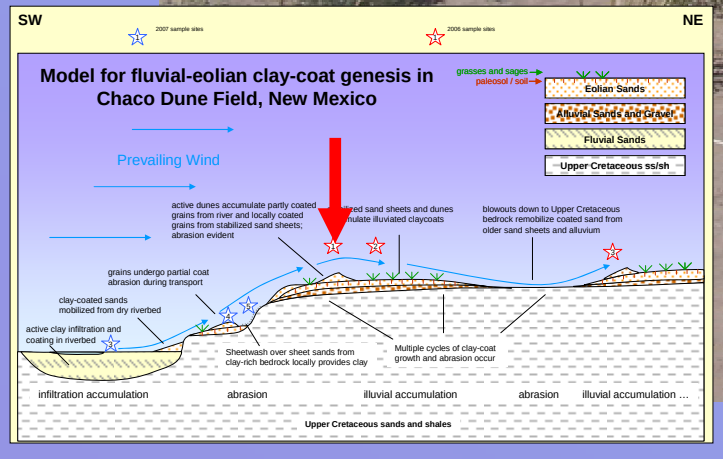
dune apron











Observations/Interpretations at Chaco site 2006-4

New Play Concepts

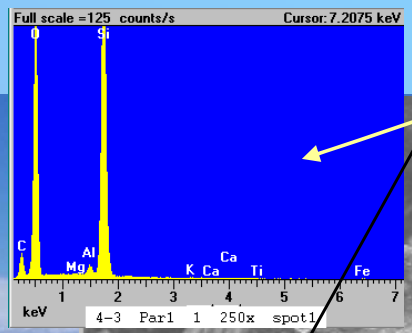
Observations:

1) Concave upward depressions in clay coatings.
2) Clay present in depressions.
3) Meniscate clay ‘fillets’ between grains.
4) Weakly developed clay ridges

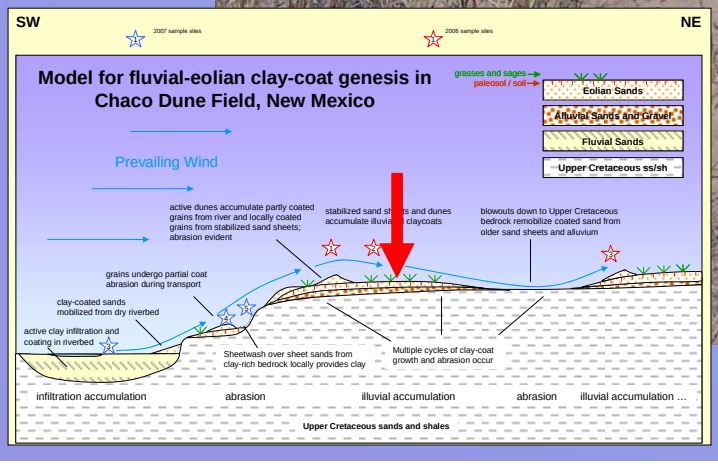
Interpretations:

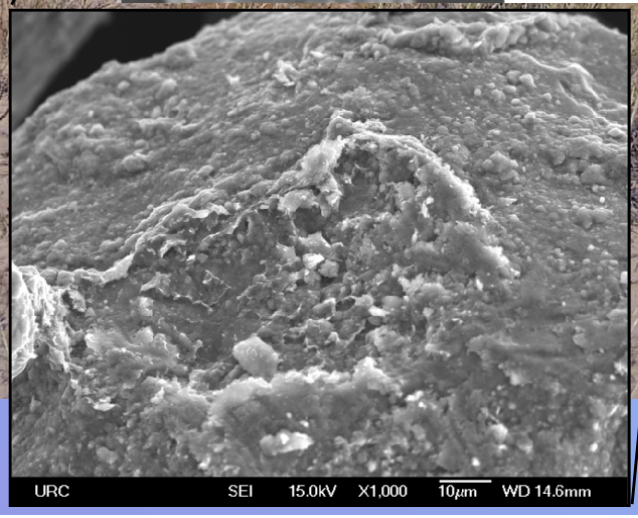
1) Grain contacts apparent.
2) Grains coated <u>before</u> deposition.
3) Clay ‘fillets’ and ridges result from post-depositional clay illuviation

