Supplementary Material

Downsystem grain-size trends and mass balance of an ancient wave-influenced sediment routing system: Middle Jurassic Brent Delta, northern North Sea, offshore UK and Norway

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Table S1. Wells in the study dataset (located in Figure 4B), and previously published sequence stratigraphic frameworks (Figure 3) that include interpretations of these wells.

Well (Figure 4B)	Well name	Stratigraphic interpretation (Figure 3)
1	34/2-4	after Fjellanger et al. (1996)
2	34/4-5	after Mitchener et al. (1992)
3	34/4-3	after Sneider et al. (1995)
4	211/13-6	Penguin Field; after Mitchener et al. (1992), Fjellanger et al. (1996)
5	211/19-6	Murchison Field; after Hampson et al. (2004)
6	211/18-21	Don Field; after Mitchener et al. (1992)
7	211/18-22	Don Field; after Fjellanger et al. (1996)
8	33/9-14	Statfjord Nord Field; after Fjellanger et al. (1996)
9	211/19-3	Murchison Field; after Hampson et al. (2004)
10	211/19-5	after Hampson et al. (2004)
11	211/19-1	Thistle Field; after Hampson et al. (2004)
12	211/18-19	Thistle Field; after Hampson et al. (2004)
13	211/16-6	Eider Field; after Fjellanger et al. (1996), Hampson et al. (2004)
14	210/20-2	after Hampson et al. (2004)
15	210/20-1	after Hampson et al. (2004)
16	210/25-2	Tern Field; after Hampson et al. (2004)
17	211/21-5	Cormorant North Field; after Hampson et al. (2004)
18	211/21-6	Cormorant North Field; after Hampson et al., 2004)
19	211/22-1	after Hampson et al. (2004)
20	211/22-2	after Fjellanger et al. (1996)
21	211/23-6	Dunlin South West; after Mitchener et al. (1992)
22	211/23-2	Dunlin South West; after Hampson et al. (2004)
23	211/24-5	after Hampson et al. (2004)
24	211/24-4	Statfjord Field; after Fjellanger et al. (1996)
25	33/9-3	Statfjord Field; after Fjellanger et al. (1996)
26	34/10-5	Gullfaks Field; after Mitchener et al. (1992)
27	34/8-1	Visund Field; after Fjellanger et al. (1996)
28	35/8-1	Vega Field; after Fjellanger et al. (1996)
29	35/8-3	after Fjellanger et al. (1996)
30	35/8-2	Vega Field; after Sneider et al. (1995)
31	35/11-2	after Sneider et al. (1995)
32	210/24-5	after Hampson et al. (2004)
33	211/26-2	Cormorant South Field; after Hampson et al. (2004)
34	211/27-3	North West Hutton Field; after Mitchener et al. (1992)
35	211/27-10	North West Hutton Field; after Hampson et al. (2004)
36	211/28-1	Hutton Field; after Fjellanger et al. (1996), Hampson et al. (2004)
37	211/28-5	after Fjellanger et al. (1996), Hampson et al. (2004)
38	211/29-3	Brent Field; after Fjellanger et al. (1996), Hampson et al. (2004)
39	211/29-2	Brent Field; after Hampson et al. (2004)
40	34/10-17	Gullfaks Sør Field; after Fjellanger et al. (1996)
41	34/10-23	Valemon Field; after Fjellanger et al. (1996)
42	2/5-3	Heather Field; after Hampson et al. (2004)
43	2/5-17	Broom Field; after Hampson et al. (2004)
44	3/1-1	after Hampson et al. (2004)
45	3/2-3	Lyell Field; after Hampson et al. (2004)
46	3/2-4	Lyell Field; after Hampson et al. (2004)
47	3/2-6	after Mitchener et al. (1992)
48	3/3-3	Ninian Field; after Mitchener et al. (1992), Hampson et al. (2004)
49	3/3-7	Ninian Field; after Hampson et al. (2004)
50	3/3-8	after Hampson et al. (2004)
51	3/4-1	Brent Field; after Hampson et al. (2004)
52	3/4-13	Strathspey Field; after Mitchener et al. (1992)
53	3/4-9	Strathspey Field; after Hampson et al. (2004)

