Analysis and Correlation of Growth Strata of the Lower Dawson Formation: Insight into the Tectono-stratigraphic Evolution of the Colorado Front Range*

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Search and Discovery Article #50908 (2013)**
Posted December 23, 2013

*Adapted from oral presentation presented at AAPG Annual Convention and Exhibition, Pittsburgh, Pennsylvania, May 19-22, 2013

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Abstract

Despite numerous studies of Laramide-style (i.e. basement-cored) structures, their 4-dimensional structural evolution and relationship to adjacent sedimentary basins are not well understood. Analysis and correlation of growth strata along the eastern Colorado Front Range (CFR) help decipher the along-strike linkage of thrust structures and their affect on sediment dispersal. Growth strata, and the syntectonic unconformities within them, record the relative roles of uplift and deposition through time; when mapped along-strike, they provide insight into the location and geometry of structures through time. We present an integrated structural- stratigraphic analysis and correlation of three growth strata assemblages within the fluvial and fluvial megafan deposits of the uppermost Cretaceous to Paleocene Dawson Formation on the eastern CFR between Colorado Springs, CO and Sadalia, CO. Structural attitudes from 12 stratigraphic profiles at the three locales record dip discordances that highlight syntectonic unconformities within the growth strata packages. Ten high-resolution syntectonic unconformities were identified at the Air Force Academy north of Colorado Springs, CO. These syntectonic unconformities provide a window of detail into the kinematics but only two of these could be correlated to the other northward stratigraphic profiles at the Air Force Academy. Three syntectonic unconformities were identified at Wildcat Mountain that correlate to the south with three syntectonic unconformities at Wildcat Tail west of Sedalia, CO. Correlation of the syntectonic unconformities show diachronous development of emerging structures first in the South, then propagating in a northward direction along the eastern side of the CFR. Lithofacies and paleocurrent analysis within the growth strata record the transition from axial fluvial deposition to fluvial megafan deposition. Sediment entry points for megafans were likely controlled by lateral linking of along strike thrust faults (i.e. traverse or transfer zones) that bound the CFR. Provenance analysis supports the linkage of thrust structures controlling the provenance and sediment entry points to the Denver Basin. The study has implication for predicting clastic sediment distribution in punctuated foreland basins, which ultimately controls reservoir presence for conventional plays and clay content for unconventional shale plays.

Selected References

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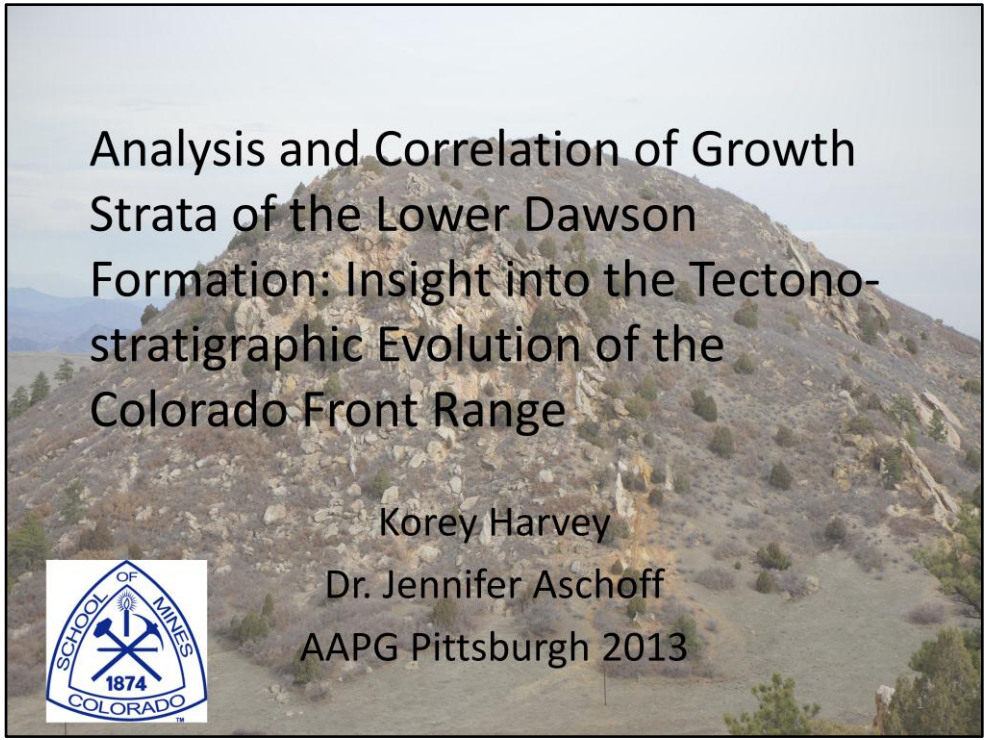

