

Chapter 5

5 Seismic Stratigraphic Reconstruction of the palaeo-Arun River

5.1 INTRODUCTION

Repeated and large-scale, climatic and sea level changes have affected the British Isles through the Pleistocene due to the initiation of extensive ice-sheet growth in the Northern Hemisphere (Woodcock and Strachan, 2000; Ehlers and Gibbard, 2003). Glacio-eustatic sea level falls resulted in the subaerial exposure of the continental shelf that links Britain to mainland Europe, the region of land regarded in Modern times as the English Channel. During these cold climatic regimes, what we now see as major rivers (e.g. Arun, Adur and Solent rivers) entering the English Channel along the southern English coast would have been smaller tributaries of a larger English Channel River system at these times (Smith, 1985; Gibbard, 1988; Antoine et al. 2003).

The study of these Quaternary fluvial systems is important in determining the role that sea level and climate change play in controlling sediment transportation and deposition. The sedimentation of gravels and sands are important as they represent a significant economic resource, which are dredged by the aggregates industry. Furthermore, and of particular interest here, is the potential these systems have for holding archaeological information. During the aforementioned subaerial exposure these drainage areas are likely to have been sites of occupation and routes for migration by early human settlers and mammals in Europe (Wymer, 1988). Consequently there is the potential for archaeological resources to be discovered in the valley. The significance of these systems for potential archaeological resources is the focus of the following chapter – Chapter 6.

This chapter is focused on the seismic stratigraphic reconstruction of the submerged palaeo-Arun Valley on the English Channel Shelf. Despite the study of similar systems in the English Channel (e.g. Dingwall, 1975; Smith, 1985; Lericolais et al., 2003), there has been little work done on the evolution of the palaeo-Arun. Bellamy (1994, 1998) represents the most significant investigation of the valley, where seismic profiles were used to study its evolution. The modern course of the Arun River drains from the South Downs and enters the English Channel at Littlehampton. The Quaternary equivalent of the Arun River valley extends to the south in the subsurface across the northern shelf of the English Channel. The position of the palaeo-Arun valley offshore is partially known by its expression as a significant topographic valley in the south of the shelf (Chapter 3). However to the

north of this there is no such topographic indication. Consequently sub-bottom profiling is required to determine the location of the valley and its course from the modern coast to the Northern Palaeovalley of the Quaternary English Channel River. The palaeo-Arun River system is represented by a series of complex incised channels filled by unconsolidated Quaternary sediments (Hamblin et al., 1992; Bellamy, 1994). To fully understand the evolution of this system it is important to determine the extent of these channels and their fill sequence. This is made possible through investigation of the available high-resolution seismic datasets.

The sequence stratigraphic approach developed during the 1970s and 1980s, and the improvement of sub-bottom profiling techniques has resulted in the enhanced investigation of subsurface geology. The approach follows basic principles of stratigraphic correlation. However, instead of direct investigation of lithological characteristics in outcrop, parameters of seismic reflection data such as configuration, continuity and amplitude are used. The identification of internal reflectors is combined with the separation of reflection packages by bounding surfaces of discontinuity and is interpreted as genetically related strata or depositional sequences. This in association with groundtruth data, such as cores, makes a powerful tool for studying subsurface stratigraphic sequences.

In this chapter, we focus on the sedimentological evolution of the palaeo-Arun valley. This is done through the synthesis of all available sub-bottom data, in the form of boomer seismic and vibrocores, high-resolution swath bathymetry, and dating of sediment (radiocarbon and optically stimulated luminescence dating). This synthesis will contribute to the determination of a fill history and a model for the depositional processes preserved in the system.

5.2 REGIONAL SETTING

The English Channel occupies an area along the southern margin of England and forms a depression that separates Britain from continental Europe (Fig. 5.1). The geology of the eastern English Channel consists of a succession of Mesozoic and Tertiary strata, upon a basement of Devonian and Carboniferous rocks (Hamblin et al., 1992). Superimposed on the solid geology is a network of Quaternary palaeovalleys, which have incised into the Cretaceous and Tertiary deposits. In the study area, the bedrock geology beneath the incised valleys is predominately Tertiary sediments of the Reading, London Clay, Poole and Barton Clay formations (Hamblin et al., 1992; BGS, 1995; James and Brown, 2002). These unconformably overlie the Cretaceous Upper Chalk, which outcrops in the north of the study area. Structurally the rocks exhibit a gentle regional dip to the south, which is disturbed by folding that has formed minor east-west synclinal and anticlinal folds (Fig. 4.56).

There is a significant variation in the lithology of the Cretaceous and Tertiary units that form the bedrock into which the Quaternary channels are carved. The Upper Chalk is typified by thickly bedded white limestone, with marls and flint and nodular bands. The base of the Reading Formation

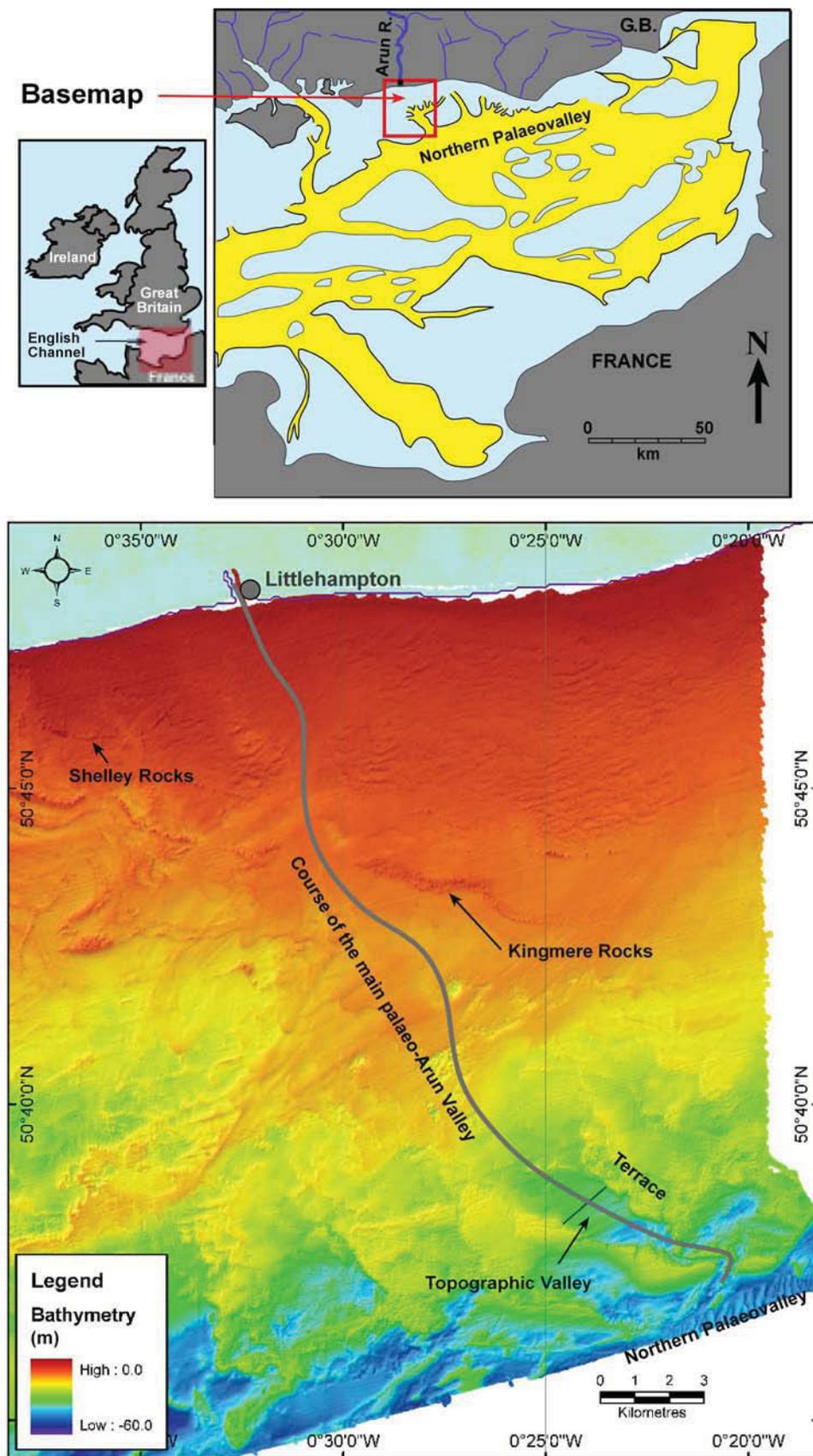


Figure 5.1 Location of the study area relative to the southern English coast. Also shown is the basemap (the location of which is highlighted by the red box) used through the chapter and the identification to key features in the study area that are referred to in the text. A detailed discussion of the sea floor morphology is presented in Chapter 3.

