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Turning Geology upside down: completely new approaches to traditional sedimentology

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Summary

Geology is no stranger to new ideas, and the sub-discipline of sedimentology (sedimentary geology) is no exception. Many of these ideas have become embedded in science, such as fining upward, the avulsion of meandering channels, sequence stratigraphy, particular types of deposits occurring in certain environments and many more. It is time to take these ideas by the scruff of the neck and to give them a good shake, and then to manipulate them to achieve a result that they were never designed for. Many of the ideas below apply concepts at a completely different scale.

Some of the ideas that will be explored include why clouds are the epitome of sedimentary deposits; compensational stacking at a continental scale; applying forensic science to ichnology (including a real murder); bayhead deltas in your back garden; why some meandering channels stop migrating laterally forever; the deposition rates of cities; really tiny sequence stratigraphy; the sedimentology of Winter and much more. Twisting basic sedimentary concepts to new ends forces us to address what these concepts really mean, and to learn more about the ramifications created by their application.

Theory

Sometimes people take what they are taught at face value, but it is crucial that, every now and again, they ask themselves why. Many publications will make a bald statement that we might never think of questioning. An example is the abundance of incised valleys in Alberta. There are literally hundreds of papers describing these features but trying to find a published explanation for their presence is a huge challenge. It might even be described as the elephant in the room. Never be afraid to ask the "why" question, several times if necessary to find the limits on our knowledge and understanding. One way to explore the boundaries of our understanding is to look at ways of applying standard theories in extraordinary ways. At worst it is pretty cool to examine geology in a whole new light, and at best it can lead to new approaches to the science.

In the following paragraphs, every effort will be made to take "standard" theories and methodologies and then apply them in new and unexpected ways. The reader will hopefully think… "wow I never thought of that", and then take those ideas on board and look at their data and interpretations in new ways. These are theories in search of a new target to apply themselves to, in ways that are hopefully entertaining at the same time.

1. The Sedimentology of Clouds and what it can teach us

When looking for new analogues in sedimentology, most geologists tend to look down rather than up. However. the sky above us provides an enormous sedimentological laboratory, where the world's largest rivers, such as the Gulf Stream, flow through rippled deposits that may stretch for hundreds of kilometres. Huge plumes of cloud rear up in response to upwelling currents. All of us are familiar with a herringbone sky, but how many have paused to wonder how such structures are formed.

There are many types of clouds, all made up of millions of tiny droplets of water and ice. These droplets are so light that they can float on air but are liable to be transported and moulded into structures by air currents. Hence, they provide a unique analogue (Figure 1) to the behaviour of sediments, such as sand grains and clay particles, under the influence of submarine and fluvial currents. The stratification of the atmosphere ensures that clouds usually behave as though in contact with an underlying bed surface.

Figure 1. A beautifully preserved dune made from transported water droplets AKA clouds.

Figure 2. Meandering channels on mudflats with incipient mangroves. Photo by Annabelle Sandes/Kimberley media, reproduced with permission.

Many of the same sedimentary structures that may be observed in ancient sediments are also clearly visible in the sky. We will examine heavenly analogues to dunes, to ripples of many kinds, and to dewatering structures. We will also look at aerial channels and coastlines. Storms provide a counterpart to catastrophic flooding events, providing us with the opportunity to see the impact of high currents on a scale rarely possible in the subaqueous realm. The study of clouds has the potential to elucidate the formation of sedimentary structures, the behaviour of very light particles, and the development of sedimentary structures on a very large scale. Analogues to virtually every class of sedimentary structure are floating above our heads and can be studied from every angle.

2. Mangrove palimpsests or why meandering channels stop migrating

An overflight of a mangrove swamp reveals striking meandering channels wending their way through the mangrove forests. The vegetation is so thickly rooted that it is impossible for the channels to avulse, except where outside agencies (such as large semi aquatic mammals or speedboats) break new passages through the mangal plants. Extrapolating this knowledge suggests that the pattern of meandering channels extant on the mudflats (Figure 2), prior to colonization by mangroves, is preserved as a palimpsest through the life of the mangroves. The channels on the mudflats, more correctly termed tidal creeks, are typically very shallow, but are eventually preserved as sand bodies with width:depth ratios <1 due to vertical aggradation in the absence of lateral channel migration.

3. Applying real forensic science to ichnology

The study of ichnology includes many concepts drawn from the study of modern traces i.e. neoichnology. There are also techniques used in forensics that can readily be applied to the study of ancient traces. Some have already found favour: the use of footprints to determine weight of the animal and speed of travel; casting techniques; forensic geology and geomorphology. Examining modern traces where "things have happened", such as animal attacks, are excellent practice in taking forensics into the fossil realm.

Figure 3. Jumbled jackrabbit footprints, Calgary. What was going on here?

Figure 4. Crime scene, close to Crowchild Bridge, Calgary. Victim (duck) found close by.

4. Sequence stratigraphy at a tiny scale

A famous paper by Henry Posamentier describes the events surrounding a delta in East Coulee as a rainstorm raises the water level in a ditch and then it drains away. The delta is only 30 cm across. The paper beautifully demonstrates the impacts of changes in relative sea level (ditch water level) through time. This method can be applied at all scales, but most easily at the decimetre to metre scale, especially examining the behaviour and impacts of climate on streams, incised valleys and deltas.

