

1 Correlation of Sequences and Changes in Facies across Shelf 2 Margin using Core and Seismic Data Offshore Canterbury Basin

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7

8 **Abstract**

9 Canterbury basin covers an approximate area of 40,000 km², Canterbury basin is largely an
10 offshore basin extending slightly onshore southward across Canterbury plains and to the
11 Southern Alps. This work aimed to correlates seismic sequences boundaries earlier interpreted
12 with sedimentary sequence surfaces observed in cores recovered from the four sites drilled
13 across the shelf by expedition 317. This work utilises well data obtained from Integrated
14 Ocean Drilling Program (IODP) expedition 317. The expedition which targeted stratigraphic
15 seismic sequences earlier interpreted from the seismic data acquired on the eastern margin of
16 the south island of New Zealand (offshore Canterbury). Three synthetic seismograms were
17 created from well U1351B, U1353C and U1352B which both contain sets of sonic and density
18 logs at variable length, this is to provide a direct means of comparison between the sequence
19 boundaries interpreted on seismic and the depth on cores recovered from holes transecting on
20 the seismic profiles. From the interpretation, nineteen boundaries were identified (U1-U19),
21 these boundaries can be broadly divided into two large units. From U19-U11 (the upper
22 units), it's dominated by downlapped seismic termination pattern along the paleoshelf and
23 truncation surfaces across the shelf edge around site U1351B, a number of channel incisions
24 were observed in this profile. The lower units (from U10-U5) consist of less truncation but
25 more common onlap on paleoshelves, it features more drift deposits with sigmoidal reflection
26 pattern. The nineteen seismic sequences boundaries correlate perfectly with sharp contacts
27 between sandstone and mud/shale on the core sections, however few are gradational contacts.

28

29 **Index terms—**

30 **1 I. Introduction**

31 The study area lies in the eastern side of south island of New Zealand, part of a continental fragment that consist
32 the Canterbury plain to the North, Campbell plateau to the Southeast and Chatham rise slightly northeast (Fig.
33 1). Canterbury basin covers an approximate area of 40,000 km², accumulating sediment since the rifting of the
34 shelf margin from Antarctica in Cretaceous.

35 This research utilises well data obtained from Integrated Ocean Drilling Program (IODP) expedition 317. The
36 expedition which targeted stratigraphic seismic sequences earlier interpreted from the MCS seismic data acquired
37 on the eastern margin of the south island of New Zealand (offshore Canterbury).

38 This work aimed to correlates seismic sequences boundaries earlier interpreted by Lu and Fulthorpe (2004)
39 with sedimentary sequence surfaces observed in cores recovered from the four sites drilled across the shelf by
40 expedition 317. From the earlier acquired MCS EW00-01 data, nineteen seismic sequences were interpreted,
41 ranging from Miocene to Recent in age. Such interpretation was based on standard interpretation techniques
42 identifying reflection termination patterns such as onlap, downlap and truncations.

45 **2 a) Stratigraphy / Sedimentation**

46 Sedimentation and stratigraphy of the basin consists traceable records of tectonic activities which created
47 accommodation space for sediments infill. Hence, stratigraphy and sedimentation history would be discussed
48 alongside tectonics. Sedimentation began about 80 Ma ago, before the rifting phase, the basin's variable facies
49 reflect transgressive to regressive cycles with the Onekara, Kekenodon and Otakou Groups being the major
50 packages deposited in various phases of sea level as transgressive, highstand and regressive deposits respectively
51 (Carter and Carter, 1982; Lu and Fulthorpe, 2004).

52 Deposition of the regionally extensive pelagic to hemipelagic Amuri and weka pass Bioclast limestone
53 Formations collectively called the Kekenodon group, consequently results from reduced terrigenous influx at
54 maximum transgressive phase approximately 30 Ma.

55 Marshall Paraconformity separates the two formations (Fig. 2C). Marshall paraconformity is confirmed from
56 drill sites to be a regional paraconformity, extending to adjacent basins and throughout the east of the Tasmanian
57 gateway. It is considered to represent the onset of thermohaline circulation from Separation of Australian and
58 Antarctica about 33.7 Ma. The overlying Otakou Group is predominantly terrigenous with little amounts of
59 mudstone and very fine to fine grained sandstone. It is dominated by siltstone and silty mudstone (Carter et al,
60 2004).

