Distinguishing Climatic from Autogenic Signatures in Alluvial Systems: A Quaternary Perspective with Implications for the Rock Record*

Adrian Hartley[1], Gary S. Weissmann[2] and Sophie Leleu[3]

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[1]Geology, University of Aberdeen, Aberdeen, United Kingdom (a.hartley@abdn.ac.uk)
[2]Earth Sciences, University of New Mexico, Albuquerque, NM
[3]Geology, University of Aberdeen, Aberdeen, United Kingdom

Abstract

To distinguish between the influence of climatic and autogenic controls on continental basin-fill successions, a high resolution chronostratigraphic scheme is required that can be applied to successions with a well known climate history, which largely limits examples to the Quaternary period. Alternatively, sedimentary deposits considered indicative of specific climatic conditions (e.g. evaporites, coals, lake deposits etc.) can be used to constrain climate in the basin, but do not contain information on the climate in the catchment. Climate in the catchment controls sediment supply to the basin and strongly influencing the development of fluvial successions in continental basins. The recognition of the distinction between the influence of climate in the catchment from climate in the basin is crucial to understanding alluvial architecture in continental basins.

Quaternary examples from the Basin and Range, Gulf of Mexico, Venice Basin and San Joaquin Basin are used to illustrate the importance of the climate regime in the catchment as a control on alluvial architecture. These examples show that: 1) sediment supply in the same basin can be at a maximum or minimum during either glacial or interglacial times, 2) adjacent alluvial systems can have a completely different stratigraphic architecture due to different catchment climate regimes and 3) marine connected incised valley-fill successions can be cut and filled during either the LGM or during post-LGM interglacial conditions.

These examples illustrate that one of the most important controls on alluvial architecture is the climate in the catchment and that predicting/invoking climate change as a control on alluvial architecture in the rock record will be extremely difficult to determine. Whilst it is recognised that the examples used to illustrate these points are developed during icehouse conditions, it is likely that climatic fluctuations during greenhouse conditions would be much more subtle and difficult to constrain, particularly as evidence for climate in the catchment is not preserved in the rock record.

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Adrian Hartley, Gary Weissmann*

& Sophie Leleu

UNIVERSITY OF ABERDEEN

*THE UNIVERSITY of NEW MEXICO

Rationale

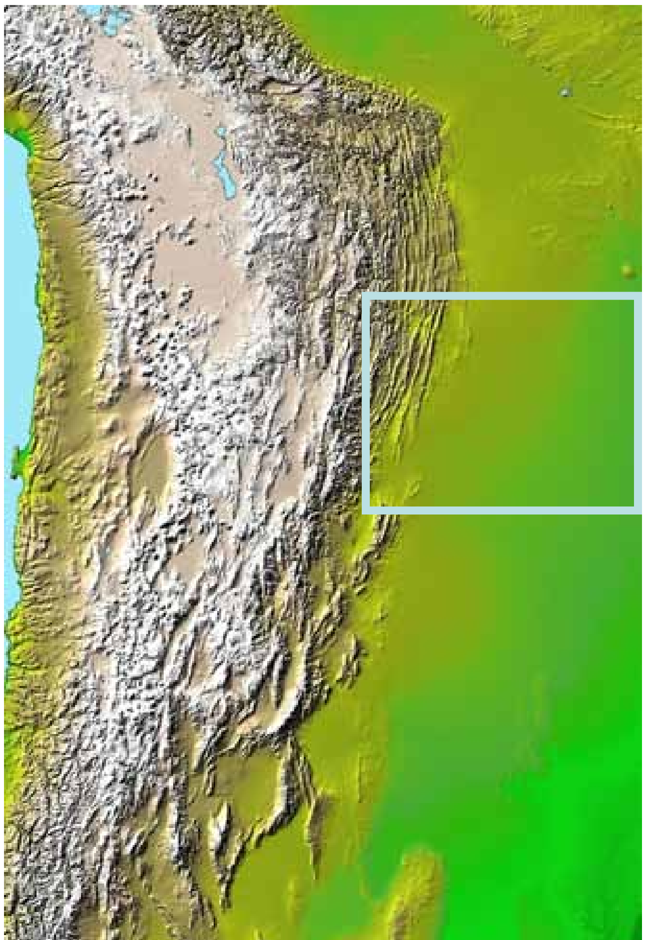
- Climate is often implicated as a control on continental sedimentary successions
- The nature of the climate control is rarely constrained
- To understand climate signatures in continental successions need to study areas with well constrained climate record