54	3/4-12	Strathspey Field; after Hampson et al. (2004)
55	3/4-8	Alwyn North Field; after Hampson et al. (2004)
56	30/2-2	Huldra Field; after Fjellanger et al. (1996)
57	31/2-4	Troll Field; after Sneider et al. (1995)
58	31/2-3	Troll Field; after Sneider et al. (1995)
59	2/10-2	after Mitchener et al. (1992)
60	3/7-5	after Hampson et al. (2004)
61	3/8-6	Ninian Field; after Hampson et al. (2004)
62	3/12-2	after Mitchener et al. (1992)
63	3/8-10	Staffa Field; after Mitchener et al. (1992)
64	3/8-1	Ninian Field; after Mitchener et al. (1992)
65	3/9-4	Alwyn North Field; after Hampson et al. (2004)
66	3/9-2	Alwyn North Field; after Fjellanger et al. (1996)
67	3/10-1	after Hampson et al. (2004)
68	29/6-1	Martin Linge Field; after Fjellanger et al. (1996)
69	30/9-2	Oseberg Field; after Fjellanger et al. (1996)
70	30/6-8	after Fjellanger et al. (1996)
71	31/4-3	Brage Field; after Fjellanger et al. (1996)
72	31/6-8	Troll Field; after Fjellanger et al. (1996)
73	30/9-8	Oseberg Sør Field; after Fjellanger et al. (1996)
74	30/11-3	after Fjellanger et al. (1996)
75	25/2-7	after Fjellanger et al. (1996)
76	79/9-3	Bruce Field; after Mitchener et al. (1992)
77	9/13-12	Beryl Field; after Fjellanger et al. (1996)
78	24/6-1	after Fjellanger et al. (1996)
79	15/3-3	Gudrun Field; after Sneider et al. (1995), Kieft et al. (2011)
80	15/3-1	Gudrun Field; after Sneider et al. (1995), Kieft et al. (2011)
81	15/3-4	after Sneider et al. (1995), Kieft et al. (2011)
82	15/9-3	Sleipner Vest; after Sneider et al. (1995), Kieft et al. (2011)
83	15/9-1	Sleipner Vest; after Sneider et al. (1995), Kieft et al. (2011)
84	15/9-2	Sleipner Vest; after Sneider et al. (1995), Kieft et al. (2011)
85	15/9-7	Sleipner Vest; after Sneider et al. (1995), Kieft et al. (2011)

Table S2. Cored intervals studied for selected wells (after table S1 of Okwara et al., 2023).

Well	Field name	Top core (m/ft)	Base core (m/ft)	Core recovery	Thickness (m)	Core-wireline shift (m/ft)
2/5-3	Heather	3350 m / 10992 ft	346 m / 11362 ft	100%	113	3.0 m / 10 ft
3/4a-12	Strathspey	2877 m / 9440 ft	3141 m / 10306 ft	100%	264	1.8 m / 6 ft
3/8b-10	Staffa	4052 m / 13294 ft	4176 m / 13701 ft	100%	124	3.0 m / 10 ft
9/9b-3	Bruce	3666 m / 12028 ft	4002 m / 13130 ft	88%	296	1.5 m / 5 ft
35/8-1	Vega	3523 m / 11557 ft	3710 m / 12171 ft	95%	187	1.2 m / 4 ft
210/20-2		2858 m / 9375 ft	2967 m / 9733 ft	100%	109	1.8 m / 6 ft
211/19-6	Murchison	3205 m / 10516 ft	3325 m / 10910 ft	100%	120	0.6 m / 2 ft
30/2-2	Huldra	3939 m / 12923 ft	4135 m / 13568 ft	100%	148	0 m / 0 ft
Total thickness					***1361***	

