

## **RSG Project 00/5: Neogene Stratigraphic Framework of NE Rockall Region**

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## **1. INTRODUCTION**

RSG / PIP supported the proposal for a detailed seismic sequence stratigraphic investigation of the Neogene geology of the NE Rockall Basin. This decision followed from recommendations made during the successful shallow geological reconnaissance across the majority of Irish Rockall Basin (Project 98/23). One of the major objectives of the investigation is to further develop the Neogene Stratigraphic Framework as described in the HAL Proposal No: 204-00.

Hydrosearch Associates Limited (HAL) were contracted using Brynterpretation Limited as geological/geophysical interpretation consultant to undertake the investigation and study together with BGS in the designated technical monitor role.

Data gathering commenced during autumn 2000. This was intended as simply extending the regional PIP99 Database with infill seismic – especially strike line data. Data management problems arose, however, and a new database covering just the NE Rockall study area was eventually generated during early March 2001. The investigation and interpretation then commenced and work continued in planned stages through to end July when map construction and iteration began in earnest.

### **1.1 Acknowledgements**

This publication uses data and survey results acquired during a project undertaken on behalf of the Rockall Studies Group (RSG) of the Irish Petroleum Infrastructure Programme Group 2. The RSG comprises: Agip (UK) Ltd, Anadarko Ireland Company, ARCO Ireland Offshore Inc, BG Exploration & Production Ltd, BP Exploration Operating Company Ltd, British Borneo International Ltd, Elf Petroleum Ireland BV, Enterprise Energy Ireland Ltd, Mobil Oil North Sea Ltd, Murphy Ireland Offshore Inc, Phillips Petroleum Exploration Ireland, Saga Petroleum Ireland Ltd, Shell EP Ireland BV, Total Oil Marine plc, Union Texas Petroleum Ltd, and the Petroleum Affairs Division of the Department of the Marine and Natural Resources.

## 2. OBJECTIVES

The main objective was to investigate the geological structure and shallow stratigraphic history of the outer shelf, the continental slope and basinal areas of the NE Rockall region, **Figure 1**. This would provide a regional Stratigraphic Framework throughout this complicated frontier province as suggested in earlier work from Project 98/23, (Austin, 2000).

The 98/23 study strongly supported and progressed the recognition of a basin-wide stratigraphic framework. This was originally developed from sound academic research (Stoker et al, 2001) in the more basinal regions of the Rockall region utilising seismic stratigraphical methodology tied to carefully selected shallow borehole locations that provided age constraints. The 98/23 study indicated that the Eocene - Recent megasequences could possibly be correlated to extend up slope towards the shelf where they might be positively identified in shallow water. The concept could not, however, be fully confirmed due to the intensity of the erosion and the complexity of the slope morphology in the NE portion of the Irish Rockall Basin as well as insufficient time and budget.

Erosion of the slope is considered to be due to: -

- a) fault movement throughout the Palaeogene and Neogene
- b) intensive canyon / valley development over all parts of the slope
- c) extensive and powerful, oceanic thermohaline current activity

By using as much of the available data as was possible it was hoped that previous areas of complexity could be unravelled allowing the unified stratigraphical concepts to be tested at least in terms of seismic stratigraphy. No new geological data was available although the investigation had the advantage of drawing on a newly mapped region of the UK shelf and slope adjacent to the median line.

Identification and interpretation of the major regional unconformity surfaces that are taken to represent megasequence boundaries was accomplished using Landmark SeisWorks 2D. The resultant maps have been gridded and constructed in PetroSys.

The report is presented as short text section, with extensive Figures including maps (at A3 and 1: 300,000 scale) and geoseismic cross sections. Abundant Data Examples (DX) are also included, the locations of which are shown on **Figure 5**.

### 3. GEOPHYSICAL DATABASE

All seismic data from the PIP99 geophysical database covering the NE Rockall region was incorporated for Project 005. In addition several proprietary datasets supplied by Enterprise, Phillips and Statoil and their partners were used to form the very extensive grid shown in **Figure 2**. As previously all these data are 2D and were acquired for exploration purposes being sampled at 0.004 seconds. This means that a data gap exists directly beneath the seabed arrival. Here up to 12.5 m of information is masked by the effects of the outgoing energy pulse due to low vertical resolution (equivalent theoretically to a quarter of the wavelength but often in reality is half of the wavelength). Further deterioration occurs because of streamer tow geometry / depth and weather.

The RSG/PIP2001 Database consists of approximately 15,000km of digital seismic data. Importantly there is no 3D seismic or high-resolution 2D data included in the database. Down slope spacing of the 2D lines normal to the continental slope varies from 3km – 10km. This is considered barely adequate given the considerable changes in slope geometry. Strike lines transverse and along the slope are more widely spaced (5 – 15km).

#### **4. GEOLOGICAL DATABASE**

12/13-1A was the single well available for the project since little useful shallow geological information has been collected at other exploration well locations. Verbally communicated data from well 15/9-1 as used in the interpretation has since been decided to be erroneous, see Section 6.5 below.

The Phillips-supplied Base Tertiary Unconformity (BTU) pick from the 153/15 well in the UK sector has been used in the interpretation in the extreme northern part of the area. Apart from this the main shallow geological input has come from the BGS Borehole programme in UK waters together with the important RSG/PIP Shallow Drilling location 11/20 SB-01. The locations of geological control are shown on Figure 2 and the inset to Figure 4.

The geological database also contains a suite of 25+ seabed gravity cores. These, however, add little value to this particular project due to the lack of penetration and the physical inability to tie their results into the low frequent exploration 2D seismic data. The suite consists of the following: -

- 10 BGS Challenger cores collected as part of the site surveys for the Shallow Drilling campaign in 1999. These are concentrated around the 11/20 SB-01 location. Only one of these, SC001 has been sedimentologically analysed by UCD and the results integrated into the project.
- 15 Geoboy samples collected for regional sediment geochemical analysis. The results are usually no more than a quick visual description of both ends of the recovered core.
- Extra Geoboy samples more specifically sited for similar more proprietary analyses
- 10 Logachev 1998 surficial seabed cores in the extreme south of the study region (not plotted).
- 1 NIOZ 2000 piston core and 2 box cores (not plotted).

## 5. REGIONAL OVERVIEW

The shallow geology of the northern and northeastern portion of the Rockall Basin is portrayed in the stratigraphic age range chart and five regional profiles shown as **Figures 3** and **4**. It is divisible into at least four post Paleocene megasequences RT-d through RT-a. Above the Base Tertiary Unconformity (BTU) these are bounded by seismically defined unconformity surfaces, (C30, C20 and C10). The surfaces are truly regional in scale being often observed over hundreds of square kilometres as a result of NE Atlantic province-wide regional (uplift and) erosion, Austin 2000a.

Comparison of just one of the megasequences coloured on the geoseismic profile lines shows considerable variation with much evidence of onlap, overstepping as well as erosive truncation. These are features indicative of an active structural and depositional history. Evidence for simple and undisturbed basinal layer cake deposition is sparse as is straightforward progradational growth of the shelf/slope margin. This is the case throughout the post C30 period of late Palaeogene and all of the Neogene including the Recent as evidenced by the faulting mapped cutting up to seabed.

It is fair to say that the NE Rockall region shows greater complexity than other parts of the basin system both in terms of structural influences, seismic facies and megasequence distribution. The NE Rockall region shows evidence of massive progradational build-out of the shelf and upper slope similar to the UK margin.

Deposition has, however, been followed by large-scale destructive processes caused by faulting along the NE/SW Erris structural trend. Slope canyon development is extensive and centred around the Donegal Canyon system in the north and the T and D Canyons located further south. The location of these canyons is shown on **Figure 11**. Remaining areas often show evidence of recent faulting as the canyon erosion processes undermine the slope causing gravity driven instability and collapse. Consequent modification, (generally erosional) by contour current activity and slope valley/canyon transport down slope is also prevalent. The existence of hanging wall deposits referred to here as the 'Gullwing-Erris toe of slope fan' (GEF) appear to represent failed late RT-c and early RT-b aged sediments now lying in water depths of greater than 2000m over much of the region (**Figure 4**).

## 6. KEY INPUTS TO THE STRATIGRAPHIC FRAMEWORK

Before looking at the NE Rockall region in more detail the following section briefly describes the evidence allowing its stratigraphic subdivision. The original skeleton framework derives from the concepts contained in the paper by Stoker et al, (2001) presented at the Dublin Conference in 1999. This work related mainly to a basinal sequence stratigraphic framework based upon seismic interpretation tied wherever possible to wells or boreholes. The ideas were explored and extended as far as possible across the Rockall Basin, being described as the regional overview contained in the PIP/RSG Project 98/23 Study Report.

The difficult NE Rockall region was previously only partially covered but the current study shows that the same Megasequences RT-d through RT-a are also developed here. A series of dip and strike geoseismic profile lines, **Figures 6 - 8** show the structural and stratigraphic development of the megasequences from north to south through NE Rockall. Their location is shown on **Figure 5** together with the data examples DX 1 – 18 that provide details of their seismic expression and subsequent interpretation.

In the NE Rockall region the analysis of the following key inputs has enabled the interpretation of the Stratigraphic Framework model defined in this study:

- 6.1 BGS mapping of the NW UK Continental Margin
- 6.2 Well 12/13-1A
- 6.3 Shallow Drilling location 11/20 sb-01
- 6.4 Well 15/9-1
- 6.5 Correlation from borehole constrained BGS mapping of the NW Rockall region and RSG Project 98/23 Study.

### 6.1 BGS mapping of the NW UK Continental Margin

The extensive British Geological Survey UKCS seismic acquisition and related borehole coring and dating campaign allowed the investigation and mapping of the NW margin of the UK shelf and slope. This has recently been updated as the Central Rockall Basin (56 deg. 58 min N – 08 deg. 15 min W) Solid Geology sheet, (Stoker and Gillespie 2000) covering the area immediately adjacent to the median line and Hebrides Terrace Seamount. Here the regional progradational, generally aggrading shelf and slope development continues as the Barra Fan and into the Donegal shelf and slope.

The shallowest megasequence is dated as RT-a confirmed from boreholes such as 88/7,7A and Ocean Drilling Programme (ODP) borehole 981. RT-a sediments (orange) sweep down uninterrupted into and across the northern Rockall Basin. In the NW they have been eroded by persistent bottom currents, active since the early Pliocene, (**Figure 4 lines A – A' and B – B'**).



The older Megasequence RT-b (blue) is dated by borehole 94/1, ODP site 981, DSDP site 610; the basal samples of borehole 94/1 also catch the underlying RT-d aged (yellow) deposits. The red Megasequence RT-c, however, is not penetrated by boreholes apart from in the north at 88/7, 7A and allegedly far to the south at the Deep Sea Drilling Programme site 610 (**Figure 3**). RT-d is named as such in this study somewhat by default since it is considered to make up the economically important remaining Palaeogene section down to the BTU. The Megasequence RT-d package has been penetrated in several wells but is outside the scope of the objectives of this report. It shows several particular seismic facies characteristics that suggest positive further differentiation is, unsurprisingly, necessary.

## 6.2 Well 12/13-1A

The 12/13-1A well location lies at the heart of the NE Rockall region and provides deeper stratigraphic age data that usefully ties the seismic data in that region. The well location is located on line WM90-391, (**Figure 6** and **DX4**). The meagre results (from cuttings samples), as confirmed in the re-analysis by Jakovides 2000, show the existence of the Megasequence RT-d (yellow) as the shallowest sediments recovered at 2009m below rotary table. This is some 1000m below the seabed above which no shallow geological samples were taken as is conventional industry drilling practice.

When integrated into the seismic interpretation the 12/13-1A well results are still very useful showing RT-d outer shelf to upper slope silts, shale and calcareous shale unconformably overlying the Base Tertiary Unconformity. This angular-unconformity relationship (and the often-transparent seismic character of RT-d sediments especially on the upper slope) provides a basis for strong correlation throughout the Donegal shelf and slope. Fortunately the correlation can be confidently extended almost as far as the southern limits of the study area.

The lack of sampling in the shallower section of the 12/13-1a well means we cannot be certain of the age of the younger megasequences above Megasequence RT-d. Here a thin (only tens of milliseconds thick) interval is observed beneath RT-a as confidently correlated from the north utilising the borehole – seismic ties from 6.1 above. The seismic interpretation of this study so far suggests the thin interval be assigned as RT-c rather than a conformable RT-b. This could of course be proven to be in error given the discussion presented below in 6.4. Only better calibration by suitably located borehole sampling would allow a more confident correlation.

The location of 12/13-1A lies on the footwall of the massive Erris Fault system and consequently the well data cannot provide definite ties across the fault that displaces over 750 meters of section. This is unfortunate since it means seismic covering vast areas of the middle and lower slope remains geologically uncalibrated since we can only rely upon intuitive jump correlation and the possibly imprecise cross-basinal links via input 6.5 below.

### **6.3 Shallow Drilling location 11/20 sb-01**

This shallow drill site is located in the headwall of the Borehole 11/20 Slide seabed feature and only penetrates RT-d rocks beneath a surficial sample of RT-a as shown in Figure 6 and DX 6. The fact that subaqueously extruded, Lower Palaeogene Basalt was encountered together with rather exotic (-interpreted as outer shelf) carbonate recovered from 1000m is a great achievement. The dates confirm the seismic stratigraphic interpretation from this and previous work relying upon input and correlation from 6.2 above. Unfortunately the results provide little further clues to aid confidence for the remainder of the Stratigraphy across the slope.

### **6.4 Well 19/5-1**

Verbal communication from trusted explorationists during the interpretation and study was of "a thin Plio-Pleistocene interval overlying Palaeozoic rocks". This information tied closely with what had been independently interpreted from the 2D exploration data, Figure 7 and DX 8. Here the seismic appears to show Megasequence RT-a as a well developed progradational sequence containing internal stronger (and weaker) westerly dipping events. This is the same prograding seismic facies as seen elsewhere in the outer shelf/upper slope environments of NE Rockall, e.g. compare to DX1, 2, 3 – 7 and Figure 6. In all cases the underlying C10 regional erosion surface is observed, as so often over Rockall and elsewhere along the NWECS, as a strongly planar (wave-base cut?) composite unconformity. This observation fits well into the concept of Neogene megasequence development and the Stratigraphic Framework as a whole.

Latest information states, however, that there is evidence to support a Plio-Pleistocene sequence as well as a question mark Upper Miocene – Pliocene interval at the 19/5-1 well location. Apparently this covers some 251 meters or more. Possibly this could be due to a locally down faulted and preserved RT-b section. As DX 8 shows the seismic data does not immediately suggest this. Naturally, it does remain a possibility but more work is recommended to integrate the well and dating results that were not readily accessed during this study since only a single seismic line passes close to the well.

Further enquiry as to where did the age dated samples come from in a presumably conventional exploration well is suggested. Cuttings samples can be notoriously anomalous. Were the faunas reworked at all or unambiguously reliable?

## **6.5 Correlation from borehole constrained BGS mapping of the NW Rockall region and RSG Project 98/23 Study.**

The lack of much firm geological stratigraphic calibration of the seismic interpretation of NE Rockall means that the concept skeleton megasequence framework must remain as such until further evidence is recovered by drilling. The framework does appear workable - unifying, simple and predictive on the one hand, but still quite possibly liable to be proved different some time in the future. It is a highly positive start and builds upon the basin-wide approach inspired by the Stoker et al model utilised systematically during Project 98/23 Study.

Taking this work a step further we can use the long distance, across-basin ties from that work as further soft stratigraphic input into our developing Stratigraphic Framework for the NE Rockall region. This essentially means using the interpretations for Line WRM96-103, NA-15 and LINE 3, (Figure 4), and attempting to bring the basinal stratigraphy up through the shallower facies of the slope. Although ambiguous and inconclusive in most places the framework concept does appear initially to meet positively with that suggested by the previous three main inputs, 6.1 – 6.4.

The seismic data along the key cross-basinal lines is of three different vintages commencing in the 1970's. Ties in the NW are often difficult due to datum and phase shifts, acquisition and multiple ghosts etc. This is also the case of course in the current area of study where better seismic imaging is required. Here there is ambiguity caused generally by the steep slopes and dips within the T and D Canyon systems, and also in particular by the presence of the GEF and the Erris Fault Zone. The GEF obscures the detailed relationship of the basinal C10 by creating seabed relief, which has subsequently been eroded and modified by contourite sedimentation. There appears to be little doubt, however, that the basinal Megasequence RT-a onlaps the GEF throughout its length, Figures 6 and 7, DX 5-10.

Increasing water depth as well as diffractive energy and multiples make the lower slope directly either side of input line WRM96-103 treacherous in terms of confident interpretation, e.g. DX 9, 10 & 11. Furthermore the position of the Erris Fault system generates the necessity to jump correlate on most seismic lines in order to progress a horizon pick upslope from the poorer imaged lower slope. Despite exhaustive attempts, it remains an objective fact that very little direct correlation has been proved allowing direct correlation between any of the three cross-basin regional lines into the NE Rockall.

The reasons above somewhat negate the influence of our fifth main stratigraphic input as a confident guide to the concept of seismic stratigraphic correlation. Since this holds at both the NW Rockall region (where there is some geological control), as well as in the NE Rockall area it does little more than maintain rather than increase the confidence of our assumed stratigraphic input. Further detailed analysis of NW Rockall in general (perhaps by using carefully processed / imaged data) and this particular problem in particular is highly recommended.

## 7. SEISMIC CORRELATION OF GEOSEISMIC PROFILES N-S ACROSS NE ROCKALL REGION

**Figures 6 to 8** show the megasequence development over N.E. Rockall as the result of the structural and seismic sequence stratigraphic interpretation of the RSG/PIP2001 Database. They are fairly self-explanatory since Megasequences RT-a through RT-d are colour coded to allow ease of correlation as one works down from the north towards the south. As line WM90-395 shows, the stratigraphy of the Donegal Shelf and upper slope is better established, Stoker and Gillespie 2000, as an extension of the western UK margin. Moving southwards on **Figure 6** to the destructive channelled slope the geology quickly becomes far from straightforward as large canyon systems such as the broad Donegal Canyon cut into the slope and outer shelf, e.g. Line WM90-391.

**Figures 6 to 8** show a most striking observation that is the relative lack of similarity between each profile and its neighbour located generally just 20 – 30 km away. Sharp differences in bathymetry and morphology of both the upper and lower slopes are apparent.

The distinct changes in outer shelf and slope gradients occur as well as differences in the convexity of the slope itself. They are thought to be the result of differing interactions of fault induced down slope mass movement processes and oceanic current regime interaction. **Figure 11** presents the slope gradient in map form clearly showing the influential Erris Fault lineament running parallel to the slope. This has been mapped for almost 200 kilometres. Often running abruptly perpendicular to this the slope trends of the D and T canyon systems can be seen with their complex and reworked sediment fill.

The history and geological development of the slope is a complicated one, which may now be studied more easily given the extended Stratigraphic Framework. More detail of canyon system morphology and on the stability of the slope in general is contained in RSG Project 00/6, Austin 2001b.

**Figure 8** is a lower slope regional strike line showing the complexity and difficulties in correlation of the megasequence framework generated in the Donegal Canyon system area. Similarly **Figure 9** from the lower / middle slope also shows the presence of the T Canyon systems incised into the slope. Aside from the progradational nature of the outer shelf and upper slope there is perhaps a flavour of overall depositional conformity elsewhere. The steep slopes or scarps along the Erris fault zone together with localised erosion and removal structurally influence this together with contourite constructive and destructive processes plus catastrophic gravity failures.

All these influences provide much thickening and thinning of the seismically defined units. Such process interactions during the past have left outlier remnants such as that of RT-c observed on Line NWI-116 for example, **DX 6**. The explanation for the local RT-c occurrence appears to be that there is a fault influence, however, an underlying lithological control by slope-aggrading contourites "working" at the fault cannot be ruled out. Likewise it seems possible there could be a similar though more limited development of

carbonate growth during Oligo-Miocene times as recognised at the Geikie Escarpment on the UK margin since further south there appears to be a ponding of outer shelf sediments behind similar localised features, Austin 2000.

The lensoid external geometry of the GEF is noticeable as one moves south, **Figure 7**, especially where it provides a focus for contourite depositional systems with their characteristic axial features (wave crests) as seen on Line DGER96-30, **DX 9** or NWI-91-112, **DX 8**. Just as recognisable is the dipping reflector defining the gull-winged or wedge-shaped external geometry of the northwest-facing leading edge to the GEF, Line NWI93-106, **DX 11**.

## **8. DISCUSSION OF INTERPRETED HORIZONS AND MAPPING UNCERTAINTIES**

### **8.1 Bathymetry**

The regional bathymetry in TWT shown as Figure 10 or 20 has been gridded using a cell size of 500m from the *seabed* horizon pick as interpreted on the RSG/PIP2001 2D Seismic Database. Although the submarine canyons are rather well portrayed their form is seen to be even more complicated when depicted by the swathe bathymetry of IFREMER or in the north from the horizon pick of the Shannon 3D Survey.

Integration between these large datasets is contained in RSG Project 00/7 but was unavailable for the interpretation of this Project. Similarly further examples of the influence of the underlying structural control upon slope morphology are presented in RSG Project 00/6.

### **8.2 C5 Horizon**

This intra Megasequence RT-a horizon was observed and mapped originally in an attempt to test the validity of the deeper regional C10 horizon. It can be seen as the shallowest (blue) horizon annotated LGU on **DX 1 – 3, 13, 16 & 18** and as the gold horizon on most of the remaining Data Examples.

The horizon exhibits strong amplitude and often shows evidence of truncation beneath and clearly onlaps older units when mapped around the region. The seismic expression of units above and below the C5 are, however, virtually indistinguishable in terms of their sub-parallel – parallel internal reflection geometries.

Given its broadly erosive nature the C5 was at one time considered a potential candidate as C10 in this region and if selected would alter the Stratigraphic Framework upwards by one Megasequence such that the currently selected horizon mapped as C10 could become C20. The definition as presented here in the Report text and maps does correlate well, however. It extends the confident BGS correlation down from the UK margin with the C10 surface as marking the exceptionally strong, truncational base of progradational Megasequence RT-a as is observed over vast regions of the NWECS shelf, **Figures 6 & 7, 12 & 21**.

Regrettably in the northern part of the area the C5 horizon becomes progressively ever more difficult to resolve on the current dataset. This is due to the interference from the dipping, strong internal reflections of the progradational depositional systems of the Donegal shelf and upper slope. Since the current thinking shows these to be undoubtedly of RT-a in age, the C5 event is more likely younger and possibly equivalent to the BGS "Glacial Unconformity" that is thought to mark the onset of widespread shelf glaciation and has thus been annotated accordingly.

### 8.3 C10 Horizon

As mentioned above the strongly truncational regional event marking the unconformable base of Megasequence RT-a has been carried southwards from the BGS mapping of the UK Continental Shelf. Like its older predecessors the C10 surface becomes a composite erosion surface progressively truncating the BTU, C30 and C20, e.g. **DX 13**.

The C10 surface certainly provides for a clear and confident pick over the Donegal shelf and the non-eroded parts of the upper slope. Elsewhere the horizon picking becomes less confident. This is due to seabed irregularity caused by 1) faults and slumps; 2) the massive canyon systems together with 3) the not-insignificant faulting cutting the dipping C10 surface itself .

Importantly, C10 can be interpreted to extend to meet the basinal C10 pick on a few lines and its presence is thought to be more widespread. The horizon is, however, tricky and very time consuming to pick unambiguously across the region. The TWT Structure Maps, **Figures 12 or 21** do show that the C10 horizon is considered to exist throughout the NE Rockall region. It should be noted, however, that the confidence of the picking decreases progressively down-slope away from the more accurately constrained, correlated and picked area in the shallower water depths. Looking at the map, the area is gradational down slope with the most confidently picked area lying to the east of the line (dashed) defining the composite nature of the erosion surface. This also coincides roughly with the major C10 fault lineament that runs sub-parallel to the shelf break south of the Donegal Canyon. Assuming the interpretation downslope of the fault to be correct, however, the C10 has been correlated as far down slope as possible throughout the region where the data allows.

The C10 map also shows how the presence of slope valley/canyon systems is recognised to be a feature of the slope development over long periods of time rather than to have been developed at any one particular time. This appears to be the case since the Megasequence RT-a is also eroded and thinned beneath the present day canyon/valley systems as defined from the seabed bathymetry. In the case of parts of the Donegal Canyon system the C10 – Seabed Isochron, **Figure 16**, even shows depositional growth whilst elsewhere further south at the D Canyon for example other systems have eroded out the RT-a sediments, **DX 11**.

