DELFT UNIVERSITY OF TECHNOLOGY

Bachelor Thesis

Untangling Sea Level and Sediment Supply History of the Panther Tongue Delta, Utah, USA

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Abstract

The Panther Tongue is a fluvio-deltaic parasequence in the lower part of the Star Point Sandstone formation in the Wasatch Plateau, central Utah, deposited during the late Cretaceous period. The sedimentology of the Panther Tongue and adjacent beach ridges parasequence has been extensively described by Hwang & Heller (2002) and Hampson et al. (2011). This study aims to produce an estimate of the magnitude of the sediment supply and the sea level fluctuations at the time when the Panther Tongue delta was formed. First, two delta sections and a beach ridges section were constructed by interpreting and correlating available logs, using the Manti geological map (Witkind et al., 1987) and geological interpretations from Hwang & Heller (2002) and Hampson et al. (2011). Next, a numerical delta and beach ridges model '2DStratSim' in MATLAB was used to simulate the delta and beach ridges sections. Forward simulations with different sea level and sediment supply scenarios were run in order to determine a model that best fits the constructed delta and beach ridges sections. The input variables of the best matching simulation are the following. The relative sea level falls 28 meters over 80 000 years. The sea level decreases 4 meters over the first 40 000 years and 24 meters over the next 40 000 years. The average bed sediment load supply is 0,03 m^3/s. The average suspended sediment load supply is 0,04 m^3/s. The bed sediment load supply varies between 0,15 m^3/s and 0,005 m^3/s. The suspended sediment load supply varies between 0,1 m^3/s and 0,005 m^3/s. The total bed sediment volume was $1{,}92 \cdot 10^{11}$ m^3. The average suspended sediment load supply was 0,04 m^3/s. The total suspended sediment volume was $1{,}55 \cdot 10^{11}$ m^3/s.

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Introduction

The Panther Tongue is a fluvio-deltaic parasequence in the lower part of the Star Point Sandstone in the Wasatch Plateau, central Utah. Deposition of the Panther Tongue and laterally adjacent beach ridges to the south, defined as parasequence Ksp 040 by Hampson et al. (2011), took place during the late Cretaceous. It is considered an excellent analogue for a subsurface deltaic hydrocarbon reservoir. Studies have been made to describe the sedimentology of the Panther Tongue and parasequence Ksp 040 by Hwang & Heller (2002) and Hampson et al. (2011). However, no study has yet quantified the changes of sediment supply and sea level change during deposition of the Panther Tongue. According to Hwang & Heller (2002) 'the Panther Tongue consists of a coarsening-upward sandstone wedge that prograded into the Western Interior Seaway'. The top of the Panther Tongue is described as 'an apparently planar transgressive surface of erosion' (Hwang & Heller, 2002). Hampson et al. (2011) states that parasequence Ksp 040 contains a 'forced regressive architecture'.

In this study we aim to quantify the sediment accumulation and sea level changes in the Panther Tongue delta complex.

This is done by interpreting logs through delta sections and through a beach ridges section. The input variables of sediment supply and sea level change over time are determined by the use of profiles constructed with the logs, geological maps in ArcMap (part of ArcGIS from Esri) and a MATLAB model '2DStratSim'.

2DStratSim is a numerical model in MATLAB that simulates the deposition of a complete deltaic sedimentary system, including the beach ridges deposition (and erosion). The simulated stratigraphy and grain size trends from 2DStratSim are compared to the geologically and topographically constructed profiles, so the best matching simulation can be found. The grain sizes in the logs and the locations of the logs are the hard data that is available, so these variables are not altered to obtain a better fit with the models.

In the best matching simulation the sediment supply decreases gradually and after 40 000 years the supply decreases a lot. As the sediment supply decreases, also the sea level falls faster. After 80 000 years a sudden sea level rise occurs, along with an increase in suspended sediment supply.

Regional Geology

During the Cretaceous period the Western Interior Seaway, or Niobraran Sea, was created as a result of increased global volcanism causing global eustasy and subsidence related to the subduction of the Farallon plate under the North American plate (Kauffman & Caldwell, 1993). The Farallon plate subduction produced the Sevier orogenic belt that stretched from present Canada through western North America to Mexico. The subduction of the Farallon plate was at a shallow angle (less than 45°), which induced geodynamic processes that caused subsidence resulting in a back arc basin behind the Sevier orogenic belt (Mitrovica et al., 1989).This back arc basin developed into the Western Interior Seaway. It was a large inland sea between Laramidia, to the west, and Appalachia, to the east (see Figure 1). These two continents nowadays form the continent of North America. The Star Point Sandstone formation was deposited during the upper Cretaceous period (late Santonian to early Campanian age [Fouch et al., 1983]), on the western side of the Western Interior Seaway, at the Wasatch Range, nowadays central Utah. The Wasatch Range is a mountain range that stretches approximately 260 km from the border between Utah and Idaho, south through central Utah in the western United States. The Wasatch mountain range was created as part of the Sevier orogenic belt. The Star Point Sandstone lies on top of – and laterally interfingers – the marine Mancos Shale deposits and is overlain by the Blackhawk formation (Hampson et al., 2011), also see Figure 2. According to Hampson et al. (2011), the Star Point Sandstone was deposited in a 'flexurally subsiding foredeep'. The Panther Tongue parasequence is located in the lower part of the Star Point Sandstone formation and contains fluvio-deltaic deposits (Hwang & Heller, 2002). It is a coarsening upward parasequence, deposited in a southward-prograding, fluvial-dominated deltaic environment during a single fall in relative sea level (Hwang & Heller, 2002). The top of the Panther Tongue consists of a transgressive erosion surface (Hwang & Heller, 2002). Hampson et al. (2011) argued that the lateral continuation of the Panther Tongue parasequence to the south along the beach ridges (parasequence Ksp 040) contains a 'forced regressive architecture'. Forced regression refers to the process of seaward migration of a shoreline in direct response to relative sea-level fall (Posamentier & Morris, 2000). Hampson et al. (2011) divides parasequence Ksp 040 into different facies: 'coastal plains', 'foreshore', 'upper shore face', 'proximal lower shore face', 'distal lower shore face', 'distal delta' and 'proximal delta' (see Figure 3). From Figure 3 can be seen that the delta prograded towards the south and southeast. The beach ridges prograded towards the east and northeast.

Figure 1, The Western Interior Seaway (Sampson et al., 2010). The Western Interior Seaway, a result of global eustasy and local subsidence, arose between Laramidia and Appalachia, approximately 76 million years ago. The present day study area is marked.

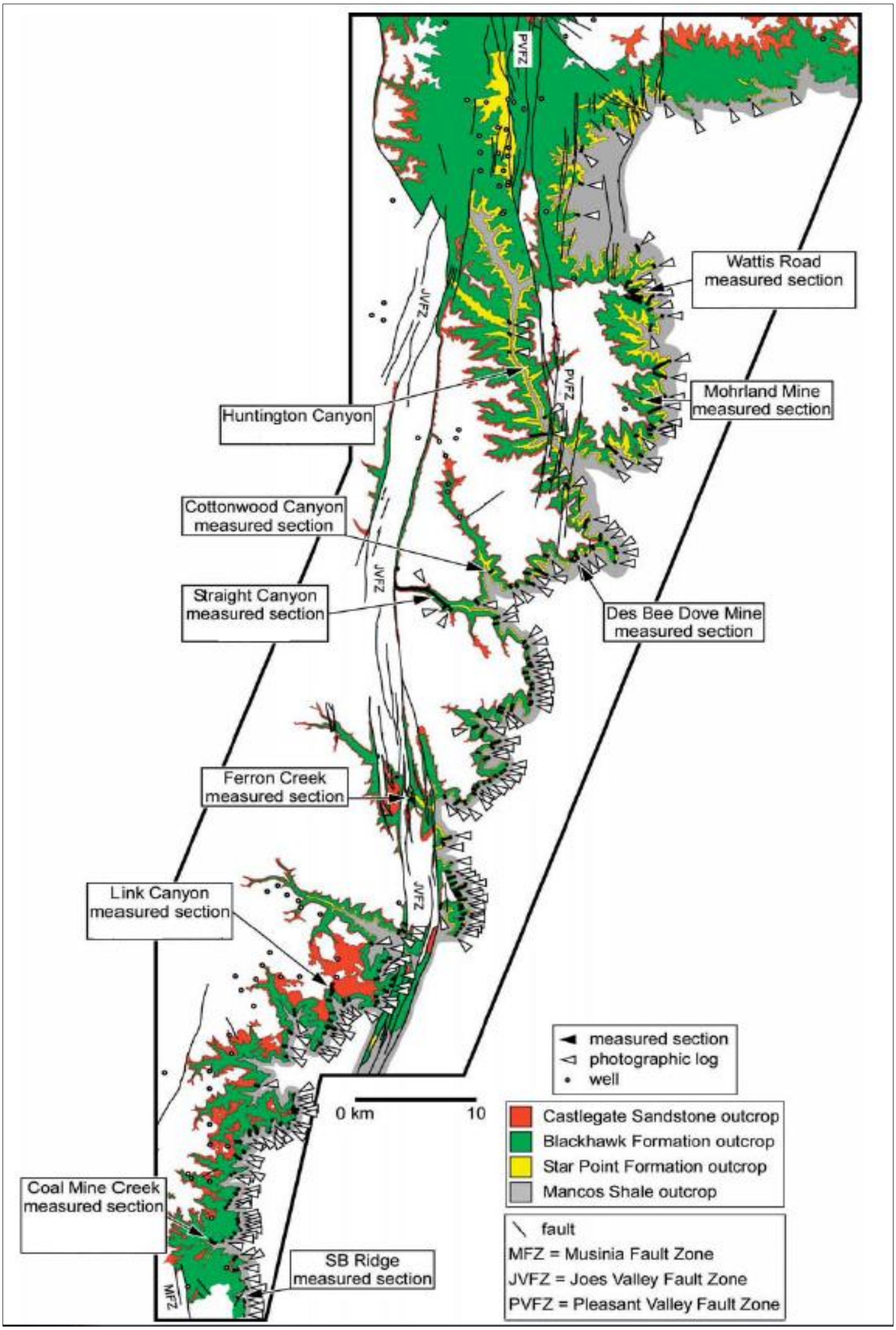


Figure 2, Geologic map of eastern Wasatch Plateau, after Hampson et al. (2011) and Witkind et al. (1987). Formation outcrops and the names of measured sections are presented.

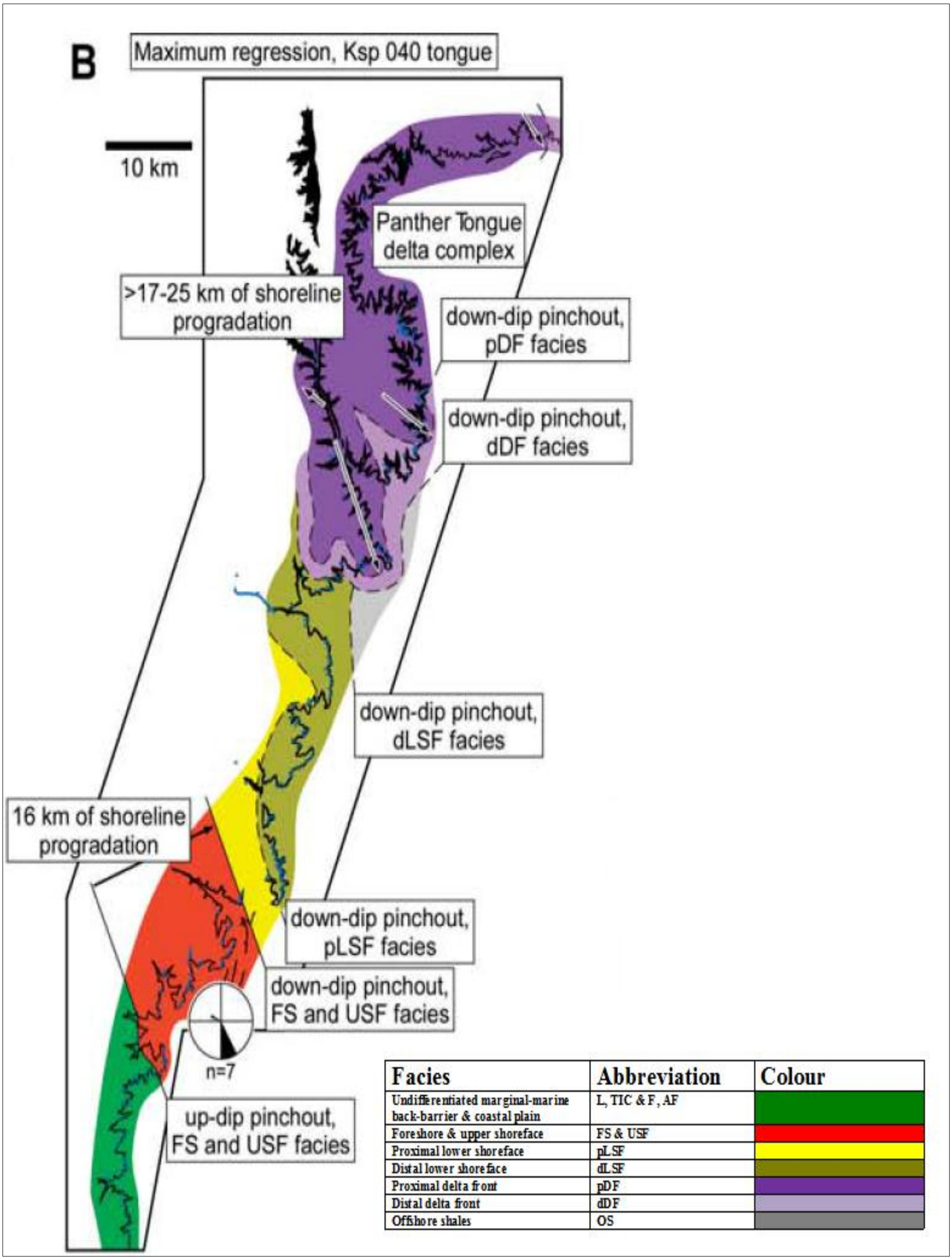


Figure 3, Geological interpretation of parasequence Ksp 40 from Hampson et al. (2011). Facies from coastal plain to offshore shales, including the delta facies, are presented at maximum regression. The Panther Tongue delta is represented by purple colours in the north. The arrows represent the delta progradation directions of two different delta lobes. The red and yellow colours represent the beach ridges area. The green colour represents the coastal plains.

Method

Cross-sections were constructed through available logs in the regions that were interpreted as the delta area by Hampson et al. (2011) and Hwang & Heller (2002). Also, a beach ridges section was constructed through the beach ridges area interpreted by Hampson et al. (2011). The geological interpretation of Hampson et al. (2011) can be found in Figure 3.

Two different delta sections were constructed through the delta region by correlating sedimentary logs and estimating the topographic altitude of the Panther Tongue in the Star Point Sandstone on the Manti geological map (Witkind et al., 1987). The closest approximation of the topographic altitude of the Panther Tongue parasequence is made by estimating the altitude of the lower part of the Star Point Sandstone in the Manti geological map, as the Panther Tongue is considered by Hwang & Heller (2002) to be located in this lower part of the Star Point Sandstone. Further, a beach ridges section is constructed by interpreting available logs through parasequence Ksp 040 (the lateral continuation of the Panther Tongue parasequence to the south).

The procedure used to construct the profiles was the correlation of logs based on grain size. Also the correlations found by Hwang & Heller (2002), such as the transgressive lag at the top of the Panther Tongue parasequence, and Hampson et al. (2011), such as the correlation based on different facies, were taken into account. The available logs were firstly digitalized, based on images. The topographic altitude of the logs was estimated using the Manti geological map and corresponding altitude map in ArcMap.

The sections and logs are simulated by a model in MATLAB called '2DStratSim'. The modelled logs are matched and compared to the observed logs. 2DStratSim is a numerical model simulating sedimentation and erosion in a fluvio-deltaic and beach ridges environment. It is an automated forward modelling of a complete sedimentary system. 2DStratSim is a combination of a delta model 'DeltaSim' and a beach ridges model 'BarSim'. The delta shelf and the shore face shelf are taken into account. There is a floodplain module available but this was not used in this investigation. The delta and shoreface shelfs are the main deposition areas (in reality and also in the 2DStratSim model). The shore face is a wave dominated area where the longshore current has effect on the amount of sediment transported to the beach ridges (also in reality and in the 2DStratSim model).

The 2DStratSim model requires certain input variables concerning sediment supply and relative sea level change. The main input variables were the following:

- Bed load supply
- Suspended load supply
- Sand ratio (determines the ratio between a coarse grain size fraction and a fine grain size fraction in the bed load)
- Sea level change
- Delta slope (delta gradient)
- Bar slope (beach ridges gradient)
- Bar width (distance between delta and beach ridges profiles)
- Bar transport (effectiveness of longshore current)

The input variables that produced the best matching model with the constructed delta and beach ridges sections give an idea of the total and average sediment supply and sea level fluctuations during the deposition of the Panther Tongue delta complex.

The different grain sizes in the digitalized logs and cross sections in this report, as well as the colours in modelled logs, are represented by the colour scale in Table 1, which is based on the Wentworth grain size classification (Wentworth, 1922).

Table 1, Grain Size Scale (Wentworth, 1922). The scale presents the median diameter lengths of grains and a corresponding colour scale. The colours in logs and sections as well as the colours in modelled logs in this report coincide with this colour scale.

Category	Median grain size (µm)	Colour scale
Coarse	500	
Medium	250	
Fine	125	
Very fine	62	
Silt	12	

Profile Locations

Delta Sections

The locations chosen for the Delta sections are based on information from Hwang & Heller (2002), on the geologic interpretation of Hampson et al. (2011) and on the available geological maps (Witkind et al., 1987). Also the availability and interval length of logs is taken into account.

Available measured sections from Hwang & Heller (2002) can be found at Huntington Creek and Cottonwood Creek (see Figure 4). 'HC' stands for Huntington Creek; the logs are taken at the Huntington Creek area. Similarly, 'C' stands for Cottonwood Creek. All the measured sections at Huntington Creek and Cottonwood Creek partly or totally cover the Panther Tongue parasequence. The Huntington Creek and Cottonwood Creek logs are described by Hwang & Heller to contain a coarsening upward sequence and a transgressive lag on top of that.

In Figure 5 the evolution of the Panther Tongue delta in relation to sea level change can be found, as interpreted by Hwang & Heller (2002).

Based on figures 5a and 5b a cross section along logs HC 1, HC4, HC 6 and HC 7 is chosen, because the progradation direction of the first delta lobe is towards the southeast from log HC 1 to log HC 7 as interpreted by Hwang & Heller (2002). Logs HC 2, HC 3 and HC 5 are discarded because these logs cover a limited interval, are incomplete and contain little information. So Delta Profile 1 has a northwest to southeast orientation.

However, if we consider Figure 5c and the interpretation of Hampson et al. (2011) of delta progradation in Figure 3, a cross section across HC 1, HC 4 and C 3 also proves meaningful. The progradation direction of the second delta lobe in Figure 5c as well as in Figure 3 is mainly to the south. So Delta Profile 2 has a north to south orientation.

In Figure 5d a transgressive period is shown. This coincides with the transgressive lag found in logs HC 1, HC 4 and HC 7.

The north-western start of the delta profiles is chosen 2,7 km to the northwest of log HC 1. This is done in order to make a better comparison with 2DStratSim models.

Beach Ridges Section

The beach ridges section is chosen across available and complete logs that include parasequence Ksp 040. Parasequence Ksp 040 is the lateral continuation of the Panther Tongue parasequence to the south (see Figure 3). The logs at Link Canyon, Ferron Creek and Straight Canyon include Ksp 40 (see Figure 2 for locations of the logs). The three logs are each characterized by a different shallow-marine facies as considered by Hampson et al. (2011): upper shoreface, proximal lower shoreface and distal lower shoreface (again see Figure 3). The beach ridges progradation direction is to the northeast (see Figure 3). The beach ridges were formed at the same time as the delta so the beach ridges section ends at the beginning of the distal lower shoreface. The Beach Ridges Profile is oriented from south-southwest to north, so the progradation direction is only partially matched. Unfortunately the limited availability of logs restricts the possible beach ridges profile locations.

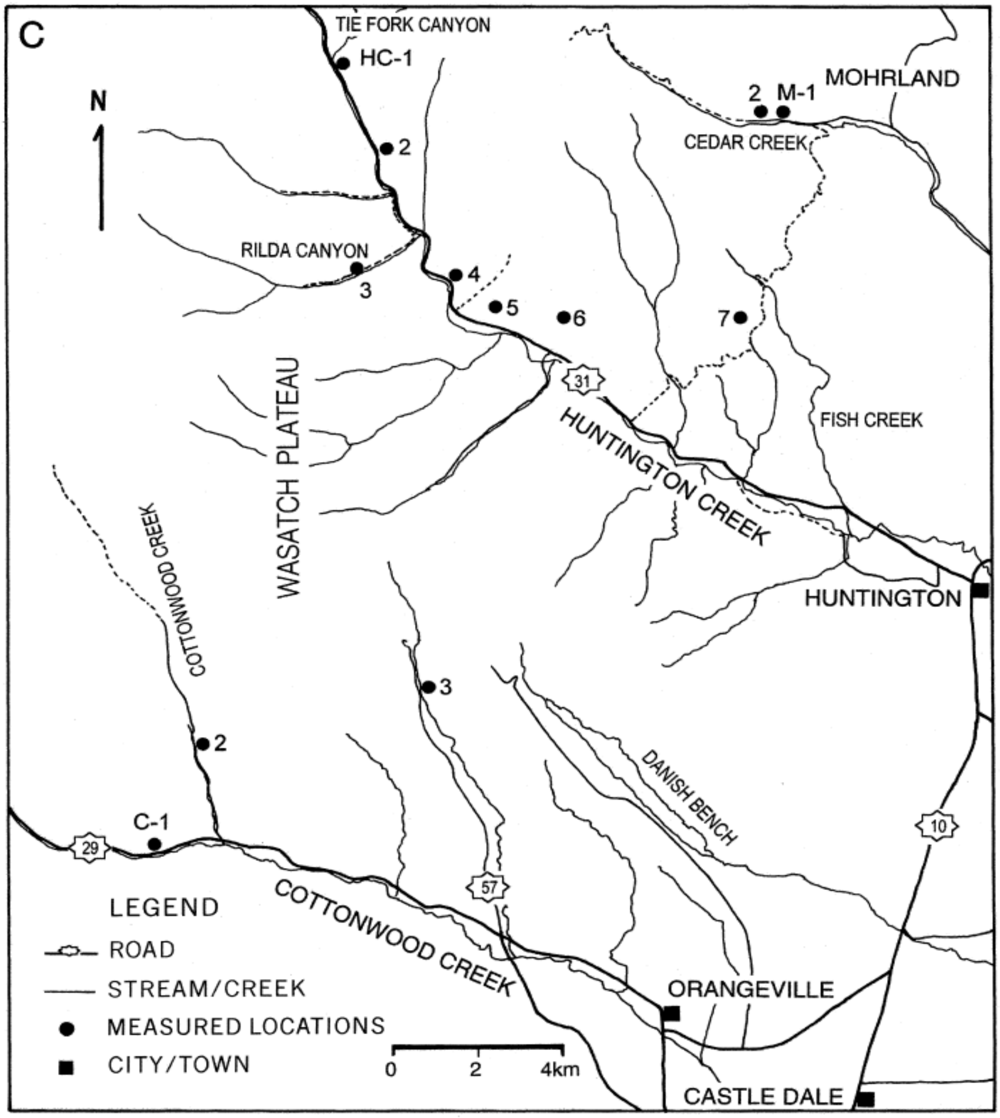


Figure 4, Location map of delta logs and place names in central Utah (Hwang & Heller, 2002). The numbers represent the logs. 'HC' stands for Huntington Creek and 'C' stands for Cottonwood Creek. The Mohrland logs are not taken into account in this study.