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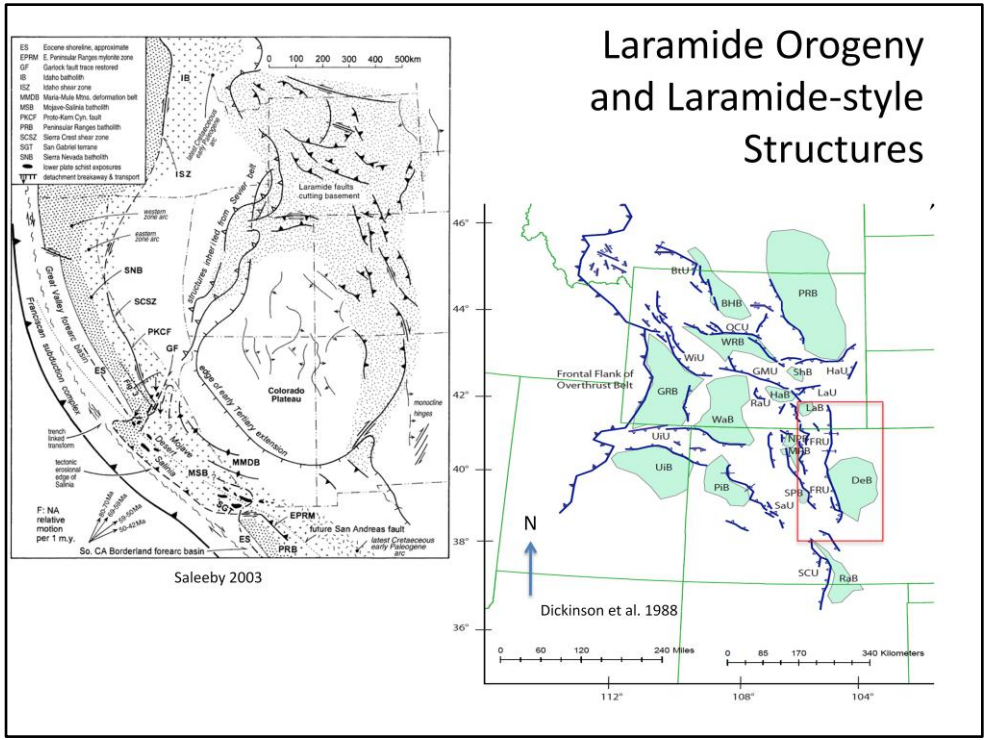
Dr. Jennifer Aschoff

AAPG Pittsburgh 2013

Outline

- Laramide Orogeny and Laramide-style Structures
- Scientific Questions and Methods
- Colorado Front Range and Denver Basin
- Growth Strata and the Colorado Front Range
- Growth strata Architecture and Geometry
- Lithofacies Analysis
- Correlation
- Petrographic Analysis of the lower Dawson Fm.
- Conclusions
- Acknowledgements

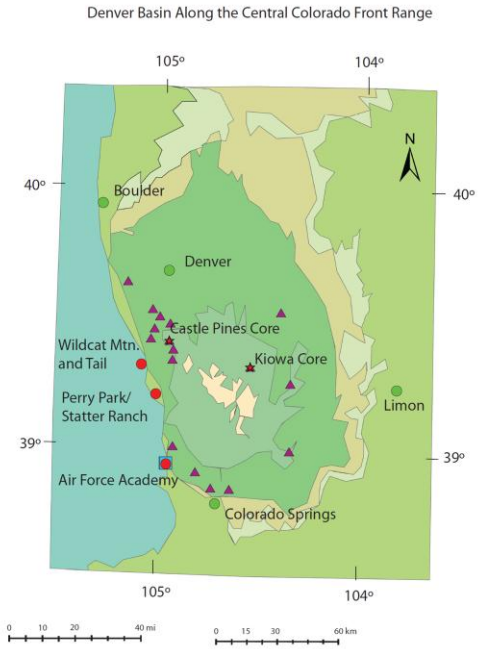


Presenter's notes: Laramide-style uplifts are thick-skinned, basement-cored uplifts with intervening sediment-filled foreland basins. In the central Rocky Mountain region, Laramide uplift began and segregated the foreland basin into discrete local basins. These emerging basement-cored uplifts were the source of orogenic sediment within the localized basins.

Scientific Questions and Methods

- (1) How did basinward-directed thrust faults develop along the strike of the Colorado Front Range?
  - Growth strata analysis at three study sites
  - Along strike correlation
  - Mapping
- (2) How did fault transfer zones control the position of coarse-grained, locally distinct clastic tongues within the lower Dawson Formation (D1) (Cretaceous-Paleocene)?
  - Facies analysis
  - Provenance analysis
  - Mapping

Colorado Front Range and Denver Basin



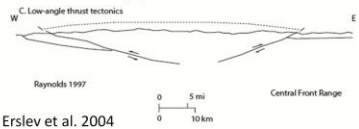
Based on Raynolds (2002)