### 8.4 C20 Horizon

The C20 surface still remains enigmatic over large portions of the region. Given the prevalence of evidence surrounding the C10 as being the most widely mappable surface tied to the BGS Stratigraphic Framework this horizon has not been very carefully mapped since its occurrence lies mainly in the basinal and complicated, poor data areas of the lower slope environment.

During the study interpretation it has only been possible to correlate the C20 from key input 5 (Section 6.5 above), which is itself based upon regional

correlation from across the opposite side of the basin. If the C20 does exist at the 15/9-1 well location it could be interpreted as being part of the composite unconformity surface interpreted as C10 (i.e. below seismic resolution) which is observed to be a strongly composite surface in the outer shelf/upper slope environment. Another possibility is of a locally down faulted and preserved RT-b section. As **DX 8** shows the seismic data does not immediately suggest this. Naturally, it does remain a possibility but more work is recommended to integrate the well and dating results that were not readily accessed during this study since only a single seismic line passes close to the well.

C20 is often a difficult pick not only in NE Rockall. It is much easier to visualise in the SW part of the investigated region since it is virtually undetectable in the NE. This is especially the case beneath the GEF as interpreted and the Donegal Canyon system. As such the maps shown **Figures 13, 17 & 22** are only of limited value but there was insufficient time and funding to spend on further evaluation.

## 8.5 C30 Horizon

The C30 regional erosion surface is often a moderately well defined seismic horizon and has been picked and correlated from two of the four key inputs of geological control - Sections 6.1 as well as 6.4 above. Positive extrapolation within the Shallow Drilling location 11/20 area also shows sufficient credibility to validate the horizon pick, Section 6.3.

The C30 surface must have been penetrated but has not been dated in well 12/13-1A. Similar to the C20 erosion surface, C30 is strongly truncated by C10 upslope. It is also quite heavily cut by the same listric fault pattern that affects the younger Megasequence RT-a. Once again despite best efforts there was insufficient resources to accurately map out the fault pattern at the C30 horizon. What is marked on the TWT Structure maps **Figures 14 and 18** are the fault cuts at the overlying C10 horizon meaning the C30 faults exist but some way down slope since virtually all the major heaves are down to the basin movements.

The interpreted RT-c “outliers” observed for example on Lines WRM90-395 and NWI-116, **Figure 6** or **DX 6** between SP 1000 - SP1200 are based upon the picking of the C30 below and the overlying C10 horizons.

Similar comments regarding the confidence of the C30 horizon pick as interpreted here apply as for the C10 horizon noted above. Best efforts have been made but the ‘envelope of confidence’ is reduced since as shown on **Figures 14, 18 & 23** the C30 surface becomes composite with C10 due to its angular discordance and truncation prior to the overstepping of Megasequence RT-a. Once again confidence is progressively reduced due to poor imaging of the C30 regional surface as it dips steeply westwards down the middle and lower slope. Some ‘windows’ of better data have been exploited and as the TWT Structure and Isochron maps show the RT-c megasequence is considered to be present over the whole region west of the truncation boundary previously mentioned. It is noticeable on **Figure 18**, however, how the gross thickness (mapped here as RT-c plus remnant RT-b



and all RT-a for convenience) is so strongly influenced by the foot wall presence of the Erris Fault Zone.

## 8.6 C35 Horizon

This is a marker horizon within the RT-d megasequence as interpreted and appears to be important in defining steeper dips and internal seismic facies changes. It occurs only in the southern part of the region where it has been partially mapped as a possible base (or more likely an older intra canyon event) for some of the main canyon systems. The C35 is easily confused with strong amplitude intrusives (sills) that are prevalent within the RT-d. As throughout the section, much more further work could be accomplished at this level.

## 8.7 BTU Horizon

The Base Tertiary Unconformity has been picked independently over large portions of the region from the truncational and onlapping characteristics. This was an essential task since the project required a fundamental basis upon which to build up the interpreted seismic stratigraphy of younger Palaeogene and thence Neogene geological units.

The BTU is often a strong amplitude event and can be extremely strong when tuned with the sills that have intruded along the associated plane of weakness. In other parts of the region assumed extrusive igneous rocks beneath (and also probably above) this major regional erosion surface create a very “woolly” and diffractive surface/zone. This makes precise interpretation difficult and again time consuming since the BTU dips steeply down the slope and is therefore naturally often incorrectly imaged in dip and strike directions by the 2D seismic.

The TWT Structure maps **Figures 15 & 24** show the fault pattern affecting the BTU, (main faults only). The fault pattern is of course closely linked to the deeper faulting effecting the Mesozoic and Palaeozoic. Comparison with the C10 fault pattern shows the considerable differences in the stress regime between these periods and naturally the faulting is far steeper than those shallow dipping listric faults cutting the C30, C10 and up to the seabed. Importantly, however, some, but not all, of the older steeper faulting can be traced directly from the BTU through the RT-d – RT-a megasequences. The **Data Examples** e.g. **1, 3, 6** and others show this clearly. This must show very recent (post-Pleistocene) reactivation and needs further investigation.

It should be noted that due to time considerations only the major faults at the BTU surface are shown. As a normal QA procedure the partially complete BTU horizon was compared with that of a major oil company to show a strong degree of similarity. Due to time constraints it was decided to continue the interpretation using the imported picked horizon. Unfortunately this surface had been interpreted to minimise the number of fault cuts at the BTU. This

effectively smoothed the irregular erosion surface to simplify and ease future mapping procedures. Thus although not shown the BTU is actually considerably more faulted than shown on **Figures 15 & 24**. In fact the younger listric faults are often seen to be linked to the BTU fault pattern and this has tried to be portrayed on the BTU – Seabed Isochron map, **Figure 19** or **Data Examples 5 & 6**. More detailed examples are shown in the Slope Stability Investigation Report, RSG Project 00/6, Austin 2001b.

## 9. CONCLUSIONS and RECOMMENDATIONS

Over 15,000km of 2D seismic data has been interpreted and integrated with as much geological information from cores and well logs as is available in the RSG/PIP Database. The interpretation has identified several regional unconformable surfaces termed BTU, C30, C20 and C10. These have been correlated across the NE Rockall region and tie into the more basal stratigraphic framework identified by Stoker et al 2000 that contains verifiable age dating of samples recovered from a limited number of shallow borings.

The occurrence of Megasequences RT-d through RT-a has been shown to exist between the major unconformities by a series of (vertically exaggerated) geoseismic cross sections. These show their depositional development to be far from straightforward or uniform. This applies westwards across the margin as well as NE/SW along the margin. The occurrence of remnant outliers, fault bounded deposits, missing sections bounded by composite unconformity surfaces clearly fits into the concept of a unified and basin wide stratigraphic framework covering the Palaeogene and especially Neogene.

Structure maps of the important regional unconformity surfaces and corresponding interval isochrons have been mapped. They reveal a dynamic structural as well as depositional history as shown by the complicated subcrop patterns and thickness changes. The ancient NE/SW trending Erris fault zone is extremely influential. Further north the listric faulting that defines the easterly region of multi-composite C10, erosion is similarly strong.

The NE Rockall region has not, however, been dominated entirely by down to the basin faulting along pre-existing lineaments sub parallel to the present day slope. Apart from the Erris zone surprisingly few faults that cut the pre Tertiary appear to have moved substantially since. Rather the younger Paleocene and Neogene faulting that can be seen appears to decoll at the BTU in most places as a response to basin subsidence and steepening of the NE Rockall slope.

Extensive modification and erosion of the younger post RT-d megasequences has occurred across the NE Rockall region. This has been as a response to the structural history and also the powerfully destructive forces of contour currents and the interference of ocean water layers as they are constrained by bathymetry. These appear to affect the deepest parts of the slope as indicated by the constructive wave crest axes in the canyon system fills as well as the outer shelf environment. This is inferred from observation of the interfingering mixture of up slope aggrading contourites with off shelf prograding seismic facies within Megasequence RT-a.

The stratigraphic framework study shows that faulting and gravitational instability has occurred throughout the Neogene. Judging from the faults mapped cutting up to the seabed the instability is apparently still continuing – ‘apparently’ since we cannot state categorically that the seabed is not a palaeo or relict surface of *presumably* RT-a age. This remains critically important and it is recommended that the study results and stratigraphic framework be further calibrated by shallow boring sample dating at carefully selected locations.

## 10. BIBLIOGRAPHY

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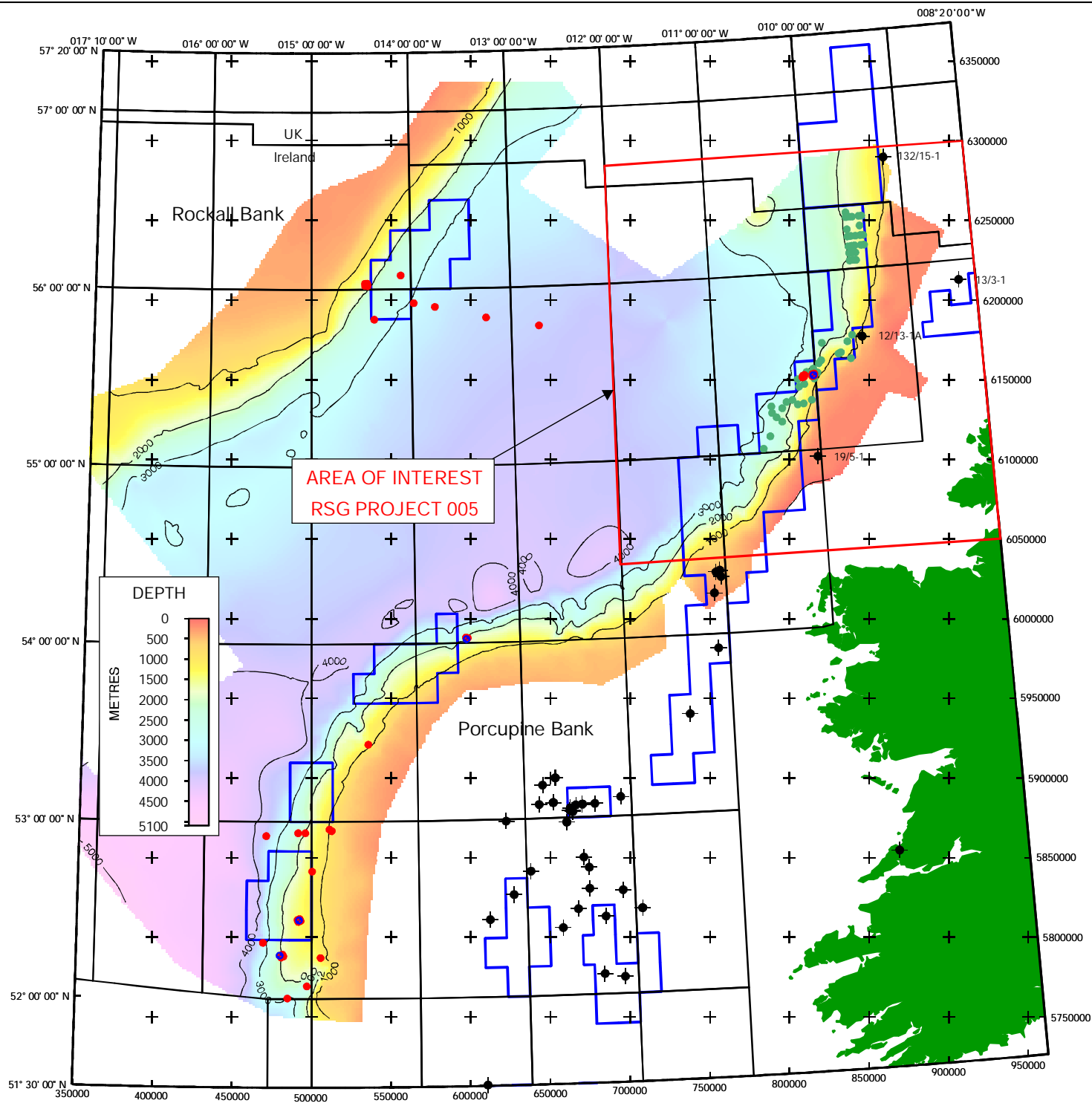
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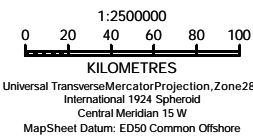
Stoker, M. S. & Gillespie, E.J. 2000. *Central Rockall Basin (56 deg. 58 min N – 08 deg. 15 min W) Solid Geology sheet*, BGS Technical Report CR/00/67.



#### Legend

- Wells ◆
- BGS Gravity Cores ●
- Shallow drilling locations ●
- Geoboy cores ●

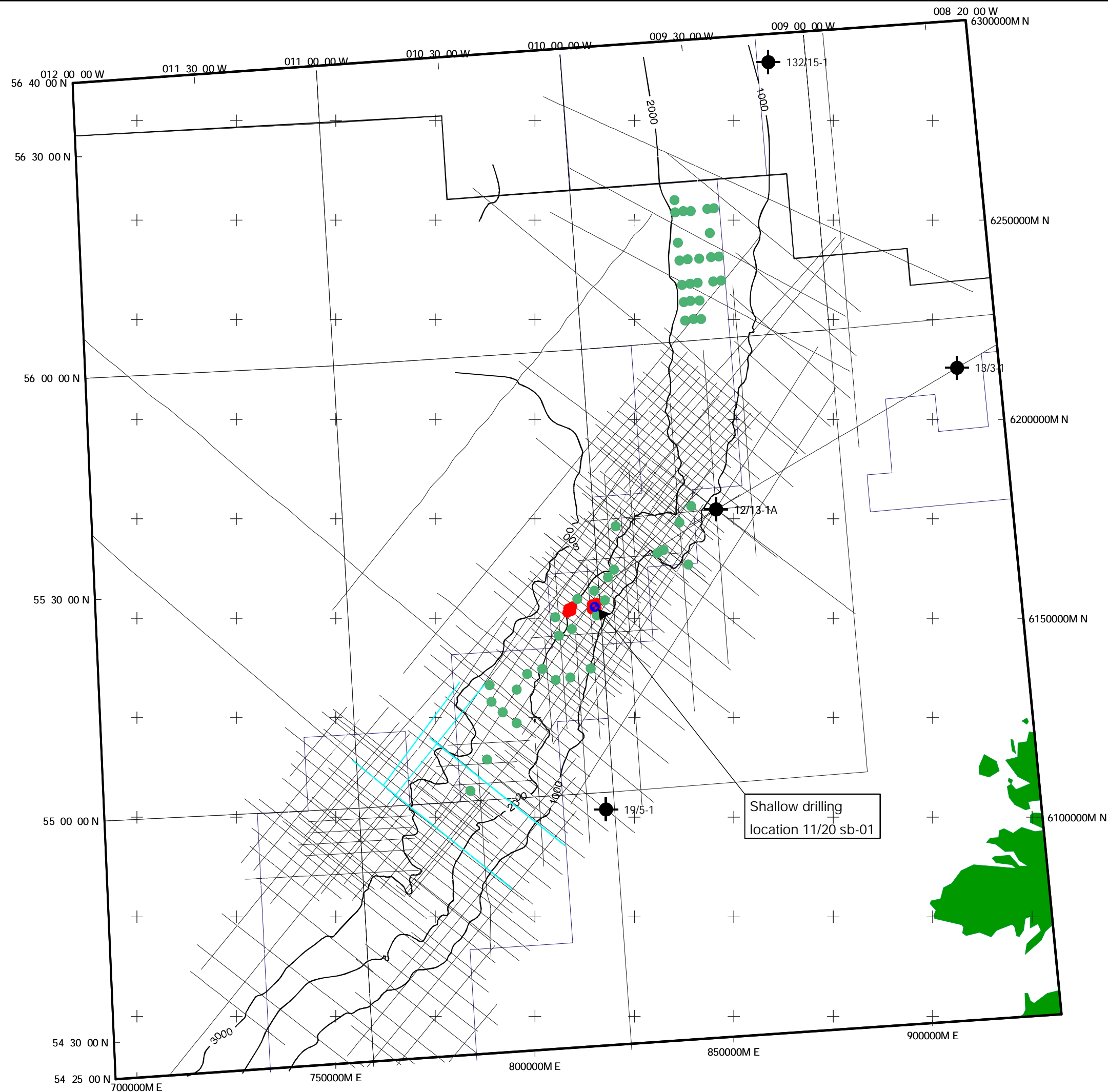
#### NOTES



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### Figure 1 LOCATION MAP

Author: BJA CWNWSW	Date: December 3, 2001
RSG Project 00/5	Revision: Final BJA



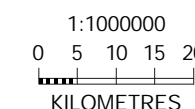
HYDROSEARCH

### Legend

- Wells ✚
- BGS Gravity Cores ●
- Shallow drilling location ⊕
- Geoboy cores ●
- 2D Seismic lines —
- NIOZ 2000 seismic lines —

### NOTES

Challenger (BGS) Hi Res Seismic (not shown), covers area of BGS gravity cores around 11/20 shallow drilling site.

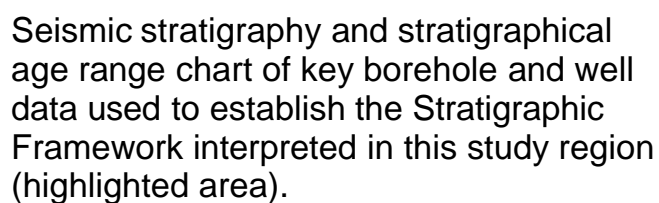


Universal Transverse Mercator Projection, Zone 28 N  
International 1924 Spheroid  
Central Meridian 15 W  
Map Sheet Datum: ED50 Common Offshore

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## Figure 2 DATABASE

Author: BJA CW NSW	Date: December 3, 2001
RSG Project 00/5	Revision: Final BJA



SECS  
TWT

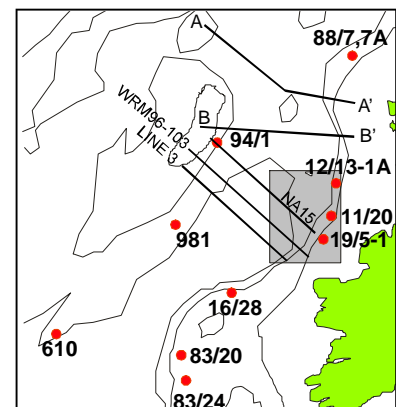
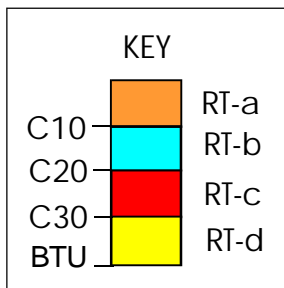
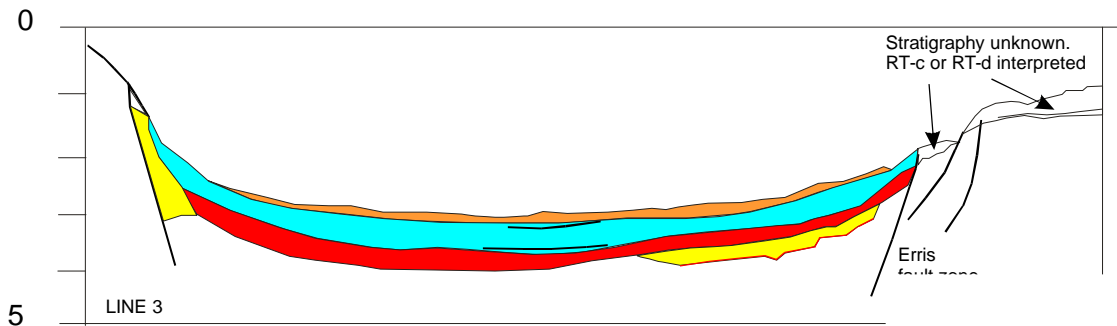
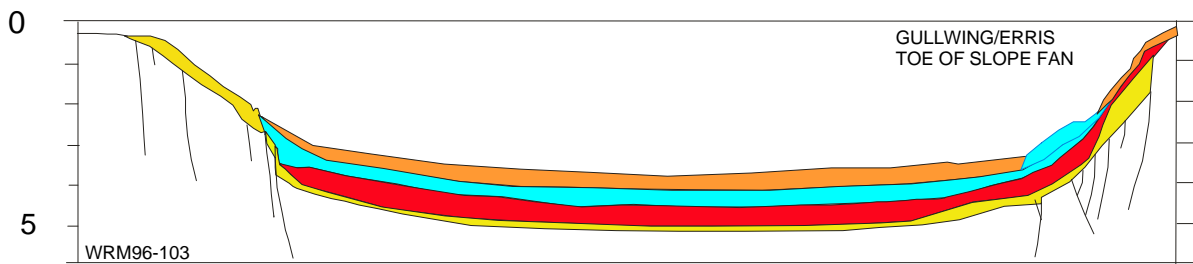
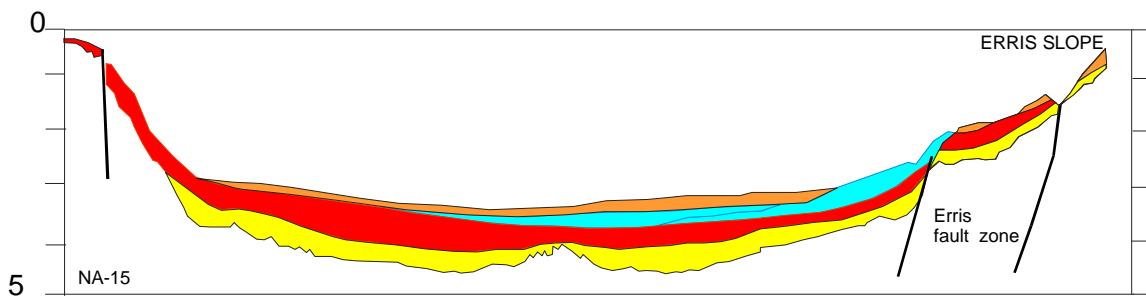
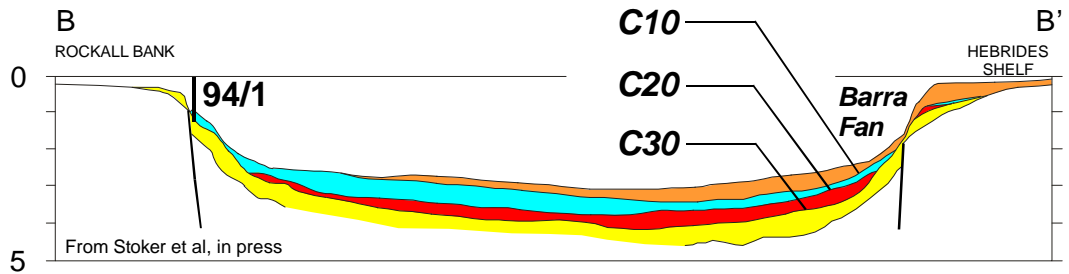
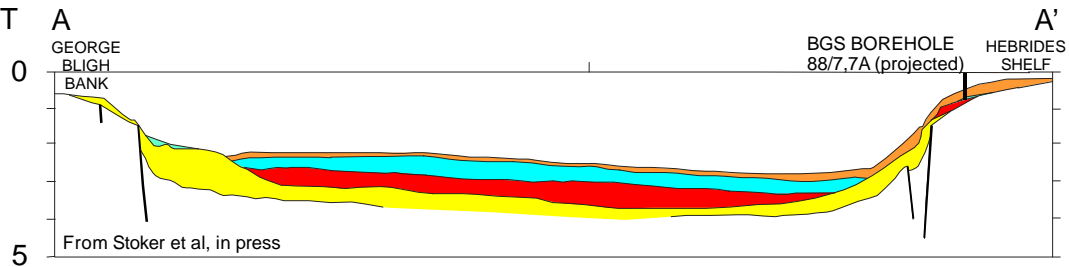
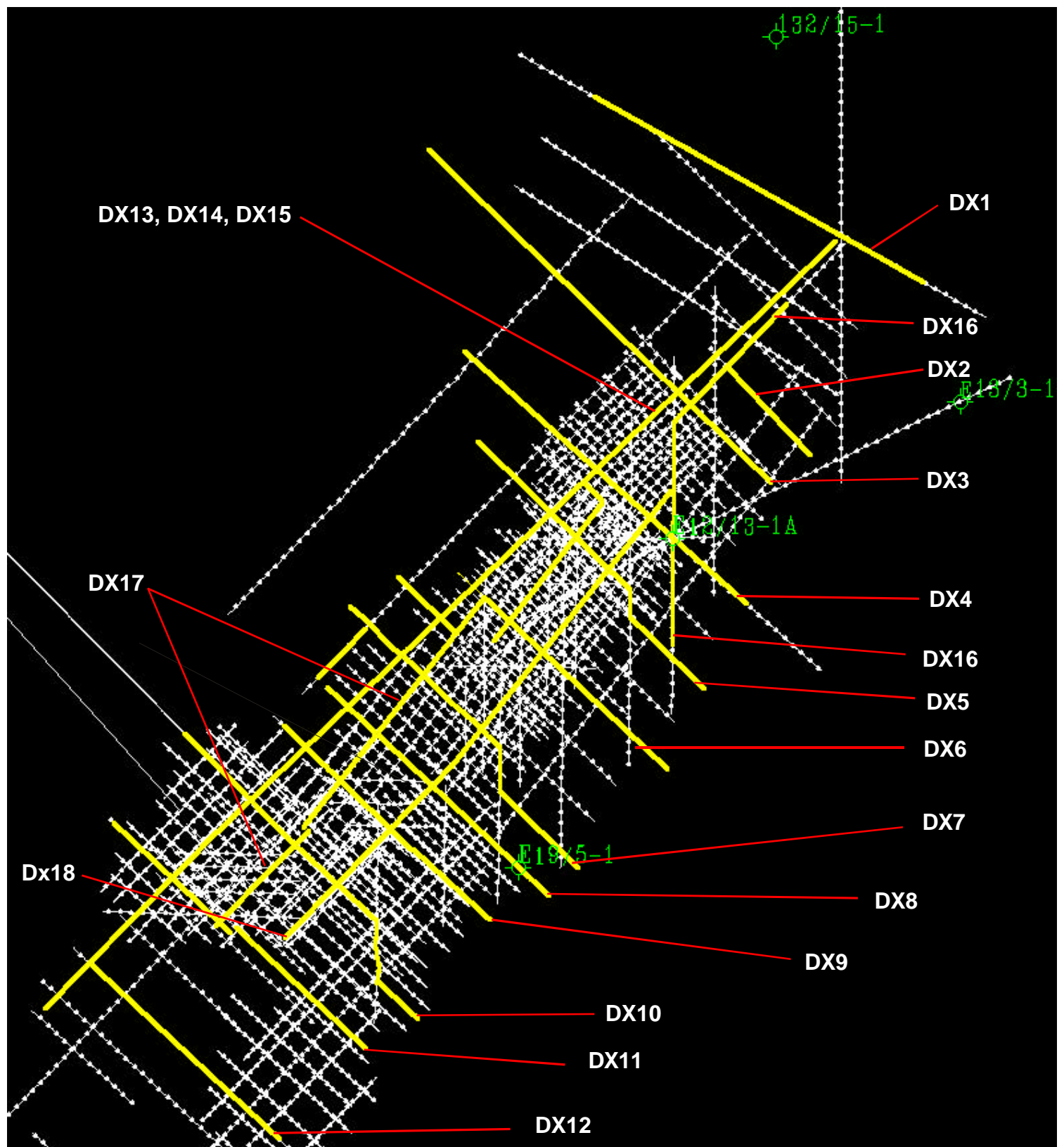


