[PS]Fluvial Architecture the Morrison Formation, Bullfrog Area, Utah, USA*

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Abstract

A 60 km cliff exposure along the edge of the Waterpocket fold in the Bullfrog area of central Utah provides an exceptional view of the fluvial architecture within the Morrison Formation. A photomosaic spanning 45 km of the Tidwell and Salt Wash Members shot from a helicopter provides a continuous strike cross section, five sedimentologic logs through this interval record vertical facies trends, and more detailed mapping of channel belt internal bedding and facies variations along more accessible side canyon exposures and across extensive bedding planes adjunct to the main cliff document vertical and lateral changes in fluvial depositional style. The 170-220 m thick Tidwell – Salt Wash interval can be divided into two successions defined by upward increases in channel belt proportion and mean channel belt thickness and grain size. Lower within a succession channel belts are thin and narrow (4-6 m thick and 100m to few 100m wide), and internal beds show little evidence for lateral channel migration. Higher within a succession the channel belts are larger (5-15 m thick and 100m to km wide), and they are commonly amalgamated. Individual storeys thicken from horizontally bedded cross-stratified sandstone near its initiation margin to thicker deposits with steeper (15 degrees) downstream dipping beds toward their downstream ends. The channel abandonment fills are generally only slightly finer grained cross-stratified sandstone. Both major successions are capped by a ten-meter thick interval in which channel belts are dominated by gravel (in contrast to the dominantly sandy channel belts lower within each succession). Although both major successions can be easily traced across the 60 km study area, the lower one in particular exhibits some lateral fining (perhaps showing increasing lateral distance from the depositional axis). Superimposed on the two regional successions are smaller-scale fluvial complexes defined by clusters of connected channel belts separated by intervals with abundant overbank deposits. These smaller scale complexes are not gravel capped and can be traced laterally over only km to 10 km before they lose distinct definition. The larger successions are interpreted to record regional progradational units, whereas the smaller complexes probably reflect the influenced of more localized channel belt avulsion patterns.

Fluvial Architecture the Morrison Formation, Bullfrog Area, Utah, USA

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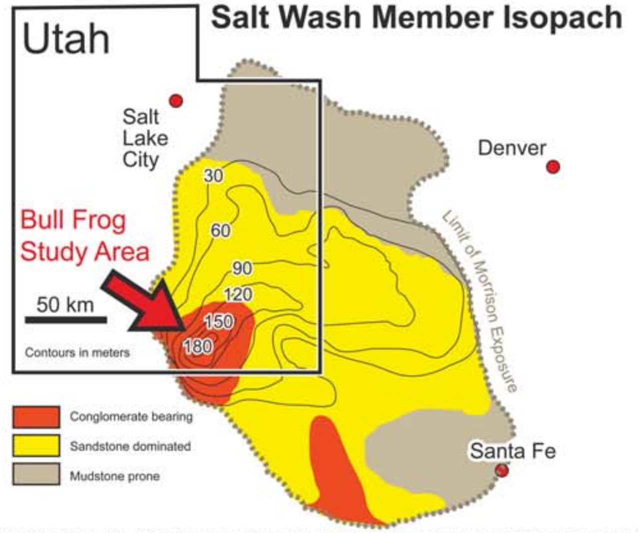
ABSTRACT

