geoconvention
Virtual Event
September 21-23
2020
CSPG · CSEG · CWLS · GAC · MAC · IAH

The Guinness Book of Sedimentology: your guide to the world's largest EVER sedimentary features

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Abstract

Sedimentary deposits from throughout Earth's geological history have been scoured with a fine toothcomb to find the biggest, the tallest, the deepest and steepest sedimentary structures and landforms. Depositional environments ranging from fluvio-lacustrine and aeolian, tidal and deltaic and a range of marine settings have been studied to identify the record breaking ripples, dunes, bars, channels, deltas, fans, sheet sandbodies and more. Each "giant in its field" is then compared to the largest modern example to get a sense for just how different ancient environments were when stacked up against their recent counterparts.

There is obviously something special about the largest bedforms and landforms ever to grace our planet, but there are also some practical aspects. The results will provide a reality check when you try to interpret unusually sizeable structures in the field. The chance, and degree, of preservation of sedimentary structures and features in each category should be evaluated. Each identified sedimentary behemoth will also be mapped against supercontinent cycles, plate tectonic setting, global sea level and temperature curves to see whether they cluster at certain time intervals. Do certain cyclic events favour the deposition of particular extreme landforms? This data also provides a predictive tool to search for further examples of the world's "greatest" sedimentary features.

Approach

The main thrust of the research undertaken was a massive literature search. To select the largest ever example of every sedimentary environment and recognizable feature would mean (theoretically) reading every paper that has ever been published on every depositional setting. Fortunately, it was possible to narrow the search by investigating only those features that were known to be sizeable. The selections made are suggestions only, as there are no guarantees that isolated, poorly known features may have been missed.

Results tabulated by depositional setting

A table has been complied detailing each of the depositional environments examined during this study, and the individual components that were evaluated. In each case the aim was to identify the biggest ever example of each category. The categories are by no means all encompassing, but rather comprise selected features which often appear in sedimentological papers.

Terrestrial:	Fluvial:	braided; meandering; alluvial fan
	Aeolian:	desert; sand dune
	Lacustrine:	lake; flood
	Waterfall:	by height
Paralic:	Estuary; mangroves; delta; beach (longest)	
Marine:	Longest shoreface; reef; barrier island; submarine canyon	

Results

Table 1 details the largest sedimentary features recorded for every chosen depositional setting, in both ancient and modern times. The size of each feature is also recorded. It is interesting that the three largest features are a desert (central Pangaea, middle Triassic), a delta (Northern Pangaea, Middle Triassic) and a lake (Pleistocene). As we will see below, Pangaea and the Pleistocene Ice Ages crop up several times in our list of giants. Figure 1 shows the location of each giant on the list, coloured by whether they are modern or ancient.

Figure 1. Map showing the location of the giant sedimentary features. There are two focal areas, one ancient (western North America) and one recent (Ganges region).

Challenges

One of the biggest drawbacks is the variation in preservation potential. This can be affected by overall setting, for example terrestrial deposits are less likely to be preserved due to the lack of accommodation space. Deserts, and in particular the associated dunes, are difficult to preserve in their entirety. Obviously the older the deposit, the less likely that it will have been preserved in the present day, especially without having been partially eroded away. Exposed features are much easier to study and measure than those preserved in the subsurface. Another challenge is the precise definitions used. Thick aeolian deposits may be made up of literally hundreds of stacked dunes. Identifying individual dunes may be difficult, especially where grain size is relatively homogeneous.

Choosing size criteria was typically based on thickness or height rather than measuring surface area. Examples of this include the thickest point bar (as opposed to the most extensive) and tallest waterfall. However, the areal extent of some features would give an equally valid dataset from which to choose the largest one. Several features date back to the Cambrian or earlier. Since their deposition, continental drift due to plate tectonics may have transported them thousands of kilometers. Their mapped location is based on where they outcrop in the present day. The sea covers a far greater area than the land, but the different depositional marine settings usually grade into one another. This makes delineation of a particular depositional environment very challenging, and hence only a few, well defined marine features have been included in this study.

Relating giants to global cycles

There are two time periods in Earth's history where the giants are congregated, the Triassic and Pleistocene. These relate directly to two extraordinary periods in Earth's history, namely the formation of supercontinent Pangaea and the Ice Ages. These events affect many of the key global cycles (relative sea level, global temperature, number of continents), rather than being impacted by changes in these cycles (Figure 2). Hence, it would seem that it is the truly one off events in Earth history that create the largest morphological features AND have preservation potential. Both the formation of Pangaea and the Ice Ages led to unusual climates which impacted the depositional character around the globe. In addition, it should be noted that higher temperatures and sea levels appear to slightly favour giant structures.