Table S3. Calculated values of downsystem extraction of cumulative sediment mass normalised against the cumulative sediment mass in the sediment routing system volume (χ; Equation 1) for genetic sequence J22 (Figures 5, 10, S2).

transverse transect for western basin margin, Shetland Platform source (Figure 10A, D)			
Wells at location	downsystem distance (km)	cumulative sediment mass extracted upsystem (x10^{12} kg)	Proportion of total sediment mass extracted upsystem (χ)
western boundary	0	0	0
210/24a-5, 2/5-17 (n=2)	16	8.70	0.03
2/5-3, 2/10a-2, 210/20-1, 210/20-2, 210/25-2, 211/26-2 (n=6)	29	87.7	0.27
3/1-1, 3/2-3, 211/16-6, 211/21-5, 211/21-6, 211/22-1 (n=6)	36	131	0.40
3/2-4, 3/2-6, 3/3-3, 3/7b-5, 3/8-6, 3/12-2, 211/22-2, 211/27-3, 211/27-10, 211/28-1 (n=10)	44	159	0.48
3/3-8, 3/3-7, 3/8-1, 3/8b-10, 211/13-6, 211/18-19, 211/18a-21, 211/18-22, 211/19-1, 211/23-2, 211/23-6, 211/28-5 (n=12)	57	217	0.66
3/4a-12, 3/4a-13, 3/4-1, 3/4-8, 3/4-9, 3/9-2, 3/9-4, 211/19-3, 211/19-5, 211/19-6, 211/24-2, 411/24-5, 211/29-2, 211/29-3 (n=14)	62	237	0.72
33/9-3, 33/9-14, 29/6-1, 3/10-1 (n=4)	77	295	0.89
34/10-5, 34/10-17, 34/4-3 (n=3) = eastern boundary	87	330	1.00

transverse transect for eastern basin margin, Norwegian Landmass source (Figure 10B, E)			
Wells at location	downsystem distance (km)	cumulative sediment mass extracted upsystem (x10^{12} kg)	Proportion of total sediment mass extracted upsystem (χ)
eastern boundary	0	0	0
31/6-8 (n=1)	39	64.2	0.12
31/2-3, 31/2-4, 35/8-3, 35/11-2 (n=4)	58	194	0.35
35/8-1, 35/8-2 (n=2)	60	208	0.38
31/4-3 (n=1)	76	293	0.53
30/6-8 (n=1)	85	334	0.61
30/9-2, 30/9-8 (n=2)	91	385	0.70
30/2-2, 34/2-4 (n=2)	107	496	0.90
34/8-1 (n=1)	110	509	0.93
34/10-23, 34/4-5 (n=2) = eastern boundary	119	550	1.00

axial transect for southern basin margin, Mid-North Sea High source (Figure 10C, F)			
Wells at location	downsystem distance (km)	cumulative sediment mass extracted upsystem (x10^{12} kg)	Proportion of total sediment mass extracted upsystem (χ)
southern boundary	0	0	0

24/6-1, 9/13-12st (n=2)	50	26.4	0.22
9/9b-3 (n=1)	74	72.2	0.60
25/2-7 (n=1)	89	97.4	0.81
30/11-3 (n=1) = northern boundary	101	121	1.00

Table S4. Calculated values of downsystem extraction of cumulative sediment mass normalised against the cumulative sediment mass in the sediment routing system volume (χ; Equation 1) for genetic sequence J24 (Figures 6, 11, S2).