Sand Sheets



Stabilized sand sheet

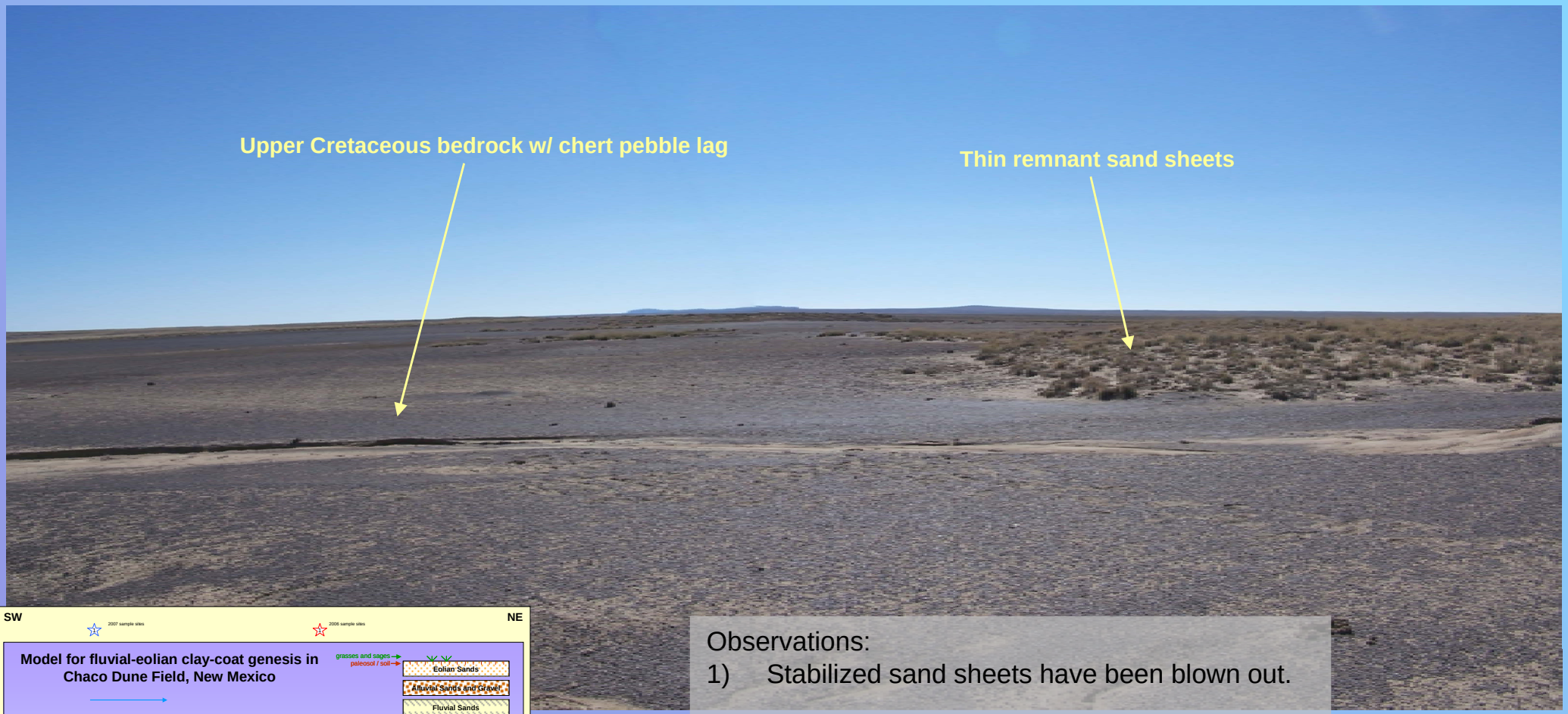


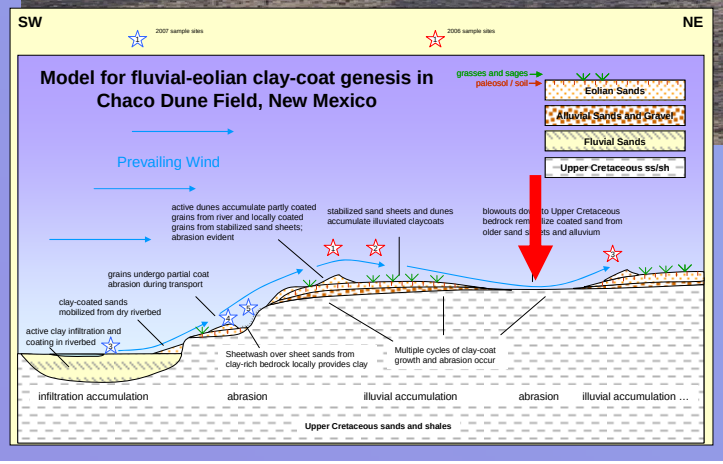


Blowouts and desert pavement

New Play Concepts

Remobilization of clay coated grains





Observations:

1) Stabilized sand sheets have been blown out.

