Paleo-Topographic Controls on Fluvial Architecture of Early Paleozoic Fluvial Strata in a Basal Cambrian-Ordovician Sandstone: Potsdam Group of the Ottawa Embayment and Quebec Basin*

David G. Lowe[1] and R.W.C. Arnott[2]

Search and Discovery Article #51334 (2016)**
Posted December 12, 2016

*Adapted from oral presentation given at AAPG 2016 Annual Convention and Exhibition, Calgary, Alberta, Canada, June 19-22, 2016
See similar article Search and Discovery Article #51004 (2014)

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Abstract

Basal Cambrian-Ordovician siliciclastic strata are currently being considered targets for CO_2 sequestration in North America, including the Potsdam Group in the St. Lawrence Lowlands of Quebec. Significantly, depositional stratal architectures and textures, which represent first-order controls on porosity and permeability distribution in Potsdam strata, are largely unknown. Work reported here suggests that braided fluvial strata, which make up about 80% of the Potsdam isopach, form two distinct end-member stratal geometries, which in turn appear to be controlled by variations in basin topography. The first geometry consists of a thick (~50-550 m), areally-extensive (~1,300-12,000 km^2) pile of coarse-grained, locally pebbly braided fluvial sandstone deposited in broad, structurally simple basins with wide (~60-120 km), low-relief floodplains. Strata are dominated by 0.4-2.2 m thick, downstream-accreting compound bar deposits that formed in shallow but wide braided channels. These, in turn stack to form 1.3-3.3 m thick, laterally extensive (> 2 km) channel belt sand bodies capped with thin (<10 cm, but rarely up to 0.8 m) fine-grained overbank deposits consisting of a mixture of fine sand, silt and locally mud, illuvial matrix and pseudomatrix. The second geometry comprises thin (5-60 m), areally-restricted (~30-200 km^2) outliers of coarse to very coarse braided fluvial sandstone with local cobble- and boulder conglomerate deposited on narrow (≤10 km) floodplains bounded by local basement highs formed above deep-seated basement structures. Channel deposits consist of 1.2-3.5 m thick compound bar deposits with steep accretion surfaces (20-35°). Channels then stack to form channel belt successions that range from 2.2-7 m with rare ~1-2 m deep, steep-sided (15-25°) confluence scours at their base. Significantly, fine-grained strata are generally

absent. The first stratal geometry would form regionally extensive reservoirs with good lateral connectivity, but because of regularly-spaced, although thin fine-grained overbank deposits, vertical connectivity would be more limited. The second geometry, however, is a comparatively better reservoir unit being more lithologically isotropic with a paucity of overbank fines, predominance of high angle fabrics, and higher porosity owing to its coarser grain size. Moreover, given its spatial relationship with basement structures it would be easy to locate geographically, but reservoirs are more limited in area and thickness.

Reference Cited

Bédard, J.H., L.B. Harris, P. Thurston, 2013, The Hunting of the snArc: Precambrian Research, v. 229, p. 20-48.

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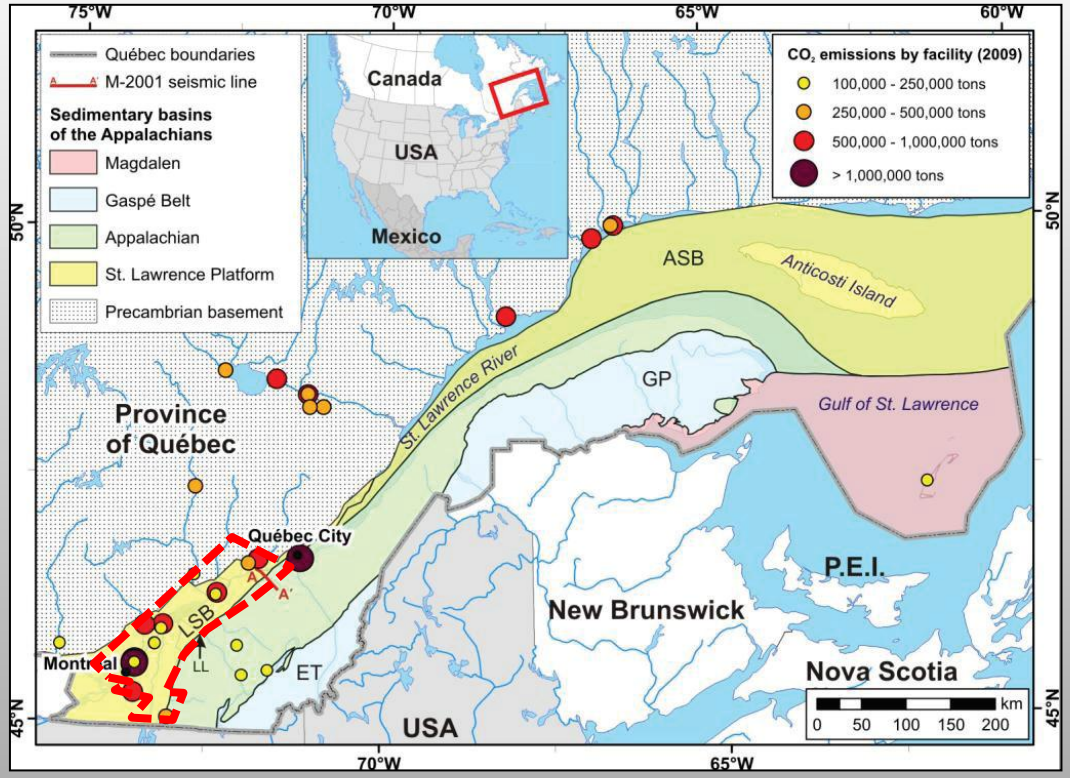
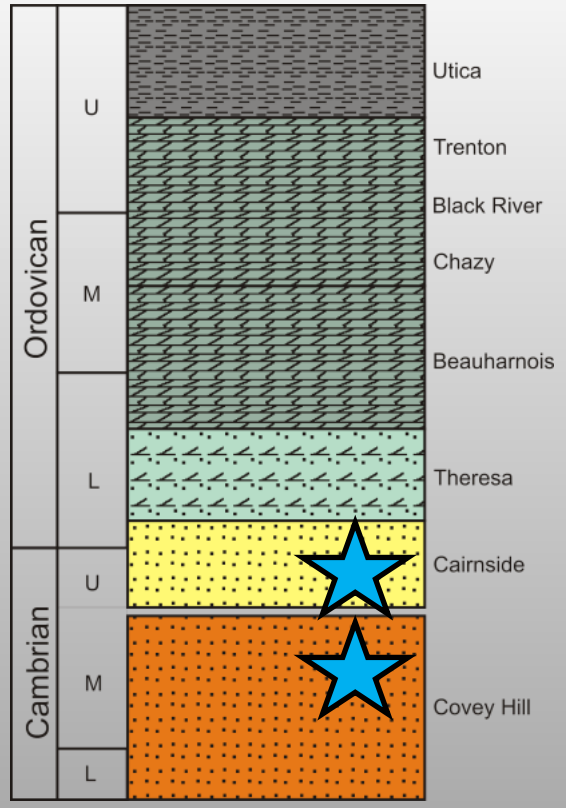
CO_2 Storage Potential in Potsdam: Quebec



Bédard et al., 2013



- Potsdam Group: Covey Hill (arkose) and Cairnside Quartz arenite.
- ~0.7 – 8.6 Gt; or ~35 – 430 years of emissions.
- Uncertainty w.r.t.:
  - isopach,
  - porosity distribution,
  - role of faults in compartmentalization, isopach and sedimentation.

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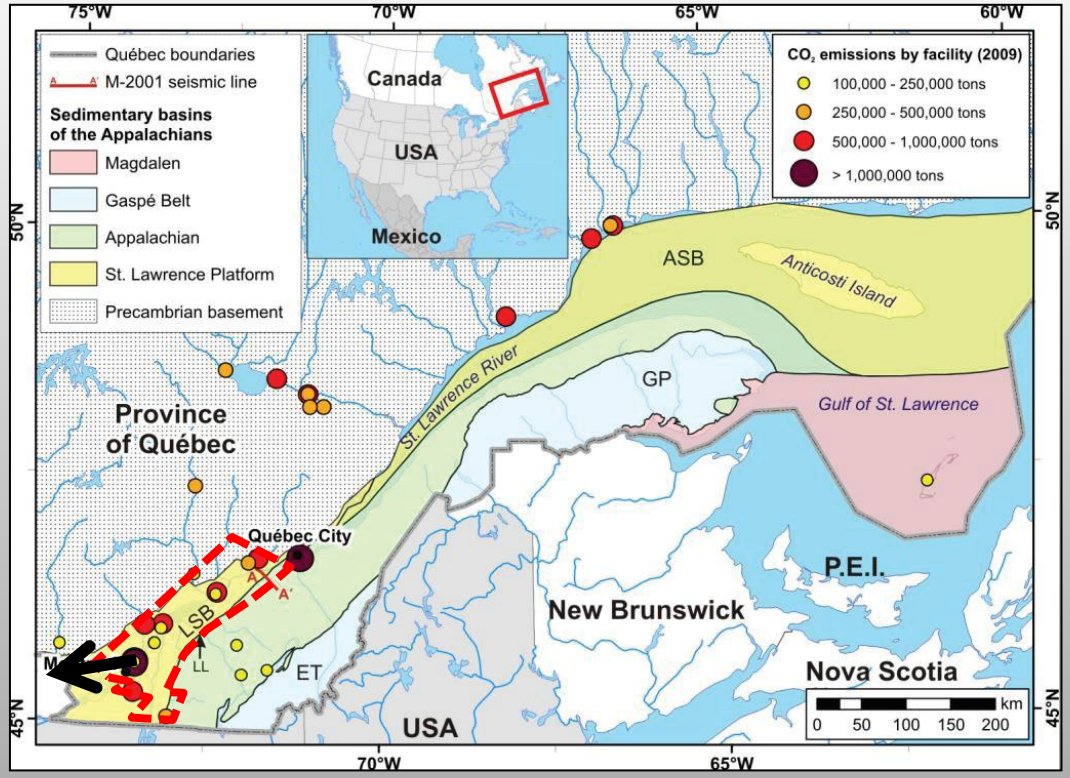

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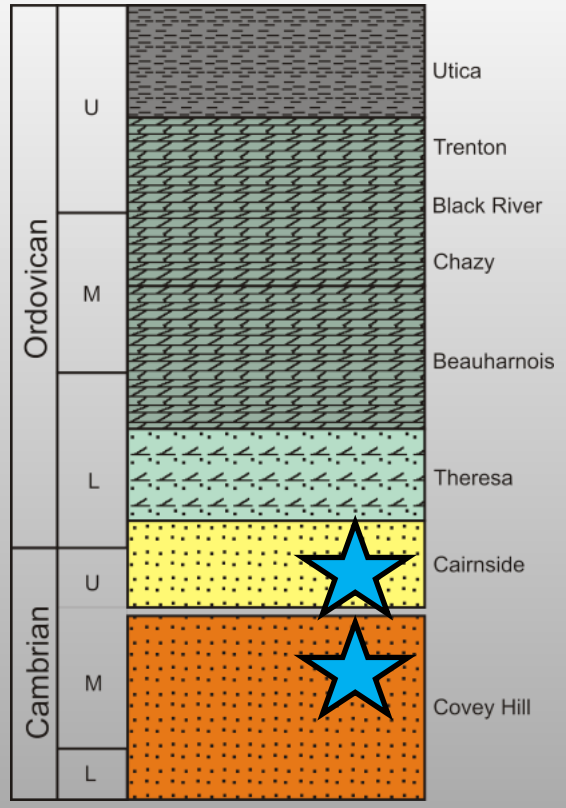

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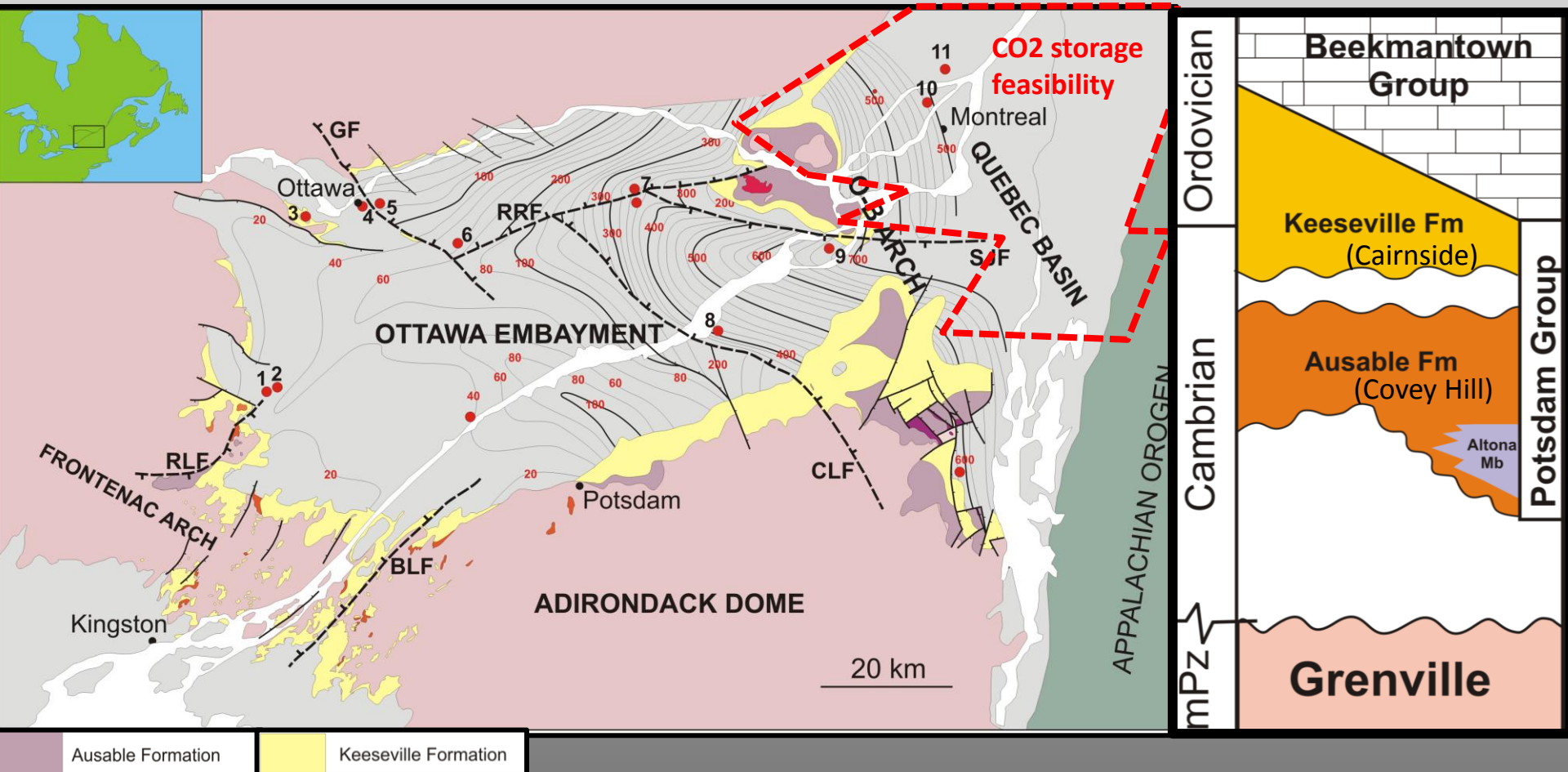
Potsdam Group: Ottawa Embayment and Quebec Basin

- 2010 – 2015: detailed sedimentary and stratigraphic study of potential storage units in adjacent region (Ausable = Covey Hill; Keeseville = Cairnside).

- Opportunity to understand **(a)** composition and stratal architectures of targeted reservoir units; and **(b)** relationship between intra-basin faults and Potsdam isopach, sedimentary composition and architecture.



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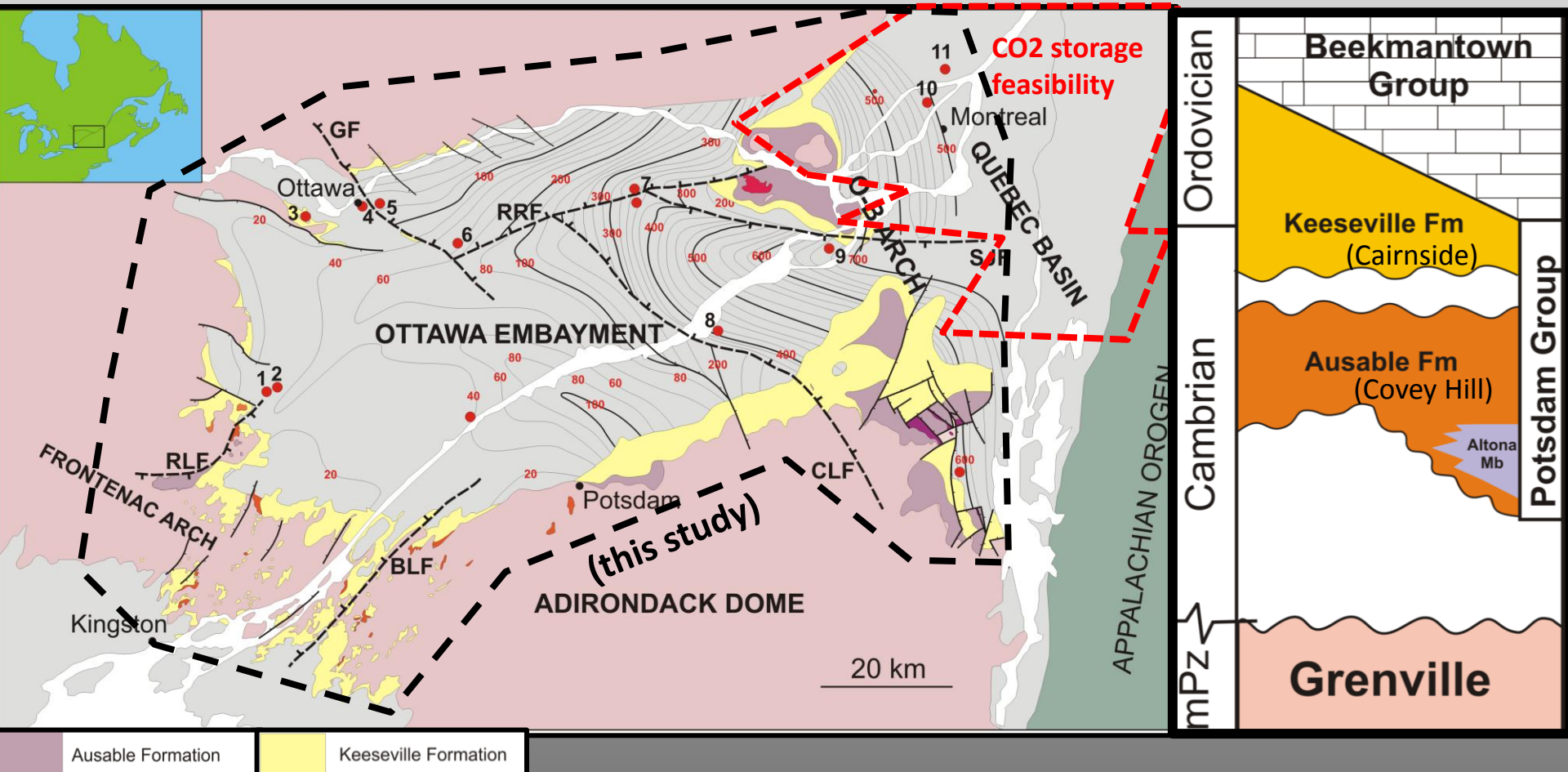
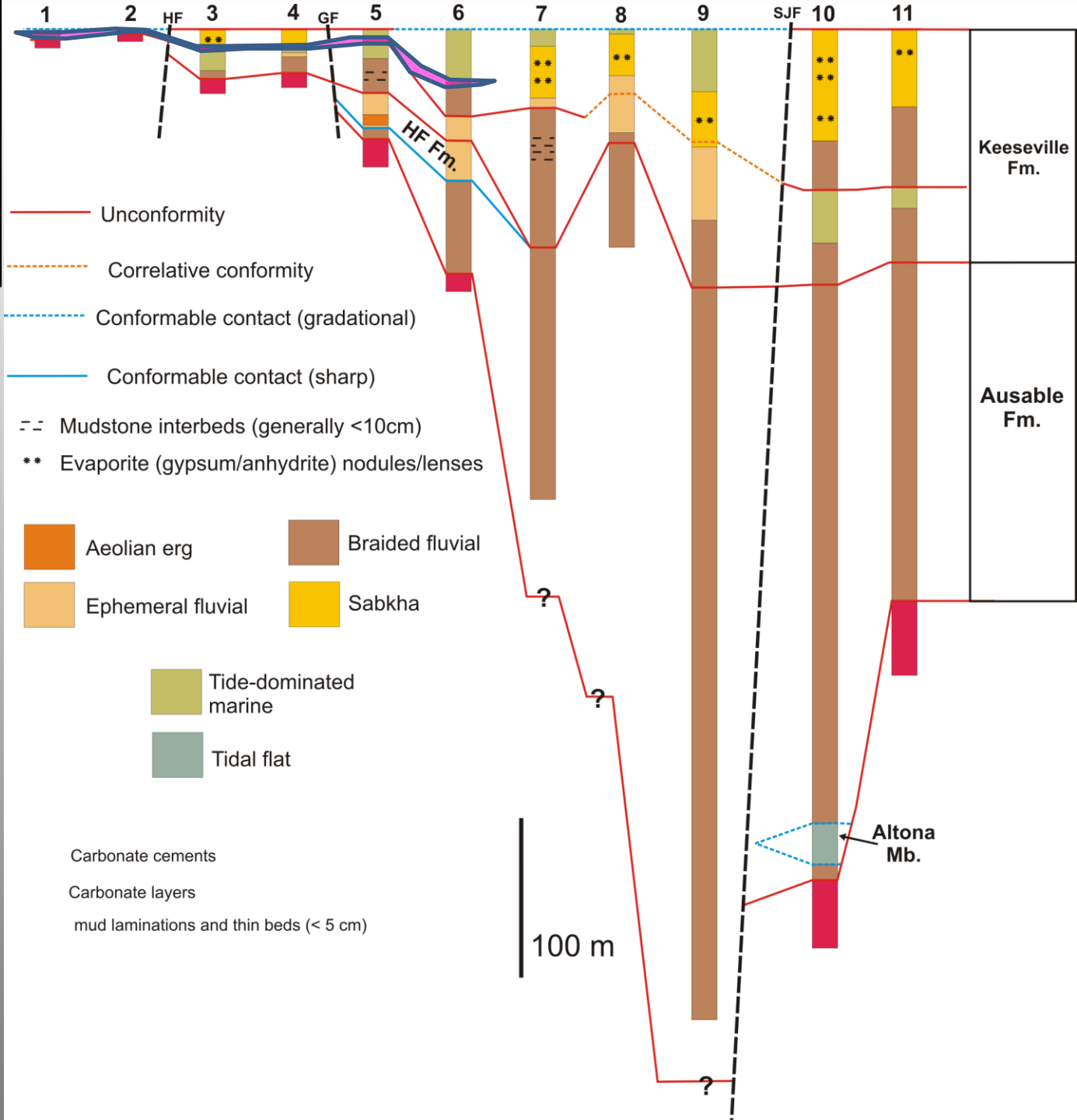


- In terms of thickness and volume, fluvial strata is by far the most abundant (~80% of Potsdam isopach).
- Most of Ausable, 50-60% of Keeseville.
- Composition, stratal architecture, and sedimentation of fluvial strata has been extensively studied.



