Timing Mismatch Between Facies Change and Provenance Change in Large River Systems: Implications for Reservoir Development in Evolving Catchments*

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Abstract

This paper explores the relationship between facies and provenance in large river systems and posits that in major drainage reorganizations, the water from the newly formed catchment (as reflected in depositional facies) can pre-date delivery of sand-grade material (reservoir sands transported as bedload) by periods of 1-10 Ma, potentially causing a major change in reservoir properties without a facies change. The main part of this work is derived from fieldwork on the Pliocene palaeo-delta of the Colorado River, which was deposited in the Fish Creek-Vallecito Basin of southern California. The delta deposits are well-exposed in the badlands of Anza-Borrego Desert State Park and record a complete delta cycle from pro-delta turbidites to delta plain deposits. There is a well-studied contrast between sands derived from the Colorado River (C-Suite) and locally derived sands (L Suite). The locally derived sands are lithic, while the C-Suite sands are quartzose; the two suites can also be distinguished on heavy mineral population and varietal mineral geochemistry. L-Suite sands underlie, are laterally equivalent to, and overlie C-suite Colorado deposits, recording initiation, deposition, and eventual abandonment of this first Colorado delta. The lower provenance change is transitional and takes place within the Pliocene Wind Caves member of the Latrania Formation. This change has been dated as younger than 5.33 Ma and used to support the lake-spillover hypothesis for initiation of the lower Colorado River and formation of the Grand Canyon. However, the main facies change is between locally derived subaerial conglomerates of the Split Mountain Group and well-sorted marine turbidites of the Lycium Member of the Latrania Formation; this change is well dated at 6.24 Ma (Messinian, Miocene). Since the depositional facies of the 100 m thick Lycium Member are consistent with those of the 200 m thick Wind Caves Member, we infer that Colorado water (representing the connected drainage) arrived in southern California about one million years before arrival of the bedload (C-Suite) sands. We will consider other examples of this phenomenon from Sakhalin (Neogene Amur River delta) and Antarctica (Permo-Triassic fluvial deposits) and draw general lessons for the effects of provenance change on hydrocarbon reservoirs that will not be apparent from facies analysis or petrophysics alone.

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Timing mismatch between facies change and provenance change in large river systems: implications for reservoir development in evolving catchments

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Outline

1. Why care about provenance?
2. The ancestral Colorado River – a new age?
3. Rates of bedload movement
4. Conclusions

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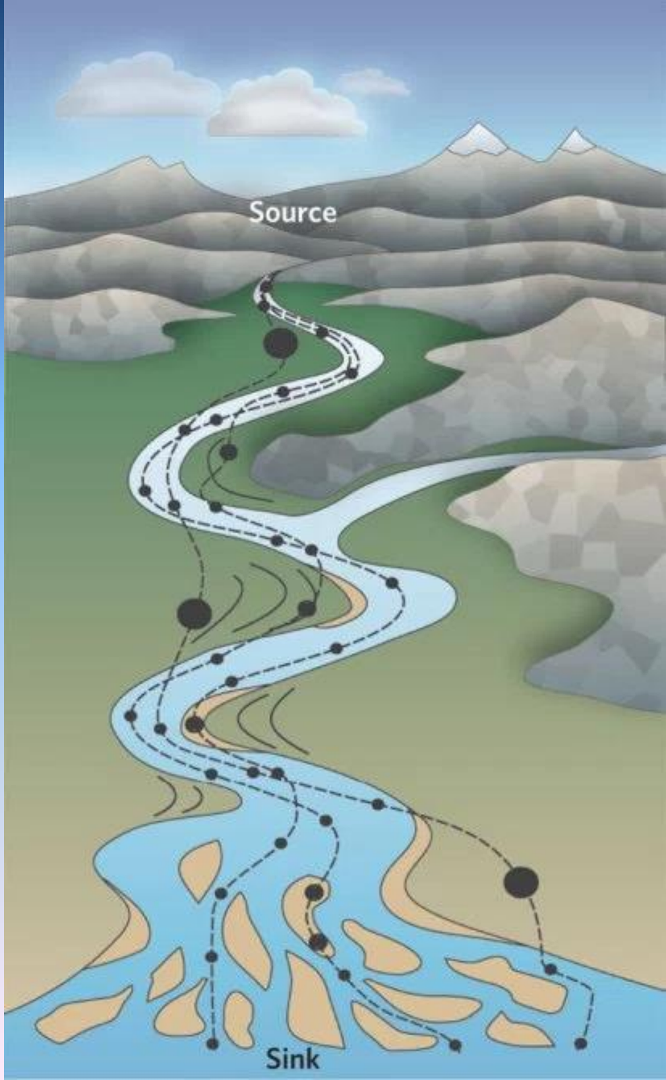
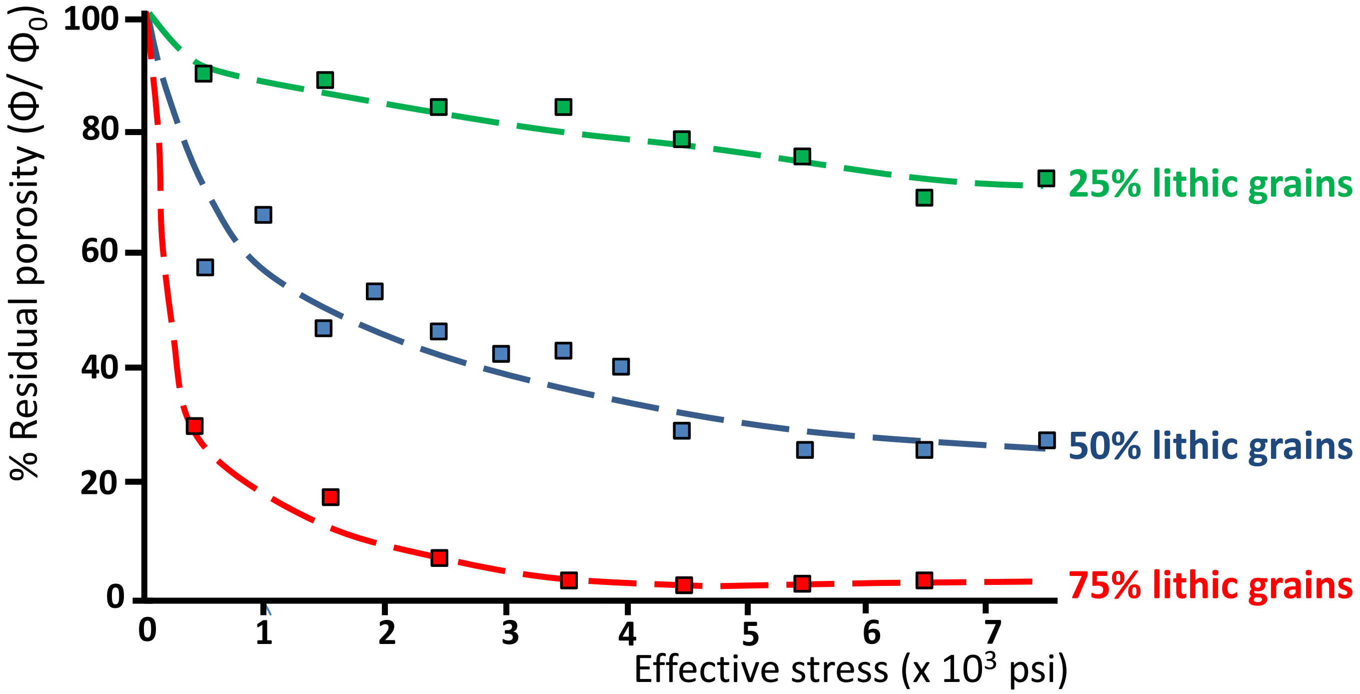
Why care about provenance?
The "academic" approach