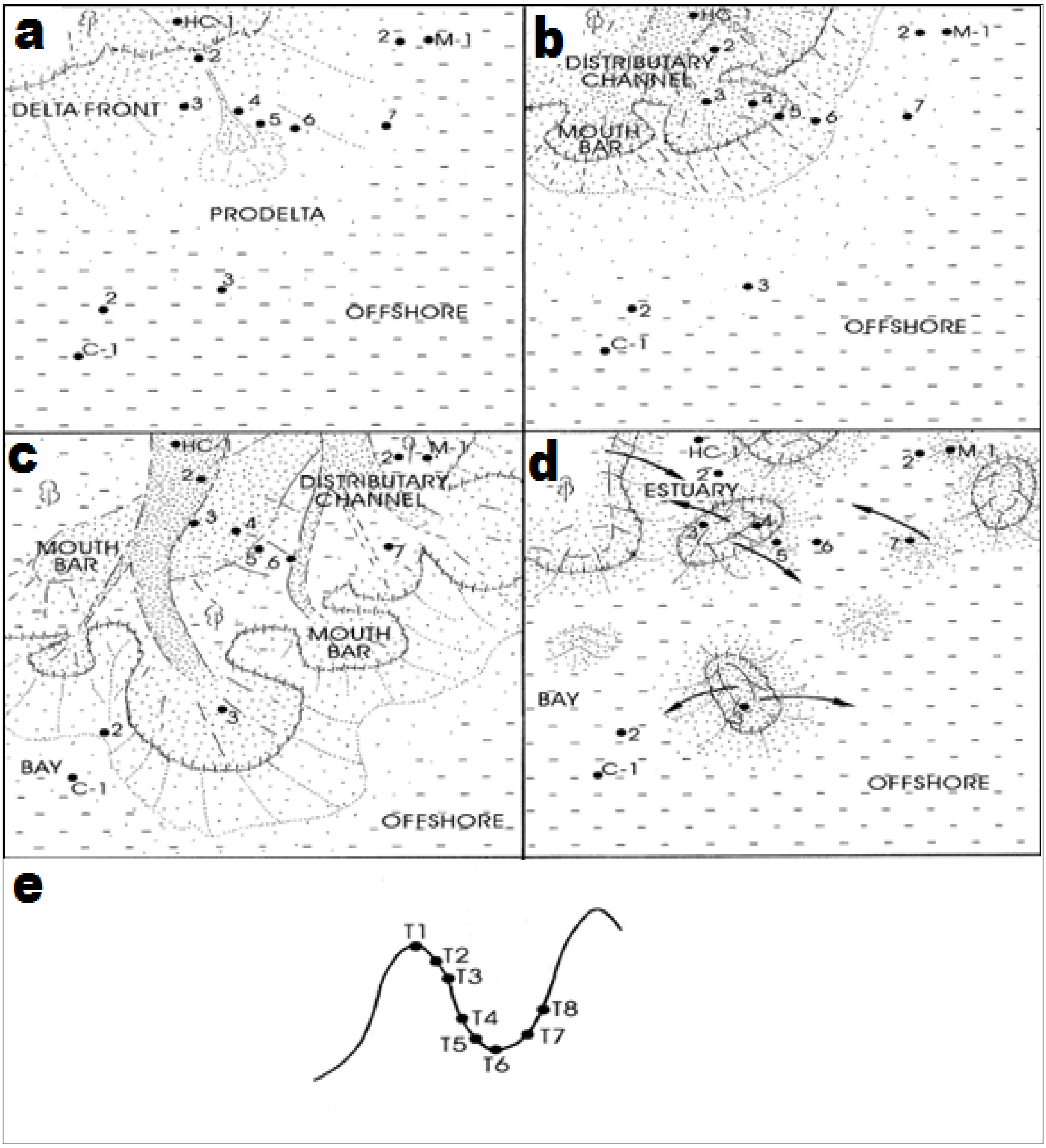


Figure 5, Evolution of the Panther Tongue delta in relation to sea level change, based on Hwang & Heller (2002). Figures a and b represent delta progradation during forced regression. Figure c represents delta progradation during lowstand. Figure d represents a stage of transgression. The numbers in figures a, b, c and d refer to logs. The 'HC' logs are taken at Huntington Creek and 'C' stands for Cottonwood Creek. The relative sea level is presented by the curve in Figure 3e. Figures a, b, c and d correspond with times T4, T5, T6 and T7, respectively.

Results

Delta Profile 1

The first delta section is located along logs HC 1, HC 4, HC 6 and HC 7 (see Figure 6). The digitalized logs are visualized in Figure 7. The length of the profile is 19 km. The topographic altitude of the top of the Panther Tongue parasequence in the profile has been topographically extended along the Star Point formation. The profile ends just after log HC 7. There are no further logs available to the east so the profile is not extended any further. The locations of the logs are presented in Table 2. The positions and corresponding topographic altitudes of the logs along the profile are determined by ArcMap. The estimated altitudes of the logs are presented in Table 3.

Based on the information from Figure 6, Figure 7, Table 2 and Table 3 the cross section presented in Figure 8 was constructed. The top end of the Panther Tongue parasequence is the top of the red sequence. The coarse grained (red) sequence shows a pinchout to the east. The overall sequence gets thinner to the east. The bottom of the parasequence is not clearly defined, because the logs do not cover the complete Panther Tongue parasequence, as the material gets finer grained.

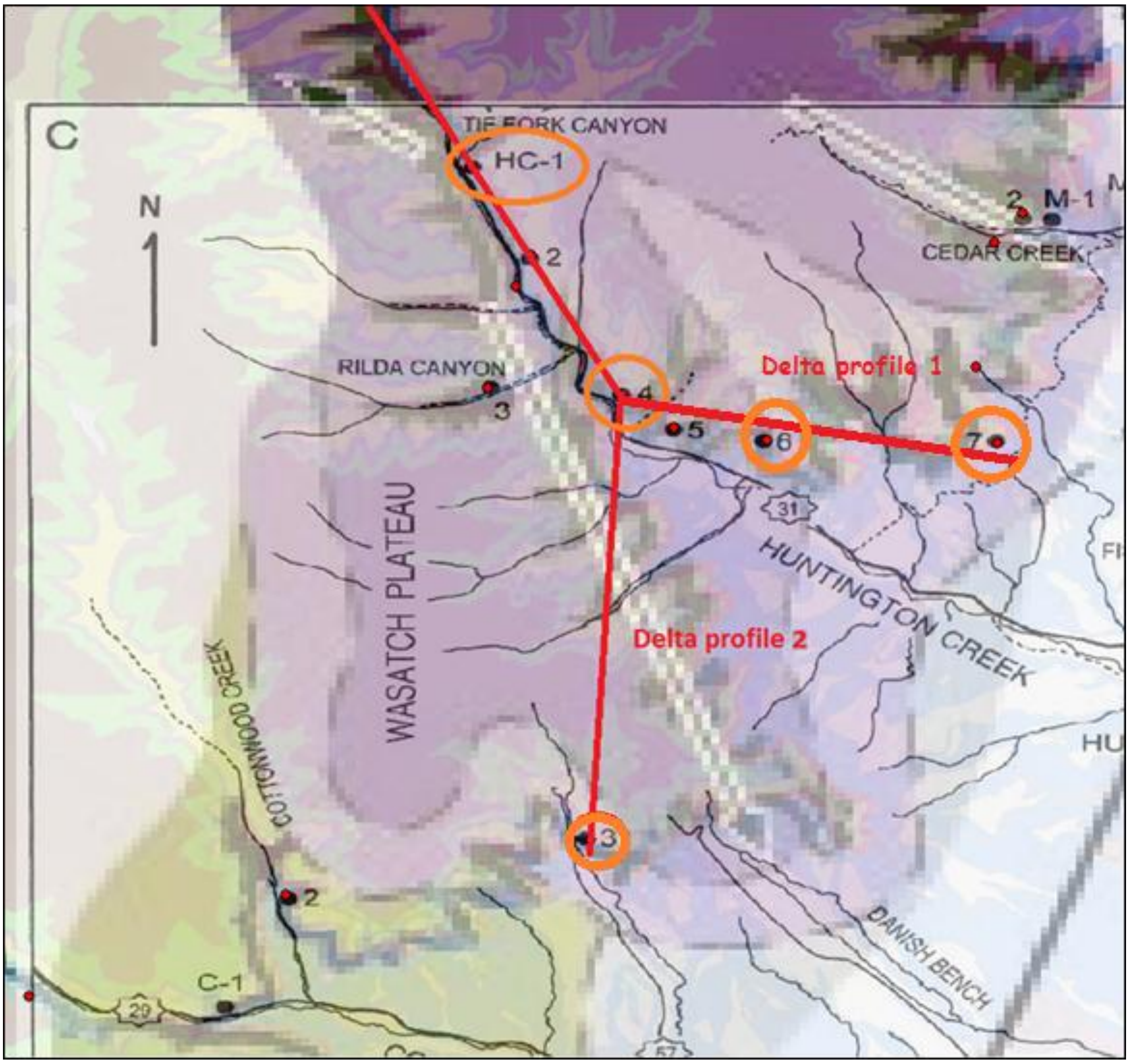
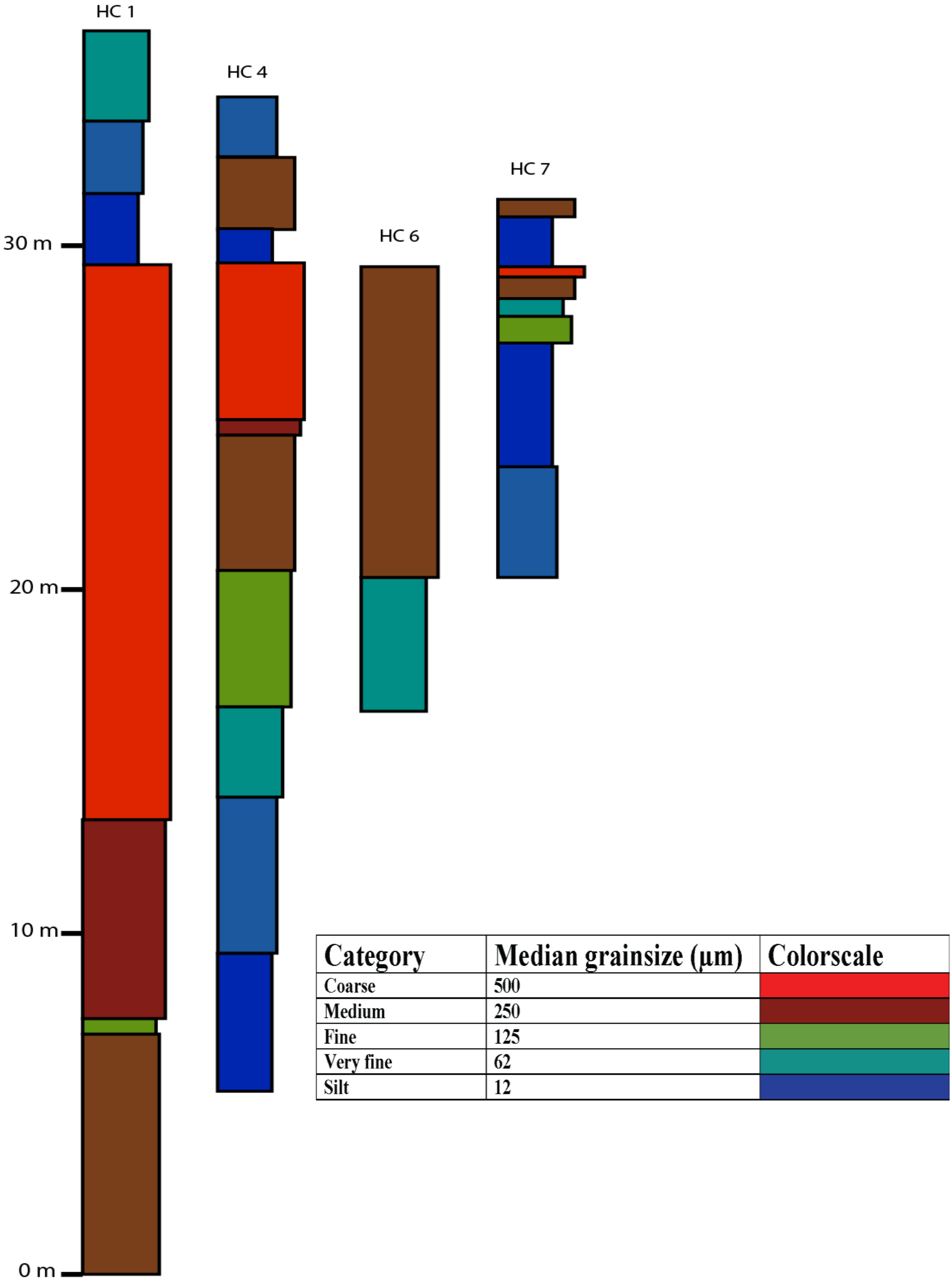


Figure 6, Location of Delta Profiles 1 and 2. The geological interpretation from Hampson et al. (2011) represented by the coloured map (Figure 3) is placed on top of the map with measured sections from Hwang & Heller (2002) (Figure 4). Locations of logs in the profiles are circled.



Category	Median grainsize (µm)	Colorscale
Coarse	500	
Medium	250	
Fine	125	
Very fine	62	
Silt	12	

Figure 7, Digitalized logs HC 1, HC 4, HC 6 and HC 7. Logs HC 4, HC 6 and HC 7 have the same vertical scale as log HC 1. The transgressive lag which is considered by Hwang & Heller (2002) to be the top end of the Panther Tongue parasequence is found at approximately 30 meters from the bottom of log HC 1. The top ends of the Panther Tongue parasequence in logs HC 4, HC 6 and HC 7 are placed horizontally next to each other (at the same height) in the figure. In reality the topographic altitudes of the top of the Panther Tongue parasequence differ depending on the location of the log (see Table 3). The bottom of the Panther Tongue parasequence is not clearly defined in the logs (the Panther Tongue may be larger than the length of the logs)

Table 2, Position of Logs measured from north-western Start of Delta Profile 1, in kilometres.

HC 1	2,7 km
HC 4	8,6 km
HC 6	11,5 km
HC 7	15,6 km

Table 3, Topographic altitude of Lower part of Star Point Formation in Logs HC 1, HC 4, HC 6 and HC 7. The altitude is measured in meters above present day sea level.

HC 1	1250 m – 1350 m
HC 4	1140 m – 1240 m
HC 6	1130 m – 1200 m
HC 7	1120 m – 1220 m

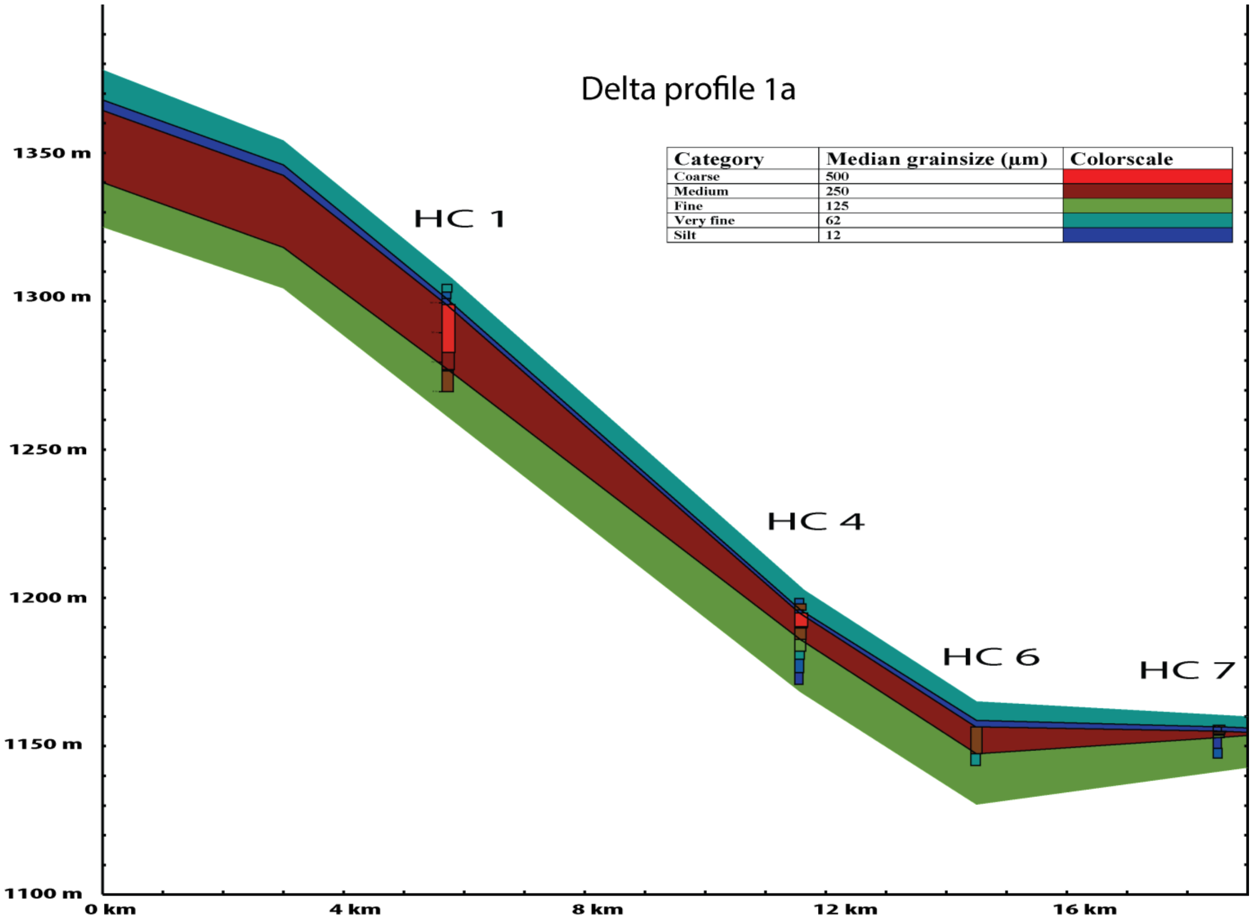


Figure 8, Delta Profile 1a. Vertical scale is the height in meters above present day sea level. Horizontal scale is the distance in kilometres from north-western start of profile (see Figure 6). The profile is oriented from northwest to southeast. The top end of the Panther Tongue parasequence is the top of the red sequence. The bottom of the parasequence is not clearly defined.

To make the best approximation of the delta section during the Cretaceous period, before tectonics, the gradient between logs HC 1, HC 4 and HC 6 is extrapolated to log 7 (see Figure 9). For reasons for this alteration see the chapter 'Discussion'.