marks the Cretaceous-Tertiary boundary and is commonly defined by a bed of pebble flints in a sandy clay matrix, which is overlain by mottled silty clays with intercalations of sandy clays that typifies the unit. The overlying London Clay Formation predominately consists of clays with varying sand content. A flint-rich pebble bed is also commonly present at the base of the unit. The overlying Poole Formation consists of fossiliferous glauconitic sandy clays and sandy limestones. The youngest Tertiary unit consists of sandy silts and silty sands that typify the Eocene Barton Clay Formation. The overlying Quaternary sequence consists of unconsolidated sediments that fill the incised channels. The fill of these channels is predominately gravel of varying sand content, and sands, silts and clays, which include shells, root nodules and peat horizons.

Although there has been no glaciation of the channel area during the Quaternary (Lambeck, 1995; Murton and Lautridou, 2003), sedimentation in the channel was influenced by eustatic sea level fluctuations. Successive fluctuations in sea level through the Quaternary lead to the English Channel becoming emergent during intervals of glacial maxima and inundated during subsequent ice retreat. With each interval of subaerial exposure river systems developed draining from southern England and northern France. The palaeo-Arun River formed one such tributary into the Northern Palaeovalley of the English Channel River.

The bathymetry of the northern English Channel shelf in the study area exhibits a generally southward sloping gradient, with depths reaching up to 50 m. A dominant feature of the sea floor is a topographic valley in the south of the study area (Fig. 5.1). The topographic valley trends northwest-southeast, is up to 2 km wide, and is approximately symmetrical in cross-section with a flat base (see Chapter 3). The gradients of the valley margins decrease to the north so that the feature merges with the relatively flat seabed. Traced southwards, the topographic valley narrows and deepens to the southeast becoming more pronounced at its southern extent. Mapping of the shelf shows that this valley feature marks the confluence of the palaeo-Arun with the Northern Palaeovalley and that the palaeo-Arun extends to the north in the subsurface.

5.3 DATA AND METHODOLOGY

High-resolution seismic interpretation of the submerged palaeo-Arun Valley was facilitated by a high resolution dataset of paper boomer seismic profiles and vibrocores obtained from Hanson Marine Aggregates Ltd and United Marine Dredging Ltd. The management and methodology of investigation of the seismic dataset is discussed in section 5.3.1. - Seismic Data Management and Interpretation. Sedimentological analysis of the vibrocores is based on core photos and reports provided by the aggregates companies. Further investigation of these cores was not possible due to their physical condition but new vibrocores were collected to enable sampling and further analysis. The new vibrocores were extracted using an electrically operated vibrocorer with a 6 m long and 84mm wide barrel (see Appendix B). Although, maximum possible recovery was 6 m, in practise this is restricted

in gravelly sediments to less than 4 m as the barrel tends to become obstructed by larger gravel clasts (>100 mm) during coring.

Organic samples were obtained from vibrocores to derive radiocarbon ages. Samples were taken from the base of peat horizons, from which plant macrofossils were extracted. Most samples were processed at the Centre for Isotope Research at the University of Groningen and measured by Accelerator Mass Spectrometry (AMS), according to the procedures described by Aerts-Bijma et al (1997, 2000) and van der Plicht et al (2000). The remaining samples were processed at the Oxford Radiation Accelerator Unit at the University of Oxford by Accelerator Mass Spectrometry (AMS), according to the procedures described by Hedges et al (1989) and Bronk Ramsey et al (2000).

Sediment rich in fine-grained quartz sand was identified and samples extracted for optically stimulated luminescence (OSL) dating. Extraction and processing of the samples was conducted at the Oxford Luminescence Research Group, School of Geography and Environment, University of Oxford. The samples were subject to single aliquot regeneration protocol for equivalent dose estimation by the method best described in Murray and Wintle (2000), to determine their age of deposition. Red light conditions were observed throughout the process to avoid resetting the light sensitive OSL signals.

5.3.1 Seismic Data Management and Interpretation

The stratigraphy of the palaeo-Arun River has been constructed from a number of boomer seismic surveys that extend across the study area (Fig. 5.2). These include the analogue seismic surveys conducted in 1990, 1991, 1995, 1998 and 2000 by the aggregates companies Hanson Marine Aggregates Ltd and United Marine Dredging Ltd (Fig. 5.3), in conjunction with digital seismic data collected by Imperial College during this study in 2003 (Fig. 5.4). Interpretation of the seismic data is based on the recognition of acoustic properties in the seismic record and the identification of key surfaces that represent stratigraphic boundaries. Where vibrocores intercept seismic lines their lithological properties are used to groundtruth the seismic facies. Further detail of this is explained through the chapter in sections that relate to seismic stratigraphy and sedimentology of the valley.

The paper seismic data was interpreted on the profile prior to conversion to a digital dataset by the digitisation of mapped reflectors. Digitisation was conducted on a CalCompTM Digitising Tablet using DidgerTM 3 software. Contouring of the seismic data was done using ArcGIS 8.3. Time-depth conversion of interpreted horizons was done using sonic velocities of 1500 m/s for seawater and 1600 m/s for Quaternary sediments. Boomer seismic data obtained from a survey in April 2003 was processed in ProMAXTM and formed a digital dataset. To integrate this digital seismic with the analogue seismic datasets provided by the aggregates companies, reflectors were picked in ProMAXTM and exported for importation in ArcGISTM allowing integration of all data.

Over the time that the surveys have been collected advances in boomer seismic technology and the understanding of the characteristics of the geology being imaged has resulted in a significant variation in the quality and resolution of the seismic data. Furthermore, the areas covered by the various