- To map the sediment routing system
- Defining diagenesis
- Bedload transit times are highly variable (Allen 2008)
- So arrival of new material takes a finite time



Why care about provenance? The commercial imperative



Residual porosity of compacted experimental sandstone mixtures under varying load (Pittman & Larese, 1991, AAPG Bulletin)

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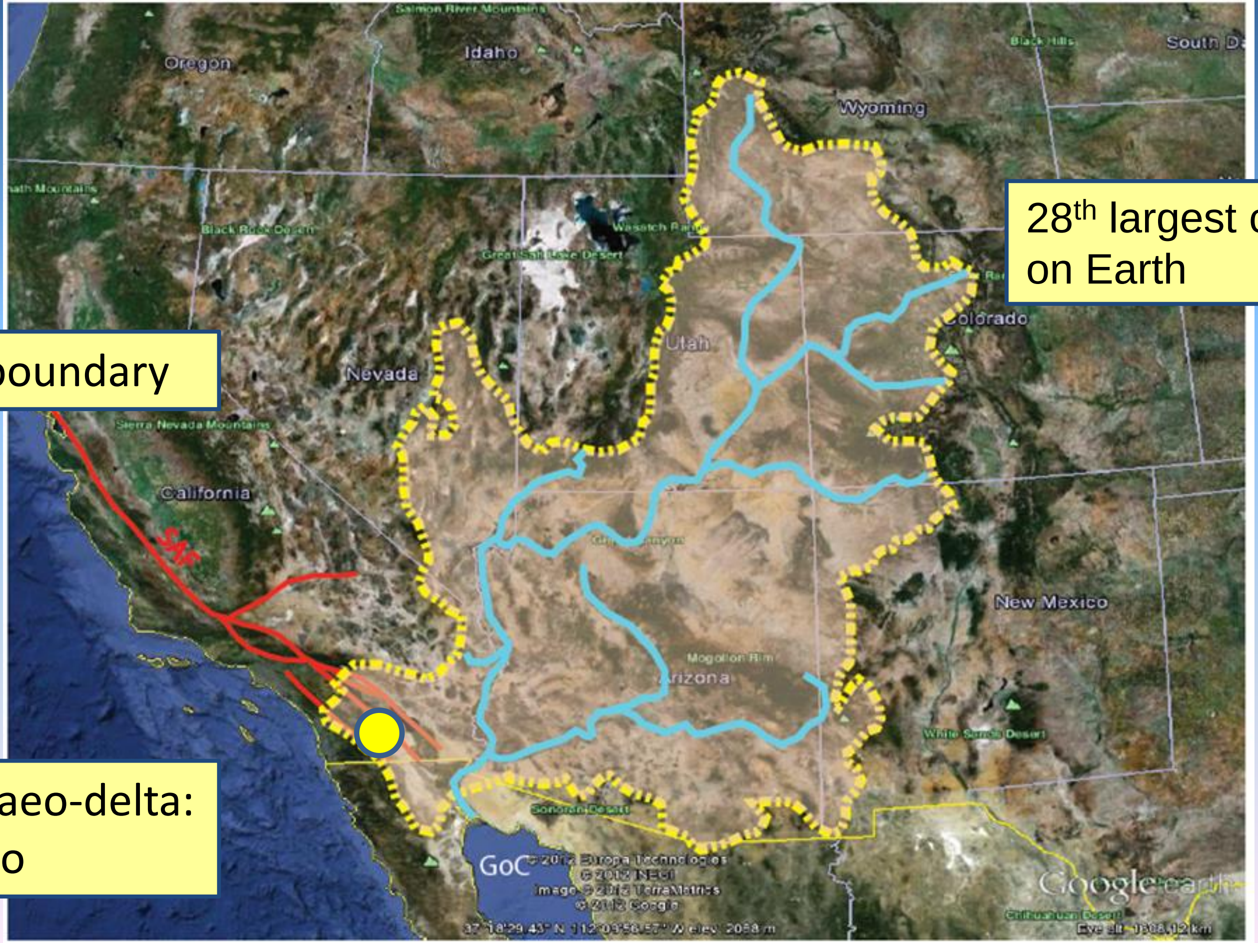
The ancestral Colorado River