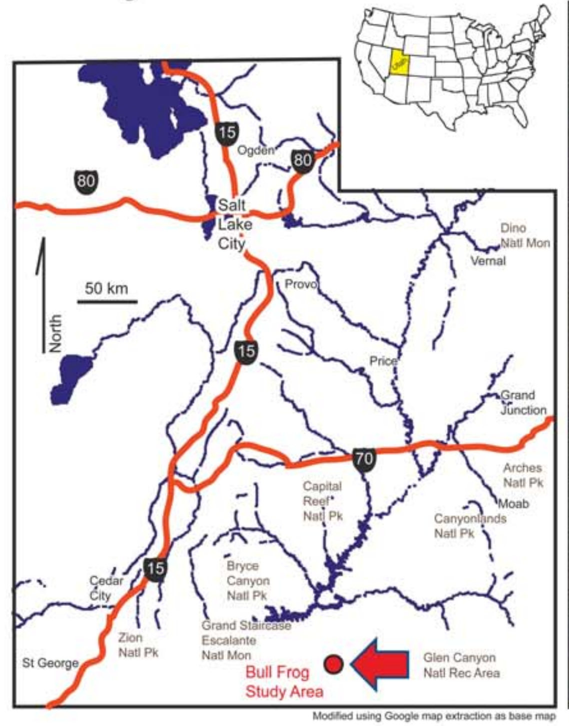
A 60 km cliff exposure along the edge of the Waterpocket fold in the Bullfrog area of central Utah provides an exceptional view of fluvial architecture within the Morrison Formation. A photomosaic spanning 45 km of the Tidwell and Salt Wash Members shot from a helicopter provides a continuous strike cross section, five sedimentologic logs through this interval record vertical facies trends, and more detailed mapping of channel belt internal bedding and facies variations along more accessible side canyon exposures and across extensive bedding planes adjunct to the main cliff document vertical and lateral changes in fluvial depositional style. The 170-220 m thick Salt Wash interval can be divided into two successions defined by upward increases in channel belt proportion and mean channel belt thickness & grain size. Lower within a succession channel belts are thin and narrow (4-6 m thick & 100 m to 300 m wide), and internal beds show little evidence for lateral channel migration. Higher within a succession the channel belts are larger (5-15 m thick and 100 m to km wide), and they are commonly amalgamated. Individual storeys thicken from horizontally bedded cross stratified sandstone near its initiation margin to thicker deposits with steeper (15 degrees) downstream dipping beds toward their downstream ends. The channel abandonment fills are generally only slightly finer grained cross stratified sandstone. Both major successions are capped by a ten meter thick interval in which channel belts are dominated by gravel (in contrast to the dominantly sandy channel belts lower within each succession). Although both major successions can be easily traced across the 60 km study area, the lower one in particular exhibits some lateral fining (perhaps showing increasing lateral distance from the depositional axis). Superimposed on the two regional successions are smaller-scale fluvial complexes defined by clusters of connected channel belts separated by intervals with abundant overbank deposits. These smaller scale complexes are not gravel capped and can be traced laterally over only km to 10 km before they lose distinct definition. The larger successions are interpreted to record regional progradational units, whereas the smaller complexes probably reflect the influence of more localized channel belt avulsion patterns.

Salt Wash Member Isopach

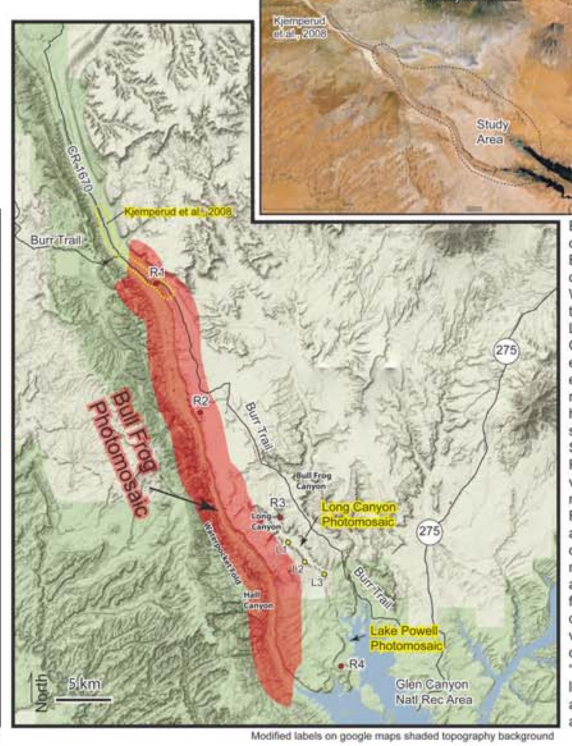


Modified from Donn, P.H., 1955, Examples of uranium deposits in the upper Jurassic Morrison Formation of the Colorado Plateau, in Page and others (eds.) , U. S. Atomic Energy Commission, USGS Prof P 300, based on data from Craig, L. C., Holmes, C. N., Cadigan, R. A., and others, 1955, Preliminary report on the stratigraphy of the Morrison and related formations of the Colorado Plateau region, U. S. Geol. Survey Bull. 1009-E, p. 125-168.

