The Gharif Formation: Improving Prospecting and Field Development Success by Understanding the Role Syndepositional Tectonism and Salt Movement Play in Focusing Sandstone Accumulations within the South Oman Salt Basin, Oman*

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Abstract

The Gharif Formation is a vertical succession of clastic deposits of Early Permian age. It has been subdivided into three members. The upper two members are almost entirely fluvial deposits while the lowermost member is primarily deltaic in nature. Found in the subsurface across Oman, it is one of the Sultanate's most prolific reservoirs.

Exploration success is not only dependent upon finding structures but also accounting for the relationship between structure, syndepositional tectonism, and reservoir sandstone distribution. The latter has proven a significant risk factor, with some in the industry stating the greatest risk for exploring the Gharif Formation is 'just finding the sands.'

Work done over the past 50 years in such disciplines as fluvial sedimentology and stratigraphy, geomorphology, and forward modelling have defined some key relationships between the interactions between fluvial systems and syndepositional tectonism. Target has successfully applied these relationships to the Gharif Formation in areas across Oman.

This paper focuses upon the formation's fluvial deposits, which contain the lion's share of the formation's hydrocarbons. It will provide examples that reflect the role syndepositional tectonism has played on the distribution of existing Gharif Formation fields. This includes the role played by salt movement, factors that enhance the risk of sediment by-pass, and factors that have led to the deposition of high reservoir quality sandstone deposits. It will conclude with a general assessment of play areas for future exploration activity.

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Agenda

Introduction to the South Oman Salt Basin

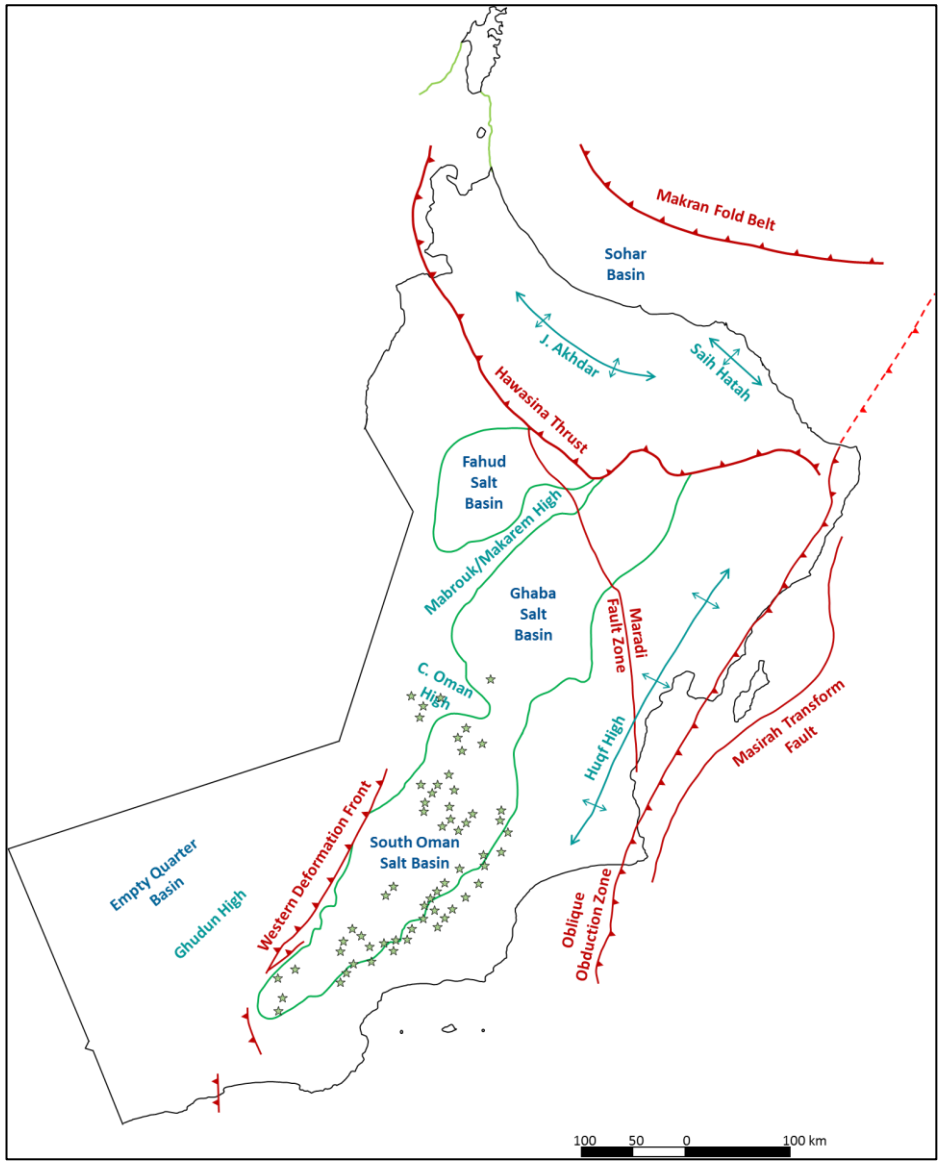
Gharif Formation Review
- **Geochronology**
- **Paleogeography**
- **Sedimentology**
- **Lateral Distribution**

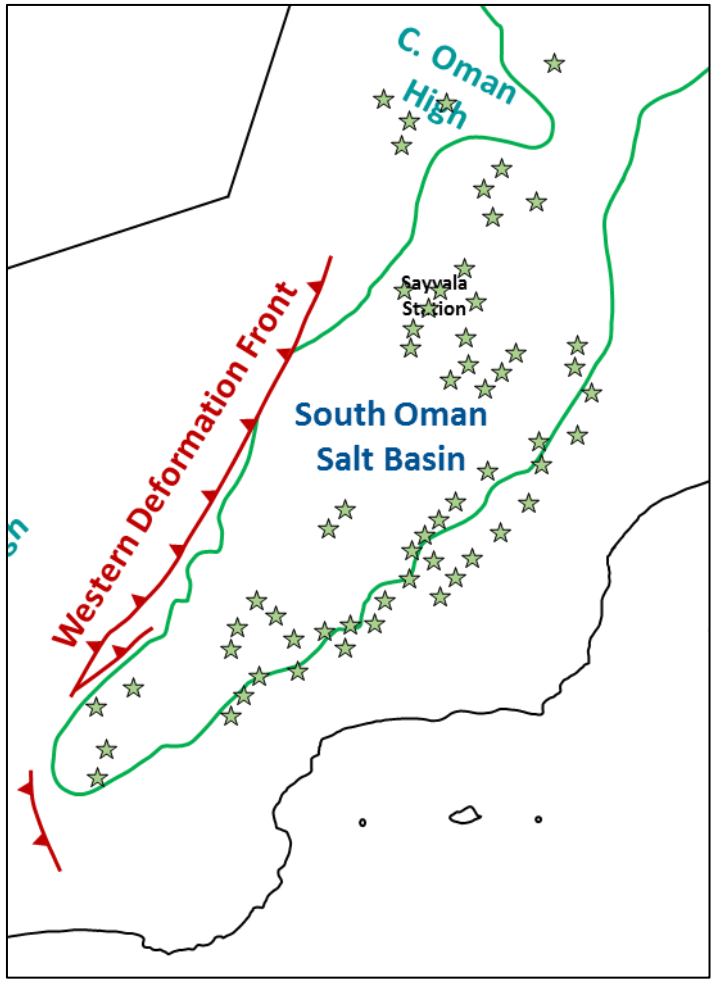
Creating Stratigraphic Traps via Syndepositional Tectonism
- **The Major Syndepositional Elements**
- **Fluvial Responses to Syndepositional Tectonics**
- **Gharif Formation Response to Syndepositional Tectonics**