Figure 4: Regional Overview of  
Stratigraphic Framework





**Figure 5: Location map of Geoseismic Profiles and Data Examples**

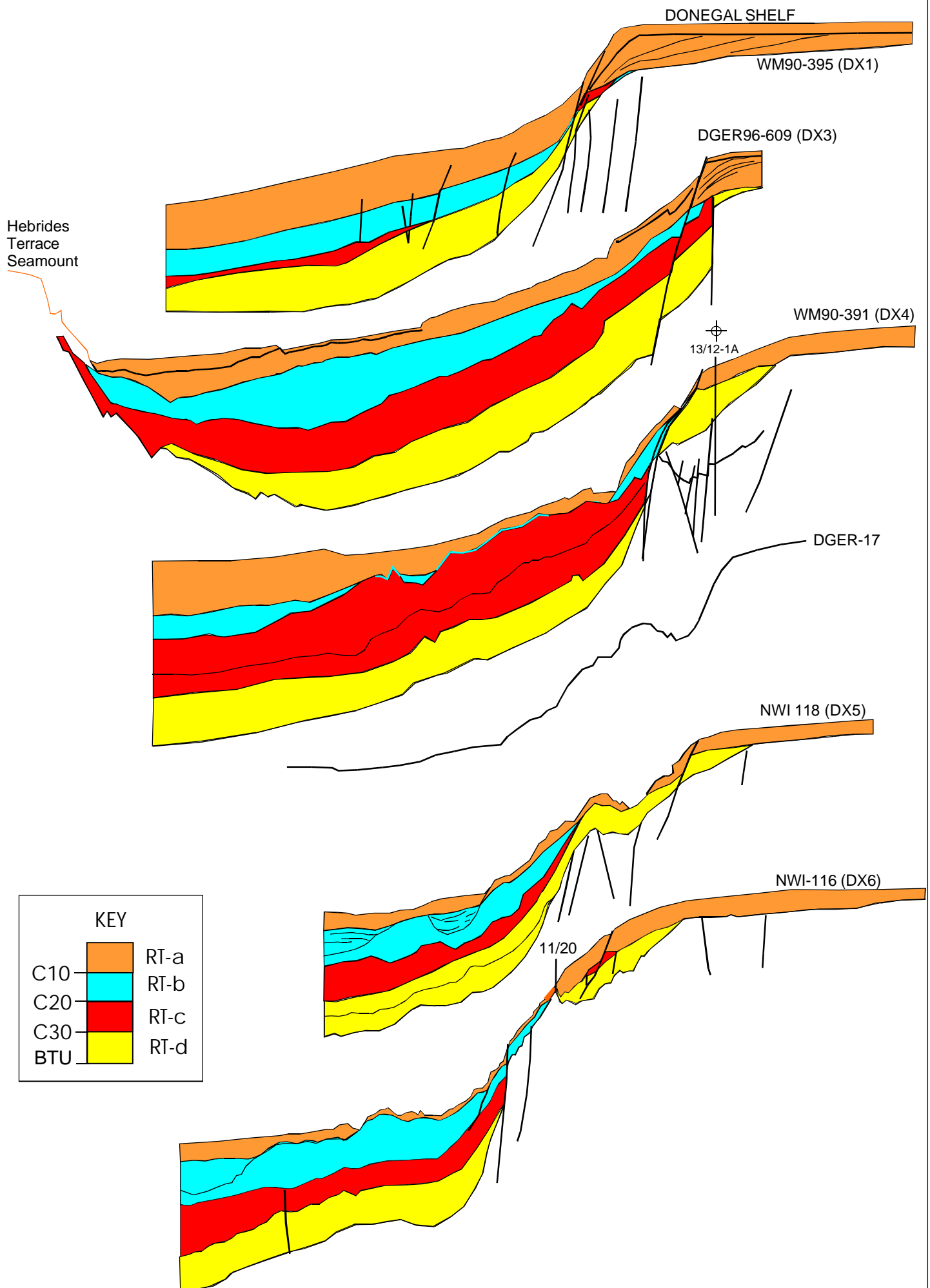


Figure 6: Bathymetric and Geoseismic Profiles - NE Rockall  
(for location see Figure 5)

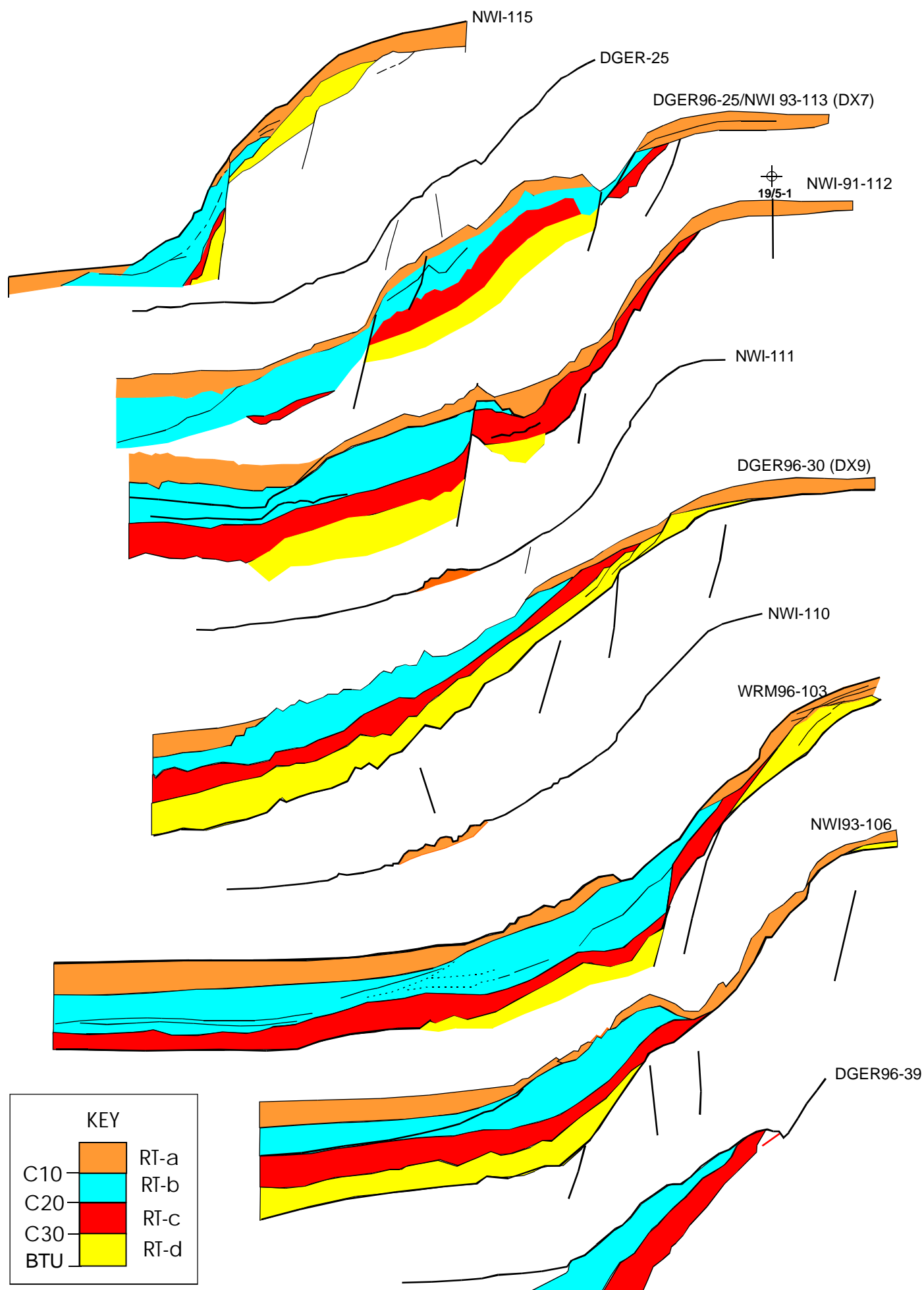


Figure 7: Bathymetric and Geoseismic Profiles - NE Rockall  
(for location see Figure 5)

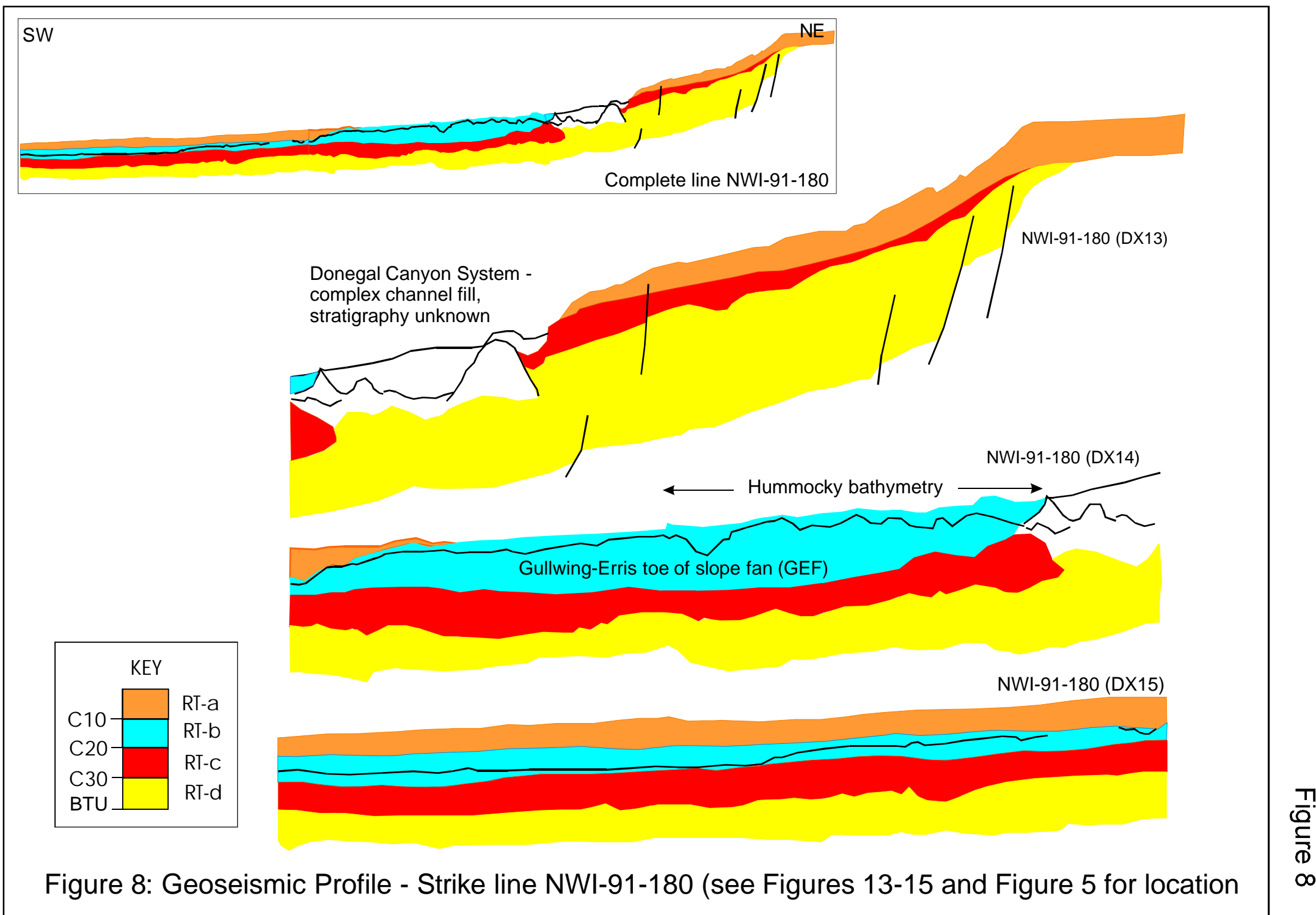




Figure 9 Geoseismic Profile - Strike

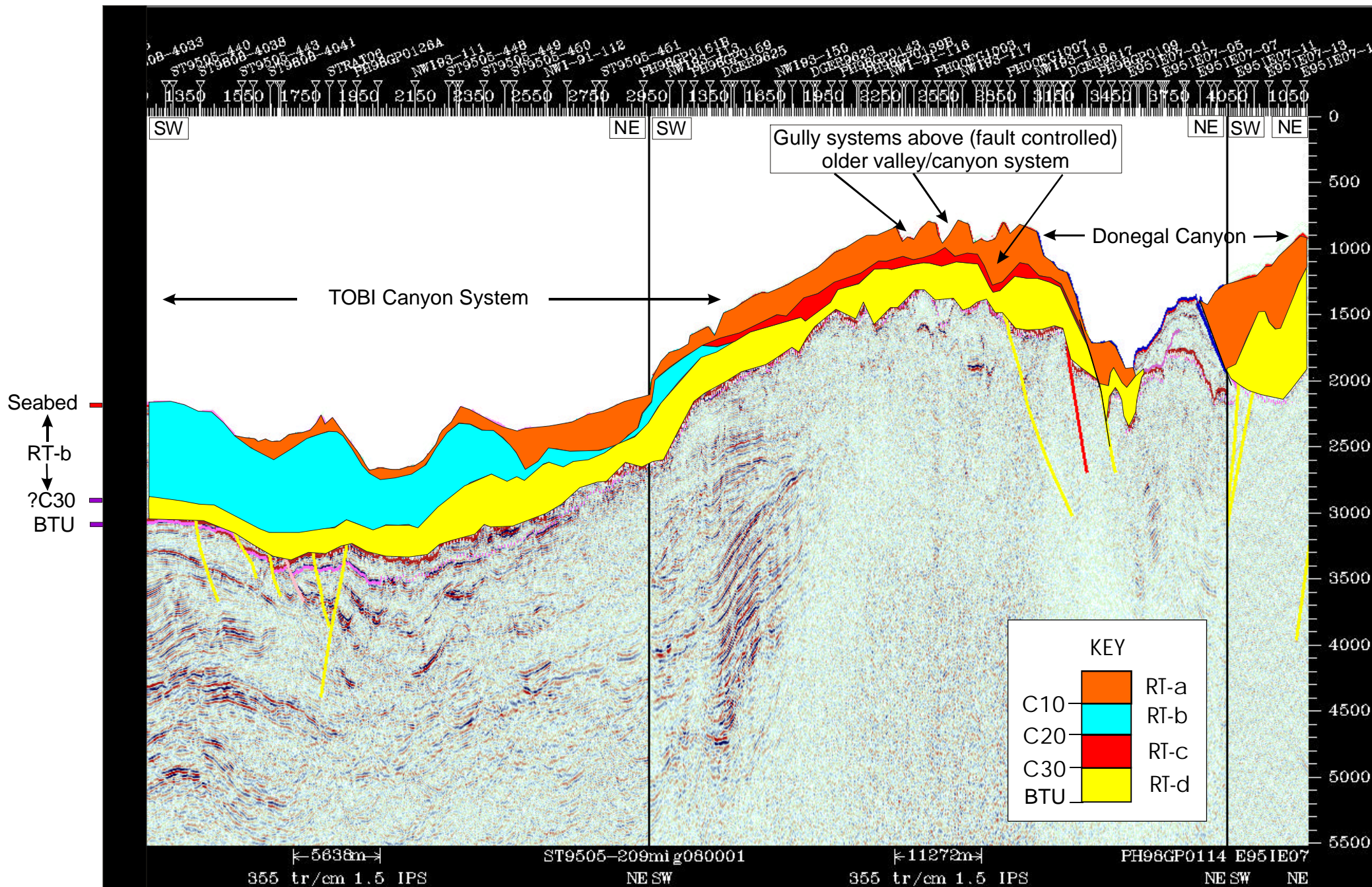
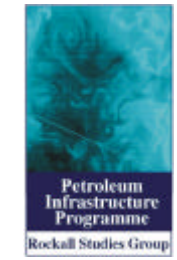
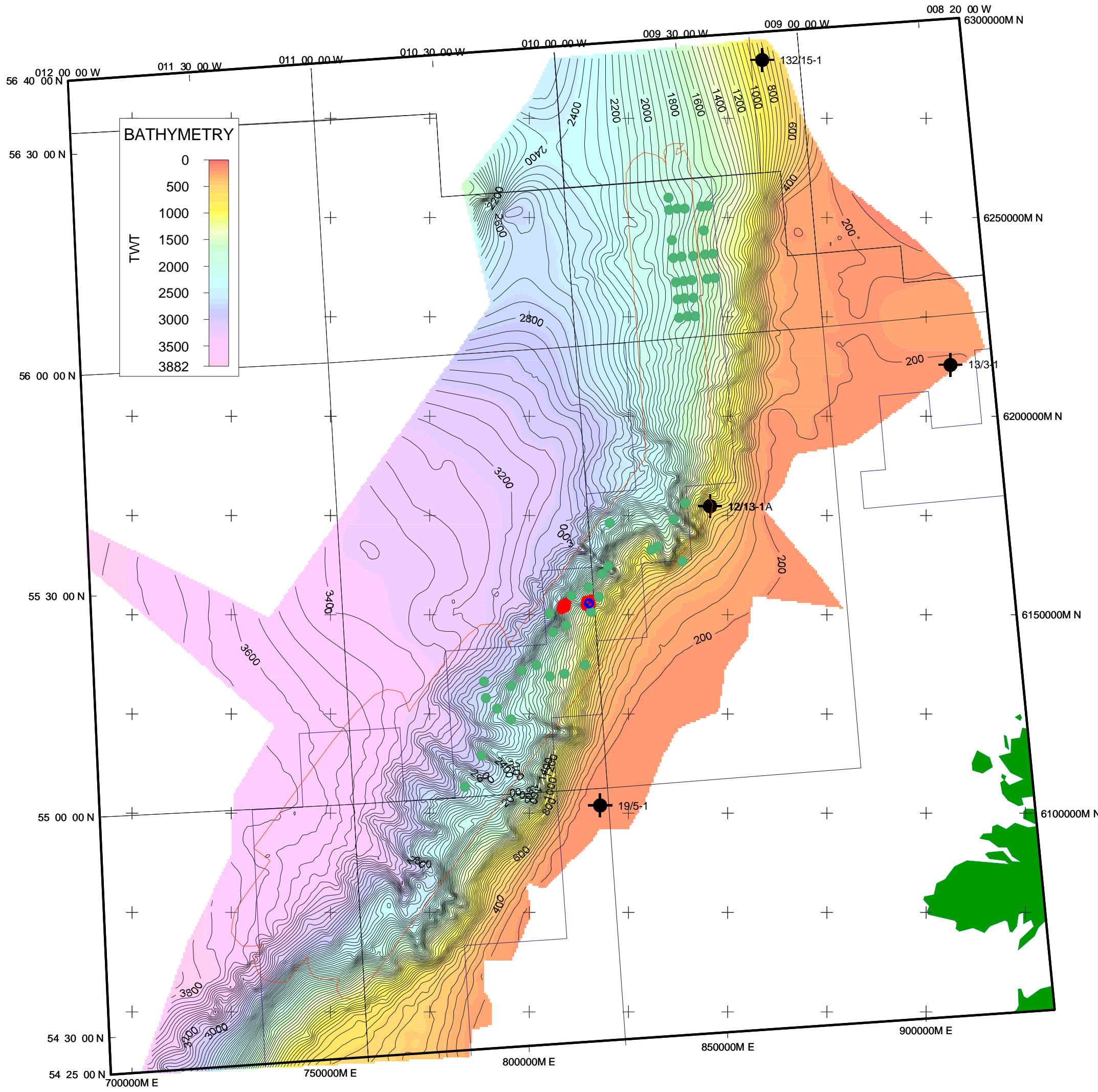


Figure 9





**Legend**

- Wells
- BGS Gravity Cores
- Shallow drilling location
- Geoboy cores
- TRIMS coverage

**NOTES**

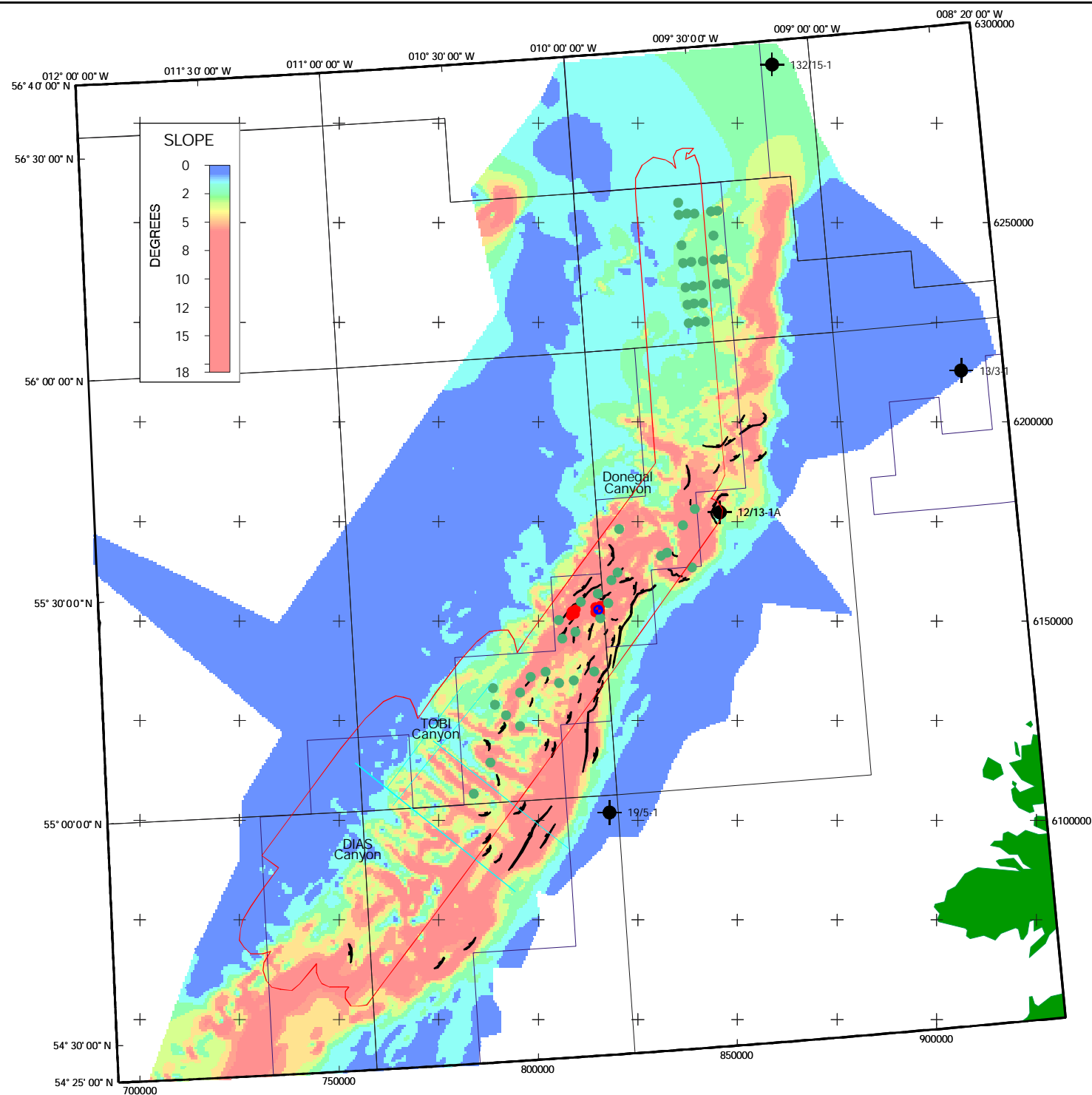
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C.I. = 50 msecs  
Values are in Two Way Travel time taken from interpreted seabed pick from RSG 2000 2D exploration dataset.  
Integrated bathymetry (in depth) covering this region can be found in RSG Project 007.