28th largest catchment on Earth

Crosses plate boundary

Pliocene palaeo-delta: Anza-Borrego

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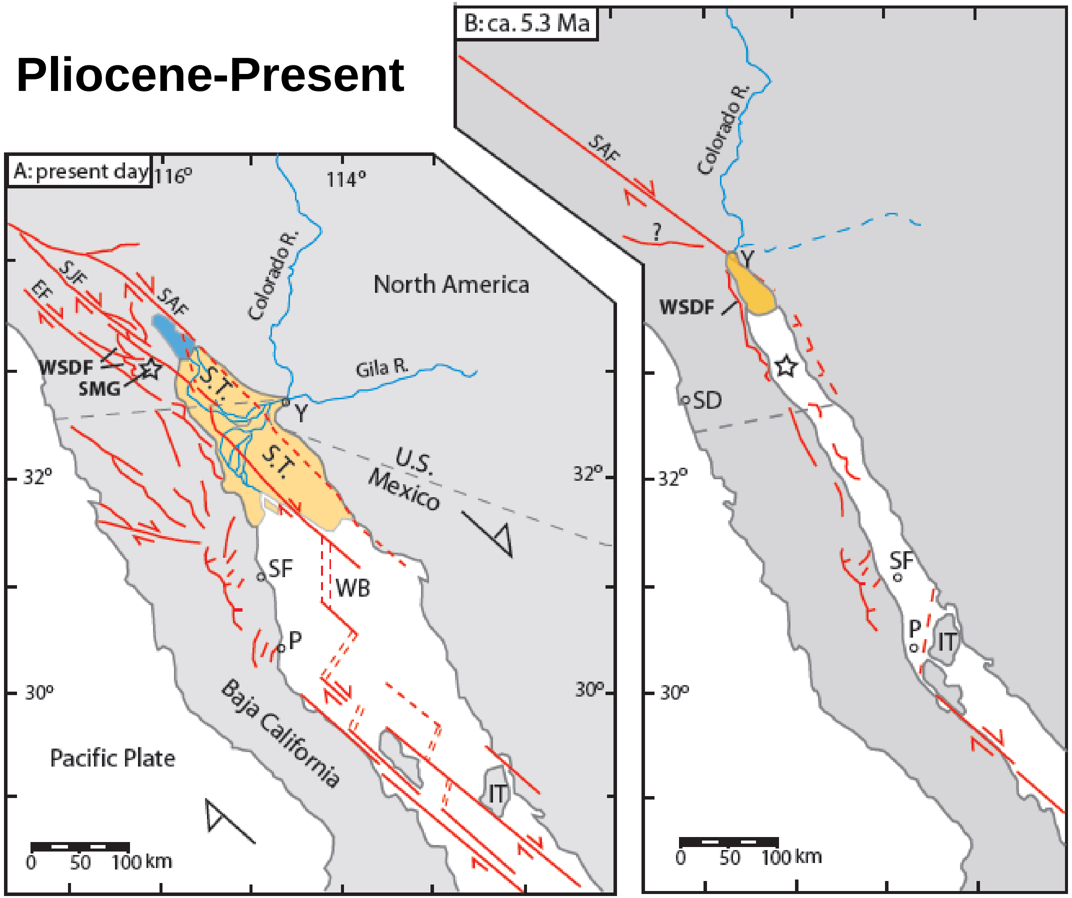
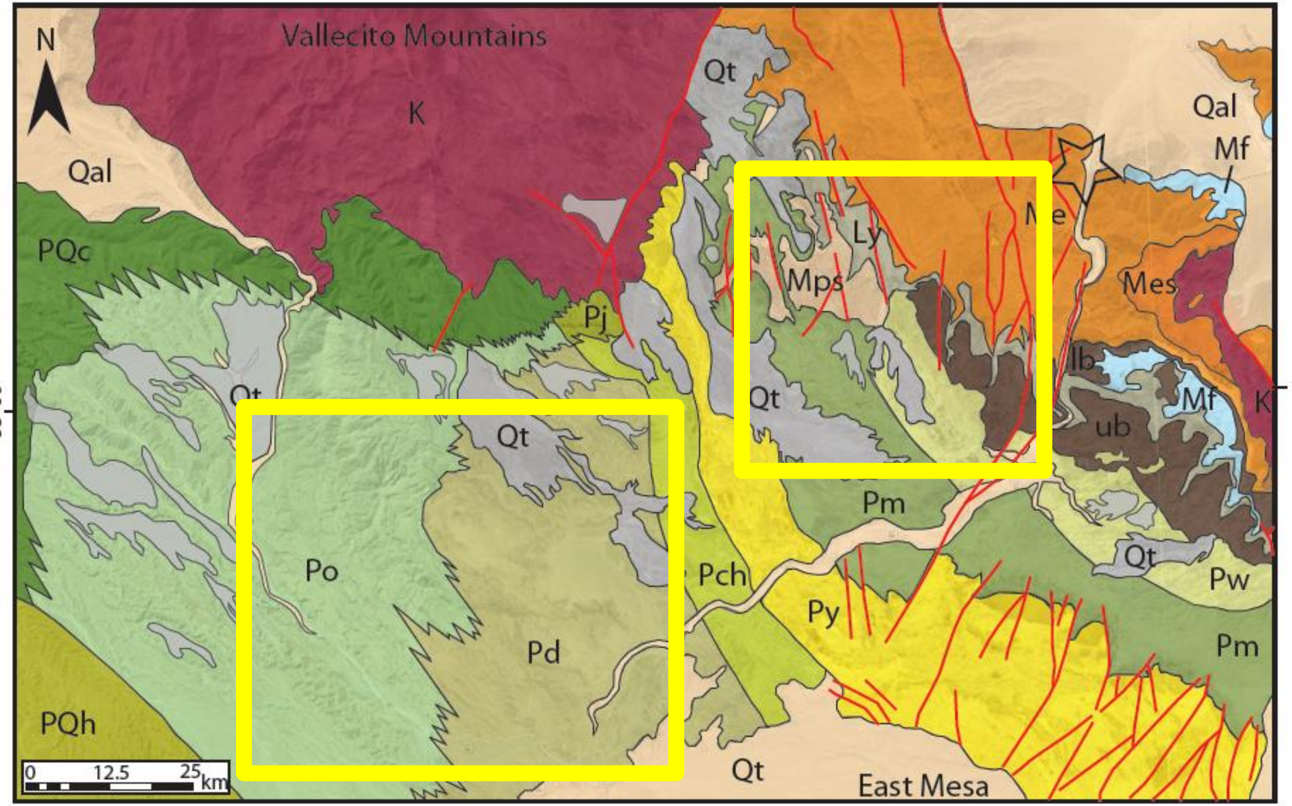
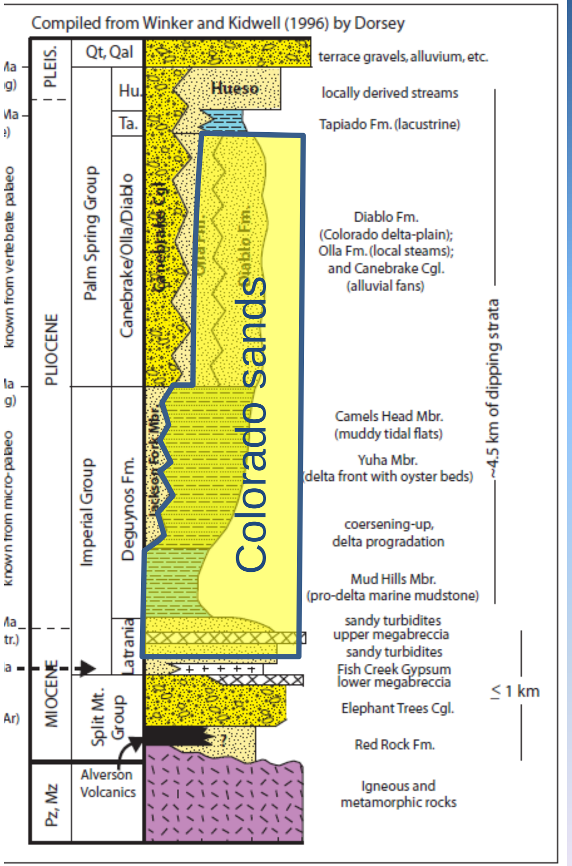
The ancestral Colorado River