axial transect for southern basin margin, Shetland Platform, Norwegian Landmass and Mid-North Sea High sources (Figure 11)			
Wells at location	downsystem distance (km)	cumulative sediment mass extracted upsystem (x10^{12} kg)	Proportion of total sediment mass extracted upsystem (χ)
southern boundary	0	0	0
24/6-1, 9/13-12st (n=2)	109	81.5	0.02
25/2-7 (n=1)	148	231	0.07
30/11-3 (n=1)	160	323	0.09
30/9-2, 30/9-8 (n=2)	197	639	0.18
29/6-1, 30/6-8, 31/4-3, 31/6-8 (n=4)	211	773	0.22
2/10a-2, 3/8-6, 3/8b-10, 3/7b-5 (n=4)	229	1050	0.30
3/2-6, 3/4-8, 3/8-1, 3/9-2, 3/9a-4, 3/10-1, 30/2-2, 31/2-3, 31/2-4 (n=9)	237	1200	0.34
2/5-17, 3/1-1, 3/2-3, 3/2-4, 3/3-3, 3/3-7, 3/3-8, 3/4a-12, 3/4a-13 (n=9)	246	1370	0.39
2/5-3, 3/4-1, 211/29-2, 34/10-23 (n=4)	256	1580	0.44
211/26-2, 211/27-3, 211/27-10, 211/28-1, 211/28-5, 211/29-3, 34/10-17 (n=7)	260	1690	0.48
210/24a-5, 211/21-5, 211/21-6, 211/22-2, 211/23-2, 211/23-6, 211/24-4, 211/24-5, 34/10-5, 35/11-2 (n=10)	277	2220	0.63
210/25-2, 211/22-1, 33/9-3, 35/8-2 (n=4)	289	2640	0.74
211/16-6, 211/18-19, 211/19-1, 211/19-3, 211/19-5, 34/8-1, 35/8-1, 35/8-2 (n=8)	301	3080	0.87
210/20-1, 210/20-2, 211/18a-21, 211/18-22, 211/19-6, 33/9-14 (n=6)	303	3180	0.90
211/13-6, 34/4-3, 34/4-5 (n=3)	312	3390	0.96
34/2-4 (n=1) = northern boundary	339	3550	1.00

Table S5. Calculated values of downsystem extraction of cumulative sediment mass normalised against the cumulative sediment mass in the sediment routing system volume (χ; Equation 1) for genetic sequence J26 (Figures 7, 12, S2).

axial transect for southern basin margin, Shetland Platform, Norwegian Landmass and Mid-North Sea High sources (Figure 12)			
Wells at location	downsystem distance (km)	cumulative sediment mass extracted upsystem (x10^{12} kg)	Proportion of total sediment mass extracted upsystem (χ)
southern boundary	0	0	0
24/6-1, 9/13-12st (n=2)	109	233	0.07
9/9b-3 (n=1)	133	437	0.13
25/2-7 (n=1)	148	617	0.19
30/11-3 (n=1)	160	750	0.23
30/9-2, 30/9-8 (n=2)	197	1190	0.36
29/6-1, 30/6-8, 31/4-3, 31/6-8 (n=4)	211	1370	0.42
2/10a-2, 3/8-6, 3/8b-10, 3/7b-5 (n=4)	229	1640	0.50
3/2-6, 3/4-8, 3/8-1, 3/9-2, 3/9a-4, 3/10-1, 30/2-2, 31/2-3, 31/2-4 (n=9)	237	1770	0.54
2/5-17, 3/1-1, 3/2-3, 3/2-4, 3/3-3, 3/3-7, 3/3-8, 3/4a-12, 3/4a-13 (n=9)	246	1960	0.60
2/5-3, 3/4-1, 211/29-2, 34/10-23 (n=4)	256	2160	0.66
211/26-2, 211/27-3, 211/27-10, 211/28-1, 211/28-5, 211/29-3, 34/10-17 (n=7)	260	2260	0.69
210/24a-5, 211/21-5, 211/21-6, 211/22-2, 211/23-2, 211/23-6, 211/24-4, 211/24-5, 34/10-5, 35/11-2 (n=10)	277	2640	0.80
210/25-2, 211/22-1, 33/9-3, 35/8-2 (n=4)	289	2850	0.87
211/16-6, 211/18-19, 211/19-1, 211/19-3, 211/19-5, 34/8-1, 35/8-1, 35/8-2 (n=8)	301	3030	0.92
210/20-1, 210/20-2, 211/18a-21, 211/18-22, 211/19-6, 33/9-14 (n=6)	303	3070	0.94
211/13-6, 34/4-3, 34/4-5 (n=3)	312	3170	0.96
34/2-4 (n=1) = northern boundary	339	3290	1.00