61 In Late Oligocene to Early Miocene Regression owing to Strike-slip movement that initiated Alpine fault
62 increased rate of sediment supply. Rakaia, Rangitata, Pereora and Waitaki have provenance tied to the Southern
63 Alps. These units are mainly coarse-grained sediments deposited in a river system (Fig. 2) (Lu and Fulthorpe,
64 2004).

65 **3 II. Data a) 2D Seismic Data**

66 Data available for this project are obtained from the integrated Ocean Drilling Project Expedition 317. However,
67 the two-dimensional high resolution seismic data was acquired by Maurice Ewing in January 2000. The EW00-01
68 grid lies between the Banks and the Otago peninsulas along the middle to outer shelf and slope offshore in water
69 depth of 40-1100 m (Fig. 3). Source for the seismic acquisition of EW00-01 is two GI air guns (45/45in3). The
70 survey yielded a total of 57 profiles approximately 3250 line-km with approximately 4840 km² coverage. Spacing
71 of seismic lines perpendicular to the margin is 0.7-3 km in the dip direction while along the strike direction
72 5.5km parallel to the margin. Vertical resolution is sufficient, within the upper 0.5 s which is approximately 5
73 m, sufficiently penetrated the Oligocene to Holocene section below the sea floor.

74 **4 b) Well Data**

75 Well data available for this project came from four different sites all within the seismic survey grid EW00-01
76 (Fig. 3). Sites designated for drilling were planned before the expedition targeting most appropriate trajectories
77 transecting sequence boundaries earlier interpreted from seismic lines. Variable successes were attained in most
78 holes drilled. Site U1351, U1354 and U1353 can be seen on EW00-01-66 seismic profile (Fig. 4B), while site
79 U1352 can only be seen on the seismic profile EW00-01-60 (Fig. 4A). U1351 as well as the other two sites on
80 seismic profile EW00-01-66 are located on continental shelf; U1352 is on the upper slope. Site U1351 is in a water
81 depth of 122 m, three wells were drilled at the site namely; U1351A, 1351B and U1351C, hole U1351B attained
82 maximum penetration depth of 1030.6 m DSF, hole U1351A and U1351C have penetration depths of 28.0 m DSF
83 and 967.3 m DSF respectively. Well U1351C was not cored, it was drilled purposely for wireline logging, 27.3
84 m and 304.5 m of core were successfully recovered from hole U1351A and U1351B respectively. Four holes were
85 drilled in site U1352. In site U1353, three holes were drilled, two holes cored (U1353A and U1353B).

86 **5 III. Methods a) Two-Way Travel Time / Depth Conversion**

87 The seismic data was taken in time, whereas, cores measurement is in meters, hence the need for two-way
88 travel time to depth conversion. Conversion is required to enable correlation of sequences boundaries on
89 actual core surfaces with sequence boundaries interpreted from seismic section. In this project two-way travel
90 time to depth conversion was carried out using complete sonic and density logs available from Clipper-1 well
91 (Fig. 5) which is within the survey area using Schlumberger petrel software 2013 version. This was done
92 by creating a synthetic seismogram; the synthetic seismogram generated was compared with precruise synthetic
93 seismogram from Lu and Fulthorpe (2004). From seismic data (EW00-01) earlier interpreted by Lu and Fulthorpe
94 (2004), nineteen sequence boundaries were identified and interpreted (U1-U19), these boundaries were confirmed
95 to be unconformities surfaces using fossils and carbon dating (Fig. 6). This interpretation was verified and
96 further correlated with their actual depth in the cores provided. The actual sediment lithologic expression of
97 the interpreted sequence boundaries in the cores were studied to determine the facie variation, sedimentary
98 packages and lithologic discontinuity across the boundaries using the provided detailed core descriptions and
99 high resolution core images. Identifying the boundaries based on rock type or lithology, with more emphasis on
100 grain size contrast, nature of contacts, sedimentary packages and variability across the contacts. Emphasis was

101 on the shallow boundaries considering the depth of penetration in the holes which provided the only gateway to
102 the actual nature of sediments seen in cores.