Pliocene-Present



The ancestral Colorado River





Focus areas (map after Winker 1987)

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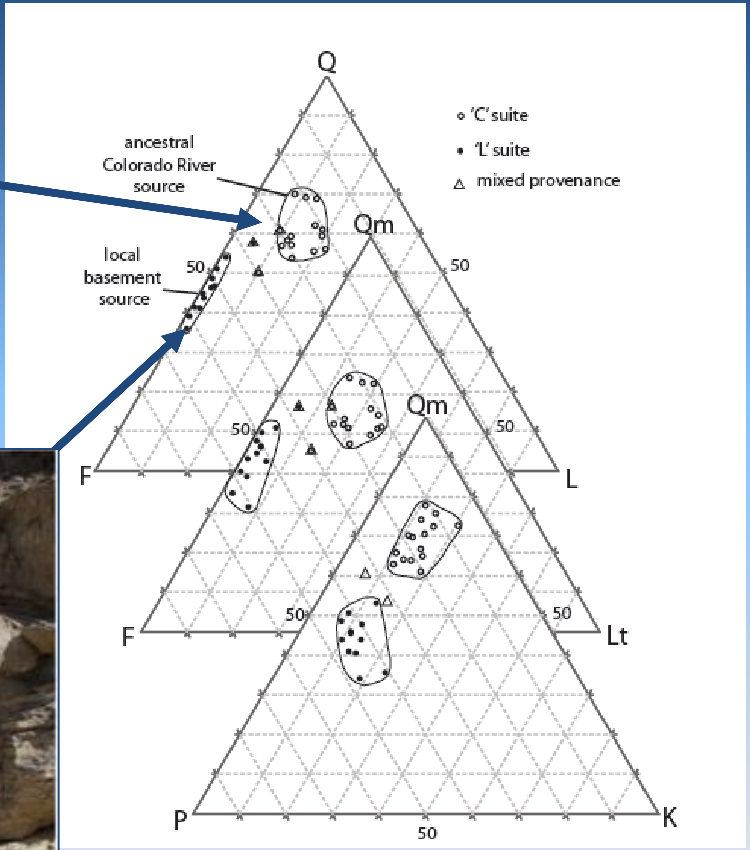
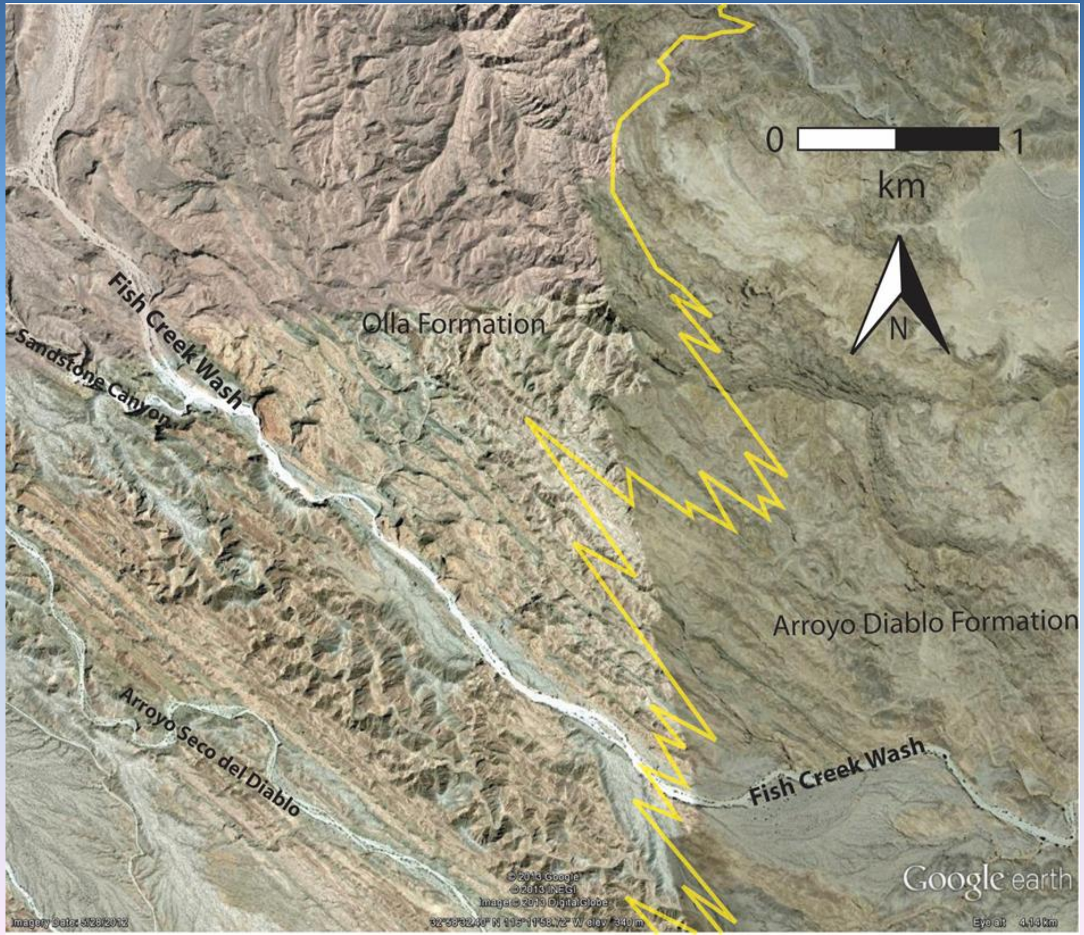
The ancestral Colorado River



Both turbidite units with the same facies – only distinguished on the basis of petrography

The ancestral Colorado River – death of the delta



Petrographic distinction visible from space!