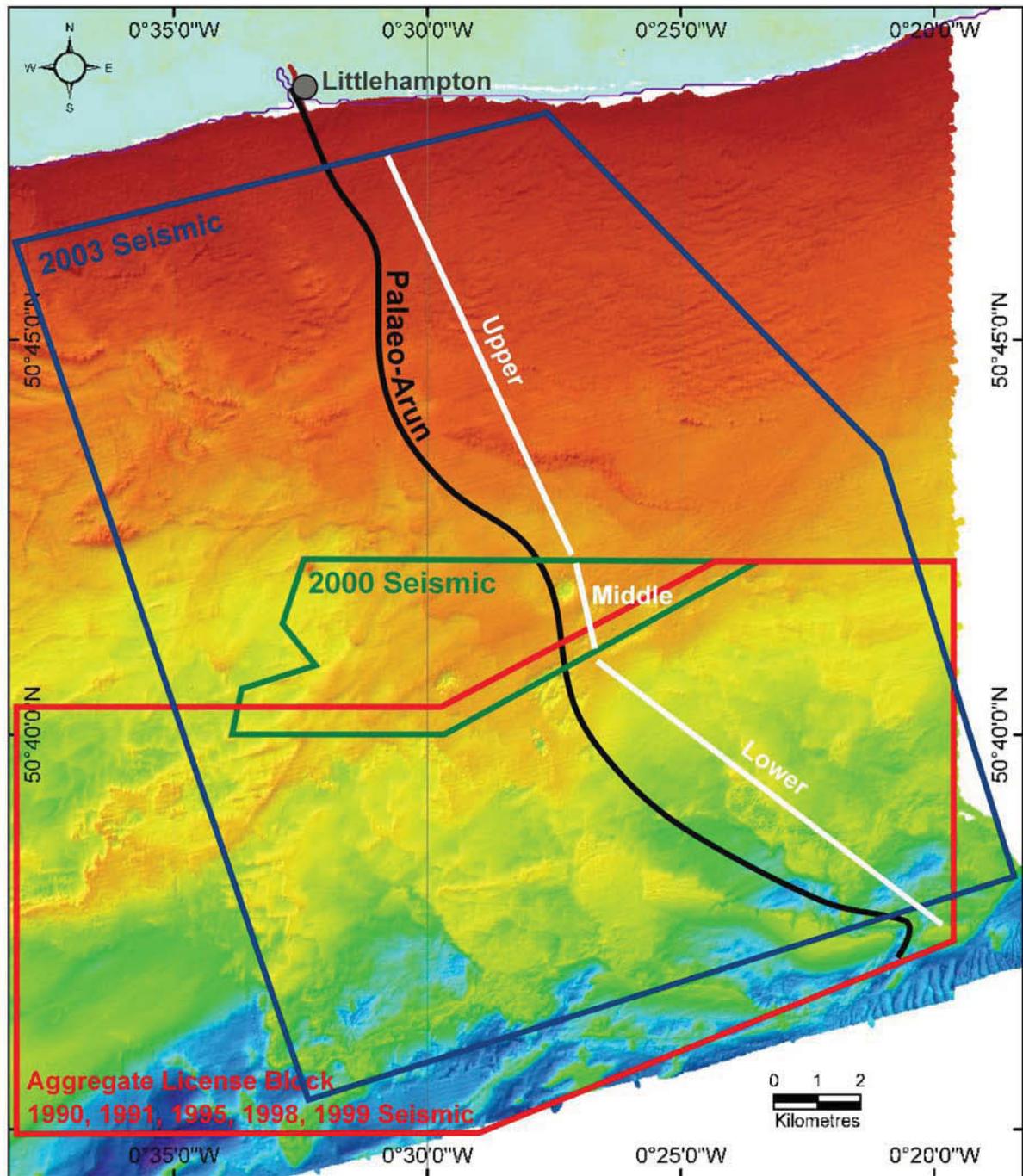


Figure 5.2 Location of seismic surveys relative to the coastline. The general course of the main palaeo-Arun Valley is marked by the black line. The division of the palaeo-Arun into upper, middle and lower sections is also indicated relative to the seismic surveys.

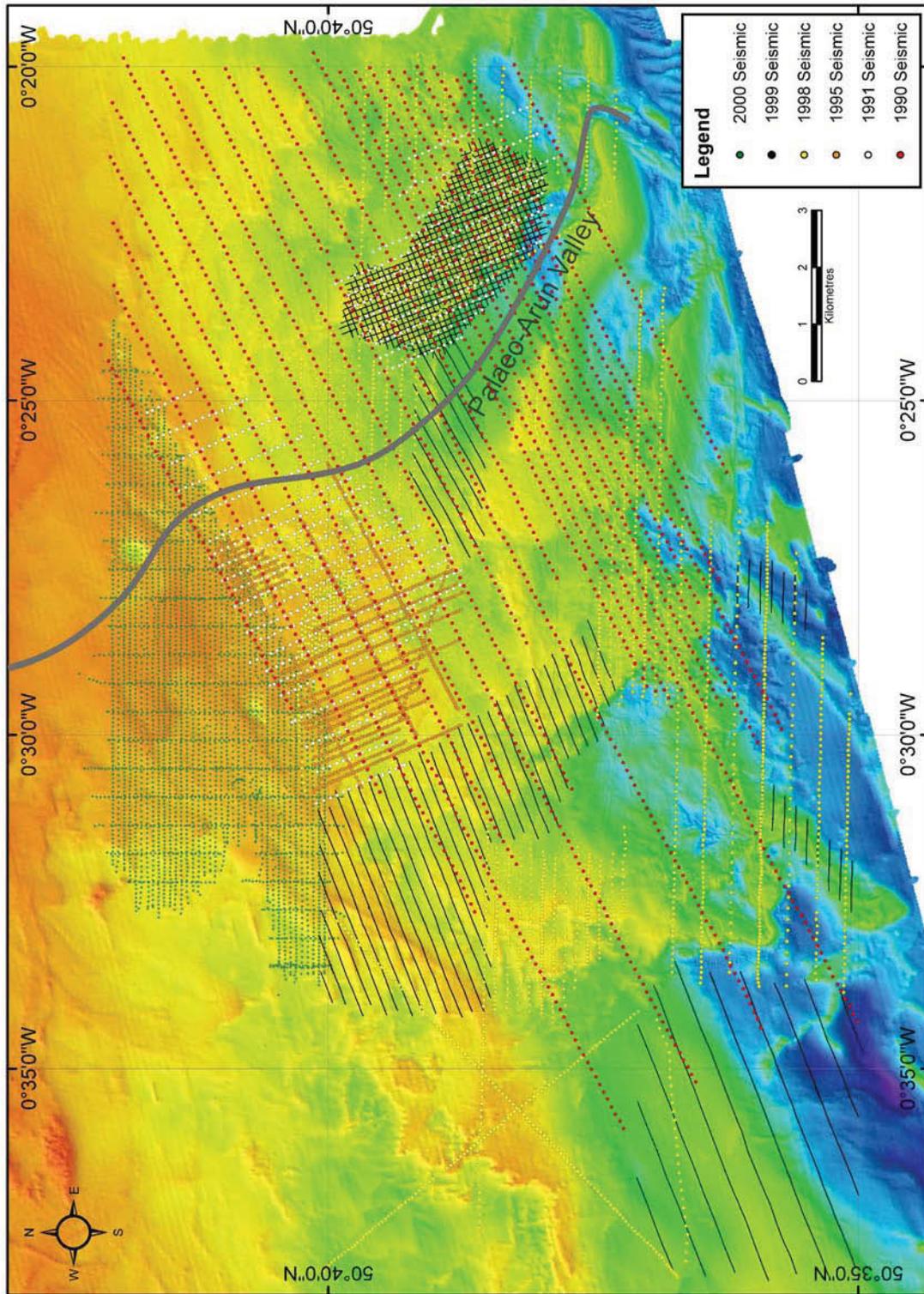


Figure 5.3 Position of seismic survey lines collected by Hanson Aggregates Marine Ltd and United Marine Dredging Ltd. The basemap is the singlebeam bathymetry for the area. See Fig. 5.2 for the position of the surveys relative to the coastline.