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Universal Transverse Mercator Projection, Zone 28 N  
International 1924 Spheroid  
Central Meridian 15 W  
Map Sheet Datum: ED50 Common Offshore

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**Figure 10**  
**BATHYMETRY (TWT)**

Author: BJA CW NSW	Date: December 3, 2001
RSG Project 00/5	Revision: Final BJA



### Legend

- Wells ●
- BGS Gravity Cores ●
- Shallow Drilling location ●
- Geoboy cores ●
- NIOZ 2000 Seismic lines —
- Faults cutting seabed —
- TRIMS coverage ○

### NOTES

Grid Cell Size = 500m

Slope values derived from Bathymetry grid, see notes Figure 10

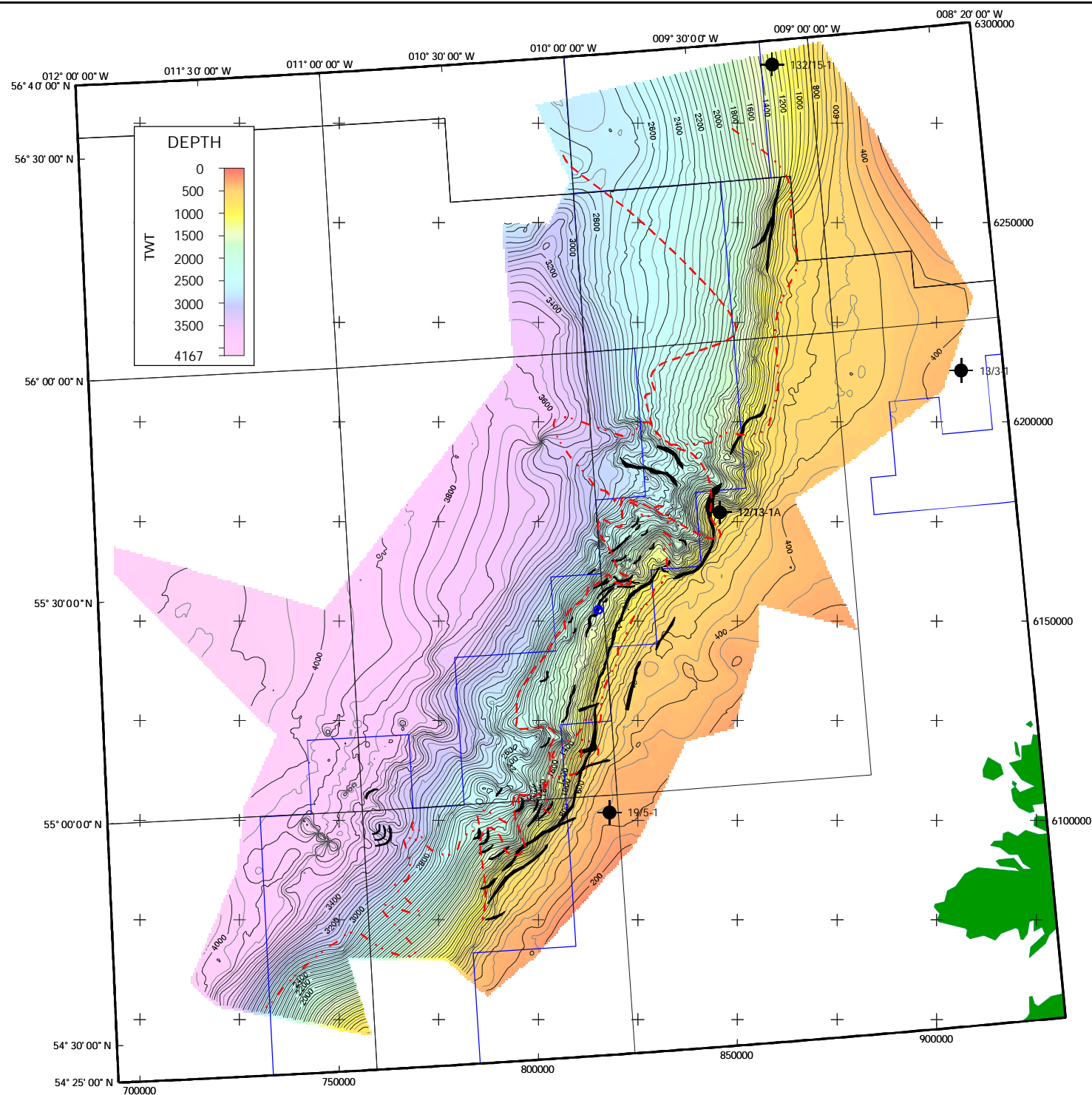
TOBI Canyon - major slope canyon/valley systems described further in RSG Project 006.

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Universal Transverse Mercator Projection, Zone 28N  
International 1924 Spheroid  
Central Meridian 15 W  
Map Sheet Datum: ED50 Common Offshore

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## Figure 11 SEABED SLOPE

Author: BJA CW NSW	Date: December 3, 2001
RSG Project 00/5	Revision: Final BJA



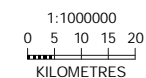
HYDROSEARCH

### Legend

- Wells ◆
- Shallow drilling location ●
- TWT structure contours (see note) —
- Faults cutting C10 Horizon —
- Updip of line, the C10 regional erosion surface becomes composite cutting the C20, C30 and the BTU - - -
- Approx. boundary between prograding and contourite sedimentary facies - - -

### NOTES

Grid Cell Size = 500m  
 C.I. = 50msec  
 TWT structure based upon interpretation of RSG 2000 2D exploration seismic data-set, see figure 2.



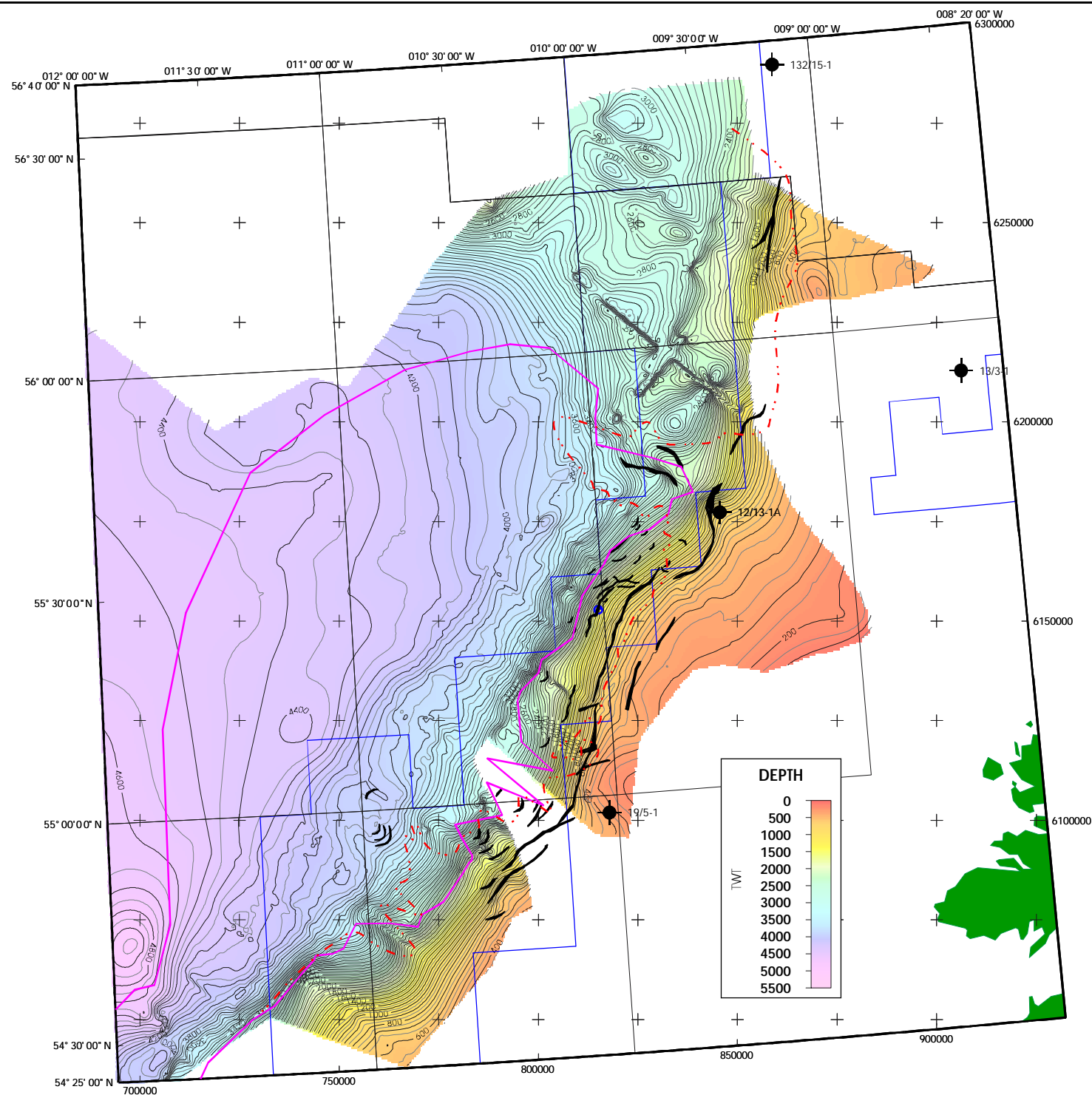
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 Map Sheet Datum: ED50 Common Offshore

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## Figure 12 C10 TWT STRUCTURE

Author: BJA CW NSW	Date: December 3, 2001
RSG Project 00/5	Revision: Final BJA





HYDROSEARCH

### Legend

- Wells
- Shallow drilling location
- Faults (from C10 Structure map)
- C20 surface becomes composite with C10 regional erosion surface
- Extent of Gullwing/Erris toe of slope fan

### NOTES

Cell Size = 500m

C.I. = 50 msecs

Interpretation of the C20 surface is from RSG Project 98/23 .

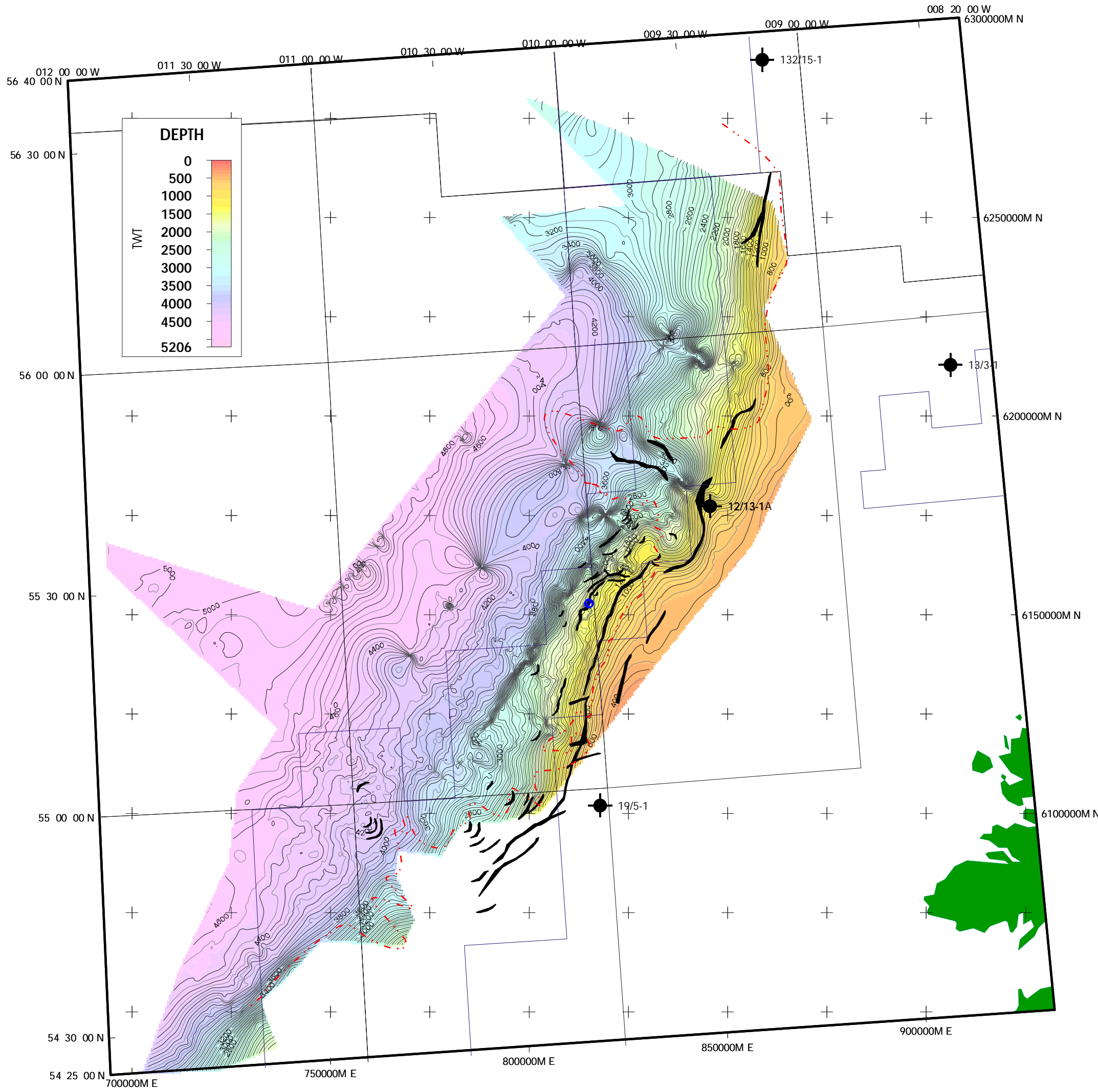
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Universal Transverse Mercator Projection, Zone 28N  
International 1924 Spheroid  
Central Meridian 15 W  
Map Sheet Datum: ED50 Common Offshore

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## Figure 13 C20 TWT STRUCTURE

Author: BJA CW NSW	Date: December 3, 2001
RSG Project 00/5	Revision: Final BJA

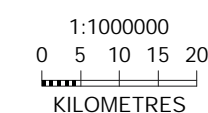


### Legend

- Wells
- Shallow drilling location
- Faults (from C10 Structure Map)
- C30 surface becomes composite with C10 regional erosion surface

### NOTES

Grid Cell Size = 500m  
C.I. = 50 msecs



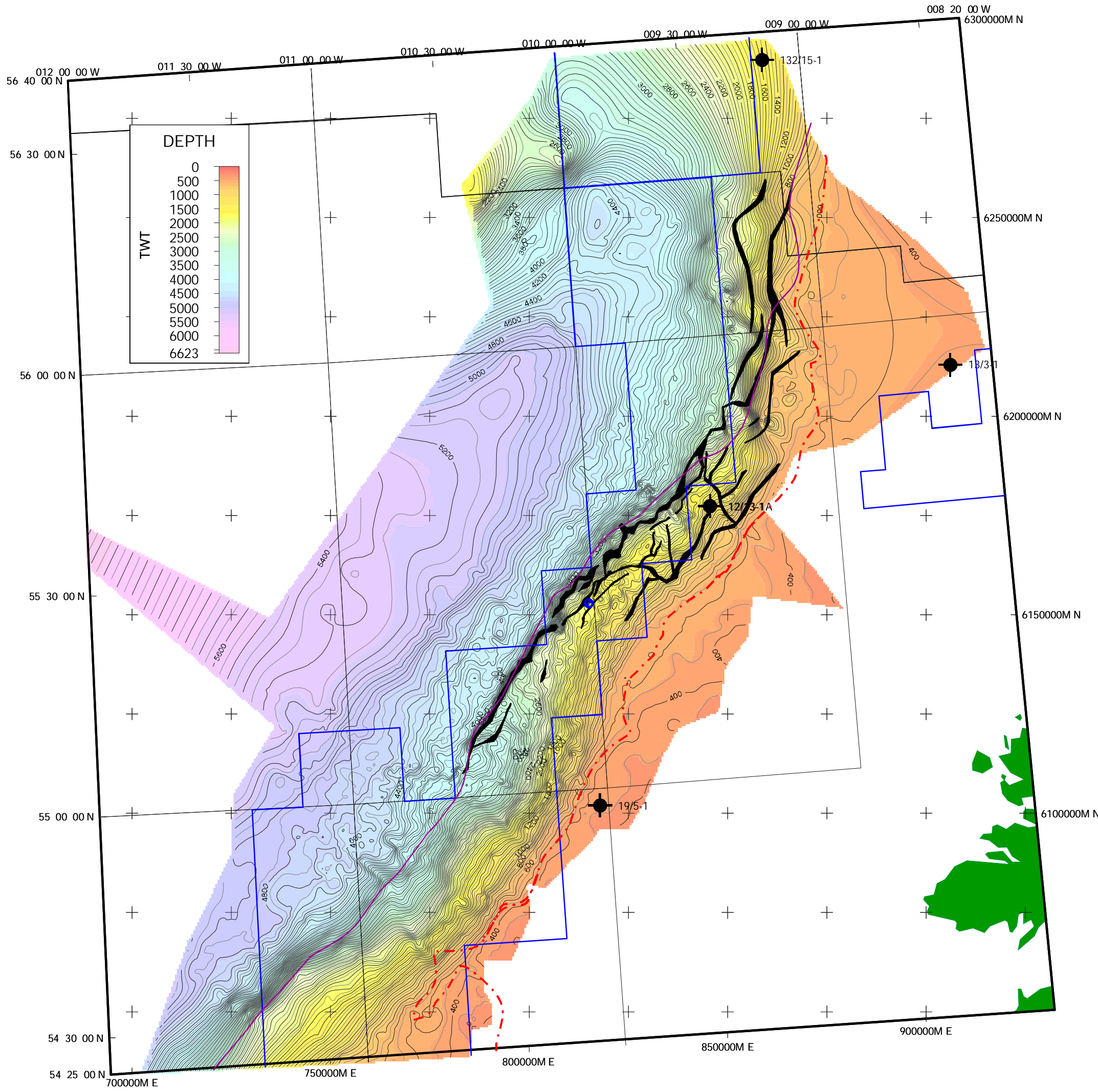
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Central Meridian 15 W  
Map Sheet Datum: ED50 Common Offshore

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Figure 14  
C30 STRUCTURE

Author: BJA CWNSW	Date: December 3, 2001
RSG Project 00/5	Revision: Final BJA





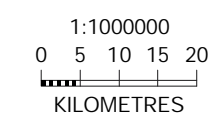
**Legend**

- Wells
- Shallow drilling location
- Fault cutting BTU horizon
- TWT structure contours (see note)
- Updip of line the BTU regional erosional surface becomes progressively onlapped by C30, C20 and C10 surfaces
- BTU subcrops at C10 erosion surface

**NOTES**

Grid Cell Size = 500m  
C.I. = 50 msec

TWT structure based upon interpretation of RSG 2000 2D seismic data set and discussions with leading explorationists. Little well control exists downslope....

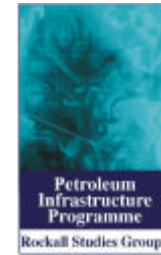
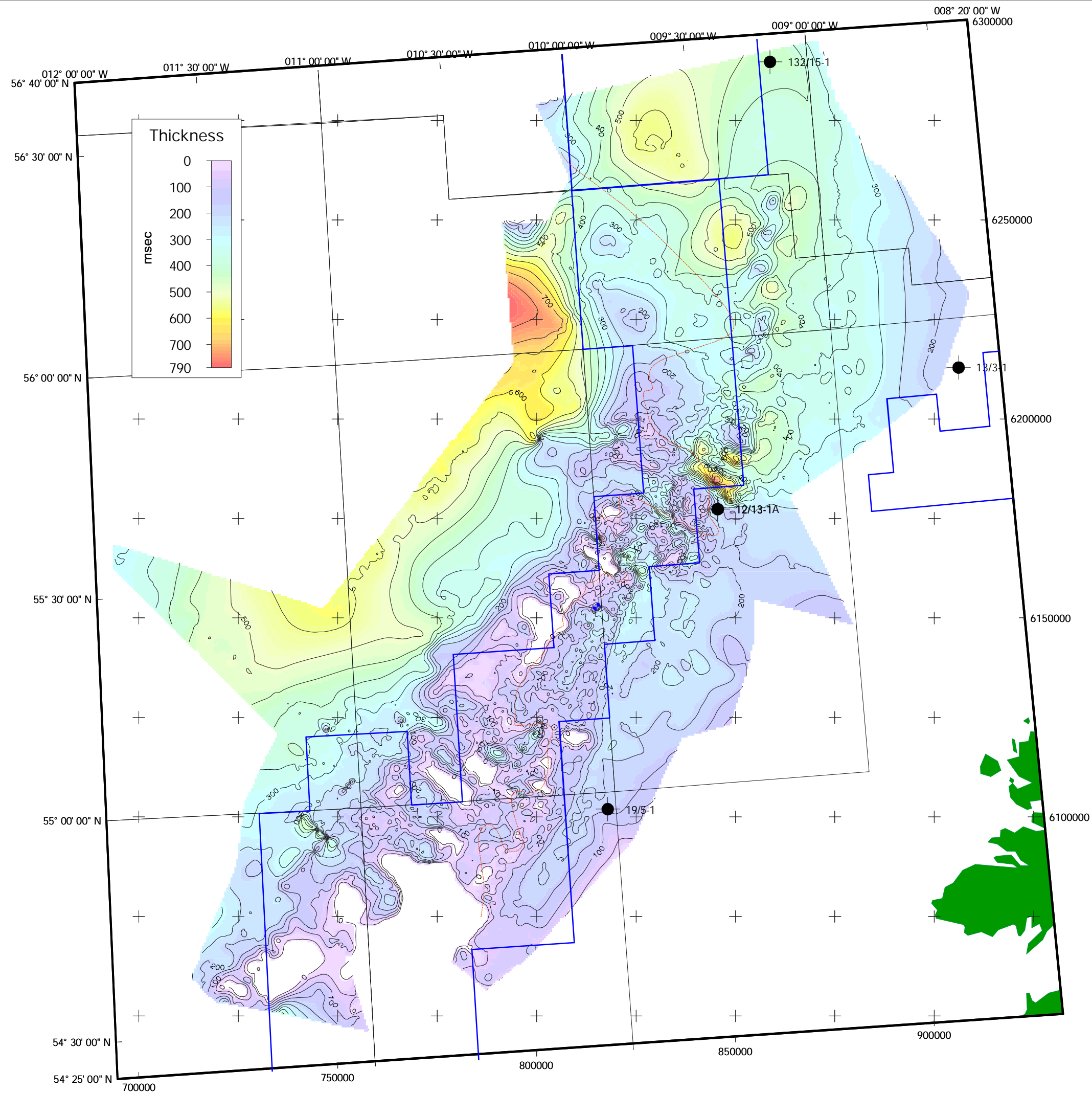


Universal Transverse Mercator Projection, Zone 28 N  
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Map Sheet Datum: ED50 Common Offshore

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**Figure 15**  
**BTU TWT STRUCTURE**

