Prediction of Paleo-Catchment Area Through Fluvial Morphology and Application of the Fulcrum Method: Festningen Member in Svalbard, Norway

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Abstract

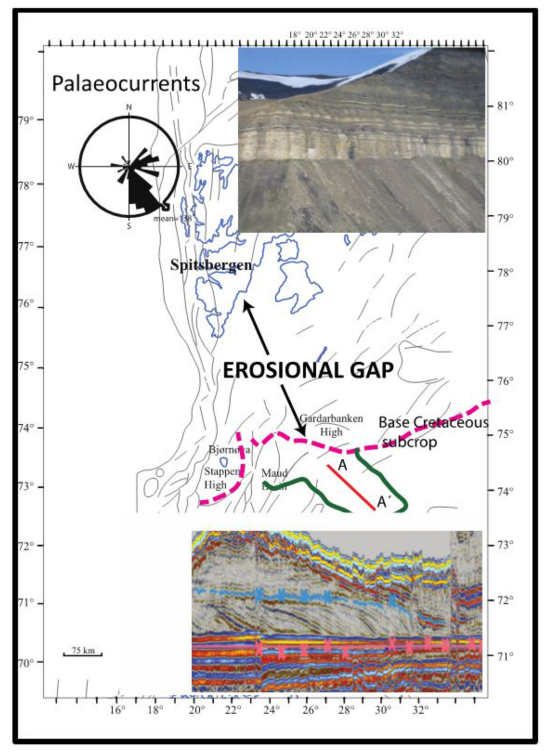
The depositional model of the Festningen Member of the Barremian Helvetiafjellet Formation is that fluvial to inner deltaic-plain conditions were established as deltas that built southeastward into the Barents Sea basin from an unknown source north-west of present-day Svalbard. Currently, models of Artic drainage provinces are nascent to non-existent. Here, evidence for a large artic drainage basin into the Cretaceous Barents Sea is suggested by using established scaling relationships and the fulcrum method in the Festningen Sandstone. Data from several locations in Svalbard: Konusdalen, Revneset, Criocerasaksla, and Hanaskogdalen. The Festningen Member sandstone sections were all initially photographed by drone in order to determine channel body dimensions and architecture in the sandstone as well as to record data for 3D photogrammetric construction of virtual outcrop models. Paleohydraulic estimates based on the fulcrum method use bankfull channel dimensions, specifically the height and width, and the D16, D50, D84, and D90 grainsizes to develop basin-process models and infer past catchment constraints. Festningen Member sandstone sections were logged and found to represent braided fluvial systems with mid-channel bars up to 3 m thick and channel-fills up to 4 m thick. Representative bedload samples were taken from approximately 10 cm above the base of channel scours for analysis and model input. The coarse grainsize and large clasts, frequently 3-4 cm and up to 15 cm in diameter, in the Festningen Member sandstone samples show that this was a large river capable of moving a coarse bedload. Scaling relationships equivalent to 4 m channels and coarse grained D-values is on the order of the modern Colorado River that flow through the southwestern United States . The Bjarmeland Platform and Fingerdjupet Subbasin in the western Barents Sea have a potential petroleum play in the Lower Cretaceous strata, which are, in part, considered to have been fed by the same Festningen fluvial system that is represented in cliff sections on Svalbard. Seismic profiles show clinoforms that may suggest deltaic facies, but remains unknown due to lack of well data. Seismic data shows that the Cretaceous Festningen fluvial system was able to deliver enough sediments onto the Bjarmeland Platform area to build clinoforms. The size of the source area sufficient to produce a trunk river on this scale remains unconstrained, but an area of 1 00,000 km^2 is necessary to produce the river found in the rock record, if the Fulcrum method is applied. Existing Arctic tectonic reconstructions do not consistently show a land area of sufficient size to accommodate this magnitude of drainage area, but results from this study may provide further input to the discussion on timing and land-mass configuration in the present day arctic during the Early Cretaceous.

Location

(Encyclopedia Britannica)

Known by it's Dutch name, Spitsburgen, meaning "jagged mountains" until 1925, Svalbard, Norway is an archipelago located in the Artic Ocean. North of mainland Europe, Svalbard marks the halfway point between mainland Norway and the North Pole. The land area of Svalbard is 61,022 square kilometers and contains glacial ice on approximately 60% of the island (Wikipedia). Repeated cycles of glacial weathering has produced large valley, fjords, and mountains that are ideal for geologic study.