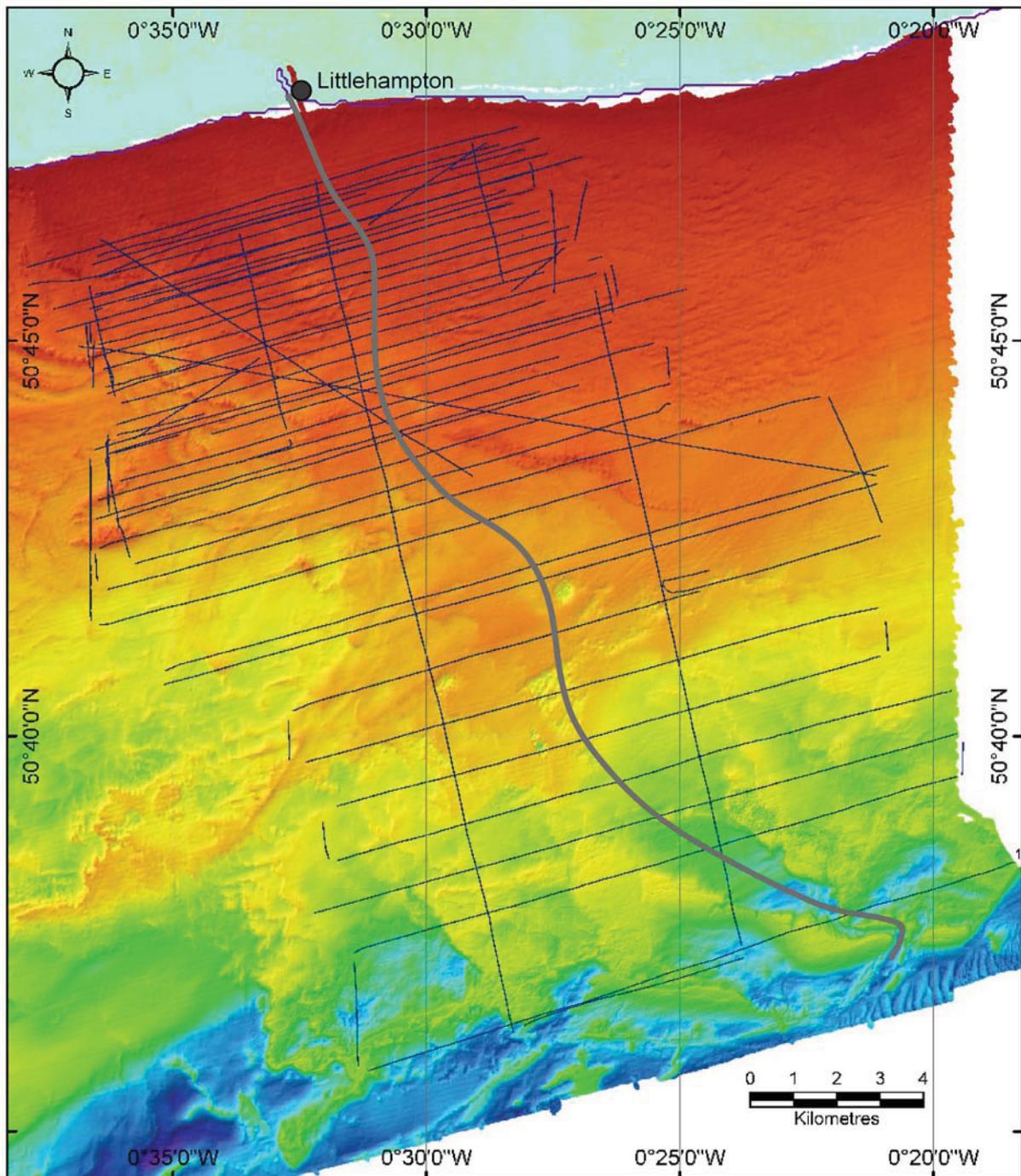


Figure 5.4 Location of the 2003 seismic survey lines collected by Imperial College. The basemap is the singlebeam bathymetry for the area. The general course of the palaeo-Arun Valley is marked by the grey line. See Fig 5.2 for the position of the 2003 survey relative to the industry seismic dataset.

seismic surveys are confined by the location of the dredging license block, resulting in different surveys targeting different areas. Consequently, for ease of interpretation and presentation the palaeo-Arun has been split into three sections – upper, middle and lower – on the basis of location on the shelf and location of seismic surveys (Fig. 5.2). The upper section is defined as the region to the north of the aggregates industry license block to the coast, where the digital boomer seismic was collected in 2003. For this area only the base of valley has been picked and no further interpretation of the internal stratigraphy has been derived. The middle section is confined to the interpretation of the 2000 seismic survey, which falls in an area in the centre of the study area and joins the older surveys in the original license block with the digital survey of 2003. The seismic dataset acquired during 2000 has been the focus of a high-resolution reconstruction. The reason for this is two-fold; one, the boomer system employed for the collection of the seismic data produced the most high-resolution output of all the datasets available to us, and two, the survey forms a close grid of lines. Both high-resolution data and close spacing of the survey lines is important because fluvial systems are potentially highly changeable through both space and time, therefore the greater the resolution the more accurately reflectors can be correlated from one profile to the next. Consequently a detailed internal stratigraphy has been constructed for the 2000 seismic survey. The lower section integrates the 1990, 1991, 1995, 1998, and 2003 (where it is available in the south) seismic surveys. The 1990, 1998 and 2000 datasets have been interpreted and digitised, and form the basis of the contouring of the main palaeo-Arun valley. These digitised datasets were chosen because they provide the most extensive cover of the area. In comparison the 1991, 1995 and 1999 were collected over smaller areas and so do not facilitate a precise correlation from one line to the next, but they have been used to assist in the interpretation of the stratigraphy gained from digitising the other surveys.

5.4 SUBSURFACE MORPHOLOGY OF THE PALAEO-ARUN VALLEY

The palaeo-Arun Valley is incised into Cretaceous and Tertiary strata of the northern English Channel Shelf. The valley is a broad, elongate feature, which is directed towards the south and turns southeasterly in its lower reaches (Fig 5.5). It is connected to the Northern Palaeovalley of the Quaternary English Channel River by a northeast trending incision. In the north the main valley connects with a western tributary where the Kingmere Rocks form a local constriction. Beyond this to the south, the main valley splits into a number of branches. The main palaeo-Arun valley, which is the focus of this study, continues seawards in a southeasterly direction, whilst the other valleys drain to the south. Smaller valleys to the east merge into the main valley at a broad depression in the south. The main palaeo-Arun valley extends to a width of 3 km, whilst the smaller valleys are only 1-2 km wide. The depth of the palaeo-Arun valley incision below the surrounding sea floor reaches a maximum depth of 30 m (Fig. 5.6). The depth of the valley from the sea surface ranges from 10 m in the north, to 30 m in the middle section, and to 60 m in the south (Fig. 5.5), with an overall averaged seaward dip of 0.2° (Fig. 5.7). The base of the valley profile indicates that although the system incises