Conclusions

Acknowledgements

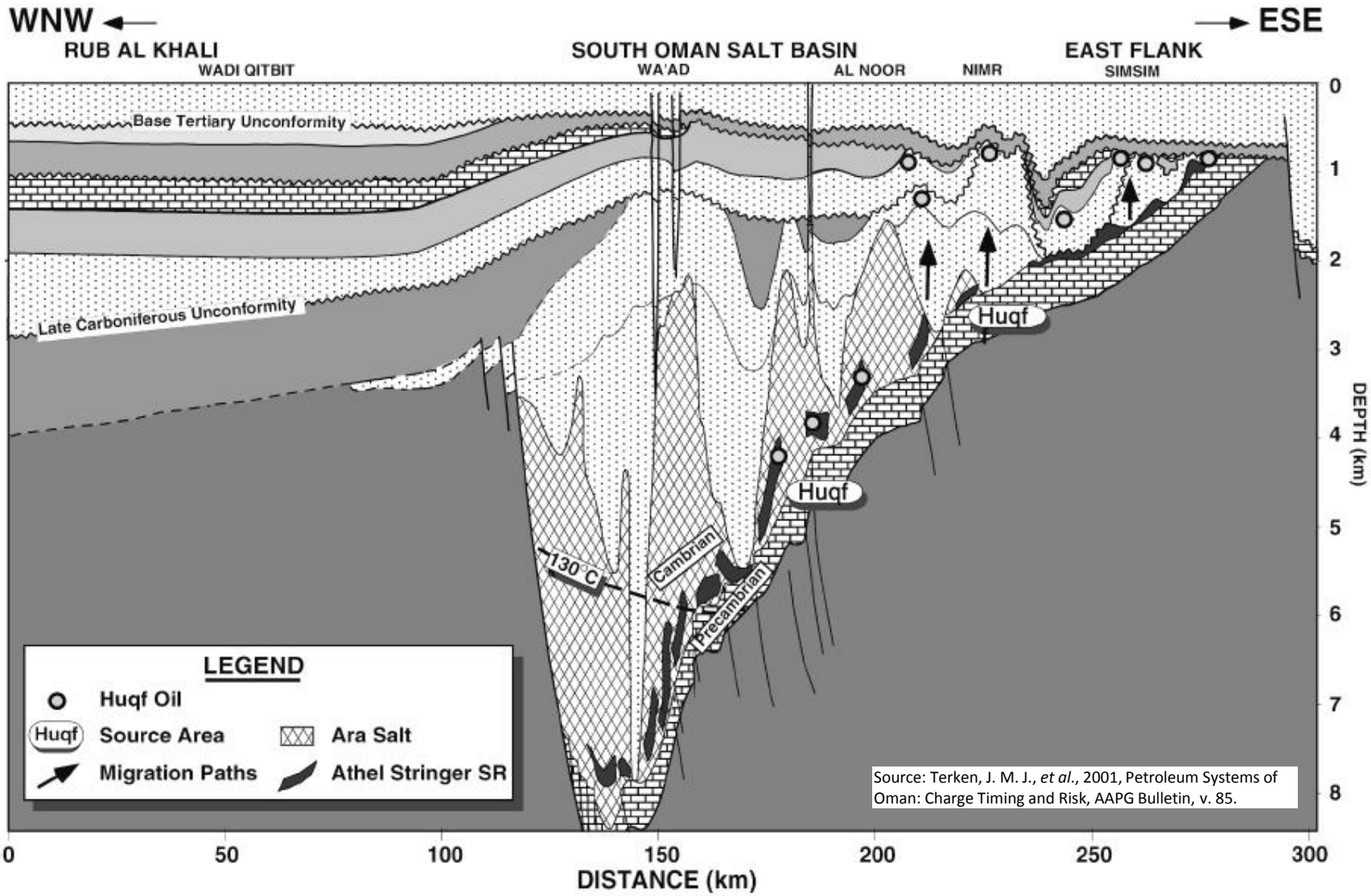
Tectonic Elements of Oman





Oil Fields

South Oman Salt Basin



Halokinesis was active through the deposition of the Gharif Formation.

Chronostratigraphy and Paleogeography of the Gharif Formation

268.8 +/- 0.5 MYA

Upper Gharif Member
- Duration: 3.5 Million Years
- 8 4th-order sequences

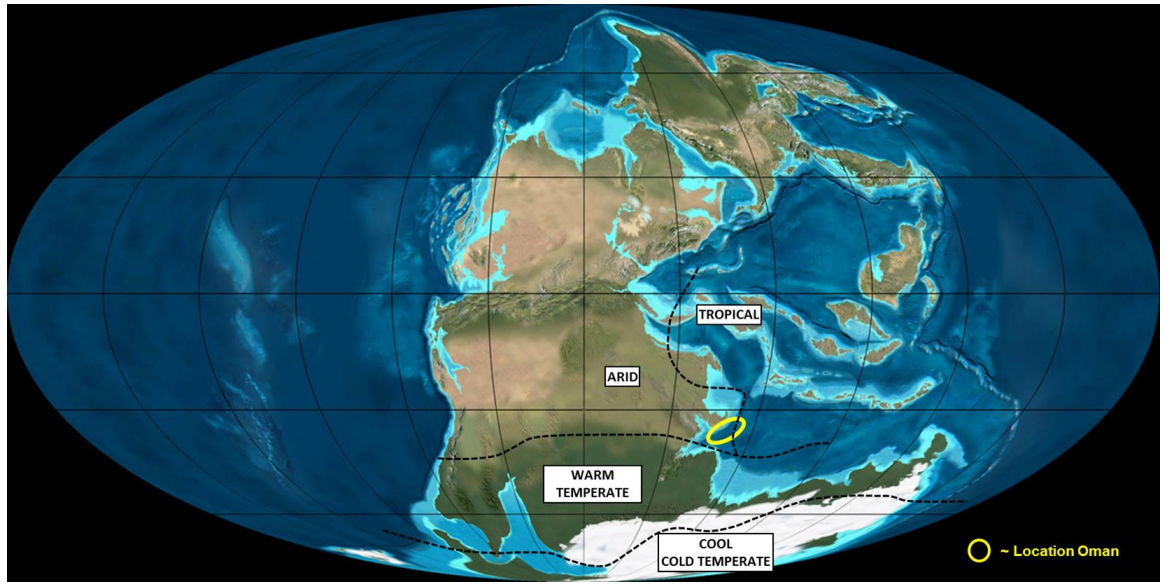
272.3 +/- 0.5 MYA

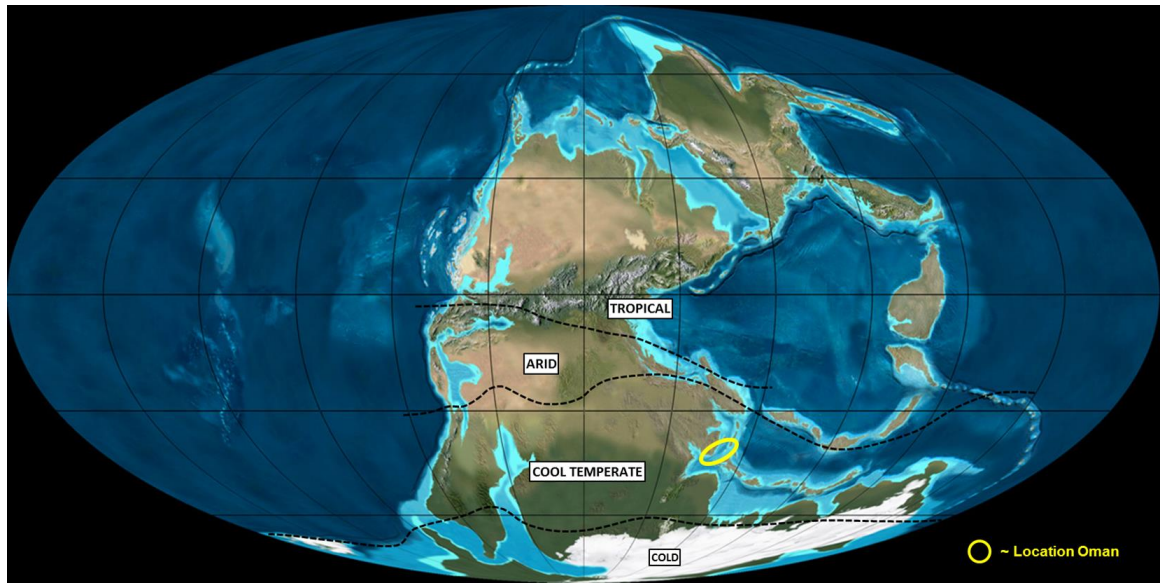
Middle Gharif Member
- Duration: 17.8 Million Years
- 45 4th-order sequences