Purpose



(Van Yperein, unpublished)

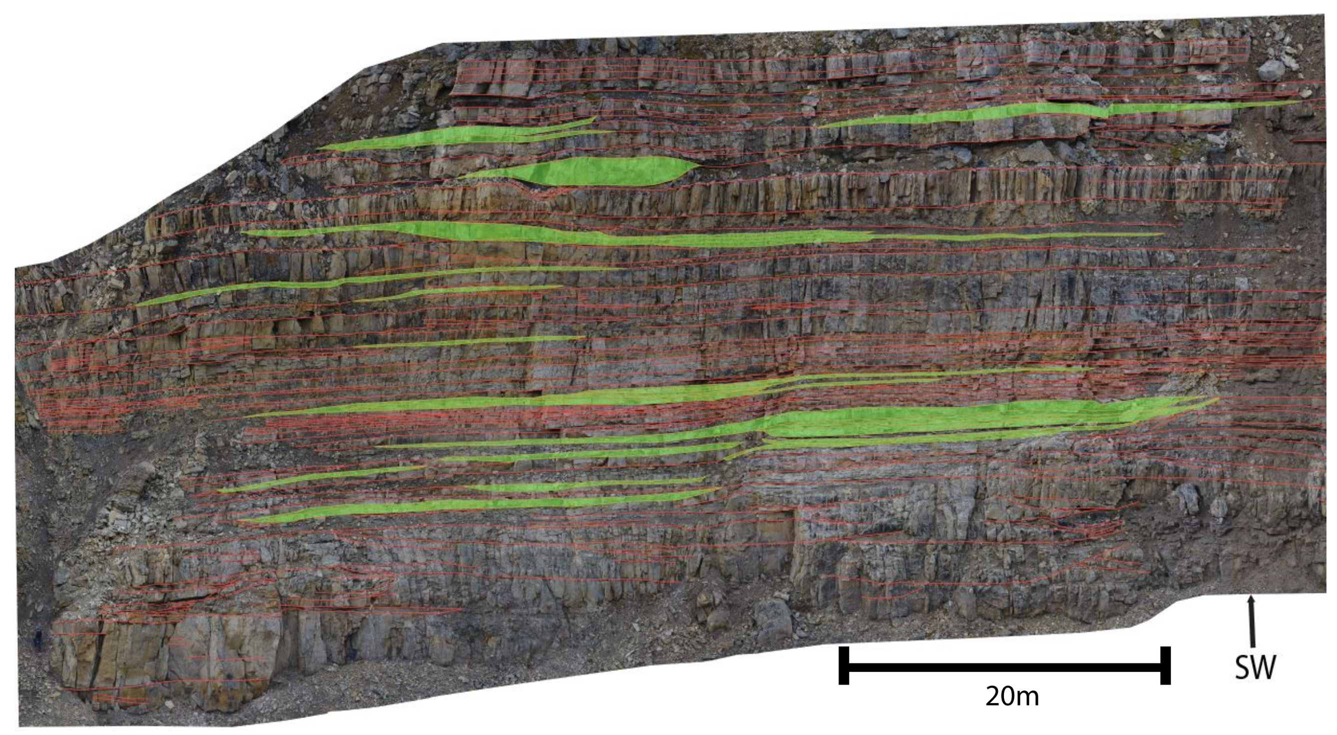
The Festningen Member is a potential oil and gas target in the Barents Sea. Little is known about the play except that clinoforms are seen in the seismic data that seem to resemble a prograding delta.

With a ~200km gap in the deltaic clinoforms and the preserved fluvial system, the quality of the reservoir is still highly speculative.

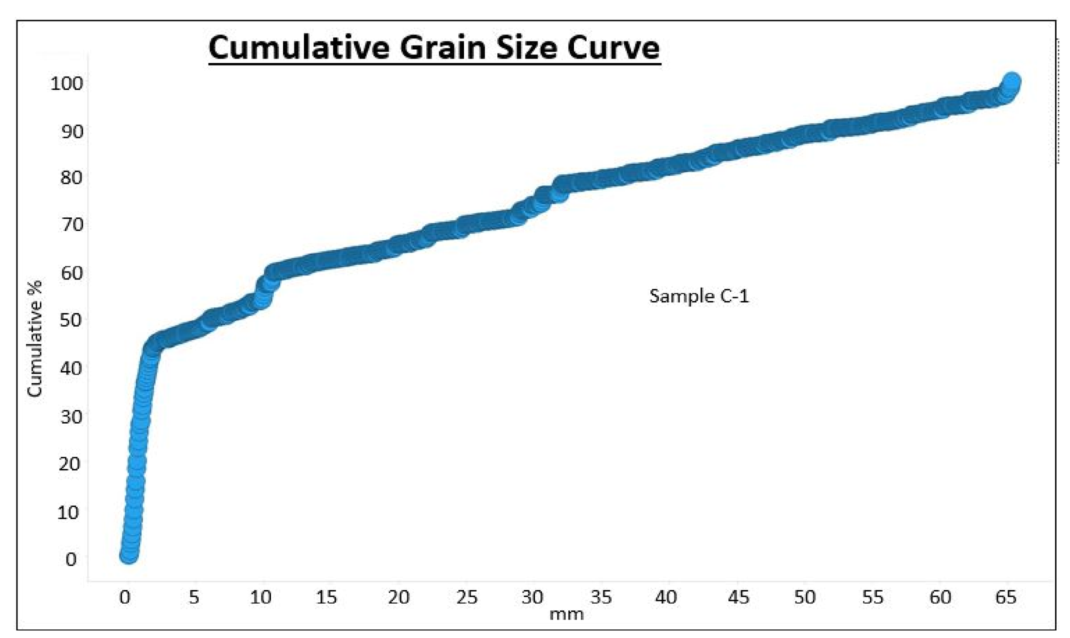
Collecting data on the fluvial system that fed the delta proves useful in defining the size and character of the river that fed the system.