Table S6. Calculated values of downsystem extraction of cumulative sediment mass normalised against the cumulative sediment mass in the sediment routing system volume (χ; Equation 1) for genetic sequence J32 (Figures 8, 13, S2).

transverse transect for western basin margin, Shetland Platform source (Figure 13A, D)			
Wells at location	downsystem distance (km)	cumulative sediment mass extracted upsystem (x10^{12} kg)	Proportion of total sediment mass extracted upsystem (χ)
western boundary	0	0	0
210/24a-5, 2/5-17 (n=2)	16	110	0.09
2/5-3, 2/10a-2, 210/20-1, 210/20-2, 210/25-2, 211/26-2 (n=6)	29	168	0.14
3/1-1, 3/2-3, 211/16-6, 211/21-5, 211/21-6, 211/22-1 (n=6)	36	196	0.17
3/2-4, 3/2-6, 3/3-3, 3/7b-5, 3/8-6, 3/12-2, 211/22-2, 211/27-3, 211/27-10, 211/28-1 (n=10)	44	241	0.20
3/3-8, 3/3-7, 3/8-1, 3/8b-10, 211/13-6, 211/18-19, 211/18a-21, 211/18-22, 211/19-1, 211/23-2, 211/23-6, 211/28-5 (n=12)	57	361	0.31
3/4a-12, 3/4a-13, 3/4-1, 3/4-8, 3/4-9, 3/9-2, 3/9-4, 211/19-3, 211/19-5, 211/19-6, 211/24-2, 411/24-5, 211/29-2, 211/29-3 (n=14)	62	448	0.38
33/9-3, 33/9-14, 29/6-1, 3/10-1 (n=4)	77	881	0.74
34/10-5, 34/10-17, 34/4-3 (n=3) = eastern boundary	87	1190	1.00

transverse transect for eastern basin margin, Norwegian Landmass source (Figure 13B, E)			
Wells at location	downsystem distance (km)	cumulative sediment mass extracted upsystem (x10^{12} kg)	Proportion of total sediment mass extracted upsystem (χ)
eastern boundary	0	0	0
31/6-8 (n=1)	39	98.3	0.04
31/2-3, 31/2-4, 35/8-3, 35/11-2 (n=4)	58	384	0.15
35/8-1, 35/8-2 (n=2)	60	414	0.16
31/4-3 (n=1)	76	794	0.30
30/6-8 (n=1)	85	1150	0.44
30/9-2, 30/9-8 (n=2)	91	1480	0.56
30/2-2, 34/2-4 (n=2)	107	2210	0.84
34/8-1 (n=1)	110	2340	0.89
34/10-23, 34/4-5 (n=2) = eastern boundary	119	2630	1.00

axial transect for southern basin margin, sourced from Mid-North Sea High (Fig. 13C, F)			
Wells at location	downsystem distance (km)	cumulative sediment mass extracted upsystem (x10^{12} kg)	Proportion of total sediment mass extracted upsystem (χ)
southern boundary	0	0	0

15/9-2, 15/9-3, 15/9-7 (n=3)	81	559	0.14
15/3-1, 15/3-3 (n=2)	130	1090	0.27
24/6-1, 9/13-12st (n=2)	198	2240	0.56
9/9b-3 (n=1)	222	2950	0.74
25/2-7 (n=1)	237	3490	0.88
30/11-3 (n=1) = northern boundary	249	3990	1.00