290.1 +/- 0.2 MYA

Lower Gharif Member
- Duration: 5.4 Million Years
- 13 4th-order sequences

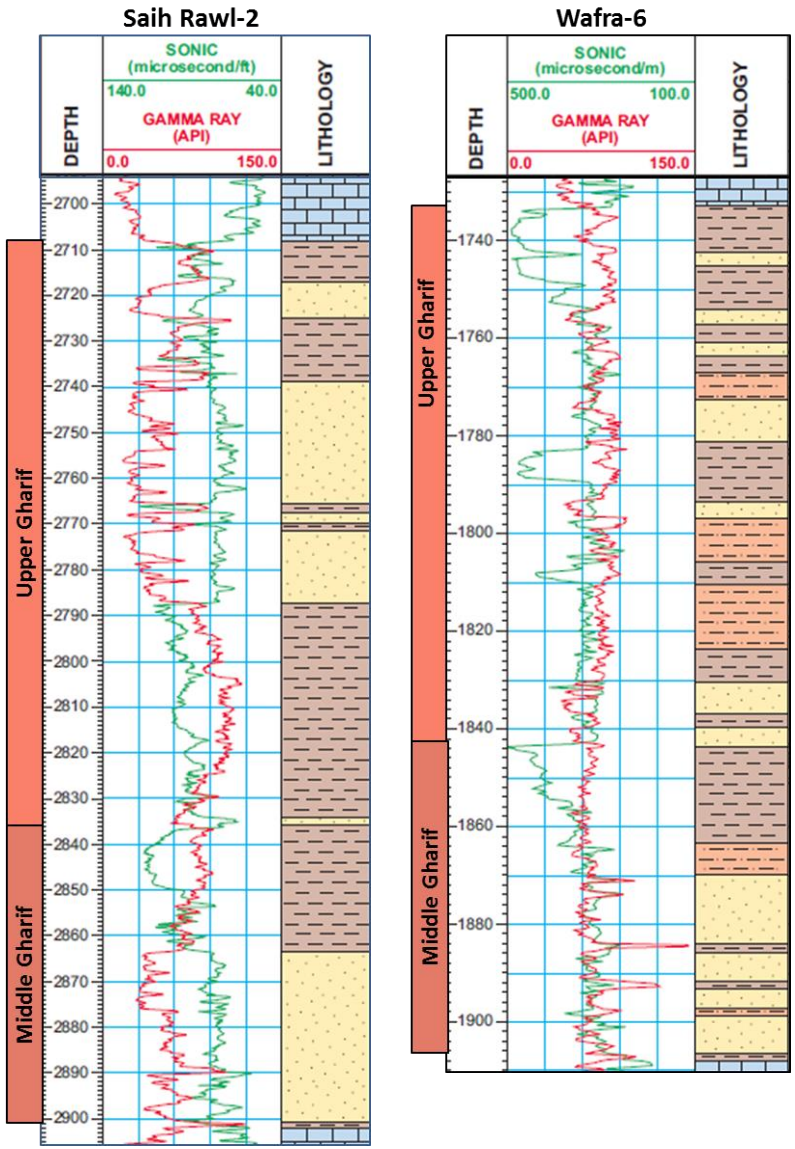
295.5 +/- 0.4 MYA

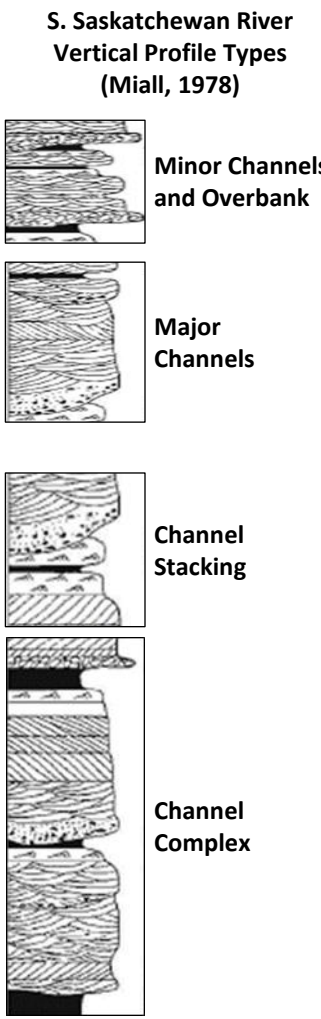


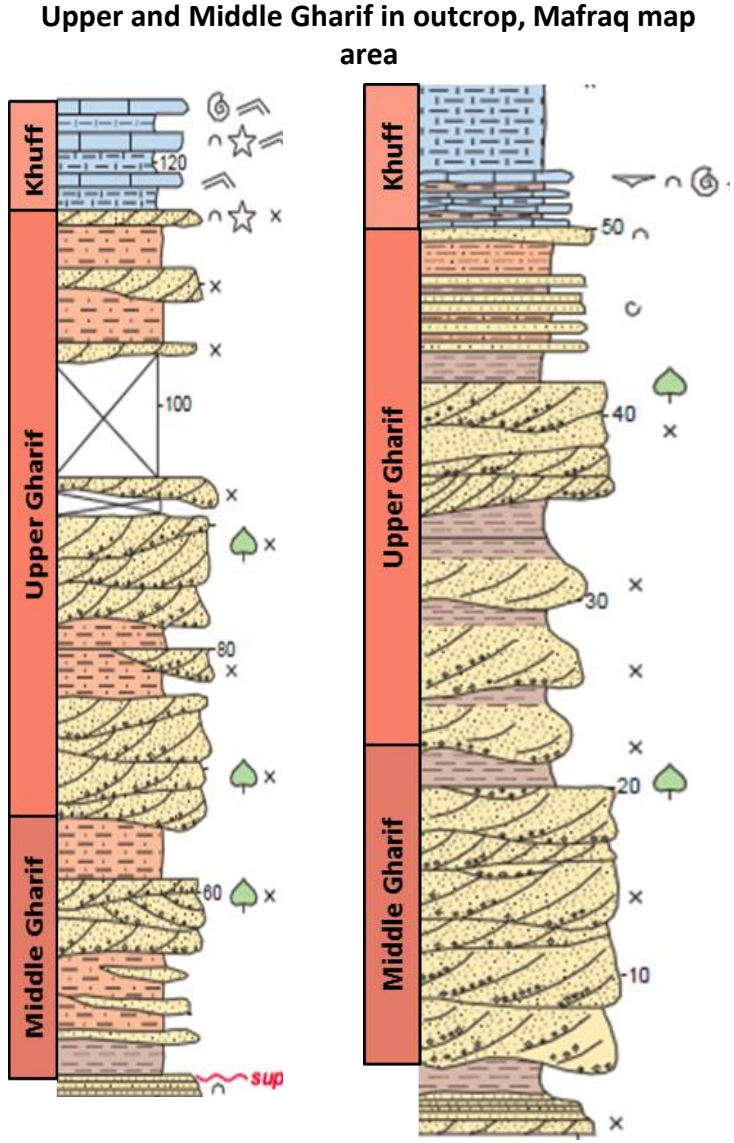


Modified after Blakey (Paleogeography) and Boucot, Xu and Scotese, 2013 (Paleoclimate)

Upper and Middle Gharif Sedimentology



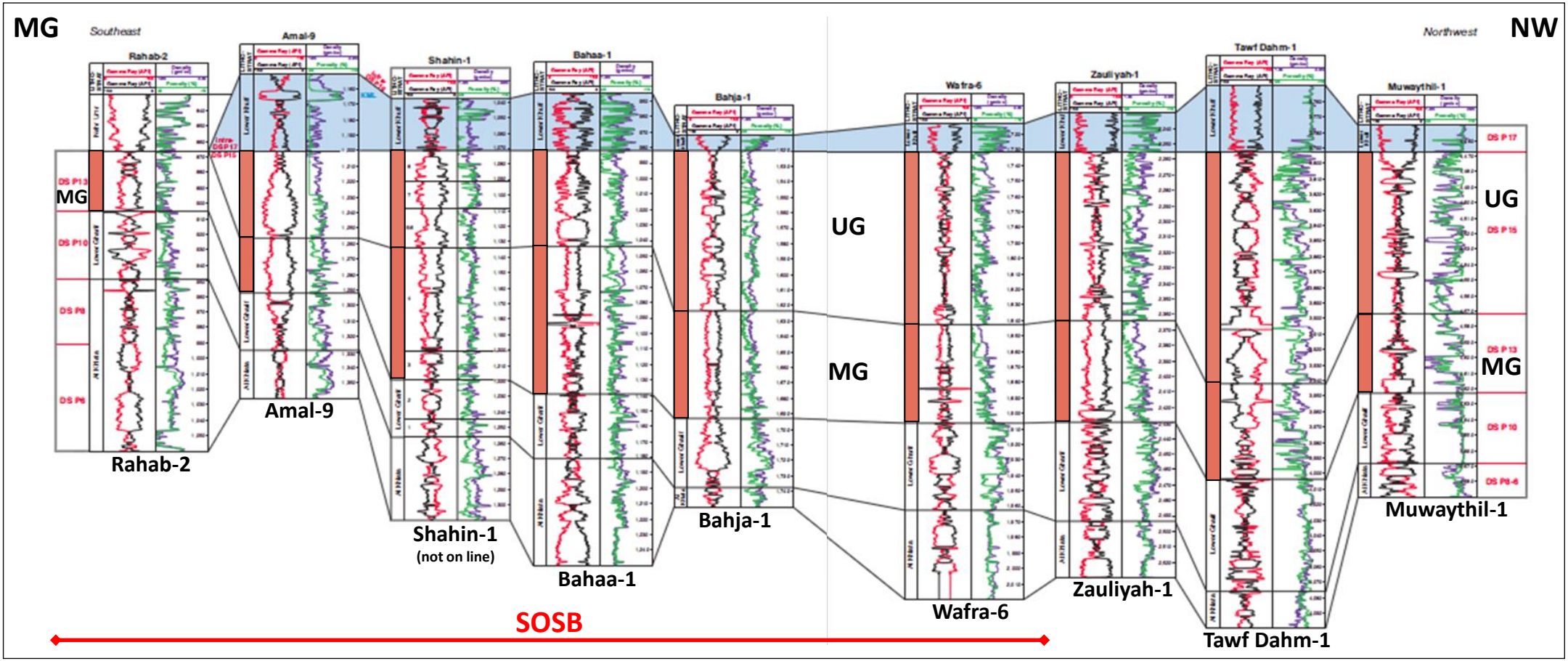


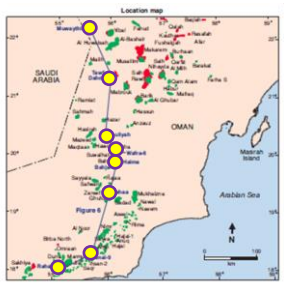


Source: Forbes, G. A., *et al*., 2010, Lexicon of Oman Subsurface Stratigraphy, GeoArabia SP5.