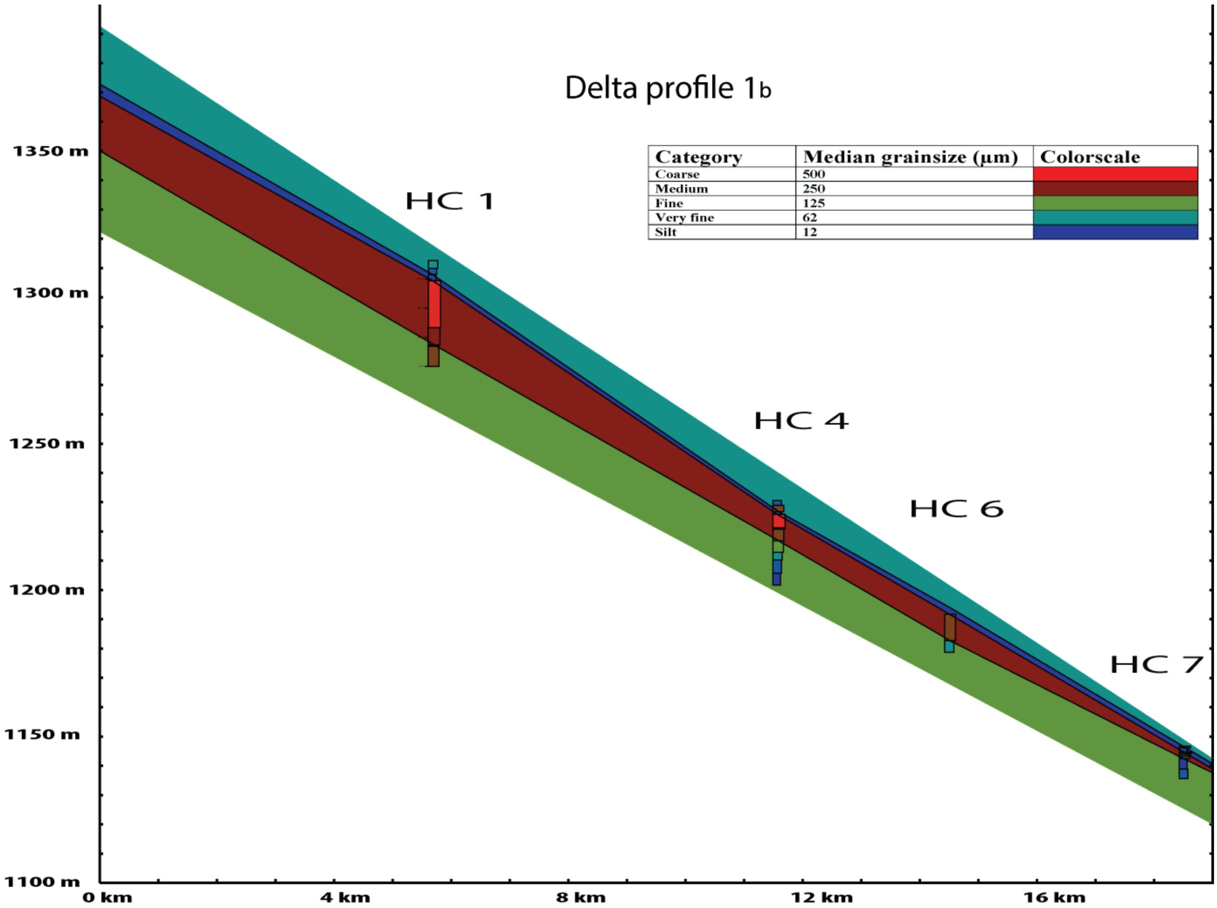
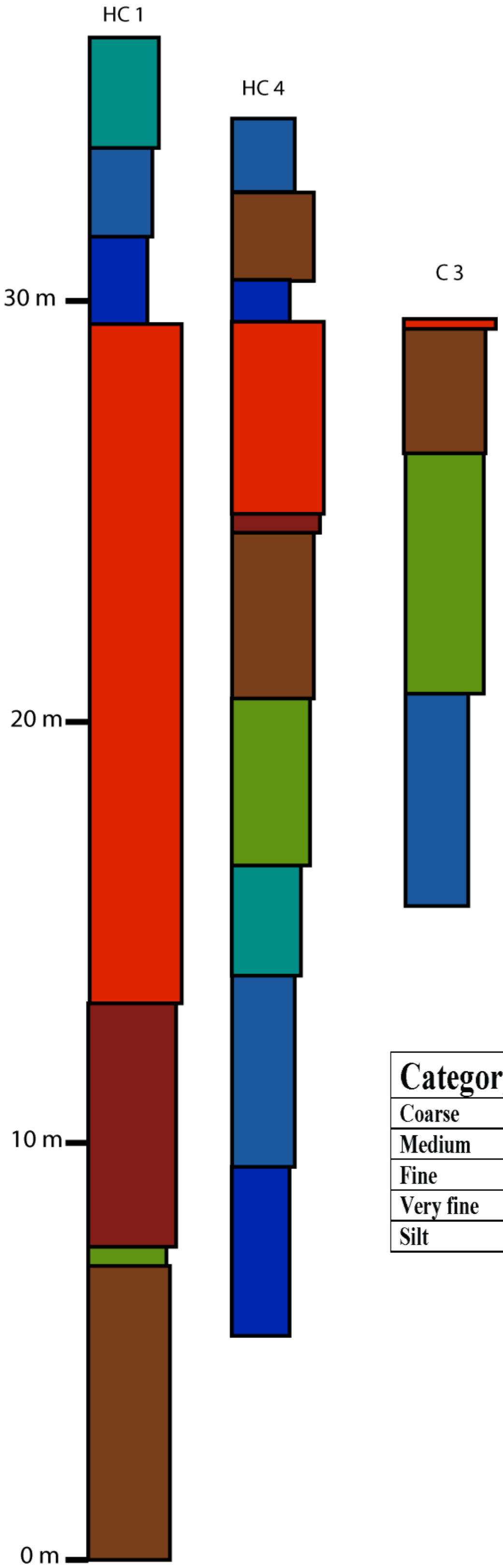


Figure 9, Delta Profile 1b. Vertical scale is the height in meters above present day sea level. Horizontal scale is the distance in kilometres from north-western start of profile (see Figure 6). The profile is oriented from northwest to southeast. The top end of the Panther Tongue parasequence is the top of the red sequence. The bottom of the parasequence is not clearly defined. A constant gradient has been determined which does not coincide with current topography.

Delta Profile 2

The second delta section is chosen along logs HC 1, HC 4 and C 3. The location of Delta Profile 2 is also presented in Figure 6. The length of the profile is 23 km. Log HC 2 is discarded because it contains little information. The locations of the logs are presented in Table 4. The corresponding topographic altitudes are estimated as described before and presented in Table 5. The digitalized logs are presented in Figure 10 and the constructed cross section is presented in Figure 11. The cross section is very similar to Delta Profile 1 and requires the same explanation.

Similarly to Delta Profile 1 the gradient between logs HC 1 and HC 4 is extrapolated to log C 3. This profile is presented in Figure 12. The gradient of profile 3b is approximately 0,0106 m / m.



Category	Median grainsize (µm)	Colorscale
Coarse	500	
Medium	250	
Fine	125	
Very fine	62	
Silt	12	

Figure 10, Digitalized Logs HC 1, HC 4 and C 3. Logs HC 4 and C 3 have the same vertical scale as log HC 1. The transgressive lag which is considered by Hwang & Heller (2002) to be the top end of the Panther Tongue parasequence is found at approximately 30 meters from the bottom of log HC 1. The top ends of the Panther Tongue parasequence in logs HC 4 and C 3 are placed horizontally next to each other (at the same height) in the figure. In reality the topographic altitudes of the top of the Panther Tongue parasequence differ depending on the location of the log (see Table 5). The bottom of the Panther Tongue parasequence is not clearly defined in the logs (the Panther Tongue may be larger than the length of the logs).

Table 4, Position of Logs from North-western Start of Delta Profile 2

HC 1	6,4 km
HC 4	12,3 km
C 3	22,7 km

Table 5, Topographic altitude of Lower part of Star Point Formation in Logs HC 1, HC 4 and C 3

HC 1	1250 m – 1350 m
HC 4	1140 m – 1240 m
C 3	1170 m – 1250 m

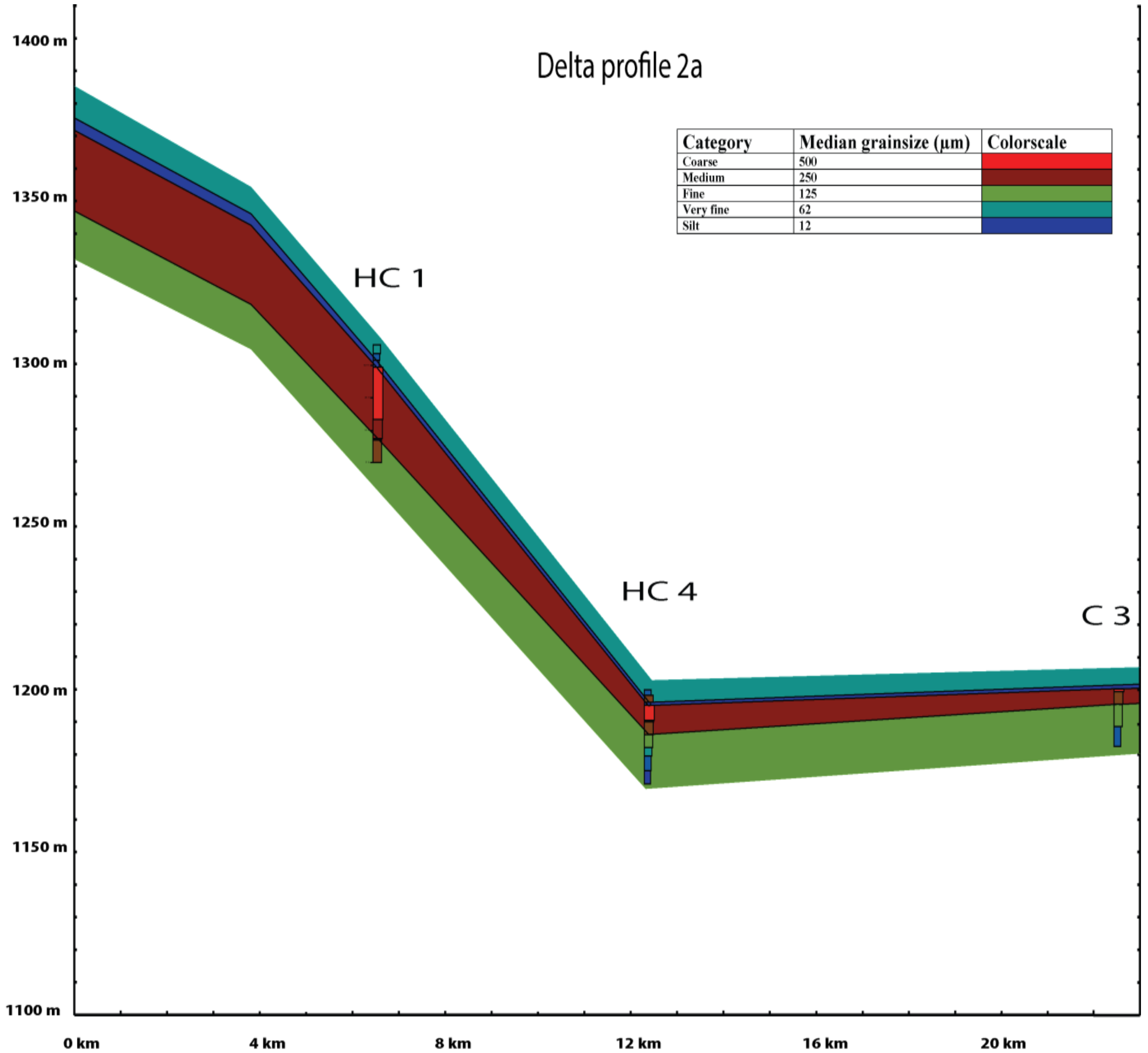


Figure 11, Delta Profile 2a. Vertical scale is the height in meters above present day sea level. Horizontal scale is the distance in kilometres from northern start of profile (see Figure 6). The profile is oriented from north to south. The top end of the Panther Tongue parasequence is the top of the red sequence. The bottom of the parasequence is not clearly defined.

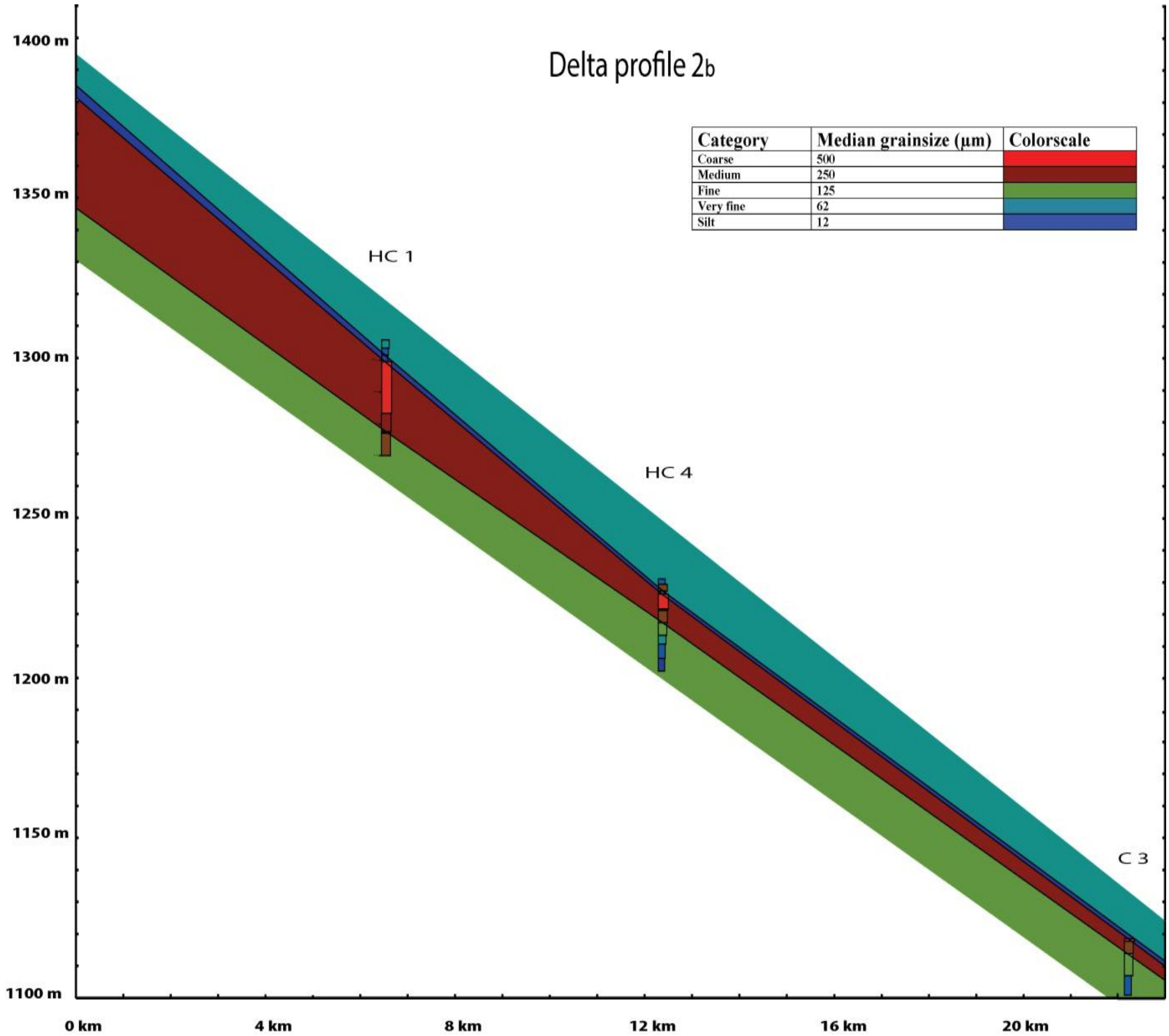


Figure 12, Delta Profile 2b. Vertical scale is the height in meters above present day sea level. Horizontal scale is the distance in kilometres from northern start of profile (see Figure 6). The profile is oriented from north to south. The top end of the Panther Tongue parasequence is the top of the red sequence. The bottom of the parasequence is not clearly defined. A constant gradient has been determined which does not coincide with current topography.

Beach Ridges Profile

The logs at Link Canyon, Ferron Creek and Straight Canyon are presented in Figure 13. The different facies defined by Hampson et al. (2011) are also presented in Figure 13.

The location of the beach ridges profile is presented in Figure 14. The progradation direction as interpreted by Hampson et al. (2011) is partially matched. However, more importantly the locations of the available logs determine the location of the profile. The length of the profile is 40 km. The locations of the logs are presented in Table 6. The corresponding topographic altitudes are estimated as described before and presented in Table 7. Similarly to the delta profiles, a beach ridges profile with a constant gradient is constructed (see Figure 15). The gradient of this profile is approximately 0,00825 m / m.

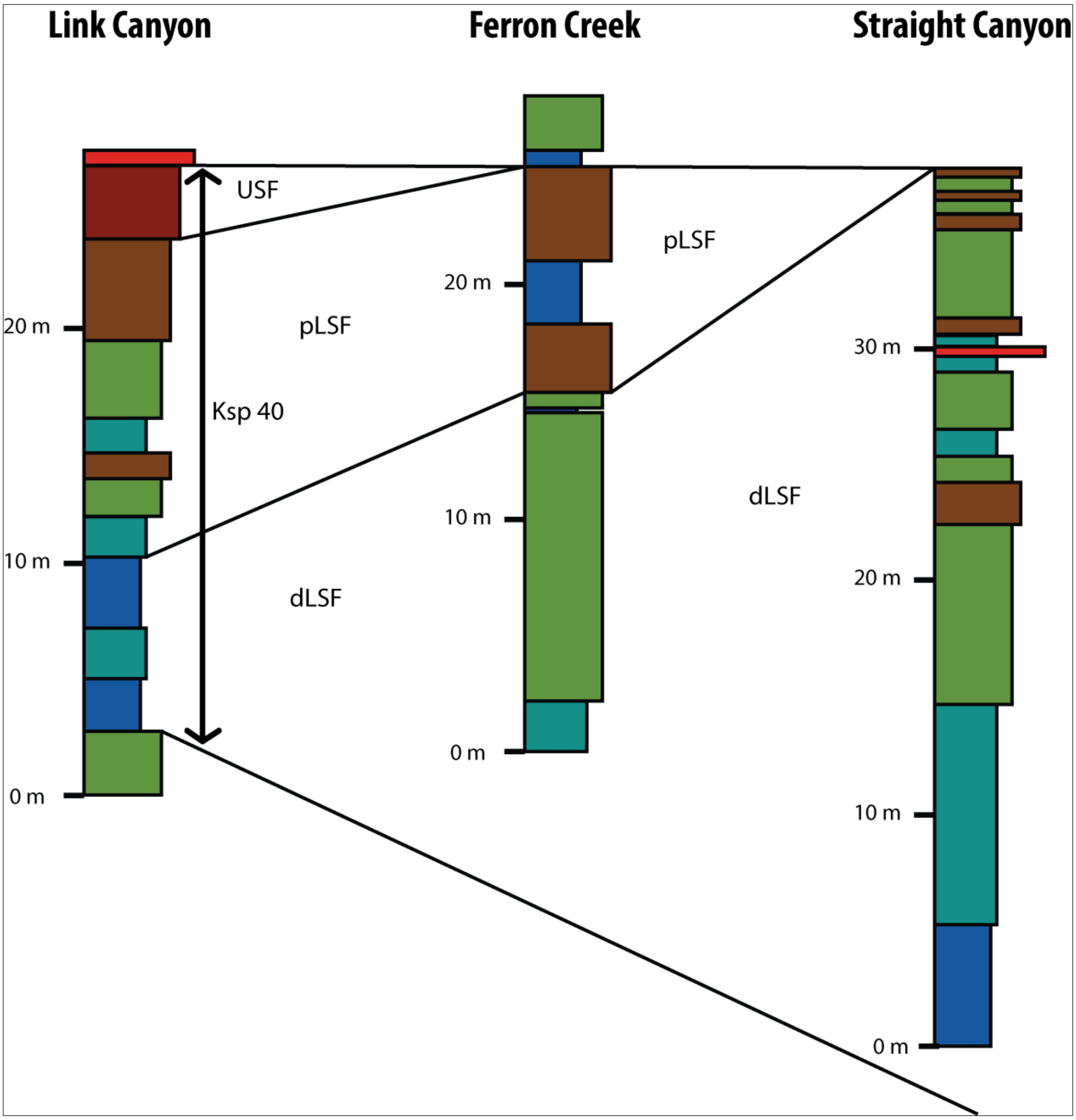


Figure 13, Digitalized Logs Beach Ridges. the logs are placed horizontally next to each other along what is considered to be the top end of the Ksp 40 parasequence by Hampson et al. The vertical scale is exact. The horizontal scale is not. 'USF', 'pLSF' and 'dLSF' respectively stand for the 'Upper Shore Face', 'proximal Lower Shore Face' and 'distal Lower Shore Face' facies as defined by Hampson et al. (2011). The different facies pinch out towards the right in the figure (towards the northeast in reality).

Figure 15 only presents parasequence Ksp 040 as defined by Hampson et al. (2011). It can be identified that the coarse grained (red) sequence shows a pinchout to the north-east. The red sequence is matched to the upper shore face facies. The green sequence is matched to the proximal lower shore face facies and the turquoise sequence is matched to the distal lower shore face facies. The overall sequence gets slightly thicker to the northeast. At Link Canyon the top and bottom of parasequence Ksp 040 is defined. The bottom of the parasequence is not clearly defined at Ferron Creek and Straight Canyon, because the logs do not cover the complete parasequence Ksp 040, as the material gets finer grained.

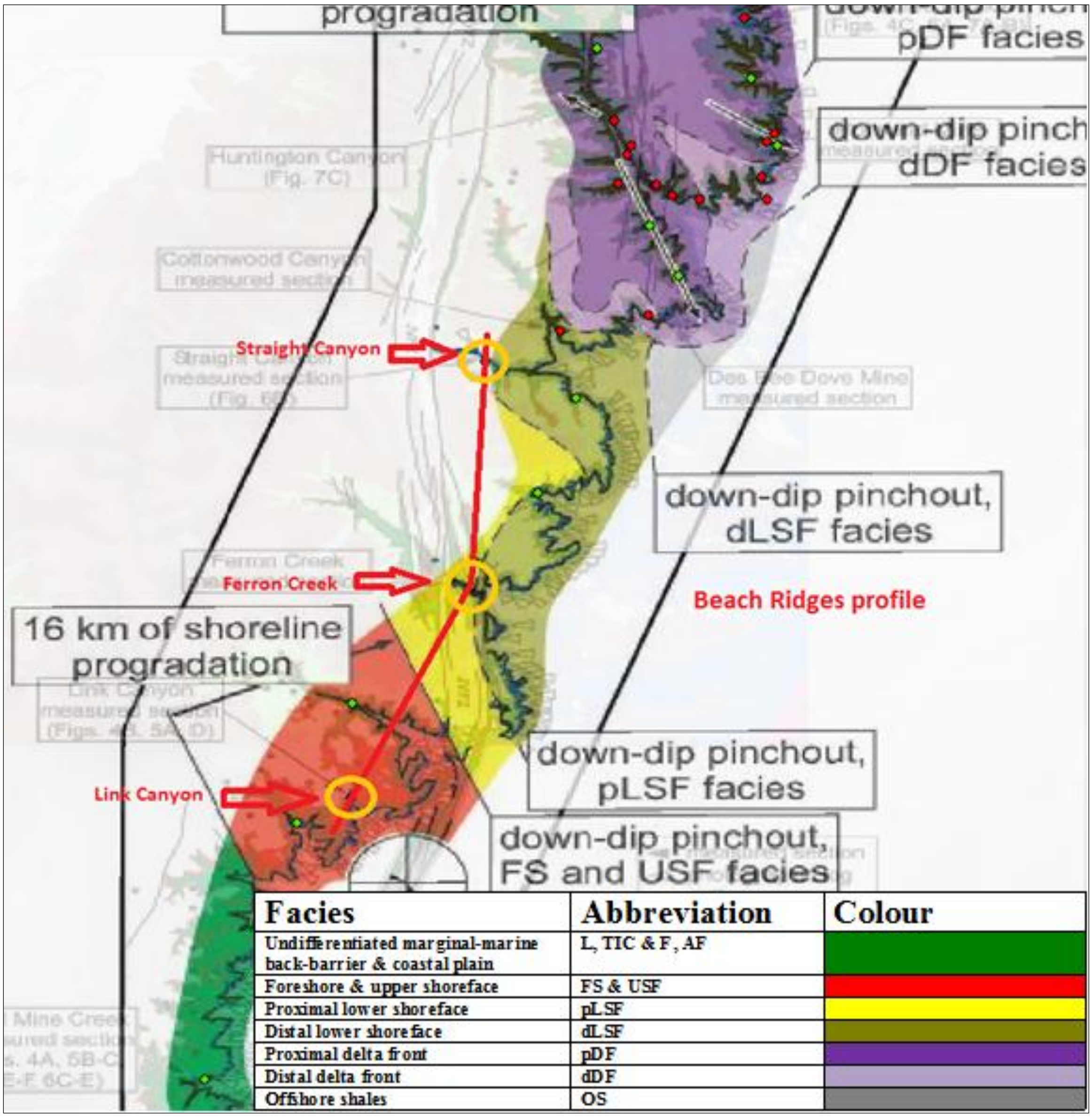


Figure 14 Location of Beach Ridges Profile. The geological interpretation from Hampson et al. (2011) represented by the coloured map (Figure 3) is placed on top of the geologic map of eastern Wasatch Plateau (Figure 2). Locations of logs in the profiles are circled. The southern starting point of the profile is not chosen further south because there was no geological map available further south.