Explanation

Geological Units

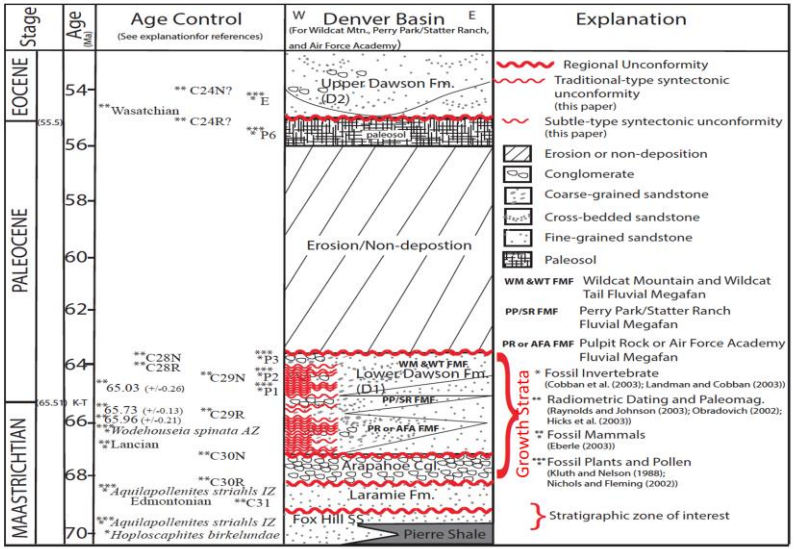
- Castle Rock Conglomerate (~36.7-35.5 Ma)
- Upper Dawson Fm. (D2) (56-55 Ma)
- Lower Dawson Fm. (D1) (67-63.5 Ma)
- Laramie Fm. (69-68 Ma)
- Fox Hills Sandstone (71-69 Ma)
- Pierre Shale and older (up to 70 Ma)
- Precambrian basement (~2.2 Ga-1.7 Ga)

- Paleomagnetism sample locations- Hick et al. (2003)
- Cities
- Field locations
- Core locations
- Palynology sample locations for Kluth and Nelson (1988) and this paper



From Erslev et al. 2004

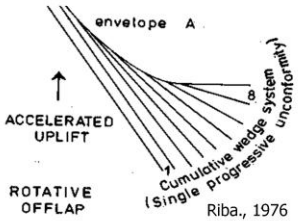
Denver Basin Synorogenic Succession

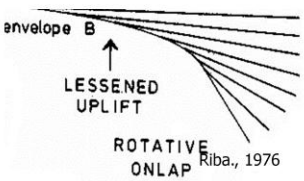


Growth Strata (Progressive Unconformities)

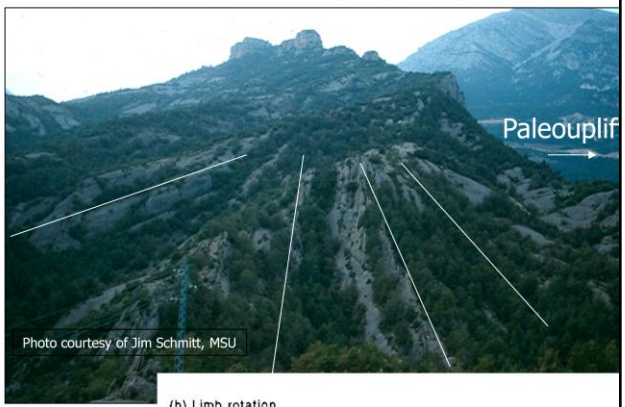
1) "Preorogenic sequence"

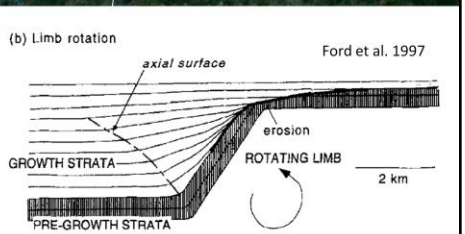
2) "Syntectonic unconformity at active front"





Riba, 1976 (Berga cgl., Spain)