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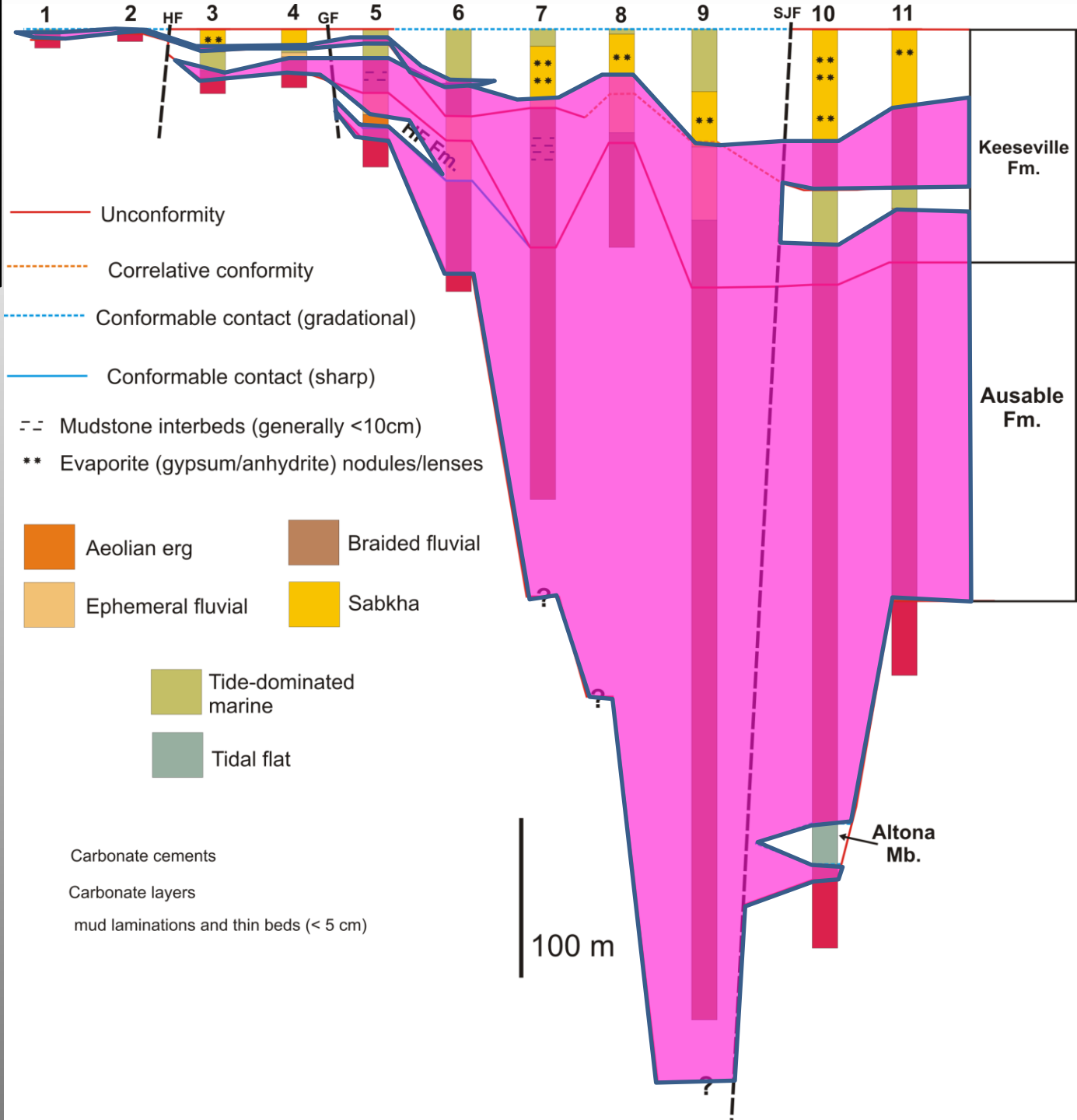
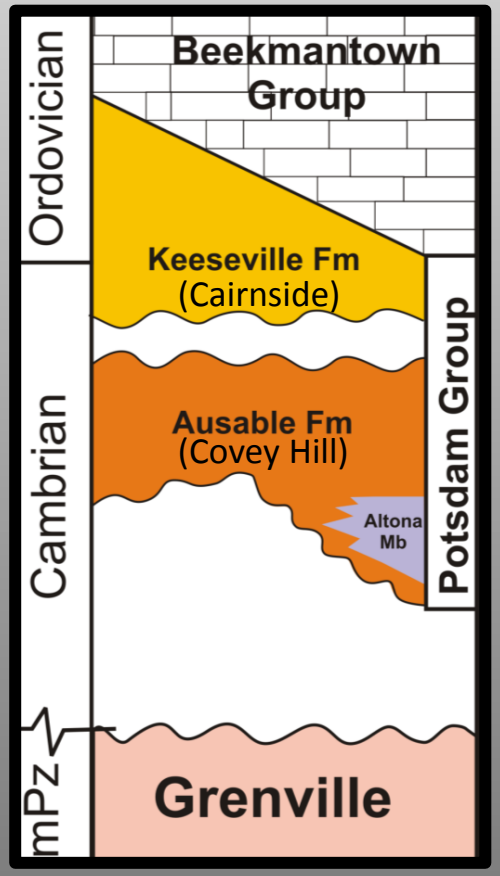
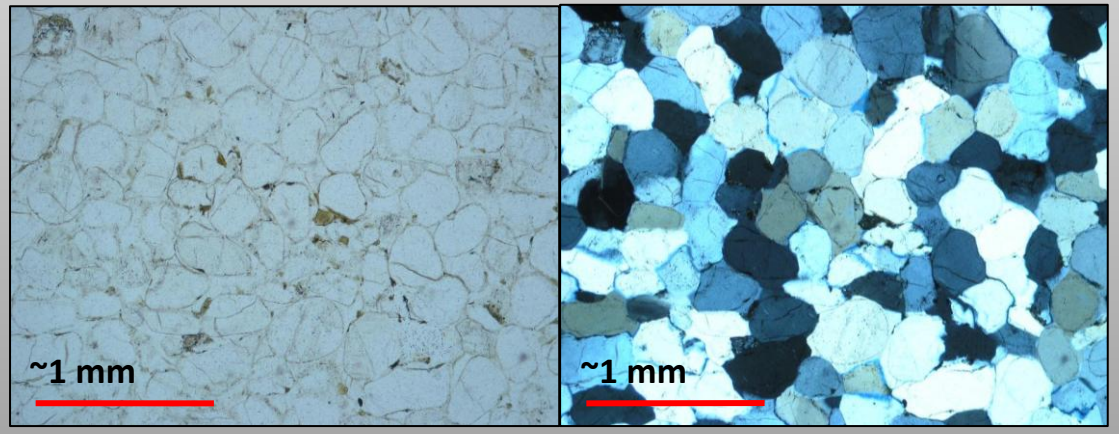


Potsdam Group: Mineralogy and Diagenesis

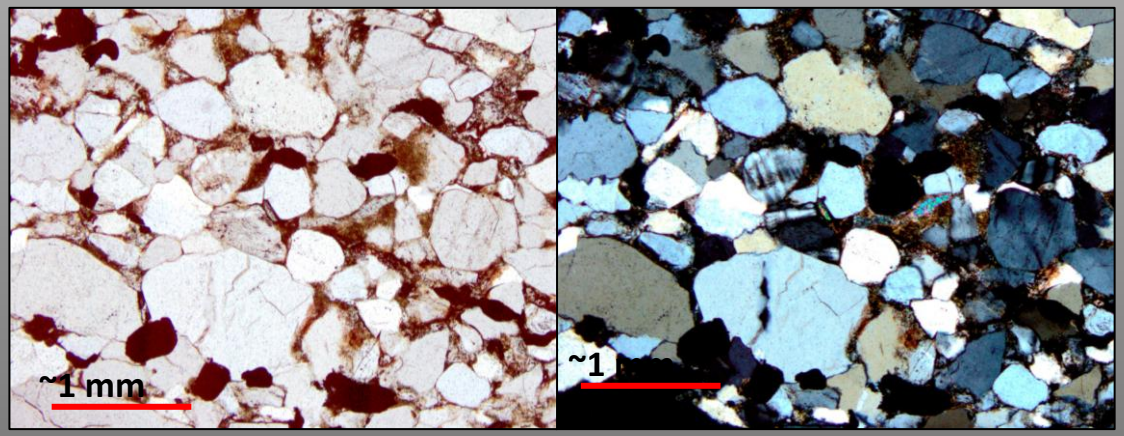
- Keeseville (Cairnside): Quartz arenite, generally well-sorted, medium-grained, tightly silica-cemented.
- Ausable (Covey Hill): coarse-grained, poorly-sorted Arkose, pseudomatrix and feldspar breakdown maybe prevents ***some*** silica cements.
- This doesn't look like a great reservoir – at least at the surface, nevertheless…



Ave. Porosity



3%

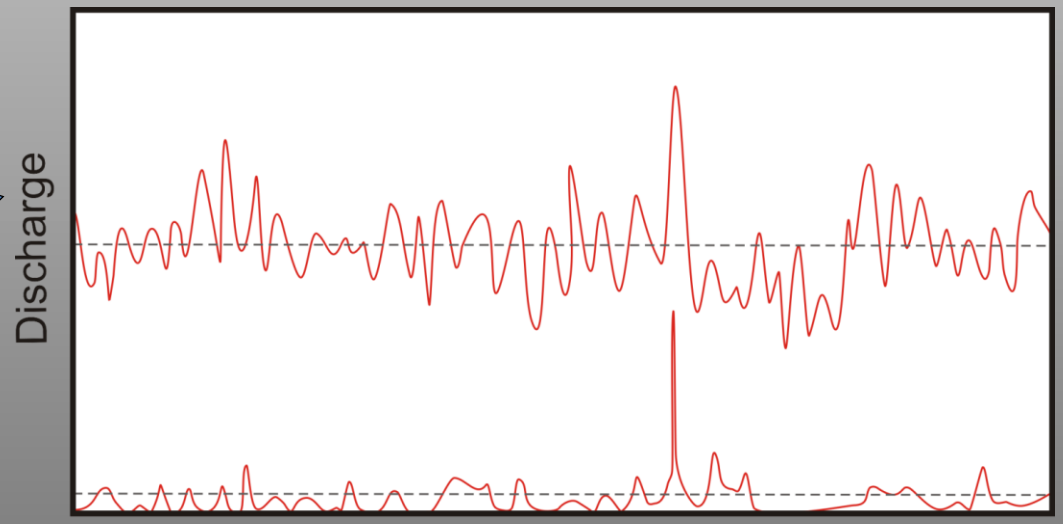


5%

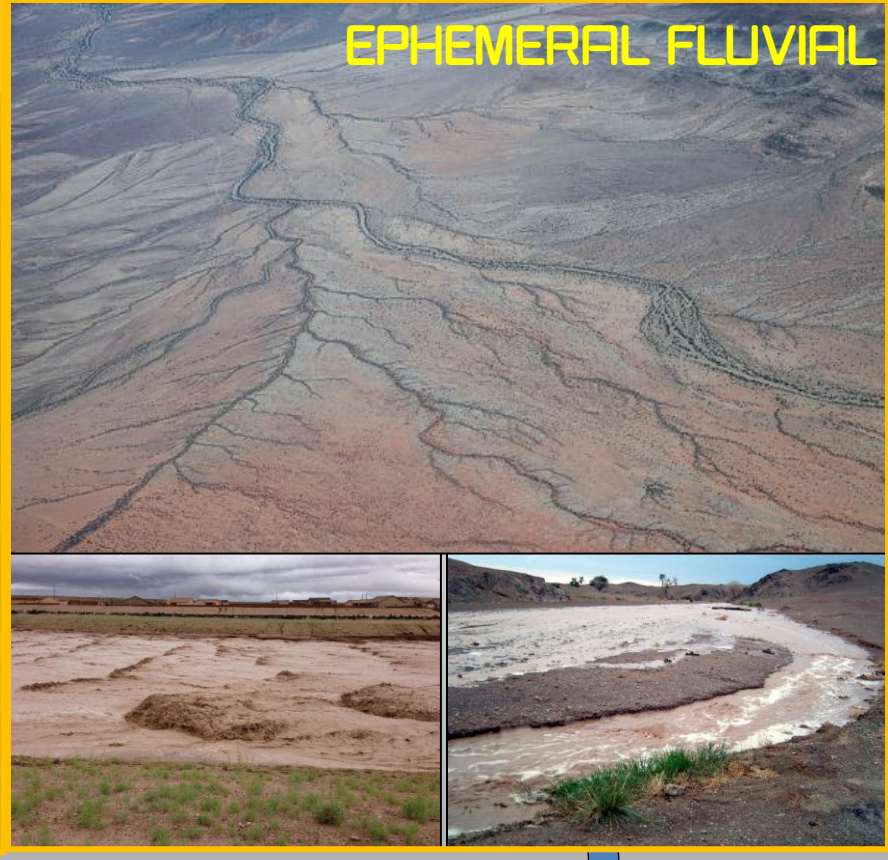
Porosity from Bédard et al., 2013

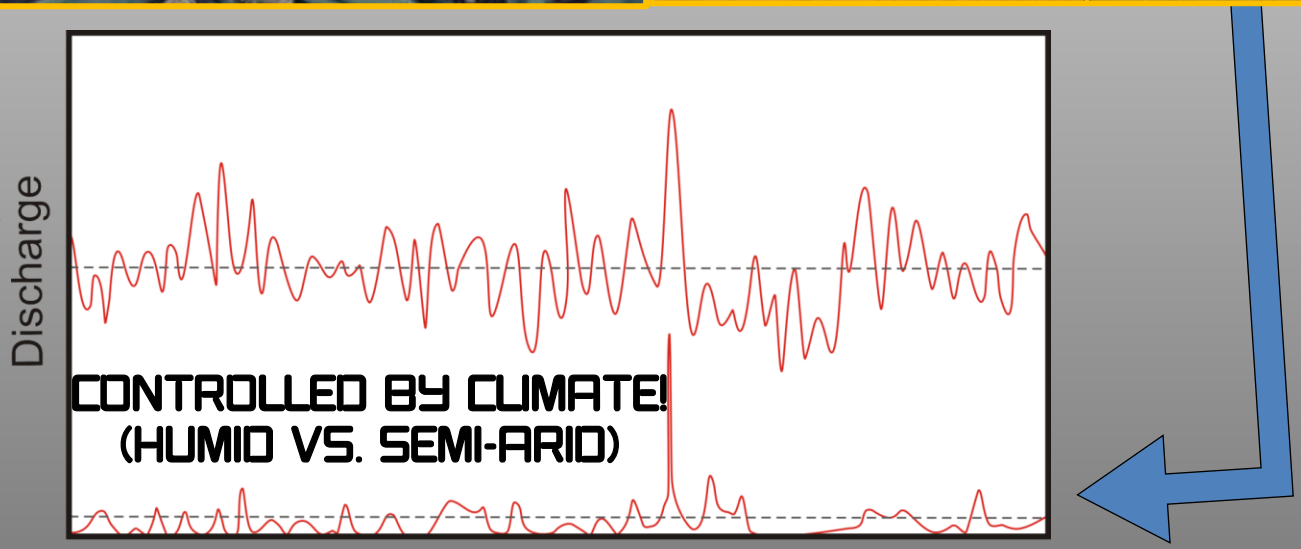

BRAIDED FLUVIAL


EPHEMERAL FLUVIAL

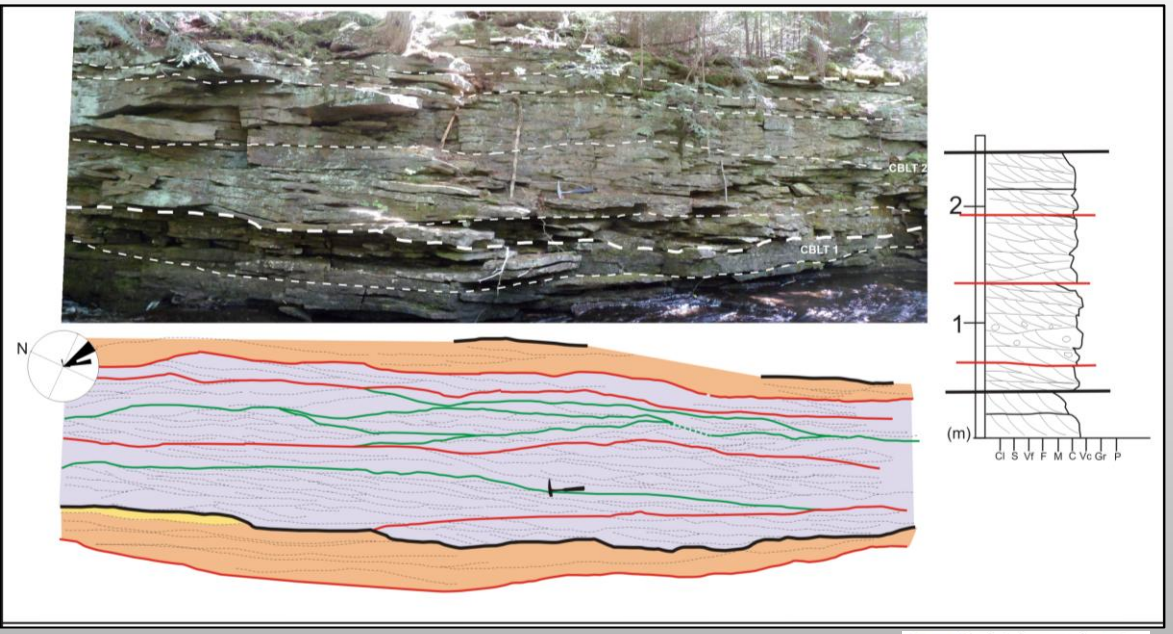

Discharge
Time (10s-100s yr)

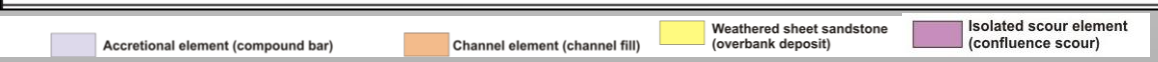

BRAIDED FLUVIAL

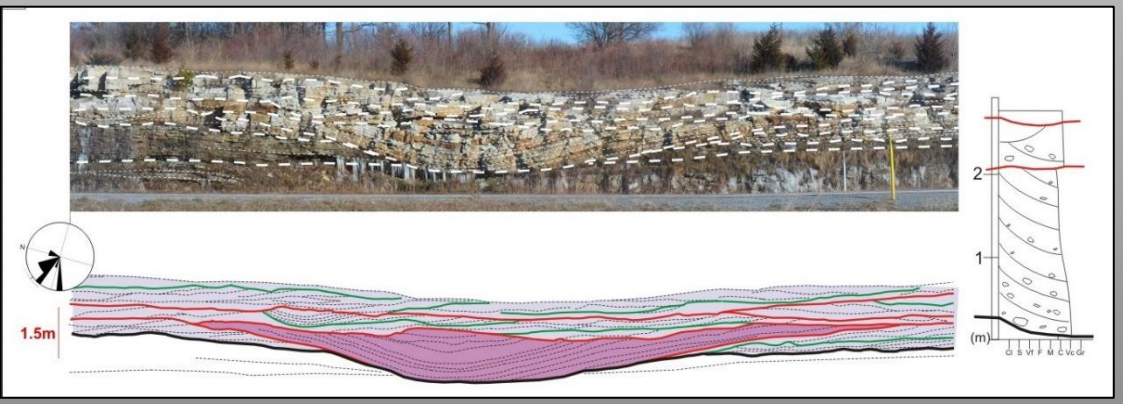

EPHEMERAL FLUVIAL

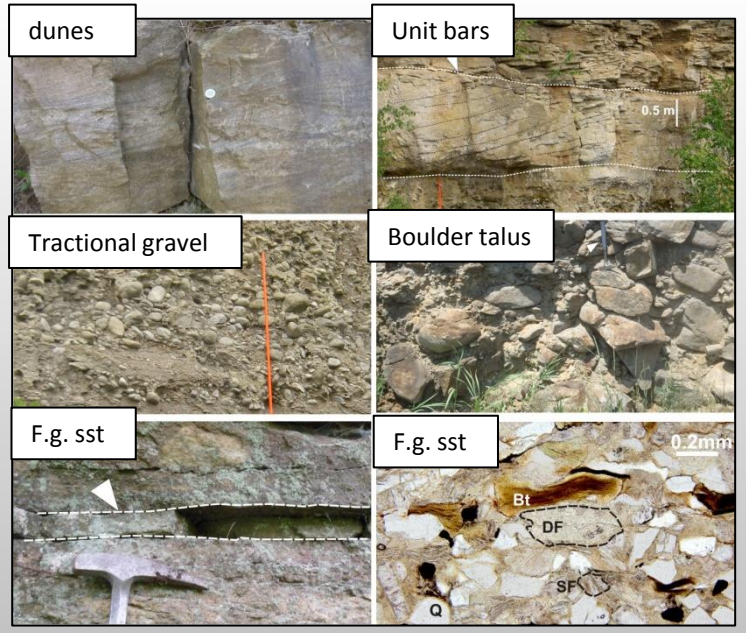

Discharge
CONTROLLED BY CLIMATE!
(HUMID VS. SEMI-ARID)
Time (10s-100s yr)

Braided Fluvial





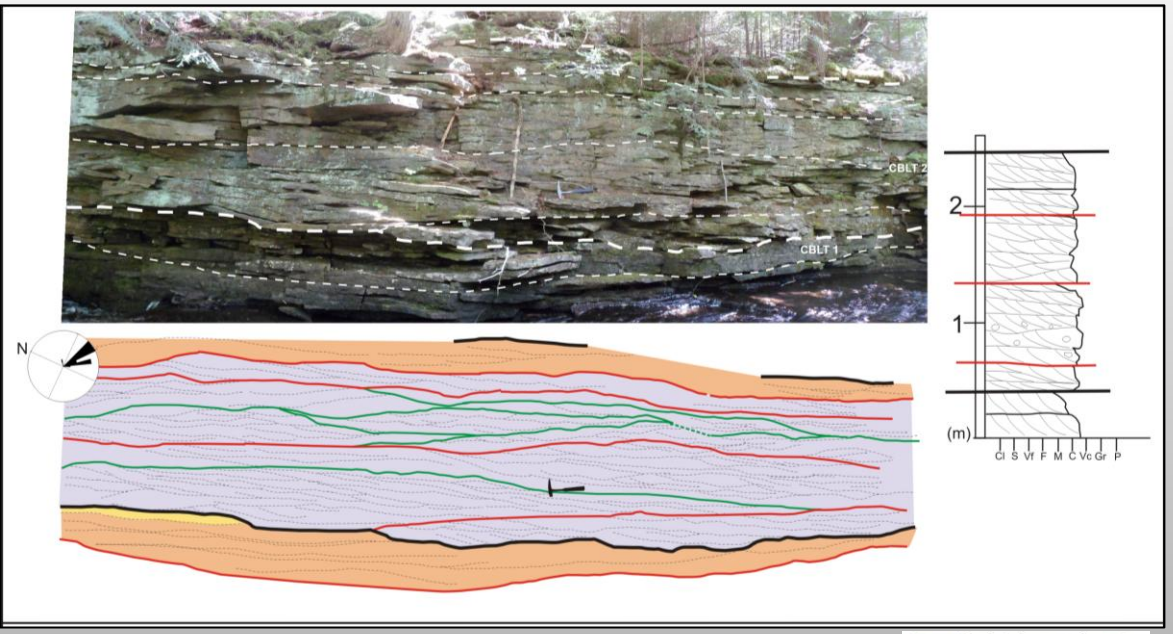




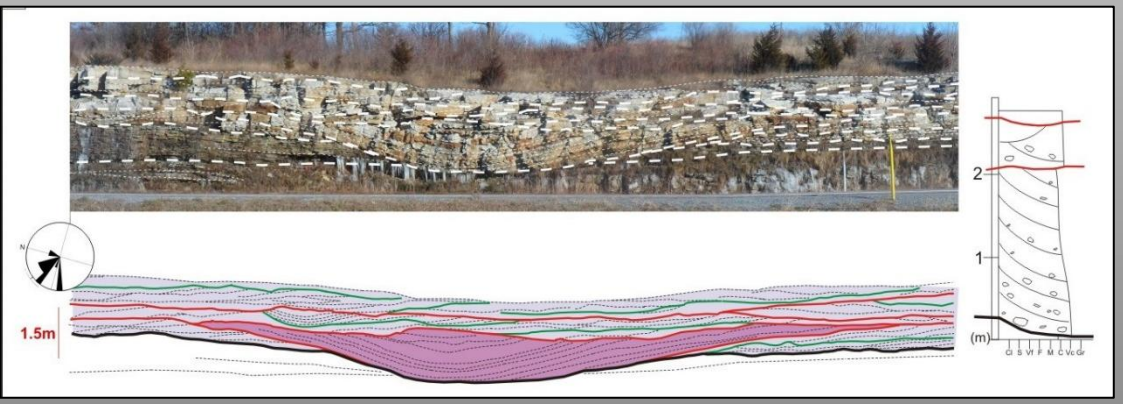
Compound bars; Confluence scours;