103 **6 IV. Results**

104 Correlation of seismic interpreted sequences boundaries with the actual lithologic expression in cores were possible
105 using seismic interpretation from Lu and Fulthorpe (2004). From the interpretation, nineteen boundaries were
106 identified (U1-U19), these boundaries can be broadly divided into two large units. From U19-U11 (the upper
107 units), it's dominated by downlapped seismic termination pattern along the paleoshelf and truncation surfaces
108 across the shelf edge around site U1351B (Fig. 6), a number of channel incisions were observed in this profile.
109 The lower units (from U10-U5) consist of less truncation but more common onlap on paleoshelves (Fig. 6), it
110 features more drift deposits with sigmoidal reflection pattern.

111 Only sites U1351B and U1352B have both sonic and density logs hence 7 boundaries (U14-U8) in site U1351B
112 and 7 boundaries (U19-U13) in site U1352B fall within the interval of the created synthetic seismogram. Other
113 sites without synthetic seismogram cannot be correlated with much certainty due to lack of both sonic and density
114 logs. However, for sites U1353 and U1354 two-way travel time picked at such boundaries were used in a function
115 (equation 3) to determine the depth. The function was derived from check-shot data obtained from Clipper-1
116 well used by expedition 317 scientists (2011). The same classification and names for the different boundaries as
117 Expedition 317 Scientists (??011) is adopted for this project with S(no) denoting a lithologic surface and U(no)
118 representing a seismic sequence boundaries.

119 **7 V. Discussion / Conclusion**

120 Cores recovered from four sites at different parts of the shelf to slope (site U1351, U1353 and U1354 at shelf to
121 site U1352 at slope) had further consolidated previous seismic interpretation. Facie assemblages observed across
122 the shelf were divided into units and sub units based on facie variability to facilitate depositional environment
123 interpretation and facies successions during different stages of sea level. At site U1351, upper to middle part
124 of lithostratigraphic unit I (50-150 m CSF) facie assemblages consist of upward fining shelly sandy mud which
125 coarsens upward into sandy mud. The presence of lag deposits above an erosional contact with upward-fining
126 intervals suggests a transgressive system tract which passes into highstand mud deposit above it. Coarsening-
127 upward sandy mud sequences suggests prograding shoreline at low accommodation space (Expedition Scientists,
128 2011). At site 1352, which is strategically located on the slope slightly different facie assemblages were observed.
129 Divided into three units, unit I which represent series of downlapping reflection termination pattern as interpreted
130 from seismic data, it's consists of few sedimentary structures and is being interpreted as lowstand delta front
131 deposits. Slump deposits observed in the upper part of the unit may suggest deposition during high rate of
132 sediment supply as part of a prodelta environment. Sharp contacts associated with dark gray sand are interpreted
133 as gravity flow deposits part of delta along the slope as mass flow deposit. The calcareous dominated unit II with
134 sandy marlstone and minor sandy mudstone suggest pelagic to hemipelagic deposit. The marlstone is interpreted
135 as drift deposit, calcareous nature of these units suggest condensed section formed during sediment starvation
136 period (Expedition Scientists, 2011). Alternating nature of lightcolored marlstone with dark mudstone and thin
137 sand Unit III is correlated with the regionally extensive Amuri limestone believed to be deposited in an outer
138 shelf to slope setting ??Field and Brown, 1989). Multiple lithologic units can be seen in cores which can be easily
139 identified as sequence boundaries existing near the predicted depth, making it difficult to identify the actual
140 sequence boundaries from lithostratigraphic data alone in site U1352. These lithologic units have potentials to
141 provide strong seismic impedance contrast, however, only a single reflector is visible on seismic section and is
142 expected at the predicted depth. Possible explanation to this scenario is that this could be related to the vertical
143 resolution of seismic data from acquisition. The ability of seismic to recognize individual closely spaced events
144 or reflectors is limited to the pulse length; maximum resolution of seismic is from 1/4 to 1/8 of the dominant
145 wavelength of the pulse. Typical vertical resolution for a reflection seismic survey with a dominant frequency of
146 50 HZ and average sedimentary velocity of 2.0 km/s is 10 m (Sheriff and Geldart, 1983). Hence, most of the
147 reflectors seen and interpreted on seismic are believed to be an order of magnitude larger and stronger than the
148 actual lithologic expression seen in cores. ¹