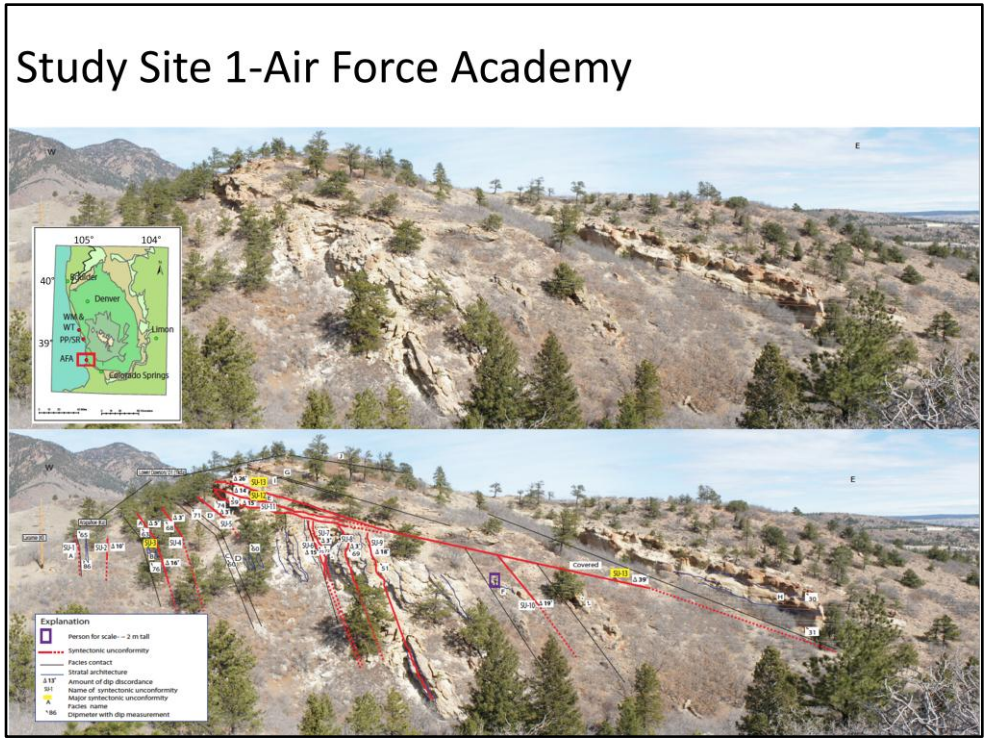


Presenter's notes: Riba first recognized syntectonic angular discordences.
Berga conglomerate unconformably overlies marine marls of the Sant Llorenc dels Morunys Fm.

Growth Strata and the Colorado Front Range

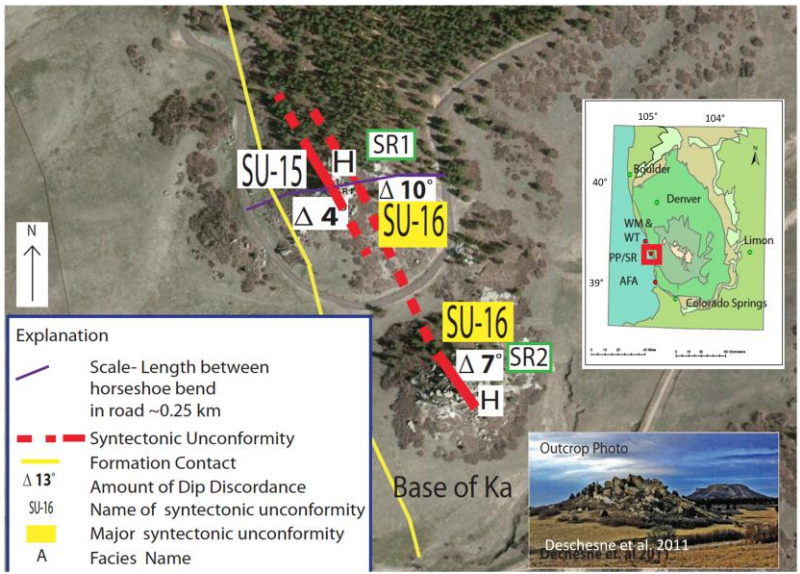
- The number of syntectonic unconformities (SU's) and their amount of dip discordance within growth strata sequences along the eastern CFR has deciphered the location and relative timing of CFR uplift during the Laramide Orogeny
- These SU's record the ratio of uplift to sedimentation through time