Source: Angiolini, L., *et al*., 2004, Saiwan, Gharif and Khuff Formations, Haushi Uplift, Oman, GeoArabia SP3.

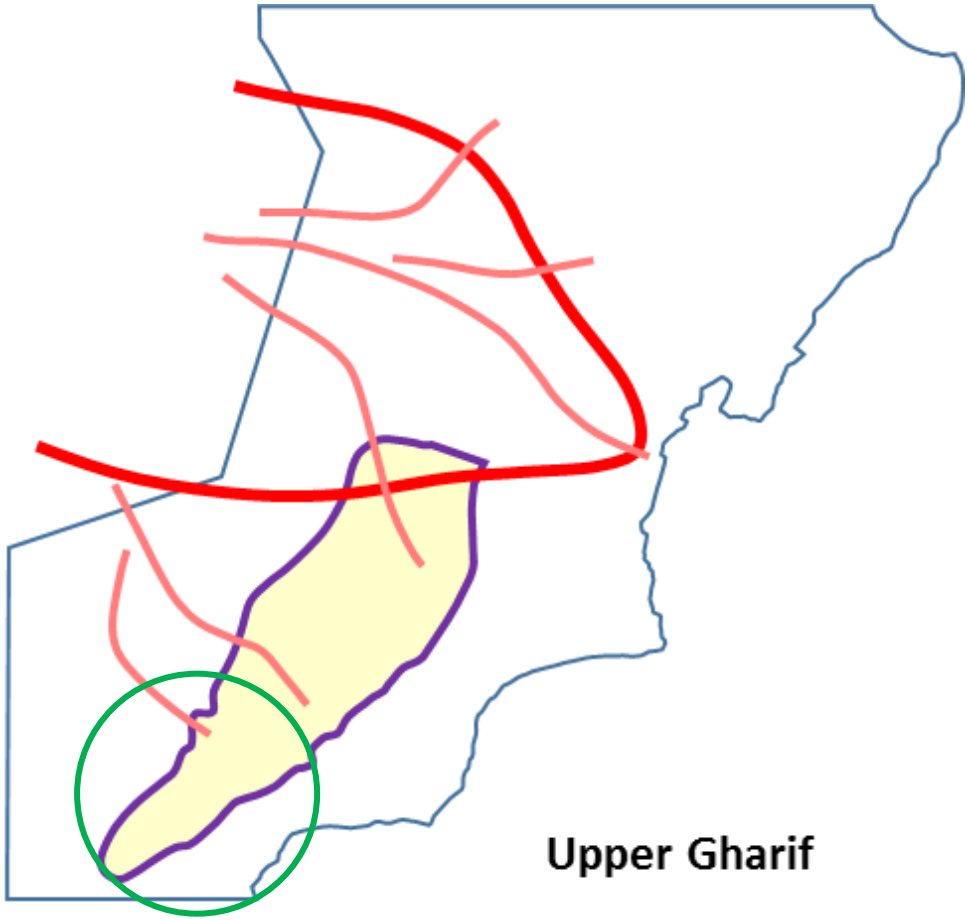
Internal Organization of the Gharif Formation

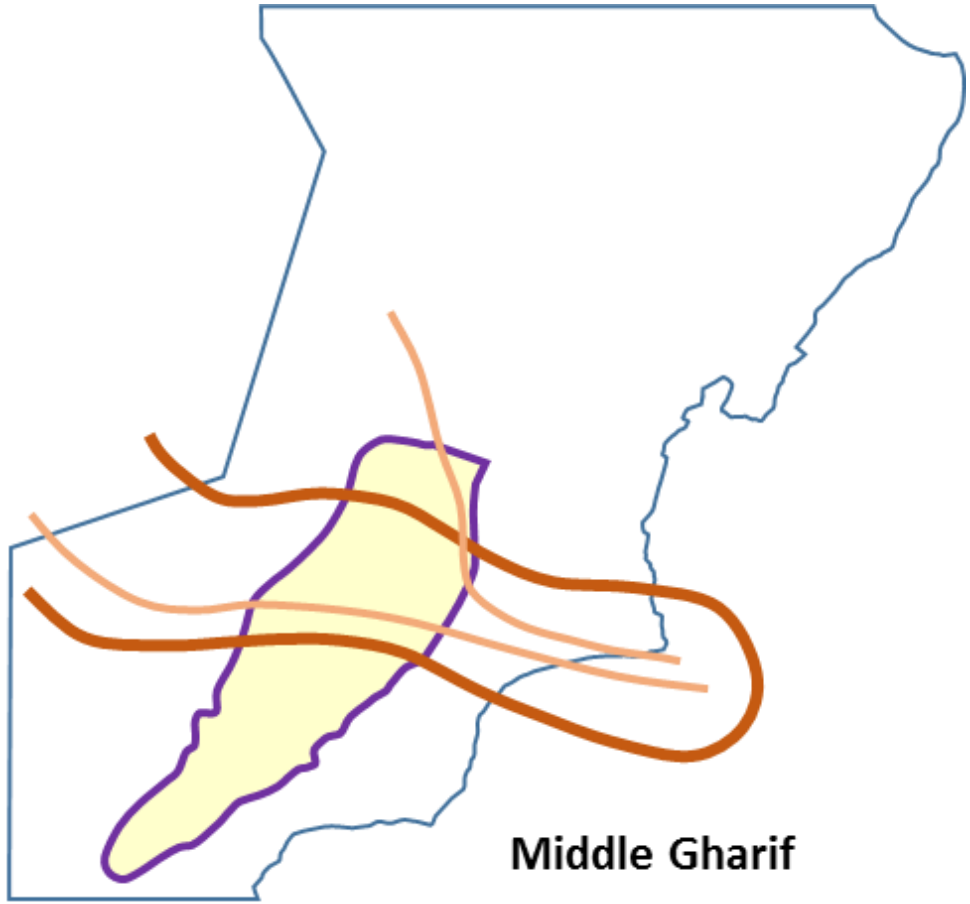




Source: Osterloff, P., *et al.*, 2004, Depositional Sequences of the Gharif and Khuff Formations, Subsurface Interior Oman, GeoArabia SP3.

Primary Depocenters for the Upper and Middle Gharif





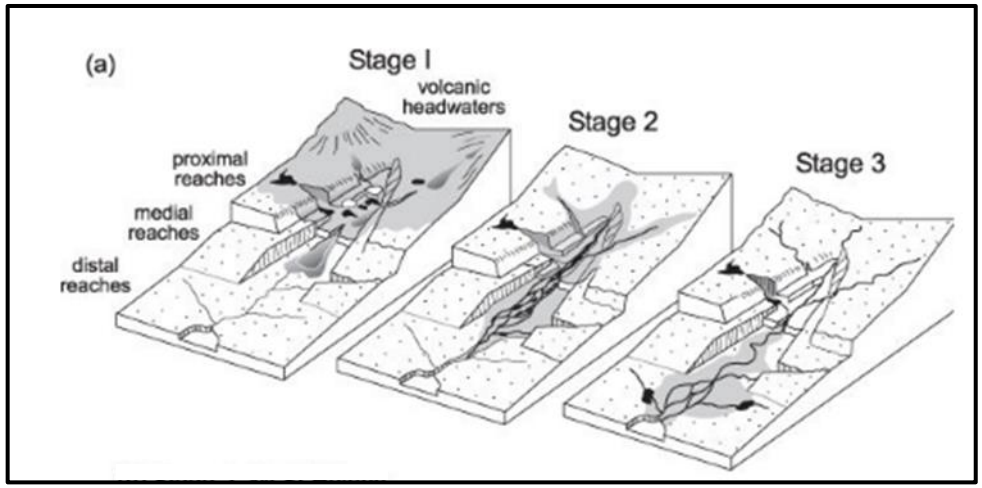
Modified from Osterloff, P., *et al*., 2004, Depositional Sequences of the Gharif and Khuff Formations, Subsurface Interior Oman, GeoArabia SP3.