Interpretations:

1) Coated grains from sand sheets can be remobilized.
2) Some grains may experience many cycles of coating and abrasion.

Observations/Interpretations at Chaco site 2006-6

New Play Concepts

Clay coats in older paleosols

north limb of parabolic dune

Qe1 paleosol

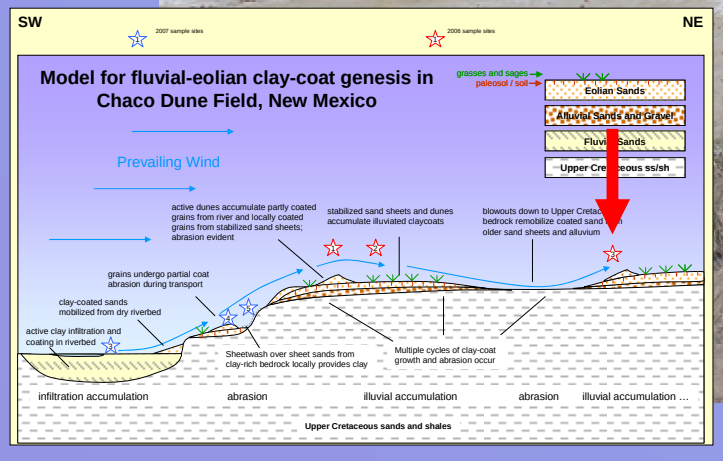
nose of parabolic dune

Interior erosion on nose of dune

Bt soil horizon (clay-rich)

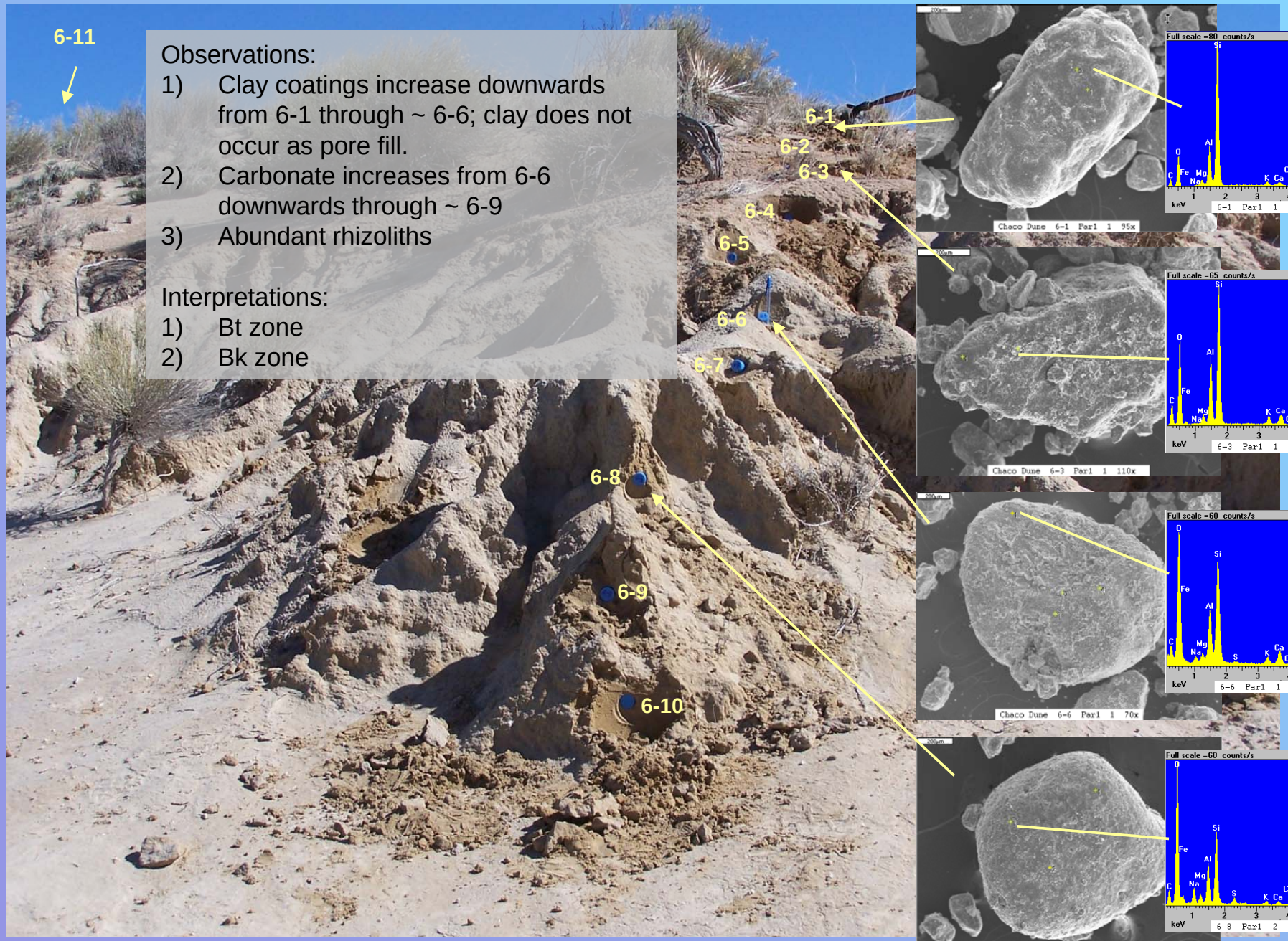
Bk soil horizon (carbonate-rich)