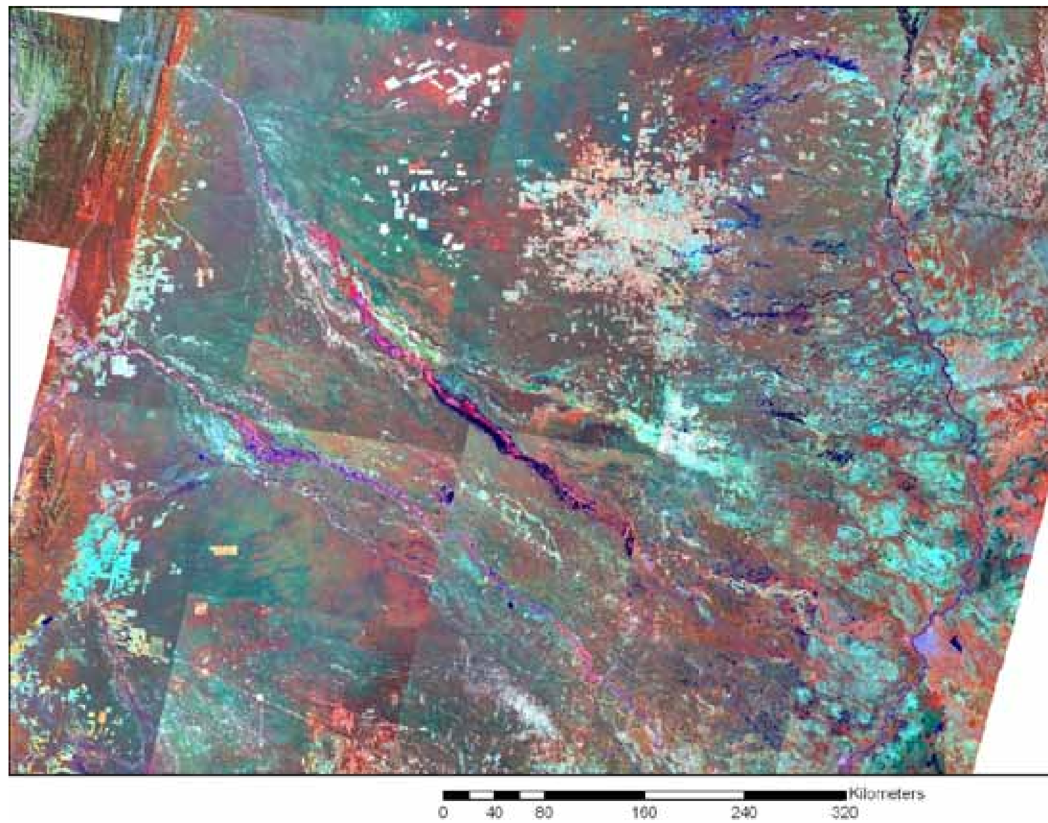
Outline

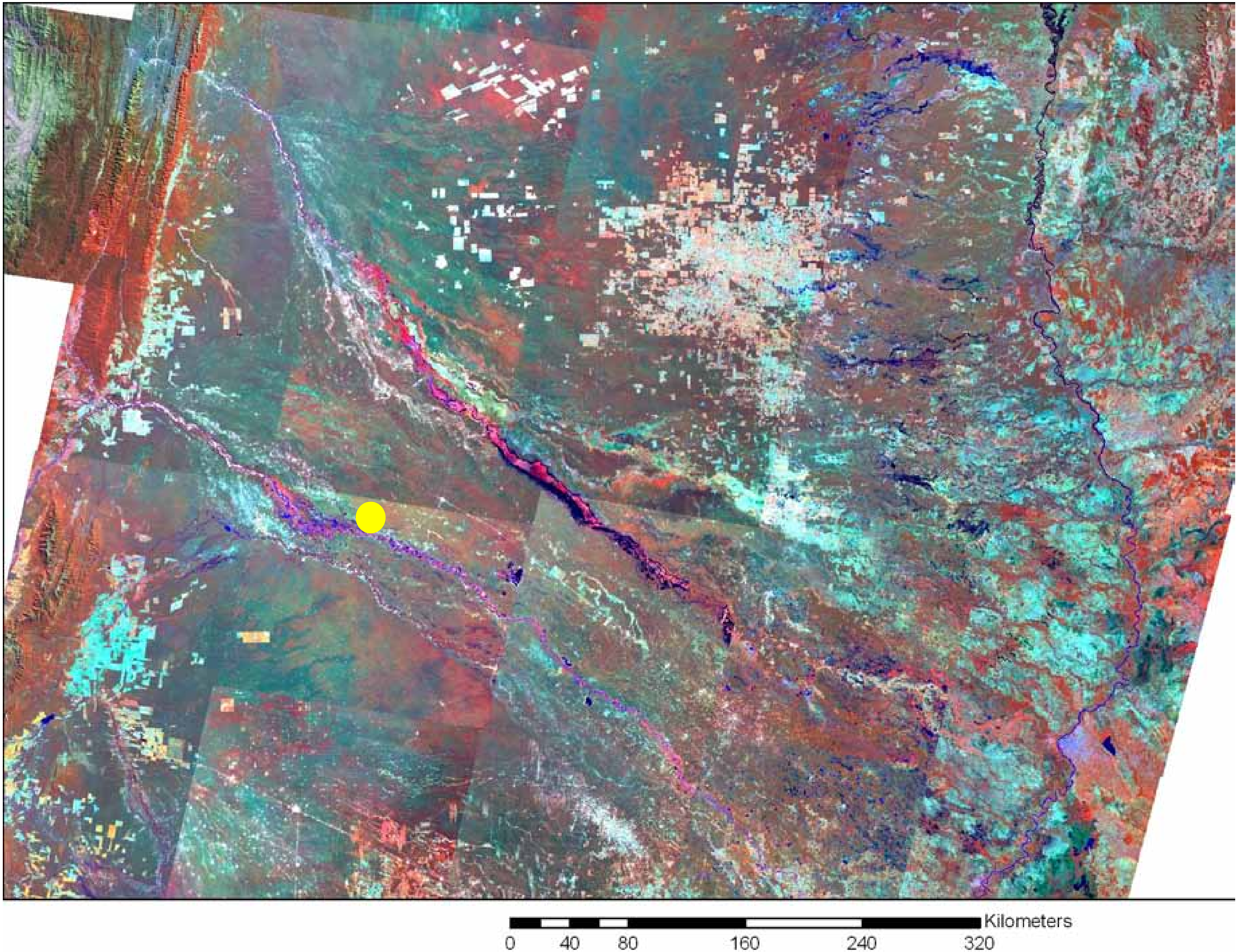
- Climate signatures
  - Modern day examples
    - Soils: Andean foreland, Argentina
    - Fluvial planform
- Climate signatures
  - Quaternary examples
    - San Joaquin Basin
    - Basin and Range
    - Venetian Basin
- Conclusions

Climate signatures: soils

- Distributive fluvial systems, Argentina



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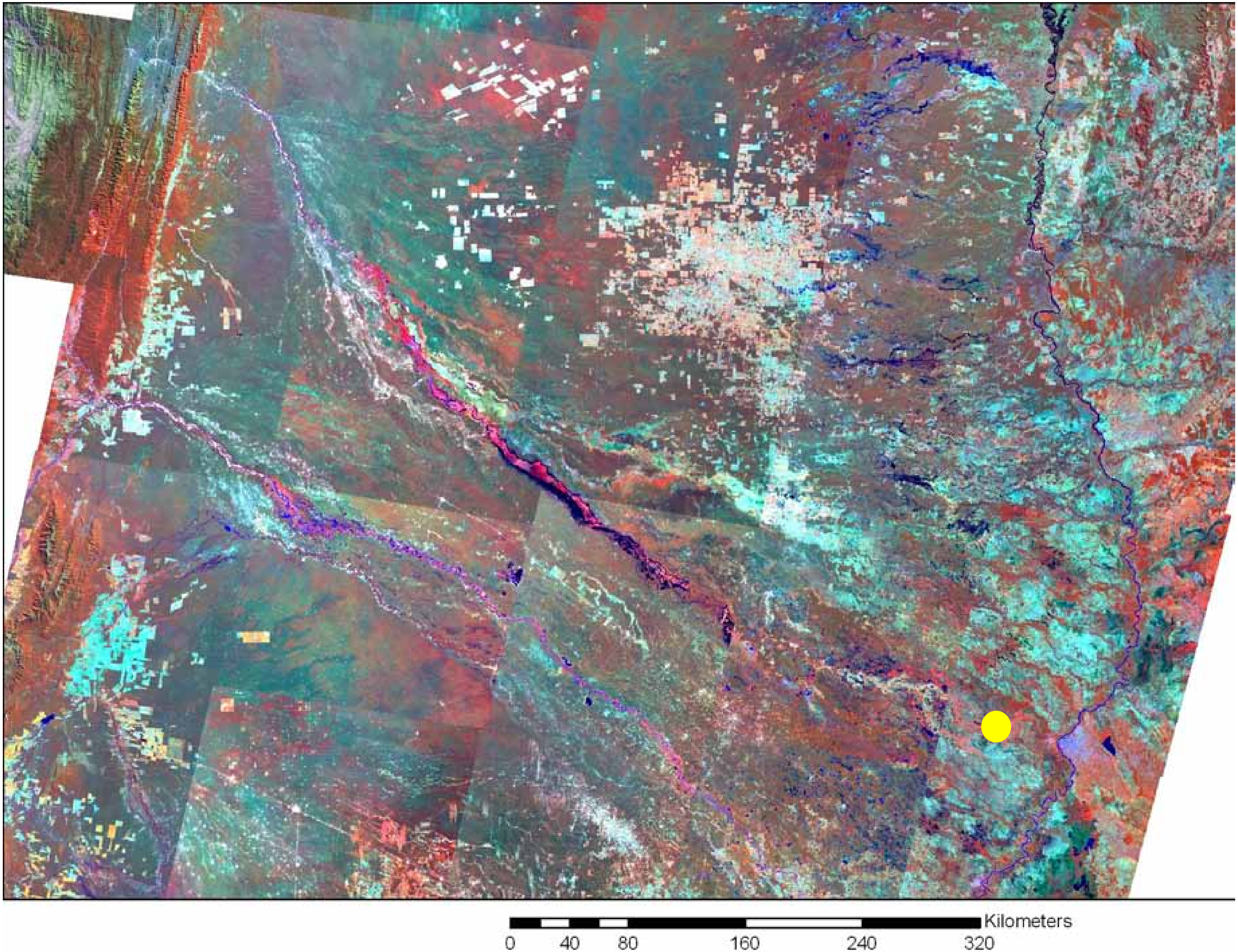