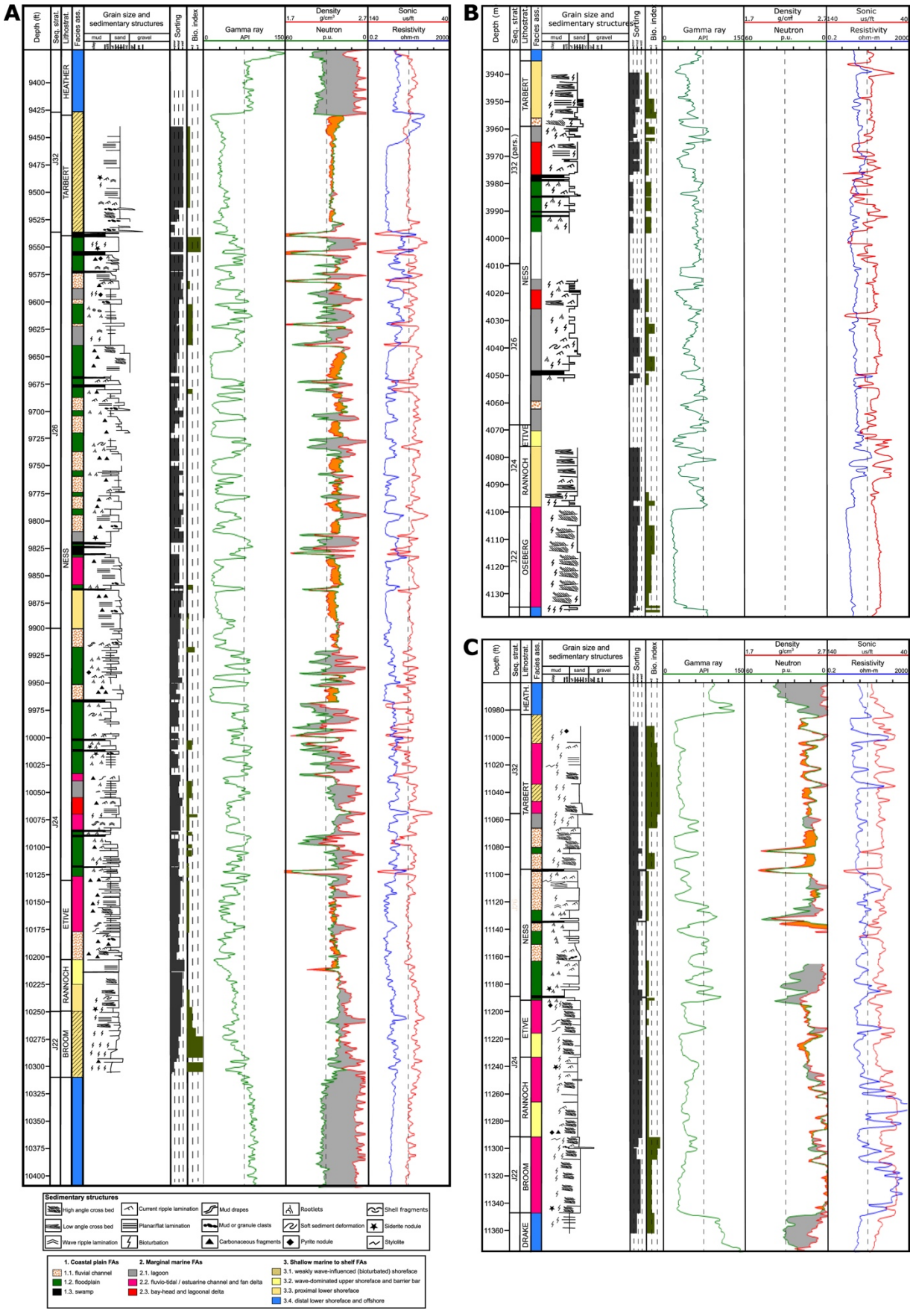
A
B
C
Depth (ft)
Depth (m)
Seq. strat.
Lithostrat.
Facies ass.
Grain size and sedimentary structures
mud
sand
gravel
Sorting
Bio. index
Gamma ray
API
Density
g/cm³
Neutron
p.u.
Sonic
us/ft
Resistivity
ohm-m
HEATHER
TARBERT
NESS
ETIVE
RANNOCH
BROOM
OSEBERG
DRAKE
J32
J32 (pars.)
J26
J24
J22
Sedimentary structures
High angle cross bed
Low angle cross bed
Wave ripple lamination
Current ripple lamination
Planar/flat lamination
Bioturbation
Mud drapes
Mud or granule clasts
Carbonaceous fragments
Rootlets
Soft sediment deformation
Pyrite nodule
Shell fragments
Siderite nodule
Stylolite
1. Coastal plain FAs
1.1. fluvial channel
1.2. floodplain
1.3. swamp
2. Marginal marine FAs
2.1. lagoon
2.2. fluvio-tidal / estuarine channel and fan delta
2.3. bay-head and lagoonal delta
3. Shallow marine to shelf FAs
3.1. weakly wave-influenced (bioturbated) shoreface
3.2. wave-dominated upper shoreface and barrier bar
3.3. proximal lower shoreface
3.4. distal lower shoreface and offshore