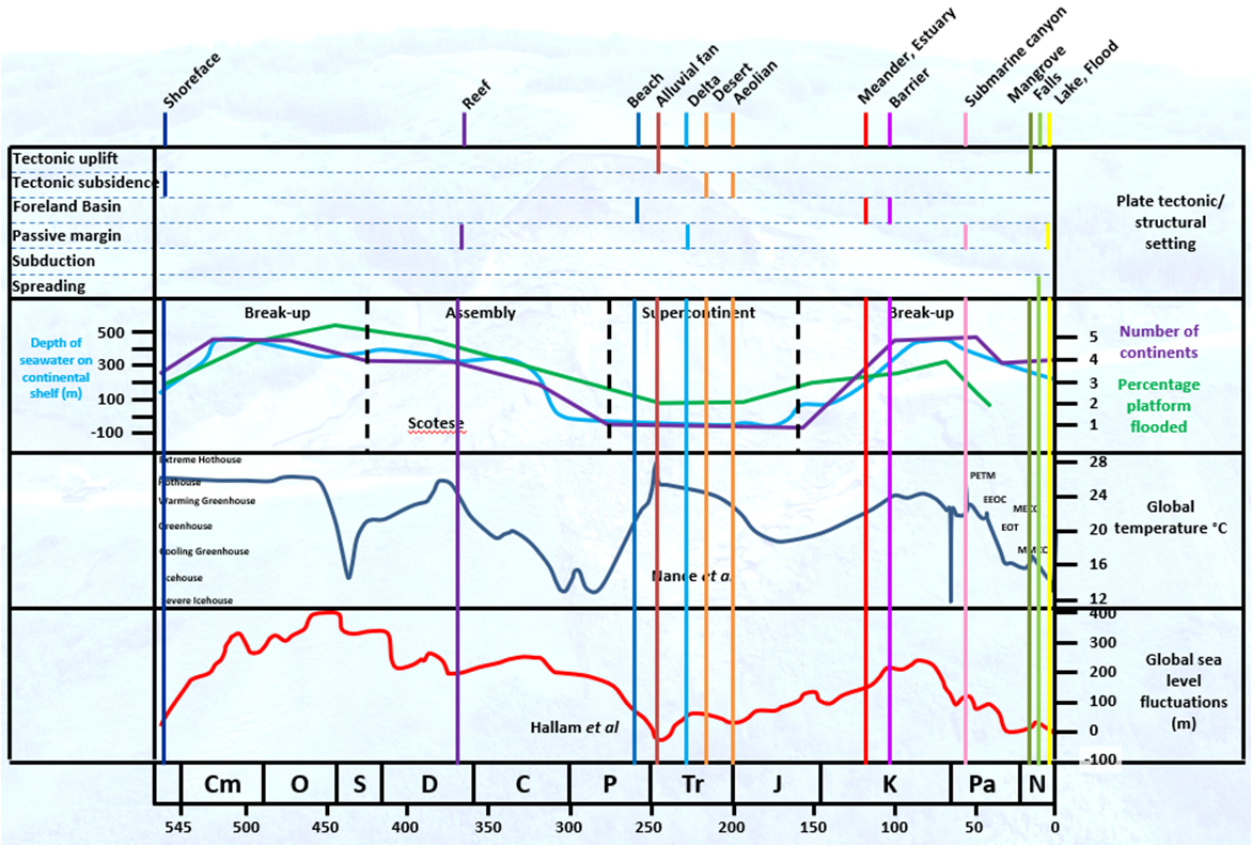

Figure 2. Graph showing when the ancient giant sedimentary features were deposited in relation to global cycles

Further work

Note that the focus of this paper is on large sedimentary features. Paucity of data in published papers meant that the largest examples (both in terms of length and thickness) of small scale sedimentary structures like ripples, trough cross-beds, hummocky cross-stratification, downstream accreting macroforms, etc., could not be identified. An exception was gutter casts, which have been studied by the author, with the largest examples seen in the Sandakan Formation in eastern Borneo. Their size is probably related to extreme storms in the Miocene. It is hoped that the current study can be extended to look at these smaller scale structures, as well as features like tsunamiites and mud filled channels. The author is also interested in deposition rates, and would like to place some constraints of these for different depositional settings.

Conclusions

This study is by no means complete, but great efforts have been made to try and explore all of the largest features recorded in the geological record. Doubtless there are many large features in the fossil record that are too deeply buried to be assessed, or have been completely eroded away, but speculations have not been included in this study. The importance of preservation potential cannot be overemphasized, especially because it affects some depositional environments more than others.

The balance between ancient and modern “winners” by category is very equal, suggesting that there are more missing giants in the past. It is unlikely that the current moment (snapshot) in history should exhibit half of the world’s largest ever sedimentary features. Much more likely that times with other climatic extremes built giants which were later eroded or subducted. Any search for more enormous features should focus on the Precambrian (pre vegetation, different atmosphere), Cretaceous (highest temperatures and relative sea level), other Ice Ages, such as the Ordovician and Permian, and any other climatic anomalies.