The altitude of Ksp 40 at Link Canyon was very difficult to measure because the Manti geological map does not stretch this far and there was no geological map available south of the Manti geological map. As a result the estimated location and corresponding altitude of Ksp 40 had to be extrapolated along the altitude map.

Table 6, Position of Beach Ridges Logs from Southern Start of Profile

Link Canyon	2 km
Ferron Creek	20 km
Straight Canyon	38 km

Table 7, Topographic altitude of Lower part of Star Point Formation in Beach Ridges Logs

Link Canyon	1200 m – 1500 m
Ferron Creek	900 m – 1100 m
Straight Canyon	900 m – 1100 m

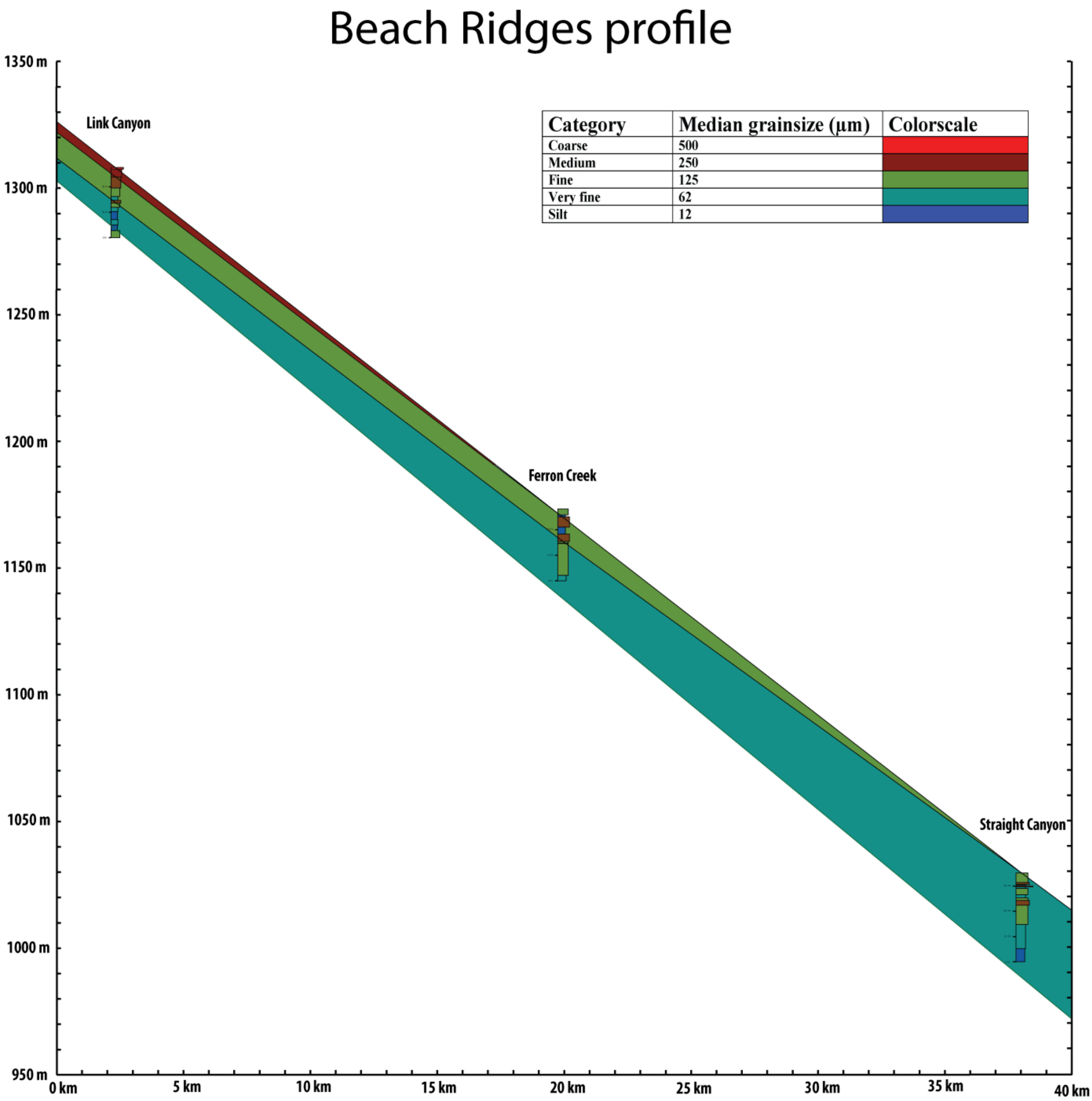


Figure 15, Beach Ridges Profile. Vertical scale is the height in meters above present day sea level. Horizontal scale is the distance in kilometres from southern start of profile (see Figure 14). The profile is oriented from south-southwest to north. The top end of the Ksp 040 parasequence is the top of the presented sequence. The bottom of the parasequence Ksp 040 is defined at Link Canyon but is not clearly defined at Ferron Creek and Straight Canyon. Different median grain sizes are matched to the different facies, which pinch out towards the right hand side in the figure. A constant gradient has been determined which does not coincide with current topography.

Model simulations

Using 2DStratSim many experiments have been made to reproduce the delta and beach ridges profiles and logs presented above. The four best fitting simulations are described below and concern Delta Profile 2b (Figure 12) and the beach ridges profile (Figure 15).

Simulation 1

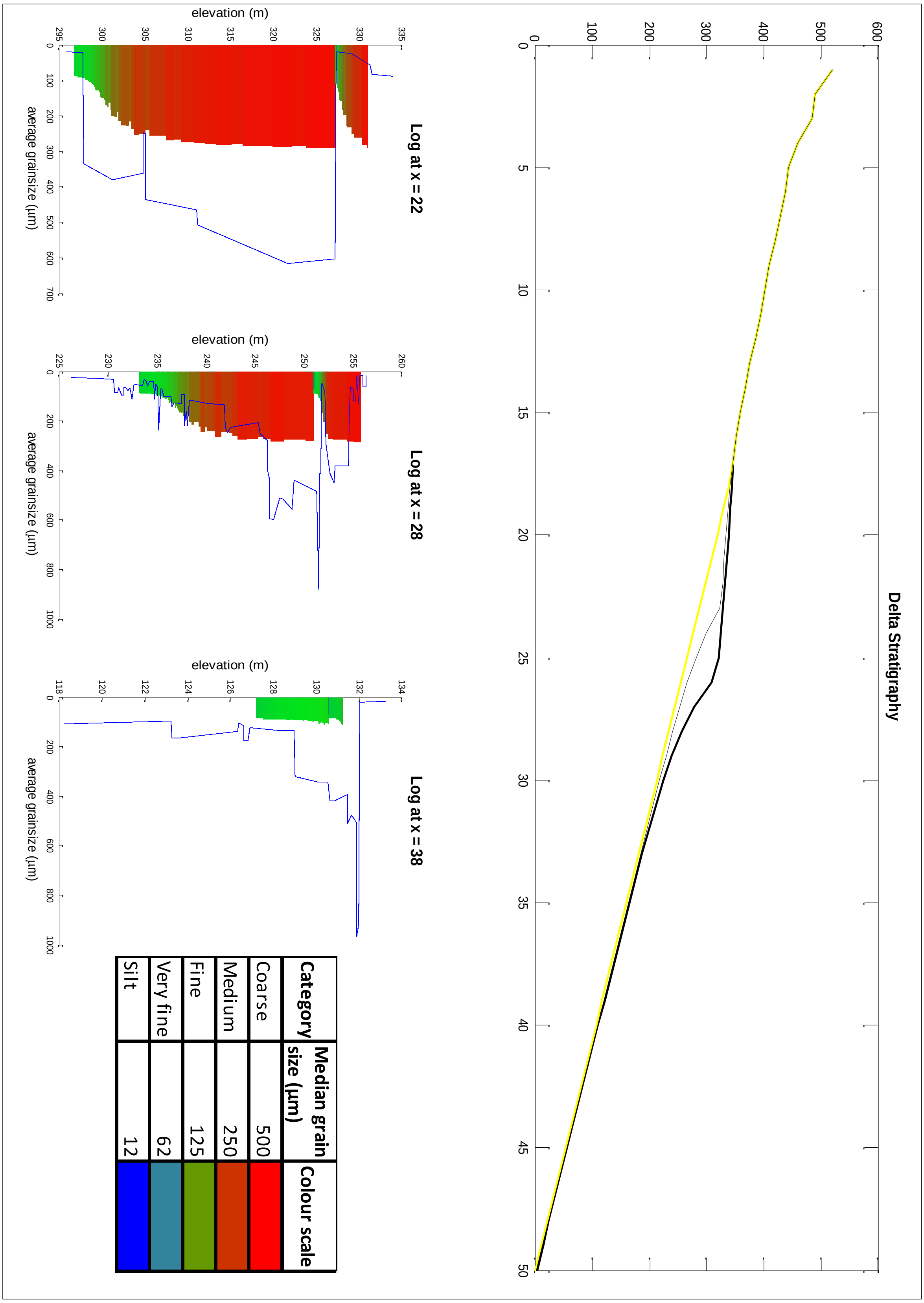
The first simulation is based on the gradients of at Delta Profile 2b and the beach ridges profile: 0,0106 m / m and 0,00825 m / m, respectively. To preserve this (steep) gradient, the delta model presented in Figure 16 provides the best approximation. The accompanying beach ridges model is presented in Figure 17. The distance between the two profiles was 20 km, based on measurements in Arcmap.

The logs in Figure 16 correspond with logs HC 1, HC 4 and C 3. They are placed at the same distance from each other as the logs in Delta Profile 2a (Figure 12). The logs in the beach ridges section correspond with Link Canyon, Ferron Creek and Straight Canyon. They are also placed at the same distances from each other as in the Beach Ridges Profile (Figure 15). The blue lines in the logs indicate the digitalized grain sizes found in Figure 10 and Figure 13.

The input variables used in Simulation 1 are presented in Figure 18. The input matrix can be found in Appendix B, Input Matrices. The accompanying configuration file is found in Appendix C. As a sand ratio of 2 is used (see Appendix B), the Bed Load 1 plot is the same as the Bed Load 2 plot. In this simulation one time step is defined as 300 years (see Appendix B), so the time span is 30 000 years. The incoherent floating point at time step 83 at the Bed Load and Sea Level plots was discarded, because it is a result of the interpolation method in the numerical model.

The bed load supply remains constant at 0,05 m^3/s until time step 80. Then a fall in the bed load supply to 0,02 m^3/s occurs. The suspended load supply gradually falls from 0,005 m^3/s to 0,003 m^3/s over 80 time steps, after which the supply remains constant. The sea level falls 200 meters from time step 0 to 80. Then there is a sharp rise of 100 meters after which the sea level falls 100 meters in 18 time steps.

In Figure 19 the sediment flow throughout the delta and beach ridges is presented.



Category	Median grain size (µm)	Colour scale
Coarse	500	
Medium	250	
Fine	125	
Very fine	62	
Silt	12	

Figure 16, Delta Simulation 1. The top part presents the delta stratigraphy simulation. Vertical scale is the height in meters. Horizontal scale is distance in kilometres. The yellow line is the base gradient. Below three logs are presented at noted locations in the stratigraphy simulation. The coloured sections represent the grain sizes of the modelled logs. The blue lines, placed on top of the modelled logs, represent the digitalized grain sizes of the observed logs from Figure 10. The distances between the modelled logs coincide with the real distances measured between the logs (see Table 4).

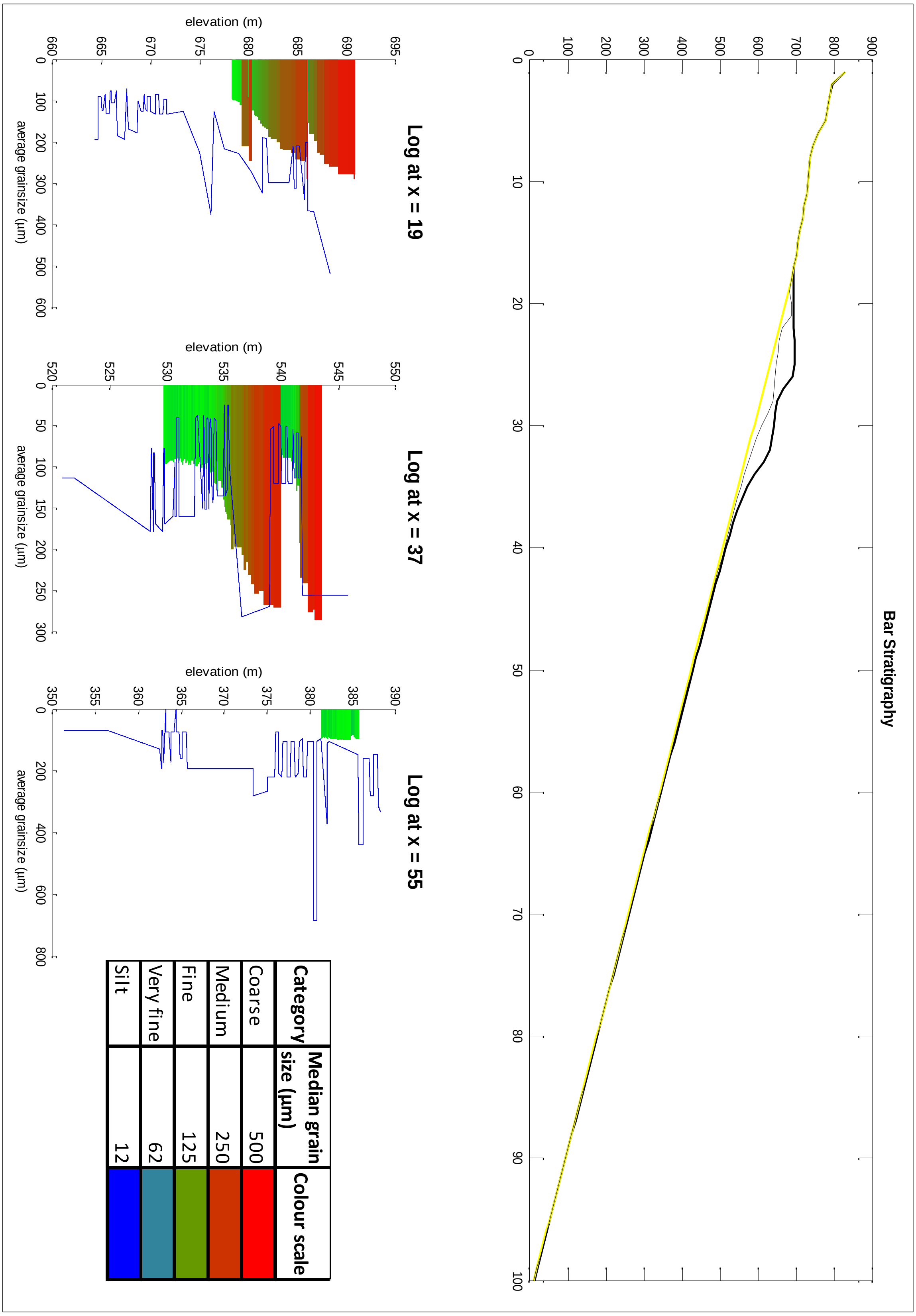


Figure 17, Beach Ridges Simulation 1. The top part presents the beach ridges stratigraphy simulation. Vertical scale is the height in meters. Horizontal scale is distance in kilometres. The yellow line is the base gradient. Below three logs are presented at noted locations in the stratigraphy simulation. The coloured sections represent the grain sizes of the modelled logs. The blue lines, placed on top of the modelled logs, represent the digitalized grain sizes of the observed logs from Figure 13. The distances between the modelled logs coincide with the real distances measured between the logs (see Table 6).

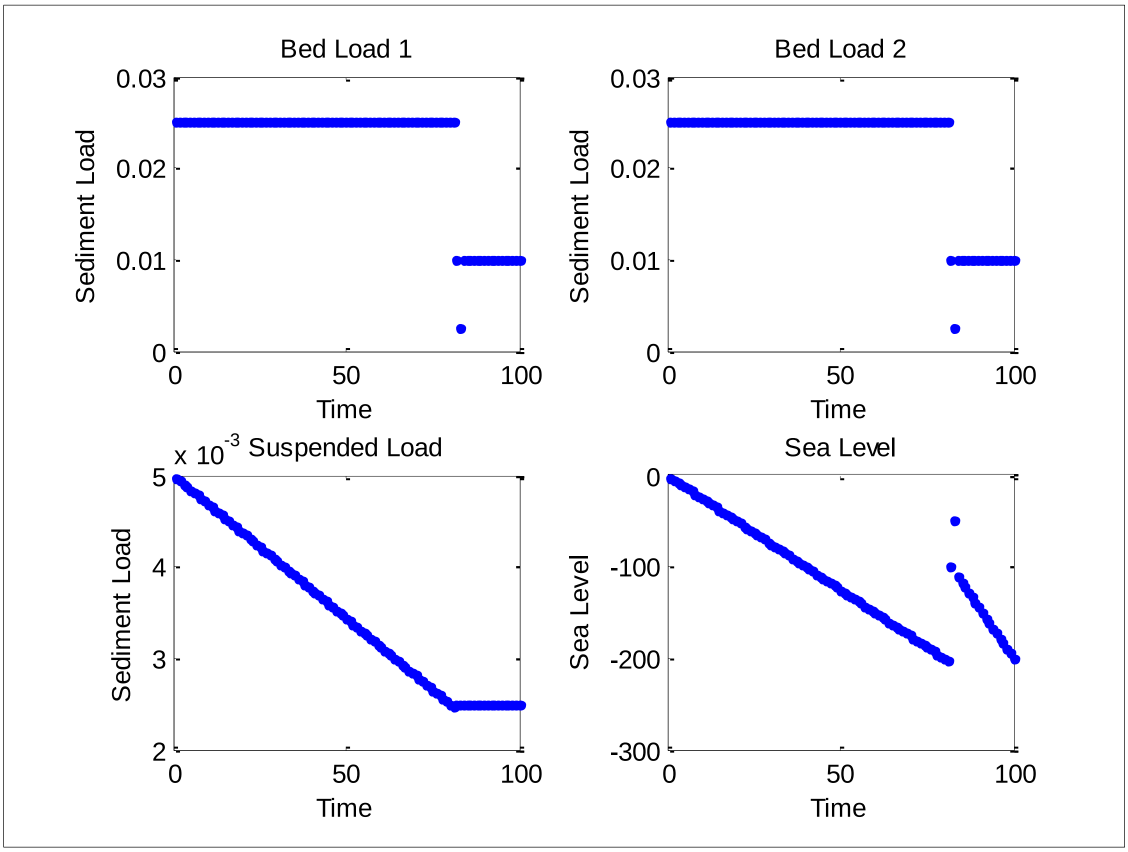


Figure 18, Sediment Supply & Sea Level Change Simulation 1. The Bed Load 1 plot defines the amount of fine grained sediment in m^3/s in the bed load over 100 time steps. The Bed Load 2 plot defines the amount of course grained material in the bed load over 100 time steps. The Suspended Load plot defines suspended load supply over 100 time steps. One time step covers 300 years (see appendix B).

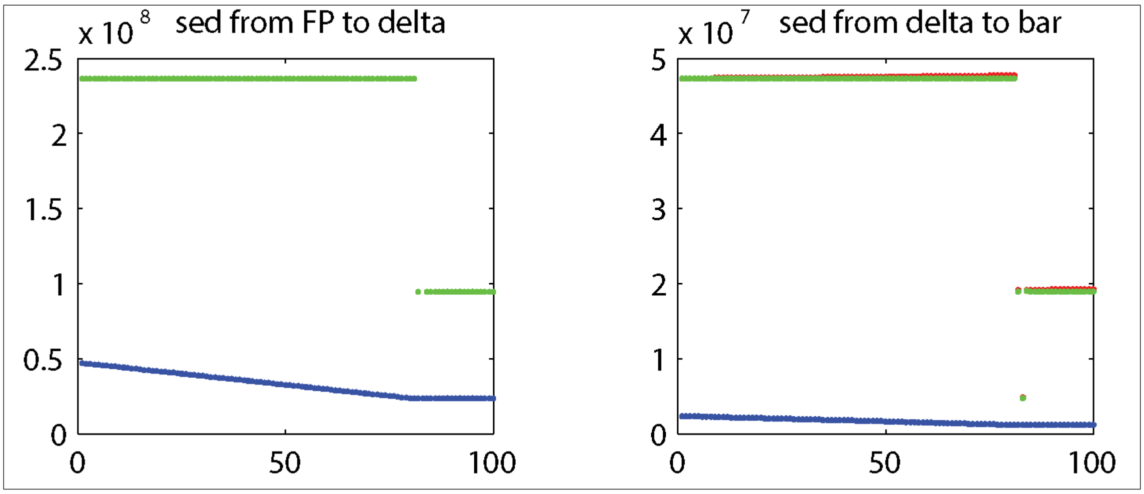


Figure 19, Sediment Flow Simulation 1. The left plot presents the sediment flow from floodplain to delta over 100 time steps. The right plot presents the sediment flow from delta to beach ridges over 100 time steps. One time step covers 300 years (see Appendix B). The red and green lines represent the bed load (coarse and fine fractions) and the blue line represents the suspended load. The sediment loads are in m^3/s.