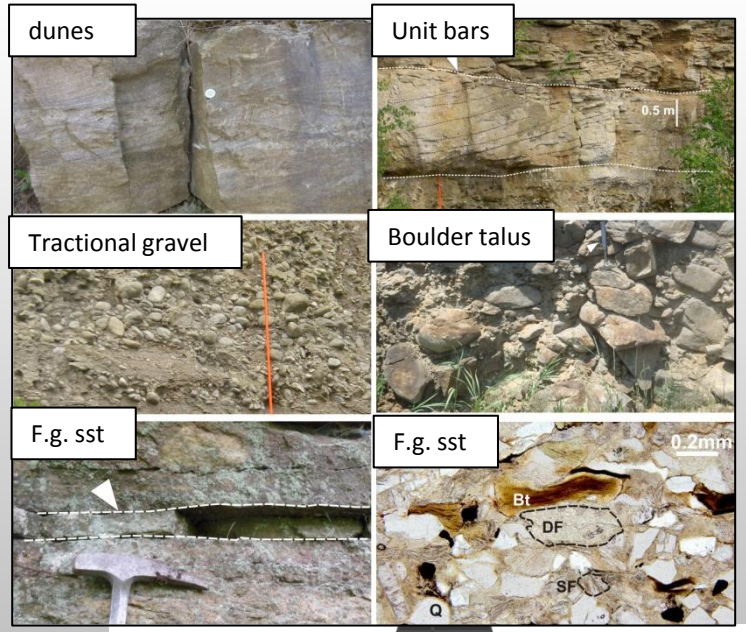
Channel fills; Overbank strata

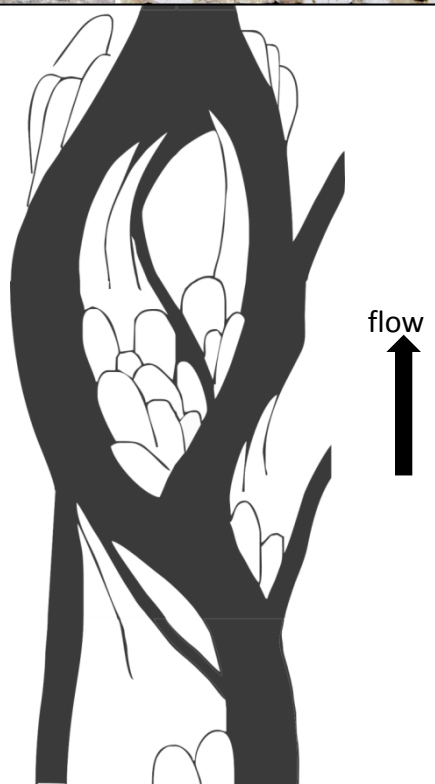
Braided Fluvial



Accretional element (compound bar) | Channel element (channel fill) | Weathered sheet sandstone (overbank deposit) | Isolated scour element (confluence scour)







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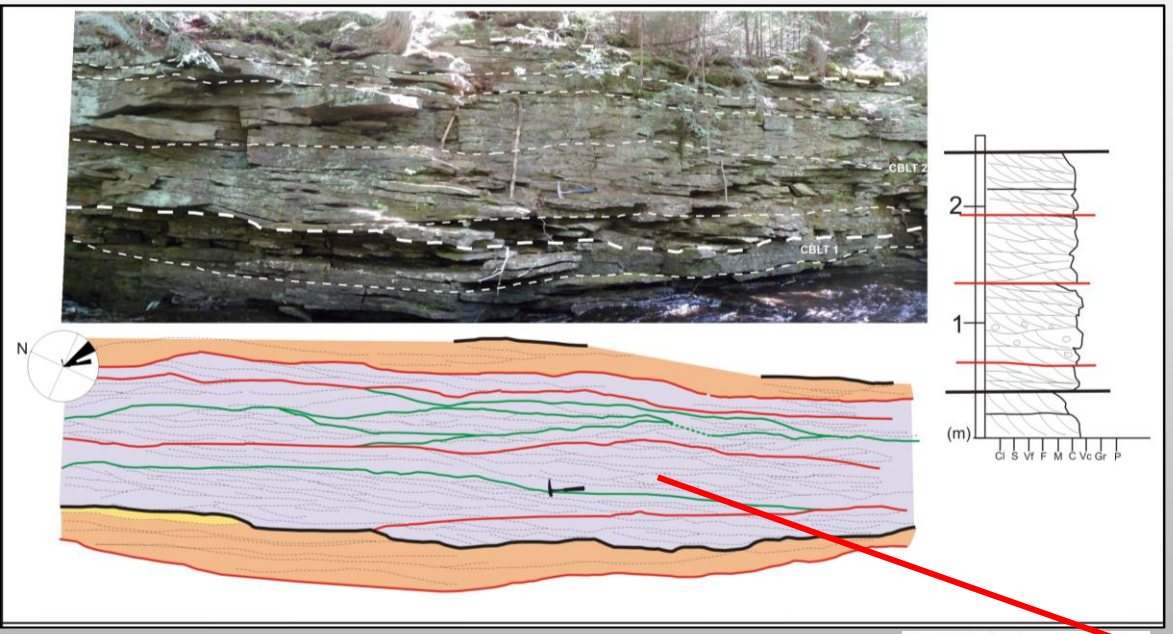

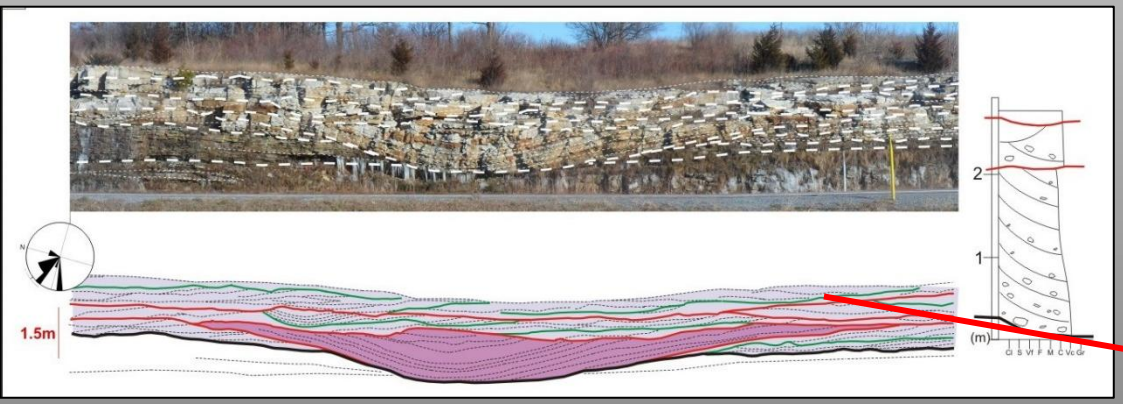

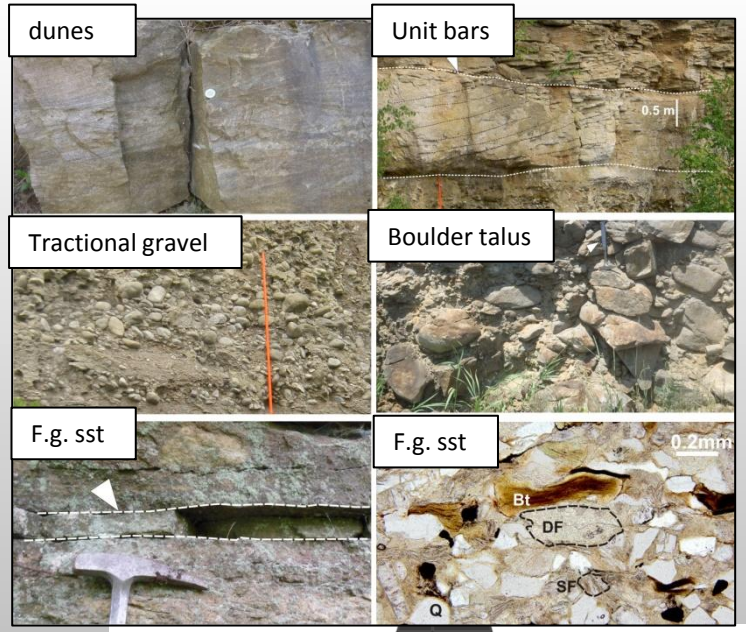

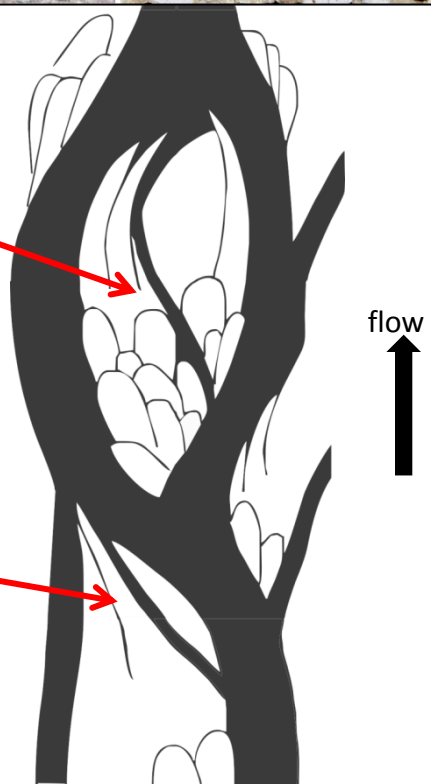

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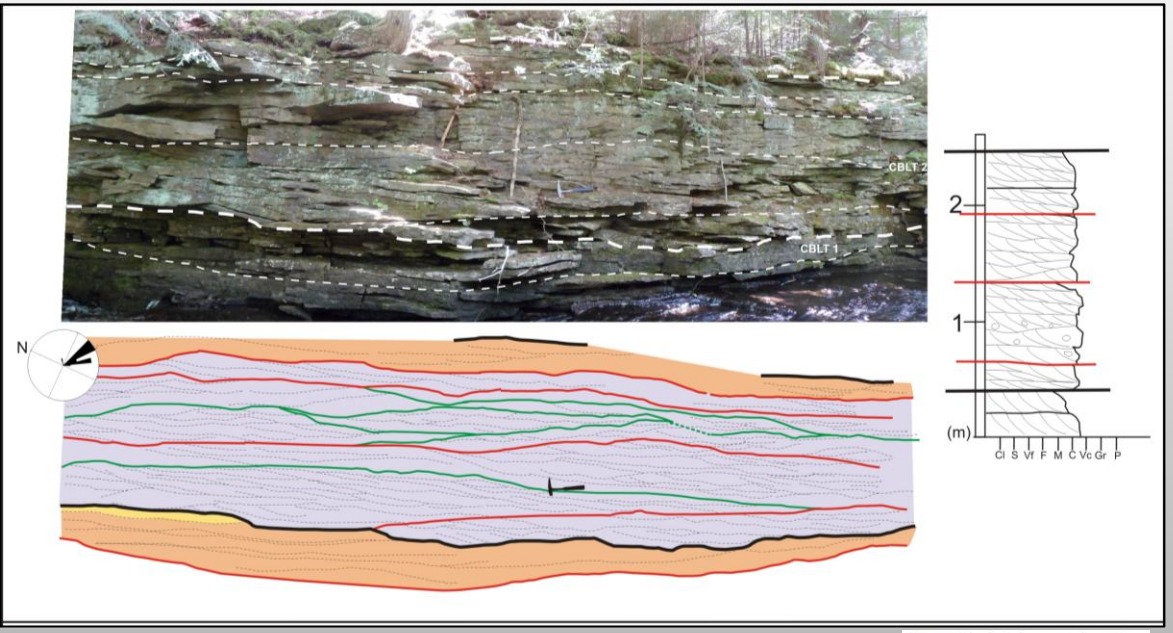
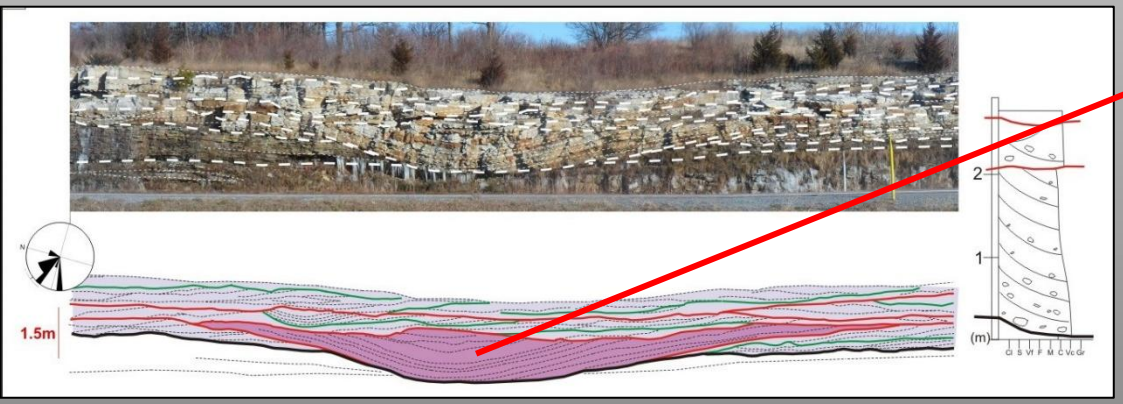
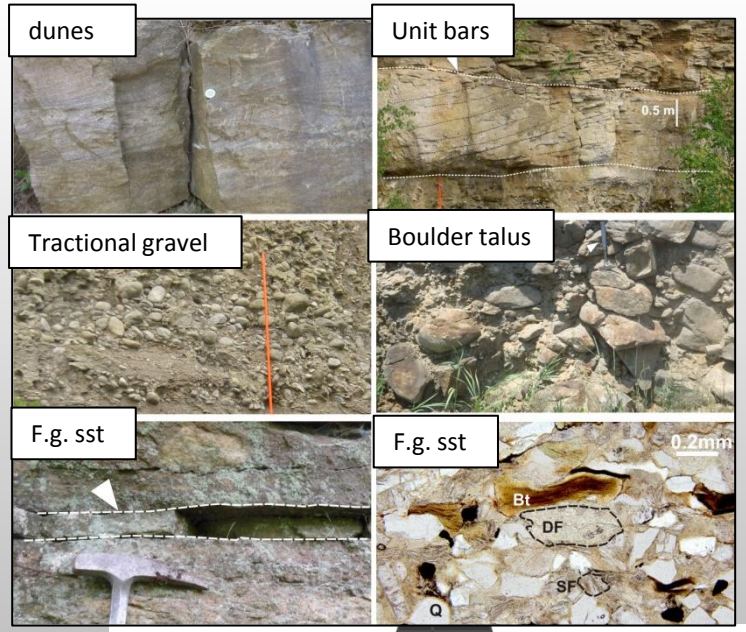
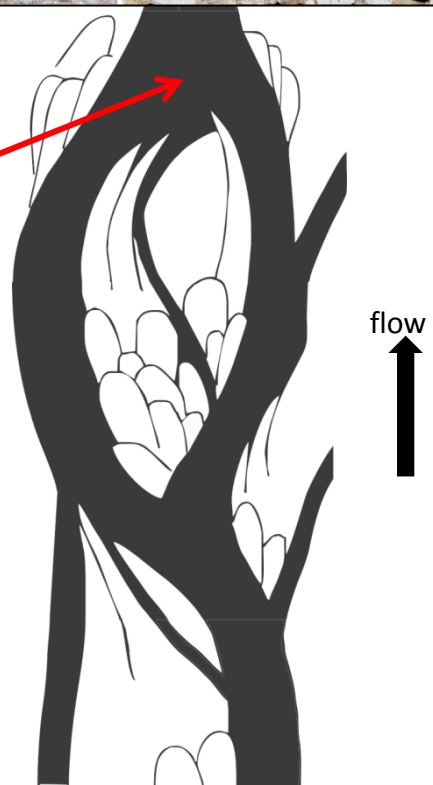


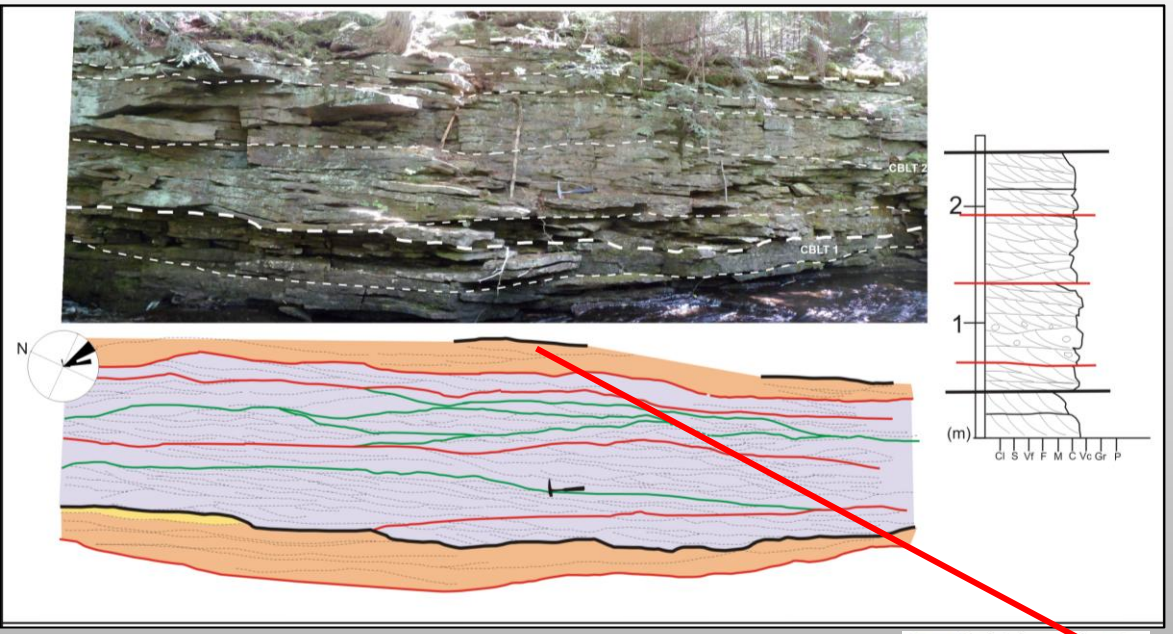


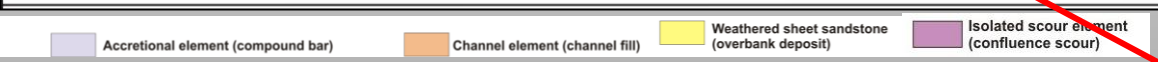


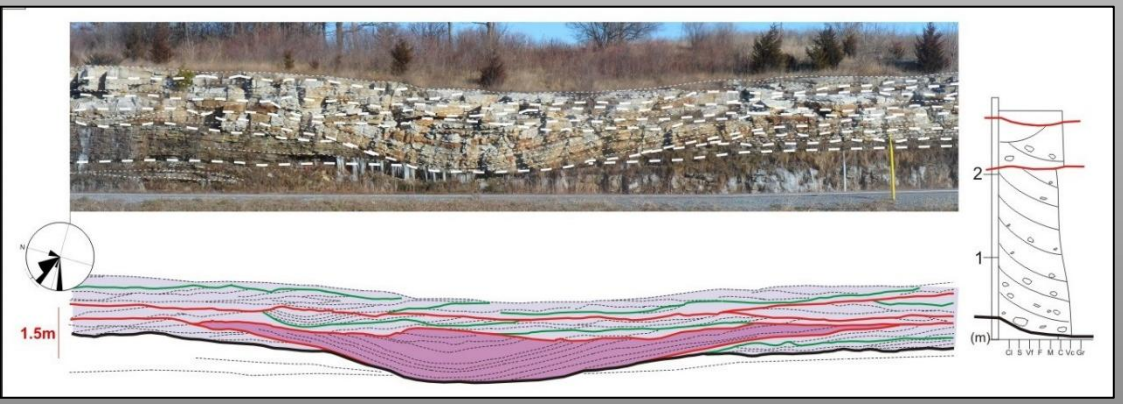


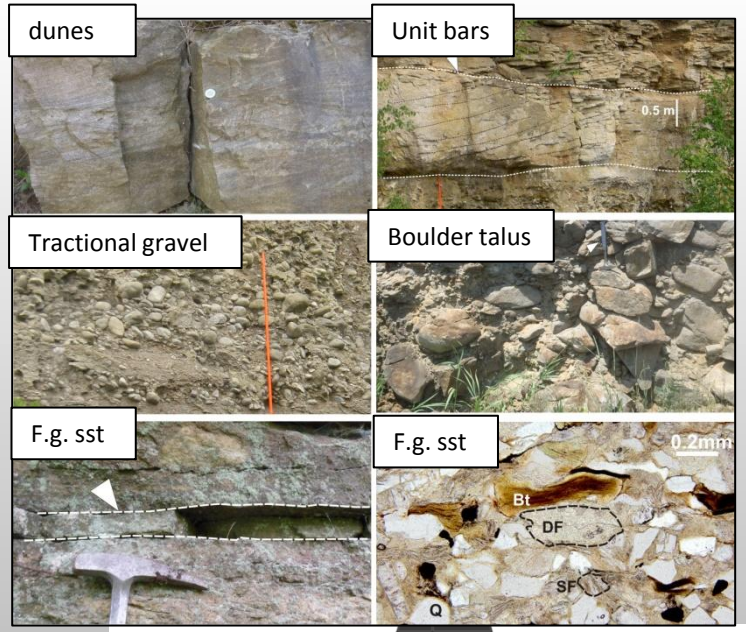
Compound bars; Confluence scours;