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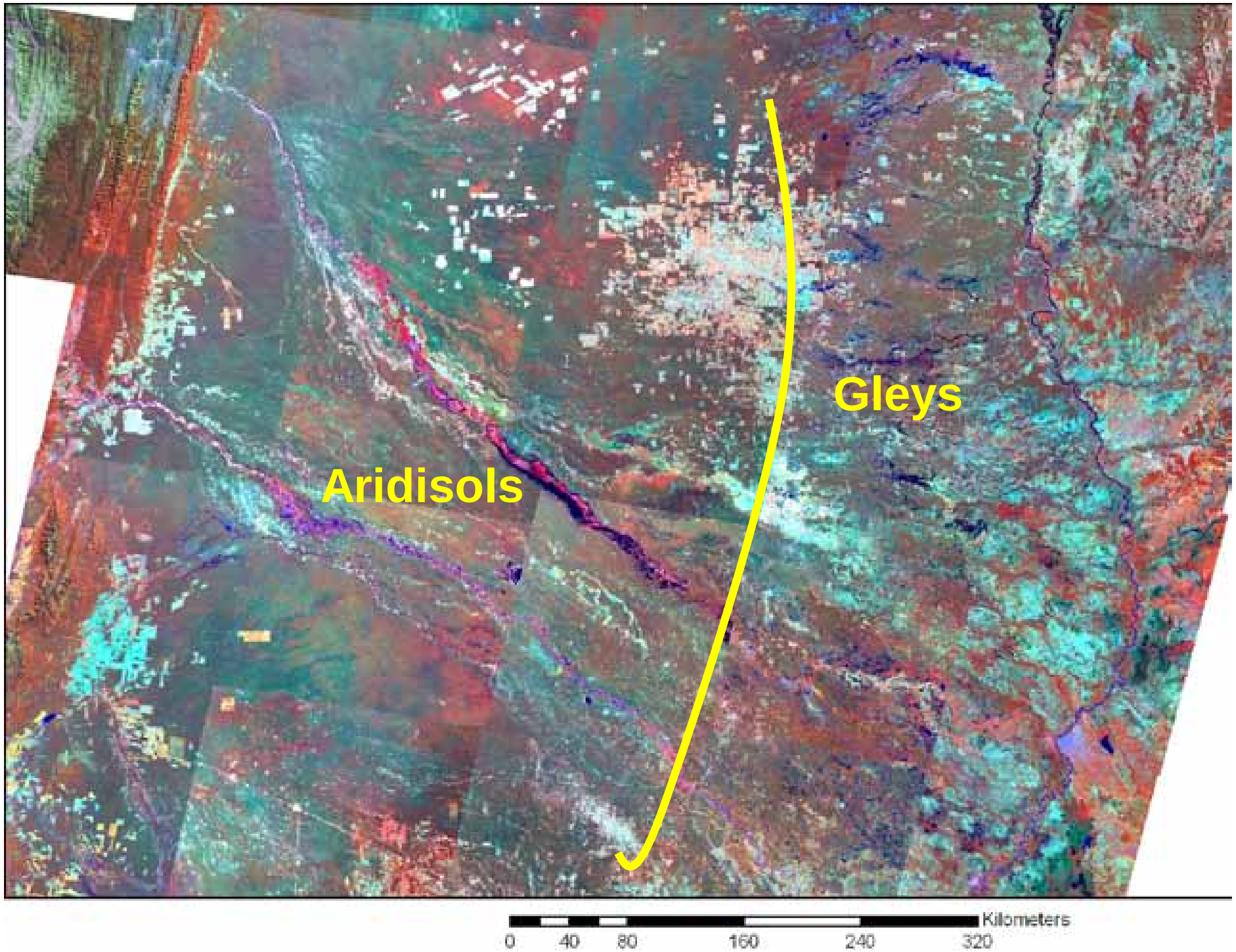
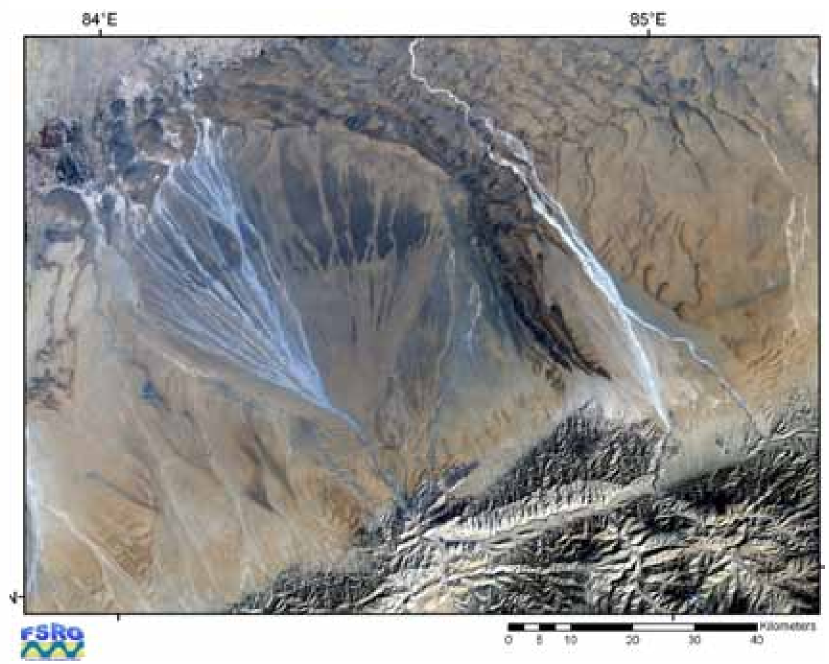
Climate signatures: soils



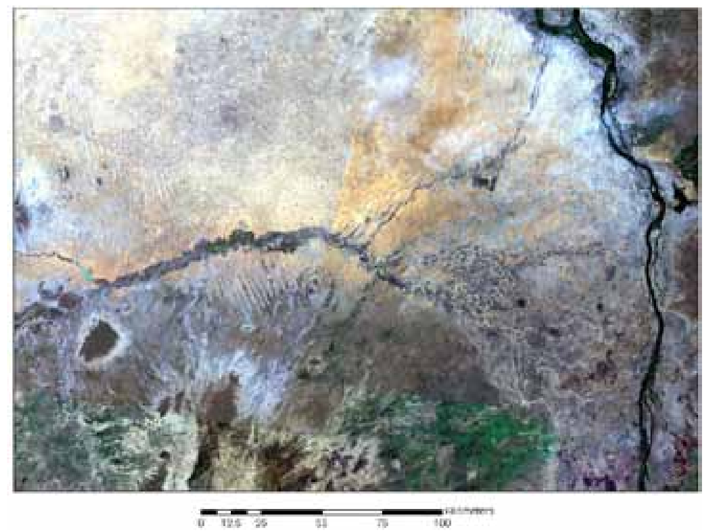
Climate Signatures: Fluvial planform

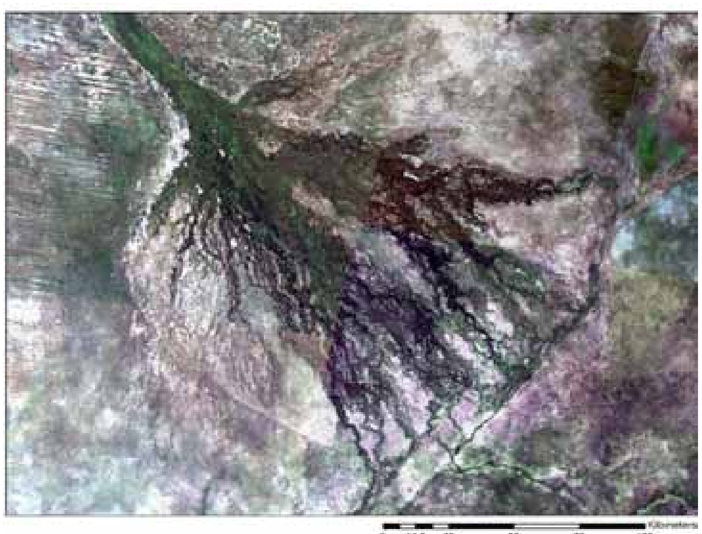
- Climate signatures only give an indication of the climate in the basin yet are often used to infer fluvial planform
  e.g. coal = meandering, arid soils = sheet-like braided system