Simulation 2

In the second simulation a gradient of 0,002 m / m was used for the delta section as well as the beach ridges section. The distance of 20 km between the delta and beach ridges is maintained. The large grain sizes of log 1 are altered. For explanations of the stated values see the chapter 'Discussion'. The delta and beach ridges models are presented in Figure 20 and Figure 21.

This model corresponds with the input variables presented in Figure 22, of which the input matrix is found in Appendix B. The accompanying configuration file is found in Appendix C. Again, a sand ratio of 2 is chosen (see appendix B). The time spans 80 000 years (see appendix B). Also there is an odd and incoherent data point again at time step 88 which was discarded. The bed load supply remains constant at 0,02 m^3/s until time step 85. Then a fall in the bed load supply to 0,01 m^3/s occurs. The suspended load supply gradually decreases from 0,05 m^3/s to 0,02 m^3/s over 85 time steps, after which the supply remains constant at 0,01 m^3/s. The sea level gradually falls at about three meters per 10 000 years. Then a sharp sea level rise occurs of 10 meters in 1600 years, after which the sea level falls again at approximately the same rate as before.

In Figure 23 the sediment flow throughout the delta and beach ridges is shown.

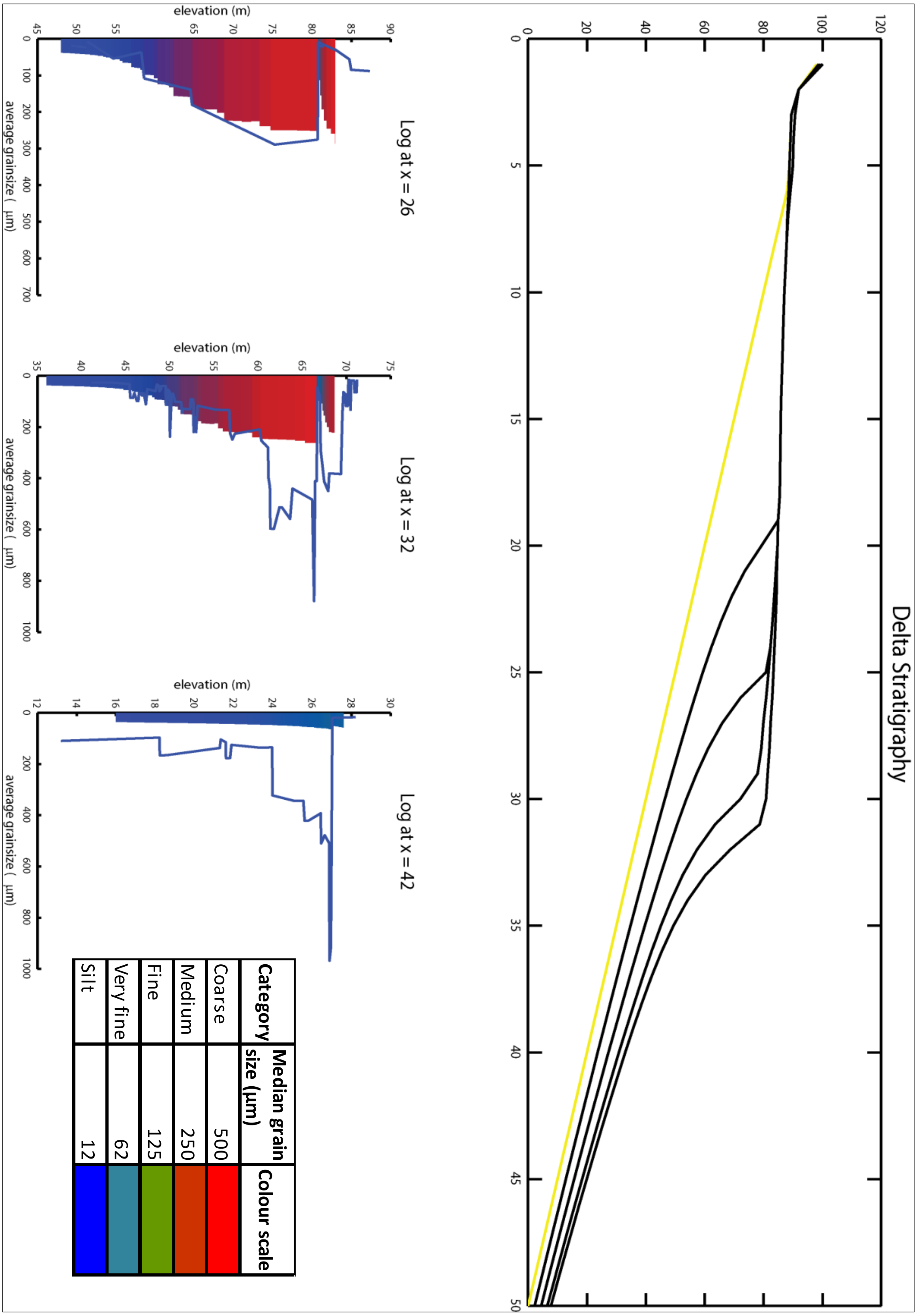


Figure 20, Delta Simulation 2. The top part presents the delta stratigraphy simulation. Vertical scale is the height in meters. Horizontal scale is distance in kilometres. The yellow line is the base gradient. Below three logs are presented at noted locations in the stratigraphy simulation. The coloured sections represent the grain sizes of the modelled logs. The blue lines, placed on top of the modelled logs, represent the digitalized grain sizes of the observed logs from Figure 10. The distances between the modelled logs coincide with the real distances measured between the logs (see Table 4).

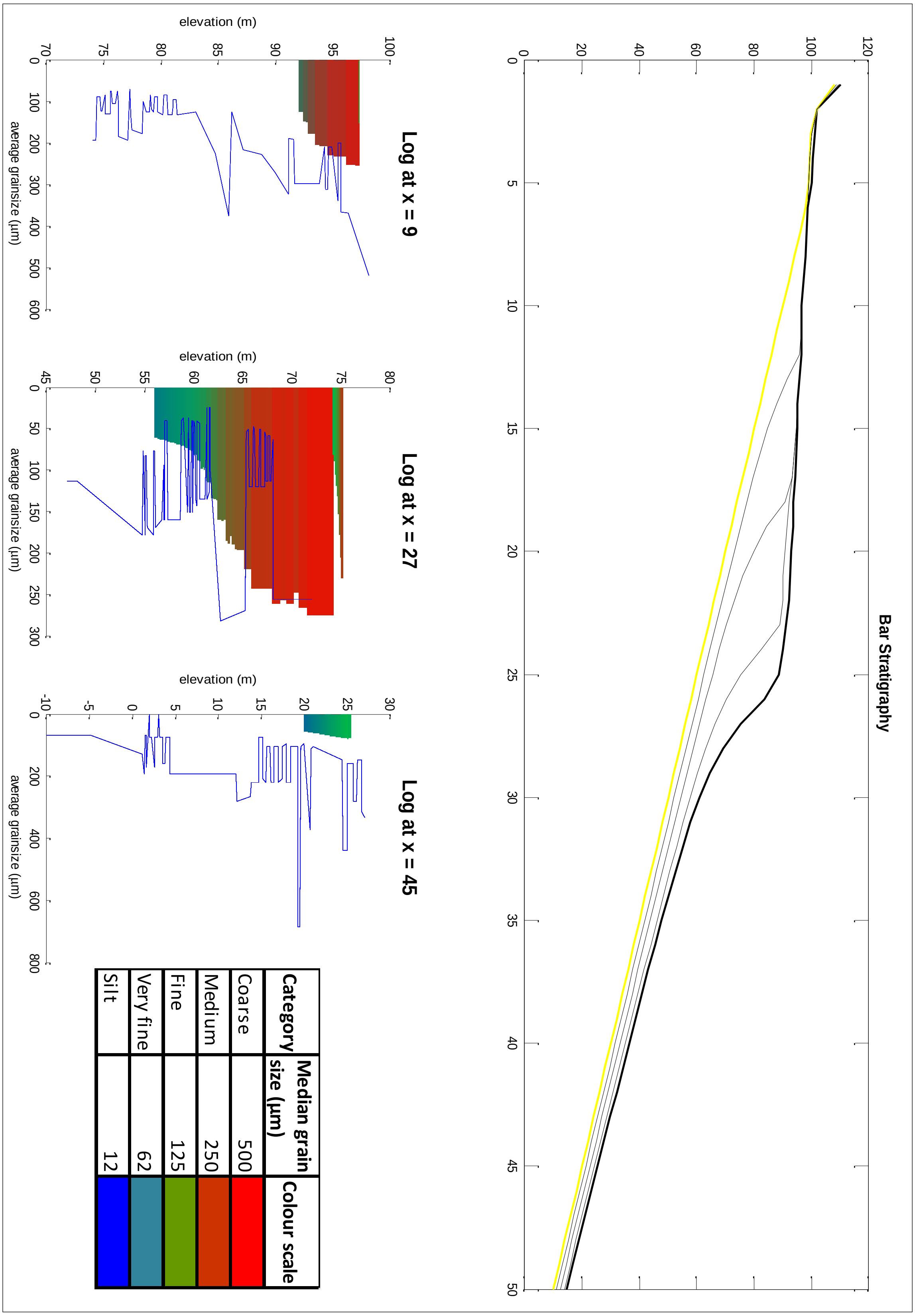


Figure 21, Beach Ridges Simulation 2. The top part presents the beach ridges stratigraphy simulation. Vertical scale is the height in meters. Horizontal scale is distance in kilometres. The yellow line is the base gradient. Below three logs are presented at noted locations in the stratigraphy simulation. The coloured sections represent the grain sizes of the modelled logs. The blue lines, placed on top of the modelled logs, represent the digitalized grain sizes of the observed logs from Figure 13. The distances between the modelled logs coincide with the real distances measured between the logs (see Table 6).

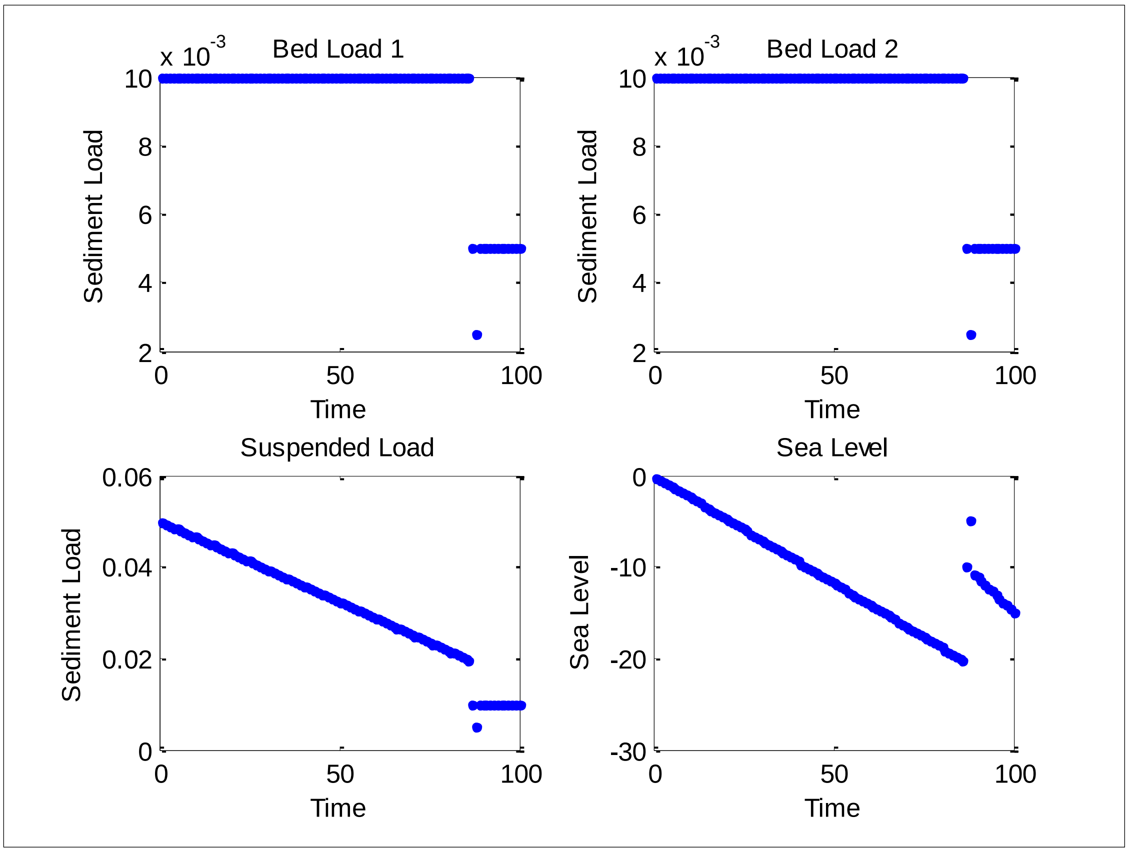


Figure 22, Sediment Supply & Sea Level Change Simulation 2. The Bed Load 1 plot defines the amount of fine grained sediment in m^3/s in the bed load over 100 time steps. The Bed Load 2 plot defines the amount of course grained material in the bed load over 100 time steps. The Suspended Load plot defines suspended load supply over 100 time steps. One time step covers 800 years (see appendix B).

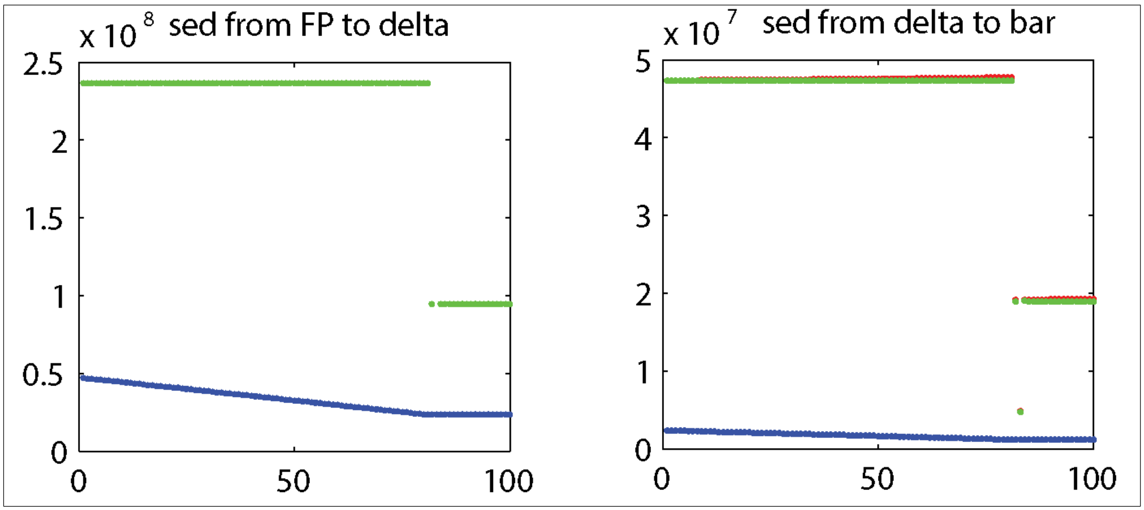


Figure 23, Sediment Flow Simulation 2. The left plot presents the sediment flow from floodplain to delta over 100 time steps. The right plot presents the sediment flow from delta to beach ridges over 100 time steps. One time step covers 800 years (see Appendix B). The red and green lines represent the bed load (coarse and fine fractions) and the blue line represents the suspended load. The sediment loads are in m^3/s.

Simulation 3

In this simulation the gradient, sand ratio, sediment supply and distance between the delta and beach ridges are altered, compared to simulation 2. The gradient and sand-ratio are both decreased. The overall sediment supply is increased. Within the time steps the sediment supply is also adjusted more often. The distance between the delta and beach ridges is decreased. The gradients of both the delta and beach ridges bases are 0,0005 m / m and the distance chosen between delta and beach ridges is 10 km.

See Figure 24 and Figure 25 for the Delta and Beach Ridges simulations, Figure 26 for the input variables and Appendix B and C for the input matrix and configuration file. In Figure 27 the sediment flow throughout the delta and beach ridges is presented.

In Figure 26, the chosen sand ratio is 1,5 (see appendix B), so more coarse grains are present in the bed load than in models 1 and 2. The time spans 100 000 years (see appendix B). The odd data point at time step 92 at the Sea Level plot should again be discarded. Concerning the input, at time step zero there is a lot of fine grained sediment supplied and at time step 90 there is much more coarse grained sediment supplied. During the same time span the sea level is gradually falling. At time step 90 the sea level rises drastically, after which it gradually falls again.

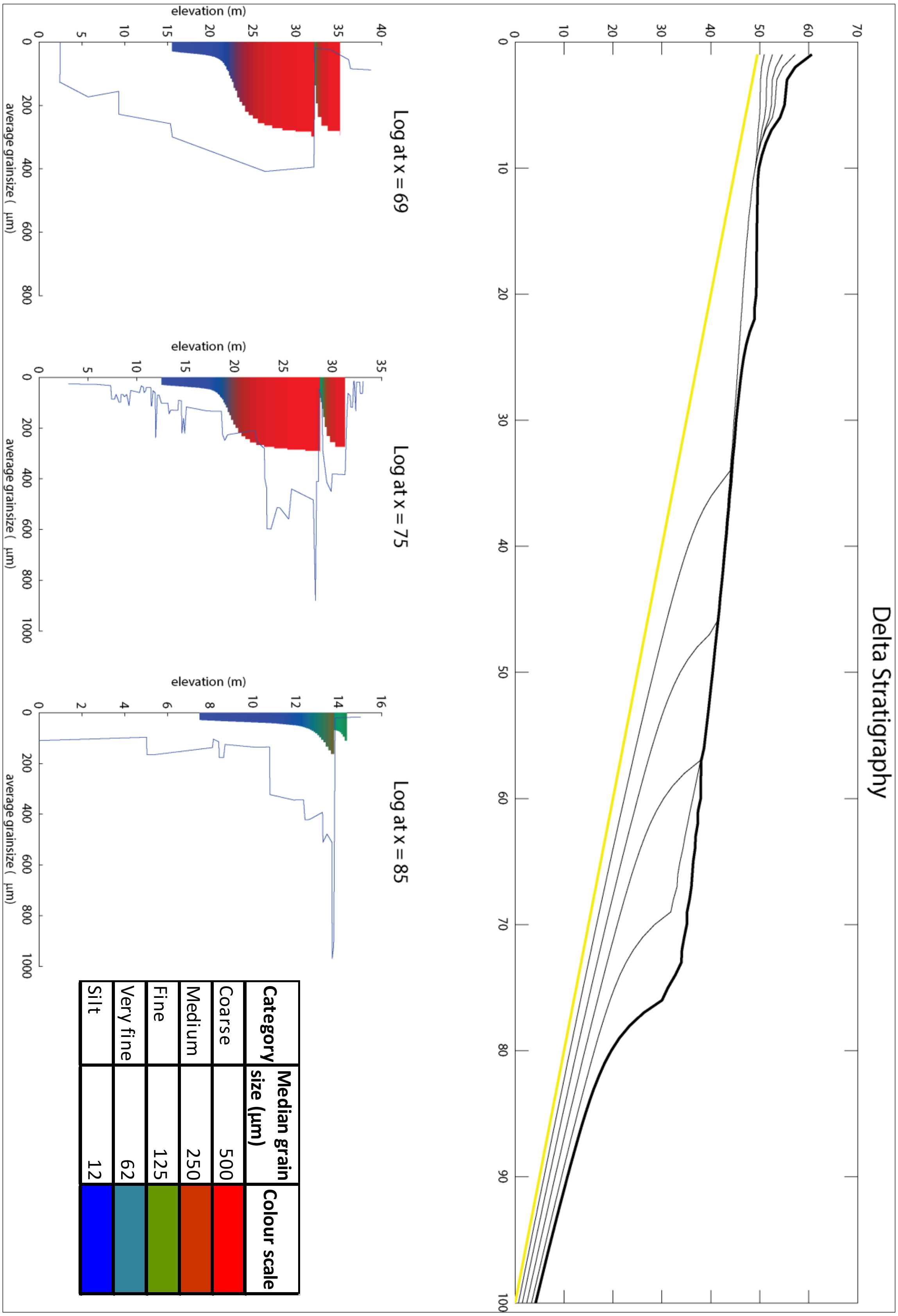


Figure 24, Delta Simulation 3. The top part presents the delta stratigraphy simulation. Vertical scale is the height in meters. Horizontal scale is distance in kilometres. The yellow line is the base gradient. Below three logs are presented at noted locations in the stratigraphy simulation. The coloured sections represent the grain sizes of the modelled logs. The blue lines, placed on top of the modelled logs, represent the digitalized grain sizes of the observed logs from Figure 10. The distances between the modelled logs coincide with the real distances measured between the logs (see Table 4).