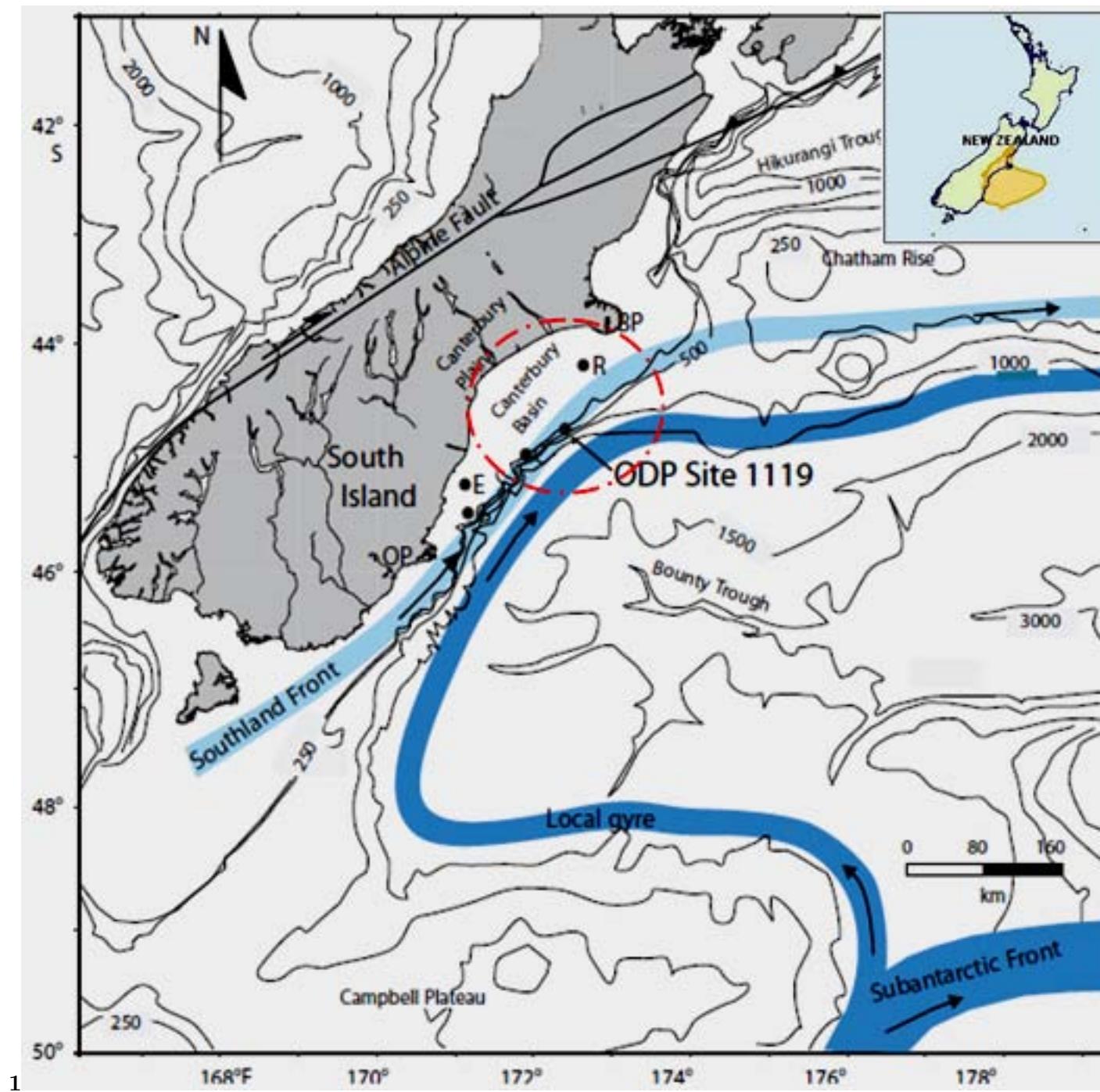


Figure 1: Fig. 1 :