Figure S1. Sedimentological core logs and wireline logs of selected, representative wells from the Brent Delta routing system(s): (**A**) well 3/4a-12, Strathspey Field, offshore UK; (**B**) well 30/2-2, Huldra Field, offshore Norway; and (**C**) well 2/5-3, Heather Field, offshore UK (Table 2, Figure 4; after Supplementary Material of Okwara et al., 2023). Core-defined facies associations (Table 1) are calibrated to wireline logs. Orange and grey colours in neutron-density log track indicate 'sand cross over' and 'shale cross over', respectively. Sequence stratigraphic divisions are synthesised from published literature (Figure 3).

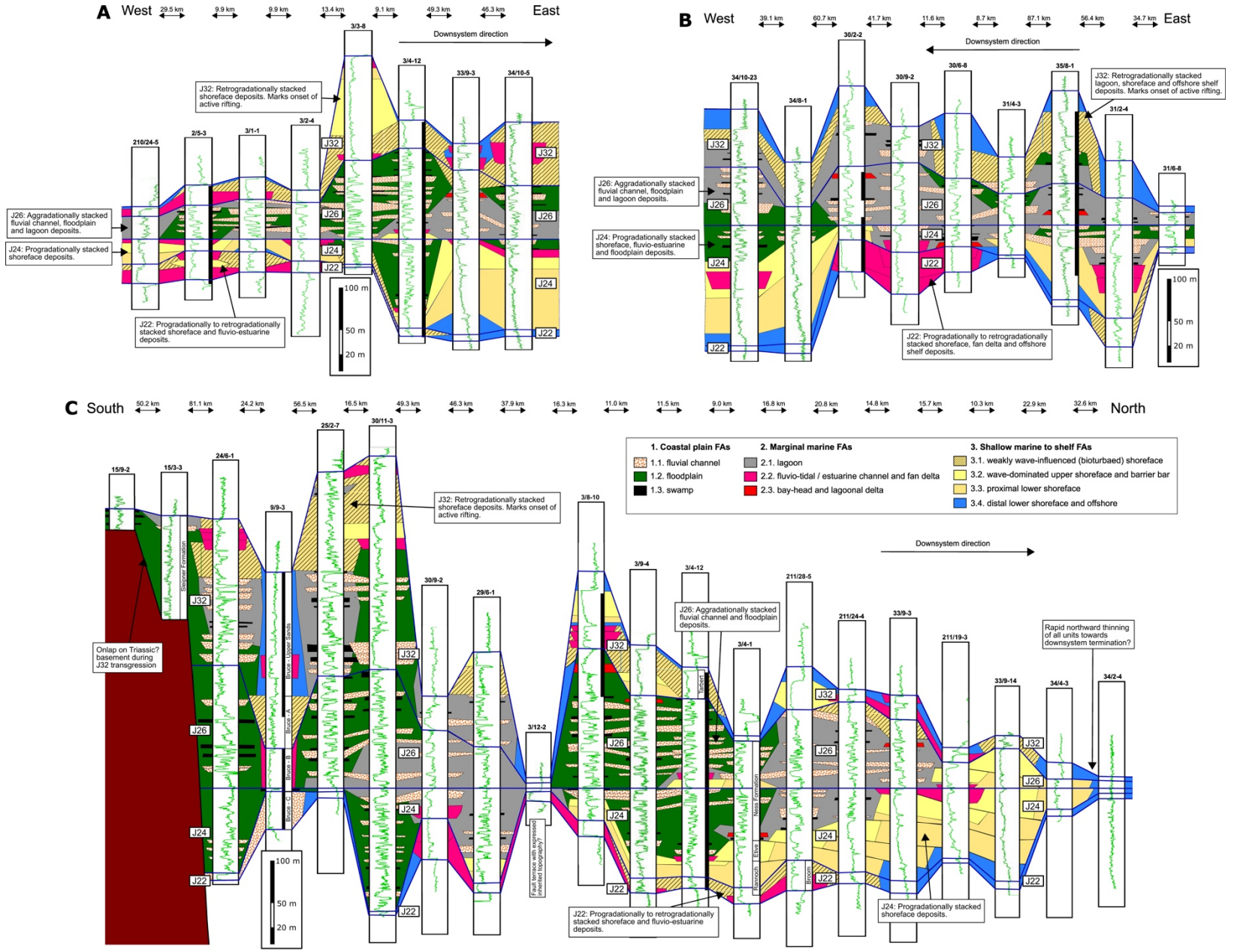
A West East
Downsystem direction
J32: Retrogradationally stacked shoreface deposits. Marks onset of active rifting.
J26: Aggradationally stacked fluvial channel, floodplain and lagoon deposits.
J24: Progradationally stacked shoreface deposits.
J22: Progradationally to retrogradationally stacked shoreface and fluvio-estuarine deposits.
100 m
50 m
20 m
B West East
Downsystem direction
J32: Retrogradationally stacked lagoon, shoreface and offshore shelf deposits. Marks onset of active rifting.
J26: Aggradationally stacked fluvial channel, floodplain and lagoon deposits.
J24: Progradationally stacked shoreface, fluvio-estuarine and floodplain deposits.
J22: Progradationally to retrogradationally stacked shoreface, fan delta and offshore shelf deposits.
100 m
50 m
20 m
C South North
1. Coastal plain FAs
1.1. fluvial channel
1.2. floodplain
1.3. swamp
2. Marginal marine FAs
2.1. lagoon
2.2. fluvio-tidal / estuarine channel and fan delta