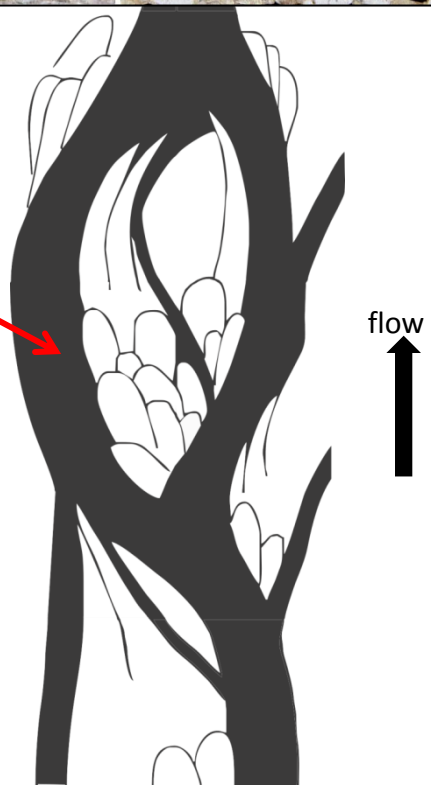
Braided Fluvial







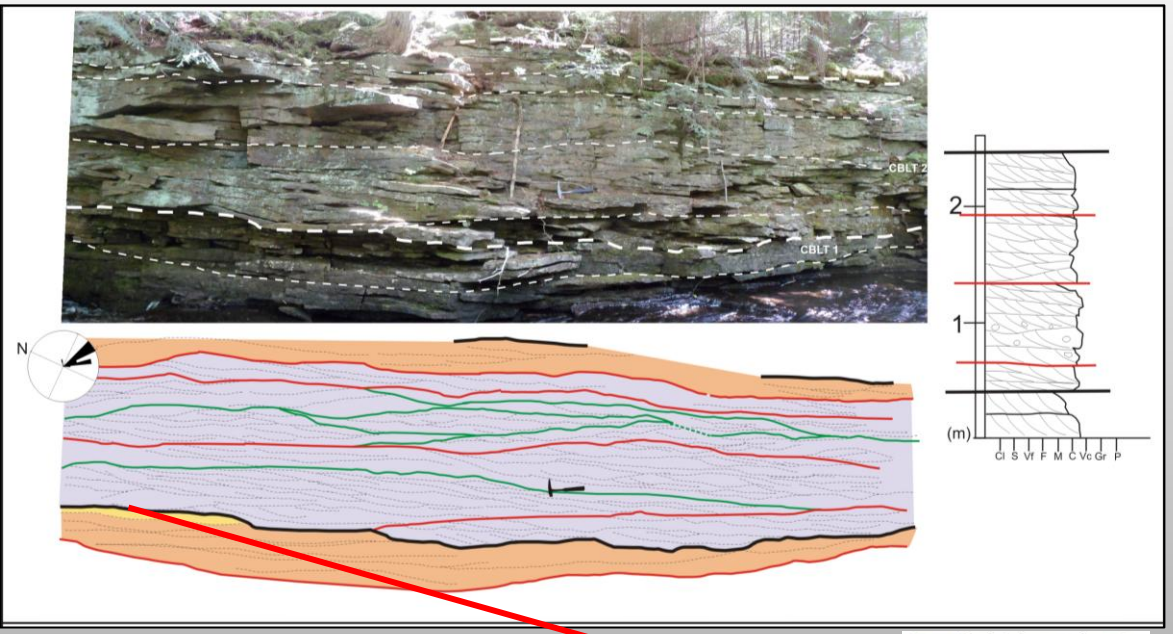


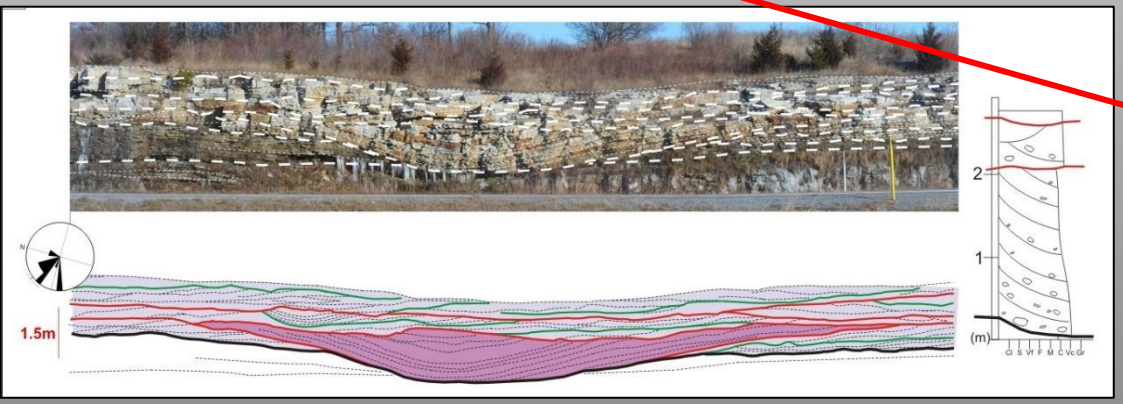


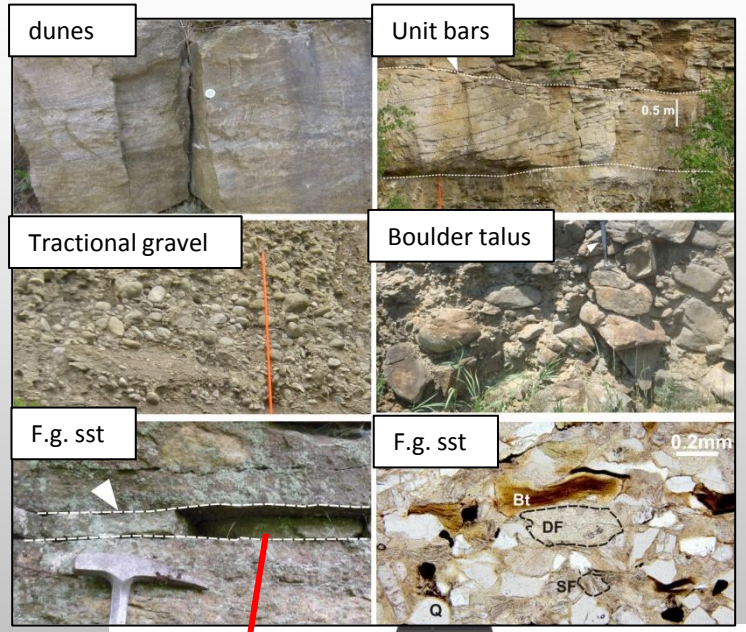
Compound bars; Confluence scours;

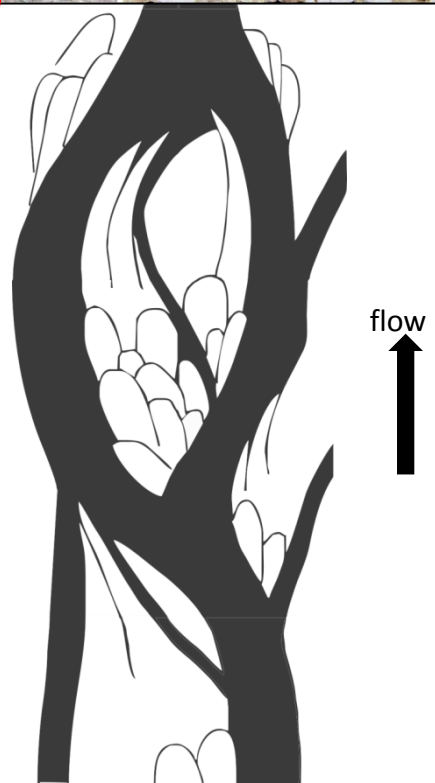
Channel fills;

Braided Fluvial





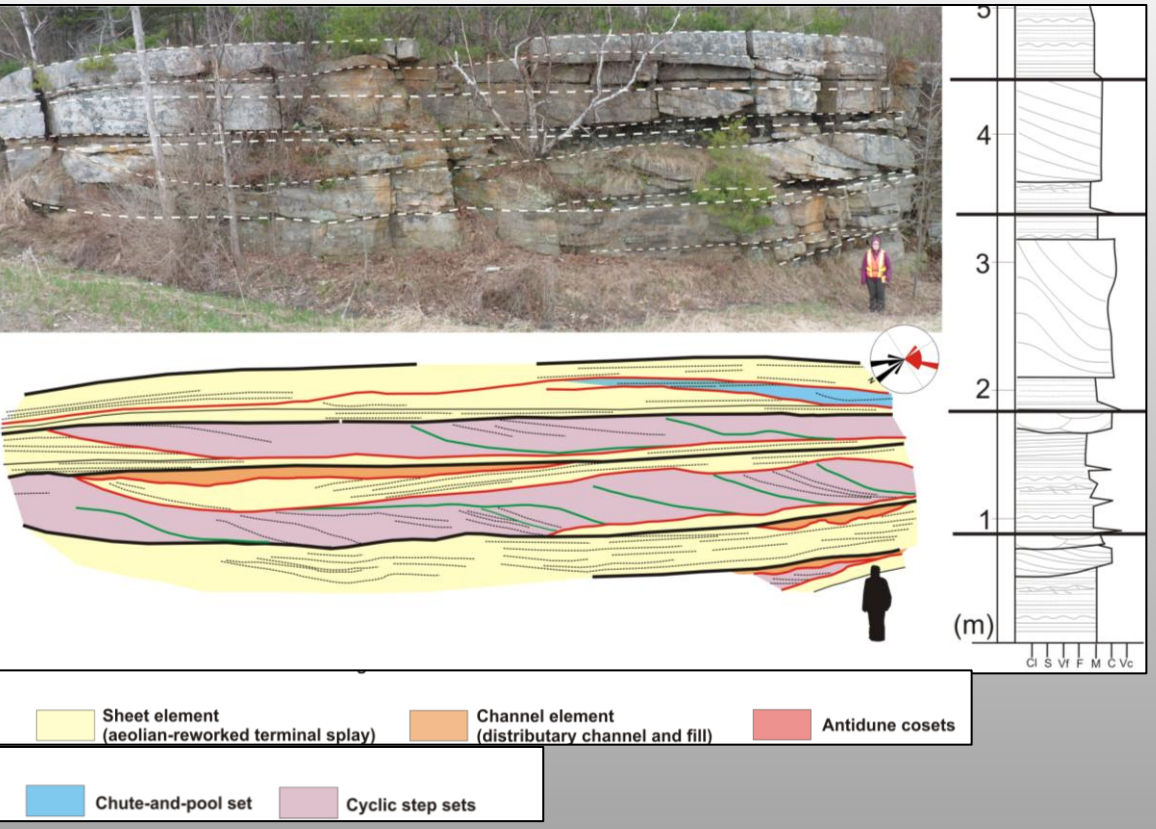




Compound bars; Confluence scours;

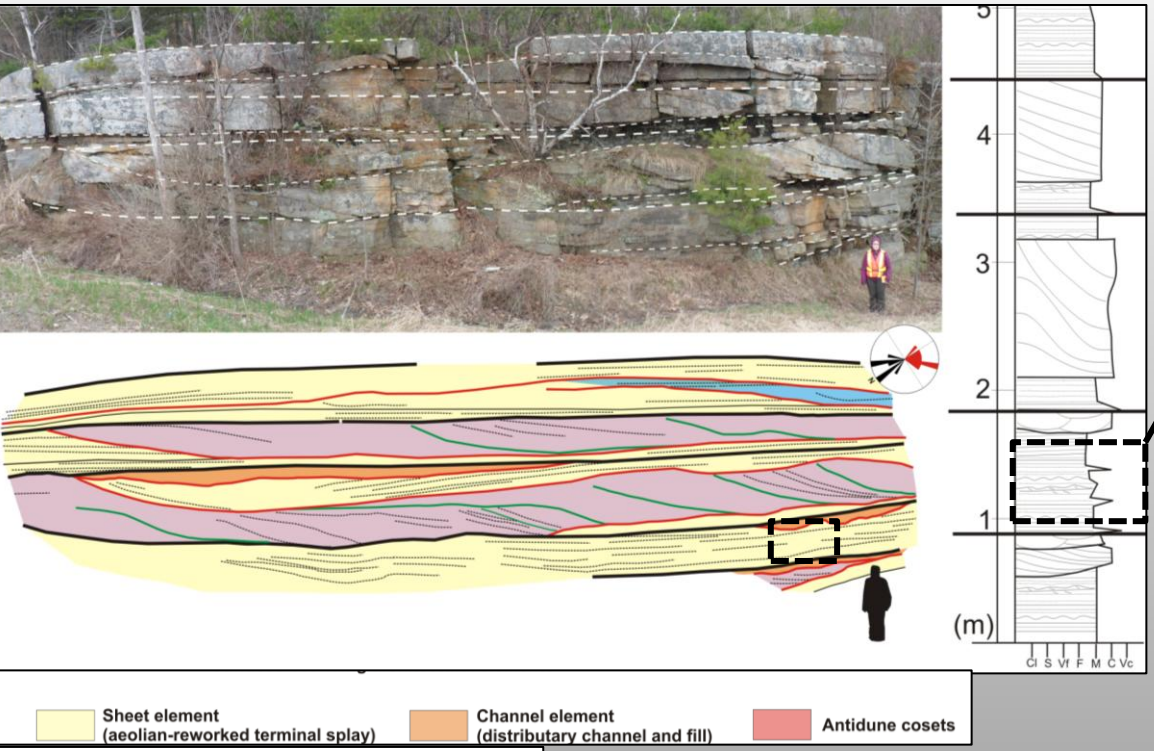
Channel fills; Overbank strata

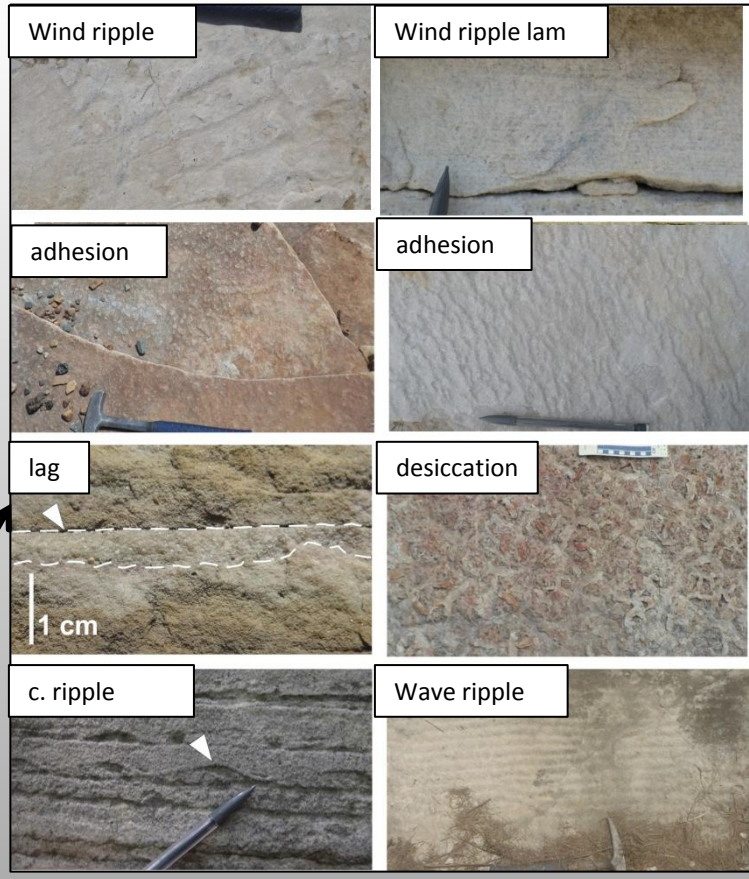
Ephemeral Fluvial



- eolian sand sheets.
- High energy, erosively-based waterlain strata.
- Thin channels and dune-cross-stratified fill

Ephemeral Fluvial





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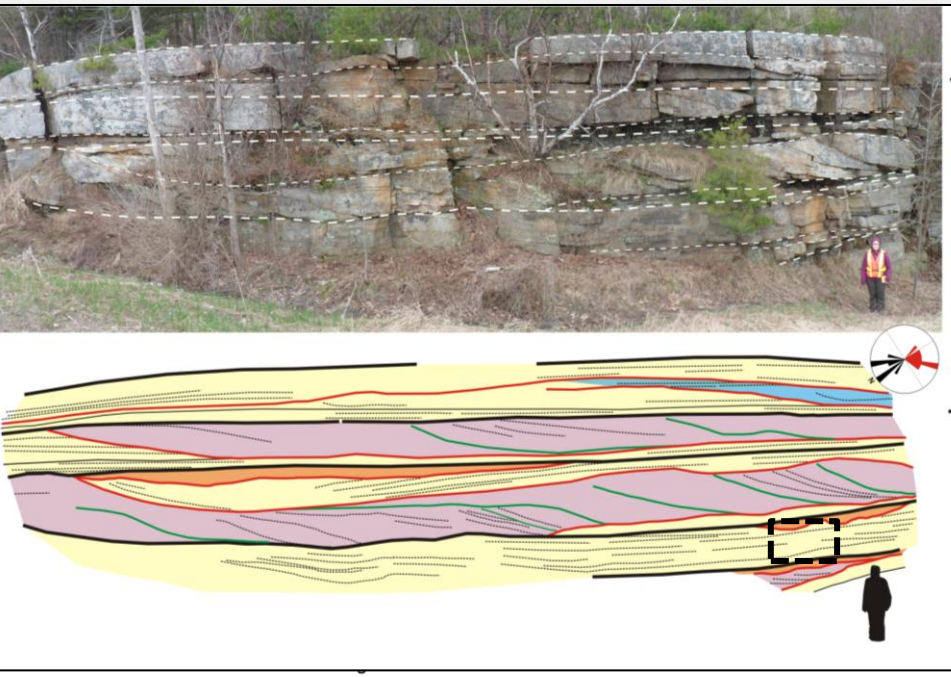

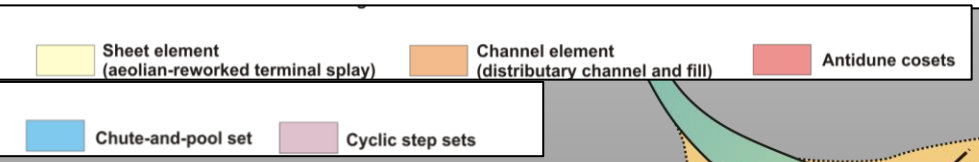

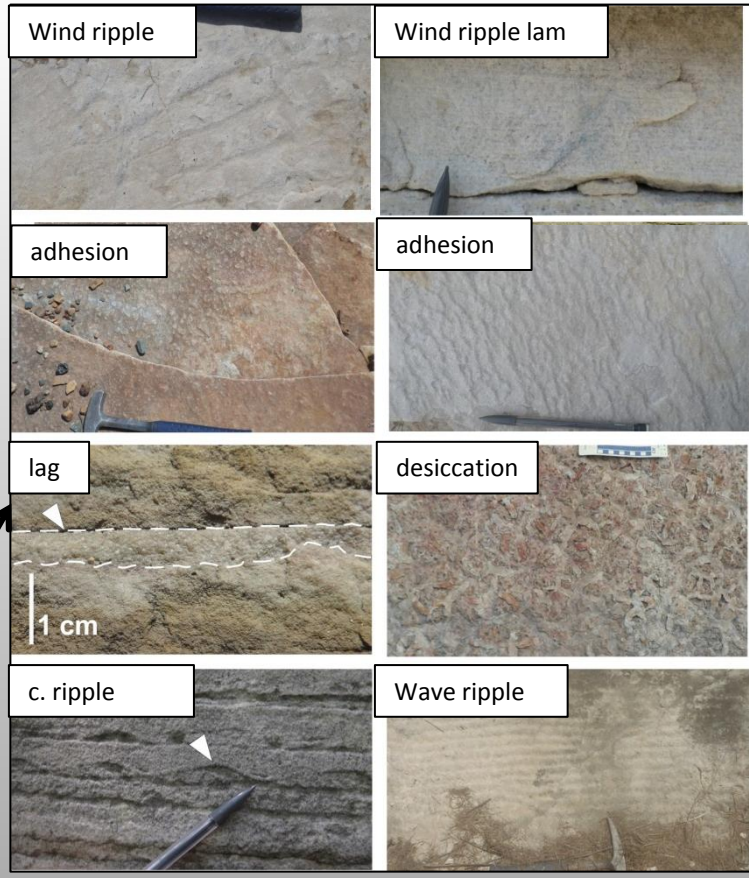

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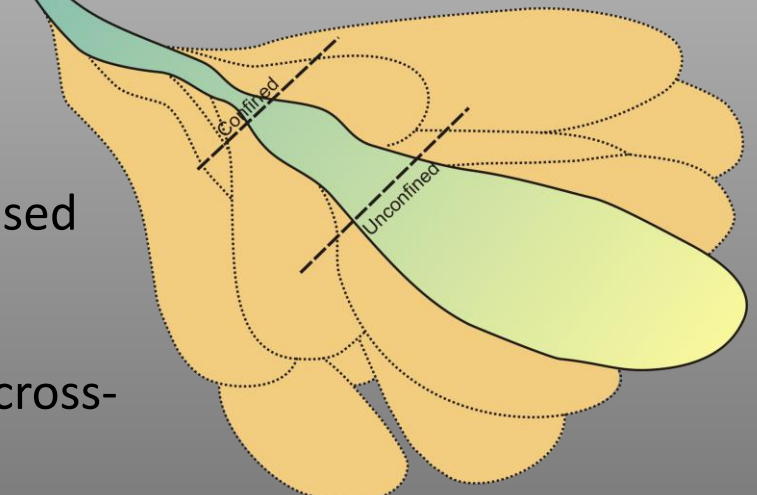
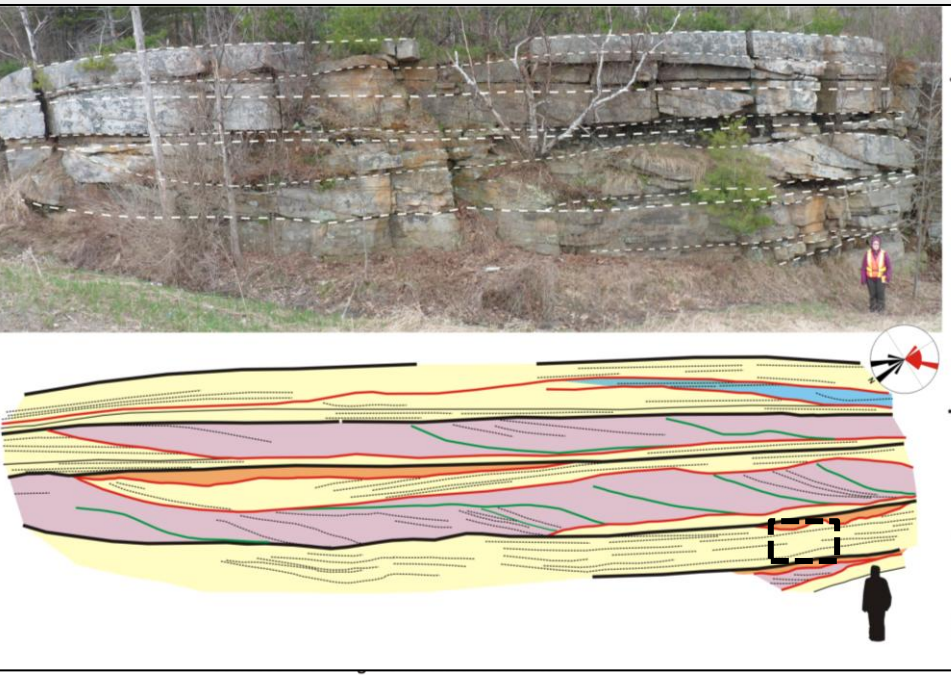
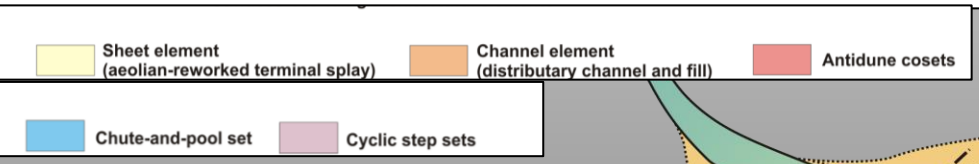
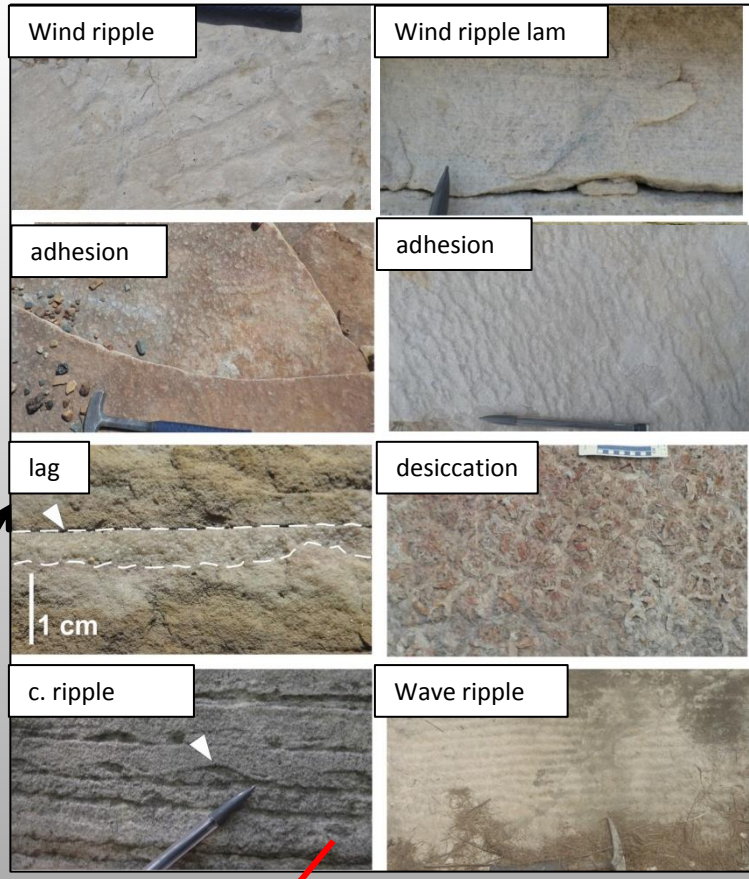