Author: BJA CW NSW	Date: December 3, 2001
RSG Project 00/5	Revision: Final BJA



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### Legend

- Wells
- Shallow drilling location
- Approx. boundary between prograding and contourite sedimentary facies

### NOTES

Cell Size = 500m  
C.I. = 50 msecs

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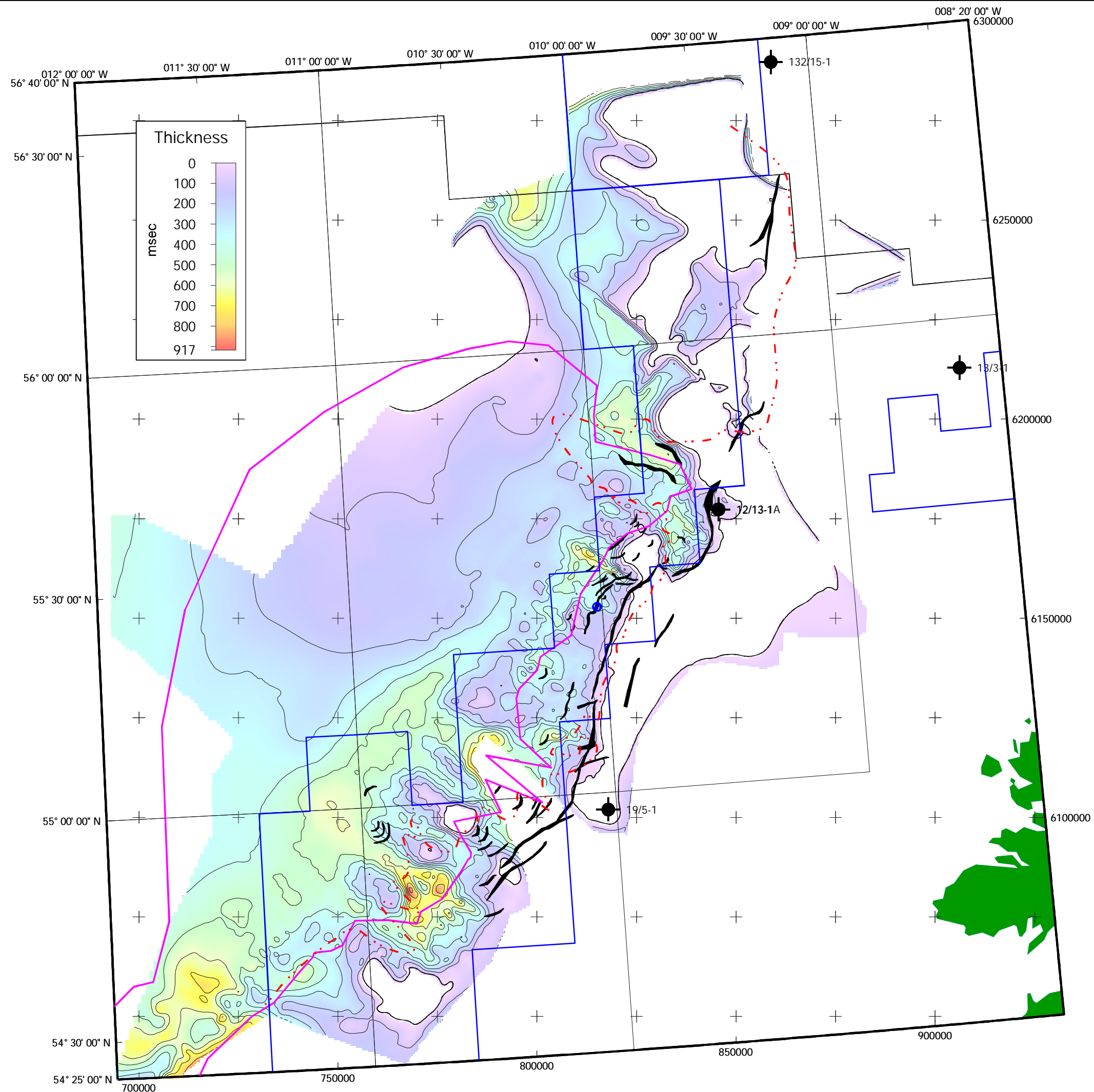
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Figure 16  
C10-SEABED  
ISOCHRON TWT

Author: BJA CW NSW	Date: December 3, 2001
RSG Project 00/5	Revision: Final BJA





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## Legend

- Wells
- Shallow drilling location
- Faults (from C10 structure map)
- Extent of Gullwing Erris toe of slope fan
- C20 surface becomes composite with C10 regional erosion surface

## NOTES

Grid Cell Size = 500m  
C.I. = 50 msecs

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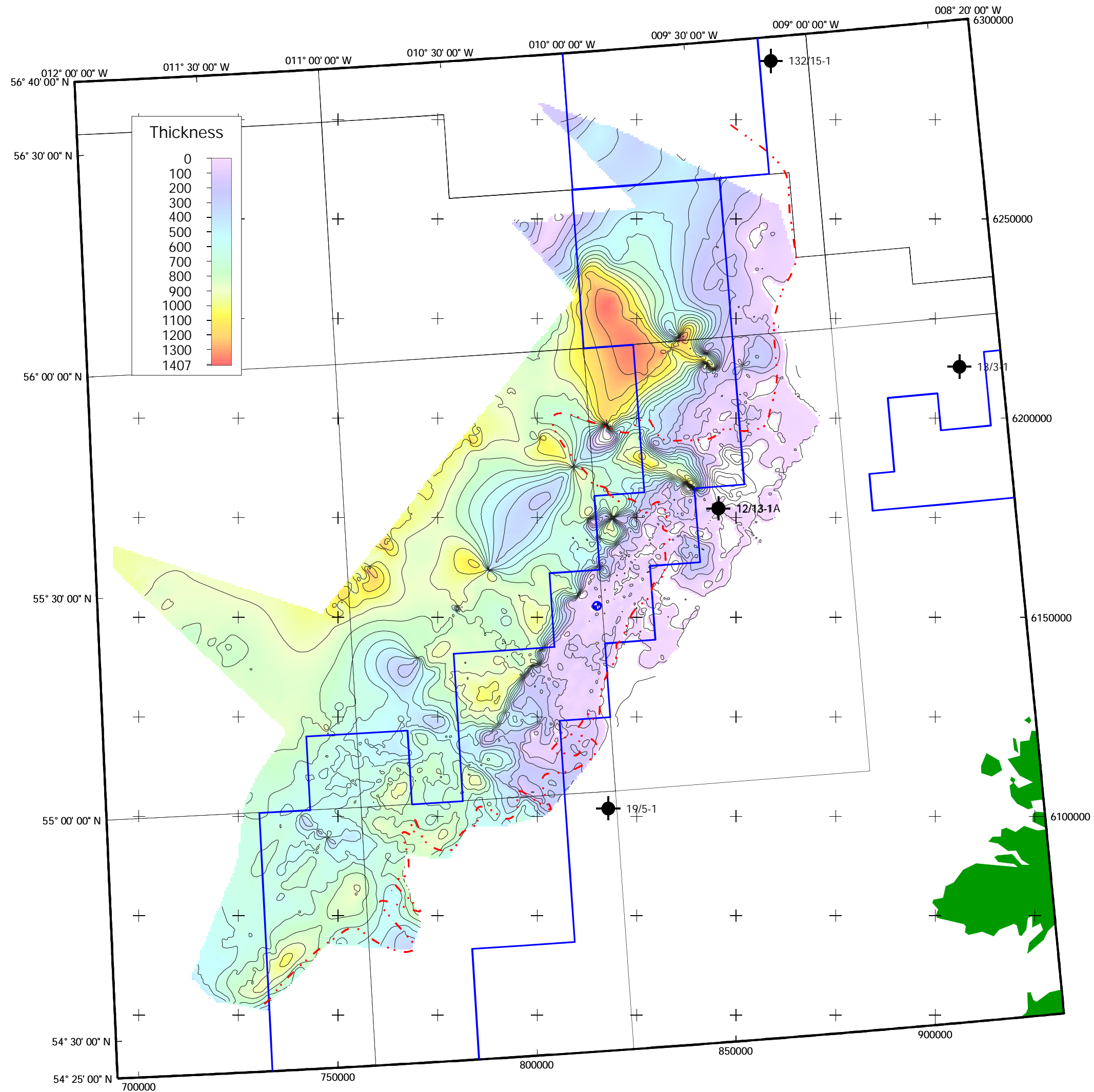
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Universal Transverse Mercator Projection, Zone 28 N  
International 1924 Spheroid  
Central Meridian 15 W  
Map Sheet Datum: ED50 Common Offshore

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Figure 17  
C20 - SEABED  
ISOCHRON TWT

Author: BJA CW NSW	Date: December 3, 2001
RSG Project 00/5	Revision: Final BJA



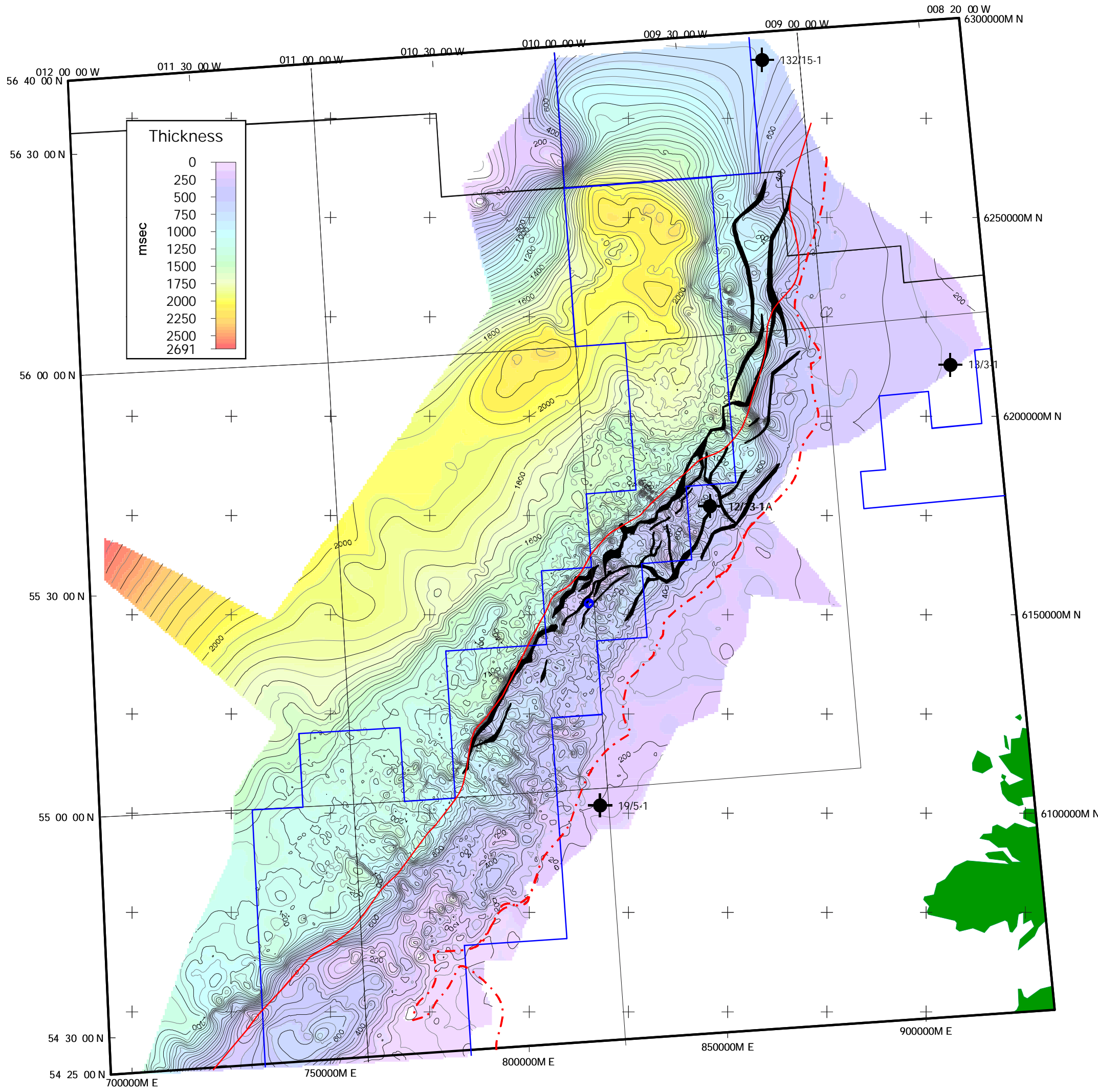
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Figure 18  
C30 - C10  
ISOCHRON TWT

Author: BJA CW NSW	Date: December 3, 2001
RSG Project 00/5	Revision: Final BJA





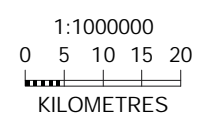
HYDROSEARCH

### Legend

- Wells
- Shallow drilling location
- Faults cutting BTU
- Updip of line, the BTU regional erosion surface becomes progressively onlapped by C30, C20 and C10 surfaces
- BTU subcrops at C10 erosion surface

### NOTES

Grid Cell Size = 500m  
C.I. = 50 msecs



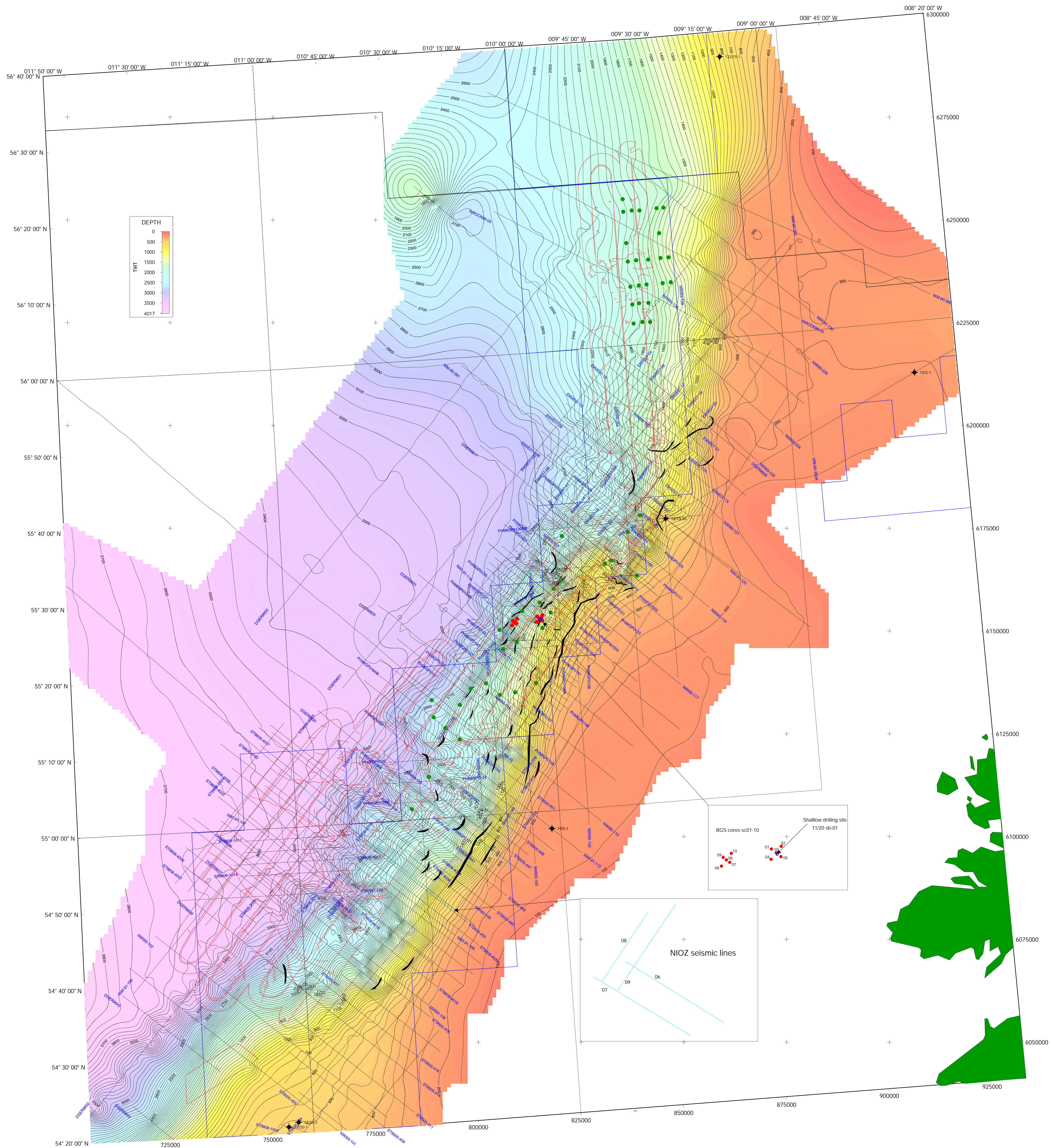
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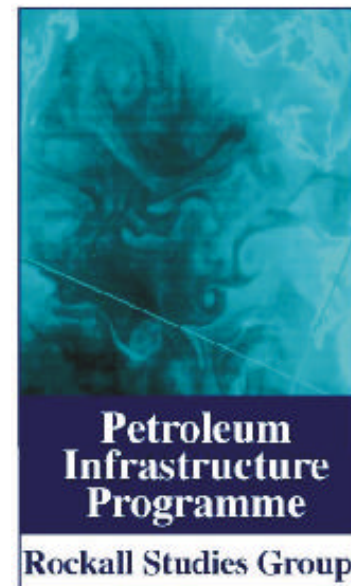
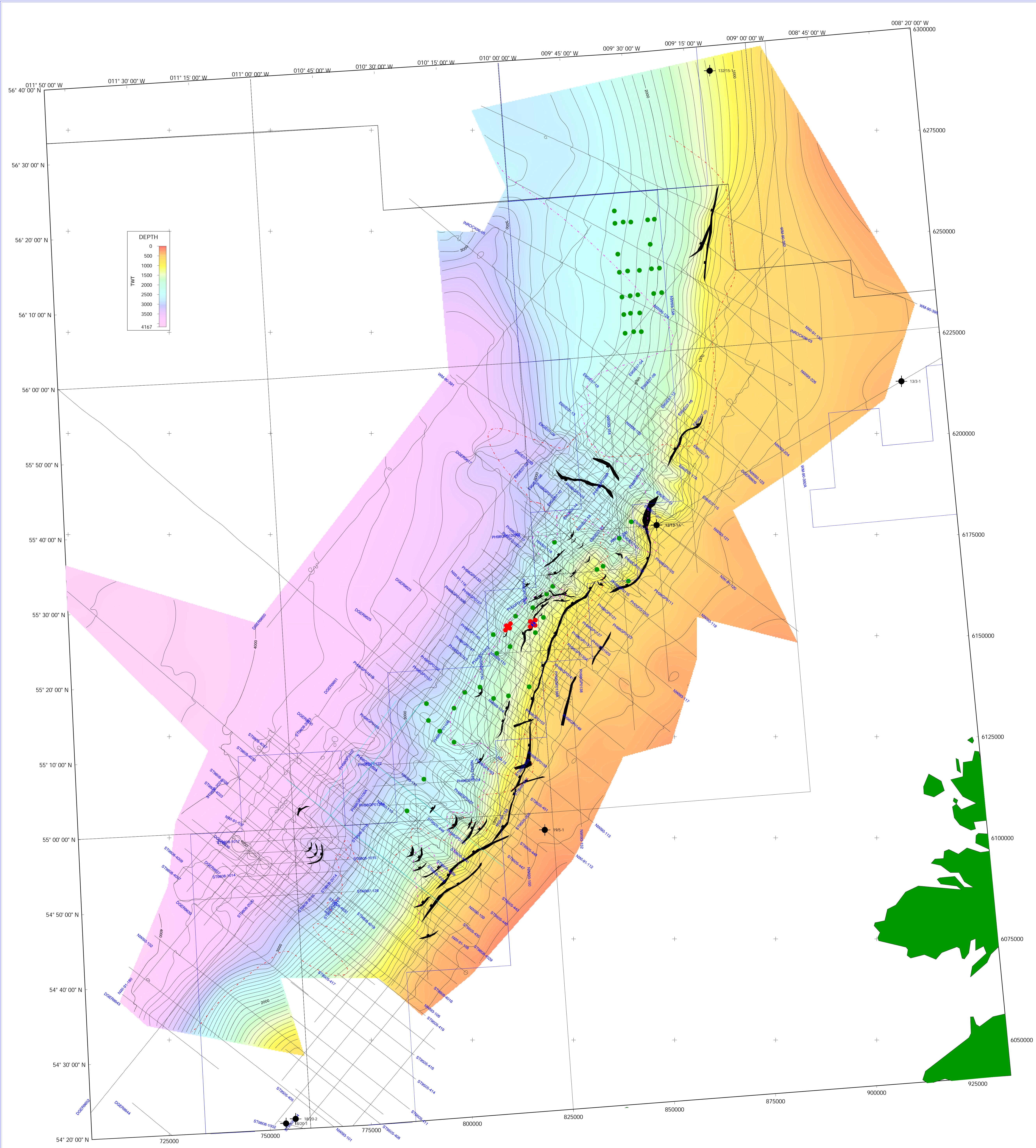
Figure 19  
BTU -SEABED  
ISOCHRON TWT

Author: BJA CW NSW	Date: December 3, 2001
RSG Project 00/5	Revision: Final BJA







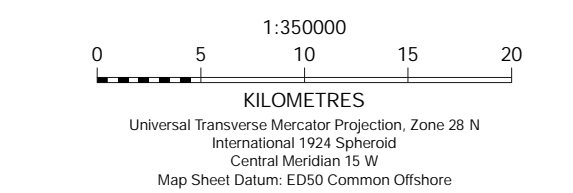


**HYDROSEARCH**

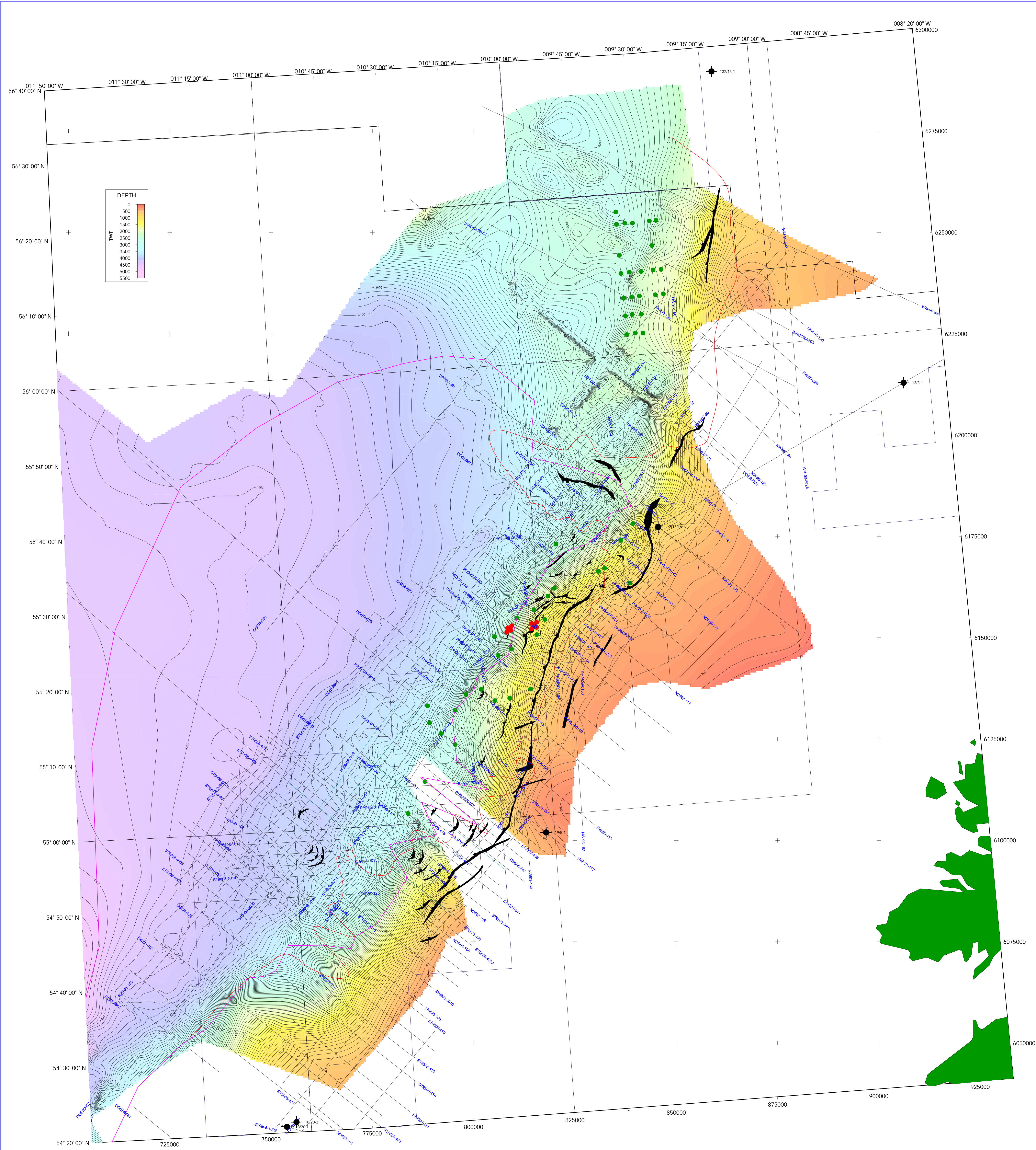
- Legend**
- Wells
  - BGS Gravity Cores
  - Shallow Drilling Location
  - Geoboy cores
  - 2D Seismic lines
  - Approx. boundary between prograding and contourite sedimentary facies
  - Uplap of line, the C10 reformation erosion surface becomes composite cutting the C20, C30 and the B1U
  - NIOZ 2000 seismic lines
  - Faults cutting C10 horizon