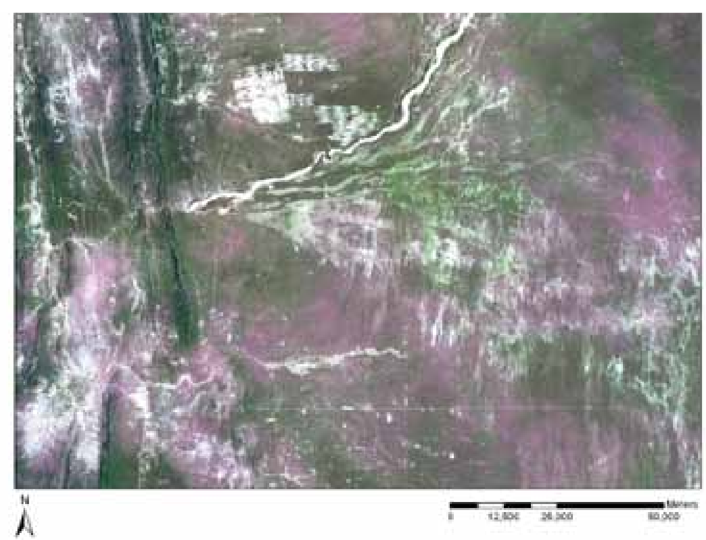


Relationship between fluvial planform and basin climate

- Drylands climate

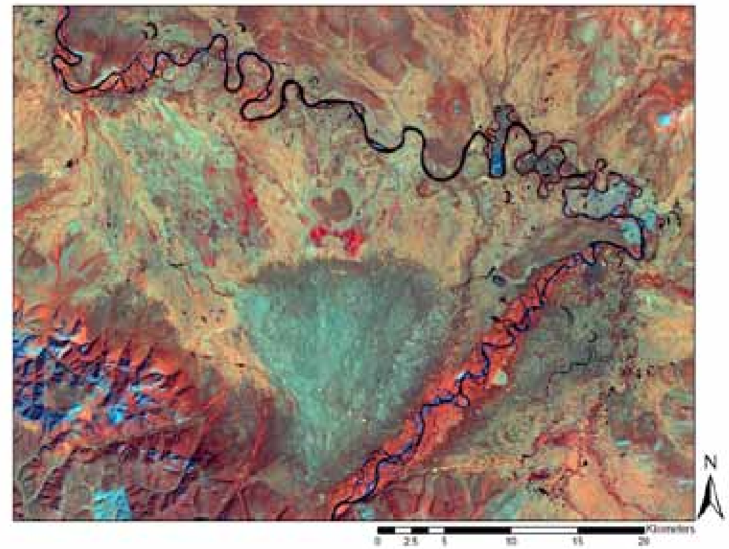


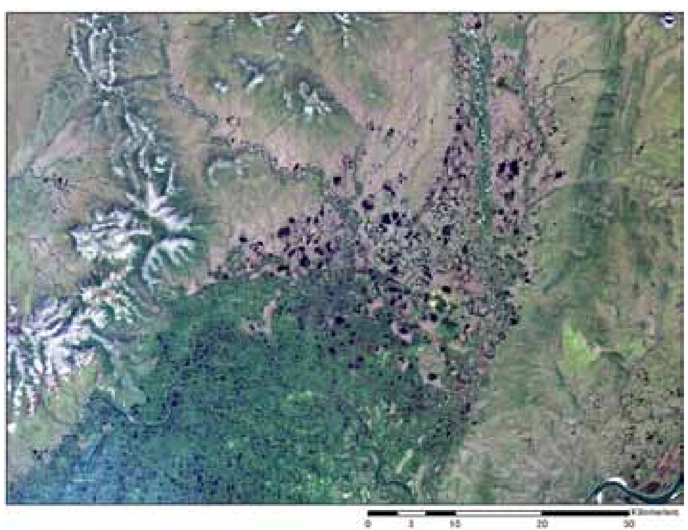


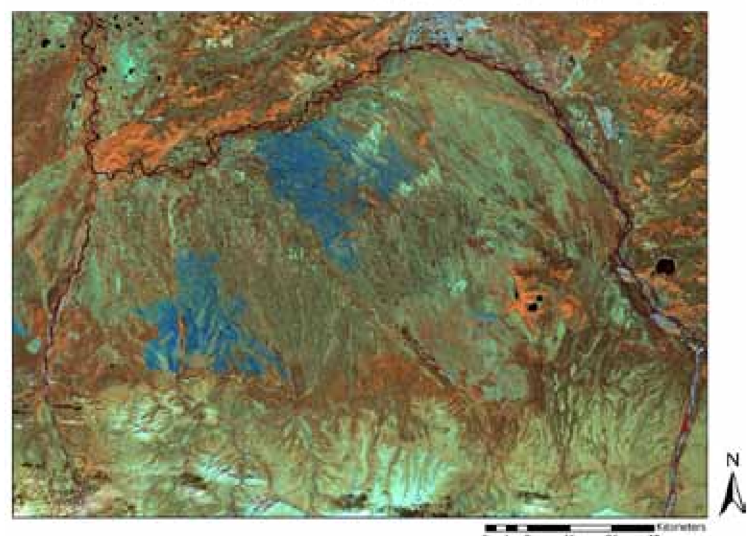


Relationship between fluvial planform and basin climate

- Subpolar climate







Controls on fluvial planform: basin climate

Climate / **Planform type**	continental	dryland	subtropical	tropical	polar
Braided bifurcating	2	116 (28%)	12	12	11
Single braided	9	25	14	10	1
Single major sinuous	7	13	2	20	1
Braided to sinuous	16	48 (12%)	7	15	3
Single sinuous bifurcating	-	24	-	13	1
Multithread sinuous	-	17	2	8	-

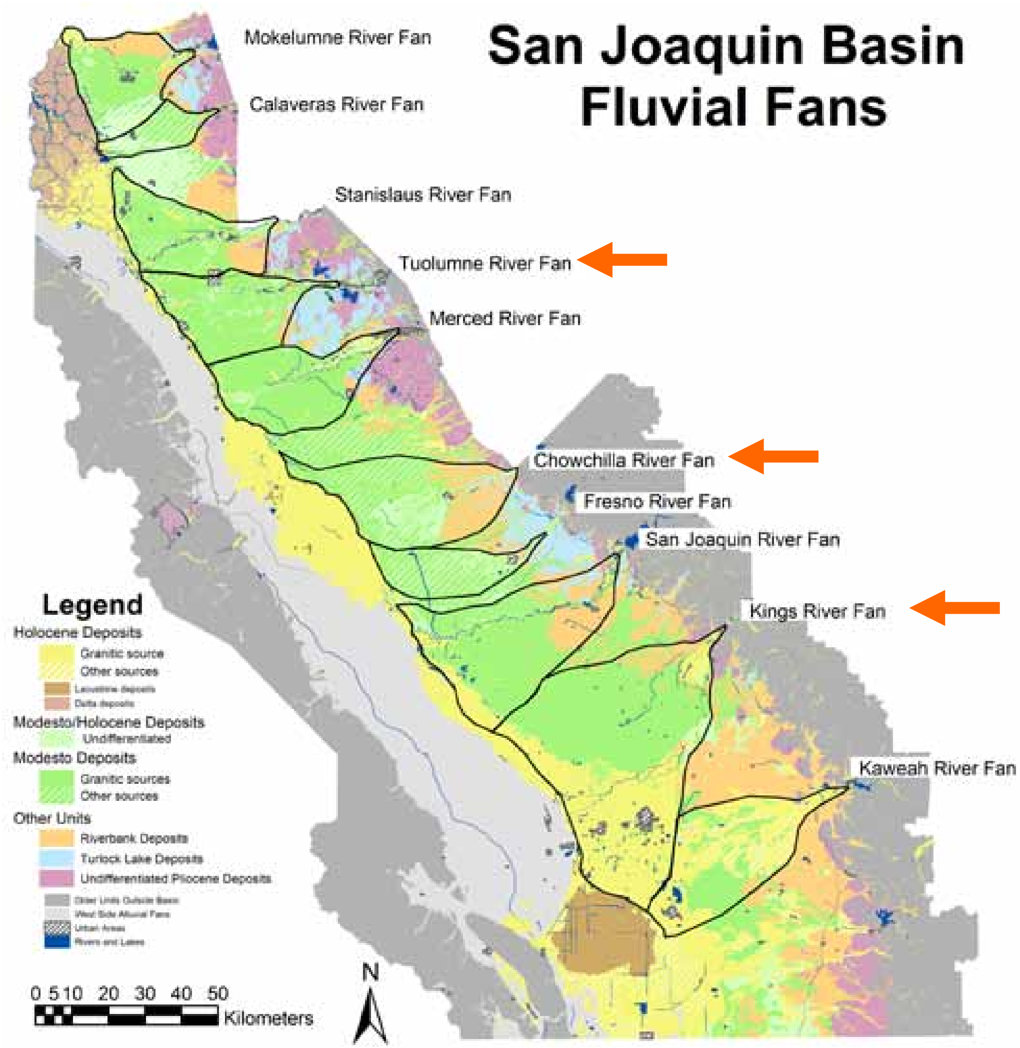
Hartley et al 2010 JSR

- No relationship between climate and planform
- Climate in catchment is most significant control