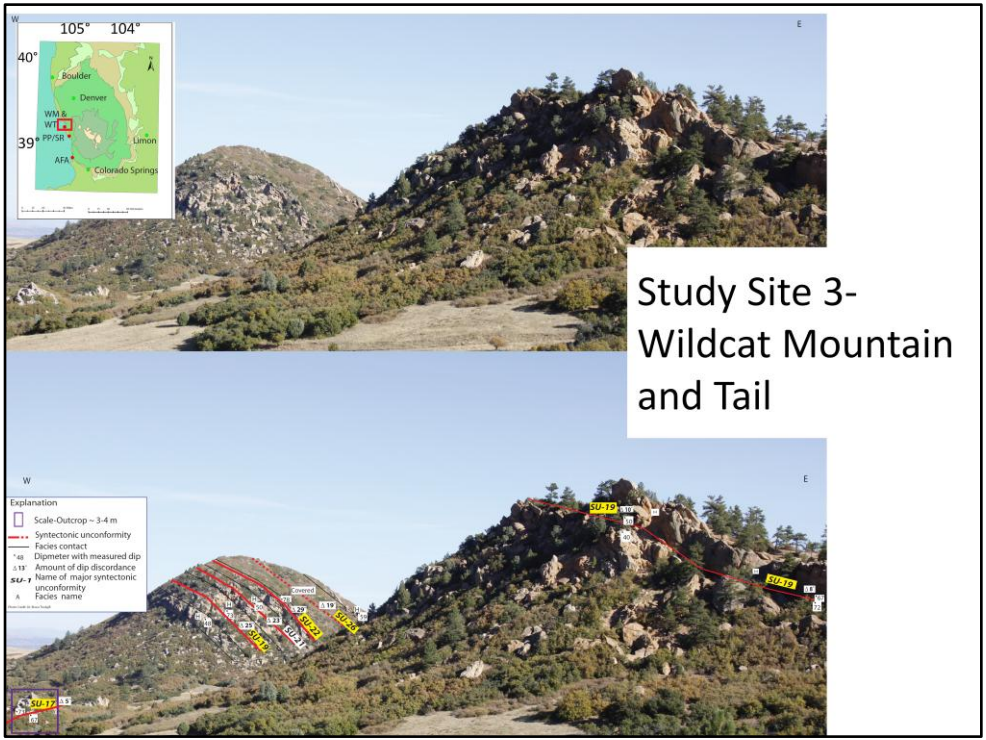
Study Site 1-Air Force Academy



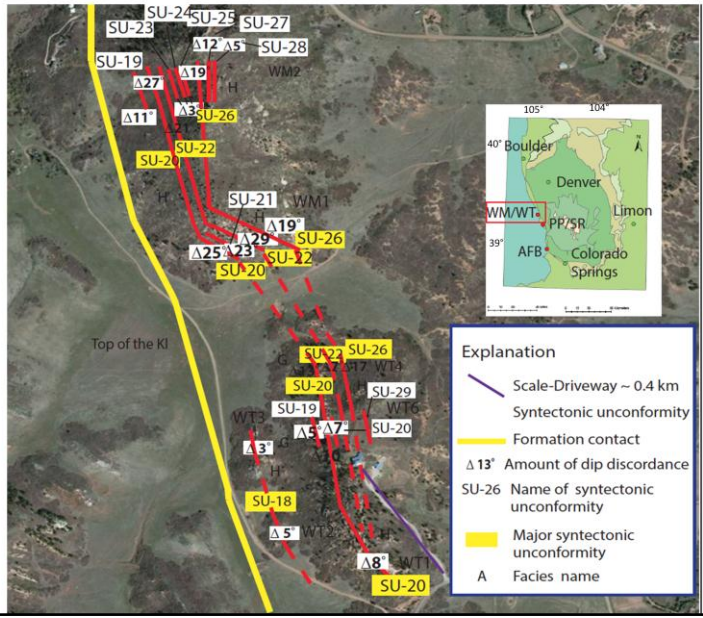
Presenter's notes: The tapering or fanning upward geometry is defined by the change in structural dip or dip discordance.
External growth strata geometries vary in relation to uplift history of an area and its on sedimentation in that area.
There is variation between all the outcrops along the CFR

Study Site 2-Perry Park




W
E
105°
104°
40°
39°
Boulder
Denver
WM &
WT
PP/SR
Limon
AFA
Colorado Springs
Study Site 3-
Wildcat Mountain
and Tail
W
E
Explanation
Scale-Outcrop ~ 3-4 m
Syntectonic unconformity
Facies contact
Dipmeter with measured dip
Amount of dip discordance
Name of major syntectonic unconformity
Facies name
SU-19
SU-18
SU-17
SU-16
SU-15
SU-14
SU-13
SU-12
Covered

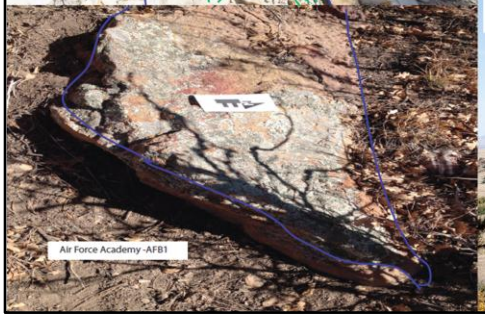
Study Site 3-Wildcat Mountain and Tail

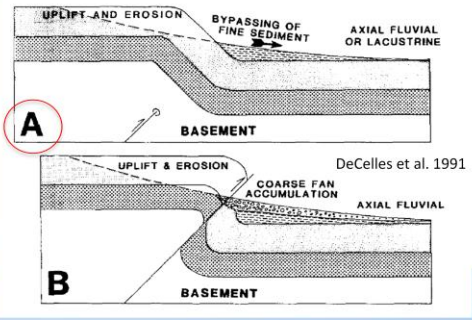


Lithofacies Analysis

- Facies Associations
  - Association 1: Fluvial (confined) (6 lithofacies)
    - Description: mudstones to pebbly sandstones, lenticular bed geometry, and unidirectional paleoflow
    - Interpretation: axial fluvial deposits either braided or meandering in nature, deposited during the onset of Laramide uplift along the CFR
  - Association 2: Unconfined Fluvial /Megafan (4 lithofacies)
    - Description: mudstones to conglomerates, tabular bed geometry, and unidirectional paleoflow with a radiating pattern
    - Interpretation: fluvial megafan deposits that developed as bounding thrust faults along the CFR began to link and control sediment entry points into the Denver Basin