**NOTES**

Grid cell size = 500m  
C.1 = 100 msec







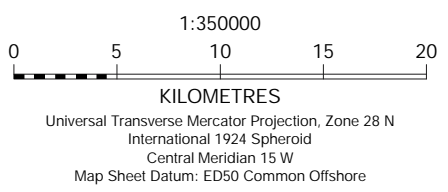
**Legend**

- Wells
- BGS Gravity Cores
- Shallow Drilling Location
- Geoboy cores
- Seismic lines
- NIOZ 2000 seismic lines
- Fault lines from C10 Structure map
- Footprint of Gullwing/Eriss
- Toe of slope fan
- C20 surface becomes composite with C10 regional erosion surface

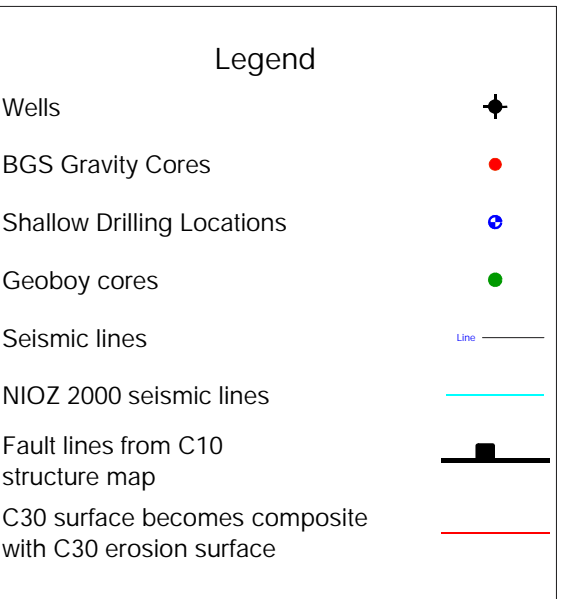
**NOTES**

Grid cell size = 500m  
C.I. = 50 msec

Challenger (BGS) Hi Res Seismic  
(not shown), covers area of BGS gravity cores

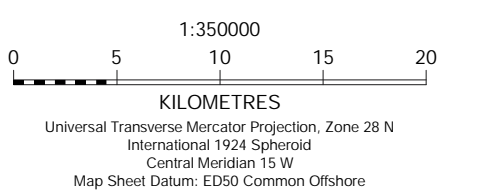






## NOTES

Grid cell size = 500m  
C.I. = 100 msecs  
Challenger (BGS) Hi Res Seismic  
(not shown), covers area of BGS  
gravity cores

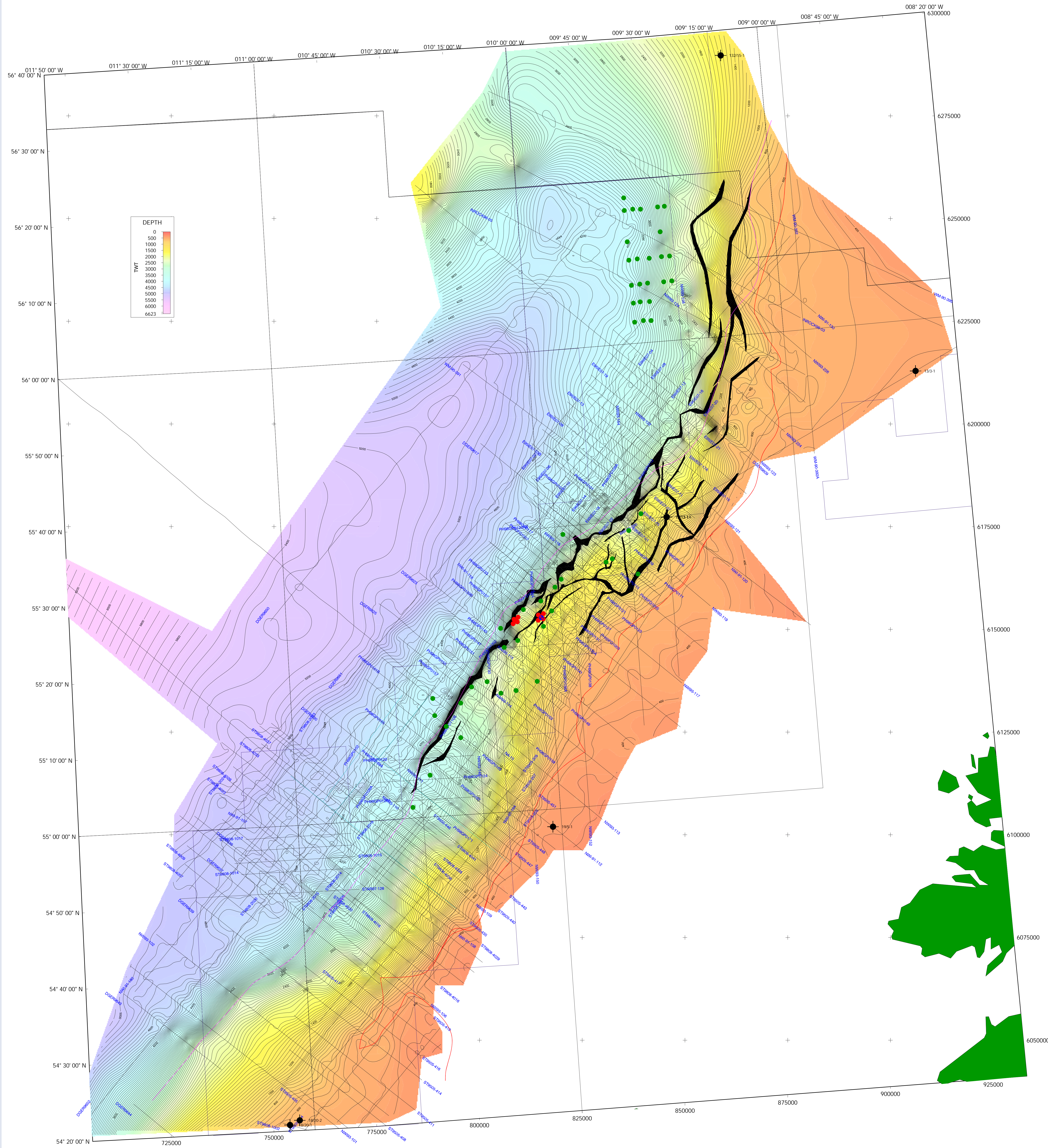


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Figure 23  
C30 TWT Structure map

Author: BJA CW NSW	Date: December 3, 2001
Project: 0035	Revision: Final BJA

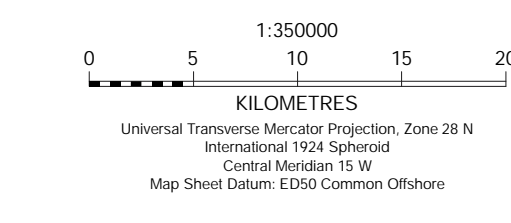




- Legend
- Wells
  - BGS Gravity Cores
  - Shallow Drilling Location
  - Geobay Cores
  - Seismic lines
  - NIOZ 2000 seismic lines
  - Faults interpreted from BTU horizon
  - Uplip of line the BTU regional erosional surface becomes progressively outcropped by C30, C20 and C10 surfaces
  - BTU subcrops at C10 erosion surface

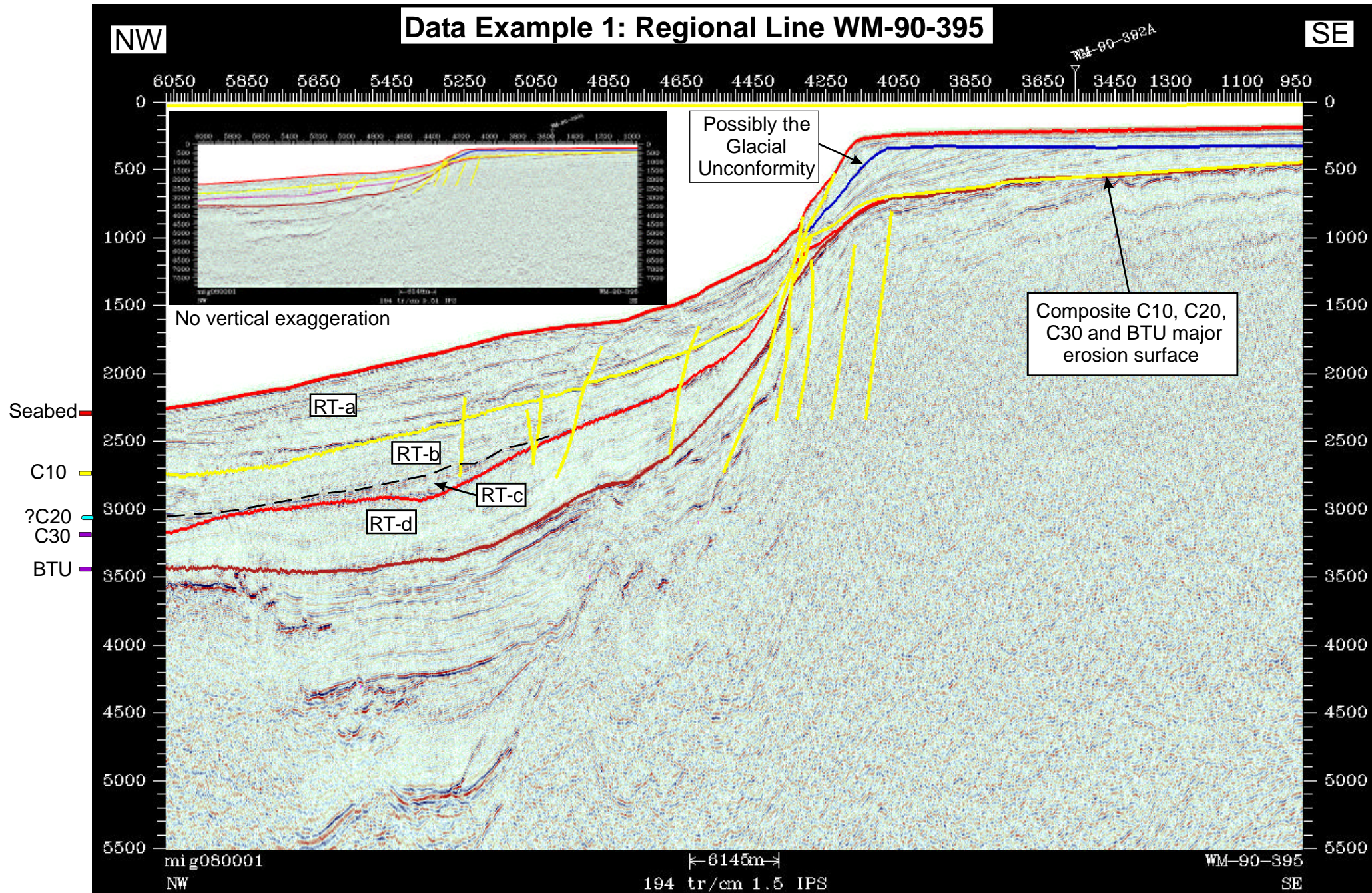
NOTES

Grid cell size = 500m  
C.I. = 50 msec  
Challenger (BGS) Hi Res Seismic (not shown), covers area of BGS gravity cores