Study Area

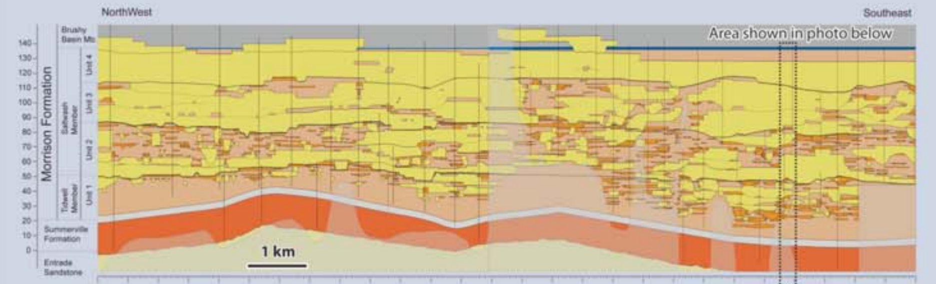


Modified using Google map extraction as base map



Modified labels on google maps shaded topography background

Exceptionally continuous outcrops of the Morrison Formation near Bull Frog National Recreation Area occur along the limbs of the Waterpocket fold. Vertical cliffs of the Salt Wash Member along Hall, Long and Bull Frog Creek Canyons are connected by extensive bedding surface exposures. The recognizance reservoir analog study reported here collected 4 continuous sedimentologic logs through the Salt Wash Member (marked R1-R4; 140-170 m thick) and various shorter logs linked to photo mosaics. The labyrinth walls of Bull Frog Canyon provide views of the alluvial architecture in different orientations. The smoother north-south cliffs of Hall Canyon along the axis of the Waterpocket fold provide a more continuous depositional strike cross section view (see continuous photo mosaic on the panel to your left, labelled "Bull Frog Photomosaic"). The location of a previous alluvial architecture study by Kjemperud and others, 2008, is also shown.



Kjemperud, A.V., Schomacker,E.R. and Cross,T.A., 2008, Architecture and stratigraphy of alluvial deposits, Morrison Formation (Upper Jurassic), Utah, AAPG Bulletin, v. 92, p. 1055–1076. Reprinted by permission of the AAPG whose permission is required for further use.

Kjemperud, Schomacker and Cross (2008) provide a remarkable cross sectional map of channel sandstones within the Salt Wash Member of the Morrison Formation. This bedding diagram was constructed by measuring vertical sedimentologic logs every few hundred meters and correlating sandstone bodies between these logs across the 13.5 km long north-south oriented panel. This depositional dip panel extends along Burr Trail Road and documents strata that dip from 45 to 80 degrees eastward along the axis of the Waterpocket fold. The stepper dips along this section of the outcrop make the exposures more accessible than the vertical cliffs along the fold closer to Lake Powell.

Kjemperud and others recognized 4 units in the Salt Wash Member defined by vertical changes in Channel belt or overbank deposit proportion, amalgamation, grain size and width/thickness ratio of channel belts, and abundance of paleosols within overbank deposits. Units were defined to progress from coarser- grained, amalgamated, sheet-like channel belts of laterally migrating braid bars to intervals with lower proportions of narrower channel belts dominated by vertical aggradition. Units were recognized to be laterally variable along the 10 km outcrop documented, and to have gradual boundaries rather than being defined by continuous erosion surfaces ("Sequence boundaries"). The units were interpreted to reflect A/S cycles (accommodation to sediment supply ratio): sandier basal parts of units inferred to reflect lower accommodation deposition and the upper muddier parts higher accommodation deposition.