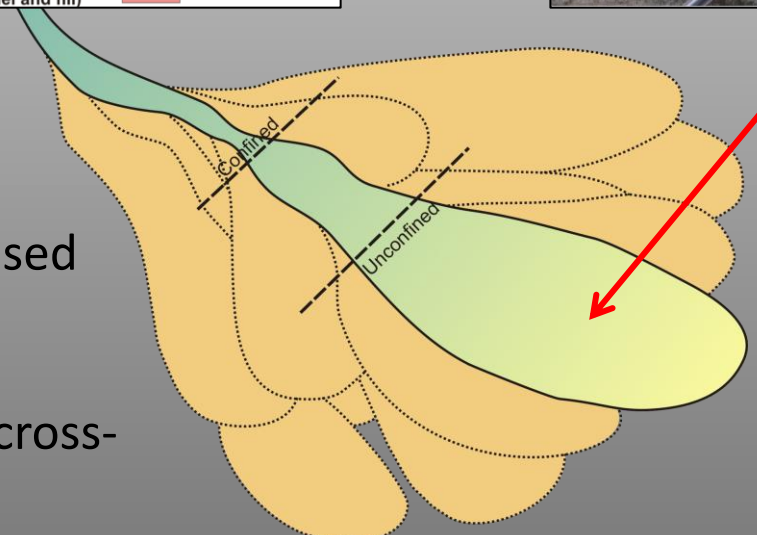
Ephemeral Fluvial





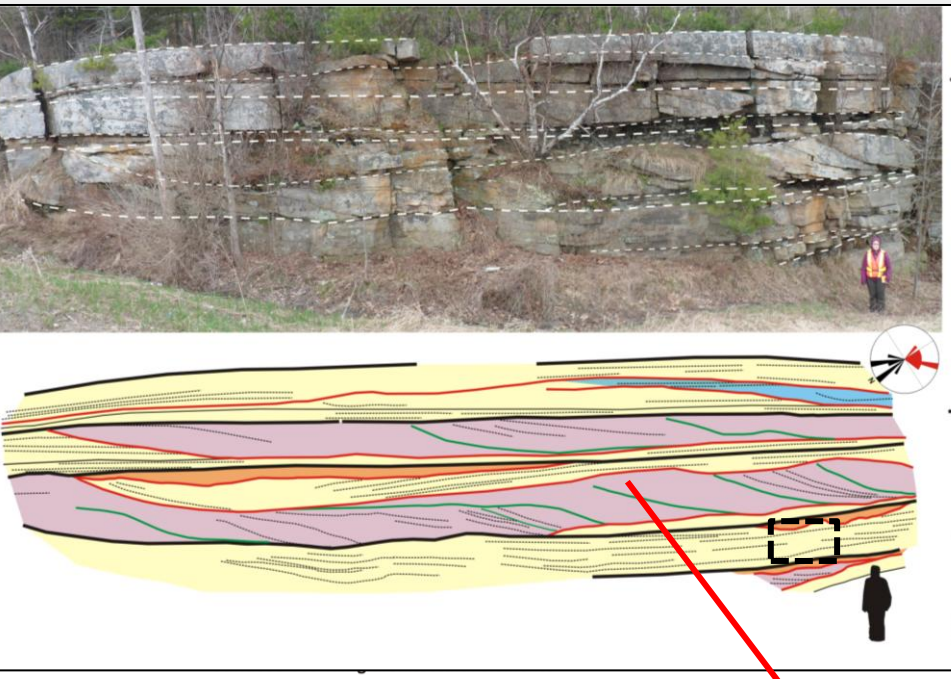


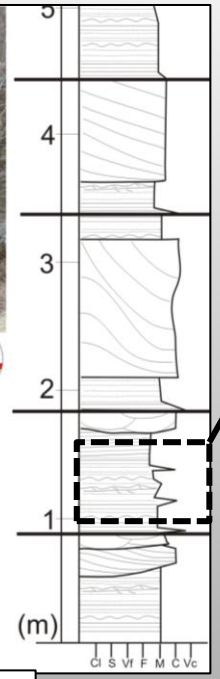
- eolian sand sheets.
- High energy, erosively-based waterlain strata.
- Thin channels and dune-cross-stratified fill

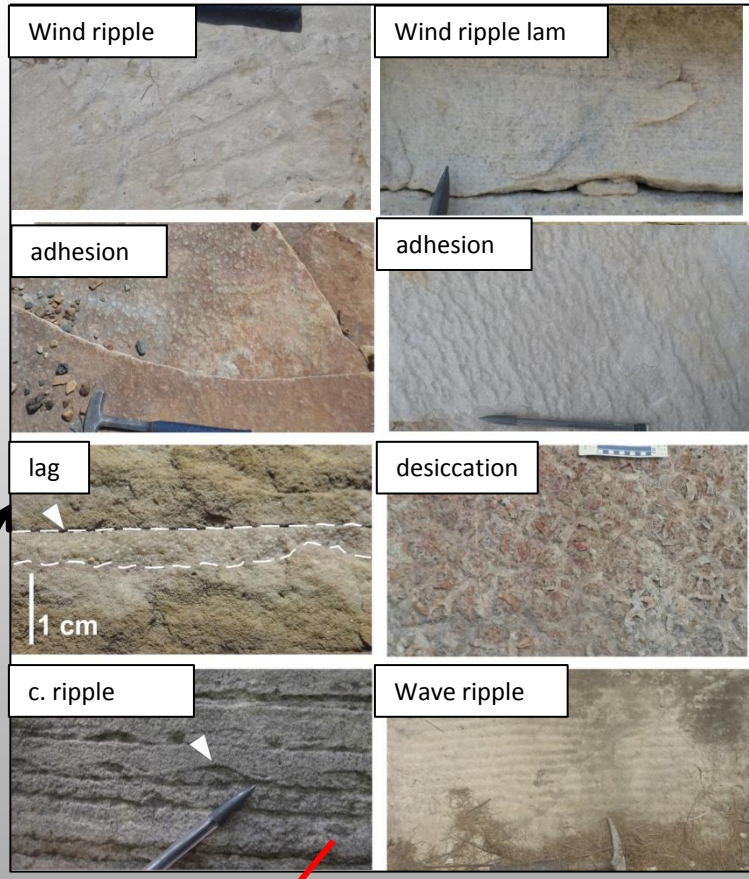


Deflated/wind-Reworked terminal splays

Ephemeral Fluvial







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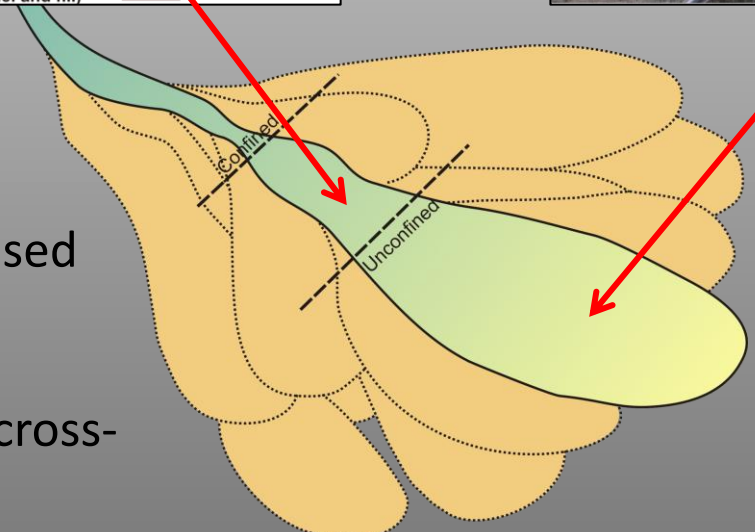


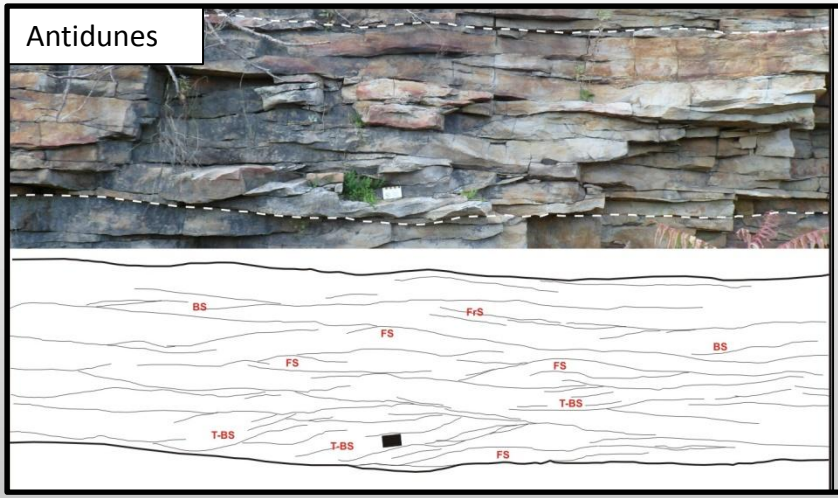
Deflated/wind-Reworked terminal splays

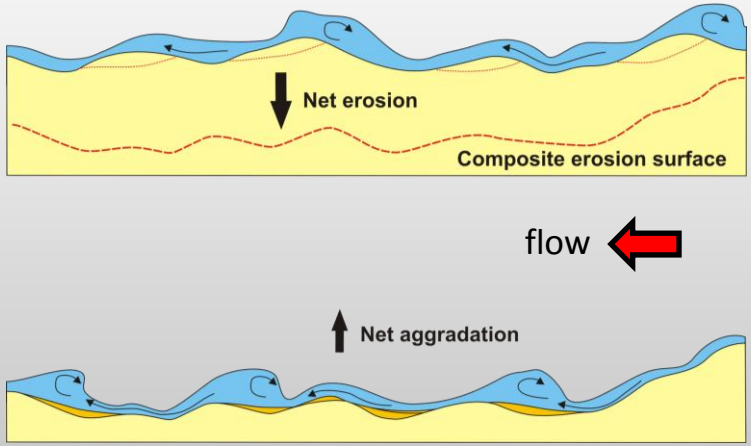
High-energy Sheetflood strata (supercritical)

Supercritical Bedform Strata

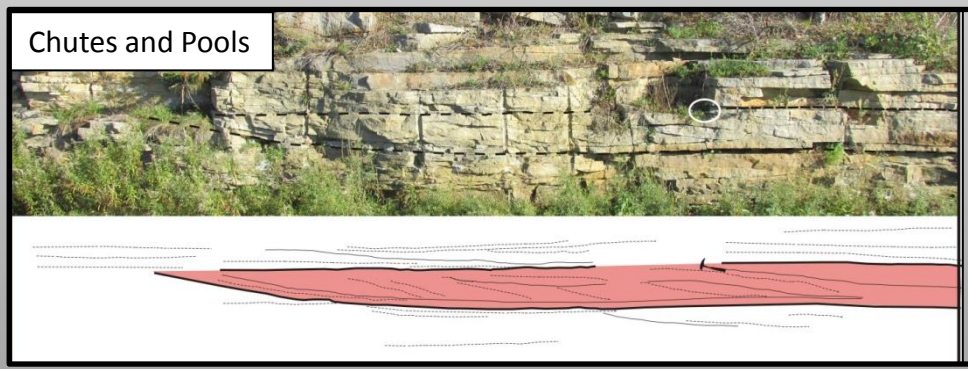
+Fr#
(+v/d)

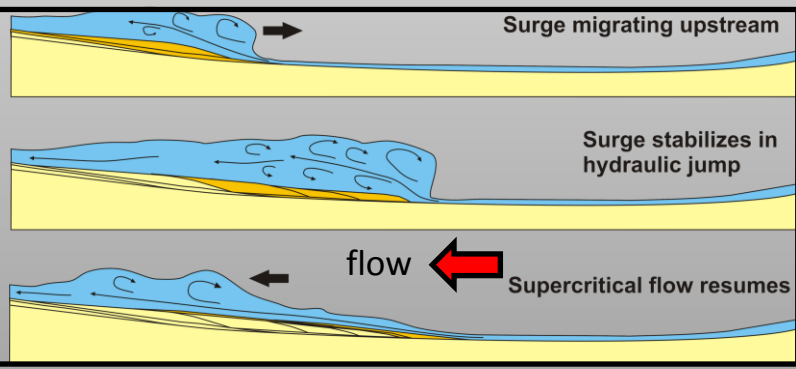
Antidunes



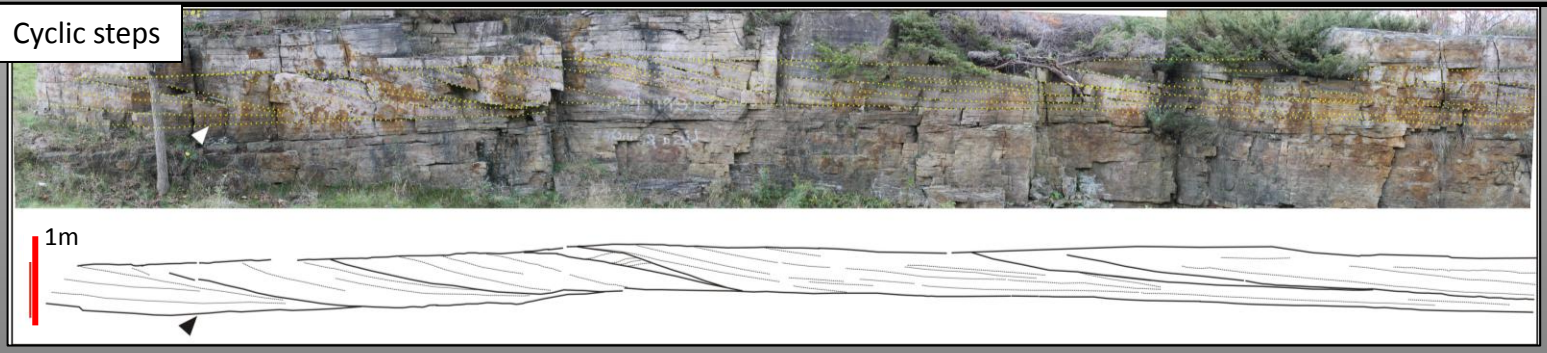


Chutes and Pools

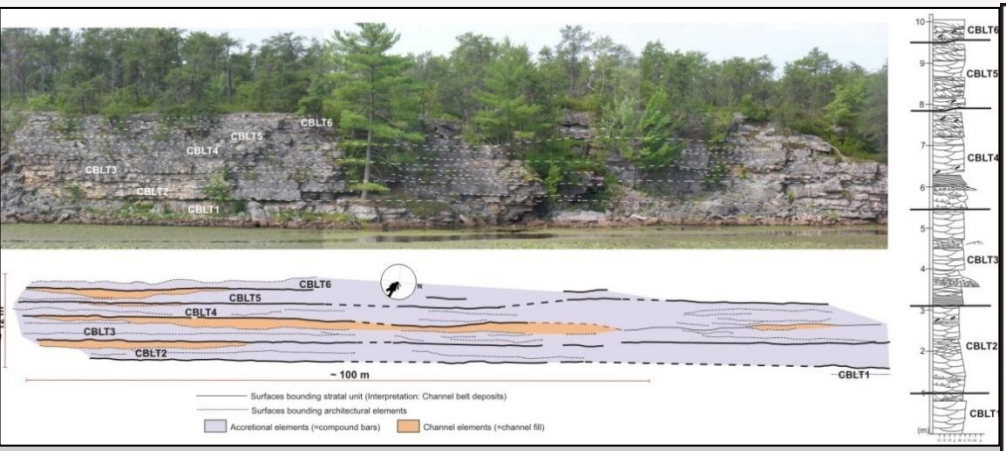


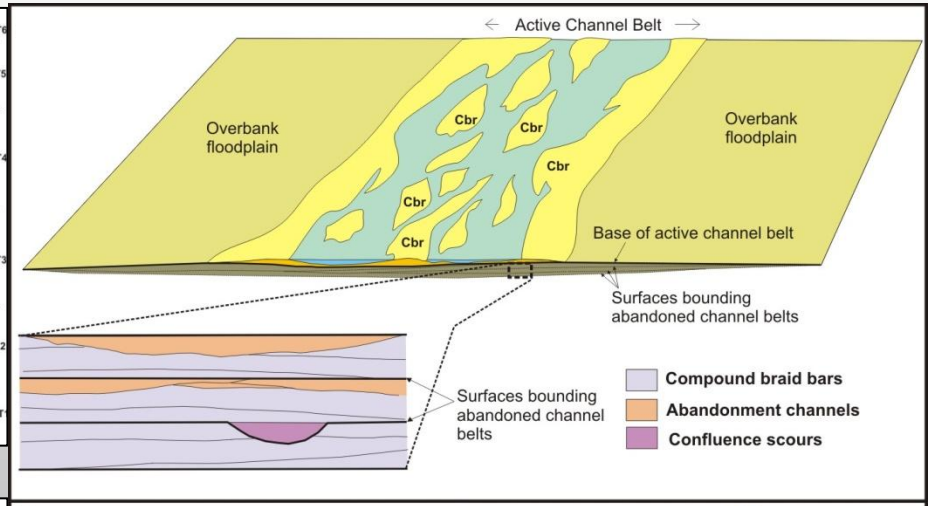


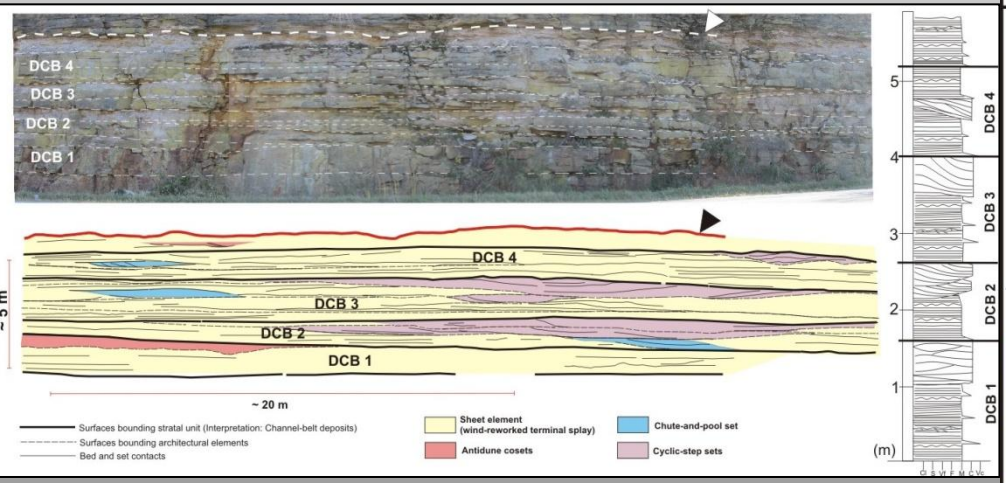
Cyclic steps

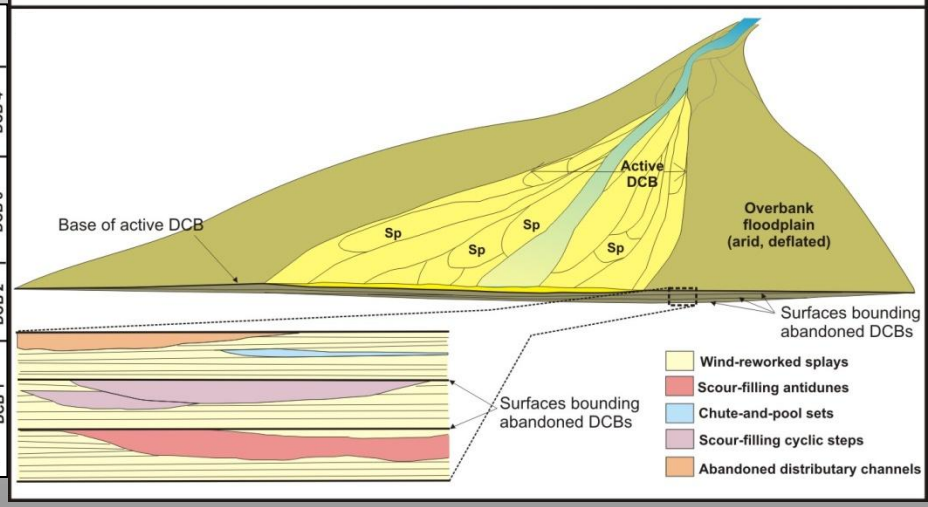


Stratal Units = Channel Belts





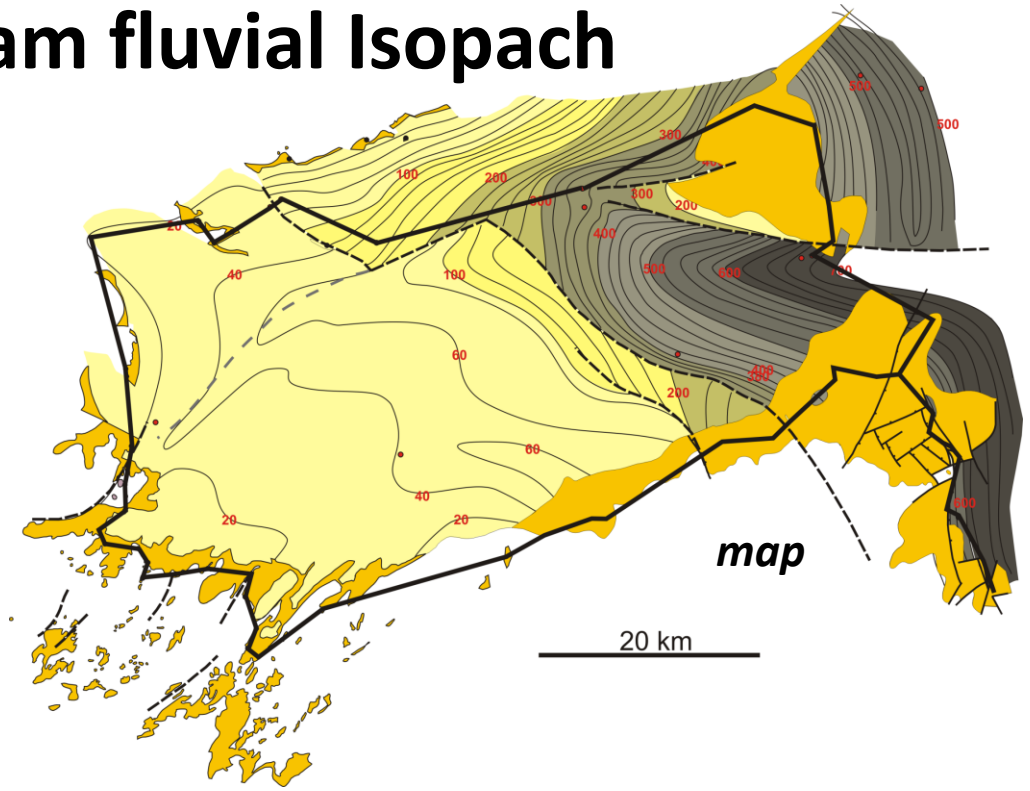


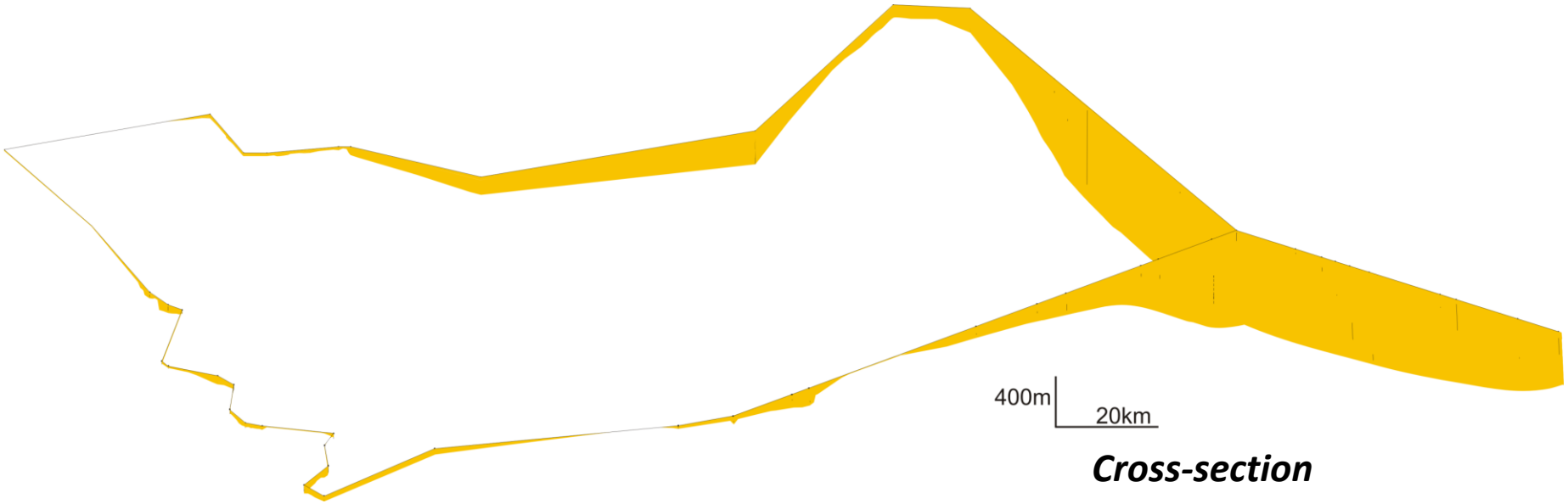


- High order surfaces subdivide fluvial strata into “stratal units” with characteristic vertical succession of facies and architectural elements.