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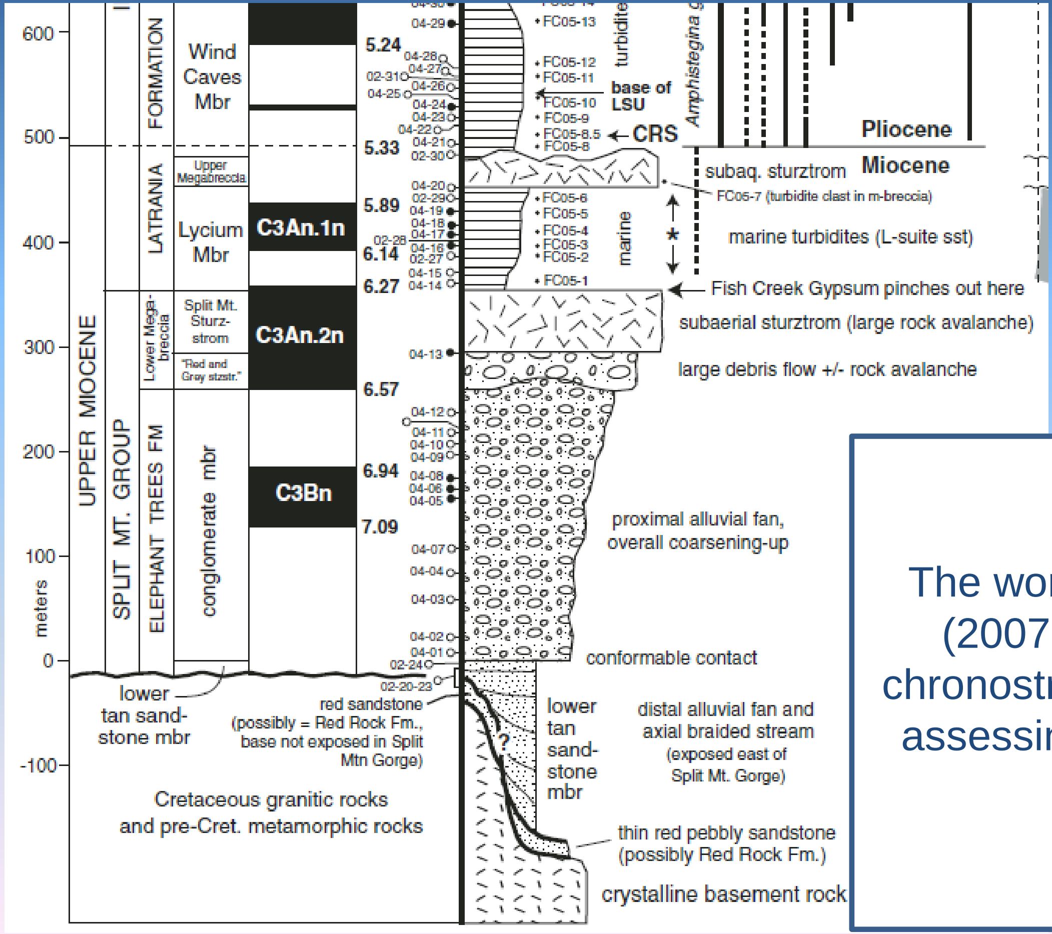
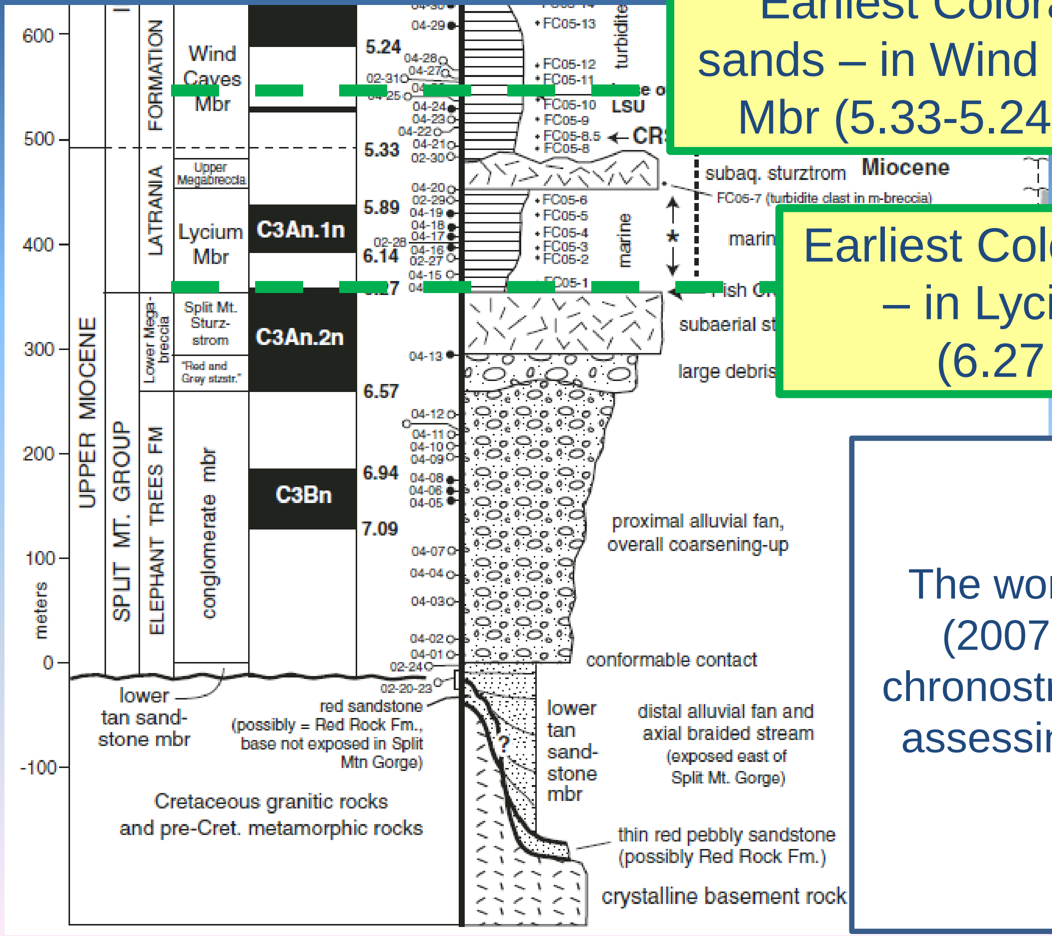
The ancestral Colorado River – some conclusions



The work of Dorsey and others (2007, 2011) gives a robust chronostratigraphic framework for assessing timing of provenance change

The ancestral Colorado River – some conclusions



Earliest Colorado sands – in Wind Caves Mbr (5.33-5.24 Ma)

Earliest Colorado water – in Lycium Mbr (6.27 Ma)?