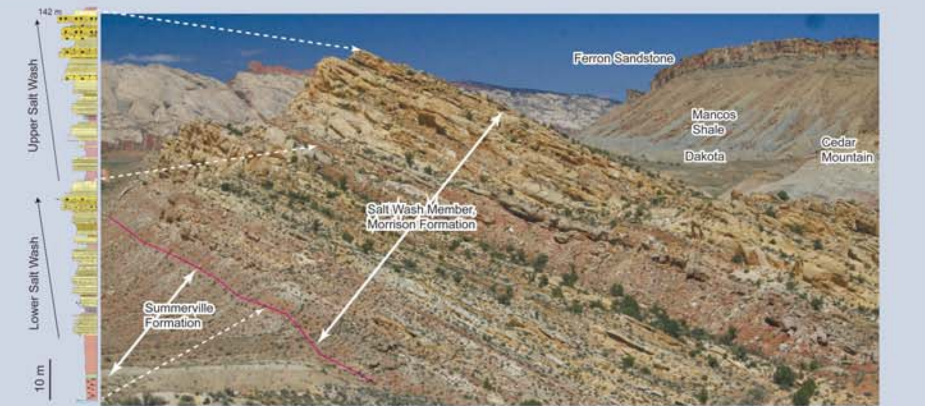
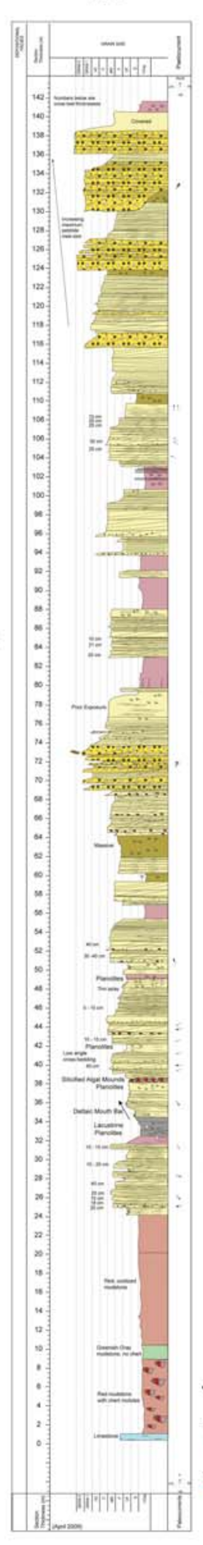


Photo of the Salt Wash Member of the Morrison Formation along the south end of the area documented by Kjemperud and others (see label on bedding diagram above) and simplified sedimentologic log measured for the study presented here.

R1



Salt Wash Stratigraphy

This study spans exposures of the Salt Wash Member across a distance of about 60 km along depositional strike; a distance that includes the cross section documented by Kjemperud and others and the main Bull Frog Photomosaic shown on the panel to the left. We recognize two stratigraphic successions within the Salt Wash that can be easily correlated across this distance (labeled here the "upper" and "lower" Salt Wash). Like the units defined by Kjemperud and others, those defined here reflect distinct vertical changes in channel sandstone body proportion and geometry. Distinct from the definition of Kjemperud's units, however, the successions we highlight are also defined by vertical changes in mean sandstone body grain size, and particularly are each capped by channel belts with distinctly more gravel than those below. We also recognize other scales of vertical and lateral change in sandstone body abundance and character, like those used by Kjemperud and others to define their stratigraphic units. We find, however, that these thinner variations can only be mapped laterally for a few kilometers to ten kilometers. Still smaller scales of sand body variation define local clustering of channel belts (in some cases perhaps a fortuitous stacking), the alignment of channel deposits along sheet flood sandstones, and alternation of bar and channel fill deposits within channel belts.

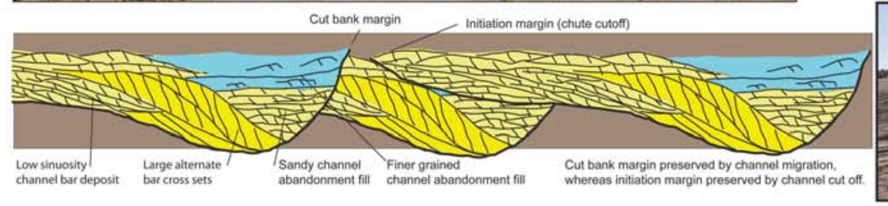
The two regional successions are defined by distinct outcrop benches associated with extensive bedding planes that reflect preferential cementing of the gravelly sandstones. Unlike the upward-fining units defined by Kjemperud and others, the large successions defined here gradually coarsen upwards. This upward coarsening is reflected both by an increase in the proportion of channel belts to overbank deposits and also by an increase in the mean size of the channel belts. There is also an associated vertical change in channel belt depositional style. Lower within successions many of the sandstone bodies are broadly sheet like with local vertically-filled channelized internal bedding. This depositional style is interpreted to be characteristic of ephemeral dryland river deposition, perhaps within a terminal distributary system. Higher within successions erosional boundaries between channel belt and adjacent floodplain deposits are more distinct and the alternation of migrating (dominantly downstream accreting) channel bars and abandonment fills within channel belts is more obvious. This depositional style is interpreted to be characteristic of a better confined fluvial channel system, where bedload discharge was mostly confined to the river and floodplains received finer overbank sediments. The simplest depositional interpretation is that the two regional successions are large-scale progradational units, with internal facies that reflect a Walter's Law shift in a river system that fined and became less confined as it expanded into the basin. Processes that formed these fluvial system progradational units is not constrained by this local study, but explanations of these types of variations commonly reference tectonic or climate changes in sediment input relative to subsidence rate. Regional avulsion of the locus of deposition across the larger scale Morrison distributive system documented by Donn 1955 (bottom left of this panel) might be a simpler explanation (see also regional study by Owen and others, this meeting).