5. The Sedimentology of Winter and what it can teach us

Snow behaves like any other material made up of sedimentary particles. It can be deposited, reworked by (wind) currents and gravity, and altered diagenetically through pressure and heating. This diagenesis typically occurs within a few centimetres of the snow surface. There are several types of snow, including snowflakes, which have their own complicated classification, hoarfrost, graupel and polycrystals. The morphology affects their behaviour and depositional character and subsequent diagenesis into ice layers. These layers are studied in ice cores.

Most dramatically snow can form mass flow deposits as avalanches, which occur as two main types, loose snow and slab avalanches, depending on terrain, weather, and snowpack. The latter is composed of ground-parallel layers that accumulate over the winter, and these can be classified depending on age and the transformation from snow to ice. Each layer contains ice grains that are representative of the distinct meteorological conditions during which the snow formed and was deposited. Avalanches may involve dry or wet snow, which in turn affects their triggering and behaviour. As a testament to their significance in human terms, they are thought to have killed more than 50,000 soldiers in the First World War alone.

Snow can also exhibit a variety of sedimentary features more familiar to us from clastic deposits, such as dunes, ripples (Figure 5) and even the preservation of footprints. Study of these features in ephemeral winter conditions, particularly as they become subject to effervescence, melting and erosion, provides lessons that can then be applied to similar deposits in other sedimentary environments.

6. Urban deposition rates: how cities build up

The Sadler Effect describes how the longer the time scale we use to observe deposition, the slower the deposition rate. This is because depositional hiati occur through time, as well as the potential for erosive events to remove sediment that has already been deposited. Focusing on Europe's great cities, Rome, Barcelona, Paris and others, as well as smaller cities like Bath in the UK, it is possible to gauge the deposition rates by examining the accumulation rates since the Roman foundations were built. Deposition comprises both the accumulation of sediments and the building and "over-building" (where one building succeeds another, directly overlying the previous building).

Astonishingly, it appears that deposition rates measured in all of these cities are consistent at around 3.6 metres/1000 years. This has been documented by the author at the Pantheon in Rome, at the streets of old Barcino beneath Barcelona (Figure 6) and at the Roman Baths in the UK. Obviously, measurement of deposition rates relies on the presence of Roman remains that can be used as a baseline. Further research is planned to extrapolate these results to other cities with Roman (or even older) remains.

Figure 5. Sedimentary structures in snow.

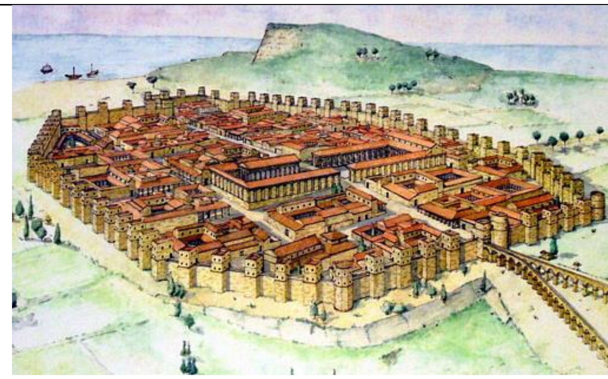


Figure 6. Reconstruction of the Roman city of Barcino (from www.barcelonayellow.com)

7. Redefining bayhead deltas

A bayhead delta is defined as a sedimentary system that forms at the head of an estuary, or embayment, where sediment laden freshwater enters brackish bay waters. Bayhead deltas form where the local rate of sediment input from rivers outpaces the rate of sea-level rise on a transgressive coastline. A significant oversight is that the definition does NOT cover deltas prograding into freshwater lakes. Such deposits are common in manmade reservoirs, where the completion of a dam downstream leads to a transgression, allowing sediment to start building up at the upstream end of the dam. In the absence of any tidal influence, there is little reworking at the delta front, and a dominantly fluvial depositional regime. Such systems provide an excellent laboratory to examine the depositional processes operating in a bayhead delta.

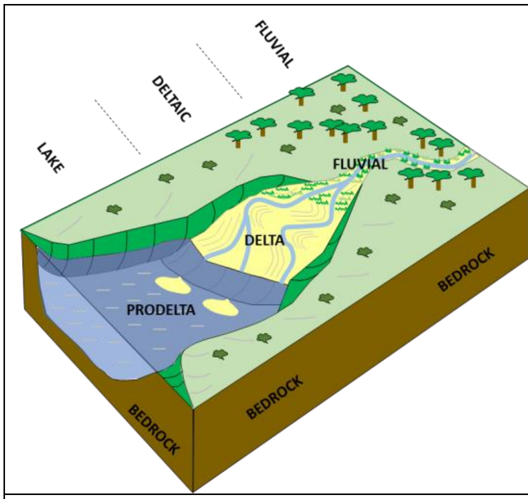


Figure 7. Sketch of Glenmore Reservoir showing a bayhead delta that only began forming following completion of the Glenmore Dam in 1935.