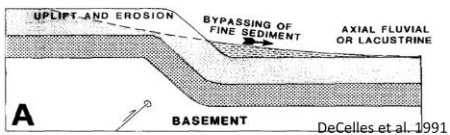
Facies Association 1-Fluvial (confined)



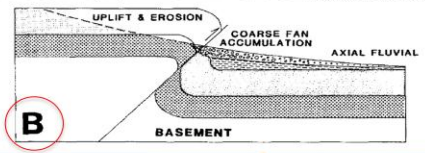


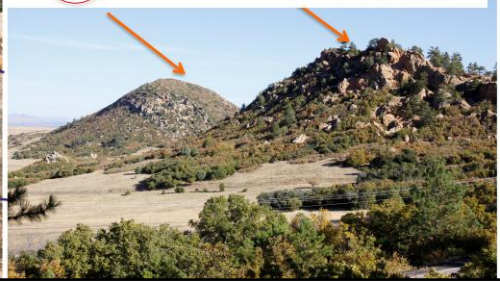
DeCelles et al. 1991

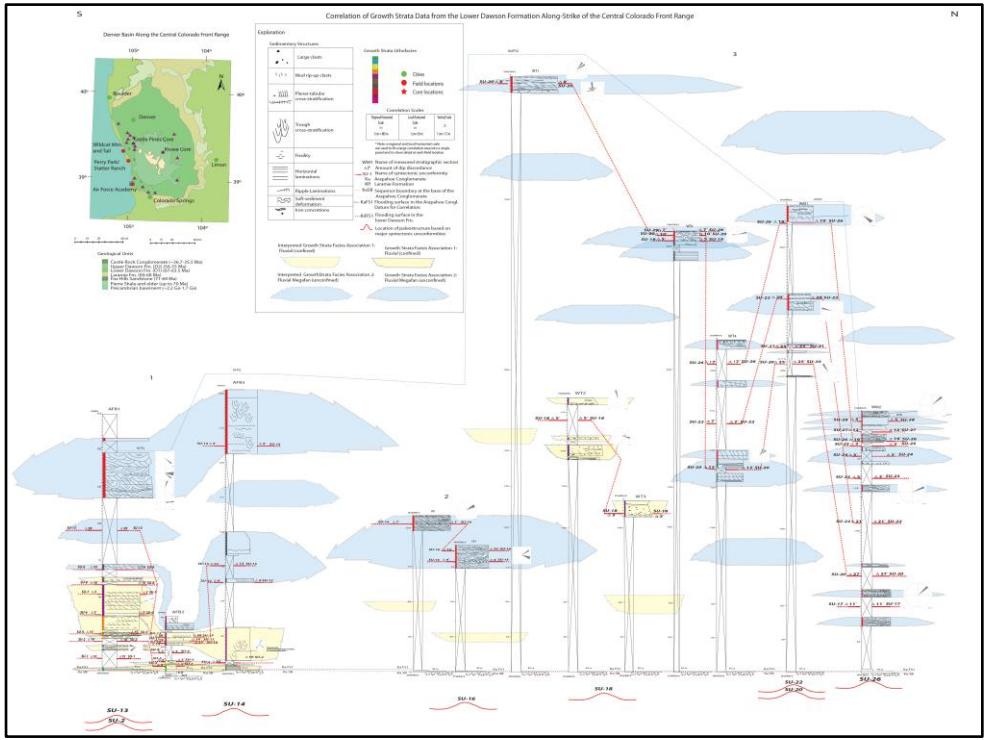
Facies Association 2- Unconfined Fluvial/ Megafan



DeCelles et al. 1991







Presenter's notes: KaSB- Arapahoe sequence boundary; base of Arapahoe Conglomerate

KaFS1- Flooding surface within the Arapahoe Conglomerate; recognized by a change from coarse to fine-grained axial fluvial material representing a change in accommodation

KdFS2- Flooding surface near the top of the lower Dawson Formation; recognized by a change from coarse-grain fluvial megafan material to fine-grained fluvial megafan material

AFB

Stratal thinning to the south towards AFB1

SU-2 and SU-13 correlate across all three sections indicating that the events represented by these were locally extensive