Stratigraphic response to Quaternary climate change

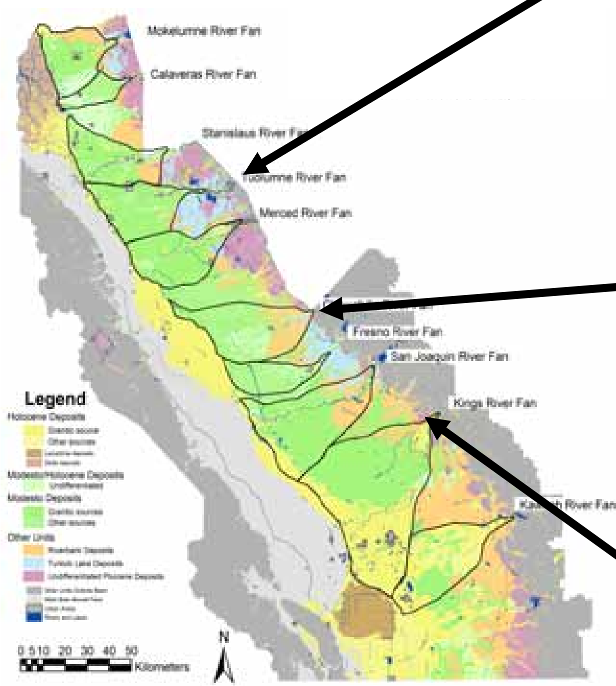
- San Joaquin Basin
- Basin & Range
- Venetian-Friulian Basin

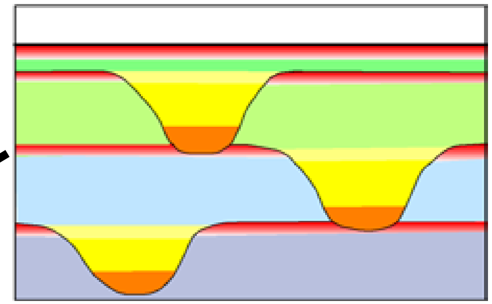
Stratigraphic response to climate change: Quaternary of San Joaquin Basin



After: Weissmann et al 2005

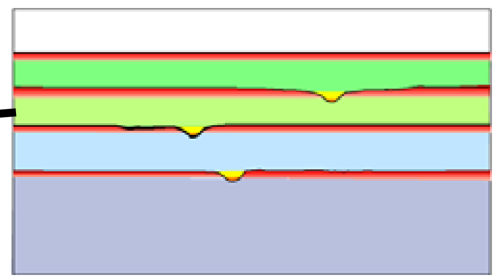
San Joaquin Basin





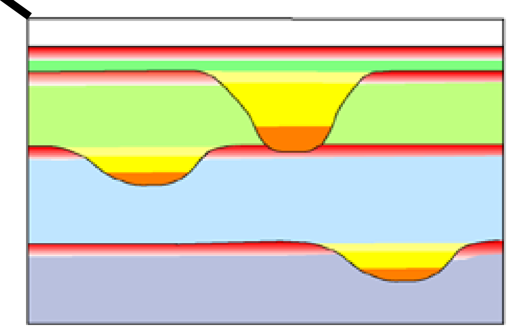
Tuolumne River Fan (glacial source; low subsidence):

- **Laterally-stacked sequences basinward**
- **Significant incised valley fill deposits; modern incised valley is ~30m deep**
- **No preservation of interglacial deposits in distal fan**



Chowchilla River Fan (foothill source; moderate subsidence):

- **Laterally-stacked sequences basinward**
- **No incised valley fill deposits; modern channels underfit**
- **Open-fan fluvial deposits that radiate outward from intersection point**
- **Interglacial deposits preserved on distal fan**



Kings River Fan (glacial source; high subsidence):

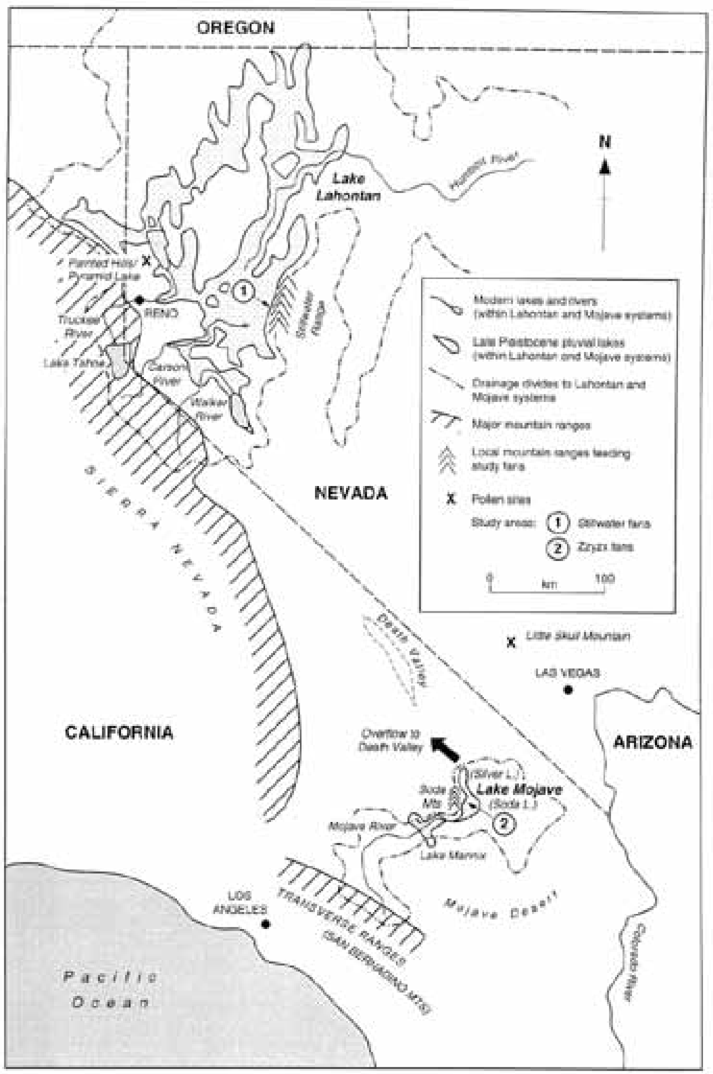
- **Vertically-stacked sequences near apex**
- **Significant incised valley fill deposits, modern incised valley is ~10m deep.**
- **Large, relatively thick open-fan fluvial deposits that radiate outward from intersection point near apex**
- **Preservation of interglacial deposits in basin**