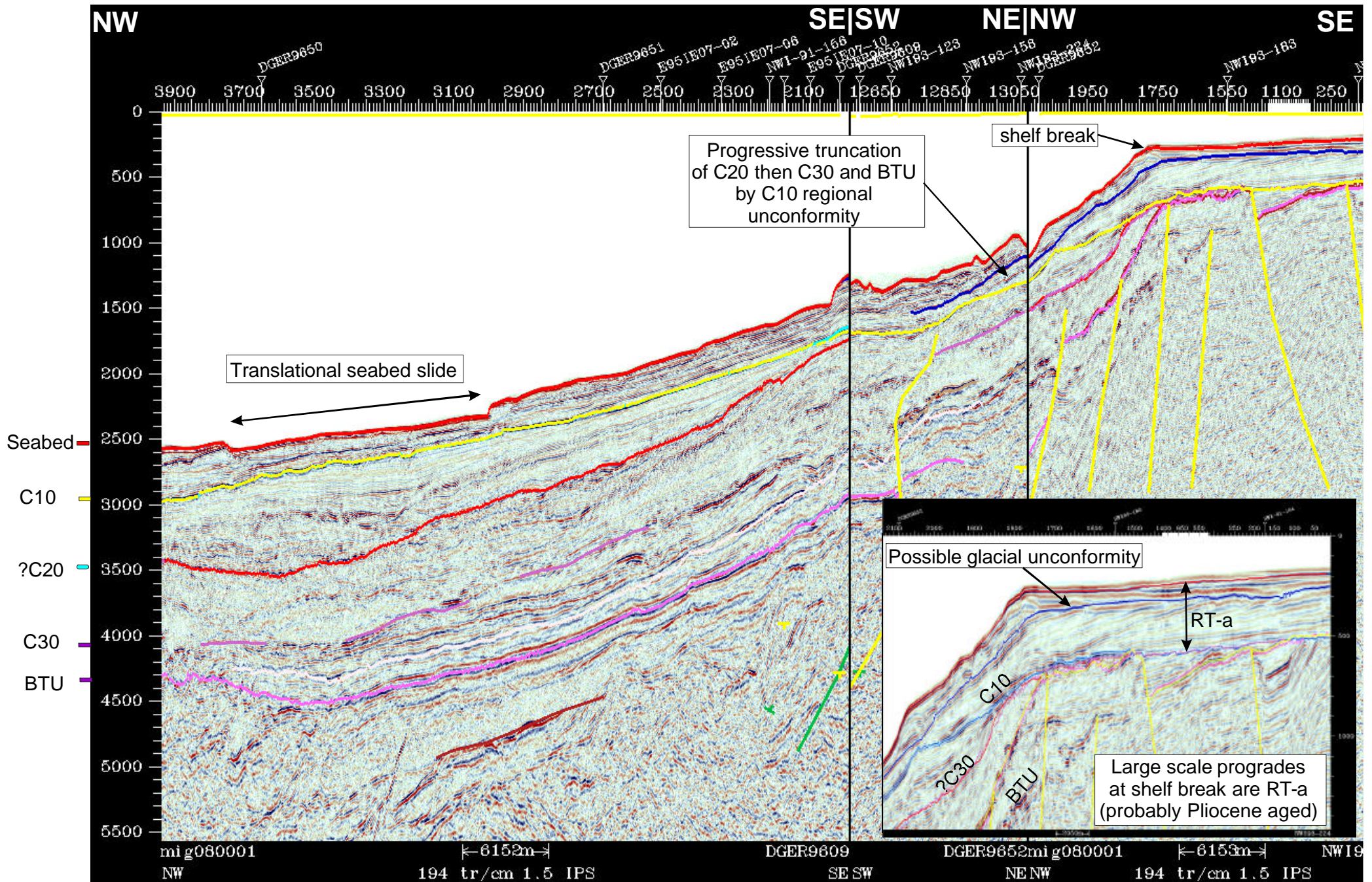


# Data Example 1: Regional Line WM-90-395



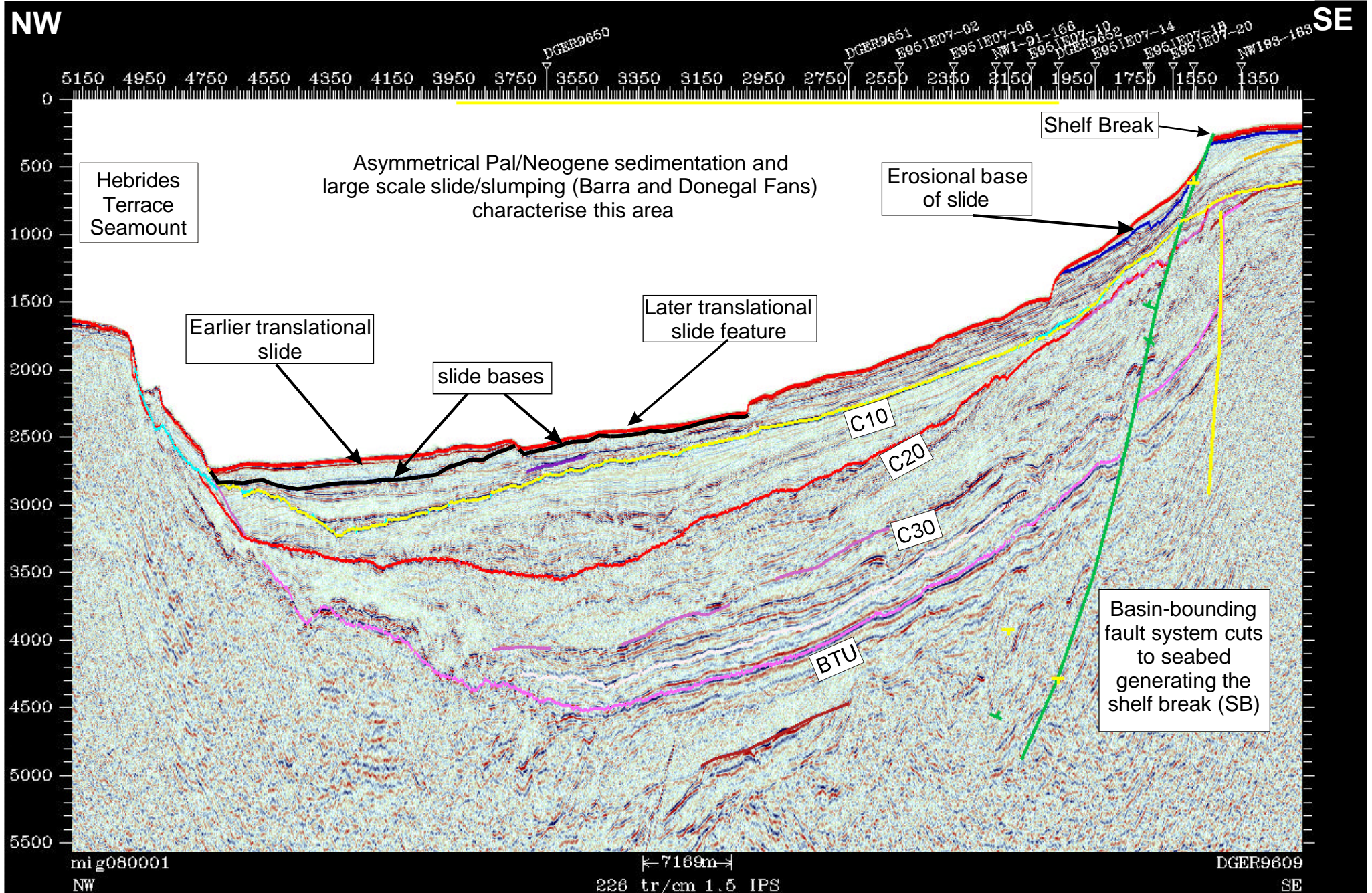


# Data Example 2: Regional Line DGER96-609-NW191-224



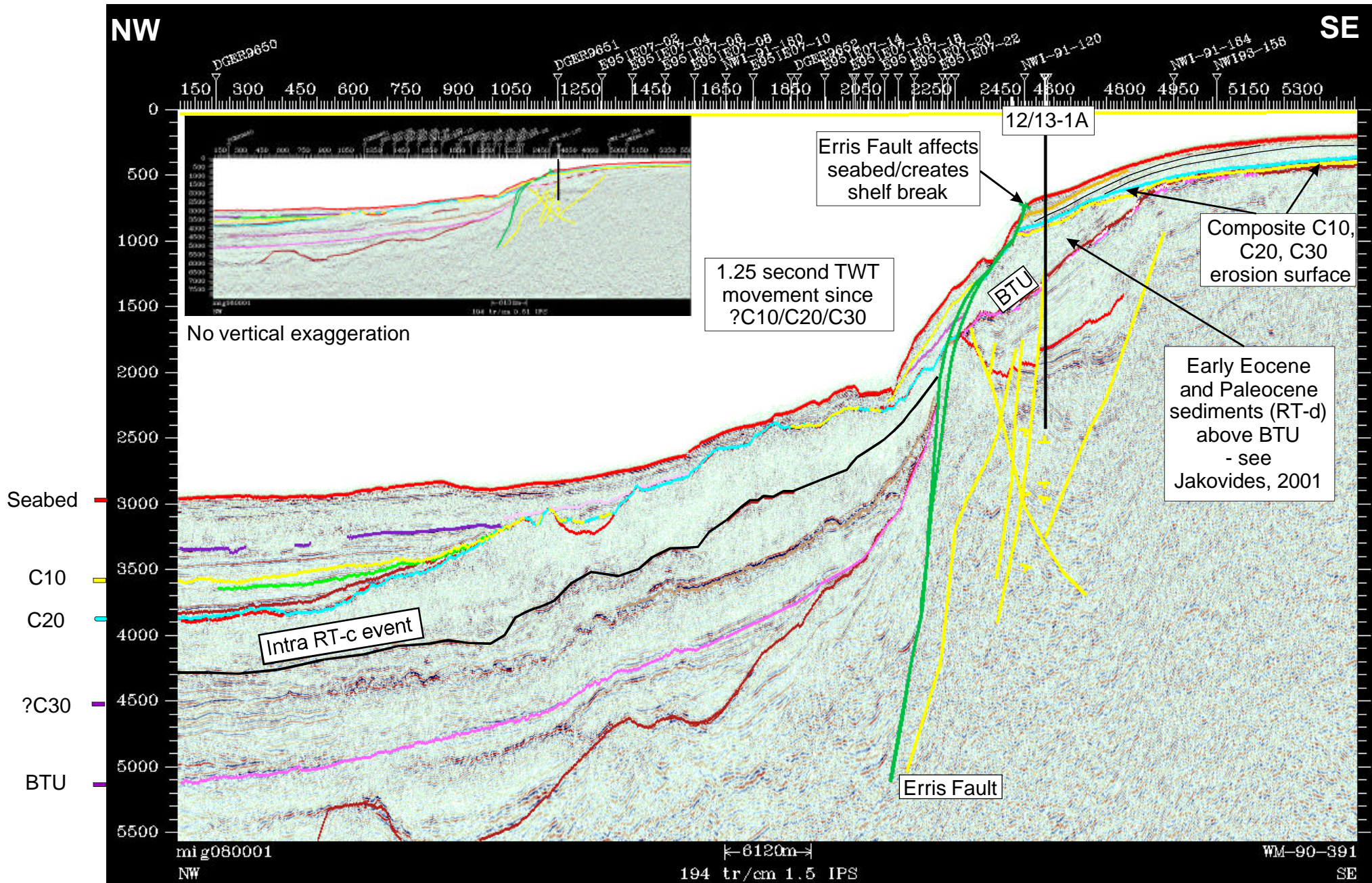


# Data Example 3: Regional Line DGER96-609 Donegal Shelf to Hebrides Terrace Seamount



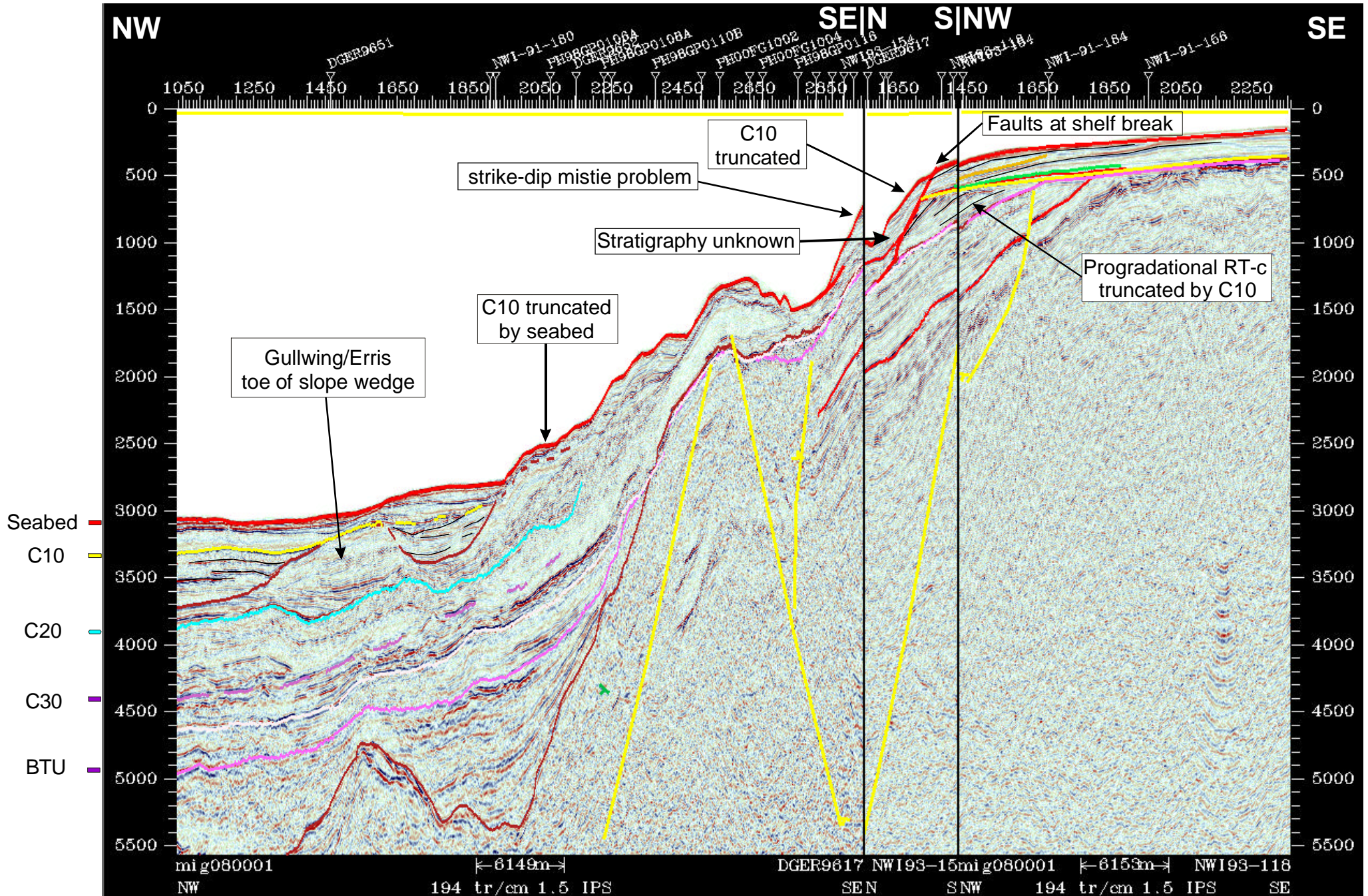


# Data Example 4: Regional Line WM90-391



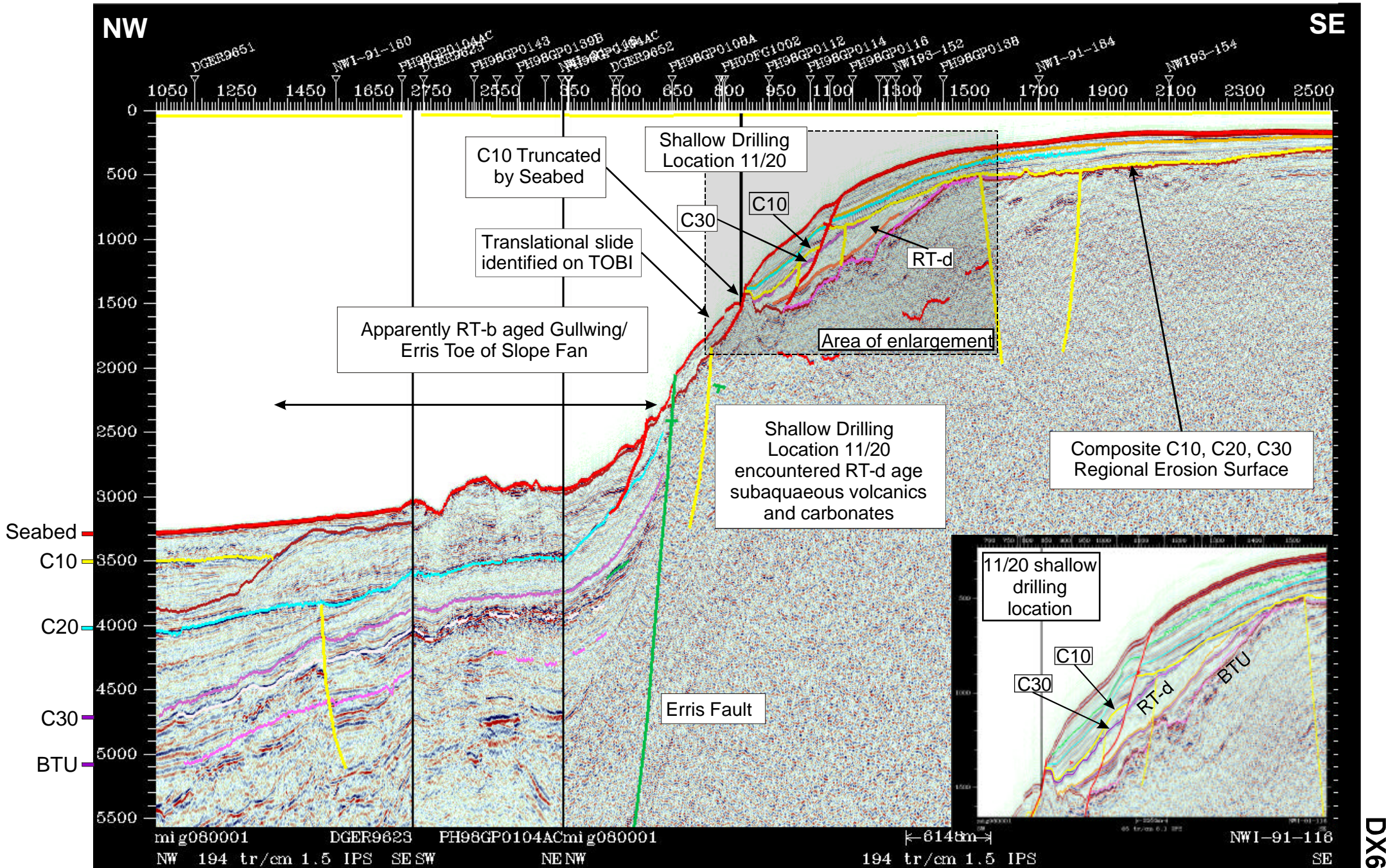


# Data Example 5: Regional Line DGER9617-NW193-118



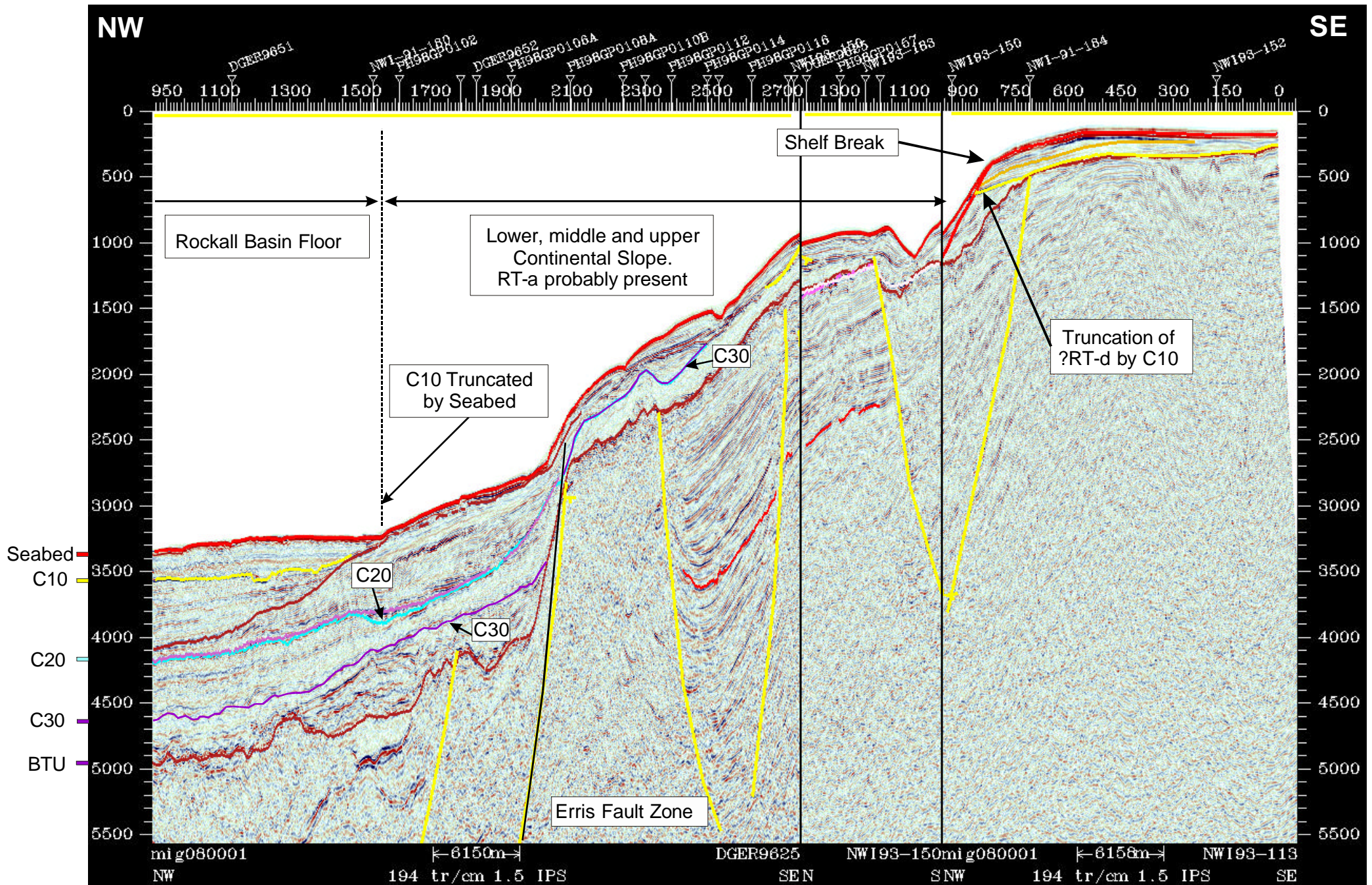


### Data example 6: Regional line through BH11/20



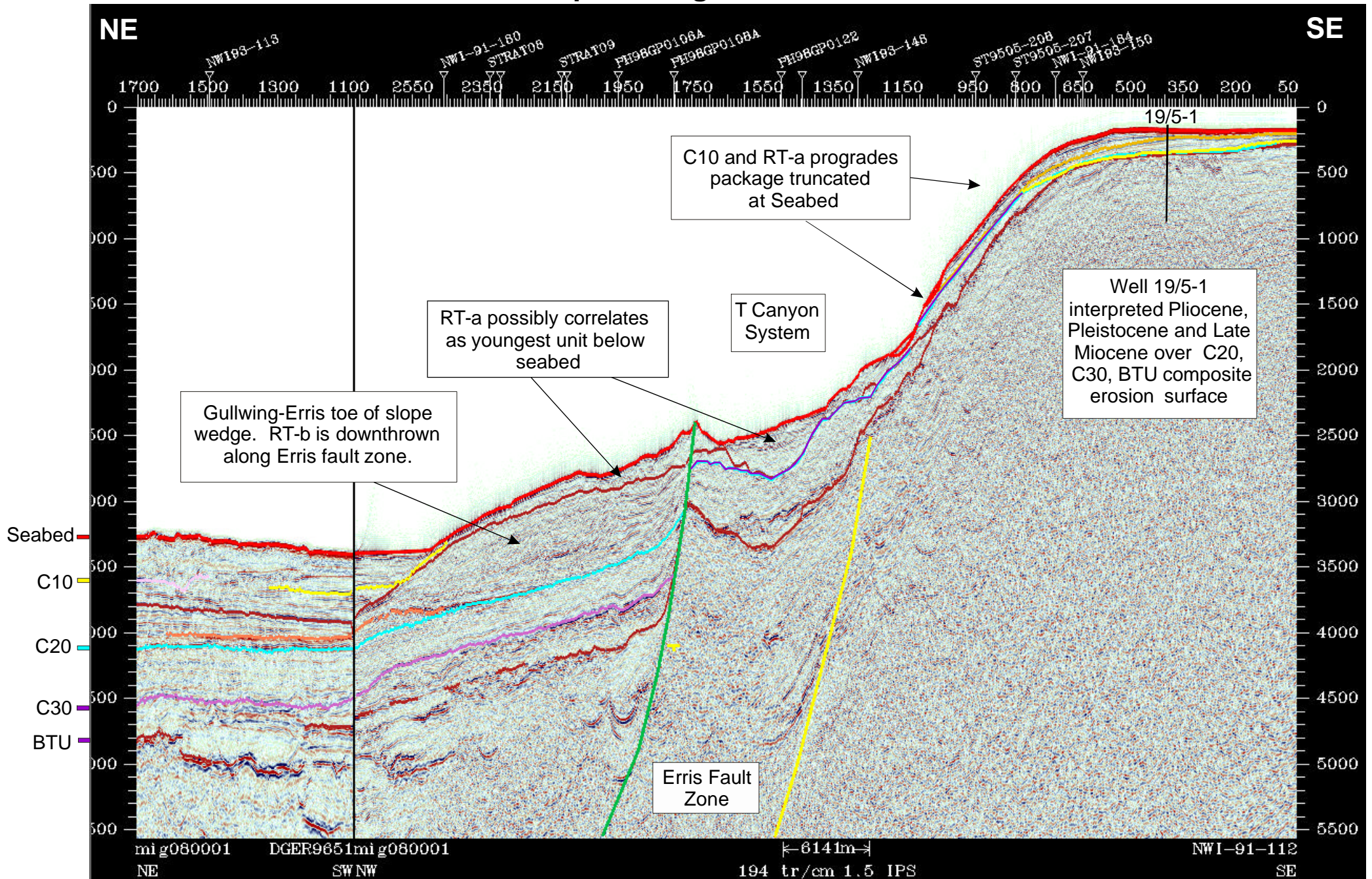


# Data Example 7: Regional Line DGER96-25 - NWI93-113



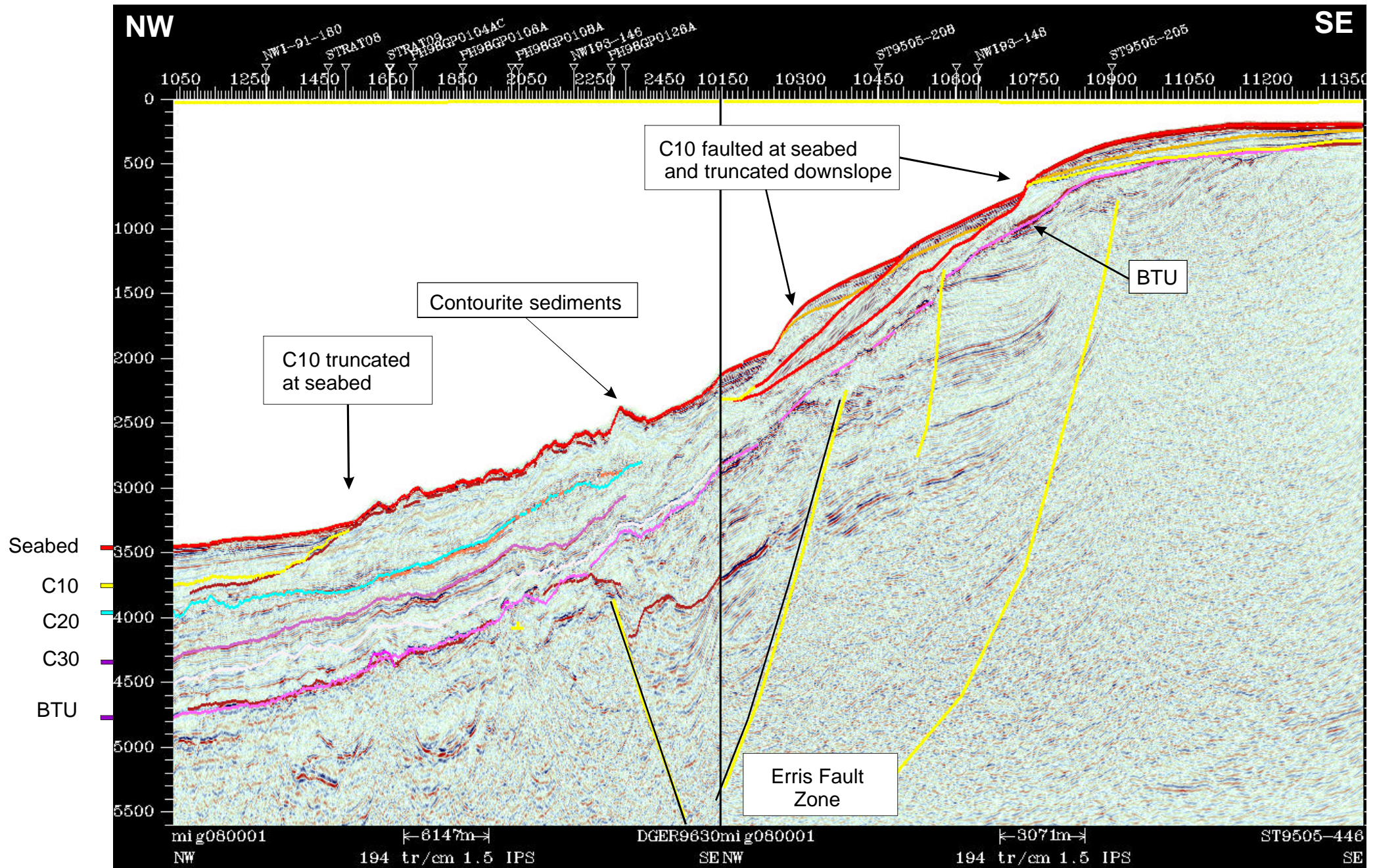


# Data Example 8: Regional Line NWI-91-112



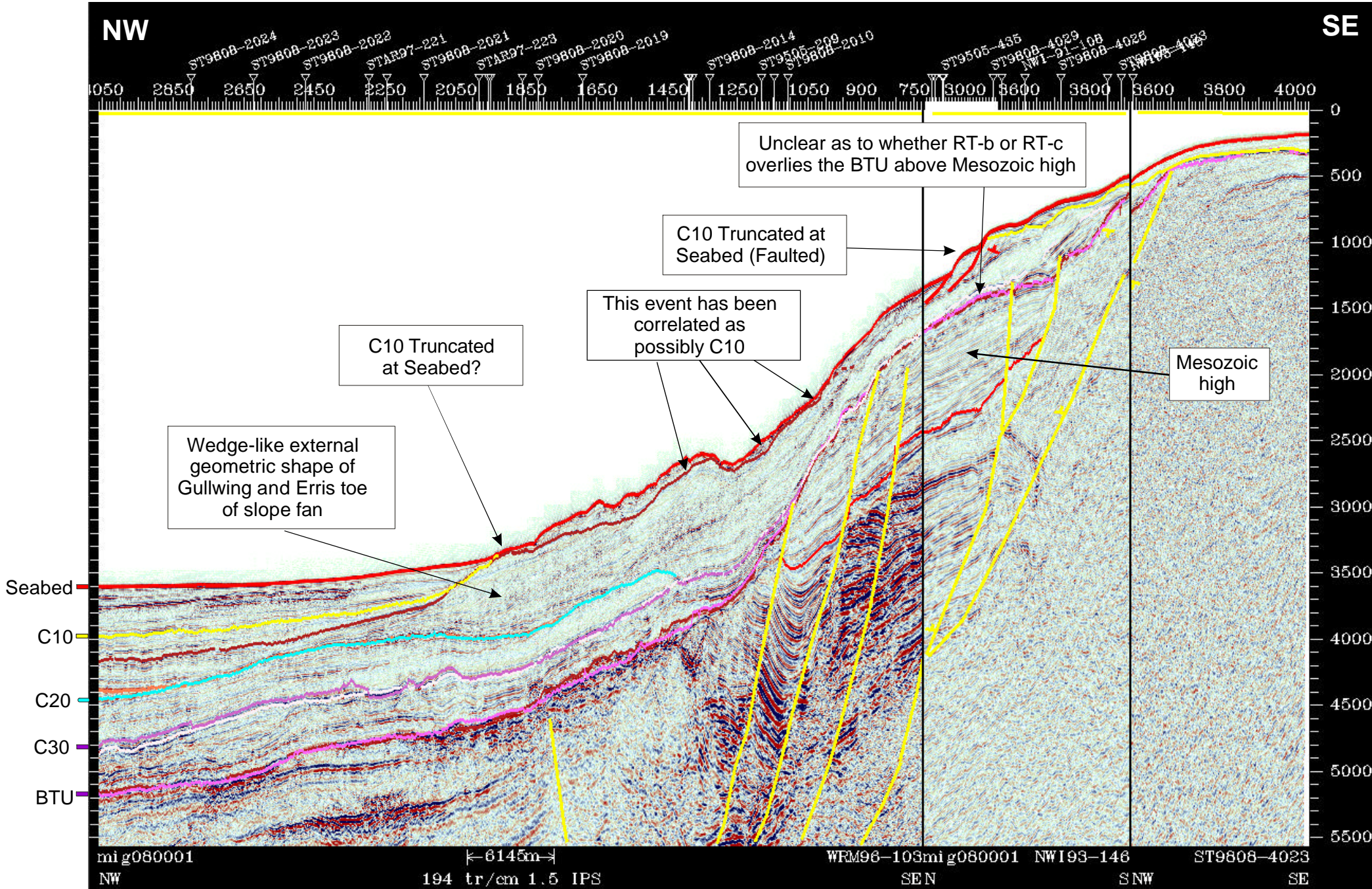