Perry Park

Increase in dip discordance and SU abundance to the north

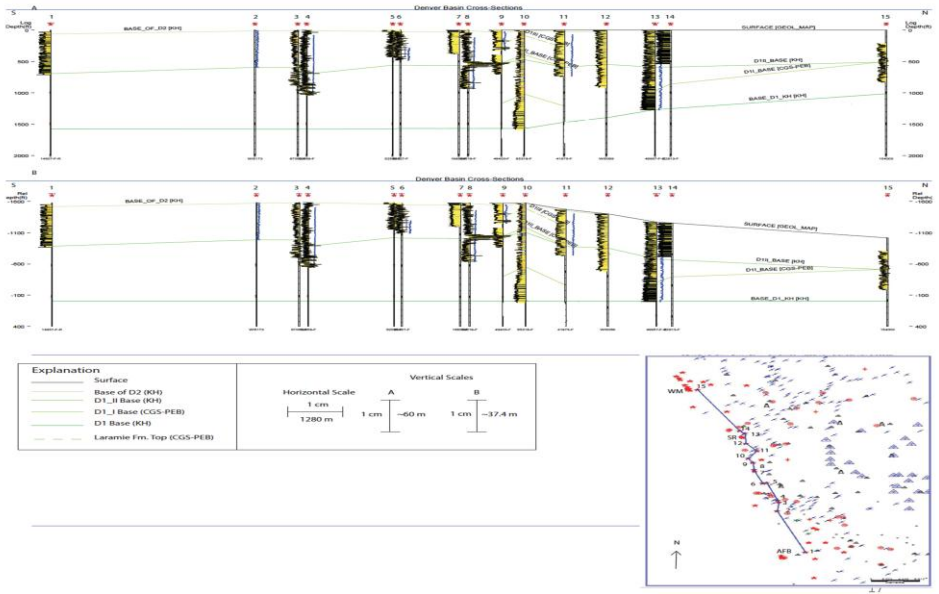
SU-16 increases in dip discordance across the outcrop supporting the "twisting of the ribbon" geometry

Wildcat Mountain/Tail

Increase in SU abundance and overall dip discordance to the north (Wildcat Mountain)

SU's identified in outcrop. 8 major SU's- SU-2 (AFB1,2,3); SU-13 (AFB1,2,3); SU-14 (AFB3); SU-16 (SR1,2); SU-18 (WT2,3); SU-20 (WT1, WT6, WT4, WM1, WM2); SU-22 (WT4, WM1, WM2); SU-26 (WT4, WM1, WM2)

Subsurface Correlation



Presenter's notes: Both gamma-ray and resistivity

Color scale was modified for the GR so that the large GR spikes represent very arkosic sandstone. This could be misleading because they are in the range of a "hot shale" due to their high potassium-feldspar content.

Identified surfaces:

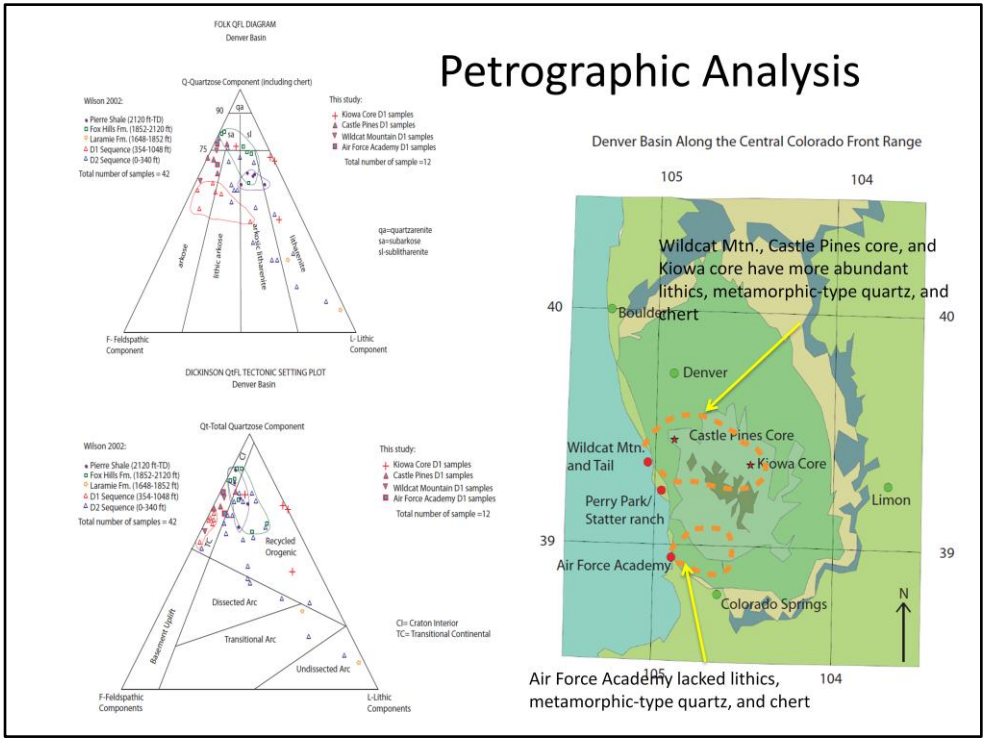
Base of the D1- top of Wildcat Fan/Arapahoe Aquifer (Arapahoe conglomerate and Dawson Formation); identified in the resistivity logs as a low resistivity followed by a high resistivity that marks the surface; chosen as the datum in this correlation because it marks a change from more proximal fan advancement to fans in the lower Dawson Formation reaching further eastward within the basin