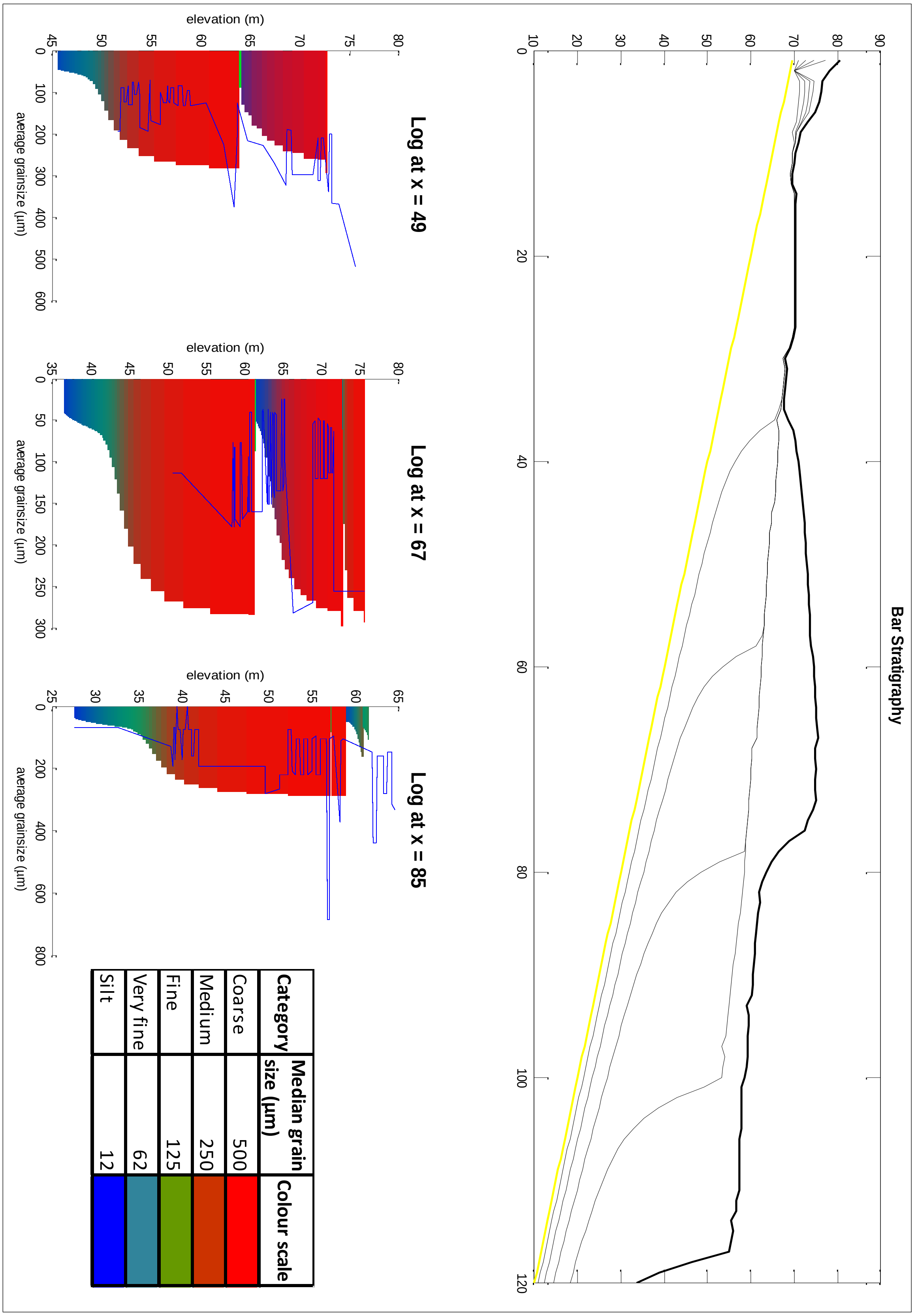


Figure 25, Beach Ridges Simulation 3. The top part presents the beach ridges stratigraphy simulation. Vertical scale is the height in meters. Horizontal scale is distance in kilometres. The yellow line is the base gradient. Below three logs are presented at noted locations in the stratigraphy simulation. The coloured sections represent the grain sizes of the modelled logs. The blue lines, placed on top of the modelled logs, represent the digitalized grain sizes of the observed logs from Figure 13. The distances between the modelled logs coincide with the real distances measured between the logs (see Table 6).

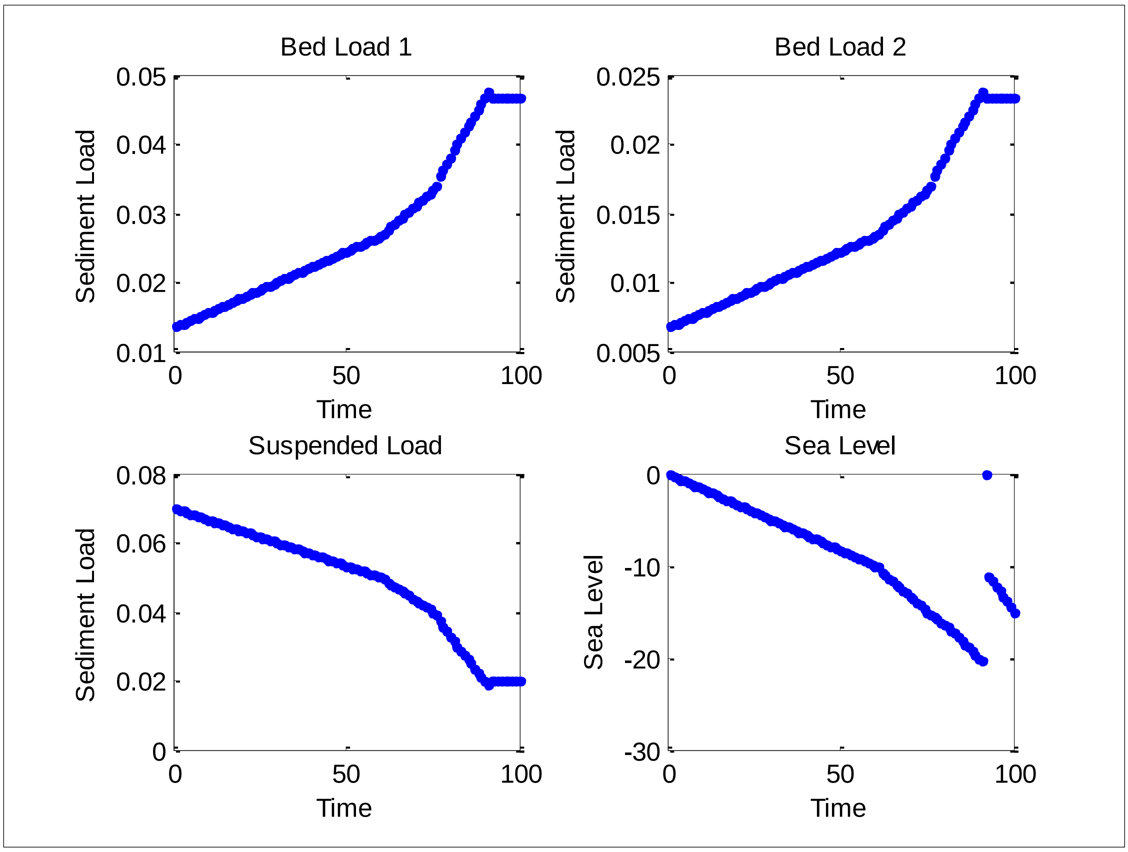


Figure 26, Sediment Supply & Sea Level Change Simulation 3. The Bed Load 1 plot defines the amount of fine grained sediment in m^3/s in the bed load over 100 time steps. The Bed Load 2 plot defines the amount of course grained material in the bed load over 100 time steps. The Suspended Load plot defines suspended load supply over 100 time steps. One time step covers 1000 years (see appendix B).

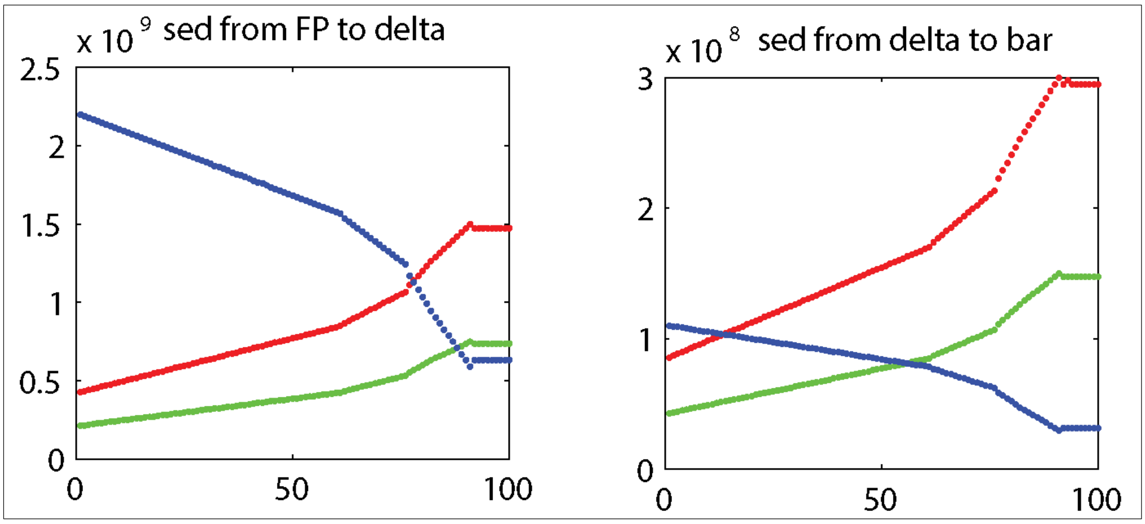


Figure 27, Sediment Flow Simulation 3. The left plot presents the sediment flow from floodplain to delta over 100 time steps. The right plot presents the sediment flow from delta to beach ridges over 100 time steps. One time step covers 1000 years (see Appendix B). The red and green lines represent the bed load (coarse and fine fractions) and the blue line represents the suspended load. The sediment loads are in m^3/s.

Simulation 4

In this simulation, the smaller scale characteristics of the sedimentary logs have been taken into account. For example, the long shore current configuration values have been altered compared to simulations 1,2 and 3. Also the input variables of sediment supply and sea level have been altered a little, compared to the simulations before. The model is presented in Figure 28 and Figure 29. The input variables are presented in Figure 30 and the sediment flow is found in Figure 31.

The time span of 100 time steps covers 100 000 years and the sand ratio is 1,4 (see appendix B).

At time step zero, the supply of coarse grained as well as fine grained sediment is about 0,1 m^3/s. The supply decreases gradually and after 40 000 years the supply decreases a lot. See Appendix B or Table 8 for exact values. As the sediment supply decreases, also the sea level falls faster. After 80 000 years a sudden sea level rise occurs, along with an increase in suspended sediment supply.

Table 8 shows the relative sea level fluctuations and sediment load supply that could have formed the Panther Tongue delta complex. The average bed sediment load supply was 0,03 m^3/s. The bed sediment load supply varies between 0,15 m^3/s and 0,005 m^3/s. The total bed sediment volume was $1{,}92 \cdot 10^{11}$ m^3. The average suspended sediment load supply is 0,04 m^3/s. The suspended sediment load supply varies between 0,1 m^3/s and 0,005 m^3/s. The total suspended sediment volume was $1{,}55 \cdot 10^{11}$ m^3/s.

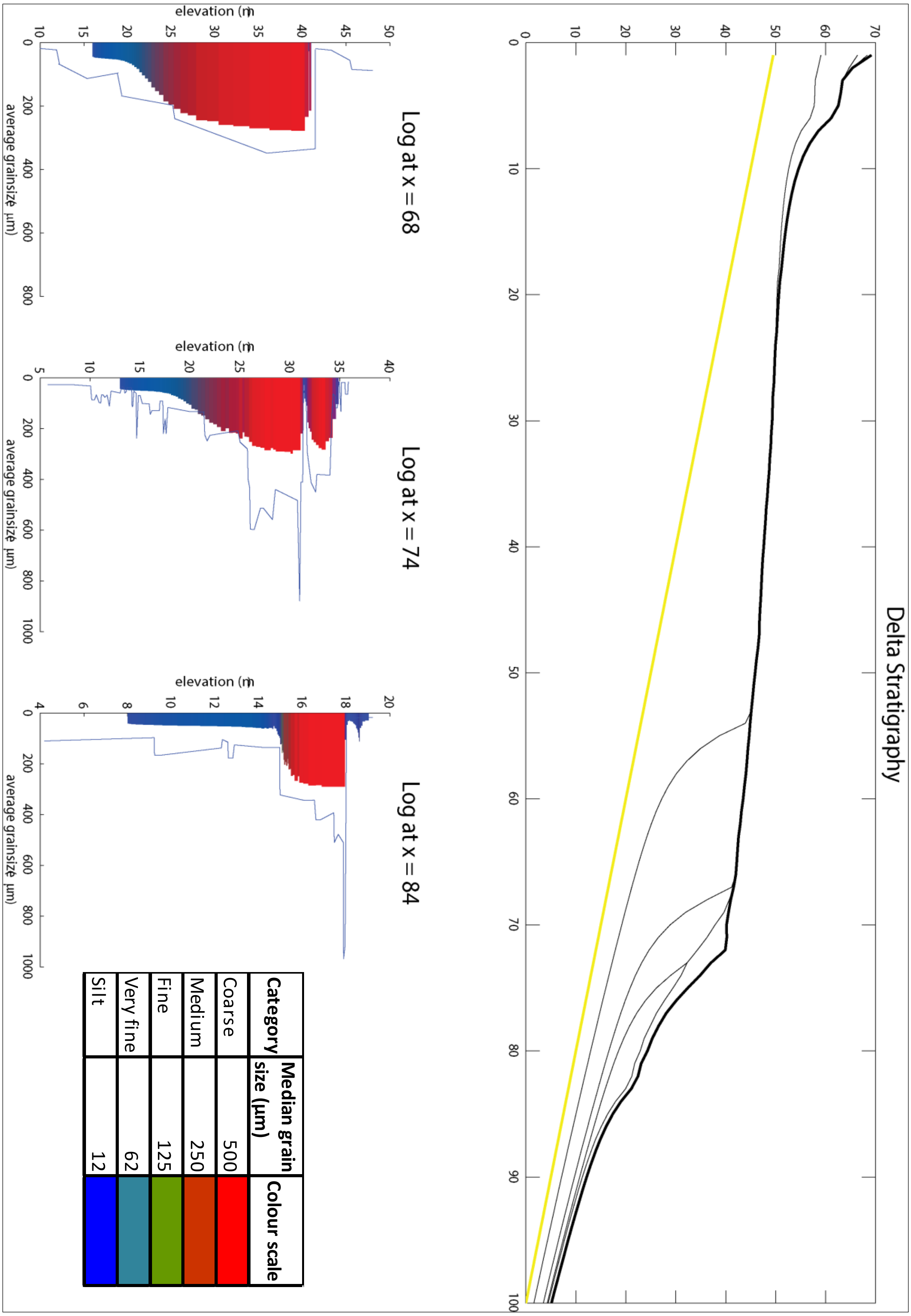


Figure 28, Delta Simulation 4. The top part presents the delta stratigraphy simulation. Vertical scale is the height in meters. Horizontal scale is distance in kilometres. The yellow line is the base gradient. Below three logs are presented at noted locations in the stratigraphy simulation. The coloured sections represent the grain sizes of the modelled logs. The blue lines, placed on top of the modelled logs, represent the digitalized grain sizes of the observed logs from Figure 10. The distances between the modelled logs coincide with the real distances measured between the logs (see Table 4).

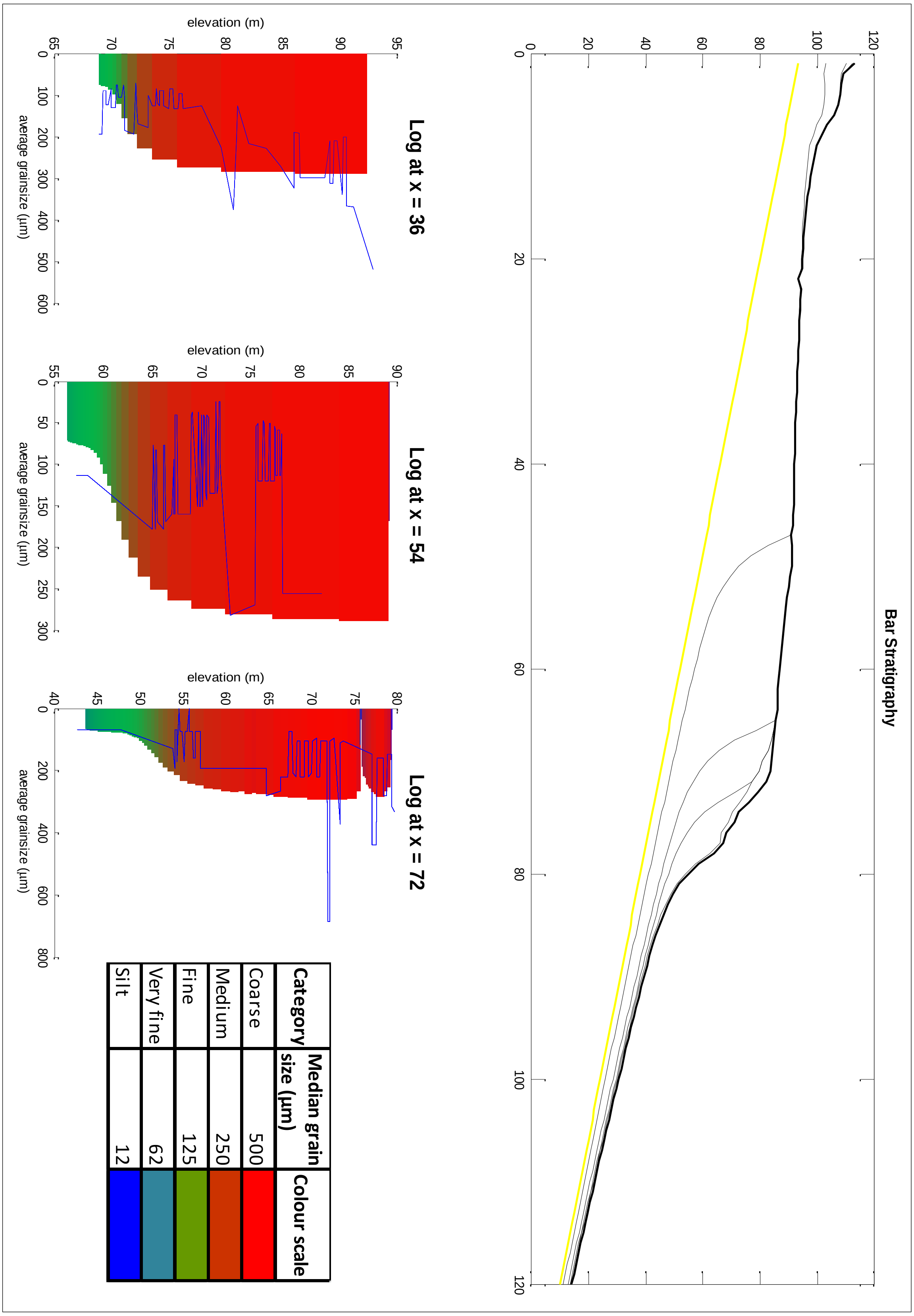


Figure 29, Beach Ridges Simulation 4. The top part presents the beach ridges stratigraphy simulation. Vertical scale is the height in meters. Horizontal scale is distance in kilometres. The yellow line is the base gradient. Below three logs are presented at noted locations in the stratigraphy simulation. The coloured sections represent the grain sizes of the modelled logs. The blue lines, placed on top of the modelled logs, represent the digitalized grain sizes of the observed logs from Figure 13. The distances between the modelled logs coincide with the real distances measured between the logs (see Table 6).

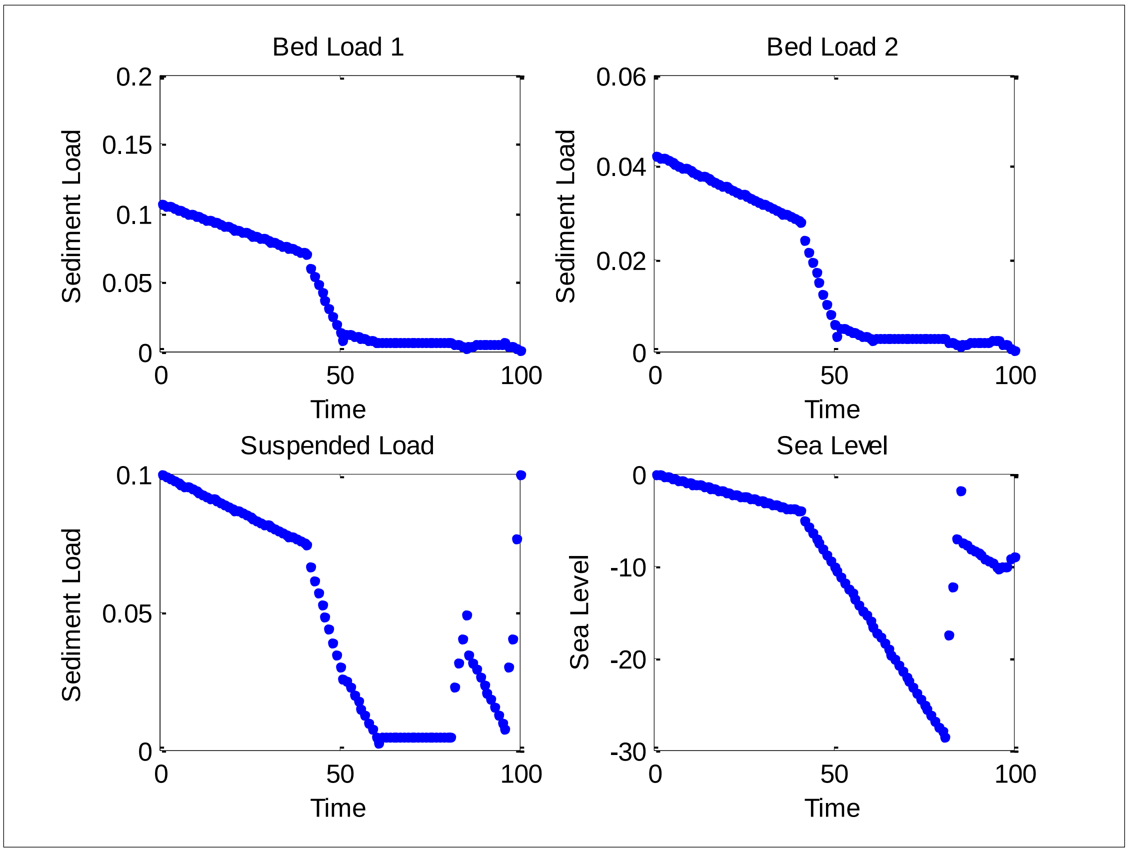


Figure 30, Sediment Supply and Sea Level Change Simulation 4. The Bed Load 1 plot defines the amount of fine grained sediment in m^3/s in the bed load over 100 time steps. The Bed Load 2 plot defines the amount of course grained material in the bed load over 100 time steps. The Suspended Load plot defines suspended load supply over 100 time steps. One time step covers 1000 years (see appendix B).