Fluvial Responses to a Change in Local Base Level

Not dependent on sea level change

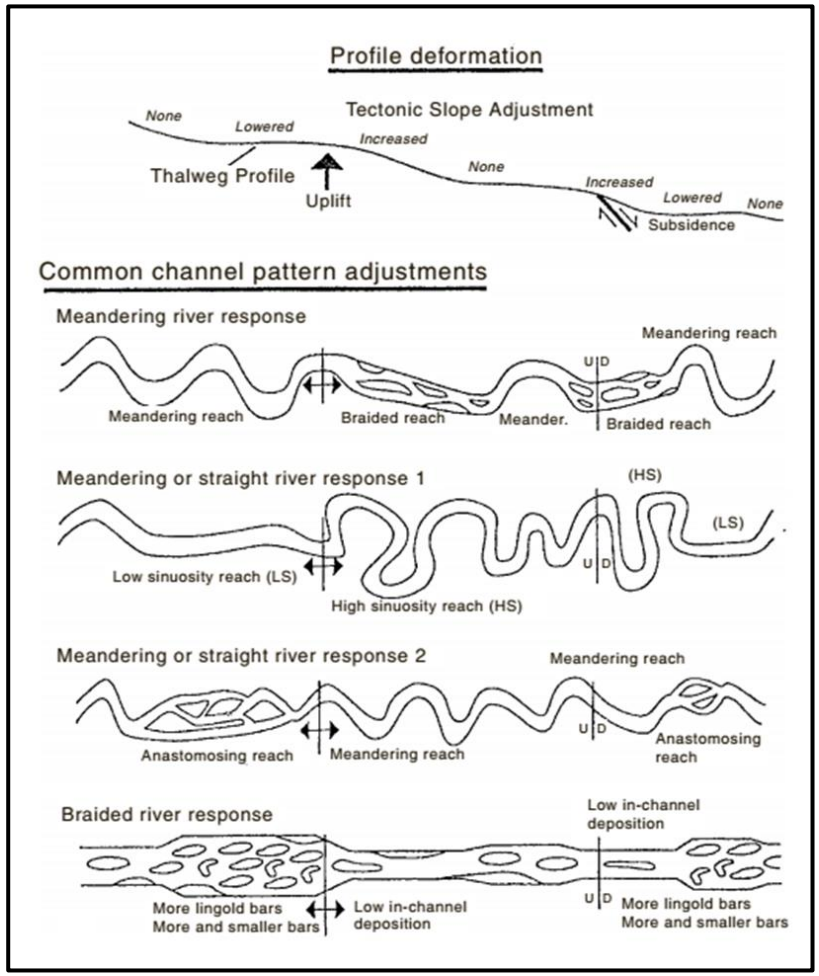
Typically a result of syndepositional tectonism

Has been studied in the field and the lab



Source: Charlton, R., 2008, Fundamentals of Fluvial Geomorphology

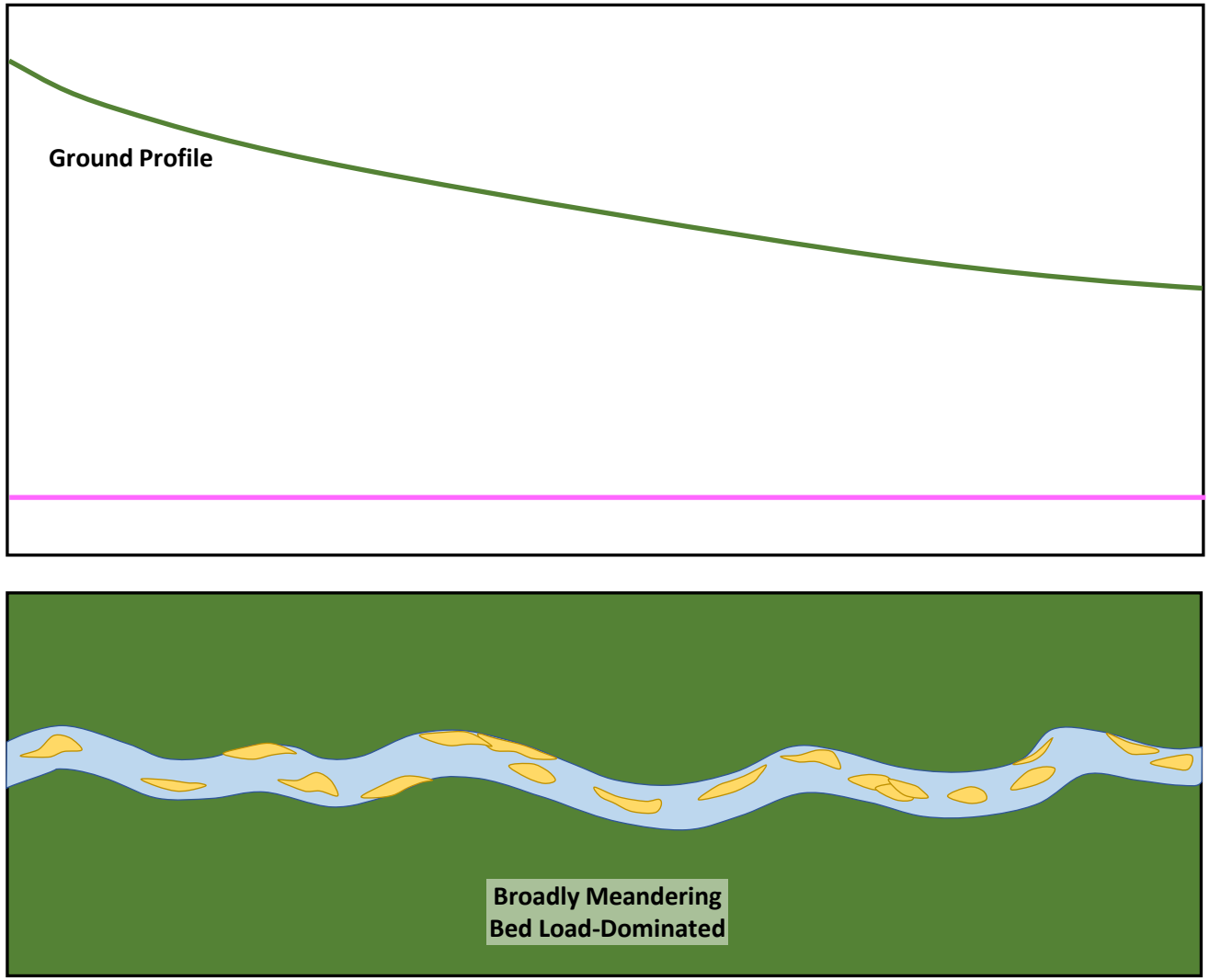
Example from a volcanic eruption:
Stage 1: Lakes due to valley damming and small channels
Stage 2: Sediment reworking, incision with knickpoint migration
Stage 3: Creation of braided streams and continued incision



Source: Schumm, S. A., 2005, River Variability and Complexity

Interpreted Responses to Gharif Fluvial System Due to Salt Movement

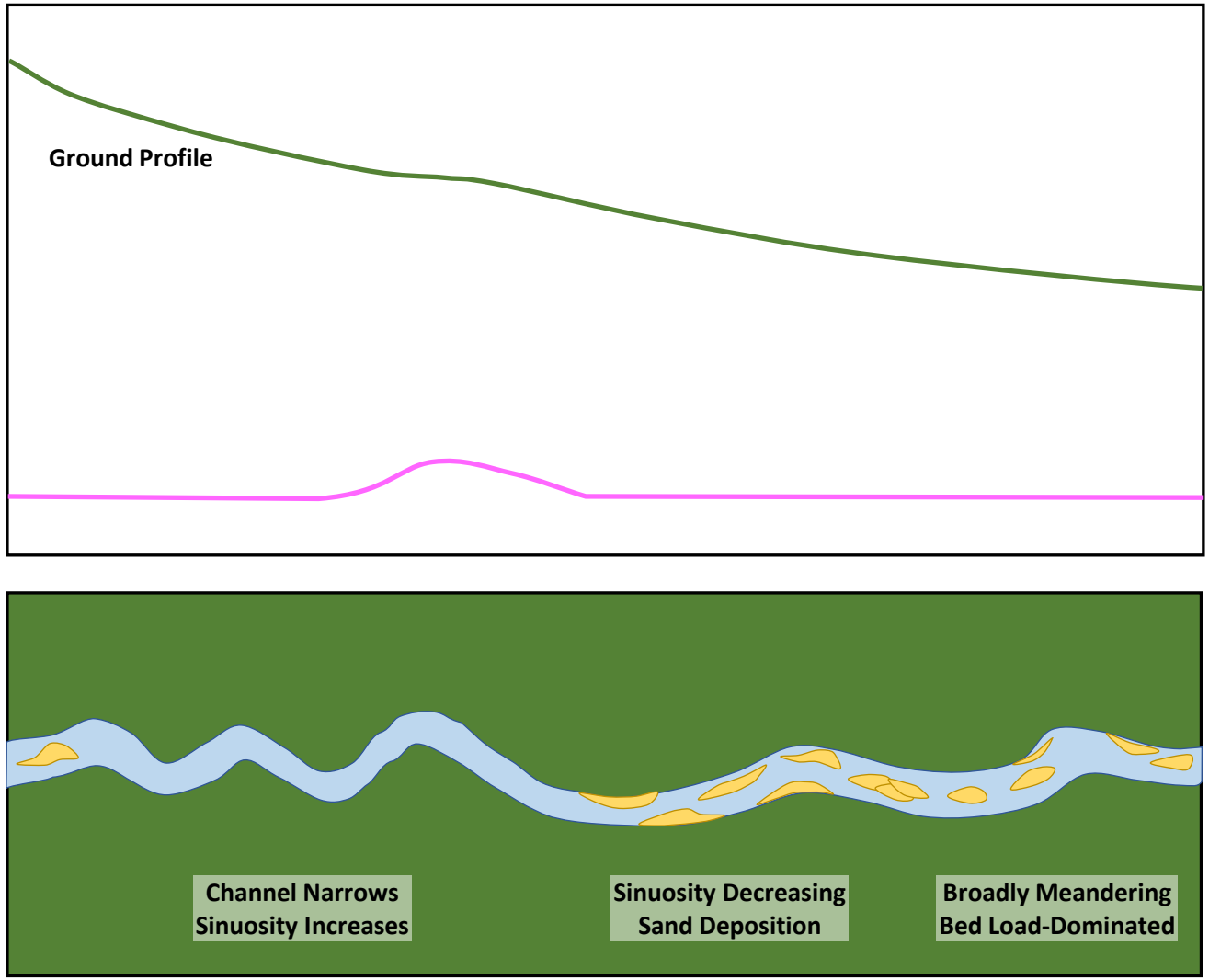
Fairly simple longitudinal profile. Major channels are broadly meandering and bed load dominated.