Base of the D1 I- CGS

Base of the D1 II- sub-unit within the lower Dawson Formation; picked by me at a change from a low gamma-ray to a high gamma-ray spike often at the base of the large arkosic GR spikes

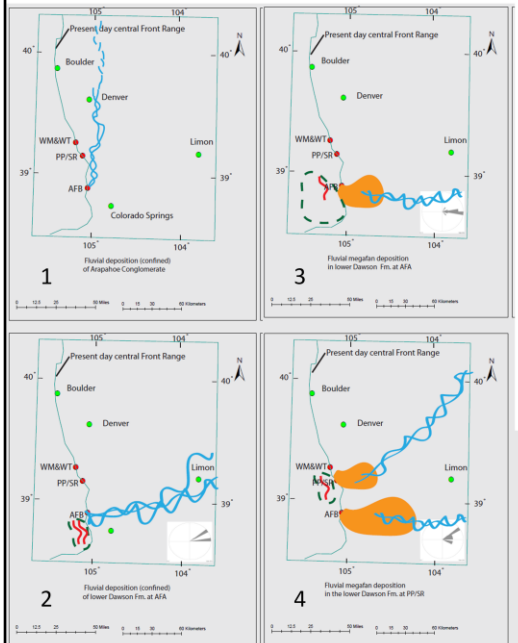
Base of the D1 III- CGS

Base of the D2- picked at an increase in the GR near the top of the log



Presenter's notes: Folk Diagram with this paper's work and previous work by Wilson 2002 on the D1
Wilson 2002's data plots in the arkose, lithic arkose, and arkosic litharenite region of the diagram
Samples from the Castle Pines core, Wildcat Mountain, and the Air Force Academy plot in the arkose and subarkose regions
Samples from the Kiowa core plot in the subarkose and litharenite regions of the diagram

Conclusions: Lateral Fault Linking and Sedimentation



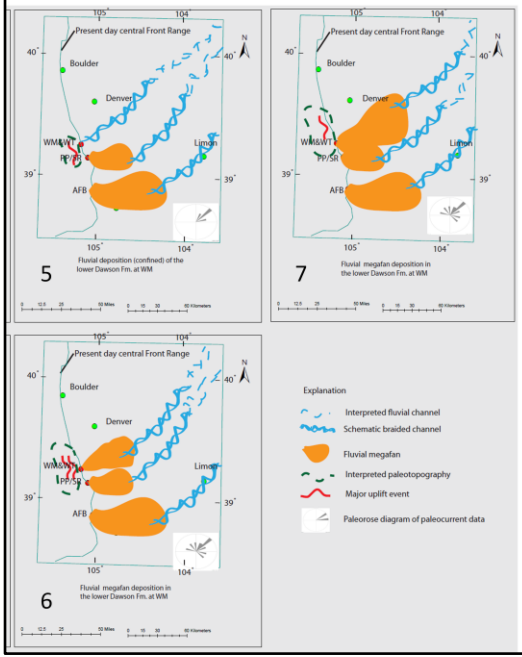
1- Fluvial (confined) deposition of Arapahoe Conglomerate

2- Emergence and early development of structures in the southern portion of the CFR near Colorado Springs, CO and fluvial (confined) deposition in the lower Dawson Formation

3- Continued development of structures in the southern CFR but a shift in deposition from fluvial (confined) to unconfined fluvial/ megafan

4-Propagation northward of structures to the Perry Park area and continued unconfined fluvial/ megafan deposition

Conclusions: Lateral Fault Linking and Sedimentation



5- Emergence and early development of structures in the northern part of the CFR near Sedalia, CO and fluvial (confined) deposition within the lower Dawson Formation

6-Propagation northward of structures towards Wildcat Mountain and a shift to unconfined fluvial/ megafan deposition

7-Continued propagation northward to the north side of Wildcat Mountain and continued unconfined fluvial/ megafan deposition

- Development of Laramide-style structures along strike of the eastern CFR was diachronous from South to North (based on syntectonic unconformity identification and correlation)
- Deposition of the lower Dawson Fm. was first fluvial (confined) then unconfined fluvial/megafan

Acknowledgements

- Funding: RMAG Babcock Scholarship, Wyoming Geological Association Dr. J. Love Field Geology Scholarship, SEPM Research Fund, and the CSM GE department Nikki Hemmesch fellowship
- Advisor: Dr. Jennifer Aschoff
- Committee: Dr. Bruce Trudgill and Dr. Chuck Kluth
- Colorado Geological Survey and Dr. Peter Barkmann
- Denver Museum of Nature and Science and Dr. Bob Raynolds
- Field Assistants: Michele Wiechman, Zane Houston, Erich Heydweiller, and Patrick Geesaman
- Department of Wildlife and Fisheries at the U.S. Air Force Academy- Dr. Brian Mihlbachler and Greg Speights
- Kamil Tazi for land access
- Fred and Diane LaRoche for land access

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