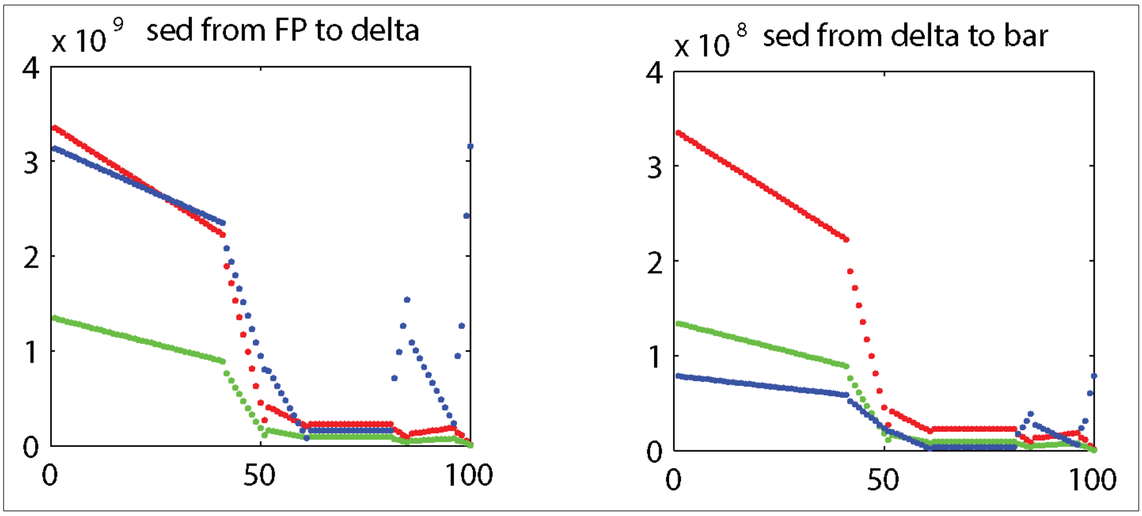


Figure 31, Sediment Flow Simulation 4. The left plot presents the sediment flow from floodplain to delta over 100 time steps. The right plot presents the sediment flow from delta to beach ridges over 100 time steps. One time step covers 1000 years (see Appendix B). The red and green lines represent the bed load (coarse and fine fractions) and the blue line represents the suspended load. The sediment loads are in m^3/s.

Table 8, Summary Sediment Supply Model 4. Time is in thousands of years, the relative sea level fluctuations in meters, the bed sediment load supply in square meters per second, the suspended sediment load supply in square meters per second, the accompanying bed sediment volume in square meters and suspended sediment volume in square meters.

Time (1000 years)	Sea Level (m)	Qb (m^3/s)	Qs (m^3/s)	Vb (m^3)	Vs (m^3)
0	0	0,15	0,1	-	-
40	-4	0,1	0,075	$1{,}58 \cdot 10^{11}$	$1{,}10 \cdot 10^{11}$
50	-10	0,02	0,03	$1{,}89 \cdot 10^{10}$	$1{,}66 \cdot 10^{10}$
60	-16	0,01	0,005	$4{,}73 \cdot 10^{9}$	$5{,}52 \cdot 10^{9}$
70	-22	0,01	0,005	$3{,}15 \cdot 10^{9}$	$1{,}58 \cdot 10^{9}$
80	-28	0,01	0,005	$3{,}15 \cdot 10^{9}$	$1{,}58 \cdot 10^{9}$
84	-7	0,005	0,04	$9{,}46 \cdot 10^{8}$	$2{,}84 \cdot 10^{9}$
95	-10	0,008	0,01	$2{,}25 \cdot 10^{9}$	8,67 · 109
97	-10	0,006	0,03	$4{,}42 \cdot 10^{8}$	$1{,}26 \cdot 10^{9}$
100	-9	0,0005	0,1	$3{,}07 \cdot 10^{8}$	$6{,}15 \cdot 10^{9}$
Average/ **Total**		0,03	0,04	**1,92E+11**	**1,55E+11**

Discussion

Profiles

Delta Profiles

The suspected delta structure is confirmed by the pinchout of the coarse grained sequence to the east in Delta Profile 1a (Figure 8), the thinning of the whole sequence to the east (Figure 8) and the coarsening upward sequence until the top of the Panther Tongue parasequence that can clearly identified in the delta logs (Figure 7). The bottom of the parasequence is not clearly defined, because the logs may not cover the complete Panther Tongue parasequence, as the material gets finer grained. This implies that the Panther Tongue could be thicker than the length of log HC 1.

In Delta Profile 1a (Figure 8), log HC 7 is located at approximately the same altitude as log HC 6. This implies that the delta would have prograded from the northwest until the location of log HC 6, where the bottomsets of the clinoform would then start. However, coarse grained material is still found in log HC 7, which indicates that the delta has prograded further than the location of log HC 7. Tectonics in the Paleogene and Neogene periods may be the cause that the Panther Tongue was measured at the same altitude in log HC 7 as in log HC 6. Furthermore, the approximations of the topographic altitudes of the logs by the use of the Manti map have an uncertainty of about 100 meters (see Table 3), thus the precise altitudes of the logs are very uncertain. To make the best approximation of the delta section during the Cretaceous period, before tectonics, Delta Profile 1b is constructed (Figure 9). The gradient between logs HC 1, HC 4 and HC 6 is extrapolated to log 7.

Delta profiles 2a and 2b require the same discussion.

Beach Ridges Profile

Due to a tectonic graben, most likely formed during the Paleogene or Neogene period, which can be identified on the Manti geological map and also in Figure 2, the Star Point Sandstone in Ferron Creek used to be positioned higher. The Ferron Creek log is therefore placed at a higher altitude than measured In Figure 15. Also, the altitude of Ksp 40 at Link Canyon was very difficult to measure because the Manti geological map does not stretch this far and there was no geological map available south of the Manti geological map. As a result the estimated location and corresponding altitude of Ksp 40 had to be extrapolated along the altitude map. Furthermore, the approximations of the topographic altitudes of the logs by the use of the Manti map have an uncertainty of about 200 meters (see Table 7). Besides, Hampson et al. (2011) suggest only a slope of 50 m over 40 km. Due to the reasons above, the profile based on topography (not presented in this report) is discarded and Figure 15 is assumed to be the best approximation of the beach ridges section during the Cretaceous period, before tectonics.

Models

Simulation 1

The modelled coarsening upward sequences in the modelled logs in the Delta simulation (Figure 16) correspond with the coarsening upward sequences detected in the digitalized delta logs (Figure 10). This coarsening upward sequence is the result of forced regression during sea level fall. However, the large sea level fall of 200 m over the relatively short time of ± 30 000 years is probably excessive, considered the absence of large ice caps during the Cretaceous period. Furthermore, the grain sizes of all the modelled logs and the thickness at the third modelled log in Delta Simulation 1 do not fit optimally with Delta Profile 2 (see Figure 16). Also, the digitalized grain sizes at log HC 1 all seem too large. As stated in the chapter 'Method', the available logs were firstly digitalized, based on images. In these images the grain size scale could not have been precise. The model does not produce grain sizes over 300 µm, so the blue line at the first delta log is moved to the left, in further simulations. Finally, the simulated stratigraphy in the beach ridges model does not match the beach ridges profile (compare Figure 15 and Figure 17). Thus, the gradients of the constructed delta and beach ridges profiles were discarded, and a gradient closer to the beach ridges gradient retrieved from Hampson et al. (2011) was used. The steep topographic gradient of the Panther Tongue and Ksp 40 could be explained by tectonics after the Panther Tongue was deposited. For example, it could be explained by tectonic tilting to the east.

Simulation 2

In the second simulation a gradient of 0,002 m / m was used for the delta section as well as the beach ridges section. This gradient is close to the beach ridges gradient retrieved from Hampson et al. (2011), which is 0,00125 m / m. The large grain sizes of digitalized log HC 1 are altered, because the grain size scale could not have been precise in the original log image.

This time the sea level fluctuations are much more realistic; 20 meters over ± 70 000 years is a credible sea level fall that could occur during the Cretaceous period. The sharp sea level rise of 10 meters in 1600 years can be matched to the transgressive lag defined by Hwang & Heller (2002). This sea level rise is accompanied by a sudden fall in bed load supply as well as suspended load supply (see Figure 22). The sharp sea level rise may seem unrealistic. However, the very sharp lag cannot be explained otherwise than by a sudden sea level rise. If the sharp sea level rise is omitted in the 2DStratSim model and only a very large decrease of (coarse) sediment supply is taken as input, a scenario with such a sharp lag is impossible to retrieve.

The first two delta logs fit quite well (see Figure 20). However, more coarse grained material should be present in the third modelled log to match the digitalized log. To solve this problem the gradient and sea level fluctuations could be altered again, as well as the sediment supply. Also the sand ratio can be altered. This is done in Simulation 3.

The beach ridges logs do not fit at all (see Figure 21). The difference between the modelled and digitalized logs could be explained by the configuration value that has been used for the distance between the delta and beach ridges: 20 kilometres. The measurement of this distance in Arcmap is merely a rough estimate: the delta may have had lobes prograding in different directions. So altering the distance between delta and beach ridges can be rectified. This is done in Simulation 3. Also the effect of the longshore current could be taken into account. This is done in Simulation 4.

Simulation 3

In this simulation the gradient, sand ratio, sediment supply and distance between the delta and beach ridges are altered, compared to simulation 2. The gradient and sand-ratio are both decreased to retrieve a better fitting stratigraphy simulation. The overall sediment supply is increased for the same reason. Within the time steps the sediment supply is also adjusted more often, with the fine grained sediment supply showing a decreasing trend and the coarse grained sediment supply showing an increasing trend. This is done to match the observed logs more precisely. The change in distance between delta and beach ridges of 20 km to 10 km is made in order to retrieve a better fitting beach ridges simulation.

Similarly to Simulation 2, the sea level fall of 20 meters over ± 90 000 years is a credible sea level fall that could occur during the Cretaceous period. The sharp sea level rise of 10 meters in 1000 years is matched to the transgressive lag defined by Hwang & Heller (2002).

In the Delta simulation there is still too little coarse grained material in the first modelled log, too much coarse grained material in the second modelled log and too little coarse grained material in the third modelled log, compared to the digitalized logs.

The modelled beach ridges logs contain too much sediment compared to the digitalized logs. This could be the result of too large values for longshore transport. These configuration values are altered in Simulation 4. Nevertheless, the overall architecture of the logs coincides with the Link Canyon, Ferron Creek and Straight Canyon logs.

Simulation 4

In this simulation, we focussed on the smaller scale characteristics of the sedimentary logs, and varied the input variables in order to match the modelled logs to the observed logs.

The modelled logs in the delta simulation fit very well with the digitalized delta logs (see Figure 28). However, the modelled logs in the beach ridges simulation fit worse than the modelled logs in Beach Ridges Simulation 3 (compare Figure 25 and Figure 29). The explanation for this is as follows. In this investigation an approach was chosen to first match the modelled logs in the delta simulation to the corresponding observed logs. When a good fit at the delta was found, the beach ridges were simulated, by altering variables that would not influence the delta simulation. The only variables altered for the beach ridges model are the distance between delta and beach ridges and the effect of longshore current. Thus it is concluded that Simulation 4 is the best fitting simulation.

At time step zero, the supply of coarse grained as well as fine grained sediment is about 0,1 m^3/s. The supply decreases gradually and after 40 000 years the supply decreases a lot. As the sediment supply decreases, also the sea level falls faster (about six times as fast). This fall in sediment supply and sea level can be matched to the increased coarsening upward in the observed delta logs. After 80 000 years the Panther Tongue formation is formed and a short transgressive period, along with an increase in suspended sediment supply, causes a sharp lag that can be found in the logs.

Table 8 presents the best fitting input variables of sediment supply and sea level change that have been found in this study. However, these variables cannot be relied on for 100 % because a perfectly fitting simulation cannot be produced as the model is limited to numerical computations, in which certain assumptions are made such as a constant gradient and a constant longshore current throughout the total timespan.

Conclusions

This study aimed to quantify the sediment supply and the sea level fluctuations of the Panther Tongue delta complex. This was done by interpreting and correlating available logs, constructing two delta sections and a beach ridges section and finally simulating these sections using a numerical delta and beach ridges model '2DStratSim' in MATLAB.

The input variables and parameters to this model that produce best matching simulation are the following.

Firstly, a much smaller base gradient is found than suspected at first insight from the geological maps. A slope of approximately 0,0005 m / m proves the best. Also a smaller distance between delta and beach ridges is found than measured on the geological map. A distance of 10 km proves the best.

Further, in the best matching simulation the relative sea level falls 28 meters over 80 000 years. The sea level falls 4 meters over the first 40 000 years and 24 meters over the next 40 000 years. The average bed sediment load supply was 0,03 m^3/s. The bed sediment load supply varies between 0,15 m^3/s and 0,005 m^3/s. The total bed sediment volume was $1{,}92 \cdot 10^{11}$ m^3. The average suspended sediment load supply is 0,04 m^3/s. The suspended sediment load supply varies between 0,1 m^3/s and 0,005 m^3/s. The total suspended sediment volume was $1{,}55 \cdot 10^{11}$ m^3/s.

The sediment supply decreases gradually and after 40 000 years, along with the faster sea level fall, the sediment supply decreases a lot. After 80 000 years a sudden sea level rise occurs, that can be matched to a transgressive lag described by Hwang & Heller (2002).

The variables stated above cannot be relied on for 100 % because a perfectly fitting simulation cannot be produced as the model is limited to numerical computations with certain assumptions.

Recommendations

It would greatly simplify the construction of cross sections if the exact topographic altitudes of logs would be measured by GPS. Unfortunately these altitudes are not present in the articles of Hampson et al., Hwang & Heller or others.

Next, a mistake appears in the interpolation function in the 2DStratSim model. One time step is miscalculated in the bed sediment load supply and sea level fluctuations. For example, in Figure 18, at time step 83 at the bed load and sea level plots, we detect one odd data point. This data point was discarded. It does not have much effect on the final outcome. However, in the future, to present a better and more complete picture of the situation, this error should be solved.

In the 2DStratSim model one single gradient throughout the whole section is used. In reality, the slope of the delta base and beach ridges base may have differed throughout the section, as proposed in delta profiles 1a and 2a (respectively Figure 8 and Figure 11). The same is true for the longshore current, which remains one constant variable throughout the whole timespan.

Finally, the main trouble with simulating the geological profiles was the deposition of coarse grained material further down the delta into the sea. Delta profiles 1 and 2 both suggest a thin layer of very coarse grained material at the top end of the Panther Tongue, in the most eastern log. In order to produce such a layer with 2DStratSim, the middle log inevitably contains too much coarse grained material. A similar problem arises between the western and middle delta logs. In order to produce the large amount of coarse grained material in the western log, the middle log will inevitably contain much more coarse grained material than the digitalized log suggests, and vice versa. Unfortunately it would not be justified to place the logs closer to — or further from — each other, or alter the grain sizes in the logs, because this is the only hard data that is present. The geological explanation for these large differences in grain size abundances could be the reworking on grains of waves.

References

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Appendices

Appendix A, 2DStratSim model

Below is an example of the scripts of the 2DStratSim model. The scripts and configuration file have been altered to produce the desired simulations.

Input script

The 'input' script reads the input matrices presented in Appendix B. An example of the script is presented below.

```
%% 2DStratSim
%INPUT
clc; clear all; fclose all;

timesteps=xlsread('2DStratSiminput','L2:L2');
timestep=xlsread('2DStratSiminput','K2:K2');
sandRatio = xlsread('2DStratSiminput','M2:M2');

fluvialtotal2(:,1)= xlsread('2DStratSiminput','A2:A5').*timestep;
fluvialtotal2(:,2)= xlsread('2DStratSiminput','B2:B5');

suspendedvolume2(:,1)= xlsread('2DStratSiminput','E2:E5').*timestep;
suspendedvolume2(:,2)=xlsread('2DStratSiminput','F2:F5');

sandvolume2(:,1)= xlsread('2DStratSiminput','C2:C5').*timestep;
sandvolume2(:,2)=    xlsread('2DStratSiminput','D2:D5');


sea(:,1)= xlsread('2DStratSiminput','G2:G5').*timestep;
sea(:,2)=     xlsread('2DStratSiminput','H2:H5');

subsidence2(:,1)= xlsread('2DStratSiminput','I2:I5').*timestep;
subsidence2(:,2)=    xlsread('2DStratSiminput','J2:J5');

%=====================================================================
% INTERPOLATE AND SAVE

nT = timesteps;
sinY = 60*60*24*365.25;
sumQ1 = 0;
sumQ2 = 0;
sumQ3 = 0;
tt=nT:-1:1;

t=1:nT;
for ttt=1:nT
    ttt
dt(ttt)=timestep;
end

sealevels = interpolate (sea, dt);
fluvialtotal= interpolate (fluvialtotal2, dt);
sandvolume= interpolate (sandvolume2, dt);
suspendedvolume= interpolate (suspendedvolume2, dt);
subsidence=interpolate(subsidence2,dt);
```

```
fid = fopen('catchFile.txt','w'); % t dt qw qs(n) sl up
fprintf(fid,'%d\n',nT);

for t=1:nT
        fprintf(fid,'%d %d %.5d %.5d %.5d %.5d %.5d %.5d %.5d \n', t,
timestep, fluvialtotal(t), ...
subsidence(t),sandvolume(t)/sandRatio, sandvolume(t)*(sandRatio-
1)/sandRatio, suspendedvolume(t),sealevels(t),0);

end


%======================================================================
% PLOT

figure;
tt=nT:-1:1;
t=1:nT;
subplot(221),plot(tt,sandvolume(tt)/sandRatio,'.','MarkerSize',5);
title('Bed Load 1'); xlabel('Time'); ylabel('Sediment Load');
subplot(222),plot(tt,sandvolume(tt)*(sandRatio-
1)/sandRatio,'.','MarkerSize',5); title('Bed Load 2'); xlabel('Time');
ylabel('Sediment Load');
subplot(223),plot(tt,suspendedvolume(tt),'.','MarkerSize',5);
title('Suspended Load'); xlabel('Time'); ylabel('Sediment Load');
subplot(224),plot(tt,sealevels(tt),'.','MarkerSize',5);title('Sea Level');
xlabel('Time'); ylabel('Sea Level');

nsT=nT;
timesstep=timestep;
save timesstep timesstep nsT
```