- Stratal units record the build-up of channel belts (br.)/ distributive channel belts (eph.) followed by bypass, incision and avulsion.

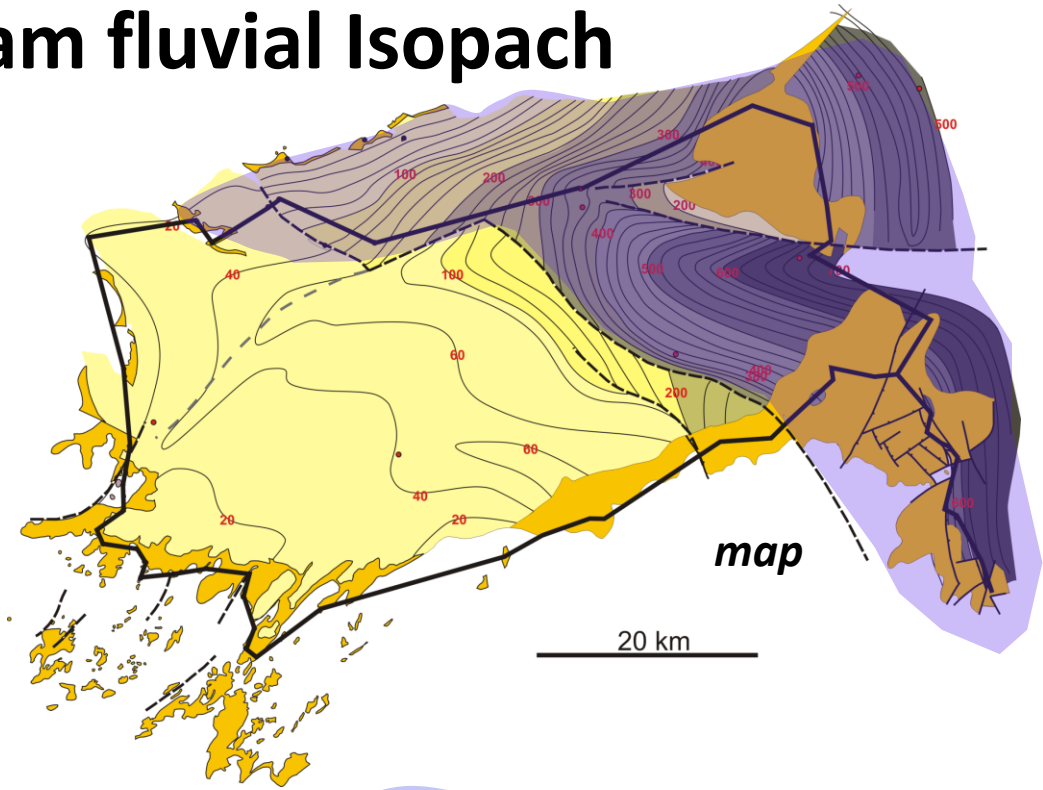
Faults and the Potsdam fluvial Isopach

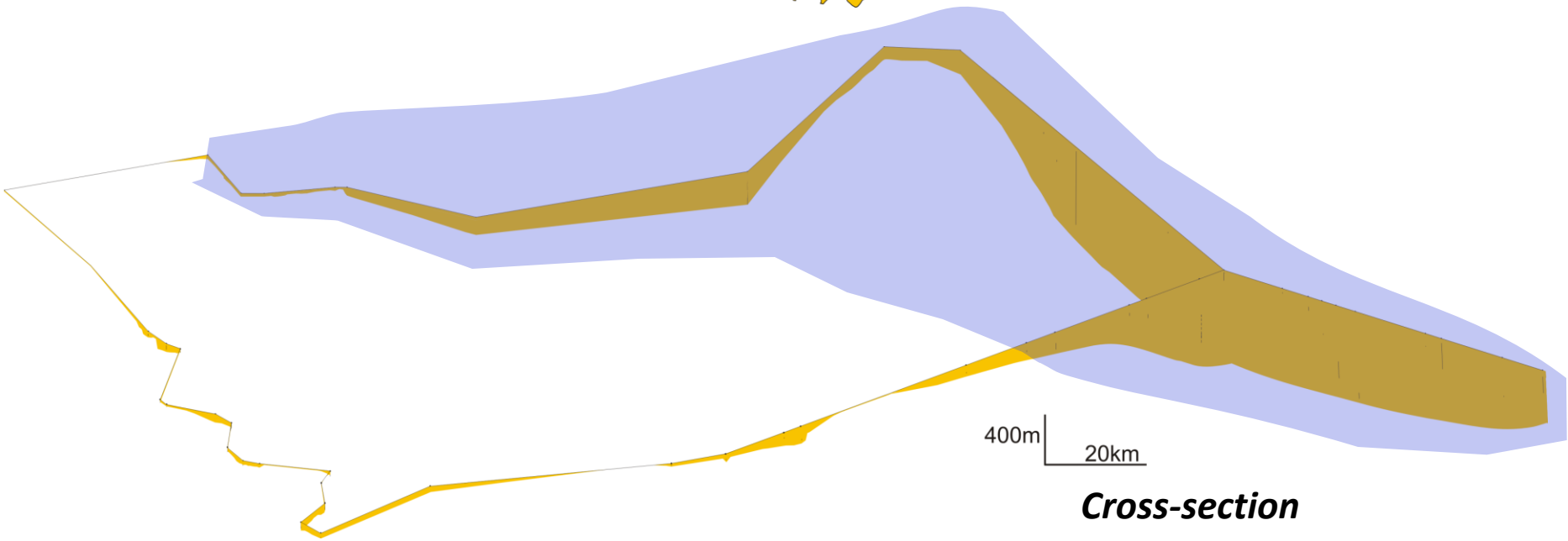




Faults and the Potsdam fluvial Isopach

Areally-expansive fluvial strata: 10s - 100s of m thick.

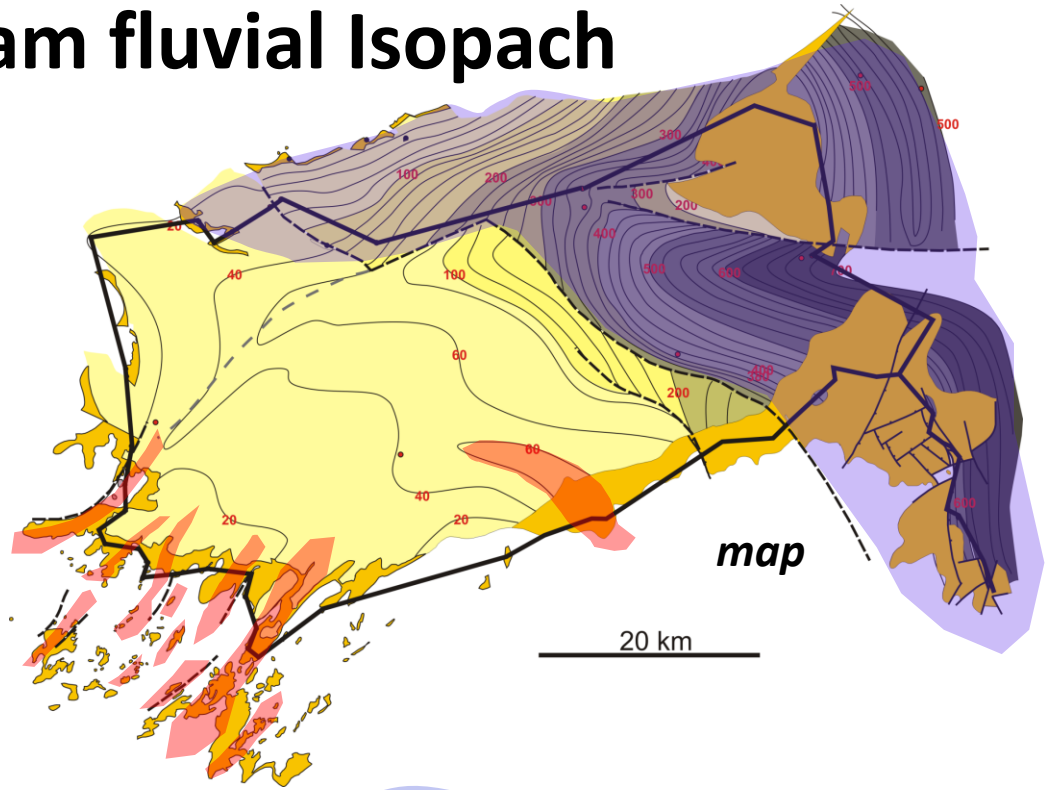


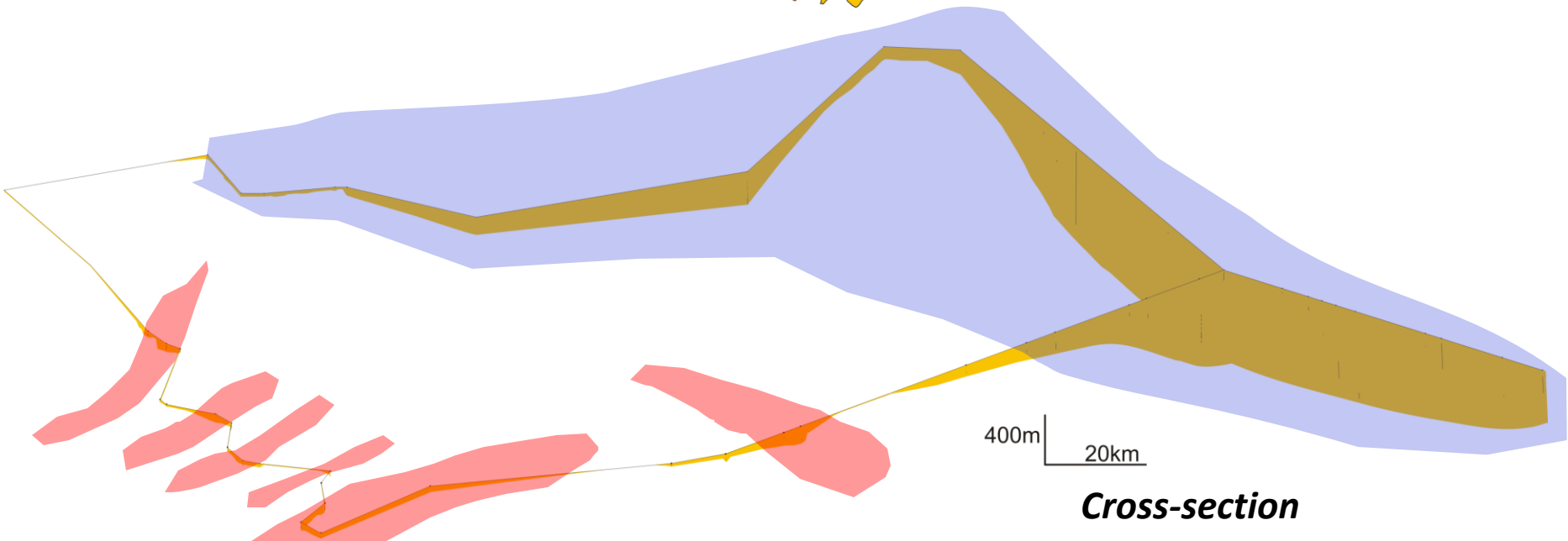


Faults and the Potsdam fluvial Isopach

Areally-expansive fluvial strata: 10s - 100s of m thick.

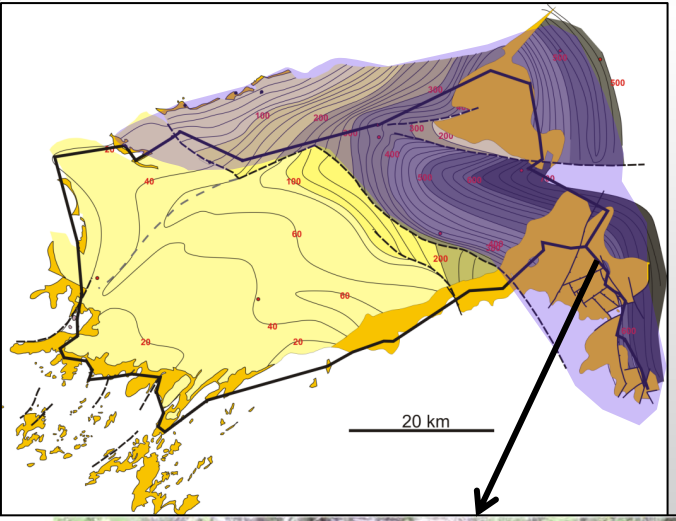
Areally-limited fluvial strata: confined by fault-bounded basement highs, < 100 m thick.

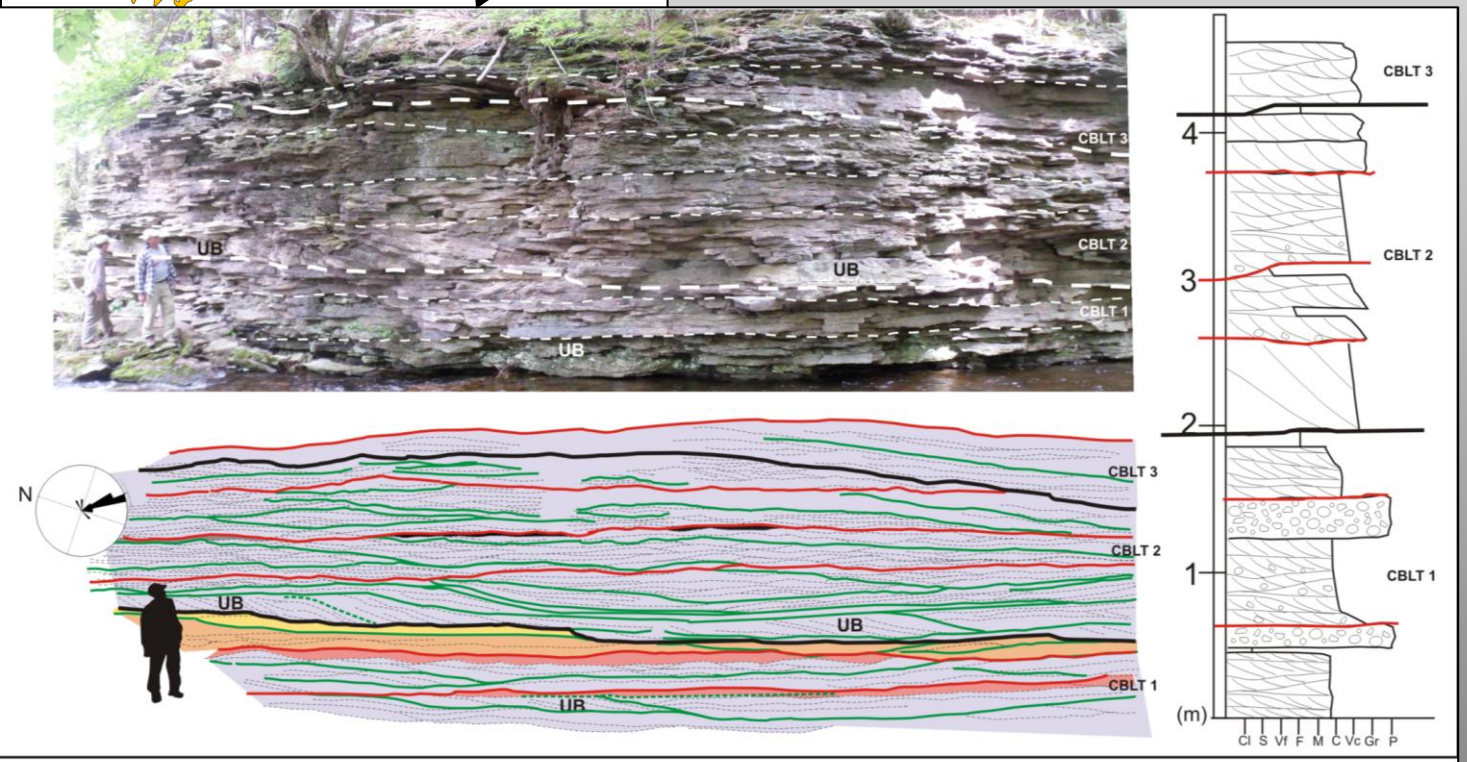




Areally-Expansive Braided Fluvial Strata

- Thin, low angle strata.
- Deposition of low-relief bars in wide, shallow channels.
- M-scale channel belt successions are capped by tight overbank strata.





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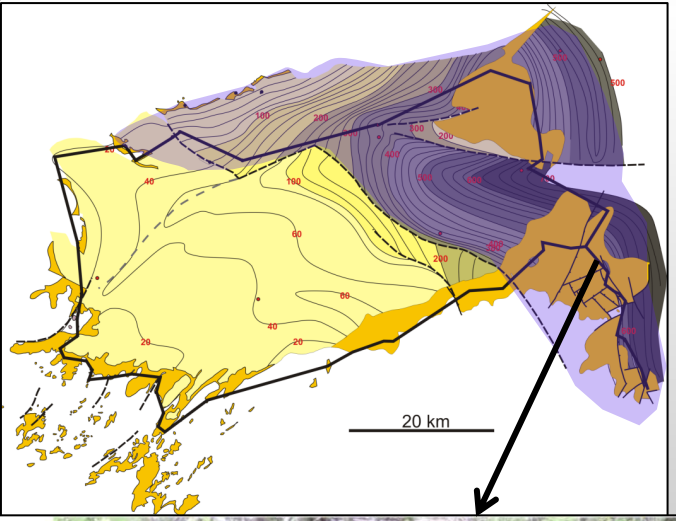

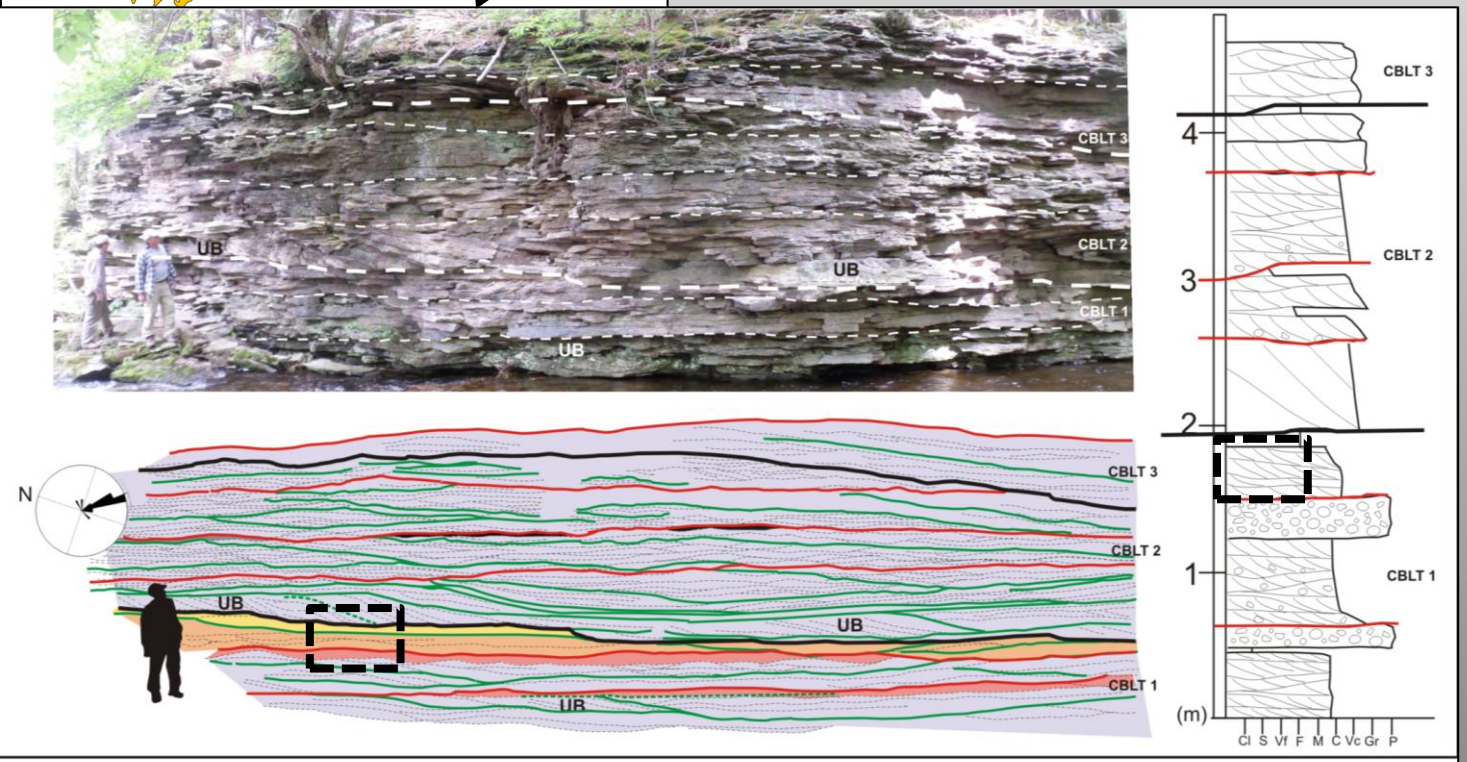

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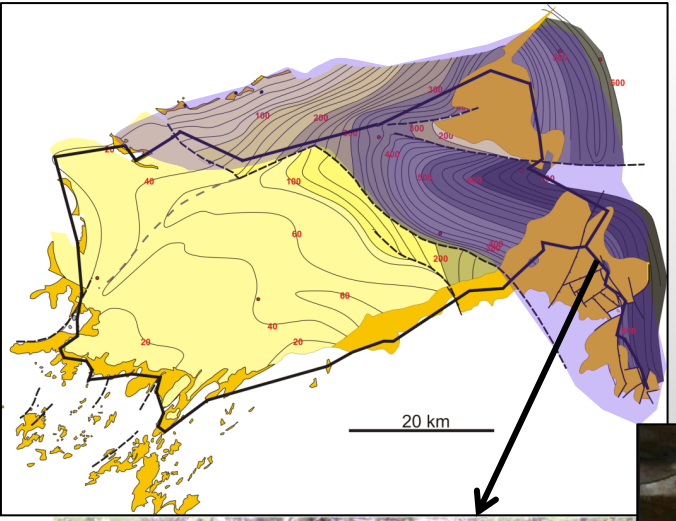