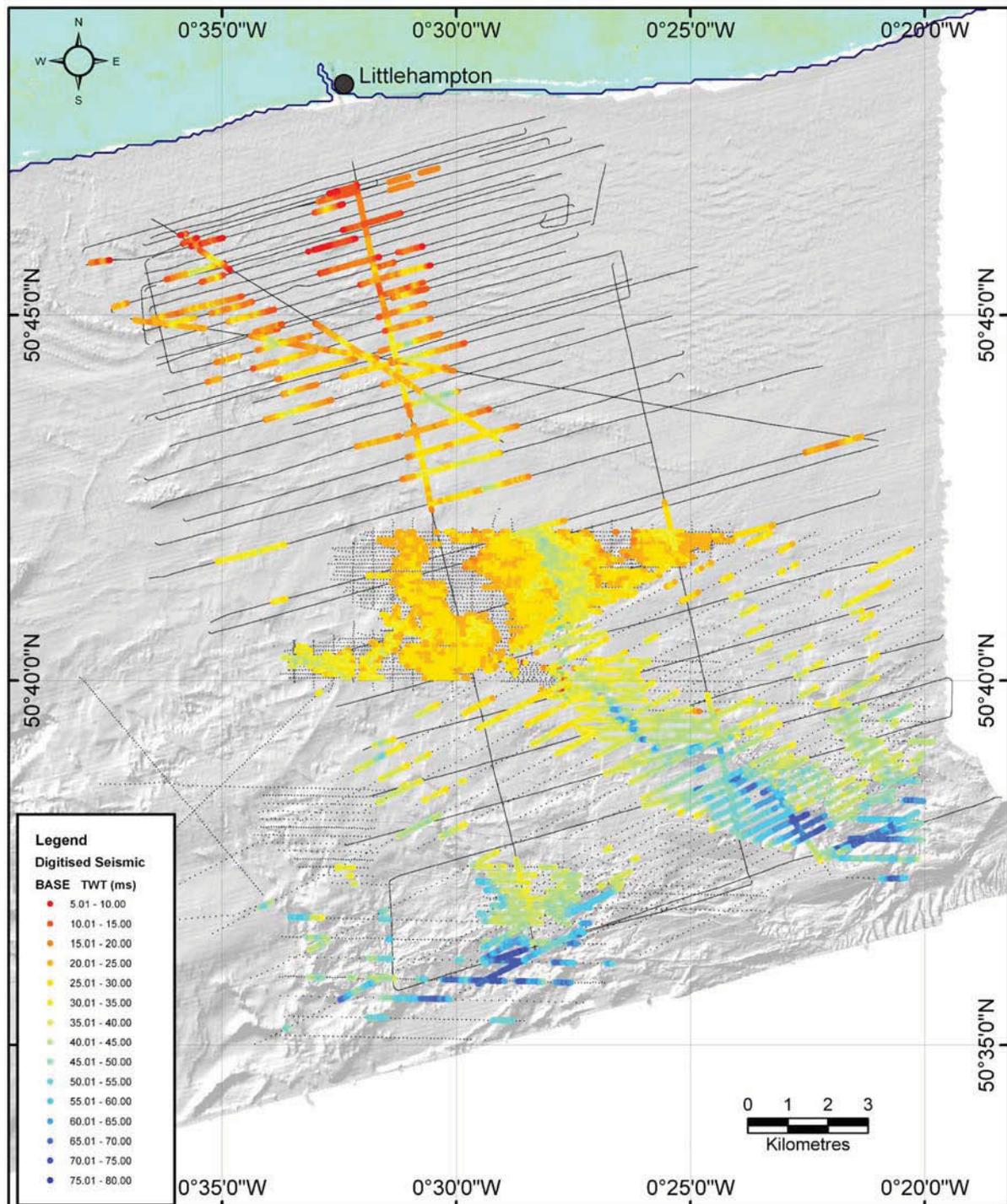


Figure 5.5 Structure contour (TWT from sea surface to base of valley) of the submerged valleys in the study area, derived from digitised 1990, 1998, 2000 and 2003 seismic surveys. The main palaeo-Arun Valley is defined as the deeply incised system that drains to the southeast in the east of the study area. The survey lines are shown behind the digitised valley to indicate the coverage of the digitised dataset. Enlargements of the middle section are shown in Figs 5.13, and for the lower section in Fig. 5.24.

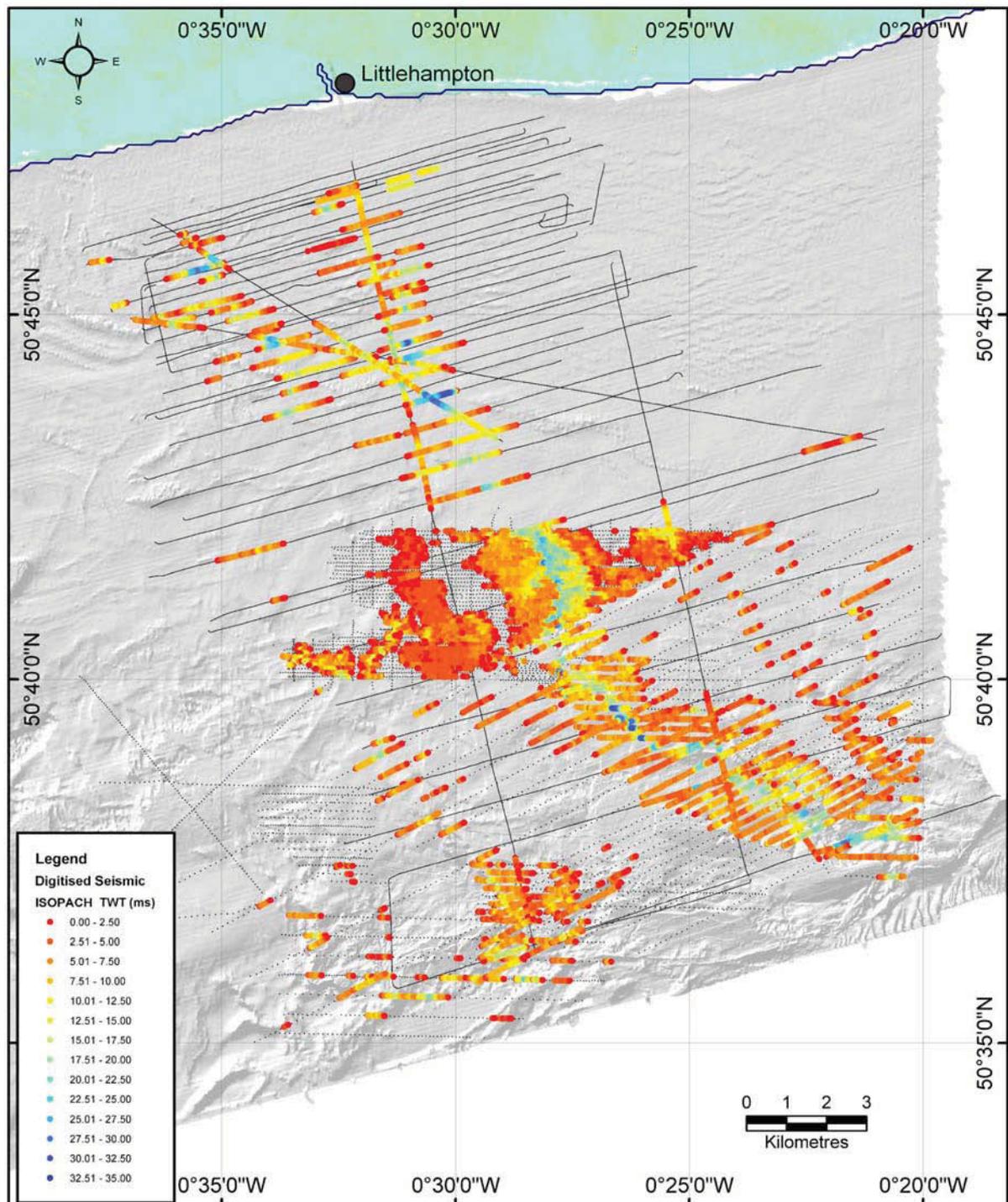


Figure 5.6 Isopach thickness (TWT from sea floor to base of valley) of the submerged valleys in the study area, derived from digitised 1990, 1998, 2000 and 2003 seismic surveys. The main palaeo-Arun Valley is defined as the deeply incised system that drains to the southeast in the east of the study area. The survey lines are shown behind the digitised valley to indicate the coverage of the digitised dataset. Enlargements of the middle section are shown in Figs 5.12 and 5.13, and for the lower section in Fig. 5.25.

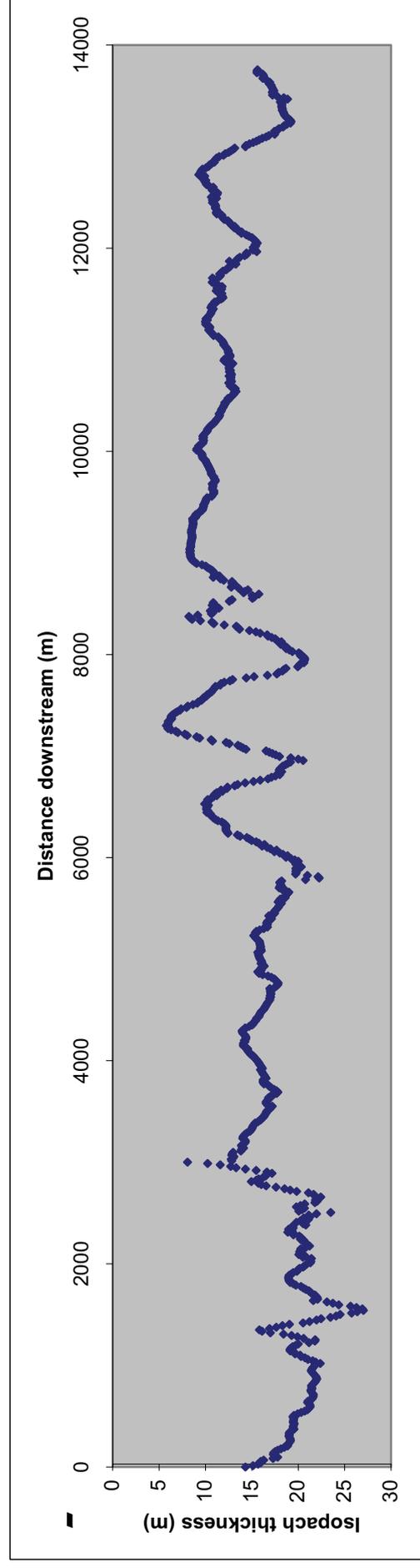
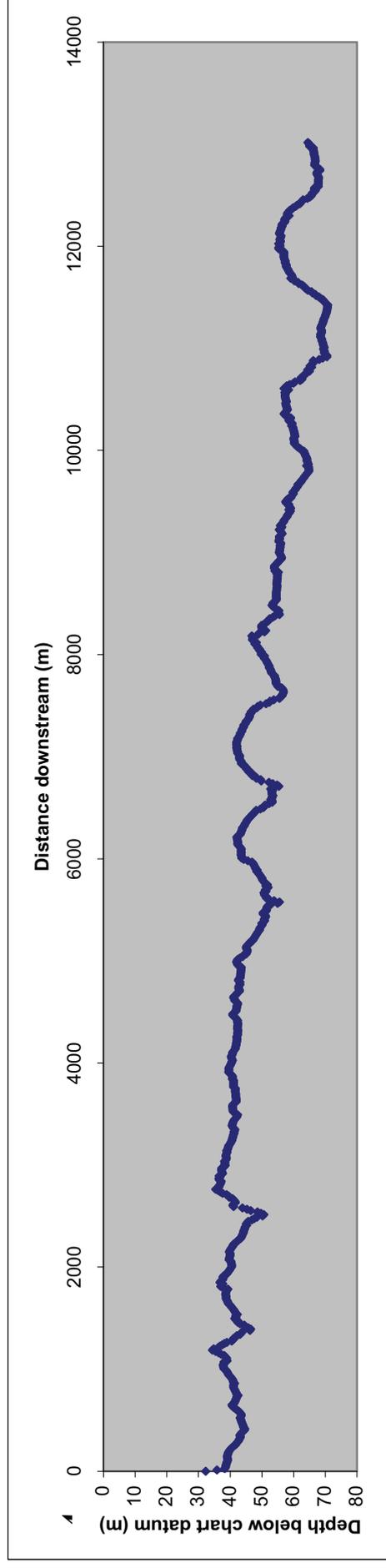