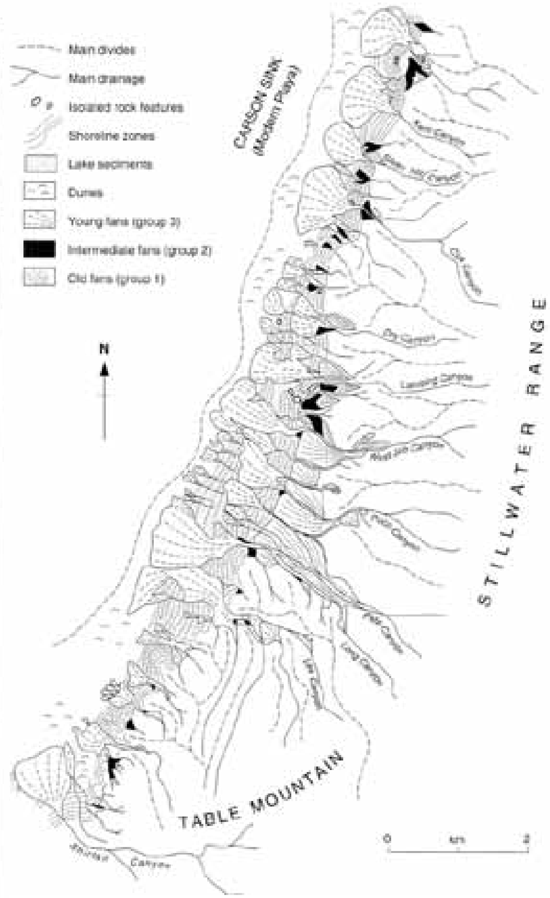
After: Weissmann et al 2005

Summary of response to climate change in Quaternary of San Joaquin Basin

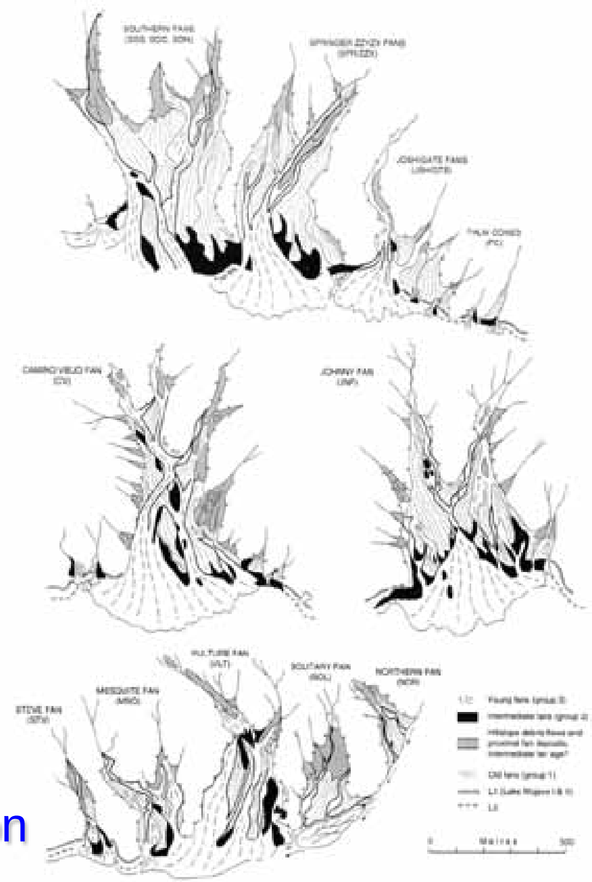
- In adjacent fans have different rates of:
  - Sedimentation
  - Soil development
  - Incision
- Can correlate using interfluve soils but they display different stages of maturity

Stratigraphic response to climate change: Quaternary of Basin & Range





Pleistocene aggradation
Holocene incision



Pleistocene incision
Holocene aggradation

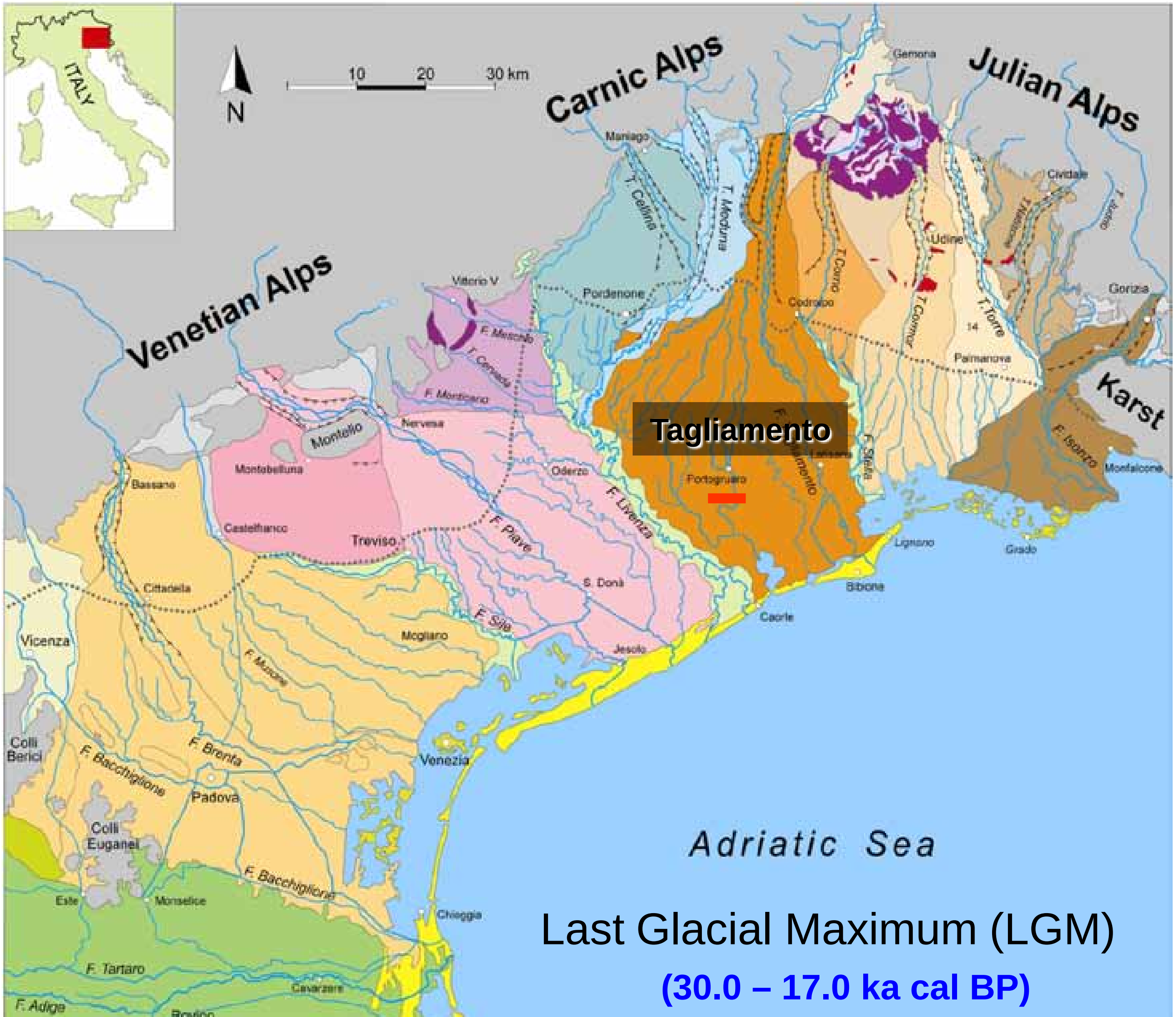
After: Harvey et al 1999

Summary of response to climate change in Quaternary of Basin & Range area

	Paraglacial	Arid + monsoons	Arid/semi arid
Holocene (dry)	Incision	Incision	Aggradation
		Aggradation	
Late Pleistocene (wet)	Aggradation		Incision
Examples:	Kings River and San Joaquin Valley Fans (Weissman et al. 2002), Montana (Ritter et al. 1995)	Providence Mountains Fans/ Mojave Desert (McDonald et al. 2003) (Bull, 1991)	Leidy Creek Fans White Mountains (Reheis et al. 1996)