Configuration file

In the configuration file certain variables may be altered. An example of the file is presented below.

```
runMode              = "Forward";              # modeling, "Forward" of
"Backward"

inversion.relVar     = 1.0;                    # relative variance
inversion.minIter    = 100;                    # minimum number of
iterations before burn-in is complete
inversion.maxIter    = 100000;                 # maximum number of
iterations before burn-in is complete
inversion.steadyIter = 1000;                   # number steady iterations
before burn-in is complete
inversion.sampleIter = 10000;                  # number of iterations for
sampling
inversion.maxTemp    = 1;                      # maximum temperature for
simmulated tempering

FPSwitch             = false;                  # floodplain, on = true
BarSwitch            = true;                   # bar, on = true
WaveSwitch           = true;                   # waves, on = true
newElev              = false;                  # create new floodplain
equilibrium profile, on = true
```

```
addNoise              = false;                  # add noise to well
measurements for inversion, on = true
elevFPFile            = "elevFPFile.txt";       # name of file which
contains floodplain elevation

simulationTime        = 6000000.0;                  # time being simulated
nTimeSteps            = 6000;                       # number of timesteps

nFloodplainCells      = 2000;                       # number of floodplain
cells
FloodPlainCellSize    = 1000.0;                 # size of floodplain cells
floodplainSlopes      = [ 0.002, 0 ];           # slope of (inititial)
floodplain, only first value is used
FPWidthValue          = 10000.0;                # width of the floodplain
FPFaultLoc            = 10;                     # location of fault on
floodplain
sideInflow            = 0.01;                   # amount of sediments which
is NOT coming from the start of the floodplain, but is added along it's
entire length

nDeltaCells           = 50;                     # number of delta cells
deltaCellSize         = 1000.0;                 # size of delta cells
rivermouth            = 100.0;                  # width of rivermouth, only
used for marine dispersion
deltaSlope            = [ 0.0106, 0.0106 ];     # slope of delta profile, 2
values are used when a change in profile is required
deltaCoastLocation    = 1000;                       # location of change in
delta profile, often equal to coast
maxGradient           = 0.01;                   # maximum gradient of the
marine part
tectonicsData         = [ 0, 400 ];             # tectonics offshore: [
type (0: none 1:graben 2:half-graben 3:rotation) , fault/hinge location in
m  ]

nBarCells             = 100;                    # number of bar cells
barCellSize           = 1000.0;                 # size of bar cells
barWidth              = 20000.0;                # width of the bar
barSlope              = [ 0.00825, 0.00825 ];       # slope of bar profile,
2 values are used when a change in profile is required
barCoastLocation      = 1000;                       # location of change in
bar profile, often equal to coast

cg                    = 0.1;                    # for h calculations, used
for locally diferent behaviour
cw                    = 1.0;                    # for h calculations, for
different waveheight
dref                  = 125.0;                  # grainsize in um for which
larger = badload, smaller is suspended load
nGrainsizeFractions   = 3;                      # number of grainsize
fraction
grainSize             = [ 500, 125, 12 ];       # grainszies, from coarse
to fine in um
hMarFact              = [  2.0, 2.0 , 1.0 ];    # h correction for marine
domain
hFluvFact             = [ 500.0, 1000.0, 2000.0 ]; ## h correction for
fluvial domain
hBBFact               = [ 1.0, 1.0 , 1.0];      # h correction backbarrier
hFPFact               = [ 10.0, 10.0, 50.0 ];   # h correction for
floodplain
waveheightFW          = 2.0;                    # fairweather waveheight
```

```
waveStorm           = 7.0;                      # storm waveheight
stormFrequency      = 50;                       # storm frequency, per
timestep
peatThickness       = 0.1;                      # maximum thickness of peat
deposition, per year in m
cc                  = 7.0;                      # ratio of wavedepth over
waveheight
ce                  = 0.05;                     # ratio of mean shoreface
to local shoreface
kf                  = 2.0e-10;                  # control fluvial erosion
in marine domain (i.e. caused by fluvial water movement)
km                  = 8.0e-15;                  # control fluvial erosion
in fluvial domain
windErosion         = 0.0;                      # maximum amount of wind
erosion per year
barTransport        = [ 0.2, 0.2, 0.05 ];      # fracion of all available
sediment on delta which gets transported to bar for each grainsize
fallout             = [ 0, 0, 0 ];              # marine sediment fall out
baseGrInSubsurface  = [ 0.5, 0.4, 0.1 ];       # fraction of sediments in
subsurface (~bedrock)
grind               = [ 0.005 , 0.005 , 0 ];   # fraction of each
grainsize which is grinded to a smaller grainsize per timestep
bioturbParameters   = [ 0.01 , 0.01 ];          # bioturbation occurs when
a layer is thinner than minmaxThick(0) and the underlying layer is thinner
that minmaxThick(1)
catchFile           = "catchFile.txt";          # data file for all
controlling parameters, format: t dt qw qs(nGr) sealevel uplift

# data when not using catchFile

upliftRate.fixed   = true;                      # whether to use this
parameter in an inversion, true means the parameter is fixed and can not be
used for inversion
upliftRate.values  = [ 0, 0, 100, 0 ];          # values between which will
be interpolated. Each set of 2 consists of time and value, e.g. [time1,
value1, time2, value2]. Using only time1=0 will keep values constant for
entire run.
upliftRate.minvals = [ 0, 0 ];                  # minimum values for
inversion. Same format as values.
upliftRate.maxvals = [ 0, 1 ];                  # maximum values for
inversion. Same format as values.
upliftRate.mindim  = 2;                         # minimum number of points
between which will be interpolated
upliftRate.maxdim  = 50;                        # minimum number of points
between which will be interpolated

seaLevel.fixed   = false;
seaLevel.values  = [ 0, 0, 100, 0 ];
seaLevel.minvals = [ 0, -50 ];
seaLevel.maxvals = [ 0, 10 ];
seaLevel.mindim  = 2;
seaLevel.maxdim  = 50;

Qw.fixed   = false;
Qw.values  = [ 0, 0, 100 , 0];
Qw.minvals = [ 0, 0 ];
Qw.maxvals = [ 0, 1e6 ];
Qw.mindim  = 2;
Qw.maxdim  = 50;
```

```
Qs1.fixed   = false;
Qs1.values  = [ 0, 0.3, 100, 0.3 ];
Qs1.minvals = [ 0, 0 ];
Qs1.maxvals = [ 0, 1e6];
Qs1.mindim  = 2;
Qs1.maxdim  = 50;

Qs2.fixed   = false;
Qs2.values  = [ 0, 0.5, 100, 0.5 ];
Qs2.minvals = [ 0, 0 ];
Qs2.maxvals = [ 0, 1e6 ];
Qs2.mindim  = 2;
Qs2.maxdim  = 50;

Qs3.fixed   = false;
Qs3.values  = [ 0, 1.4, 100, 1.4 ];
Qs3.minvals = [ 0, 0 ];
Qs3.maxvals = [ 0, 1e6 ];
Qs3.mindim  = 2;
Qs3.maxdim  = 50;

Subs.fixed   = false;
Subs.values  = [ 0, -1.3, 25, 0 , 100, 0 ];
Subs.minvals = [ 0, -10 ];
Subs.maxvals = [ 0, 1e6 ];
Subs.mindim  = 2;
Subs.maxdim  = 50;

wellFile             = "wells.conf";

well1.kind           = "Thickness";
well1.region         = "Delta";
well1.position       = 3000.0;

well2.kind           = "Phi1";
well2.region         = "Delta";
well2.position       = 3000.0;

well3.kind           = "Phi2";
well3.region         = "Delta";
well3.position       = 3000.0;

well4.kind           = "Thickness";
well4.region         = "Delta";
well4.position       = 4500.0;

well5.kind           = "Phi1";
well5.region         = "Delta";
well5.position       = 4500.0;

well6.kind           = "Phi2";
well6.region         = "Delta";
well6.position       = 4500.0;

well7.kind           = "Thickness";
well7.region         = "Delta";
well7.position       = 2000.0;

well8.kind           = "Phi1";
```

```
well8.region          = "Delta";
well8.position        = 2000.0;

well9.kind            = "Phi2";
well9.region          = "Delta";
well9.position        = 2000.0;

well10.kind            = "Thickness";
well10.region          = "Delta";
well10.position        = 2500.0;

well11.kind            = "Phi1";
well11.region          = "Delta";
well11.position        = 2500.0;

well12.kind            = "Phi2";
well12.region          = "Delta";
well12.position        = 2500.0;
```

Plotstrat script

The ‘plotstrat’ script produces the simulation of the delta and beach ridges. An example of the script is presented below.

```
%% 2DStratSim
% MAIN SCRIPT

clear all; close all; clc;

load timesstep
load logplot

%============================================================================
%SWITCHES

logSwitch = 1;
stratSwitch = 0;
simpSwitch = 0;
newData = 1;
nGr = 3;
runSwitch=1;
comparisonswitch=1;
inputplotswitch=1;

%============================================================================
%TIMELINES
timeLines = 1;
nTimes=nsT/2*(timesstep/(10000));
nTimeSteps = nsT;

%============================================================================
%LOGS POSITION
deltaLogs = [22,28,38];
FPLogs = [20, 130, 200, 500];
barLogs = [19,37,65];
```

```
%=========================================================================
%MODEL RUN
if runSwitch==1
runTest = dos('2DStratSim.exe');
end

%=========================================================================
%PLOTS

fprintf('\nStart plotting results:\n\n')

for plotNr=1:2:3 % 1:delta 2:floodplain 3:bar
% load data
    h = figure('Units','normalized','Position',[0 0 1 1]);

    if newData == 1
        if plotNr == 1
            fprintf('load delta data\n')
            A = importdata('outputD.out');
        elseif plotNr == 2
            fprintf('load floodplain data\n')
            clear('A');
            A = importdata('outputFP.out');
        else
            fprintf('load bar data\n')
            clear('A');
            A = importdata('outputB.out');
        end

        B = 0.0001*ones(size(A,1),8);
        B(:,1:5+nGr) = A;
        A = B;


        nx = A(end,1);
        startelev = 1.2089;
        A = A';
        A(1,:) = A(1,:) + 1; % for MATLAB numbering
        A(2,:) = A(2,:) + 1; % for MATLAB numbering
        nx = A(1,end);

        fprintf('making strat array...')
        dataSize = size(A,2);
        startV=1;

        % fill strat
        for x=1:nx
            endV = startV + find(A(2,startV+1:end) == 1,1,'first')   ;
            for l=1:endV-startV
                strat(x,l,:) = A(3:nGr+5,startV+l-1);
            end
            startV = endV;
        end


        for c=1:size(A,2)
            strat(A(1,c) , A(2,c) , :) = A(3:end,c);
        end
```

```
        fprintf('done\n')

%% simplify stratigraphy

        if simpSwitch == 1
            fprintf('simplifying stratigraphy\n')
            minThick = 0.01;
            maxThick = 0.1;

            for x=1:nx
                nLayer = find(strat(x,:,1) == 0,1,'first') - 1;
                if sum(nLayer) == 0;
                    nLayer = size(strat,2);
                end
                fprintf('\nx=%.0f totalThick=%.0f
nLayer=%.0f',x,sum(strat(x,:,1)),nLayer)
                l = 1;
                while l<nLayer
                    l=l+1;
        %              fprintf('l=%.0f, nLayer=%.0f, thickness=%.4d,
below=%.4d, totalThick=%.0f',l,nLayer,strat(x,l,1),strat(x,l-
1,1),sum(strat(x,:,1)))
                    if ((strat(x,l,1)<minThick) && (strat(x,l-1,1) <
maxThick ))%combine
        %                  fprintf(' combine')
                        strat(x,l-1,2) = ( strat(x,l-1,2)*strat(x,l-1,1) +
strat(x,l,2)*strat(x,l,1) ) / (strat(x,l-1,1) + strat(x,l,1)); %time
averaged relative to thickness
                        strat(x,l-1,4) = ( strat(x,l-1,4)*strat(x,l-1,1) +
strat(x,l,4)*strat(x,l,1) ) / (strat(x,l-1,1) + strat(x,l,1)); %phi
averaged relative to thickness
                        strat(x,l-1,5) = ( strat(x,l-1,5)*strat(x,l-1,1) +
strat(x,l,5)*strat(x,l,1) ) / (strat(x,l-1,1) + strat(x,l,1)); %phi
averaged relative to thickness
                        strat(x,l-1,6) = ( strat(x,l-1,6)*strat(x,l-1,1) +
strat(x,l,6)*strat(x,l,1) ) / (strat(x,l-1,1) + strat(x,l,1)); %phi
averaged relative to thickness
                        strat(x,l-1,1) = strat(x,l-1,1) + strat(x,l,1);
%thickness

                        strat(x,l:nLayer-1,:) = strat(x,l+1:nLayer,:);
                        strat(x,nLayer,:) = [0 0 0 0 0 0];
                        nLayer = nLayer-1;
                        l=l-1;
        %                  fprintf(' thick combined=%.4d, nLayer=%.0f,
l=%.0f\n',strat(x,l,1),nLayer,l)

                    else
        %                  fprintf(' do not combine\n')
                    end
                end
        %          fprintf('x=%.0f totalThick=%.0f\n',x,sum(strat(x,:,1)))
        %          pause
                fprintf(' nLayer=%.0f\n',nLayer)
            end
            fprintf('\n')
        end


    else
```

```
        if plotNr == 1
            load('Dstrat good')
            nx=size(strat,1);
        elseif plotNr == 2
            load('FPstrat')
            nx=size(strat,1);
        else
            load('Bstrat good')
            nx=size(strat,1);
        end
    end



    %% stratigraphy

    minR = 0;
    maxR = 1;
    minG = 0;
    maxG = 1;
    minB = 0;
    maxB = 1;

% strat format: [thickness, time, peat, phi, phi, phi]
    if (stratSwitch == 1)
        fprintf('plot stratigraphy\n')
        for x=1:nx
            fprintf('%.0f ',x)
            nLayer = find(strat(x,:,1) == 0,1,'first') - 1;
            if sum(nLayer) == 0;
                nLayer = size(strat,2);
            end
            for l=2:nLayer
                if l==1
                    sedtop = 0;
                else
                    sedtop = sum(strat(x,1:l-1,1));
                end

                if strat(x,l,5) == 1

                    subplot(2,4,1:4),rectangle('Position',[x-
0.5,sedtop,1,strat(x,l,1)],'FaceColor',[0 0 0],'LineStyle','-') ;

                else


                    r = (strat(x,l,4) - minR) / (maxR - minR);
                    g = (strat(x,l,5) - minG) / (maxG - minG);
                    if (maxB-minB ) == 0
                        b=0;
                    else
                        b = (strat(x,l,6) - minB) / (maxB - minB);
                    end
%                     fprintf('r=%.3f g=%.3f b=%.3f\n',r,g,b)
                    subplot(2,4,1:4),rectangle('Position',[x-
0.5,sedtop,1,strat(x,l,1)],'FaceColor',[r g b],'LineStyle','none') ;
                end
            end
```

```
    end
    if plotNr == 1
        axis([0 nx 0 60])
        axis ('auto y')
    elseif plotNr == 2
        axis([0 nx 0 60])
        axis ('auto y')
    elseif plotNr == 3
        axis([0 nx 0 60])
        axis ('auto y')
    end
    xlabel('x location (cells)'); ylabel('elevation (m)')
    set(gca,'FontSize',7)

    hold on;


    fprintf('plot elev (k)')
    elev=NaN*ones(nx);
    for x=1:nx
        elev(x) = sum(strat(x,:,1));
        if (elev(x) == 0)
            elev(x) = NaN;
        end
    end
    subplot(2,4,1:4),plot(elev,'k','LineWidth',2)
    hold on;
    fprintf(' done\n')



end

fprintf('\n')
%% elevation
if (stratSwitch == 0)
    fprintf('plot elev (k)')
    elev=NaN*ones(nx);
    for x=1:nx
        elev(x) = sum(strat(x,:,1));
        if (elev(x) == 0)
            elev(x) = NaN;
        end
    end
    if plotNr==1
        elev=elev-10000;
    end

    subplot(2,4,1:4),plot(elev,'k','LineWidth',2)
    hold on;
    fprintf(' done\n')


    fprintf('plot base (y)')
    base=NaN*ones(nx);
    for x=1:nx
        base(x) = strat(x,1,1);
        if (base(x) == 0)
            base(x) = NaN;
```

```
            end
        end

           if plotNr==1
            base=base-10000;
        end
        subplot(2,4,1:4),plot(base,'y','LineWidth',2)
        fprintf(' done\n')


        if plotNr == 1
            axis([0 nx 0 60])
            axis ('auto y')
        elseif plotNr == 2
            axis([0 nx 0 60])
            axis ('auto y')
        elseif plotNr == 3
            axis([0 nx 0 60])
            axis ('auto y')
        end
    end

    if timeLines == 1
        for t=1:nTimes
            for x=1:nx
                timeLoc = find (strat(x,:,2) >=
t*nTimeSteps/nTimes,1,'first');
                timelines(x) = sum(strat(x,1:timeLoc,1));
                if (timelines(x) == 0)
                    timelines(x) = NaN;
                end
            end
                    if plotNr==1
            timelines=timelines-10000;
        end
            subplot(2,4,1:4),plot(timelines,'k')
        end
    end



    if plotNr == 1
        title('Delta Stratigraphy','FontSize',12,'FontWeight','bold')
    elseif plotNr == 2
        title('Floodplain Stratigraphy','FontSize',12,'FontWeight','bold')
    elseif plotNr == 3
        title('Bar Stratigraphy','FontSize',12,'FontWeight','bold')
    end

    drawnow

    %% logs
    if logSwitch ==1
        fprintf('plot logs\n')
        for LogLoc = 1:3
            fprintf('log %.0f... ',LogLoc)

            if plotNr == 1
                xLoc = deltaLogs;%[ceil(nx/3), ceil(nx/2), ceil(nx*2/3) ];
```

```
            elseif plotNr == 2
                xLoc = FPLogs;%[1, 50, 100, 150];
            elseif plotNr == 3
                xLoc = barLogs;%[20, 130, 200, 500];
            end
            x=xLoc(LogLoc);

            movingAv = 0;
            nLayer = find(strat(x,:,1) == 0,1,'first') - 1;
            if sum(nLayer) == 0;
                nLayer = size(strat,2);
            end

            for l=2:nLayer
                if l==1
                    sedtop = 0;
                else
                    sedtop = sum(strat(x,1:l-1,1));
                end

                r = (strat(x,l,4) - minR) / (maxR - minR);
%                 strat(x,l,4)
                g = (strat(x,l,5) - minG) / (maxG - minG);
%                 strat(x,l,5)
                b = (strat(x,l,6) - minB) / (maxB - minB);
%                 strat(x,l,6)

                grSizes = [300 , 100 , 25];
                avGrSize = strat(x,l,4)*grSizes(1) +
strat(x,l,5)*grSizes(2) + strat(x,l,6)*grSizes(3);
                    if plotNr==1
            sedtop=sedtop-10000;
                    end


subplot(2,4,4+LogLoc),rectangle('Position',[0,sedtop,avGrSize,strat(x,l,1)]
,'FaceColor',[r g b],'LineStyle','none') ;

                if comparisonswitch==1;
                %===========================================================
                %COMPARISON

                %-----------------------------------------------------------
                %DELTA
                if plotNr==1
                       if LogLoc==1;
                           hold on; plot(HC1plot(:,2),HC1plot(:,1)-1+
base(xLoc(LogLoc)))
                       end
                       if LogLoc==2
                           hold on; plot(HC4plot(:,2),HC4plot(:,1) -7+
base(xLoc(LogLoc)))
                       end
                       if LogLoc==3
                           hold on; plot(C3plot(:,2),C3plot(:,1) -9+
base(xLoc(LogLoc)))
                       end
                end

                %-----------------------------------------------------------
```

```
                %BAR
                if plotNr==3
                       if LogLoc==1;
                           hold on; plot(linkplot(:,2),linkplot(:,1)-
4+base(xLoc(LogLoc)))
                       end
                       if LogLoc==2
                           hold on; plot(ferronplot(:,2),ferronplot(:,1)-
9+base(xLoc(LogLoc)))
                       end
                       if LogLoc==3
                           hold on;
plot(straightplot(:,2),straightplot(:,1)-20+base(xLoc(LogLoc)))
                       end
                end

                %============================================================
                end
            end



            title(['Log at x =
',num2str(x)],'FontSize',12,'FontWeight','bold')
            xlabel('average grainsize (\mum)'); ylabel('elevation (m)')
            set(gca,'FontSize',7)
        end
    end
    fprintf('\n\n')



end


if inputplotswitch==1;
plotYearlyData
end
```

Appendix B, Input Matrices

Below the input matrices are presented of all the simulations presented at the chapter 'Results'.

Table 9, Input Matrix Simulation 1

Qwtime	Qw	Qbtime	Qb	Qstime	Qs	seatime	sea	subtime	sub	time step length	# time steps	sandratio
0	500	0	0,05	0	0,005	0	0	0	0	300	100	2
80	500	80	0,05	80	0,003	80	-200	80	0			
82	500	82	0,02	82	0,003	82	-100	82	0			
100	500	100	0,02	100	0,003	100	-200	100	0			

Table 10, Input Matrix Simulation 2

Qwtime	Qw	Qbtime	Qb	Qstime	Qs	seatime	sea	subtime	sub	time step length	# time steps	sandratio
0	500	0	0,02	0	0,05	0	0	0	0	800	100	2
85	500	85	0,02	85	0,02	85	-20	85	0			
87	500	87	0,01	87	0,01	87	-10	87	0			
100	500	100	0,01	100	0,01	100	-15	100	0			

Table 11, Input Matrix Simulation 3

Qwtime	Qw	Qbtime	Qb	Qstime	Qs	seatime	sea	subtime	sub	time step length	# time steps	sandratio
0	500	0	0,02	0	0,07	0	0	0	0	1000	100	1,5
30	500	30	0,03	30	0,06	30	-5	30	0			
60	500	60	0,04	60	0,05	60	-10	60	0			
75	500	75	0,05	75	0,04	75	-15	75	0			
82	500	82	0,06	82	0,03	82	-17	82	0			
90	500	90	0,07	90	0,02	90	-20	90	0			
91	500	91	0,07	91	0,02	91	-10	91	0			
100	500	100	0,07	100	0,02	100	-15	100	0			

Table 12, Input Matrix Simulation 4

Qwtime	Qw	Qbtime	Qb	Qstime	Qs	seatime	sea	subtime	sub	e step len	time step	sandratio
0	500	0	0,15	0	0,1	0	0	0	0	1000	100	1,4
40	500	40	0,1	40	0,075	40	-4	40	0			
50	500	50	0,02	50	0,03	50	-10	50	0			
60	500	60	0,01	60	0,005	60	-16	60	0			
70	500	70	0,01	70	0,005	70	-22	70	0			
80	500	80	0,01	80	0,005	80	-28	80	0			
84	500	84	0,005	84	0,04	84	-7	84	0			
95	500	95	0,008	95	0,01	95	-10	95	0			
97	500	97	0,006	97	0,03	97	-10	97	0			
100	500	100	0,0005	100	0,1	100	-9	100	0			
Total			**0,3195**		**0,4**							

Appendix C, Model Configurations

Below all model configurations are presented of the simulations presented in the Chapter 'Results'. Note: only the altered variables are presented.

Table 13, Configuration Simulation 1

```
nDeltaCells         = 50;
deltaCellSize       = 1000.0;
rivermouth          = 100.0;
deltaSlope          = [ 0.0106, 0.0106 ];
deltaCoastLocation  = 1000;

nBarCells           = 100;
barCellSize         = 1000.0;
barWidth            = 20000.0;
barSlope            = [ 0.00825, 0.00825 ];
barCoastLocation    = 1000;

grainSize           = [ 500, 125, 12 ];
hMarFact            = [  2.0, 2.0 , 1.0 ];
hFluvFact           = [ 500.0, 1000.0, 2000.0 ]

waveheightFW        = 2.0;
waveStorm           = 7.0;
stormFrequency      = 50;

barTransport        = [ 0.2, 0.2, 0.05 ];
```

Table 14, Configuration Simulation 2

```
nDeltaCells         = 50;
deltaCellSize       = 1000.0;
rivermouth          = 100.0;
deltaSlope          = [ 0.002, 0.002];
deltaCoastLocation  = 1000;

nBarCells           = 50;
barCellSize         = 1000.0;
barWidth            = 20000.0;
barSlope            = [ 0.002, 0.002 ];
barCoastLocation    = 1000;

grainSize           = [ 500, 125, 12 ];
hMarFact            = [  2.0, 2.0 , 1.0 ];
hFluvFact           = [ 500.0, 1000.0, 2000.0 ]

waveheightFW        = 2.0;
waveStorm           = 7.0;
stormFrequency      = 50;

barTransport        = [ 0.2, 0.2, 0.05 ];
```

Table 15, Configuration Simulation 3

```
nDeltaCells         = 100;
deltaCellSize       = 1000.0;
rivermouth          = 100.0;
deltaSlope          = [ 0.0005, 0.0005 ];
deltaCoastLocation  = 1000;

nBarCells           = 120;
barCellSize         = 1000.0;
barWidth            = 10000.0;
barSlope            = [ 0.0005, 0.0005 ];
barCoastLocation    = 1000;

grainSize           = [ 500, 125, 12 ];
hMarFact            = [  2.5, 2.5 , 1.5 ];
hFluvFact           = [ 500.0, 1000.0, 2000.0 ];

waveheightFW        = 2.0;
waveStorm           = 7.0;
stormFrequency      = 50;

barTransport        = [ 0.2, 0.2, 0.05 ];
```

Table 16, Configuration Simulation 4

```
nDeltaCells         = 100;
deltaCellSize       = 1000.0;
rivermouth          = 100.0;
deltaSlope          = [ 0.0005, 0.0005 ];
deltaCoastLocation  = 1000;

nBarCells           = 120;
barCellSize         = 1000.0;
barWidth            = 10000.0;
barSlope            = [ 0.0007, 0.0007 ];
barCoastLocation    = 1000;

grainSize           = [ 500, 125, 12 ];
hMarFact            = [  2.5, 2.5 , 1.5 ];
hFluvFact           = [ 500.0, 1000.0, 2000.0 ]

waveheightFW        = 2.0;
waveStorm           = 7.0;
stormFrequency      = 100;

barTransport        = [ 0.1, 0.1, 0.025 ];
```