The work of Dorsey and others (2007, 2011) gives a robust chronostratigraphic framework for assessing timing of provenance change

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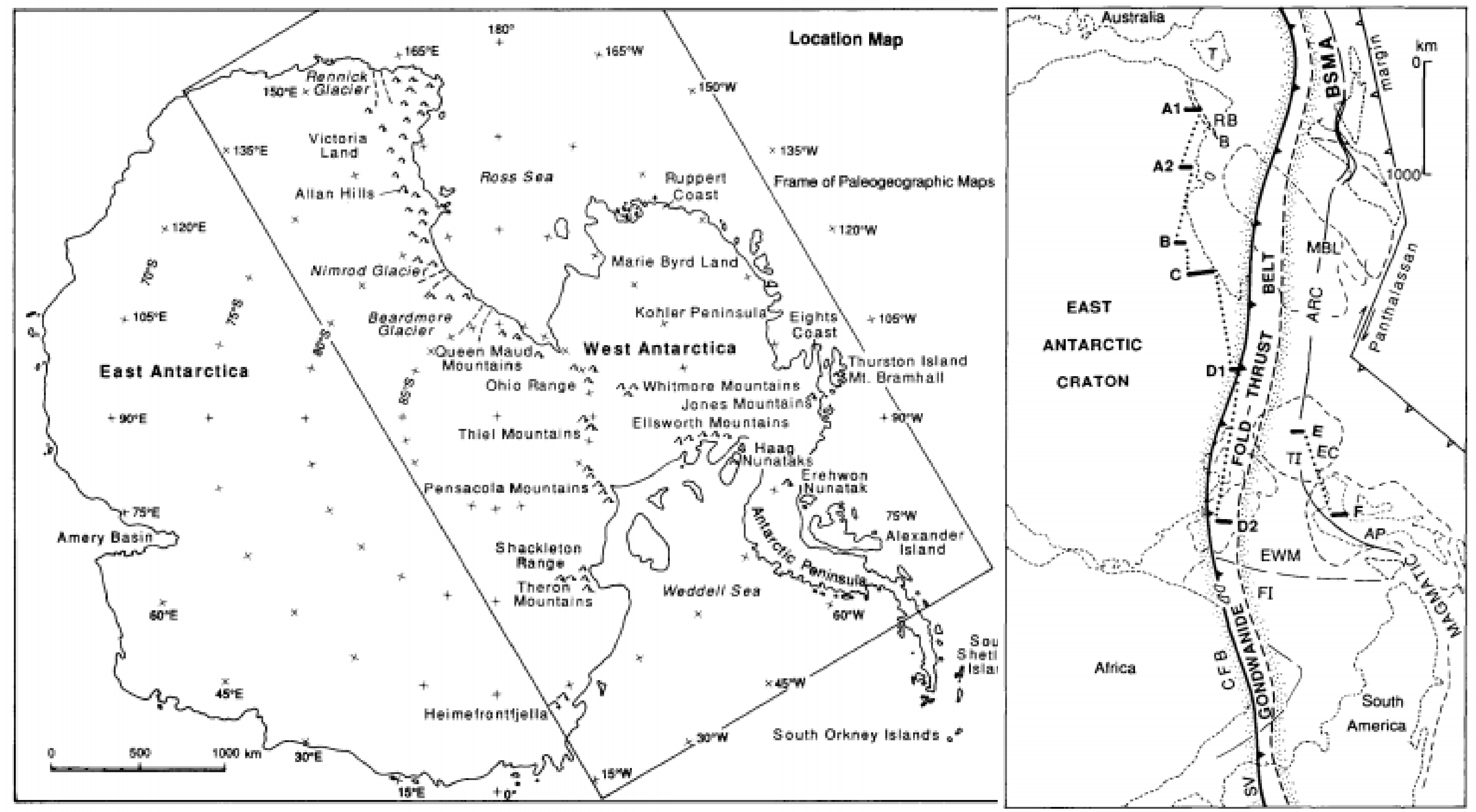
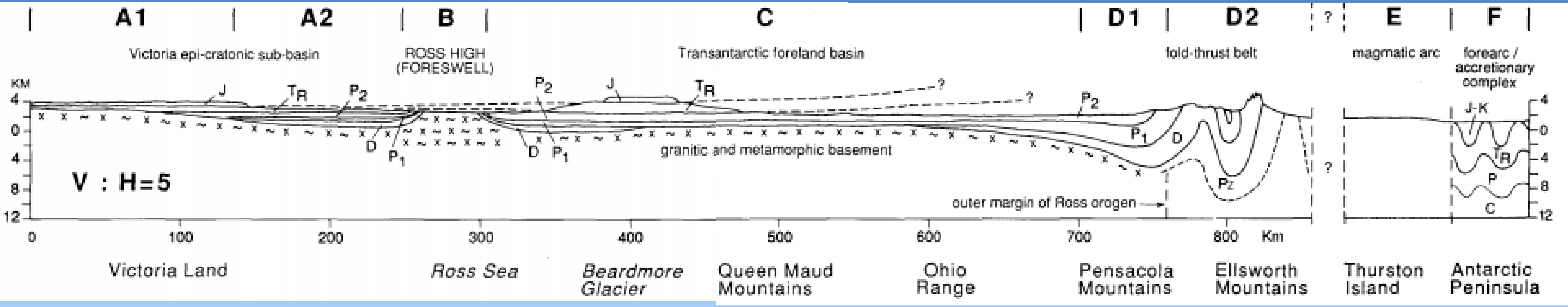
Deriving rates of bedload movement