Compiled by Archer 2006

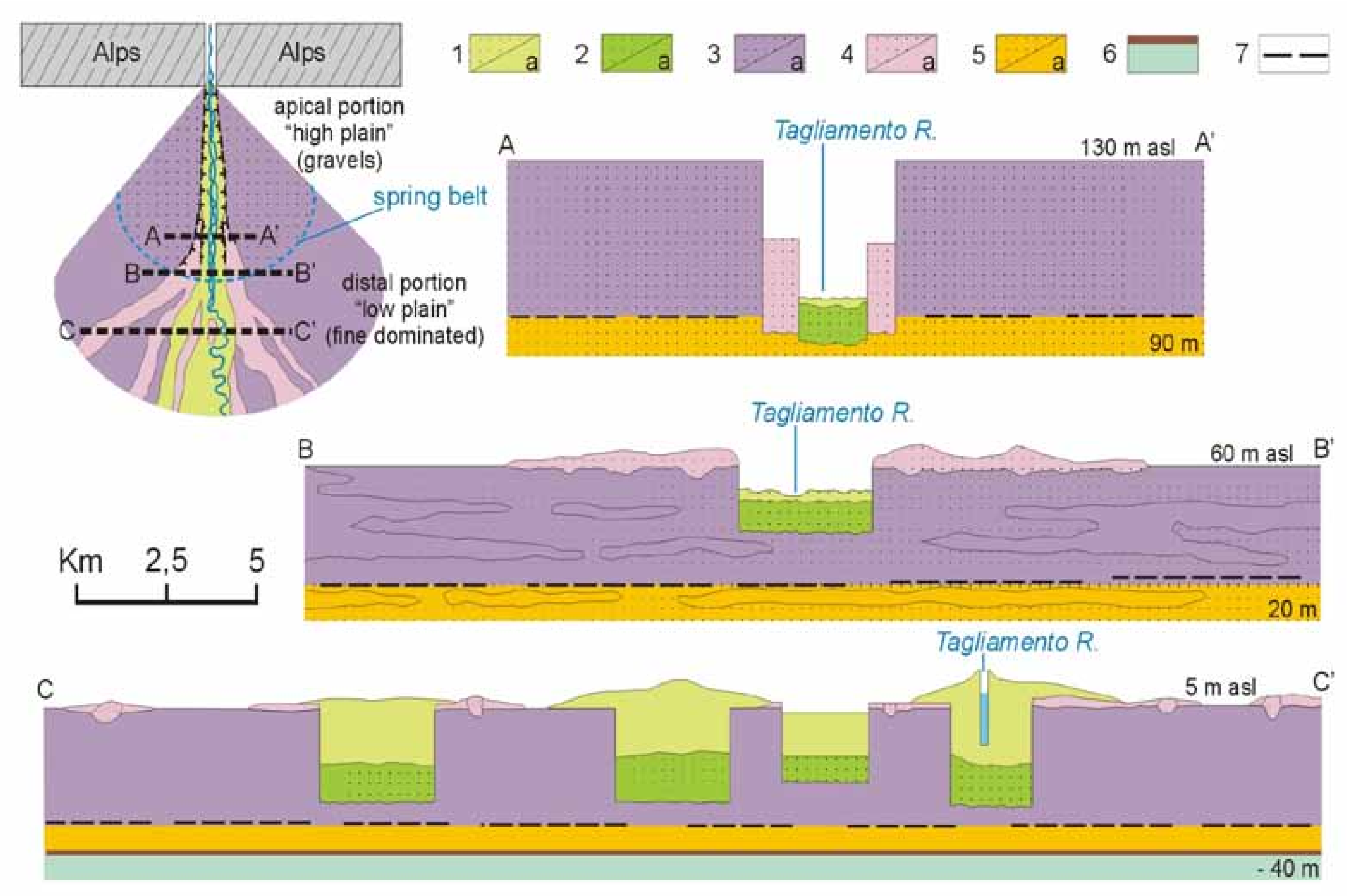
Venetian-Friulian Basin



- Distributive fluvial systems in Alpine foreland

Fontana et al 2008

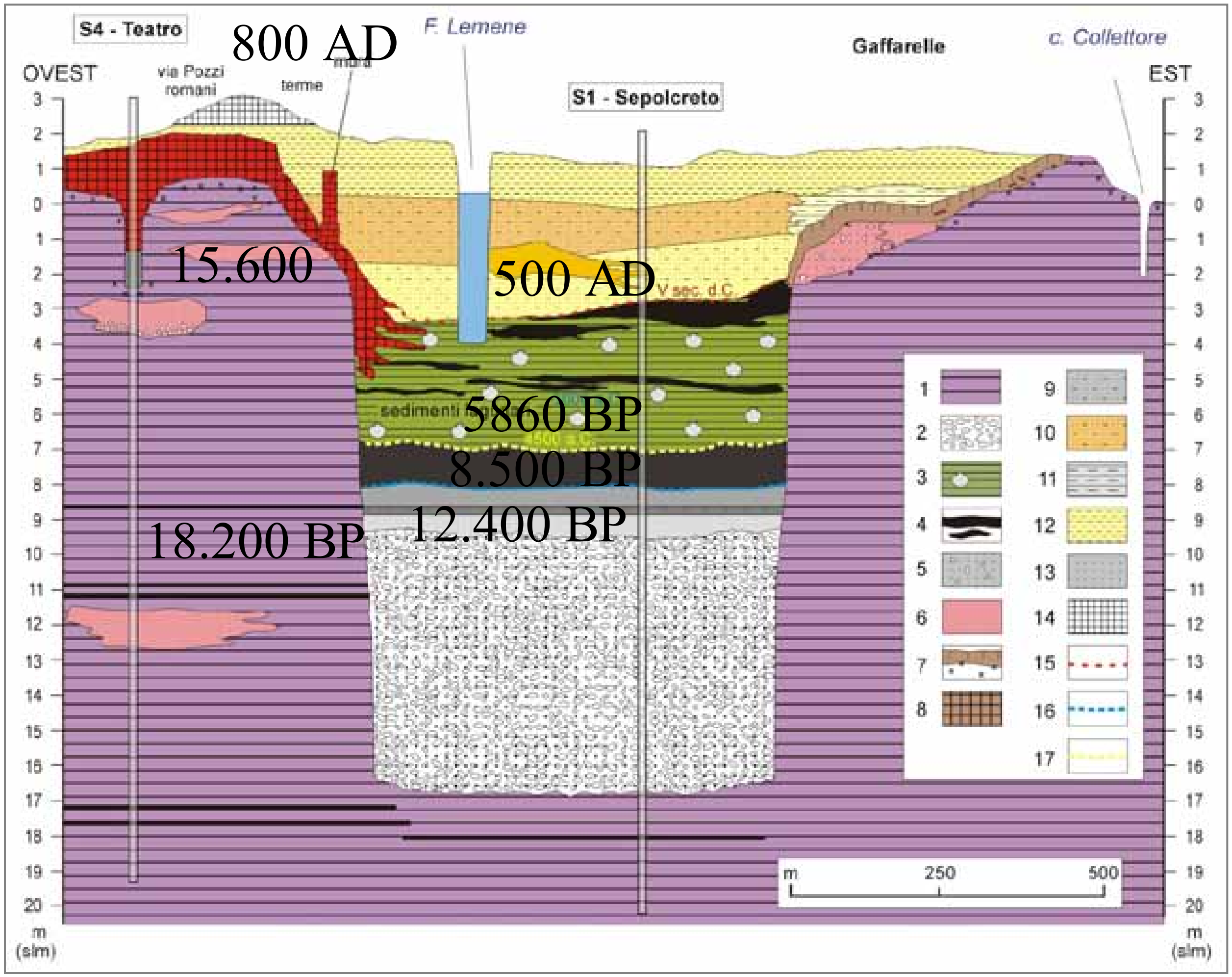
SCHEME OF TAGLIAMENTO MEGAFAN



Scheme of the telescopic alluvial megafan of Tagliamento River (Fontana et al. 2008). 1) Middle/late Holocene sediments, 2) Late glacial/early Holocene sediments, 3) LGM alluvial deposits, 4) Late LGM deposits, 5) MIS 3 and 4 alluvial sediments, 6) lagoon and shallow-marine deposits dating to MIS 5, 6) boundary between LGM and pre-LGM deposits.