exposed Upper Cretaceous bedrock



Observations/Interpretations at Chaco site 2006-6

New Play Concepts

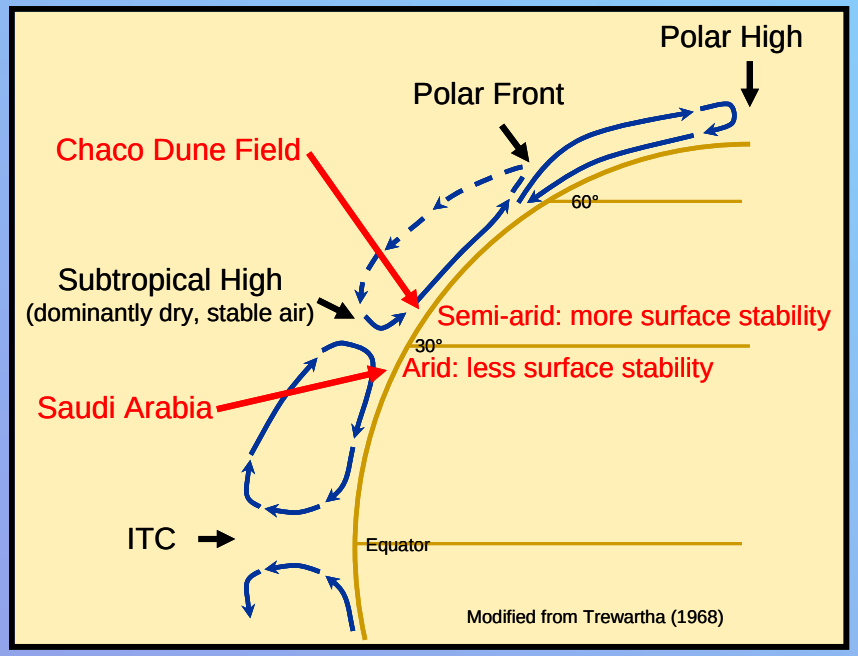


Summary of hypothesis testing at Chaco

New Play Concepts

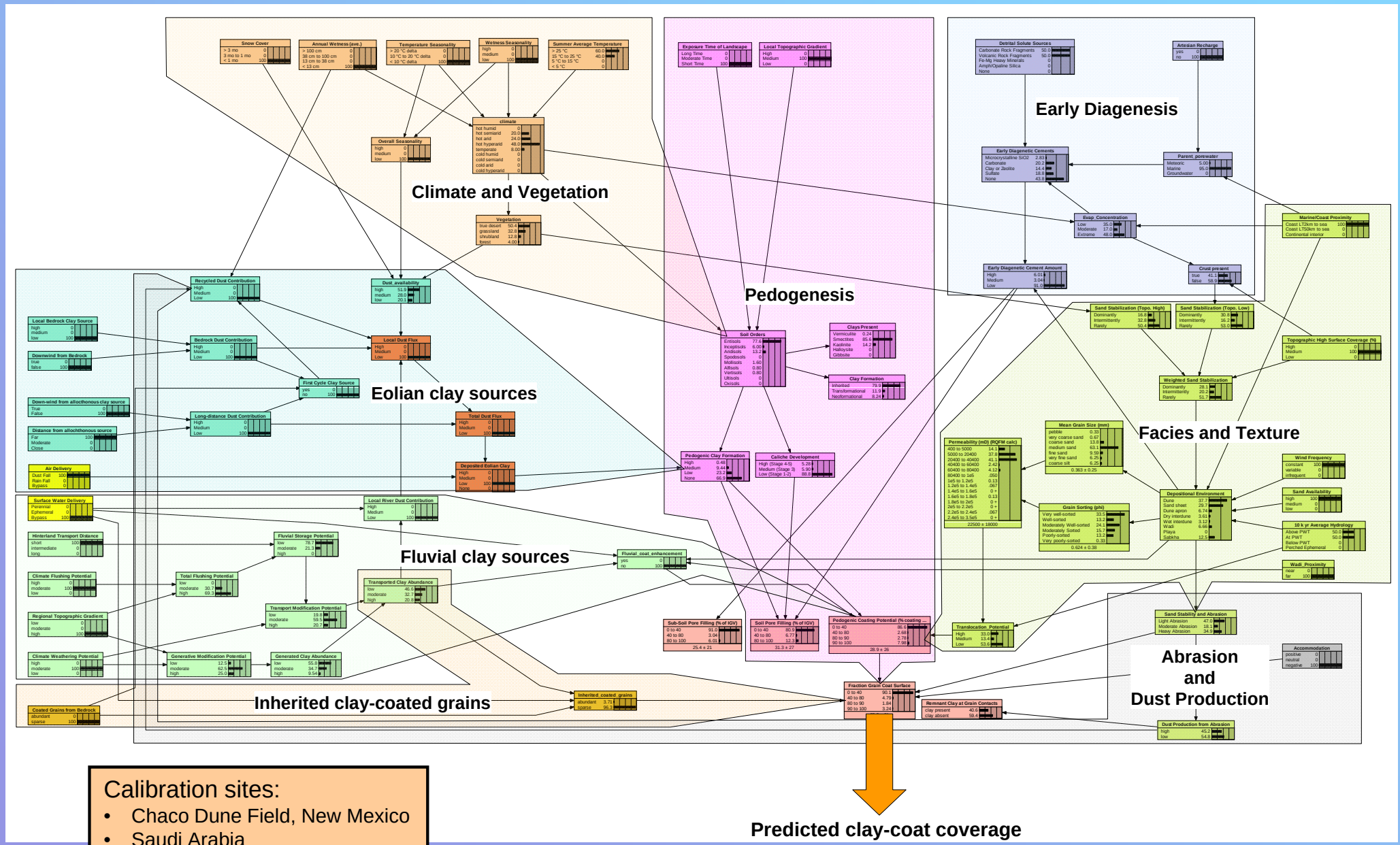
Results of hypotheses testing at Chaco:

- Sand stabilization is required for grain coat development
- Grain coats in eolian systems form very near the surface in association with arid-climate soils
- Grain coats form rapidly
- Clay coats form from eolian dust
- Climate is a key control on surface stability and grain coat development



Prototype Probabilistic Eolian Grain Coat Model

New Play Concepts



Calibration sites:

- Chaco Dune Field, New Mexico
- Saudi Arabia
- Coastal Namib Sand Sea
- Interior Namib Sand Sea

Future Work

New Play Concepts

Analytical Methods:

- SEM-image-analysis grain coat quantification
  - Esch and Rudnicki in progress

Calibration and Testing:

- Refine predictions based on quantitative data from modern study sites
  - Chaco Dune Field
  - Interior and Coastal Namib Desert
  - Saudi Arabia
- Validation ongoing in ancient eolian sandstones

Selected References

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