References

Please see the author for a huge list of references

Depositional setting	Ancient	Size km^2	Modern	Size km^2	Other noteworthy examples
TERRESTRIAL					
Braid plain	Witwatersrand Basin, South Africa: Precambrian braid plain filling giant meteor crater	45000	Brahmaputra River Basin, Bangladesh: braid plain associated with world's tallest mountains and 9th largest river	651,334	Rough Rock, Carboniferous, UK, 1000 km^2 New Zealand braided rivers; Iceland braid plains
Point bar (thickest)	McMurray Fm, Cretaceous, deposited by enormous river system from Mississippi	Thickest IHS package 58 m	Amazon River:	up to 50 m thick point bars, river possibly 100 m deep in places	
Alluvial fan	Buddleigh Salterton, UK, lower Triassic, Pangaea	30 to 100 m thick 20 to 30 km in length	Taklimakan Fan, China: world's largest alluvial fan	57 km wide and 61 km long: 3477 km^2	Prudhoe Bay: Ivishak Sandstone, fan deltas and alluvial fans, overall 864 km^2 Kosi Megafan is a Distributive fluvial system (DFS) and is 160 km long and 120 km wide, area 15,000 km^2
Desert	Pangaea; not all desert, arid area estimated from Blakeley's maps	24,000,000 km^2	Antarctic desert, with little rain or snow. Snows builds into sheets of ice	14,250,000 km^2	Different types of desert (sandy, stony, etc.) make selection difficult
Sand dune (thickest)	Wingate Fm, Triassic, Pangaea	Formation 609 m thick	Duna Federico Kirbus, Argentina, composite but huge	1230 m	Namibian Dune 7 is 383 m tall, a single dune Pleistocene dunes in Mediterranean to 200 m tall
Lake	Lake Agassiz, Canada and USA, formed by glacial meltwater in dammed lake	440,000 km^2 Area larger than Great Lakes	Caspian Sea, endorheic basin to E of Caucasus Mountains	370,886 km^2	Lake Baikal larger by volume, 23,013 km^3, Lake Mega Chad 360,000 km^2 mostly dried up 5000 years ago
Flood	Missoula Floods, formed when ice dammed lakes were released, Pleistocene	386 million m^3/second max flow >44,700 km^2 flooded	Floods on the Brahmaputra River Delta: may flood 75% of Bangladesh	26,000 km^2 flooded	
Waterfall	Filled Mediterranean after Messinian Salinity Crisis, Miocene	1500 m high Peak discharge of over 100,000,000 m^3/sec	Angel Falls, Venezuela	Height 979 m, plunge of 807 m, flow 16990 m^3/sec	Victoria Falls, Zimbabwe; Niagara Falls, Canada and USA

Depositional setting	Ancient	Size km^2	Modern	Size km^2	Other noteworthy examples
PARALIC					
Estuary	McMurray Fm., Cretaceous, 300 km drainage from GOM	Minimum 21630 (from maps in Fustic et al 2020)	Gulf of St Lawrence, Canada, connecting Great Lakes to Atlantic	226,000 (also quoted as 1010095 in many texts)	Most estuaries formed by post glacial sea level rise. Chesapeake Bay 64,000 km^2
Mangroves	Mallorca, Miocene, arid, carbonate dominated	44	Sundarbans, coastal delta at Ganges, Brahmaputra confluence	10,000	Few ancient examples recognized
Delta	Boreal Ocean Delta, Barents Sea, Middle Triassic, passive margin of North Pangaea	1,650,000	Ganges, downstream from Himalayas, arcuate delta	105,000	Amazon does not have a delta due to tidal bore (some sources); Mekong 93,800 km^2; Mississippi Delta is a birdsfoot delta
Beach (longest)	Waterford Fm., Permian, South Africa, vast shallow Ecca Sea	>90 km long	Cadaley-Dhimbii, Somalia, large Mesozoic basins underlie coast	700 km long	Swakopmund second longest at 420 km; Praia do Cassino Beach, Brazil only 254 km; Book Cliffs (Cretaceous) may feature
MARINE					
Shoreface (longest)	Gog Group, Canada, Lower Cambrian, subsiding continental margin	2300 km long	Argentina/Uruguay Coast, passive margin	Max 2700 km, but thought to be broken up	
Reef	Kimberley Basin, Australia, Middle Devonian, fringing continent	17,500	Great Barrier Reef, Australia, made up of 2900 individual reefs	344,000	May well be bigger ancient reefs in Middle East
Barrier Island	Hoadley Gas Field, Alberta, in transgressive foreland basin, 7 Tcf gas	3885 (area of gas field only)	Fraser Island, Australia, on east coast, largest sand island in world	2706	Hoadley similar to Texel and other islands offshore Netherlands
Submarine canyon	Unnamed canyon, USA, Paleocene Wilcox Fm. Crossing Louisiana shelf	90 km long	NAMOC, Greenland, former spreading centre	3800 km long	Zhemchug Canyon is deepest at 2.6 km

Table 1. Details of the largest sedimentary features from modern and ancient settings. The largest identified feature in each category is highlighted in green.