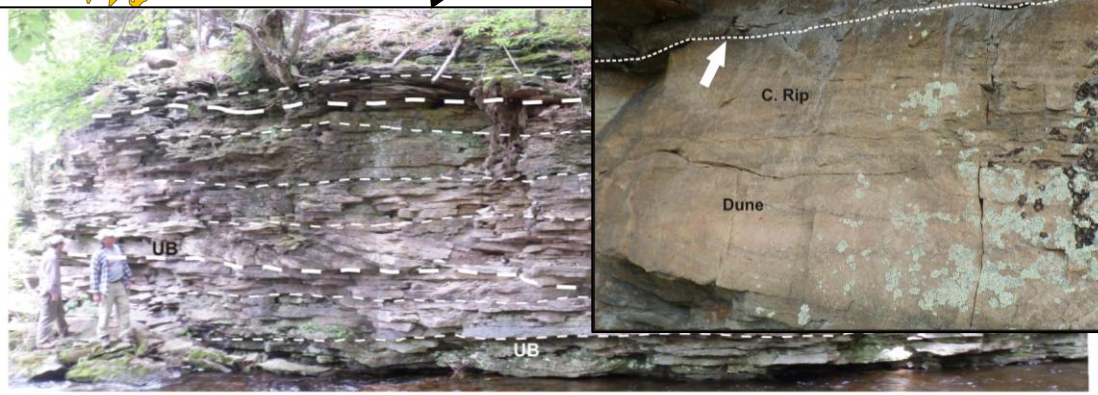

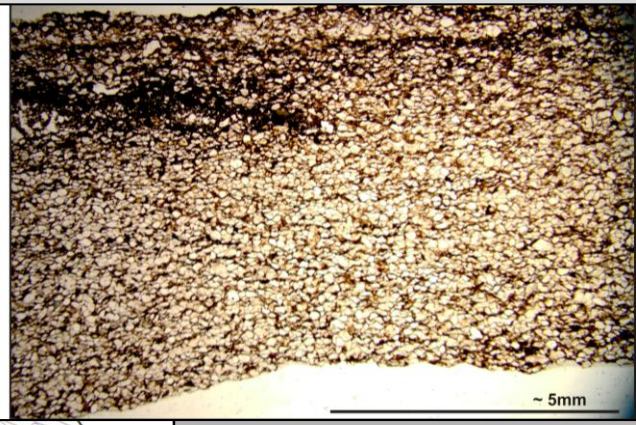

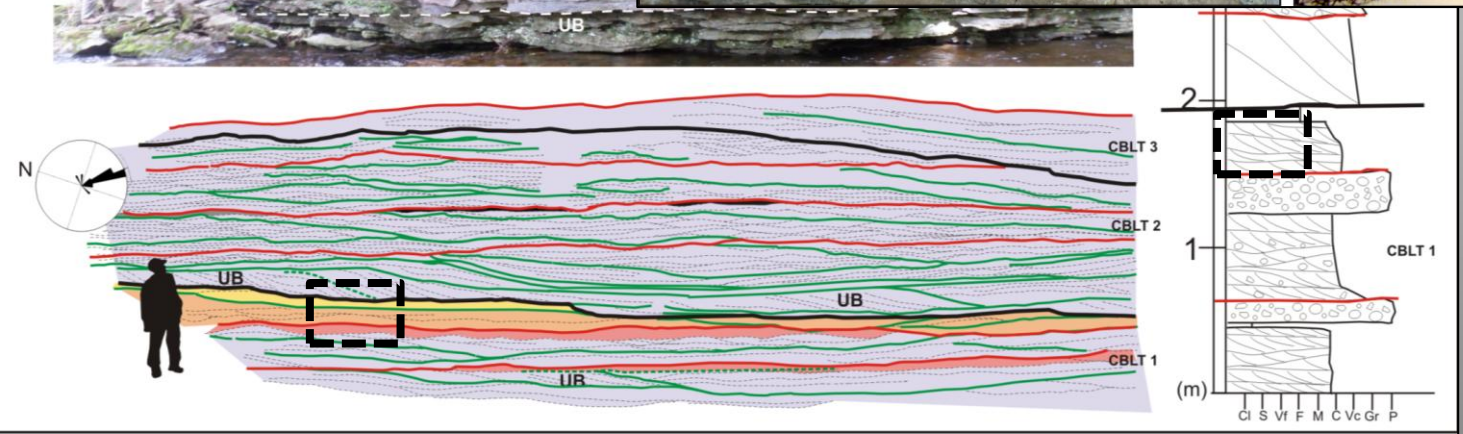

Surfaces bounding stratal units (channel belt deposits)
Surfaces bounding architectural elements
Internal bounding surfaces in architectural elements
Set/bed and coset boundaries

Accretional element (compound bar)
Conglomerate sheet element (bar top)
Channel element (channel fill)
Muddy siltstone (bar top fines)
Weathered sheet sandstone (overbank deposit)

Areally-Expansive Braided Fluvial Strata

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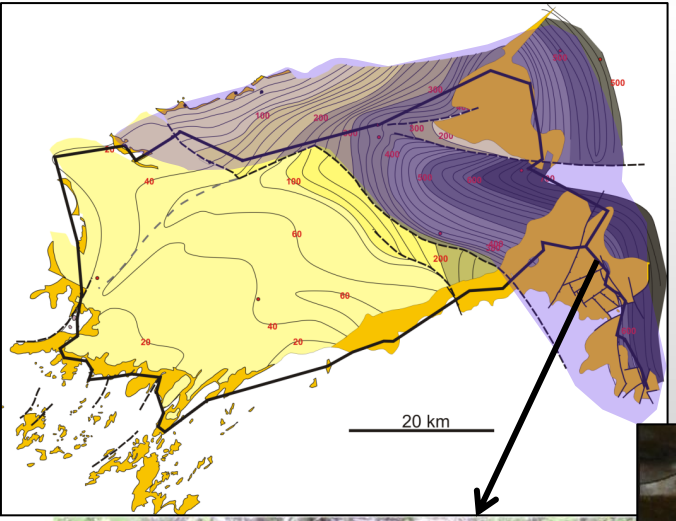
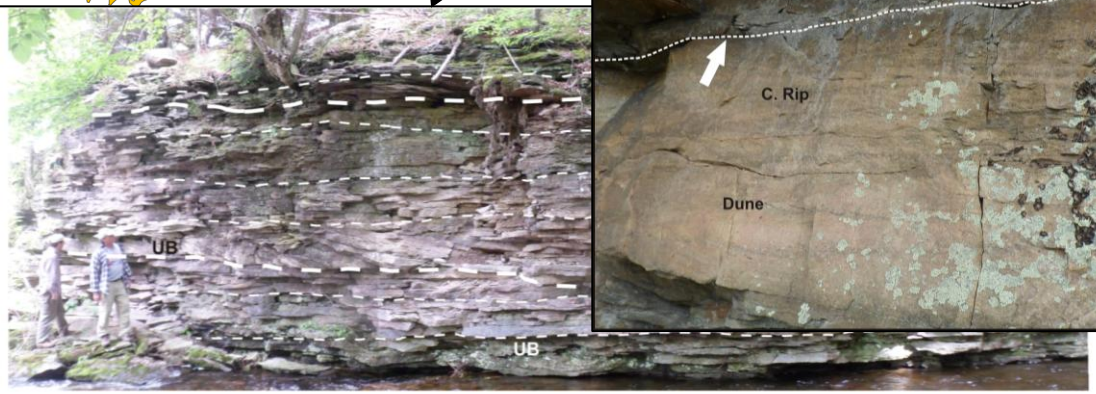
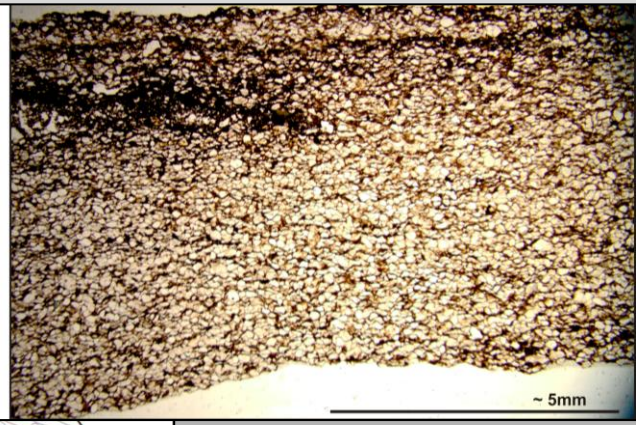
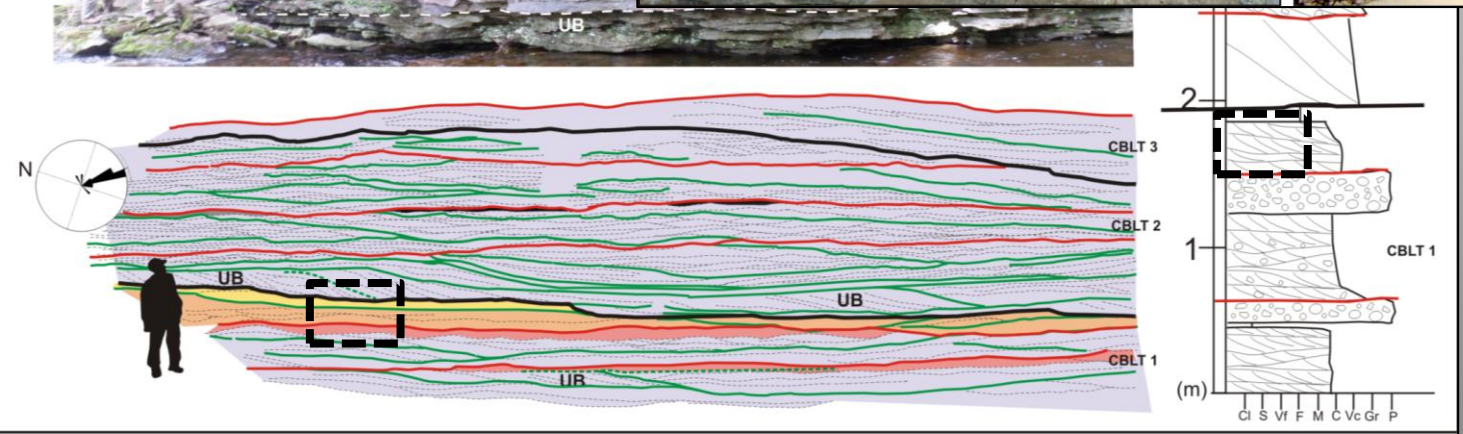
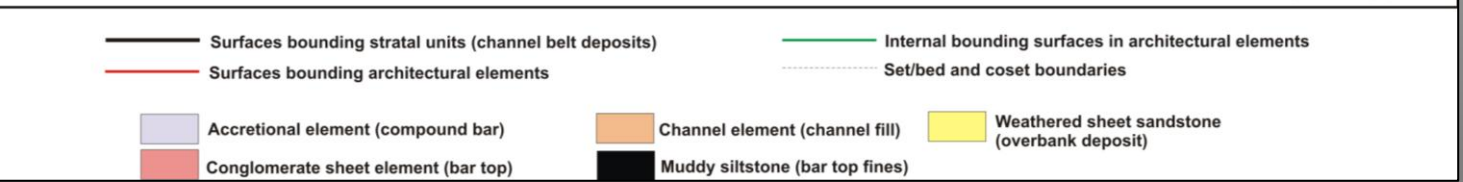
- M-scale channel belt successions are capped by tight overbank strata.







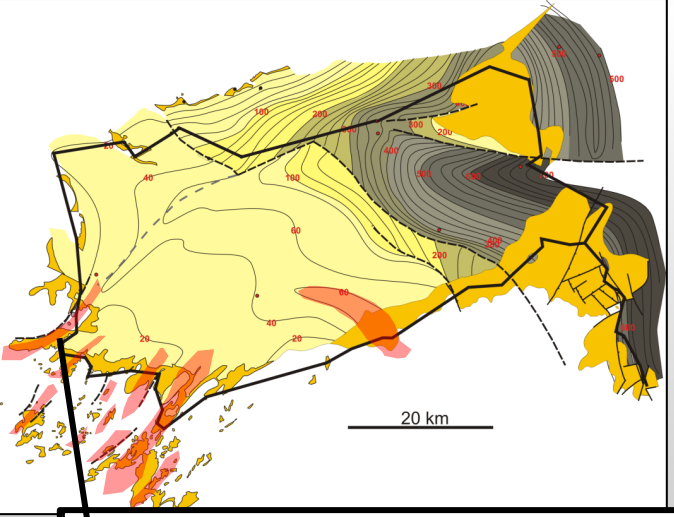


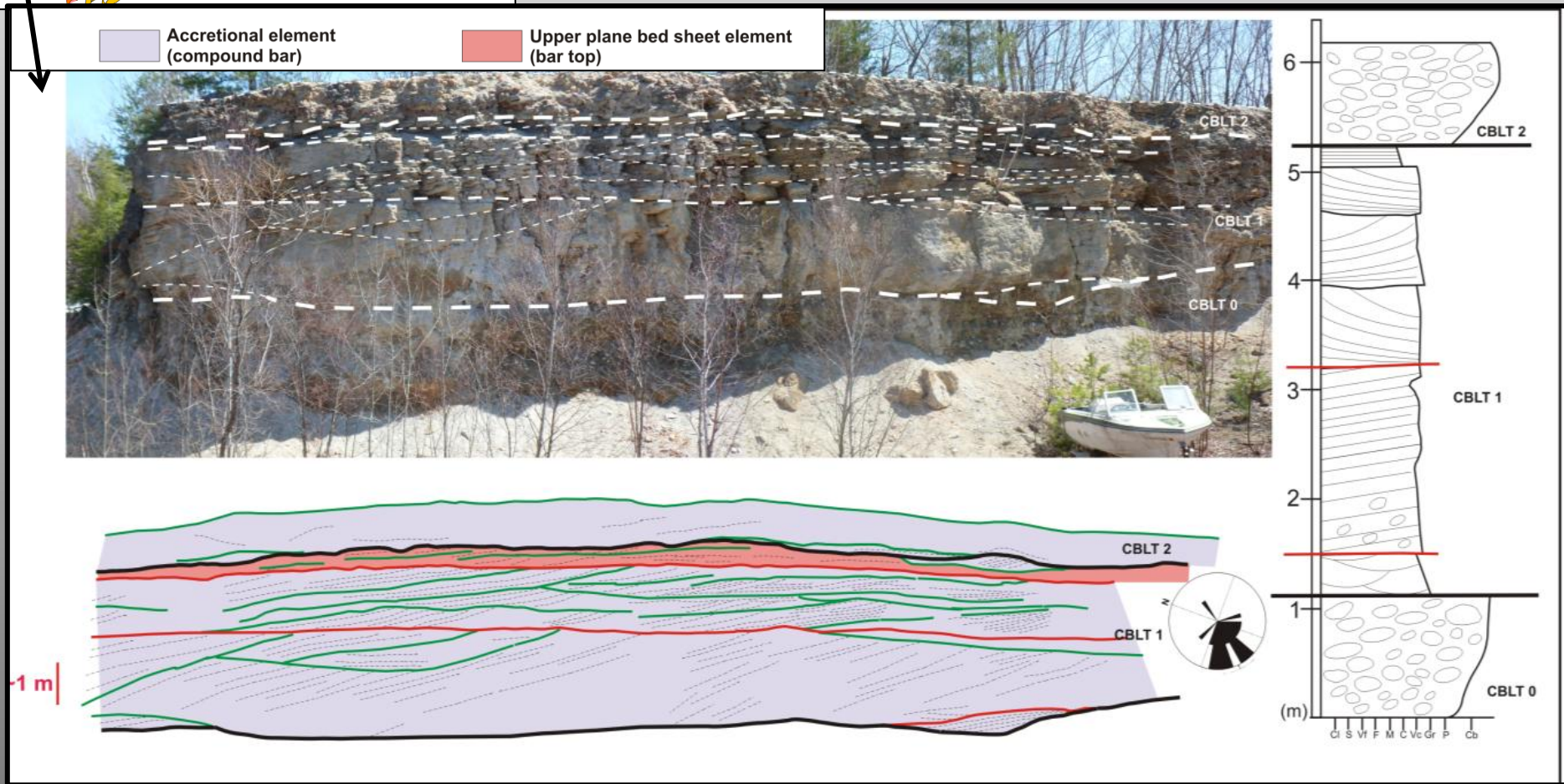


- Reservoir with good lateral connectivity, but more limited vertical connectivity.

Aerially-Restricted Braided Fluvial Outliers

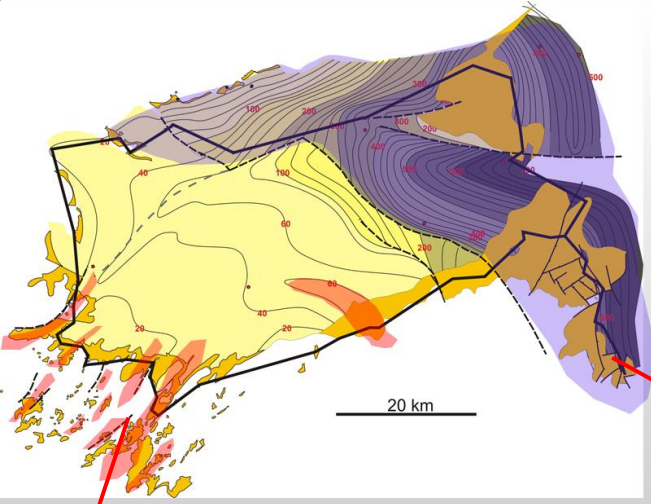
- Deeper flow due to lateral confinement.
- Thicker, high angle architectural elements; lateral accretion – meandering??!?!.
- No tight overbank strata.
- More isotropic reservoir.

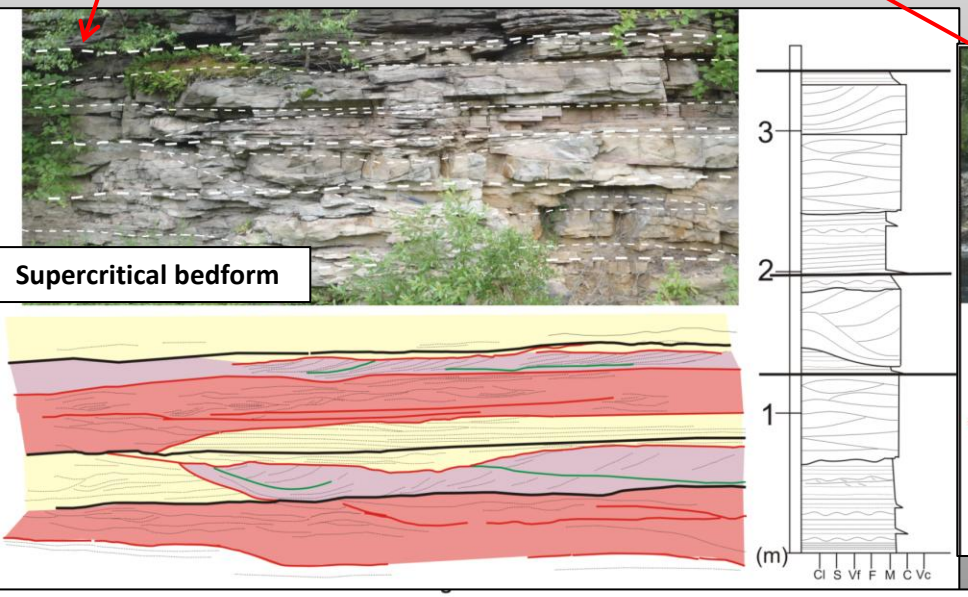


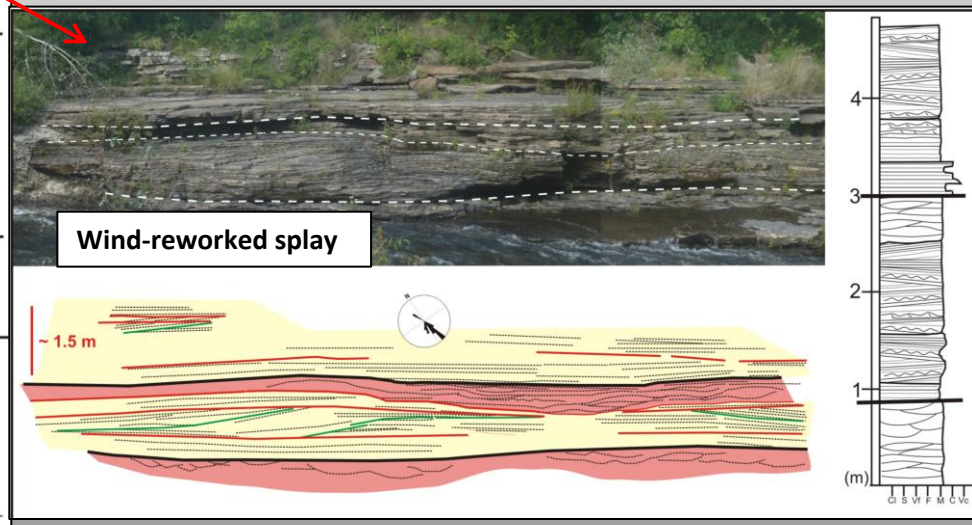


Ephemeral Fluvial vs. Topographic Setting

- In areally-restricted outliers, ratio of supercritical bedform strata to aeolian-reworked splay strata is higher than elsewhere.