Fig. 5.7 Plots showing the profile of the depth to base of the main palaeo-Arun valley below chart datum (A) and the isopach thickness of the sediment fill from the base of the main palaeo-Arun valley to the sea floor (B). (Derived from digitised 1990 and 2003 seismic survey contours).

to a greater depth in the south, the thickness of sediment fill becomes relatively less (Fig 5.7), suggesting that the depositional regime changes downstream. The valley has a flat to slightly concave-upward floor, which in places become undulating. It is bounded by margins with a maximum slope of about 6° on the western margin and a gentler slope of $3\text{-}4^\circ$ on the eastern margin. Mapping of the main valley floor (Figs 5.5 and 5.6) indicates that the system has a broadly symmetrical geometry with a central incised valley flanked by a shallow shoulder forming a terrace. In the north, the valley margins are concave-up regular surfaces. The shape of the valley is a broad U-shaped valley with a thin (5m) terrace extending from the margins of the central basin (Fig. 5.8). No terraces are evident in the topography of the sea floor and the valley is completely filled. In the south, the valley has steep margins and a well-developed terrace on the eastern margin (Fig. 5.8). The presence of a significant topographic valley in the bathymetry (Fig 5.1) is suggestive that the lower section is only partially filled by sediment. To the south, a central depositional channel becomes more prominent within the valley and appears to represent the thalweg of the valley (Fig. 5.5). At the base of the valley in the study area, the channel deepens and widens, prior to draining through a narrow incision of a bedrock ridge.

5.5 SEISMIC STRATIGRAPHY OF THE UPPER PALAEO-ARUN SECTION

The seismic stratigraphy of the upper section of the palaeo-Arun was derived from analysis of the digital 2003 Imperial College seismic survey. The position of the palaeo-Arun valley was mapped here by the identification of basal channel reflections only (Fig. 5.9). No internal stratigraphy was mapped for this data and no vibrocores were collected in this area. Mapping of the basal erosion surface of the upper palaeo-Arun shows two valleys draining from the north (Fig. 5.9). These valleys appear to converge at a point where the valley has breached through a prominent ridge in the bedrock that outcrops at the seafloor to the east and west, and is known as Kingmere Rocks (Fig. 5.1). The valley to the east is considered to represent the main palaeo-Arun Valley as it drains from the vicinity of the onshore Arun River. The valley continues downstream in a southeasterly direction. The valley extends to a width of 2 km and incises to a depth of 15 m below the sea floor. The cross sectional geometry exhibits a broad symmetrical valley with gently sloping margins of $2\text{-}3^\circ$ (Fig. 5.8A). The upper section becomes more incised in the centre of the valley as it flows to the south. This central incised zone connects with the east valley of the middle section. The thickness of the sediment fill in the upper section is variable from line to line (Fig. 5.9). This probably reflects the difficulty in determining the base of valley in the seismic record due to the shallow water depth producing sea floor multiples at a higher level in the seismic profile.

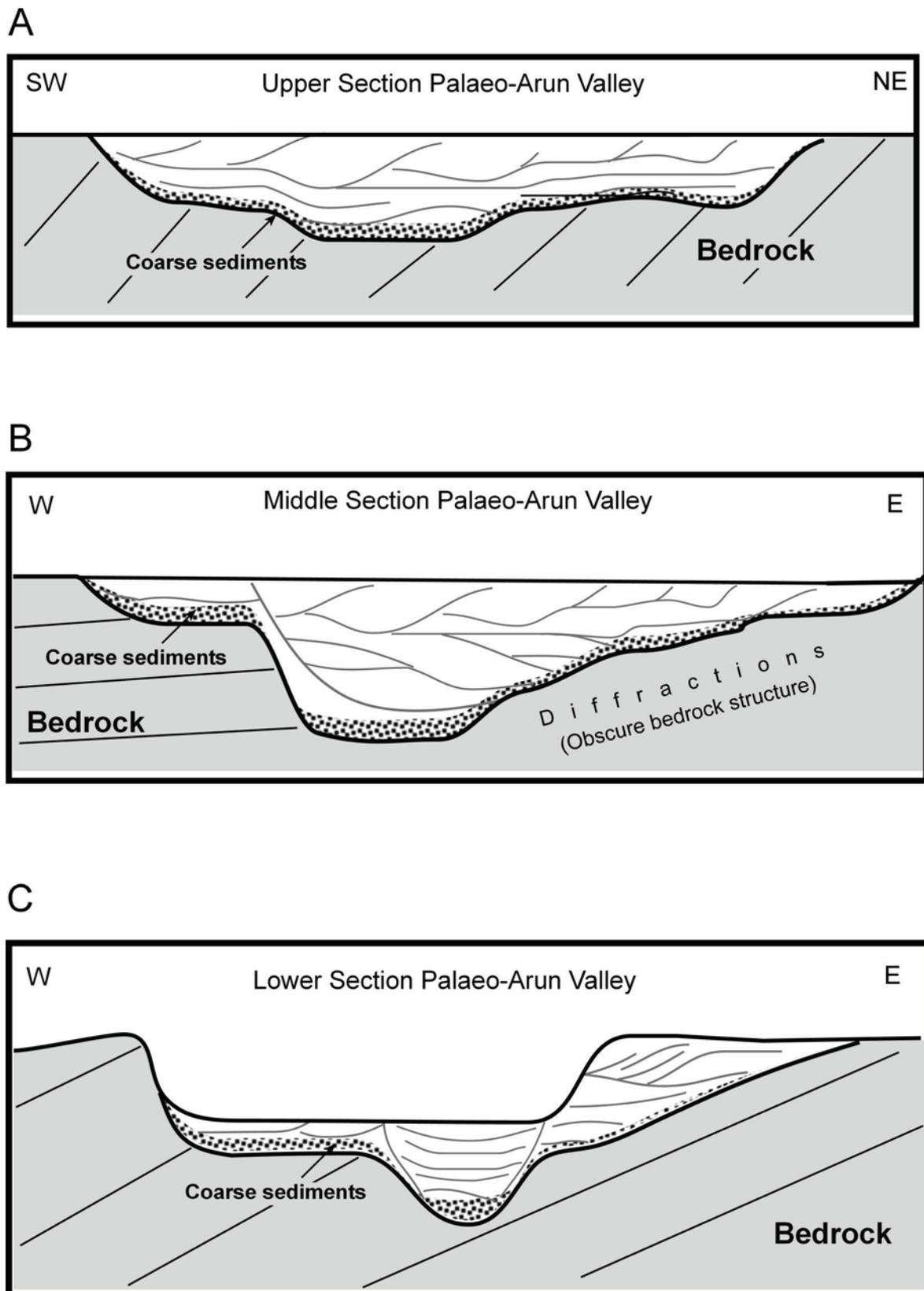


Figure 5.8 Schematic illustrations to show the subsurface morphology of the upper (A), middle (B) and lower (C) sections of the main palaeo-Arun valleys. Also shown are the general fill geometry and the typical bedrock structure in each section.