Smaller scale vertical and lateral variations in channel belt proportion and style (a few to a few tens of meters thick), that can be traced only kilometers to tens of kilometers, are very likely to reflect local autocyclic shifts in deposition. These smaller-scale variations are obvious in the intervals with lower overall proportion of sandstone, where one can see a clear clustering of sandier channel belts separated by areas dominated by muddier overbank deposits. These lateral variations can also be defined within sandier intervals by recognizing lateral changes between the relative abundance of thinner more sheet like channel sandstones and clusters of thicker channel belts with distinct internal bar deposits.

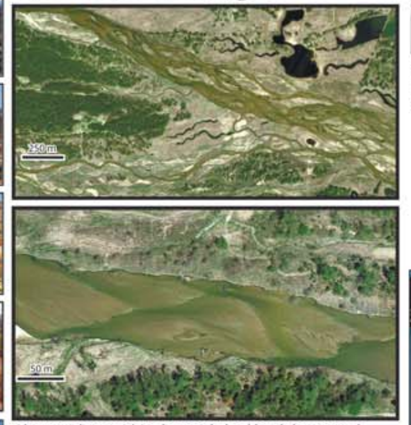
Core Log Symbols and Legend

Salt Wash Sedimentology

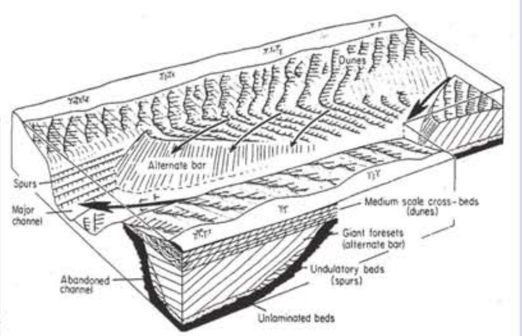
Downstream Accretion Dominated Channel Belts



Modern Analog



Alternate bars within the sandy bed load dominated Platte River in central Nebraska, USA. Images from Google Earth @ Google, image Landsat.

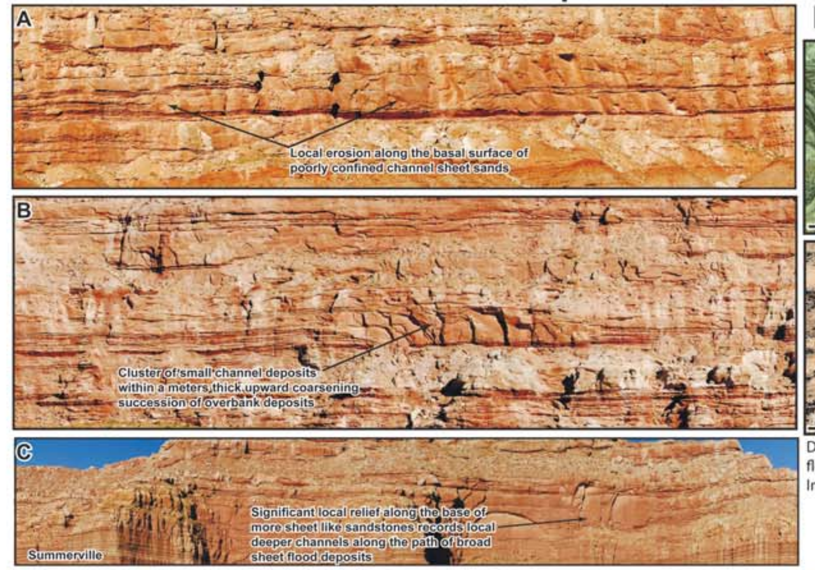


Bluck, B.J., 1976, Sedimentation in some Scottish rivers of low sinuosity, R. Soc. Edinburgh Trans.