Interpreted Responses to Gharif Fluvial System Due to Salt Movement

Fairly simple longitudinal profile. Major channels are broadly meandering and bed load dominated.

Minor initial movement only perturbs the system in the vicinity of the movement. Channels narrow and sinuosity increases. Deposition downstream as profile stabilizes.



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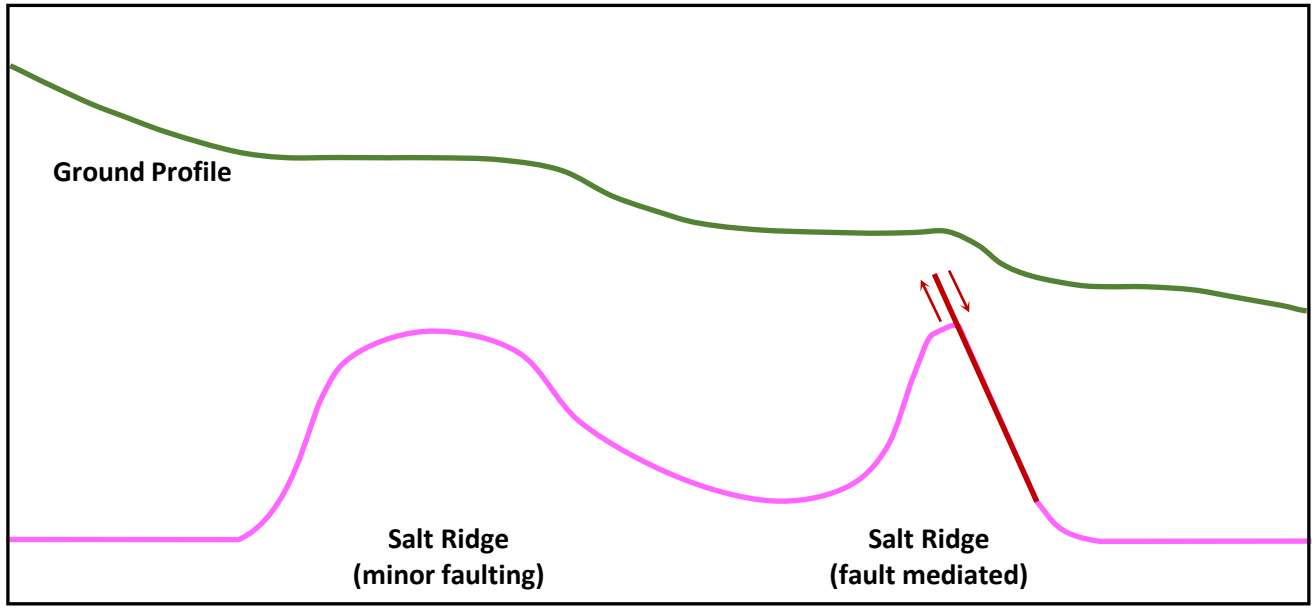
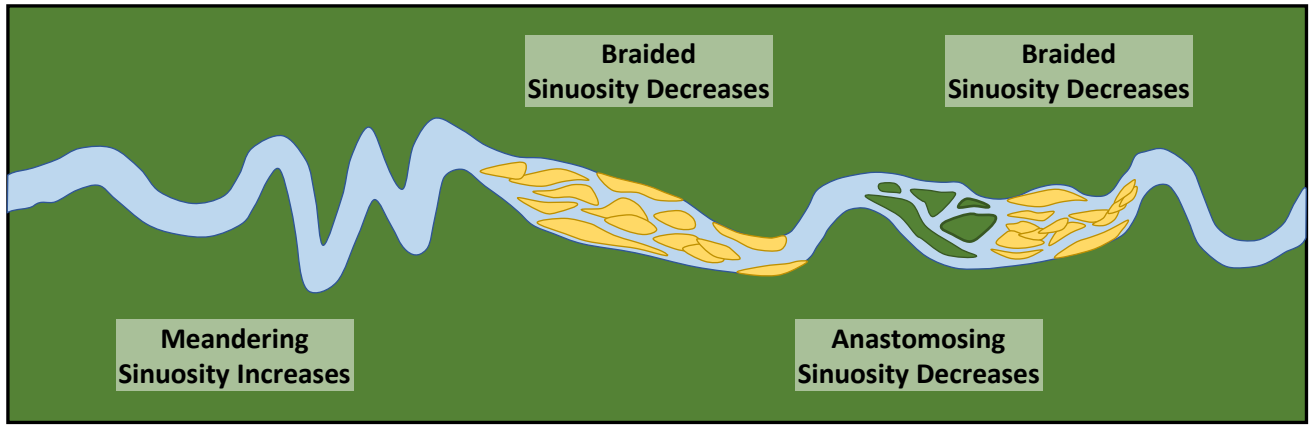
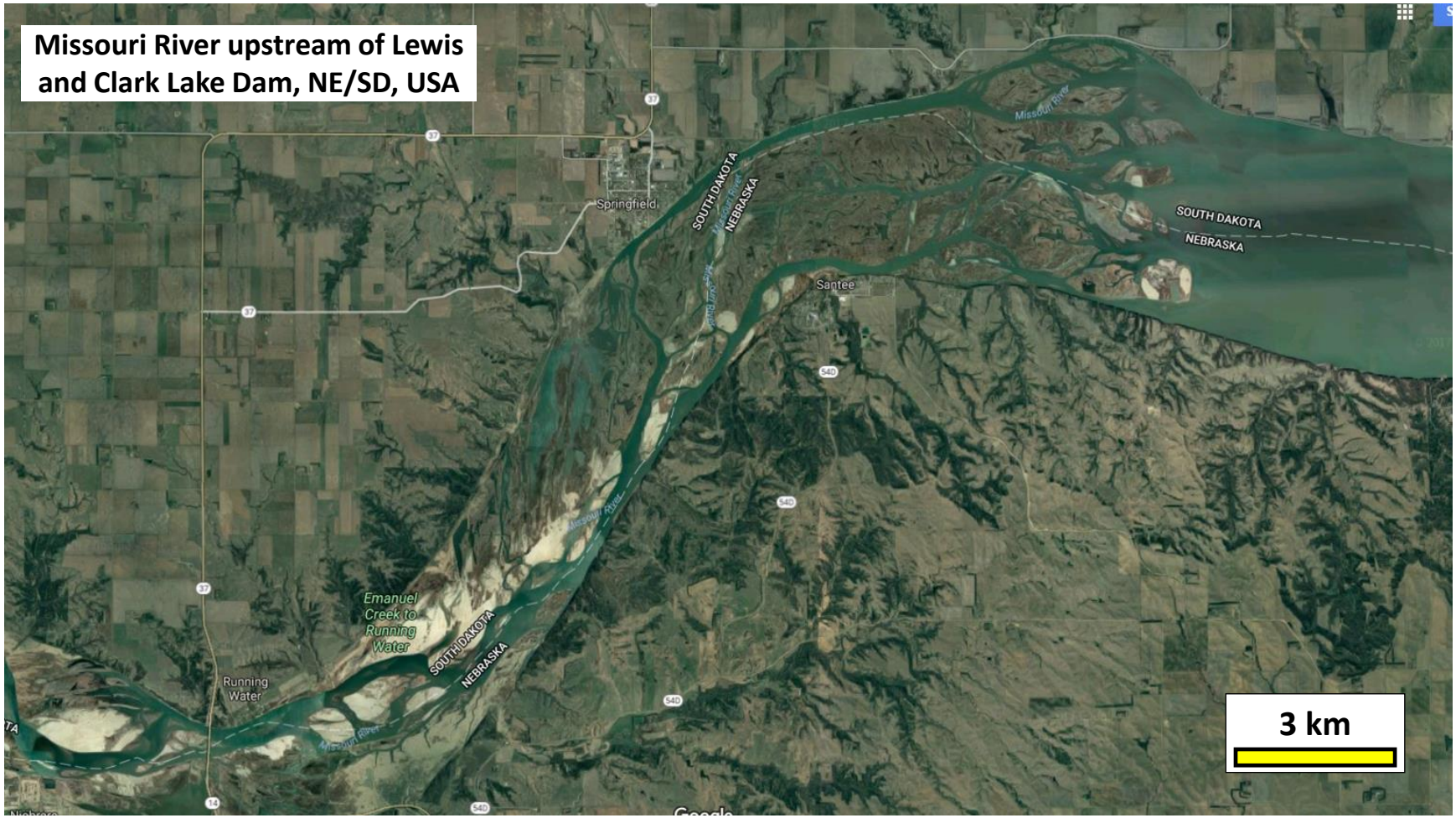
Continued movement deranges major channels and results in complex local and regional responses. Sand deposition downstream of ridge and highly meandering or anastomosing upstream.