Rock sample analysis and 3D modeling of the Festningen Sandstone are used to place constraints on the maximum and minimum size of the fluvial system thereby giving an estimate on the amount of discharge one would expect into the delta.

Methods



3D immagry was created by using drone photographs and Photoscanner software. Models were used to draw bounding surfaces (Miall, 1985) and determine bar heights and anbranching channel widths. Anabranching channels are seen here in cross-sectional view with a few being exposed obliquely. Agerage anabranch-channel width seen here is 22.5m.



Cumulative grain size curves were obtained by performing point counts on thin sections. Point counts were conducted according to the Gazzi-Dickinson method where at least 300 points were recorded per sample. Larger inclusions that were present in outcrop were integrated into the thin section point count data by visual weight percentage to create the final cumulative curve that is used for the fulcrum analysis.

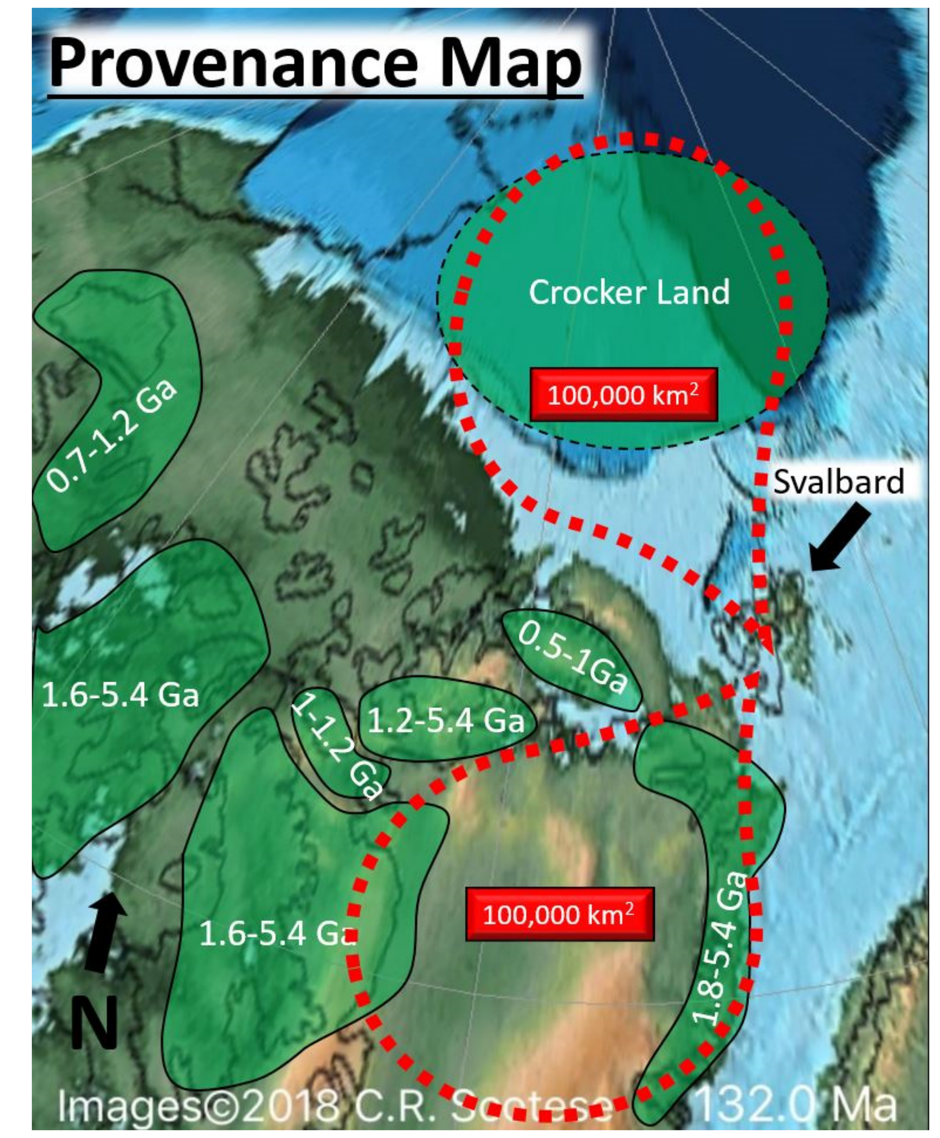
INPUTS

Channel Story name/number	Average Bankfull Channel Depth, H_{bf} (m)[also called d_m=0.5(channel story thickness)]	Bankfull Channel Width, B_{bf} (m) [measured or estimated]	Hydraulic Radius (m) [R=(channel x-sec. aera)/(channel wetted perimiter)=~d_m]	Grain Size from Cumulative Curve				Sediment Density (g/cm^3)	Year Averaged Bankfull Flow Duration, t_{bd} (days). [Assume t_{bd}=7.3 days as default]	Dimensionless Multiplier, b. [b=1/(bankful annual proportion); Assume b=2 as default]
				D_{16} (mm)	D_{50} (mm)	D_{84} (mm)	D_{90} (mm)			
C-1	2.5	1000	2.45	0.8	7	48	57	2.65	7.3	2

(Holbrook, 2014)