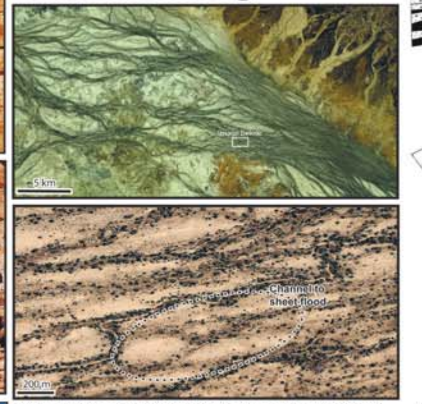
Alternate bar on the Platte River, Nebraska, displays a steep front accretion surface prograding downstream into a flood scour that was partly filled during the subsequent period of low flow.

Channel belts composed of a laterally stacked string of downstream accreting bars. Individual storey deposits are thinner bedsets of cross stratified sandstone above the initiation margin, that thicken as beds increase in dip in the direction the bar growth. Storeys thin and become finer grained sandstone within the final abandonment fill adjacent to the cut bank margin. Amalgamated channel belts define laterally continuous reservoir sandstones.

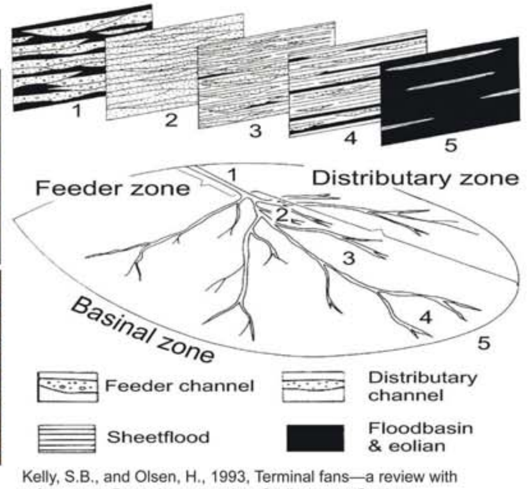
Cut and Fill Sheet Flow Channel Deposits



Modern Analog



Dryland river with deposition dominated by ephemeral flooding, Diamantina River, west Queensland, Australia. Images from Google Earth @ 2014 Cnes/spot image.



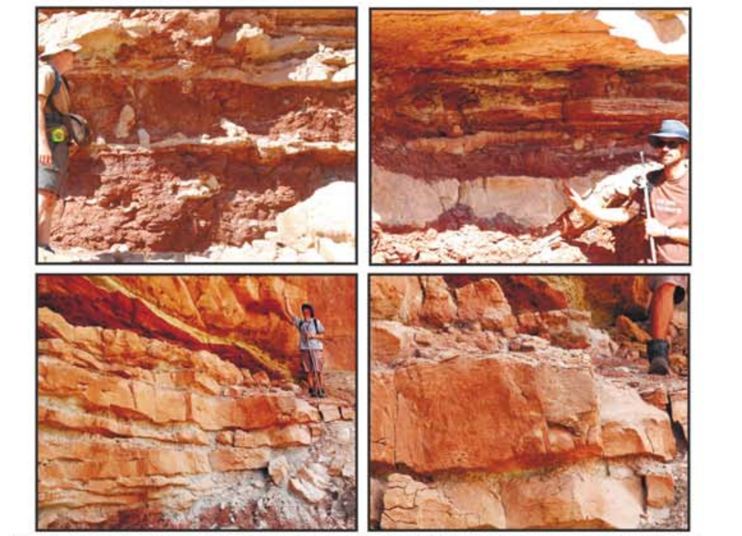
Kelly, S.B., and Olsen, H., 1993, Terminal fans—a review with reference to Devonian examples. Sedimentary Geology.

Sheets of sandstone, with gradational or weakly erosional basal contact, can thicken abruptly laterally at the margin of a channel belt sandstone. The distinction between sheet and channel sandstones is not always obvious, but the former is generally dominated by rippled and planar beds whereas the latter is generally cross stratified. Sheet sandstones that extend as "wings" from the margins of channel sandstones generally taper to mudstone within just a few hundred meters. Layers of amalgamated sheet and channel sandstones can be distinct over kilometers to ten kilometers. These deposits formed within weakly confined river channels where bed load transport of sands was continuous from deeper channel areas onto the adjacent floodplain.