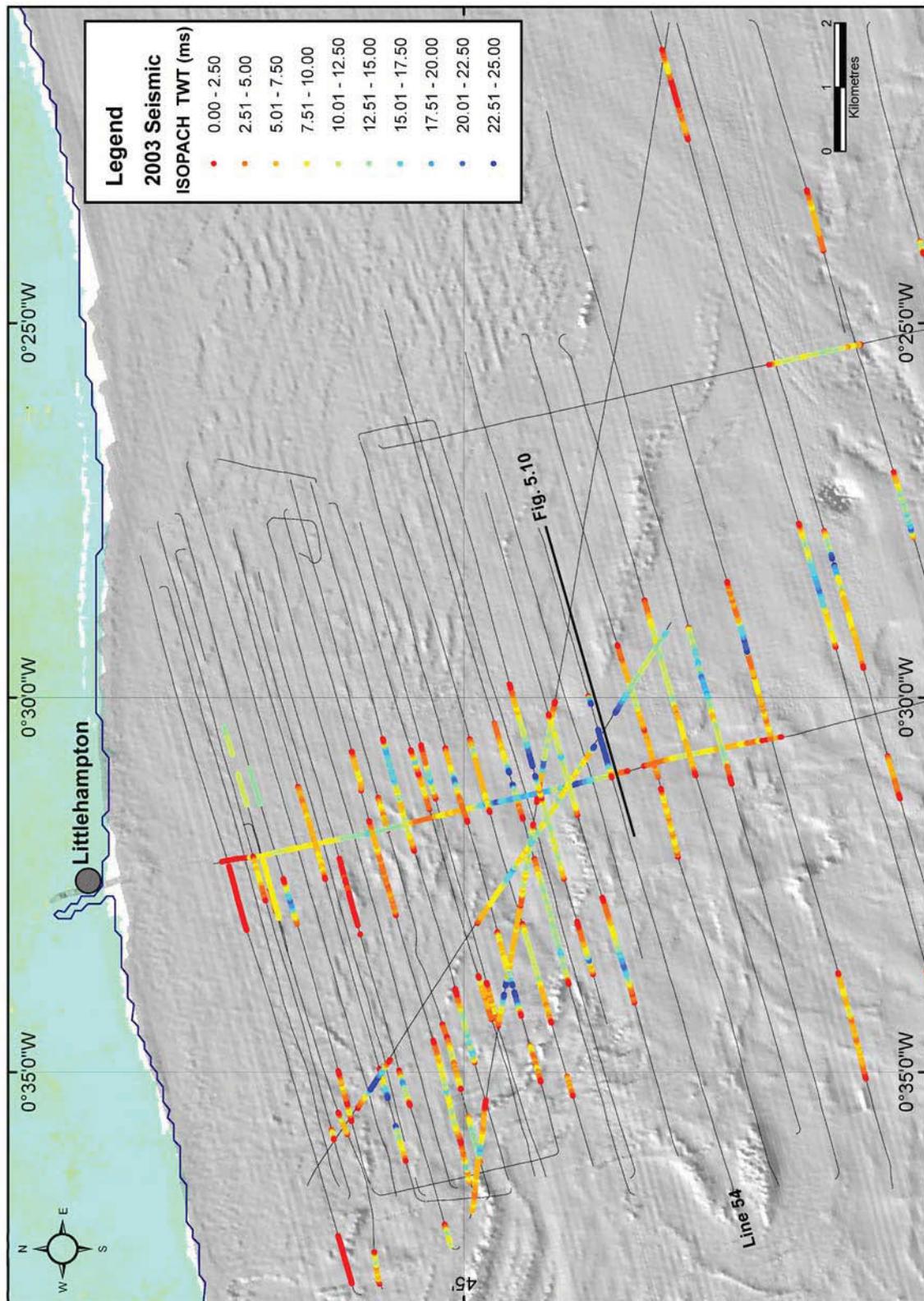


Figure 5.9 Isopach thickness (TWT from sea floor to base of valley) of the submerged valleys in the upper section of the study area, derived from digitised 2003 seismic survey. The survey lines are shown to indicate the coverage of the digitised dataset.

5.5.1 Seismic Character

5.5.1.1 Bedrock

The bedrock that lies beneath the Quaternary channels has a very distinct seismic character. The lower bounding surface extends below the vertical resolution of the seismic profiles. The upper bounding surface is either truncated at the sea floor or by the incision of the overlying channel unit. Moderate to high-amplitude, continuous, parallel and even reflectors of varying dip (0-10°) typifies the bedrock (Fig. 5.10). The resolution of the 2003 seismic identifies the strong structural fabric of the bedrock as indicated by its deformed beds.

5.5.1.2 Valley

The base of valley is characterised by the truncation of bedrock reflectors and is typically characterised by high-amplitude, uneven and continuous reflector. The identification of the true base of valley is made difficult in some profiles by additional multiples resulting from the shallower water depths (Fig 5.10). However, coarse sediments, which typically line the base of the valley, produce diffractions as a result of their irregular geometry and enable valleys to be identified on the basis of this interference in the seismic record. The internal reflectors of the valley are highly variable, but generally are low to high amplitude, parallel to chaotic, semi-continuous and uneven (Fig. 5.10).

5.5.2 Source of the palaeo-Arun Valleys

A key objective of the 2003 seismic survey was to collect data on the position of the palaeo-Arun from its offshore position to the coast. Although the position of the palaeo-Arun offshore had previously been established (e.g. Hamblin et al., 1992; Bellamy, 1994), no data was available to ascertain if it did in fact connect with the modern Arun River. However, the mapped basal reflector indicates that this is the case and that the palaeo-Arun flowed to the south through a break in the bedrock at Kingmere Rocks (Fig. 5.9). A seismic profile to the east indicates that the Kingmere Rocks are a structurally controlled fold sequence (Fig. 4.55). The character of the bedrock where the valley cuts through at Kingmere Rocks is obscured by diffractions from the coarse sediments; however, it is assumed that the structure to the east continues to the west. The mapped 2003 seismic also suggest that there is another valley to the west that flowed from an area of the modern coast. The Aldington Rife enters the English Channel with some proximity to this valley and it is possible that although it is now only a minor tributary it may have been more significant through the Quaternary.

5.6 SEISMIC STRATIGRAPHY OF THE MIDDLE PALAEO-ARUN SECTION

The middle palaeo-Arun Valley section has been interpreted based on the 2000 seismic survey and associated vibrocores (Fig 5.11). This survey has been the focus of a high-resolution reconstruction because of the detailed seismic record and the close spacing of the survey lines. Consequently, accurate correlation of internal stratigraphy from one profile to the next is possible and the mapping