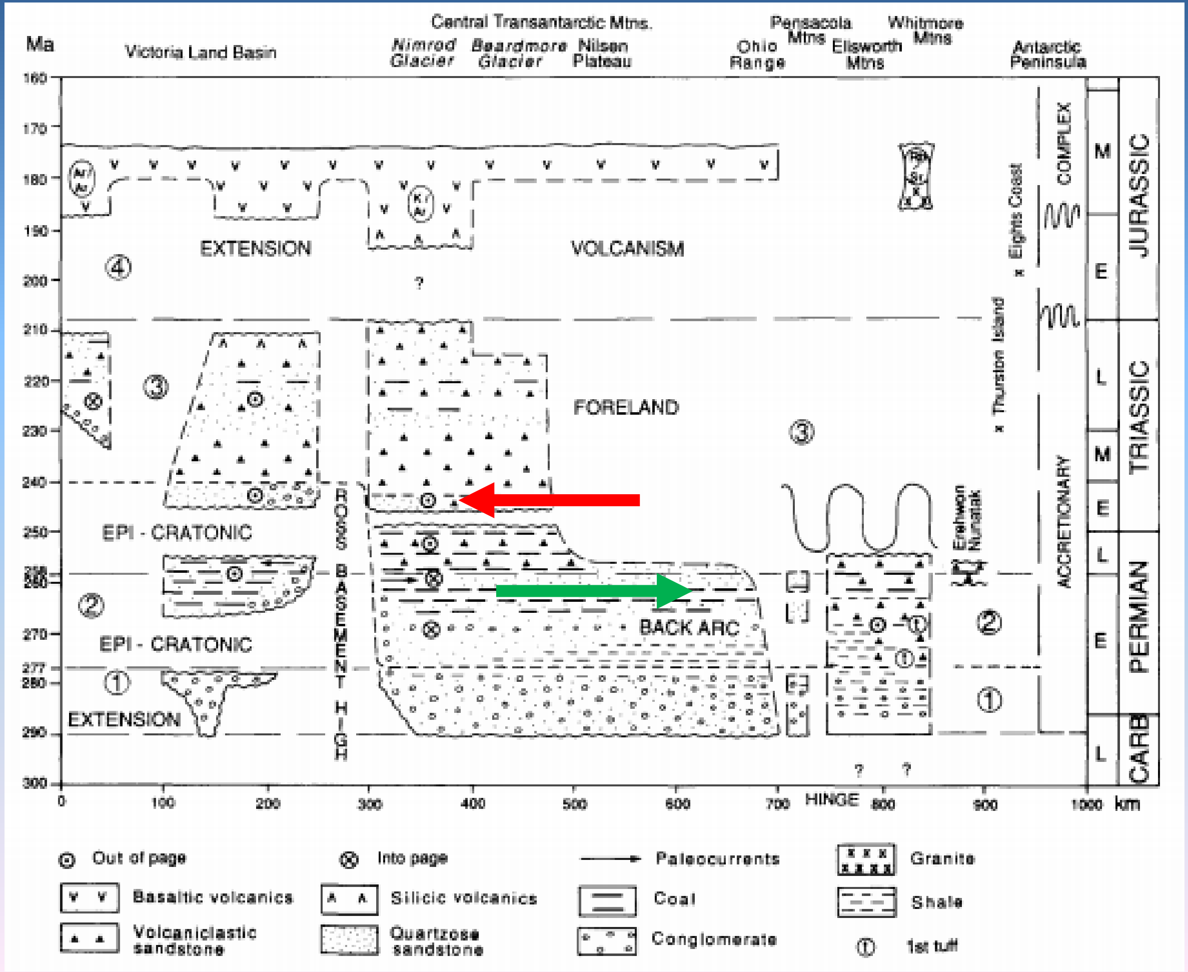
Best defined provenance change – Beacon Supergroup (D-Tr), Antarctica (Collinson et al 1994)

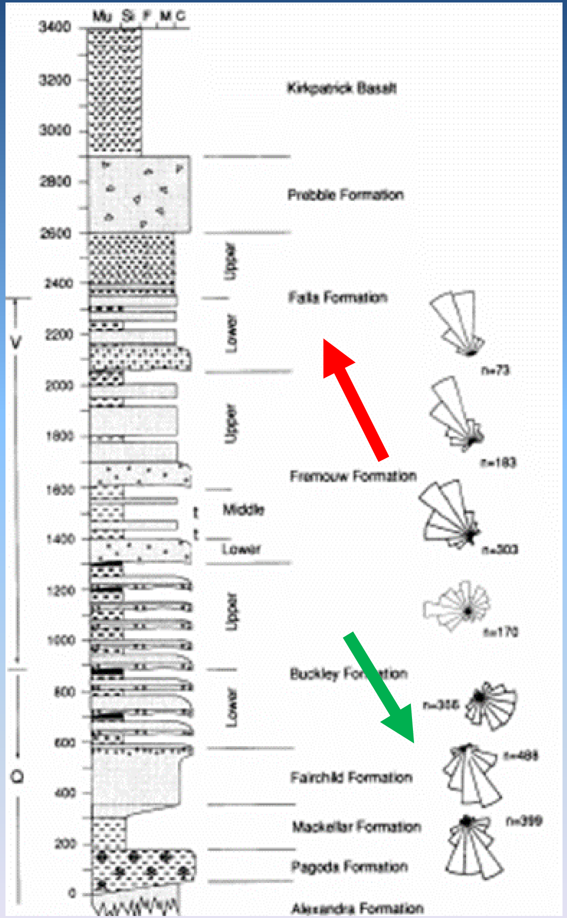
Deriving rates of bedload movement:
Pacific to Atlantic