2.3. bay-head and lagoonal delta
3. Shallow marine to shelf FAs
3.1. weakly wave-influenced (bioturbaed) shoreface
3.2. wave-dominated upper shoreface and barrier bar
3.3. proximal lower shoreface
3.4. distal lower shoreface and offshore
Downsystem direction
J32: Retrogradationally stacked shoreface deposits. Marks onset of active rifting.
Onlap on Triassic? basement during J32 transgression
J26: Aggradationally stacked fluvial channel and floodplain deposits.
Rapid northward thinning of all units towards downsystem termination?
J22: Progradationally to retrogradationally stacked shoreface and fluvio-estuarine deposits.
J24: Progradationally stacked shoreface deposits.
Fault terrace with expressed inherited topography?
Skipper Formation
Bloom - Upper Sands
Bloom A
Bloom B
Bloom C
Tarbert
Ness Formation
Etive
Rannoch
Bloom
100 m
50 m
20 m

Figure S2. Regional sequence stratigraphic correlation panels: (**A**) transverse panel from the western basin margin, adjacent to the Shetland Platform source area, to the basin centre; (**B**) transverse panel from the eastern basin margin, adjacent to the Norwegian Landmass source area, to the basin centre; and (**C**) axial panel from the southern basin margin, adjacent to the Mid North Sea High source area, to the northern limit of the basin (after Mitchener et al., 1992; Sneider et al., 1995; Fjellanger et al., 1996; Hampson et al., 2004; figure 5 of Okwara et al., 2023). Panels are located in Figure 4, and flattened on the top of the J24 genetic sequence. Given the large well spacing, only stratigraphic surfaces bounding genetic sequences J22, J24, J26 and J32 (Figure 3) are shown.