Venetian-Friulian Basin

Tagliamento River: Concordia Sagittaria section



- Aggradation during LGM (24 to 15 ka)
- Incision late LGM early Holocene (14 to 8 ka)
- Limited mid to late Holocene aggradation

- This is the complete opposite of standard stratigraphic models

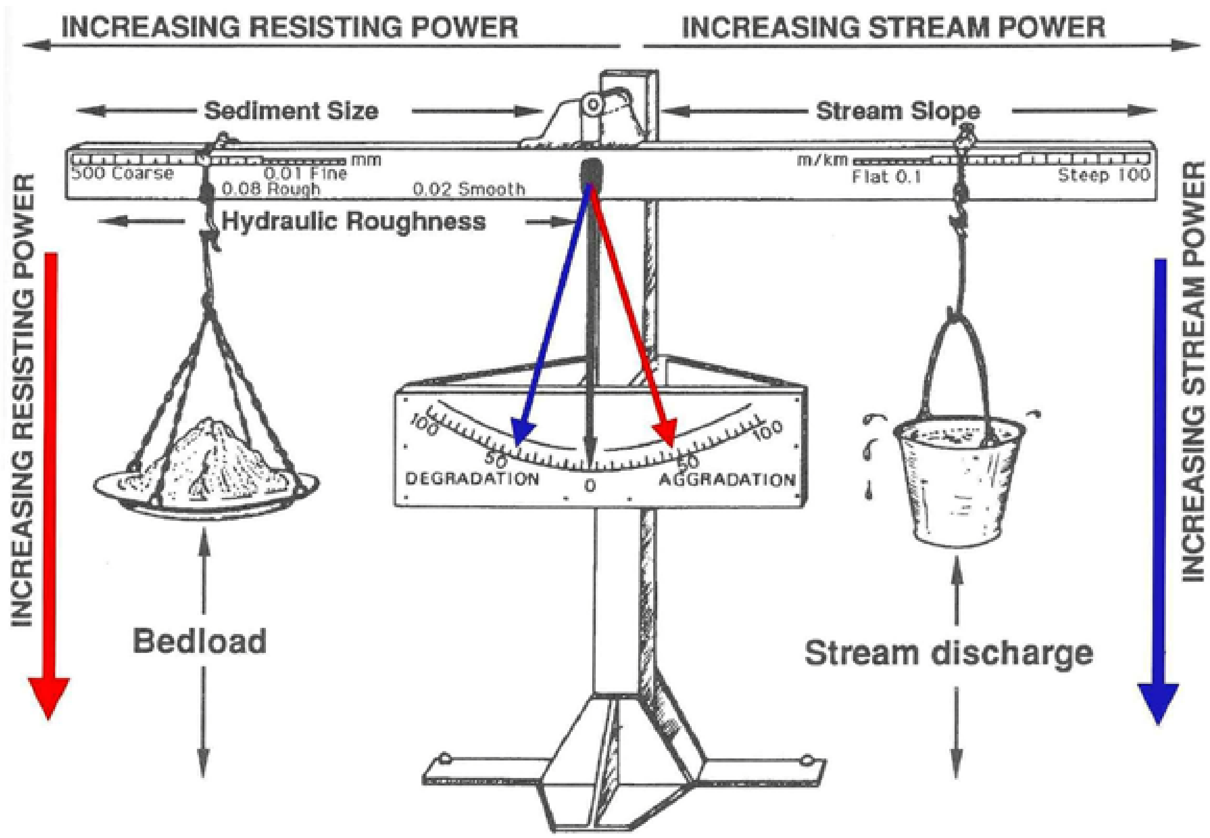
Fontana et al. 2008

Discussion

- Illustrated examples show that continental deposits can preserve different (often opposite) stratigraphic responses to the same climate event within:
  - an individual basin
  - in adjacent basins
  - within a tectonic province
  - and in marine connected systems

Discussion: Why?

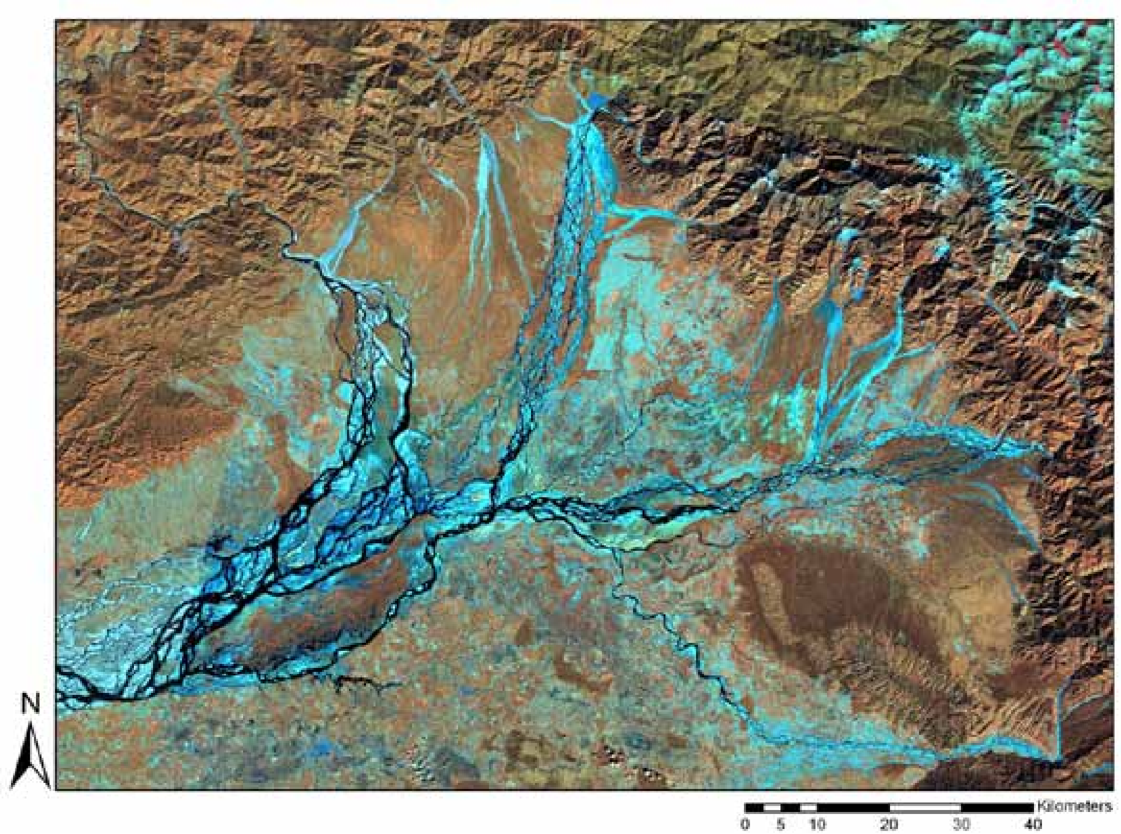
- Different stratigraphic responses are due to variations in the sediment supply to discharge ratio



Based on original diagram by Borland from equation by Lane 1955

Conclusions: climate signatures

- For continental deposits the **climate in the catchment** controls the nature of the fluvial system and strongly influences facies architecture
- Climate in catchment controls sediment/discharge ratio which dictates whether deposition or erosion takes place and the fluvial planform type



Conclusions: climate signatures

- In the rock record only the basin-fill is (normally) preserved
  - the basin-fill is used to interpret the climate
- The climate signature in the basin has limited influence on the development of alluvial architecture
- Climate signatures that we infer from the rock record are those of the catchment
- It is easy to misinterpret a change in springline location as a change in climate
- To have a predictive model it is necessary to have a good understanding of both regional basin setting and climate

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