Conclusions

- Bull Frog exposures of the Morrison Salt Wash Member expose a broad fluvial distributive system that spans southern Utah.
- Two 100 m thick progradational successions increase upward in channel belt proportion, channel belt thickness and grain size. These successions are capped by more gravelly sandstone intervals.
- Fluvial style changes upward within successions from poorly confined fluvial systems with sheet-like sandstones cut by isolated vertically filled channels to more distinct channel belts dominated by downstream accreting bar deposits and associated channel abandonment fills. Individual channel storeys are generally less than 5 m thick and 250 m long, but rivers were likely braided (making it difficult to estimate full river discharge).
- Smaller clusters of fluvial channel deposits (10-20 m thick), that extend laterally for only km to 10 km, are likely related to higher order river avulsions within the fluvial system.
- Evidence for uniformly dry paleosols and thin laterally extensive overbank sheet-flood sandstones indicate a dryland river system, but abundant large dinosaur tracts and huge tree casts indicate that paleoenvionments were not a barren desert.

Overbank Deposits



Morrison overbank deposits comprise decimeter-thick sheet sandstones, dominated by planar and ripple cross lamination, interbedded with pedogenetically disrupted red mudstones. Weak soil horizonation, dominance of vertic (shrink- swell) structures, abundant calcite nodules, and vertebrate burrows extending meters down into paleosols all indicate dry floodplains. Although floodplains were clearly dry, abundant decimeter-diameter trample casts under thin sheet overbank sandstones and tree trunk casts up to a meter in diameter indicate this was not a barren desert.

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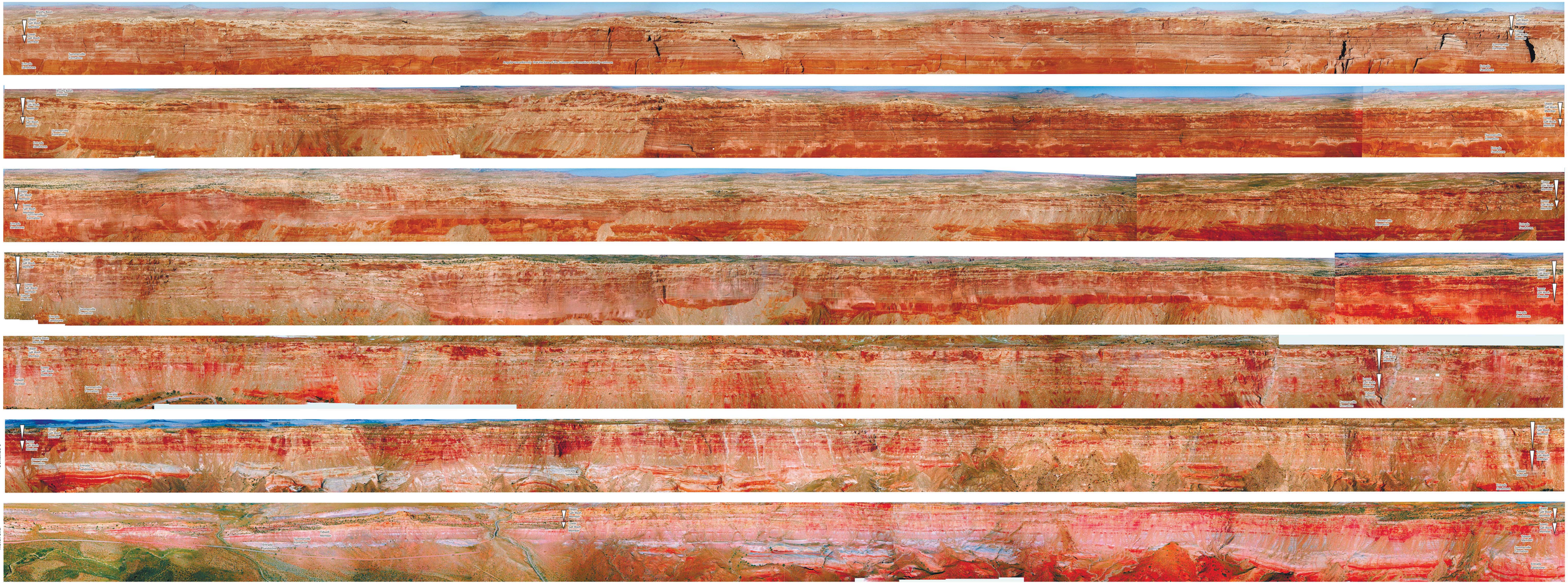
Chevron



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