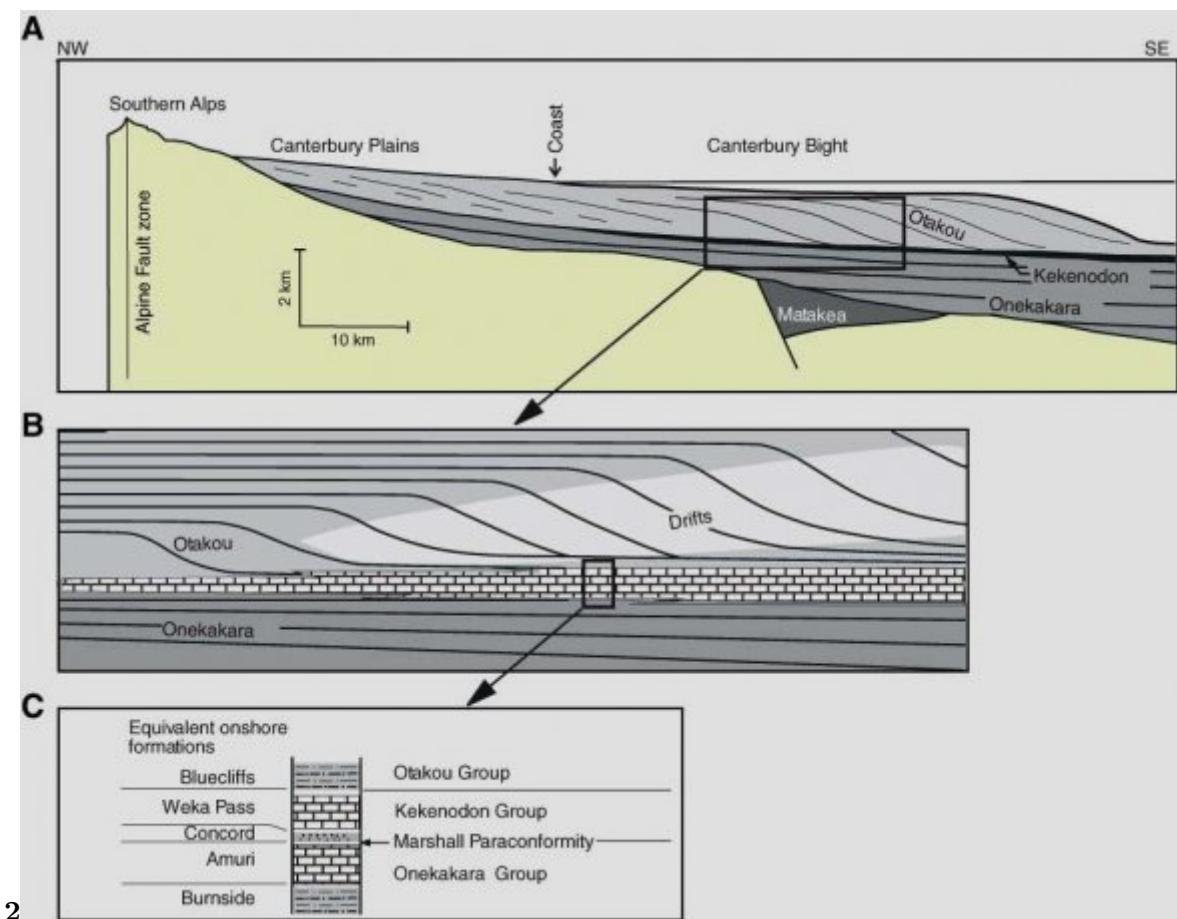


Figure 2: Fig. 2 :