## Data example 9: Regional Line DGER96-30



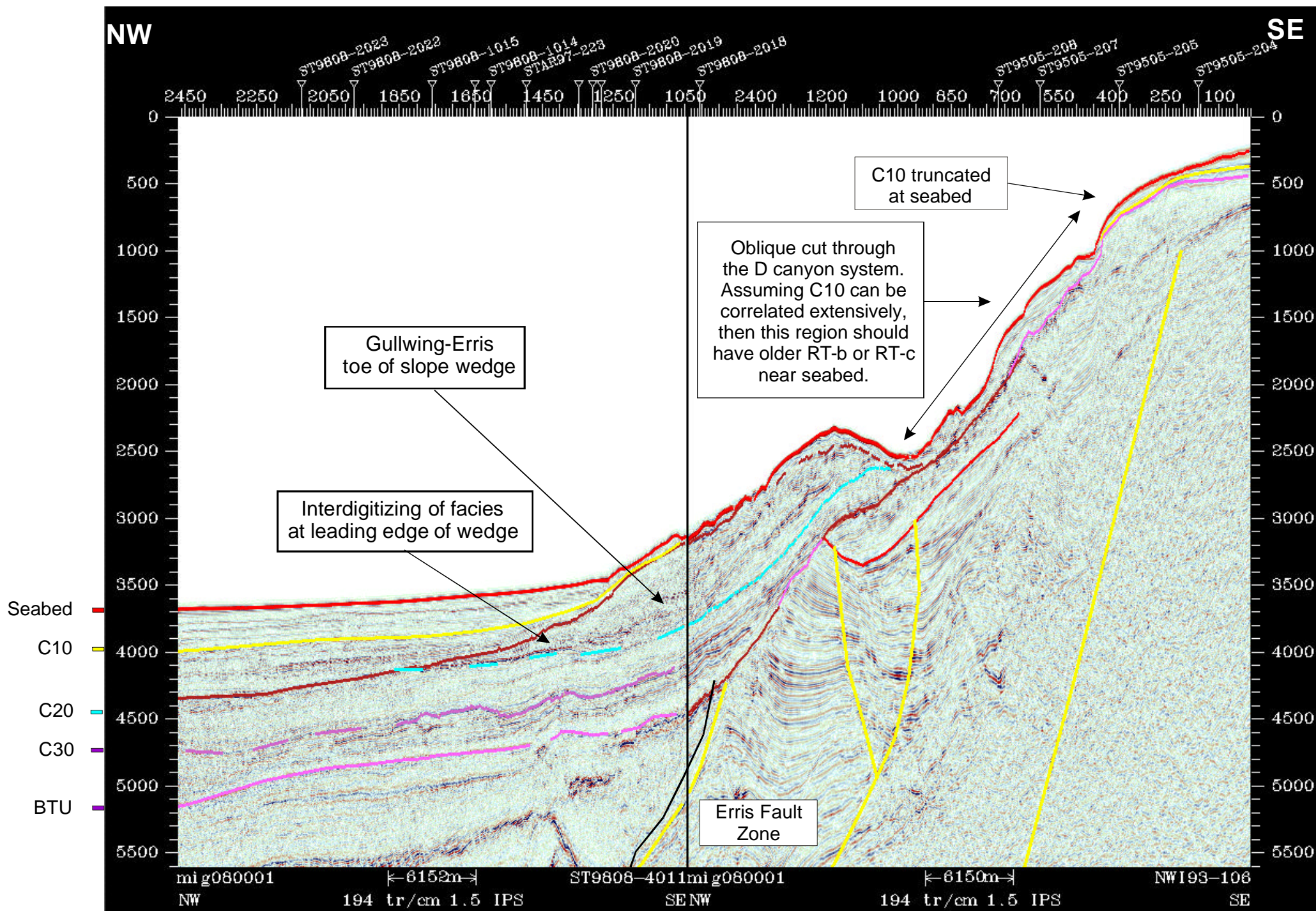


Data Example 10: Regional Line WRM96-103



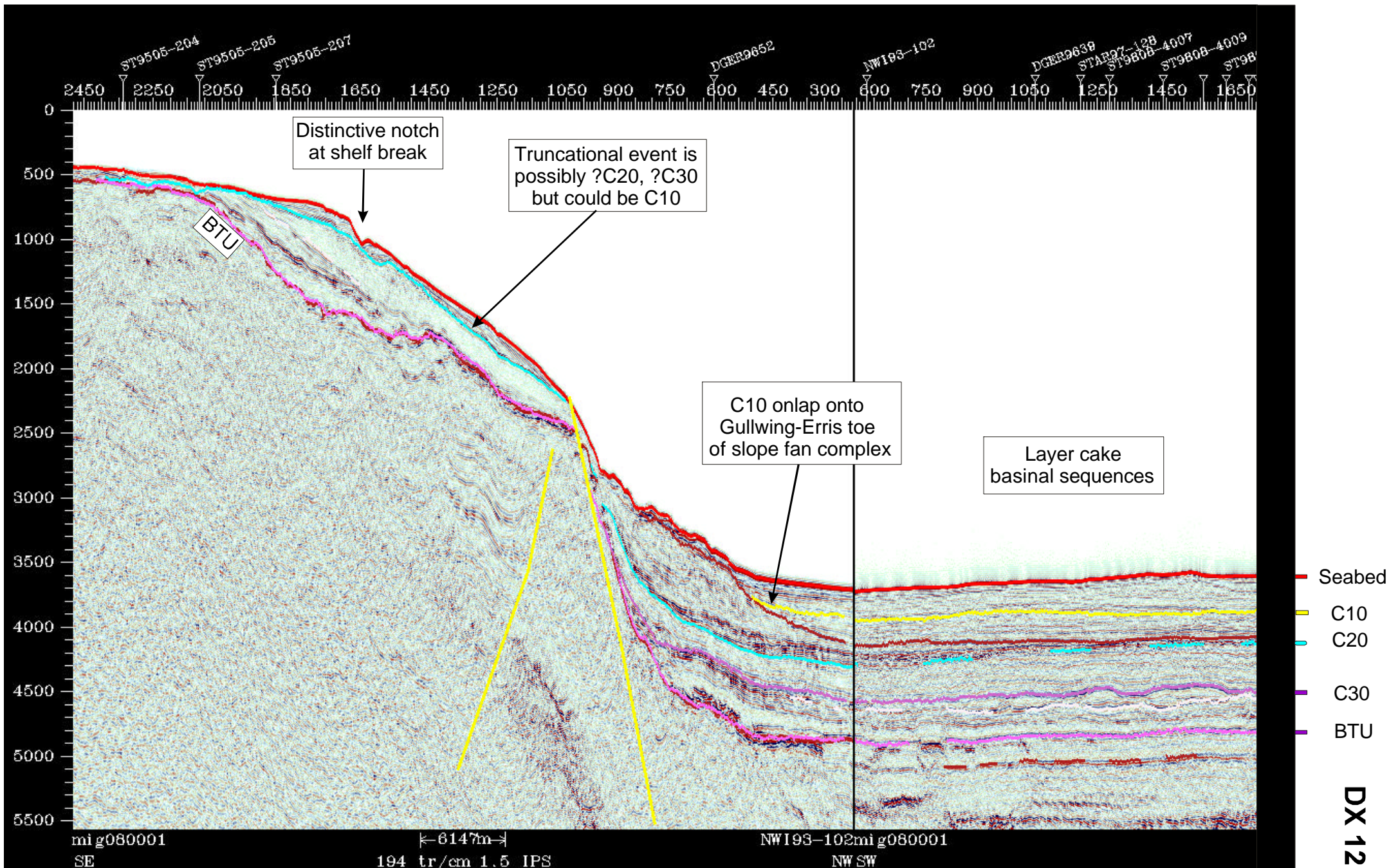


# Data Example 11: Regional Lines ST9806-4011 and NWI96-106



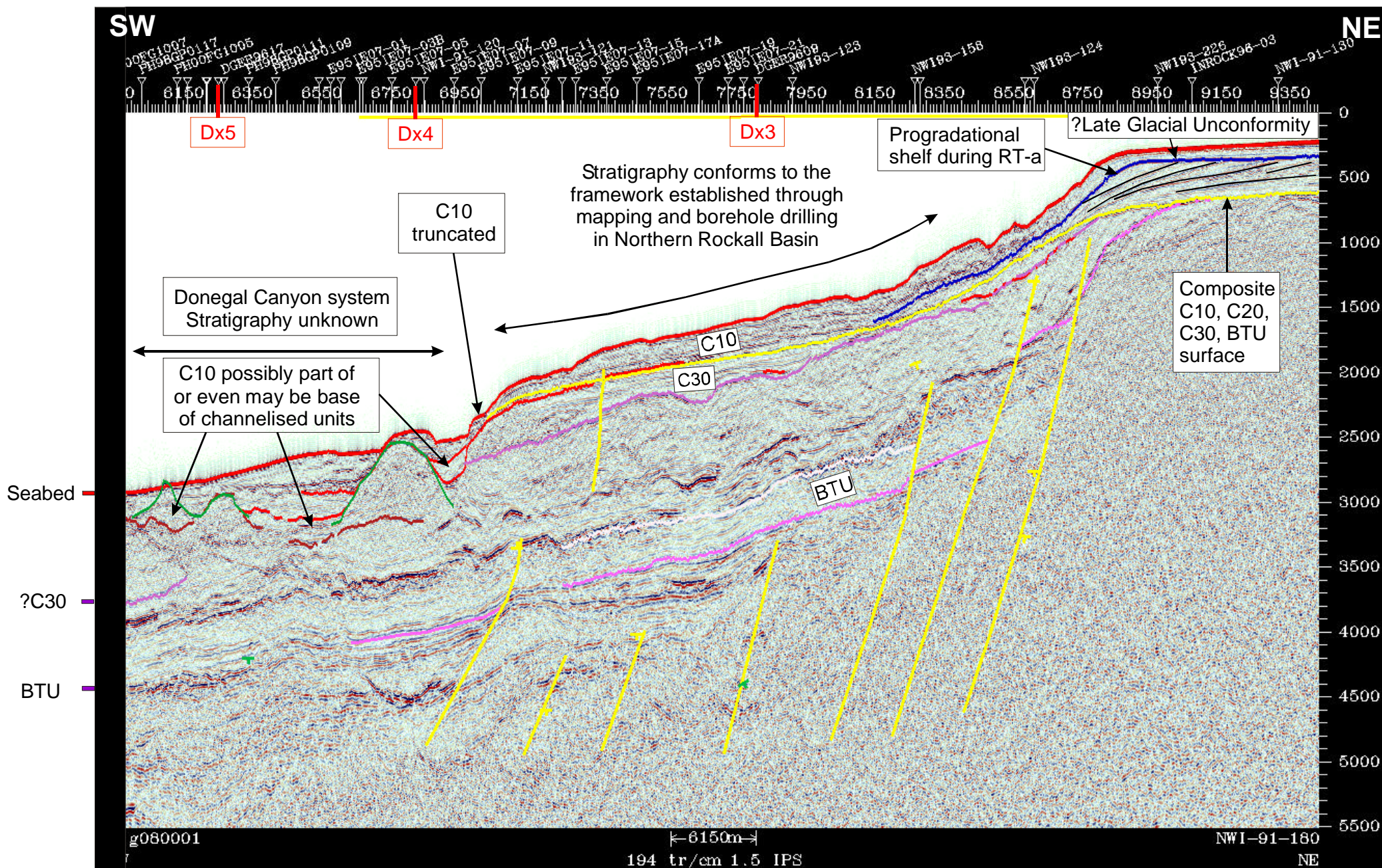


# Data Example 12: Dip NWI91-102-180





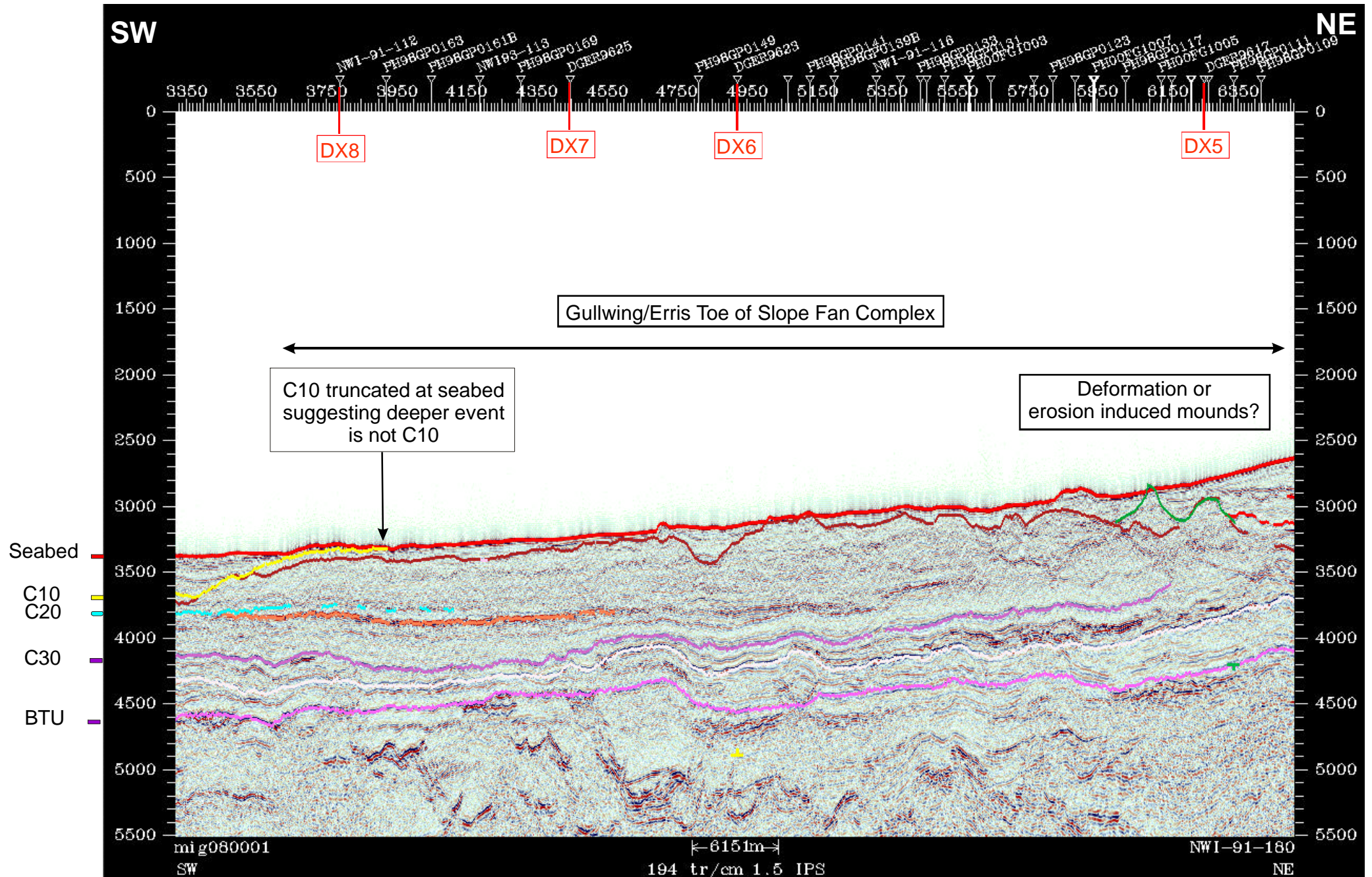
# Data Example 13: Strike Regional Line NW1-91-180 (NE part)



DX13

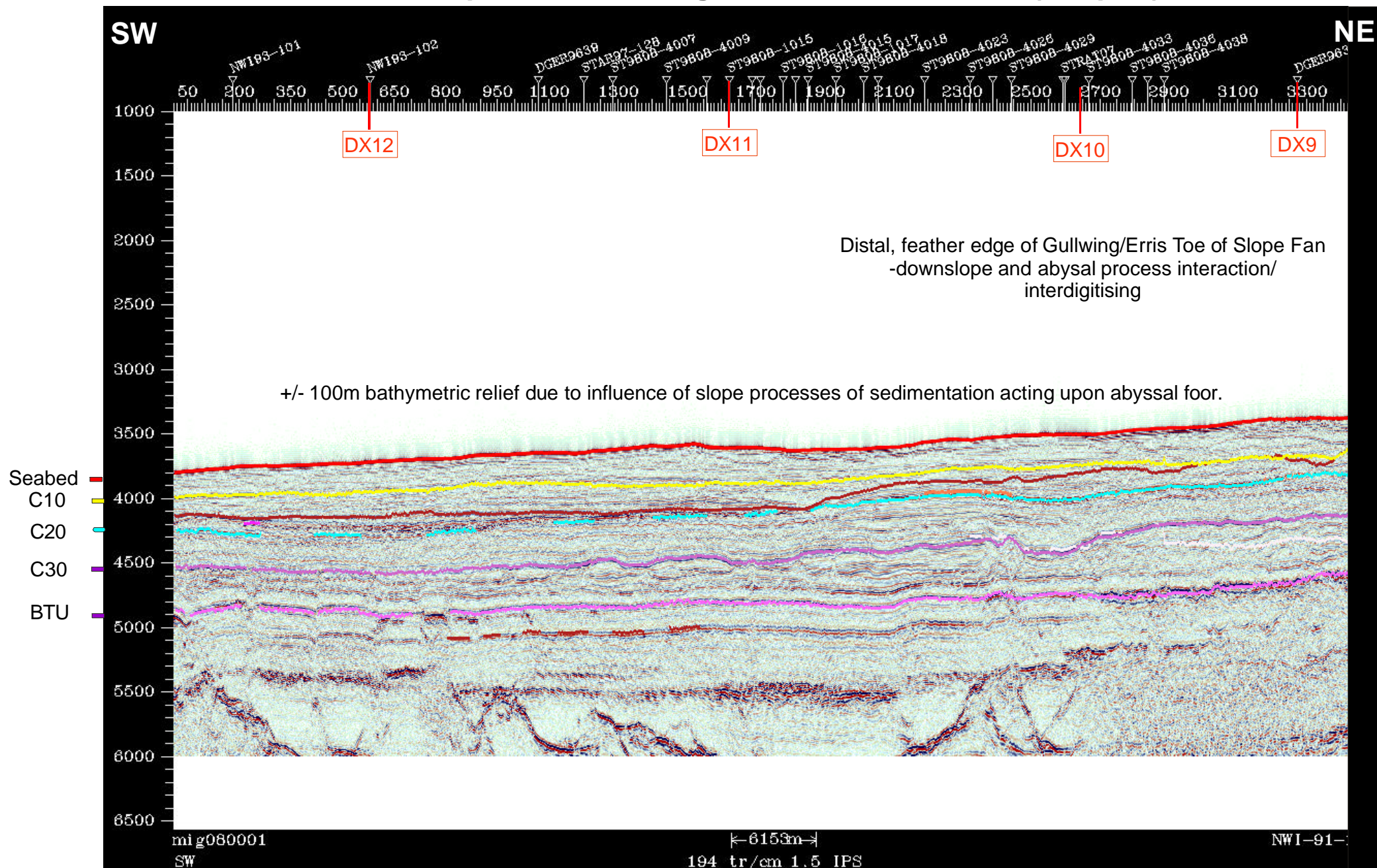


# Data Example 14: Strike Regional Line NW1-91-180 (Central part)



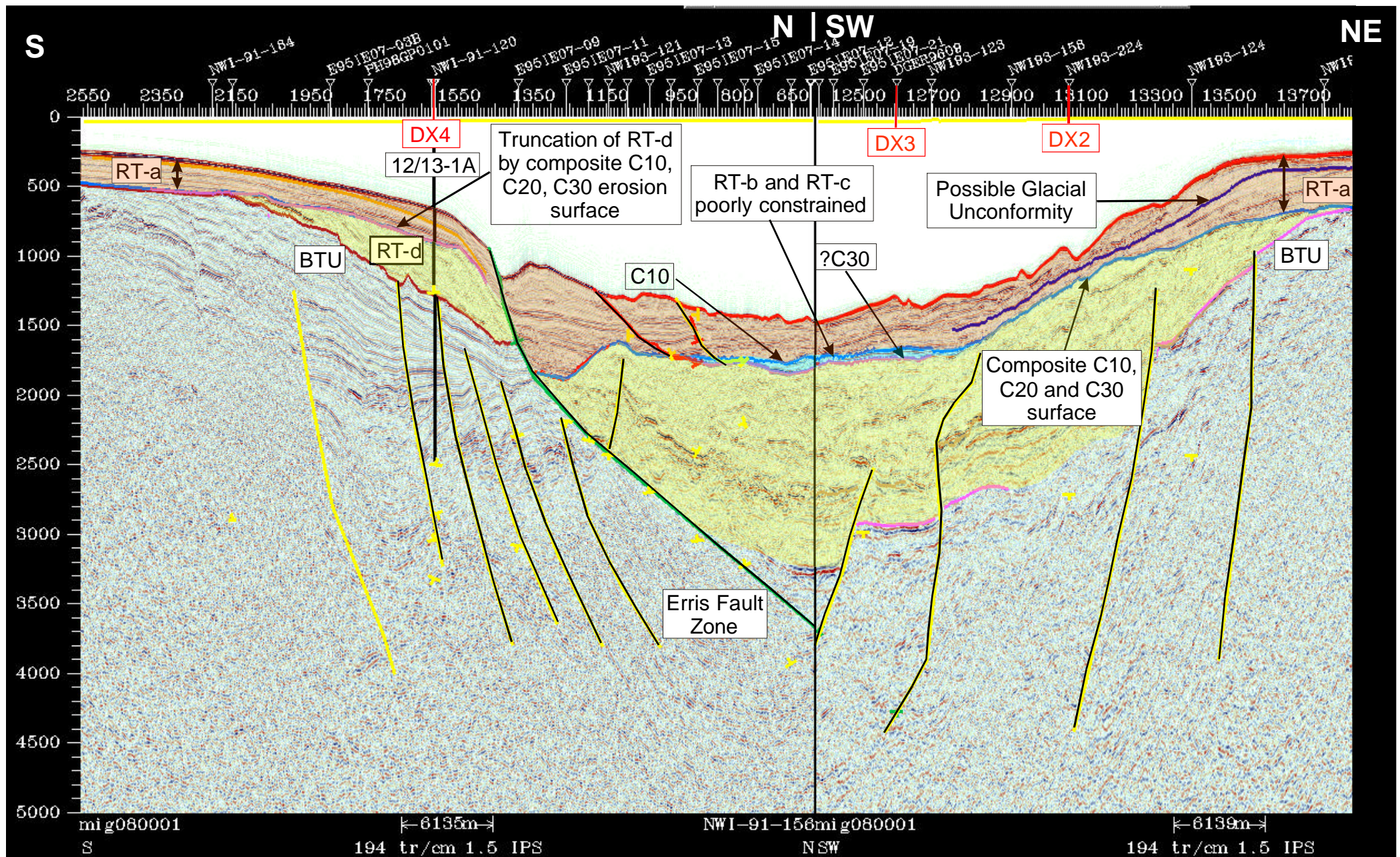


# Data Example 15: Strike Regional Line NW1-91-180 (SW part)



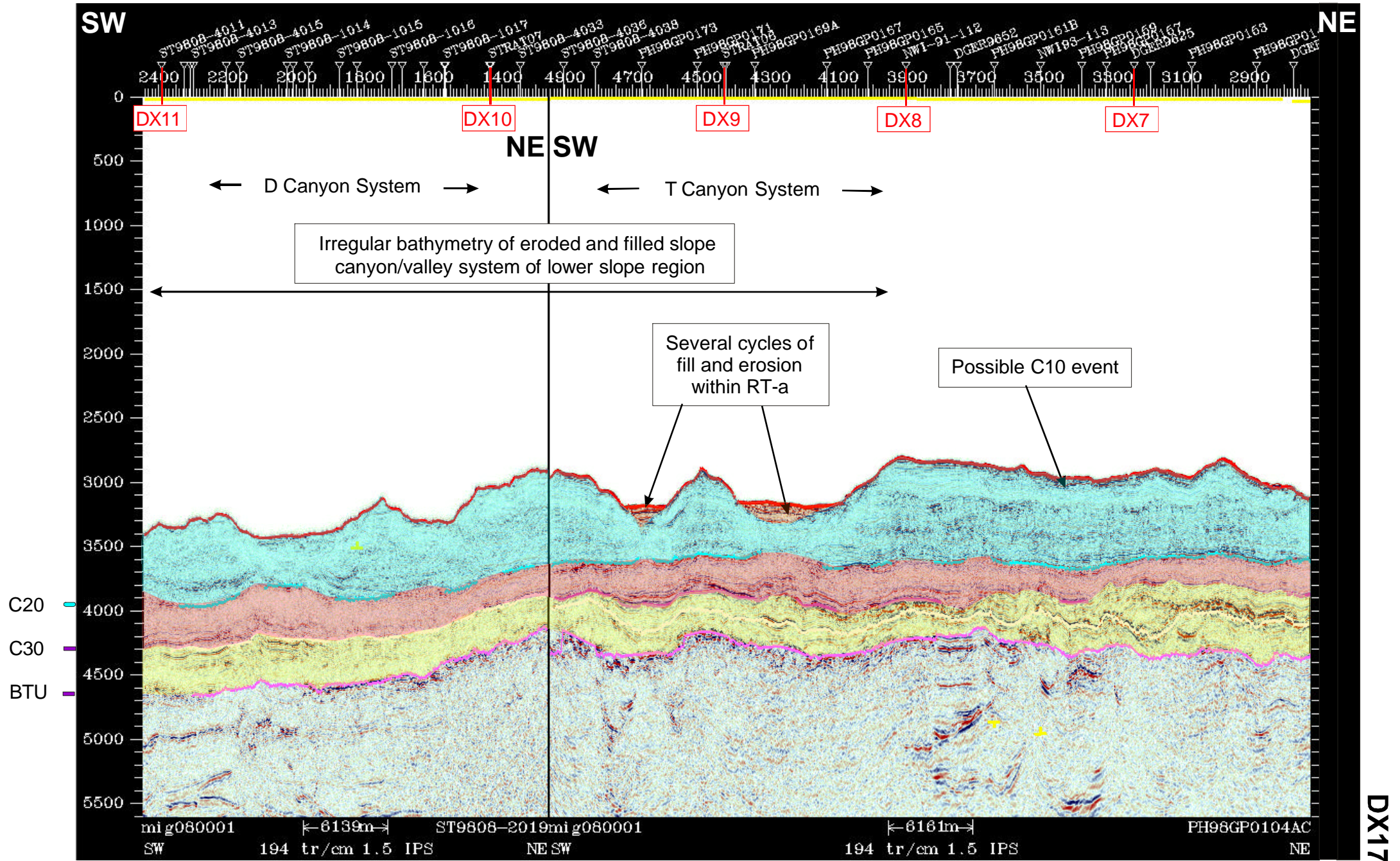


# Data Example 16: Strike Regional Line NW1-01-156-DGER96-52





# Data Example 17: Strike Line ST9808-2019-PH98GP0104AC





# DX 18