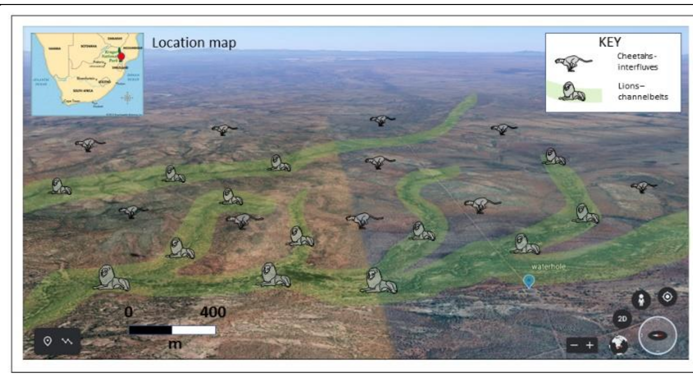


Figure 8. Lions and cheetahs - see text, from an example in Kruger National Park, South Africa.

8. Compensational stacking at a continental scale

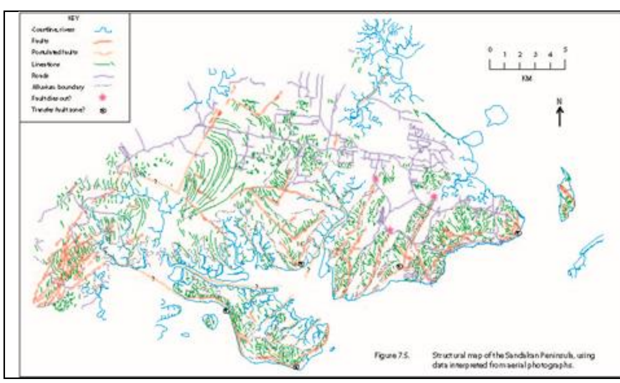
A key target when exploring for hydrocarbons in ancient fluvial settings is to identify fluvial channel belts. These belts can extend for many kilometres and are separated by upland areas, or interfluves. While most channel belts are associated with small rivers, where the world's major rivers are concerned, the fluves and interfluves may be hundreds of kilometres across. I term these geomorphological features as lions and cheetahs (Figure 8) – lions ambush their prey, so are found in the river valleys, while cheetahs prefer high, open ground to chase down their prey i.e. interfluves.

9. How quickly can cementation occur?

Many geologists envisage cementation as happening on a geological time scale. Cementing up a reservoir may take millions of years. However the extraordinary three dimensional preservation of some fossils in cemented siderite nodules demonstrates that the sideritization process must occur prior to compaction. Fossil mangrove lobsters (*Thalassina anomala*) from Gunn Point, northern Australia, which were possibly inundated by muds during tropical storms, appear to have been fully fossilized in less than 500 years. What this means for hydrocarbon reservoirs is that extremely early cementation may be a possibility..

10. Are creeks helpful?

The word "creekology" was used to describe a petroleum prospecting method which appeared in the 19th century in US south gas-oil states. In its simplest form, it was the search for above-ground indications of oil, such as natural seeps. Creekologists also placed wells on singular points of a territory in accordance with landscape features. The placing of wells often occurred near, or on, linear objects - erosion relief forms (valleys, creeks, etc.) - giving rise to the term creekology. However, the definition can be expanded to include the interpretation of linear creeks as relating to potential subterranean faults. Extrapolating on a world scale suggests that straight coastlines may relate to deep seated basement faults.



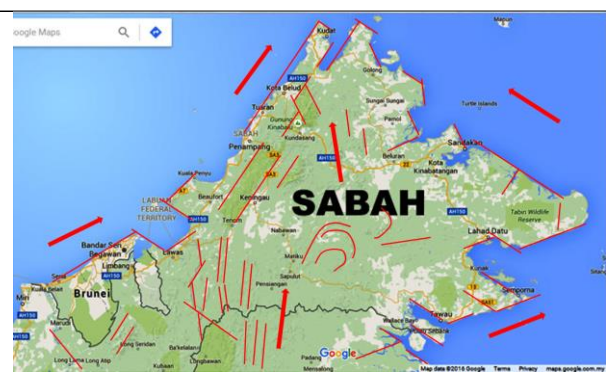


Figure 9. Map of the Sandakan Peninsula, annotated to show how the creeks follow structural lineations	Figure 10. Interpretation of eastern Borneo and its basement faults.

Should time allow we may also explore whether hydrocarbons can host gold and how often did trilobites have birthdays?

Conclusions

We have seen how looking at geology "upside down" or extrapolating wildly, can open up new avenues of discussion and new ideas to test. Rather than taking geological truisms at face value, I strongly recommend asking the "why" question whenever relevant, as it may lead to very different interpretations than those are published.

Acknowledgements

To every geologist who has ever scribbled an idea on the back of a beer mat.

References

Posmetier, H.W., Allen, G.A. and James, D.P. 1992. High resolution sequence stratigraphy; the East Coulee Delta, Alberta. Journal of Sedimentary Research (1992) 62 (2): 310–317.