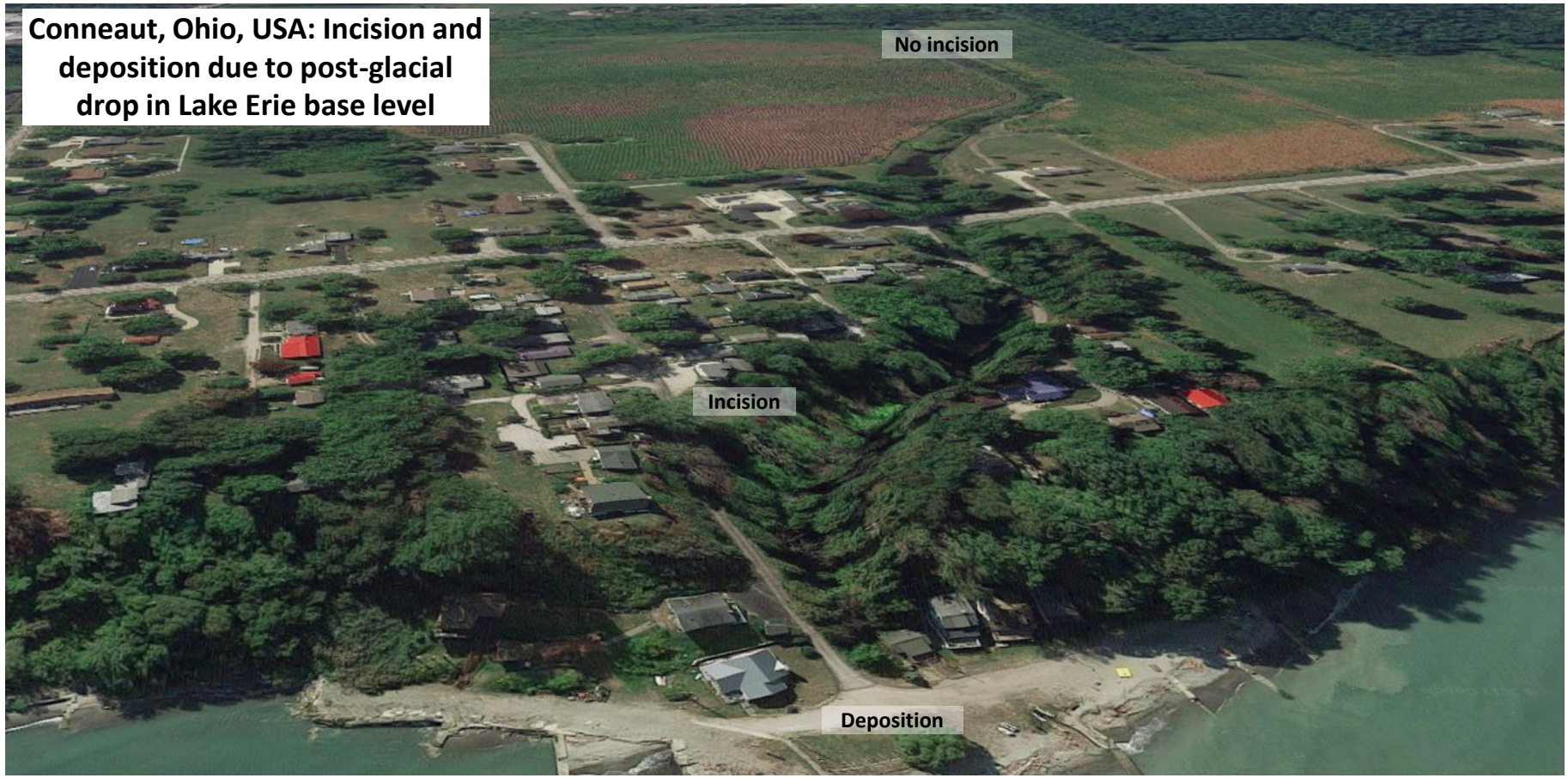
Increased Base level

Results in anastomosing pattern with broad FP and lakes



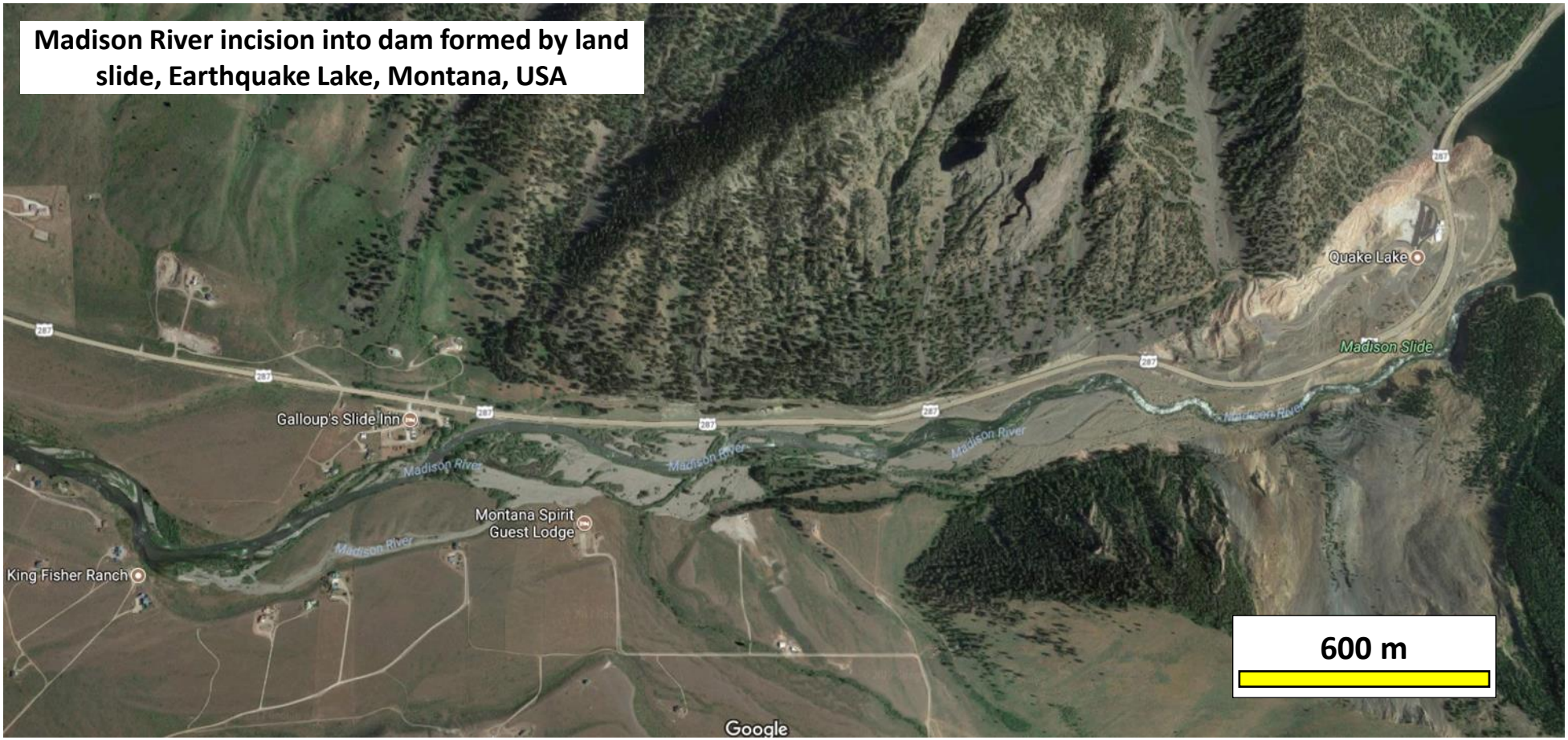
Source: Google Maps

Across a Sudden Drop in Local Base Level



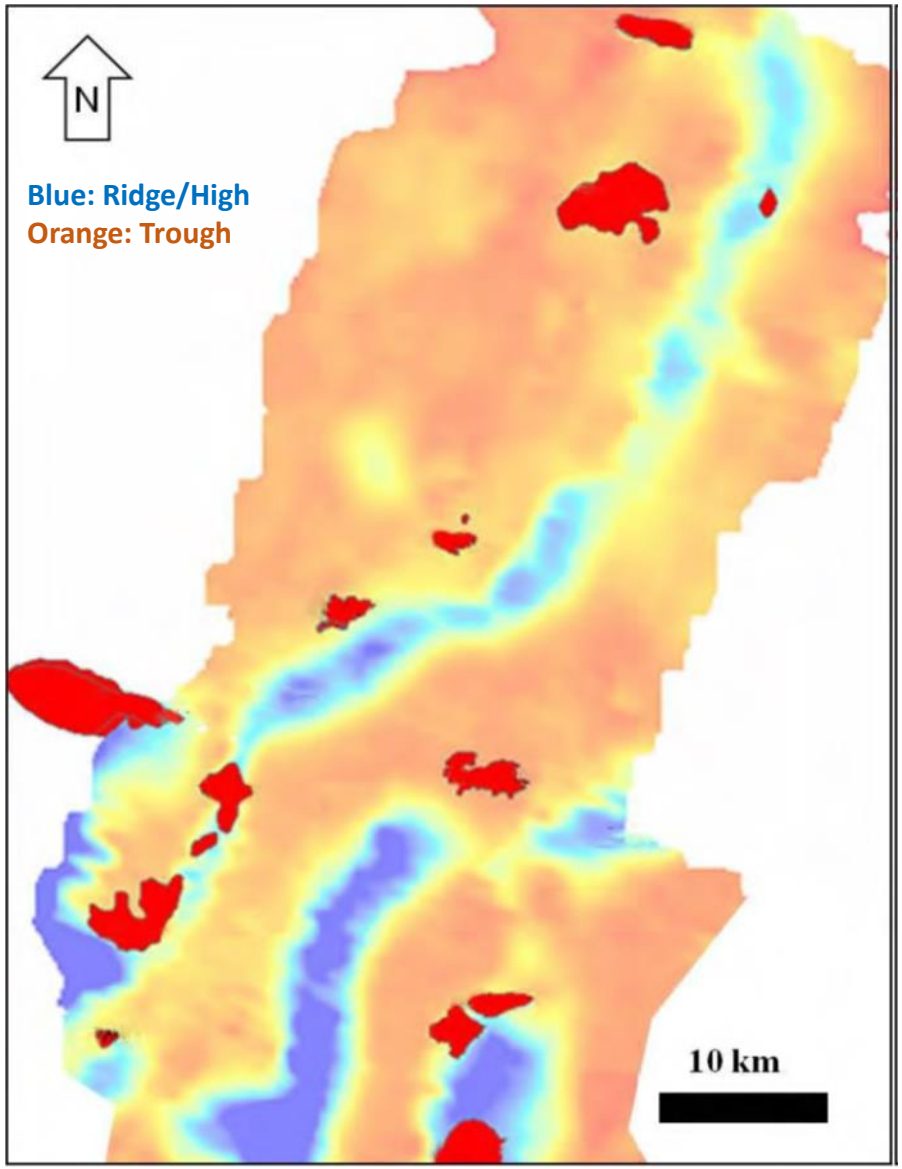
Source: Google Maps

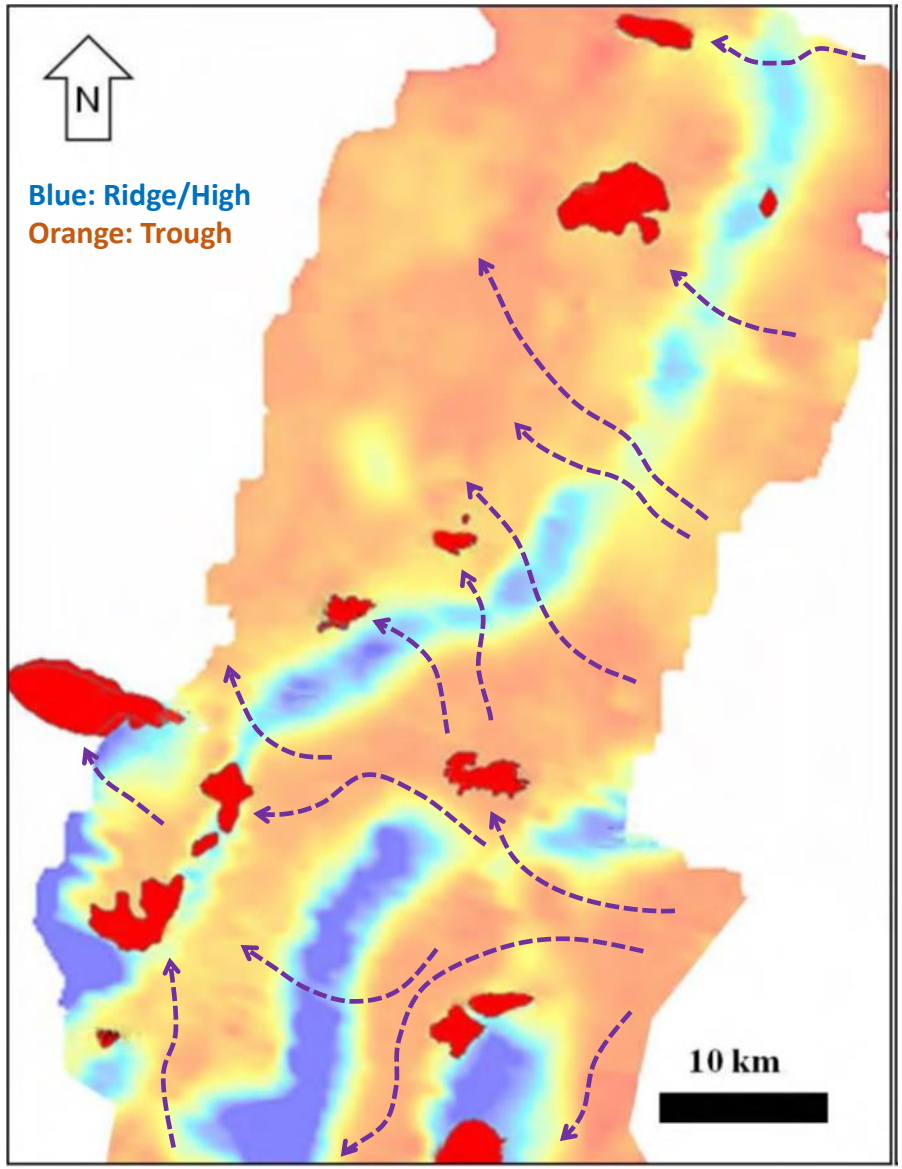
Incising through an obstacle



Source: Google Maps

Gharif Formation Fields Exist on Down-Flow Side of Salt Ridges





Source: Al Kindy, M. H. and P. D. Richard, 2013, The Main Structural Styles of the Hydrocarbon Reservoirs in Oman, in-press copy of paper that is found in Rollinson, H. R., M. P. Searle, I. A. Abbasi, A. Al Laski and M. H. Al Kindy, 2014, Tectonic Evolution of the Oman Mountains, GSL SP392.

Conclusions

The Gharif Formation provides a good example of stratigraphic traps due to syndepositional salt movement.

Greater reservoir quality, greater continuity/amalgamation of sandstone deposits occur downstream of the salt ridges.

- **Demonstrated by the location of Gharif Formation fields.**

Upstream of the salt ridges the Gharif Formation can still possess reservoir quality sandstones, but these will be less continuous and amalgamated.

There is remaining potential for exploration of the Gharif Formation within a salt ridge play in the South Oman Salt Basin.

Acknowledgements

Those who have previously published their work on the Gharif Formation, and Oman geology in general. Their doing so has resulted in a vast library which helps all of us better understand this region's geological complexity.

The Oman Ministry of Oil and Gas

Our co-workers at Target Oilfield Services whose cumulative knowledge of the Gharif Formation has helped unravel some of this formation's complexity at both the exploration and production scales.

The management of Target Oilfield Services who actively encouraged this presentation/publication.

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