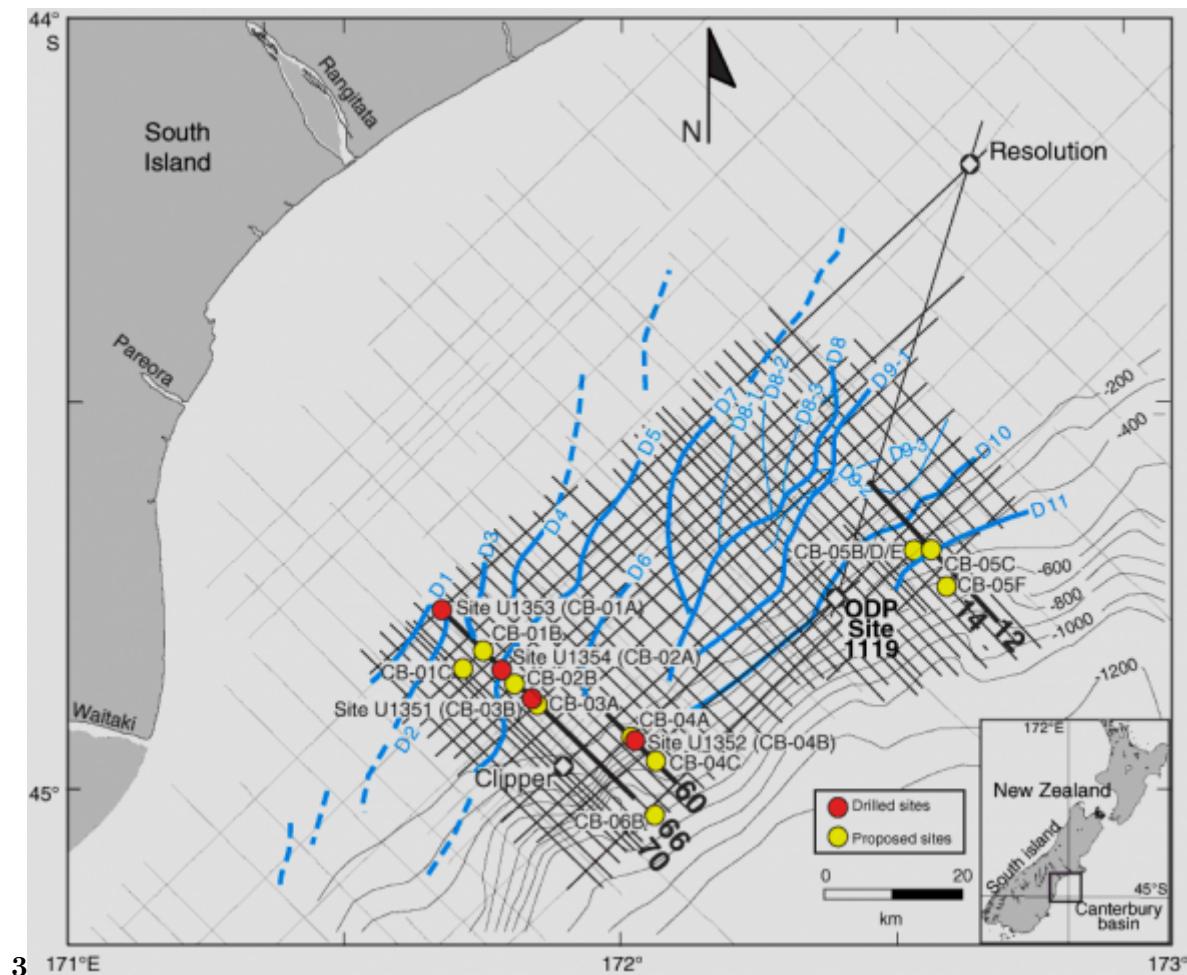


Figure 3: Fig. 3 :