Sheet element (aeolian-reworked terminal splay)

Channel element (distributary channel and fill)

Antidune cosets

Chute-and-pool set

Cyclic step sets

~1mm

~1mm

Ephemeral Fluvial vs. Topographic Setting

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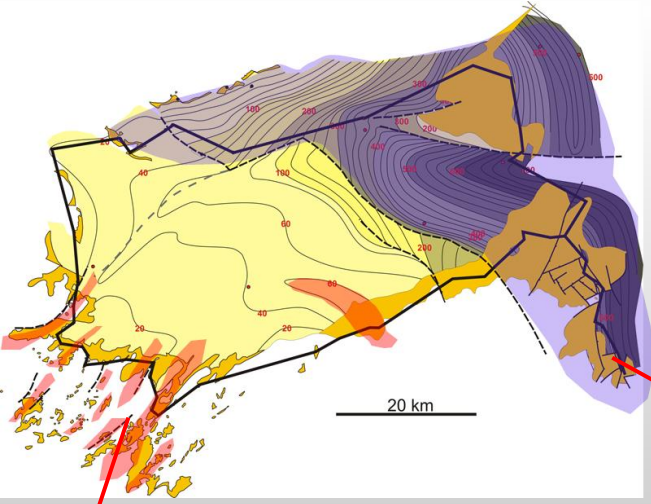
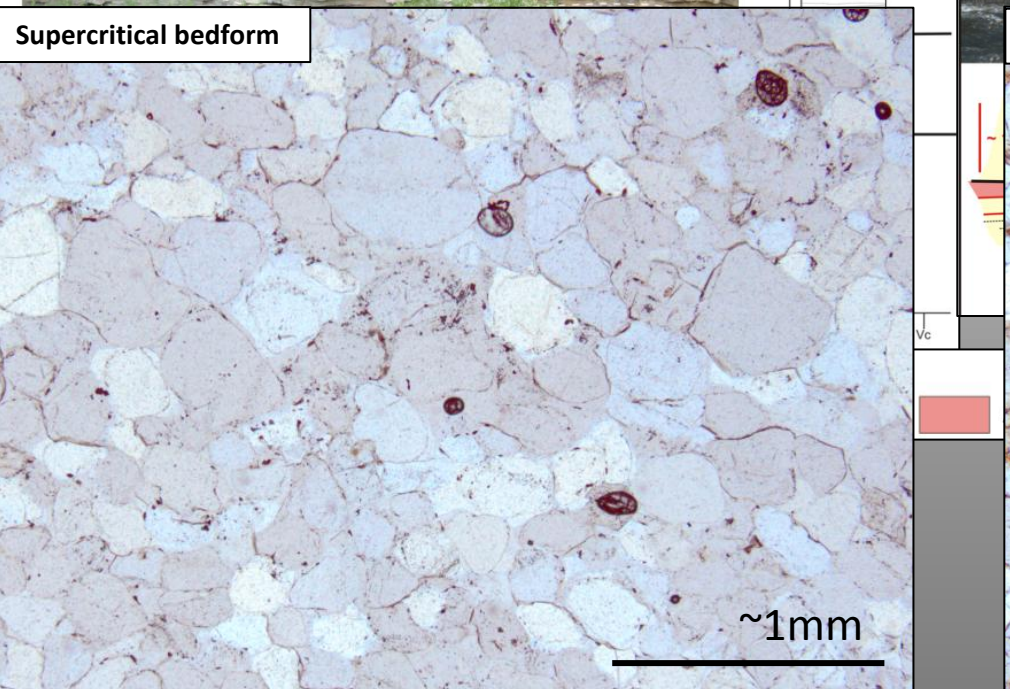
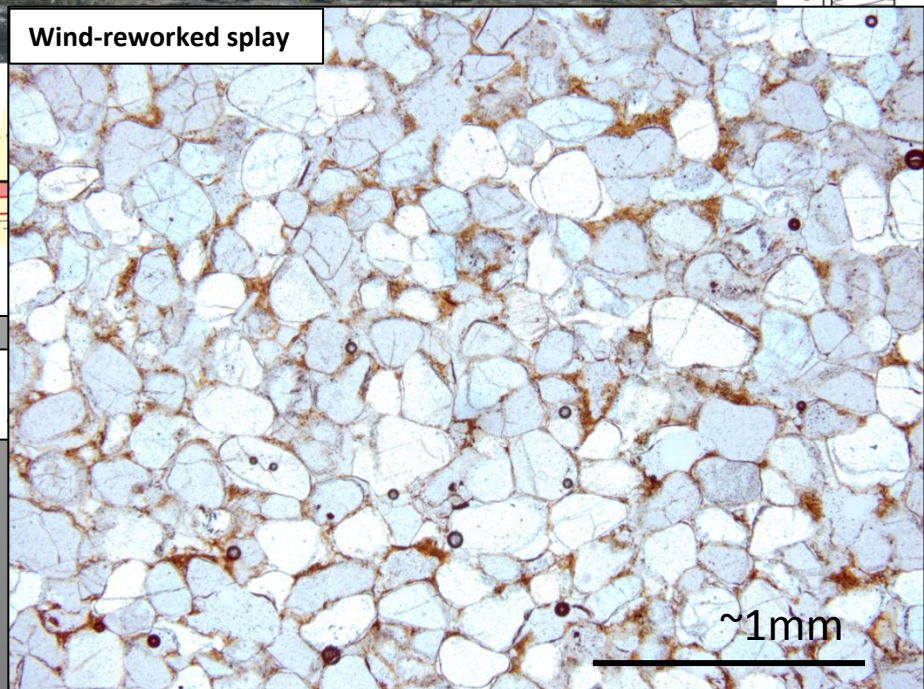


Supercritical bedform



Wind-reworked splay



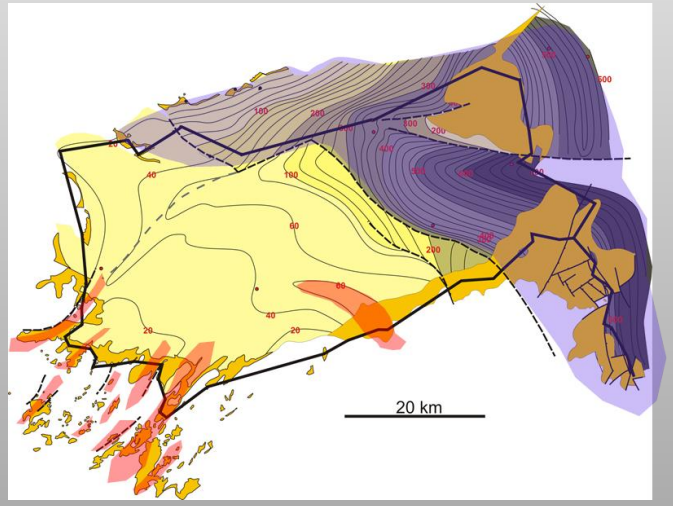
Summary

- Fluvial strata (braided and ephemeral) makes up most of the Potsdam Group in the OE –QB and presumably also in the adjacent St. Lawrence Lowlands Basin.

- Faults exerted control over fluvial isopach, composition and stratal architecture, with important reservoir implications:

Areally-limited:

- Thin isolated outliers bounded by faults.
- **Braided fluvial:** isotropic reservoir, leaky faults?
- **Ephemeral Fluvial:** Higher proportion of potentially porous supercritical bedform and dune cross-strata – but may be cemented tight!



Areally-expansive:

- Large areas of thick. well-connected reservoir.
- **Braided fluvial:** good lateral but more limited vertical connectivity (overbank strata).
- **Ephemeral fluvial:** wind-reworked terminal splays with early matrix inhibits silica cements, but also reduces primary porosity.

General Implications for CO_2 storage in the adjacent St. Lawrence Basin:

- Fault control on isopach and architecture, but are they leaky?
- Lack of mudstone reduces compartmentalization, but makes traps and seals an issue.
- Investigate the degree of silica cementation/compaction -- how much primary porosity is left @ depth??

Acknowledgements

Bruce Sanford (retired, Geologic Survey of Canada).

Field Assistants: Gurvir Khosa, Chris Barnes, Ed Desantis.

US colleagues: Dave Franzi (SUNY Plattsburgh), Jeff Chiarenzelli (St. Lawrence University), Bruce Selleck (Colgate University), Char Mehrtens (UVM).

Québec colleagues: Mario Lacelle (Ichnos.ca), Pierre Groulx.

Martin Gibling (Dalhousie University)

Natural Sciences and Engineering Research Council of Canada (NSERC)

Ontario Graduate Scholarship Program

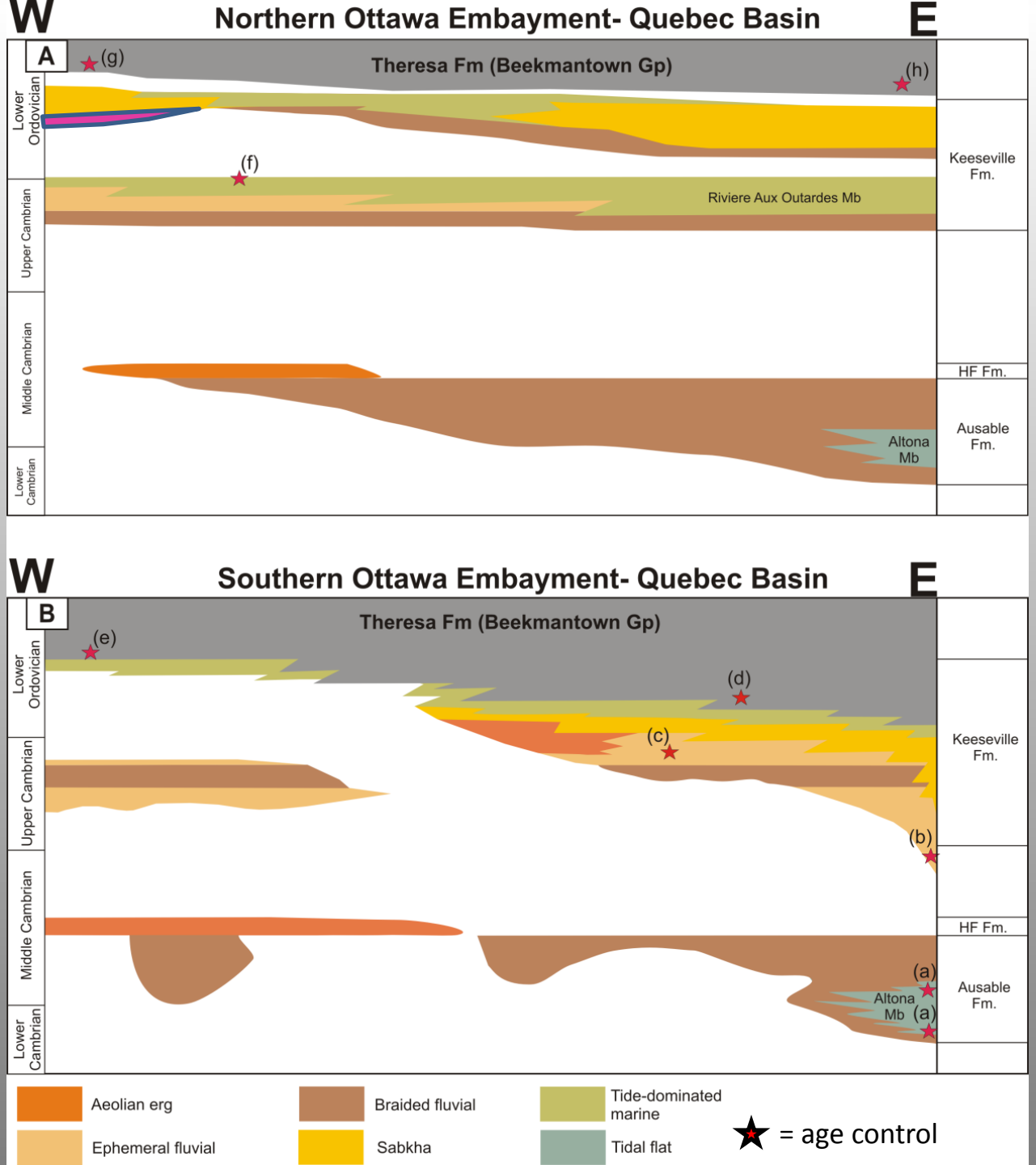
uOttawa

Questions??

NSERC CRSNG

- Potsdam correlation.
- Stratal complexity: 6 paleoenvironments, 2 unconformities.
- Mostly terrestrial, more specifically mostly fluvial.
- Braided and ephemeral fluvial recognized.

From measurement and correlation of 296 outcrop sections and 12 subsurface cores



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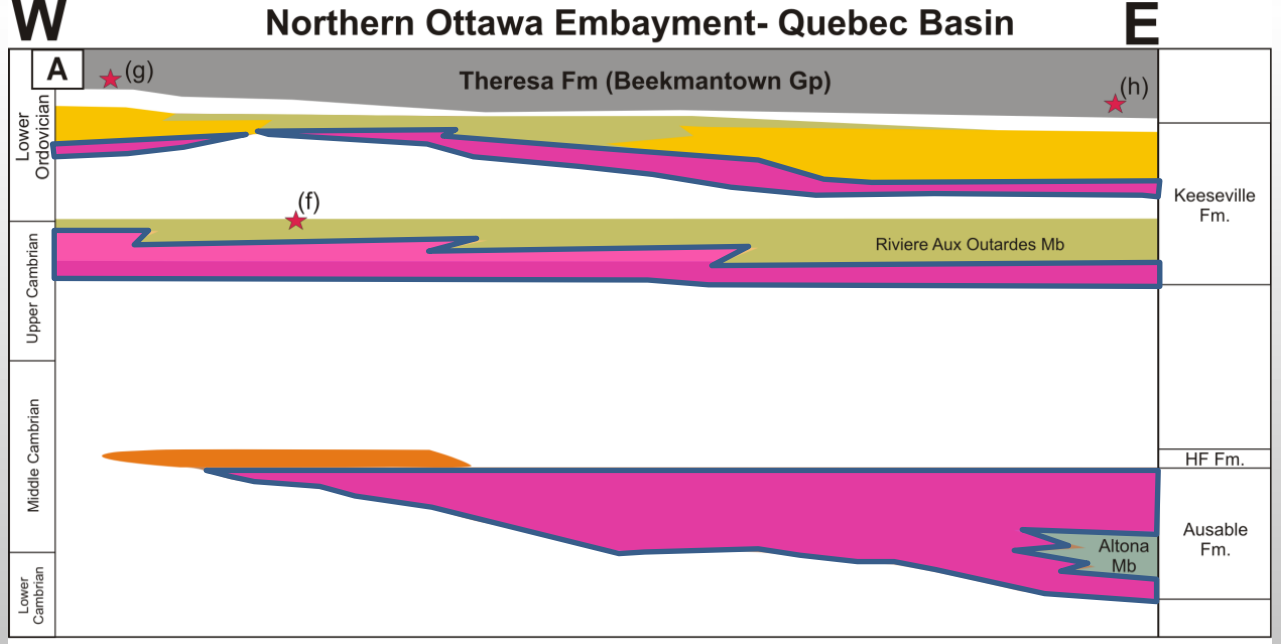
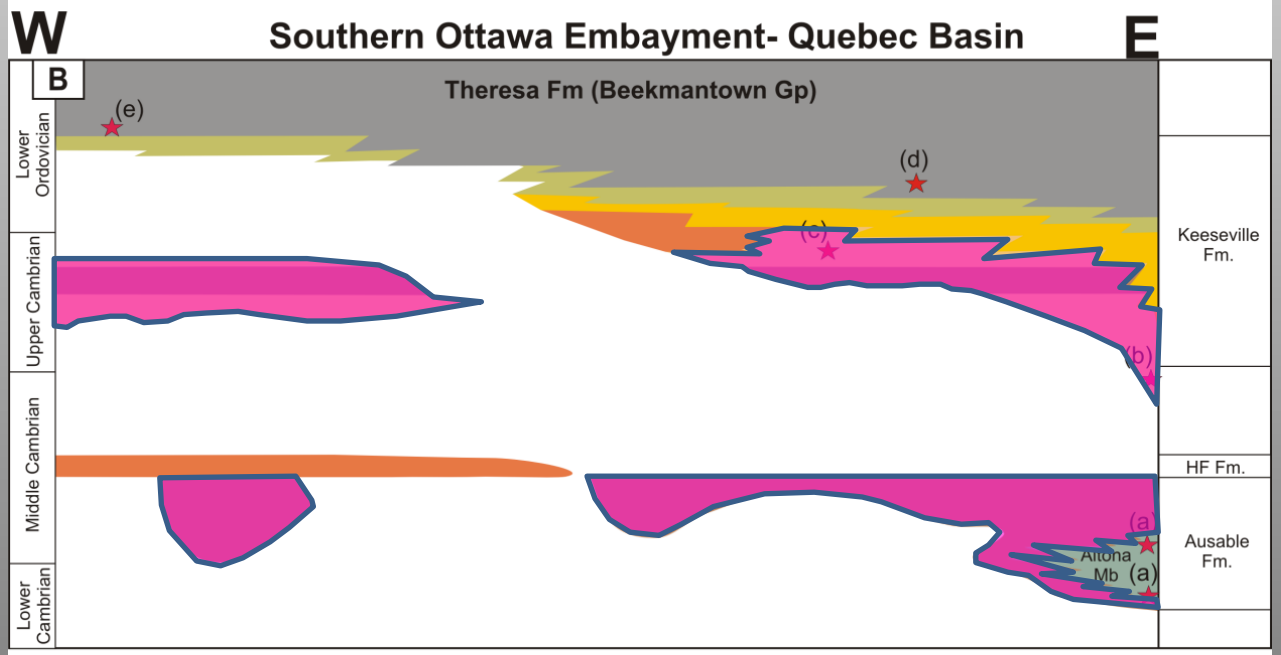
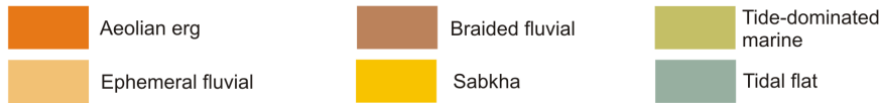
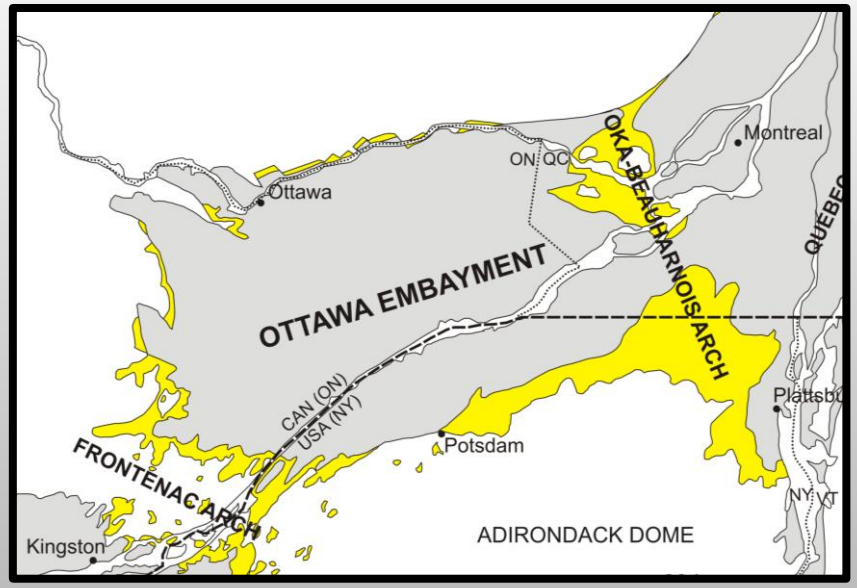
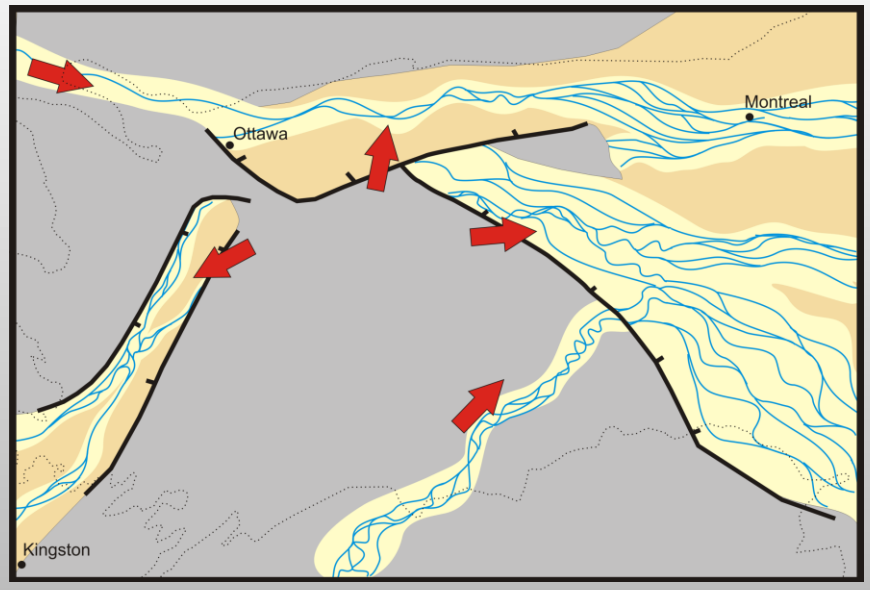




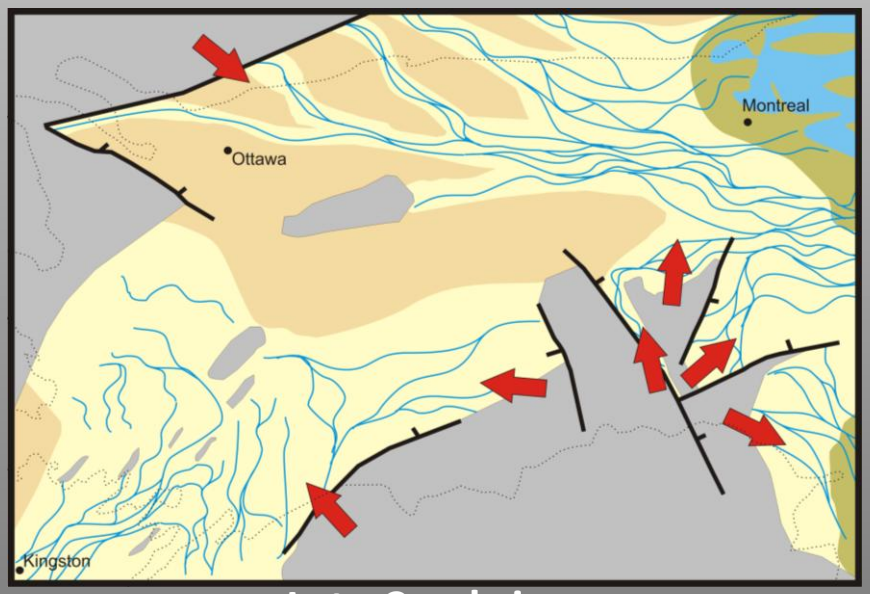


Structural Controls on Fluvial Sedimentation

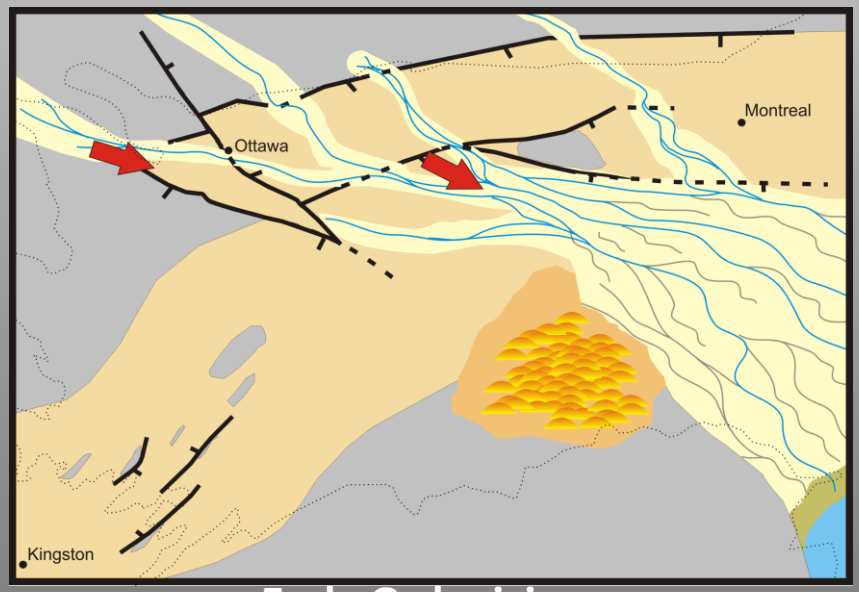




Middle Cambrian



Late Cambrian



Early Ordovician

Areally-Restricted Fluvial Outliers

- Clear evidence that faults generated topography that affected fluvial sedimentation:
  - Debris/talus along fault margins