Measured sections give the average bankfull channel dimensions. The average channel height is 5m. Bankfull channel width is found by comparing channel height with previous works (Parker, 2007) and photomosaic. "D" values are attained by reading the cumulative grain size curve.

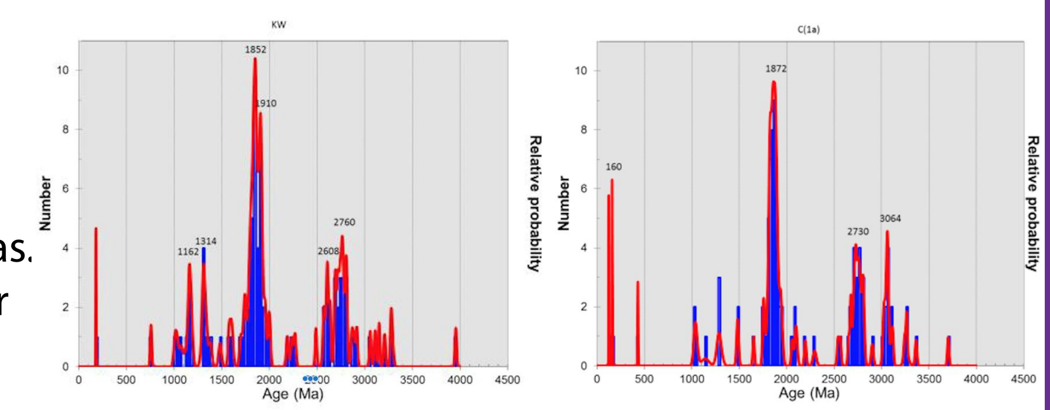
Results



(Scotese, 2018)

Bankfull channel discharge values for the Festningen fluvial system are approximately 14,000 m^3/s. This amount of bankfull discharge correlates to a drainage area of roughly 100,000 km^2 (Blum, 2016). The exact source for this system is still up for debate. Drawing a catchment area of 100,000km^2 on a paleo-reconstruction map and comparing it with zircon data from Svalbard we get the lower catchment area on image to the left. However, some (Embry, 2013) believe that Crocker Land could be a viable Artic sediment source during Cretaceous time.

Zircon data collected from Svalbard shows the largest spike at 1.8 Ga. The map above shows ages of modern rocks in green areas. These ages are the basis for the potential catchment area (red dotted line).



Discussion

The Festningen Sandstone in Svalbard preserves a large braided river system capable of moving large amounts of sediment. The catchment area for this system was most likley ~100,000km^2 which means 100's of kilometers of transport distance, however, the grains are mostly sub-angular which usually represents a short transport distance. It is possible that some of the river was glacially fed since Svalbard is well North of 60 degrees latitude during the Barremian and local orogenic events occuring at this time could have increased elevation thereby promoting glacial growth. If this is true, the catchment area for the fluvial system could have been much smaller and still produced the same amount of sediment.

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