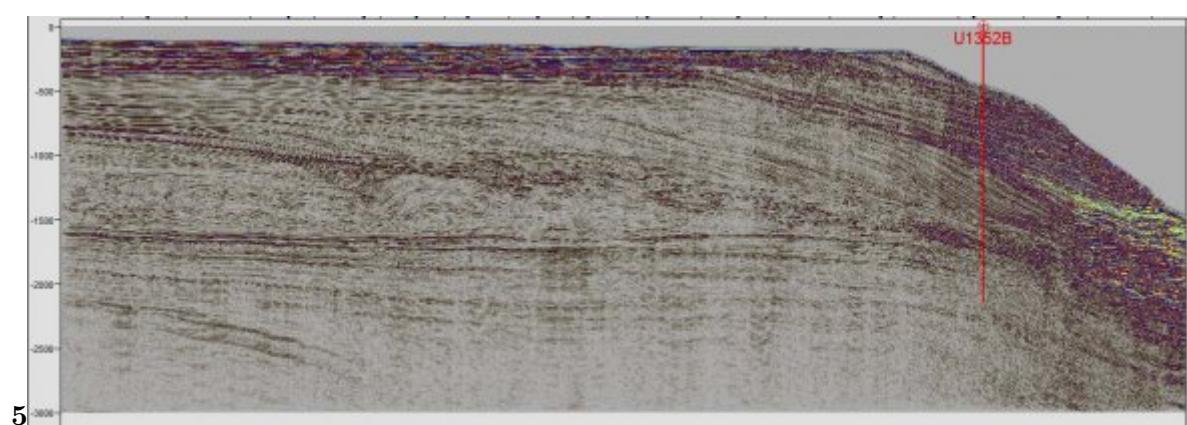


Figure 4: Fig. 5 :

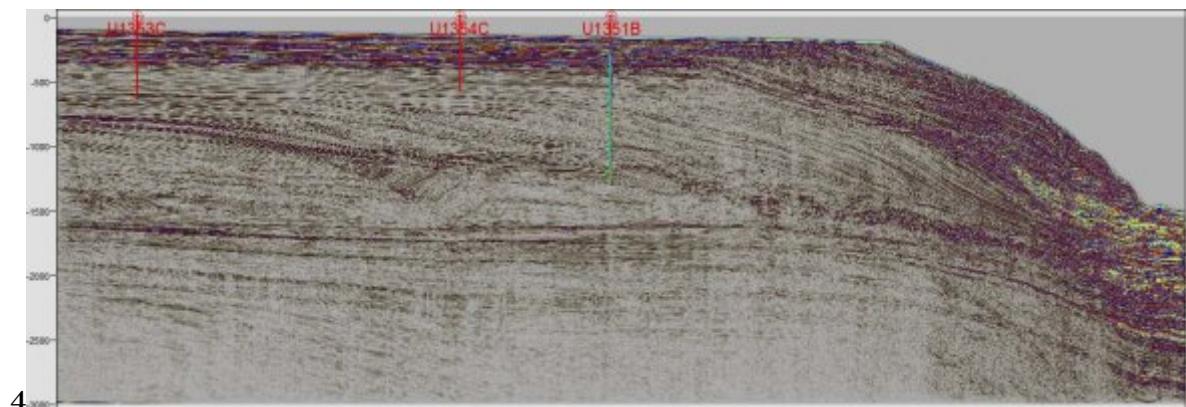


Figure 5: Fig. 4 :