Collinson et al 1994

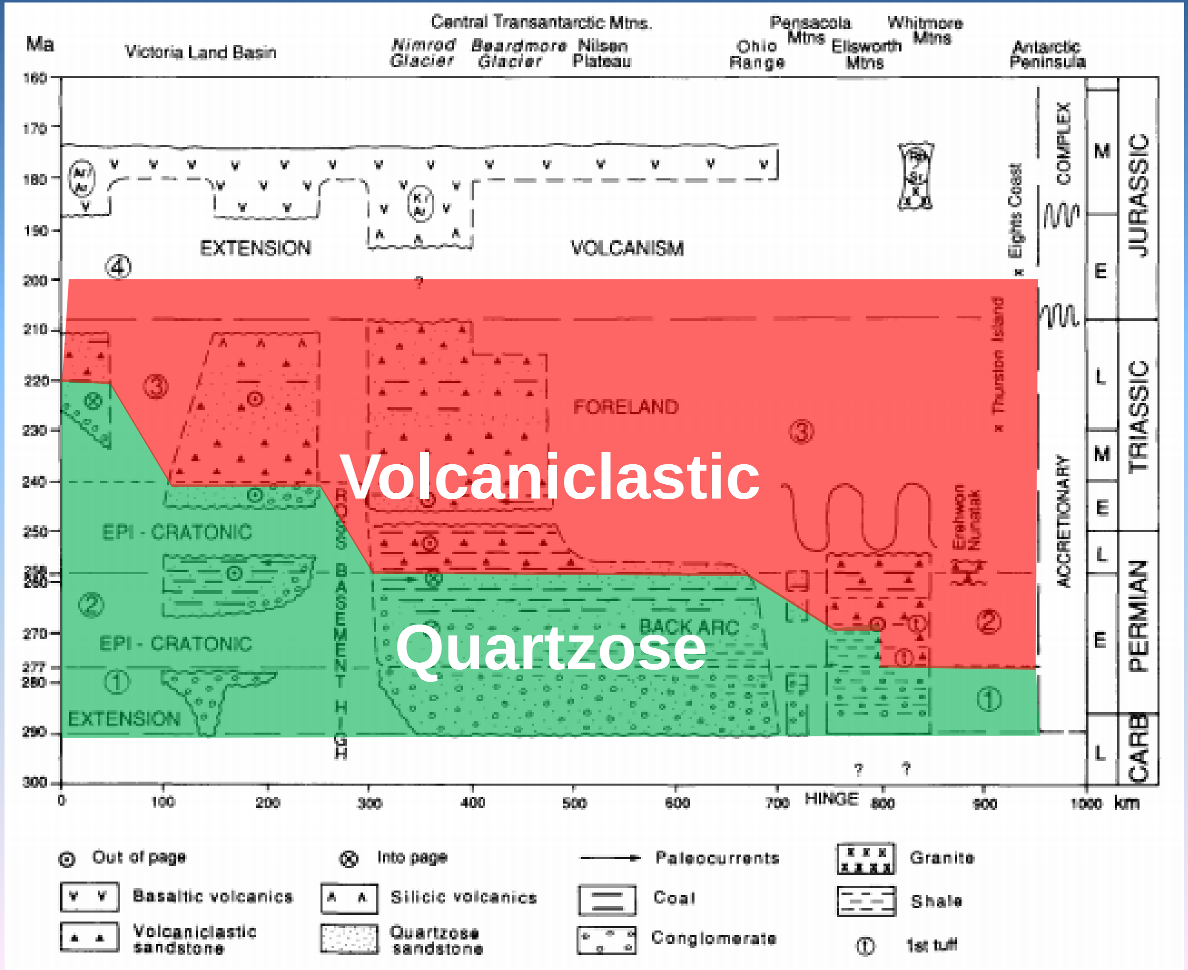
Deriving rates of bedload movement

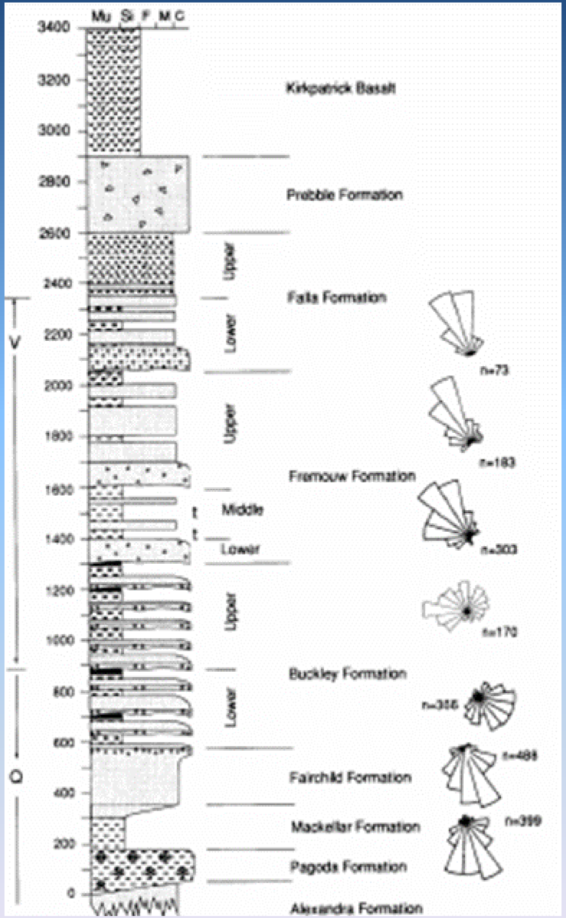




Palaeocurrent reversal (Collinson et al 1994, 2004)

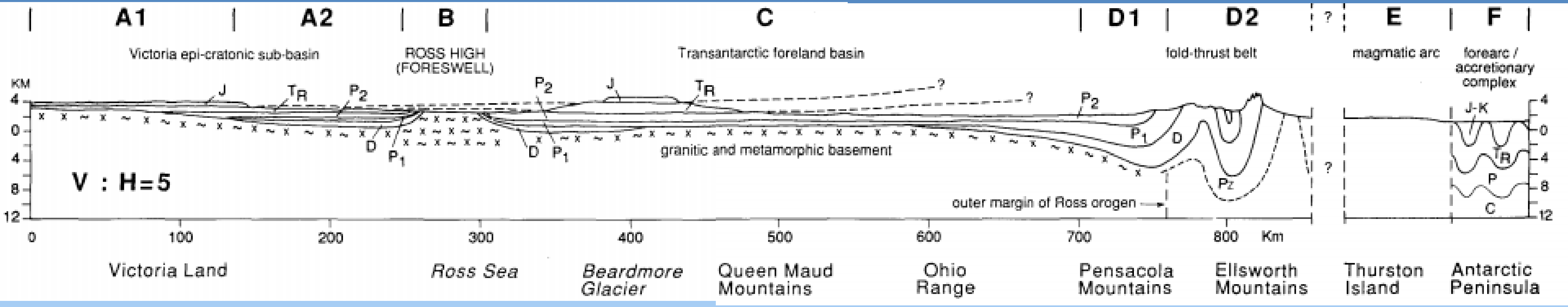
Deriving rates of bedload movement

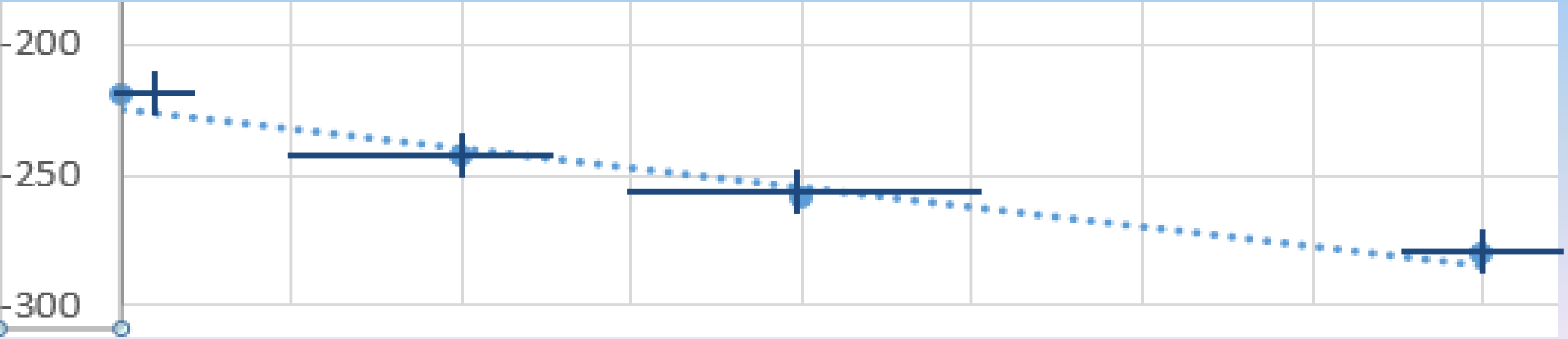




Petrographic change (Collinson et al 1994, 2004)

Deriving rates of bedload movement:
Pacific to Atlantic





Mean rate of bedload migration: 18.6 km/Ma +13.8/-9.4

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Conclusions

1. Water from a changed catchment arrives before bedload
2. Water determines the sedimentology
3. Rates of bedload movement average to km/Ma
4. Colorado connection to ocean may be older than thought

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Sculpture Park, Anza Borrego Desert State Park