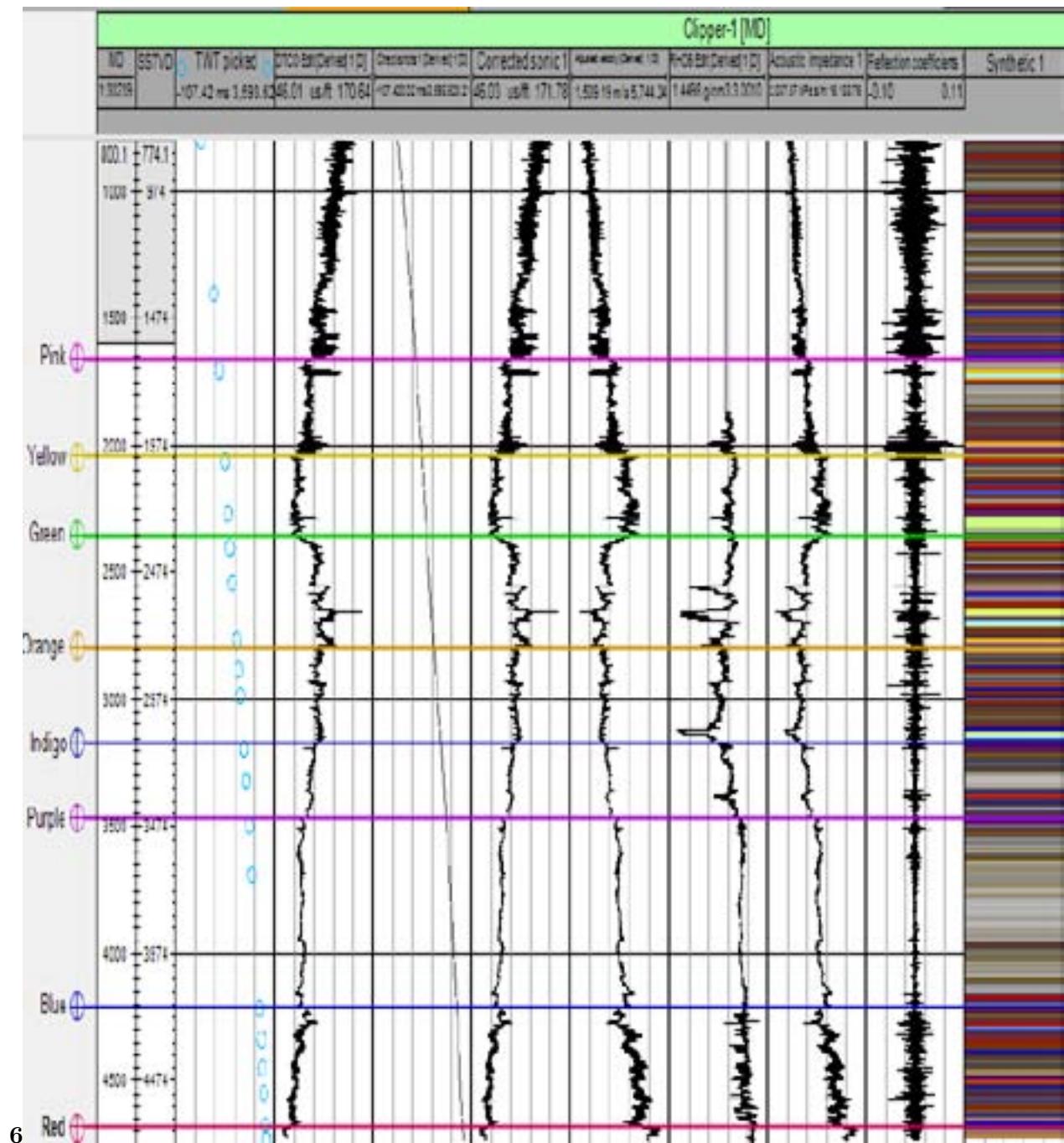


Figure 6: Fig. 6 :

1

Lithology		Overlying	Sediment Expression at Contacts		Sharp	Sequence	Year	2018
Sur-	Lithology		Contact Between Silty and Clayey Mud			Bound-		
face	Clayey	Mud	Sharp Contact, Intercalated in Mud			aries		
S1	Very	Fine	Sharp Contact, Thin Sand with Mud			U19	U18	
S2	Sand Mud					U17		
S3								
S4	Sandy	Mud	Gradational Contact in Shelly Sand In-		U16	U15	23	
S5	Medium		complete Core Recovery					
S6	Very	Fine	Sharp Contact with Mud Sharp Contact		U13	U12	Volume	
S7	Shelly	Sand	with Clay Beneath Sharp Contact with		U10		XVIII	
S8	Muddy	Sand	Basal Silty Mud				Issue	III
	Very	Fine					Version	I
	Muddy Sand							

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Figure 7: Table 1 :

2

- a) Lithologic Expression of Sequence Boundaries at Site U1351
- b) Lithologic Expression of Sequence Boundaries at Site U1352

Lithologic Surface	Overlying	Sediment Expression at Contacts	Sequence	Bound-
	Lithology			aries
S1	Mud	Sharp Contact with Muddy Sand Beneath	U19	
S2	Muddy	Sharp Bioturbated Basal Contact	U18	
S3	Sand			
S4	Muddy	Sharp Highly Bioturbated Basal Contact with Mud Beneath	U17	
S5	Sand			
S6	Muddy	Sharp Bioturbated Basal Contact with Underlying Mud	U16	
S7	Sandy	Sharp Basal Contact Slightly Bioturbated	U15	
S8	Mud			
S9	Sandy	Sharp Bioturbated Basal Contact	U13	
U1352C-S9	Mud			
	Limestone	Sharp Basal Contact With Marlstone Beneath	U9	

Figure 8: Table 2 :

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