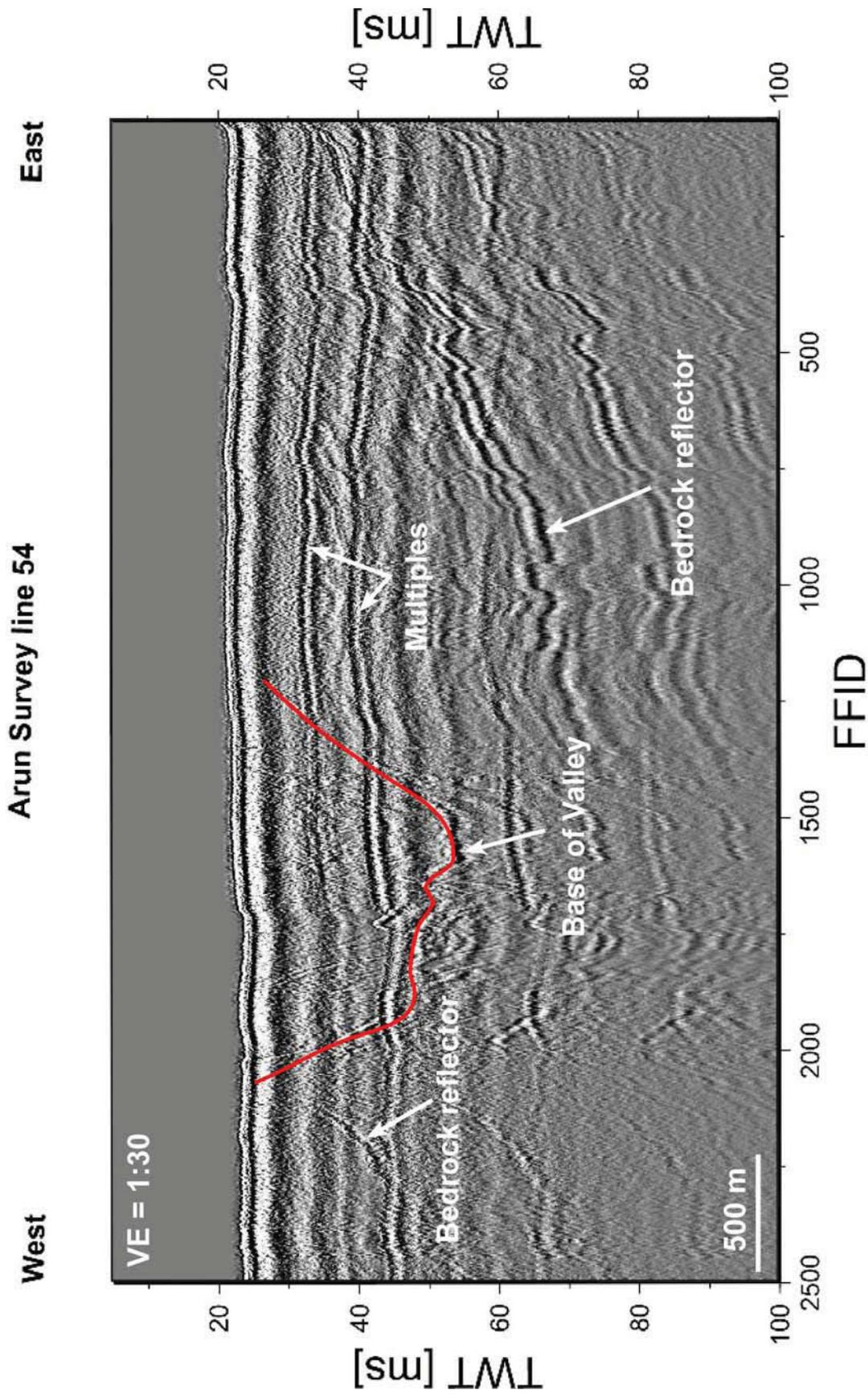


Figure 5.10 Seismic line 54 from the 2003 survey illustrating the character of the bedrock and valley in the upper section of the palaeo-Arun Valley. The red line denotes the mapped basal erosion surface of the valley. Note the presence of sea floor multiples high in the profile that interfere with the clear imaging of the valley. These are due to a shallow water depth. See Fig 5.9 for the location of the seismic line.

of horizons identified in these seismic profiles have allowed the internal stratigraphic architecture of this middle section of the buried valley system to be constrained. As with the upper- and lower-sections the mapping of the basal erosion surface has determined the location of the palaeo-Arun Valley and the overall morphology of the valley incision (Fig. 5.12). Two dominant valleys are identified in the middle-section, one to the east, and the other to the west. The mapping of the palaeo-Arun through the study area (Figs 5.5 and 5.6) indicates that the valley to the west is the main palaeo-Arun system. The valley to the east connects with a system that has been identified draining to the south. This valley is not as extensive or deeply incised as the main palaeo-Arun, but reaches a width of 2km in places and a depth of 10 m. Gridding of the basal surface (Fig. 5.13) suggests that the two valleys merge in the south to form one system with a thin (5 m) floodplain or terrace feature between. However, examination of the digitised data (Fig. 5.13A) indicates that this is an artefact of the gridding process. It is difficult to determine the relative age of this system to the main valley but it possibly represents a smaller river that flowed concurrently to the main valley. The mapping of the basal erosion surface of the main palaeo-Arun Valley through the middle-section illustrates the broad width of the valley, which reaches a maximum of 3 km, and the central incised zone (Fig. 5.12). Through the middle-section the overall valley drains to the south, however the position of the central incised zone meanders from a southeasterly direction to a more southwesterly direction. In cross-section the valley exhibits a broad U-shaped basin, which represents the central incised zone, and is flanked by shallow margins that extend for hundreds of metres (Fig. 5.8). The central zone of the valley is more deeply incised along its western margin to a maximum depth of 20 m and shallows to the east (Fig. 5.8B). However, the thickness of the sediment fill in the area flanking the central zone is greater on the western side. This represents the complex fill sequence that overlies the basal erosion surface and forms the focus of this section. To facilitate the mapping of horizons that represent the internal stratigraphy it is necessary to first define acoustic facies evident in the seismic and from groundtruth data (vibrocores) determine their lithological composition. This provides a basis for identifying key architectural features that combine internal and external characteristics to define depositional elements.

5.6.1 Seismic Facies

Six seismic facies have been identified that define the fill of the palaeo-Arun valley in the 2000 dataset (Fig. 5.14). These are based on acoustic properties identified in the boomer profiles, which include the presence or absence of reflections and their relative amplitude, reflector geometry and where discrete reflections are not apparent the relative amplitude of backscatter. A description of the strata that the infill facies incise is also given.

- I Parallel to subparallel, continuous to discontinuous, high-amplitude reflectors.
- II Discontinuous, irregular, high-amplitude reflections, commonly with short dipping segments, producing an overall chaotic appearance.

- III Parallel to subparallel, continuous, moderate-amplitude, high-angle oblique reflections.
- IV Parallel to subparallel, low-amplitude reflections, commonly intervals lack coherent reflectors and high ambient noise is prevalent.
- V Parallel, continuous to semi-continuous, moderate-amplitude reflections.
- VI Parallel, continuous, high and moderated-amplitude landward-stepping oblique reflectors.

The reflectors of the seismic facies I-VI consistently overlie a basal unit A (Fig. 5.15). The upper bounding surface of this unit is formed by truncated reflectors beneath the seismic facies, which characterise the fill of the palaeo-Arun, or at the sea floor. Moderate to high amplitude, continuous, parallel, even reflectors of varying dip typify the internal character of the unit. This unit is interpreted to represent the Tertiary strata that forms the bedrock of the region. The dip of the reflectors indicates the strata have been deformed and exhibit a strong structural fabric. Consequently, the fill of the palaeo-Arun Valley overlies an erosional angular unconformity across the area.

5.6.2 Sediment Characteristics of Seismic Facies

Correlation of the seismic acoustic facies to cores allows information regarding the lithological characteristic of the sediment to be determined. This is important as it aids the interpretation of the sequential development of the valley. The cores collected in the study area are vibrocores and as such only have a potential maximum penetration of 6 m, but in the majority of cases the cores only achieve a retention of ~2-3 m sediment. Therefore they are not long enough to penetrate to the base of the valley succession and consequently not all facies imaged by the seismic. However, it is possible to target different seismic facies where they are present with proximity to the sea floor surface. Another controlling factor on groundtruthing the seismic data is that the aggregates company are interested in sourcing gravel and sand resources and hence do not target fine-grained lithologies. Because of this there is a bias in the core data to coarser-grained acquisition. Nevertheless, the vibrocores all fall directly on the seismic survey lines (Fig. 5.11) and there is an extensive enough suite of cores to determine the lithological characteristics of the seismic facies. Furthermore, the characteristics of the seismic reflectors give a good indication of the sediments they are passing through, particularly when unconsolidated Quaternary strata are imaged (Sheriff and Geldart, 1995). Below is a description of the sediment of each facies and an interpretation of the depositional environment, which is summarised in Table 5.1.

Facies I is typically observed at the base of the valley incision, and because of the limited penetration of the cores it has not been sampled. However, the high-amplitude nature of the reflections indicates major acoustic impedance and the sampling of similar high-amplitude facies indicate the cause to be coarse-grained massive gravels with sands. The position of this facies at the base of incision and their parallel nature suggests the gravel deposits are basal lag deposits marking the base of channel and deposited in high-energy environments.

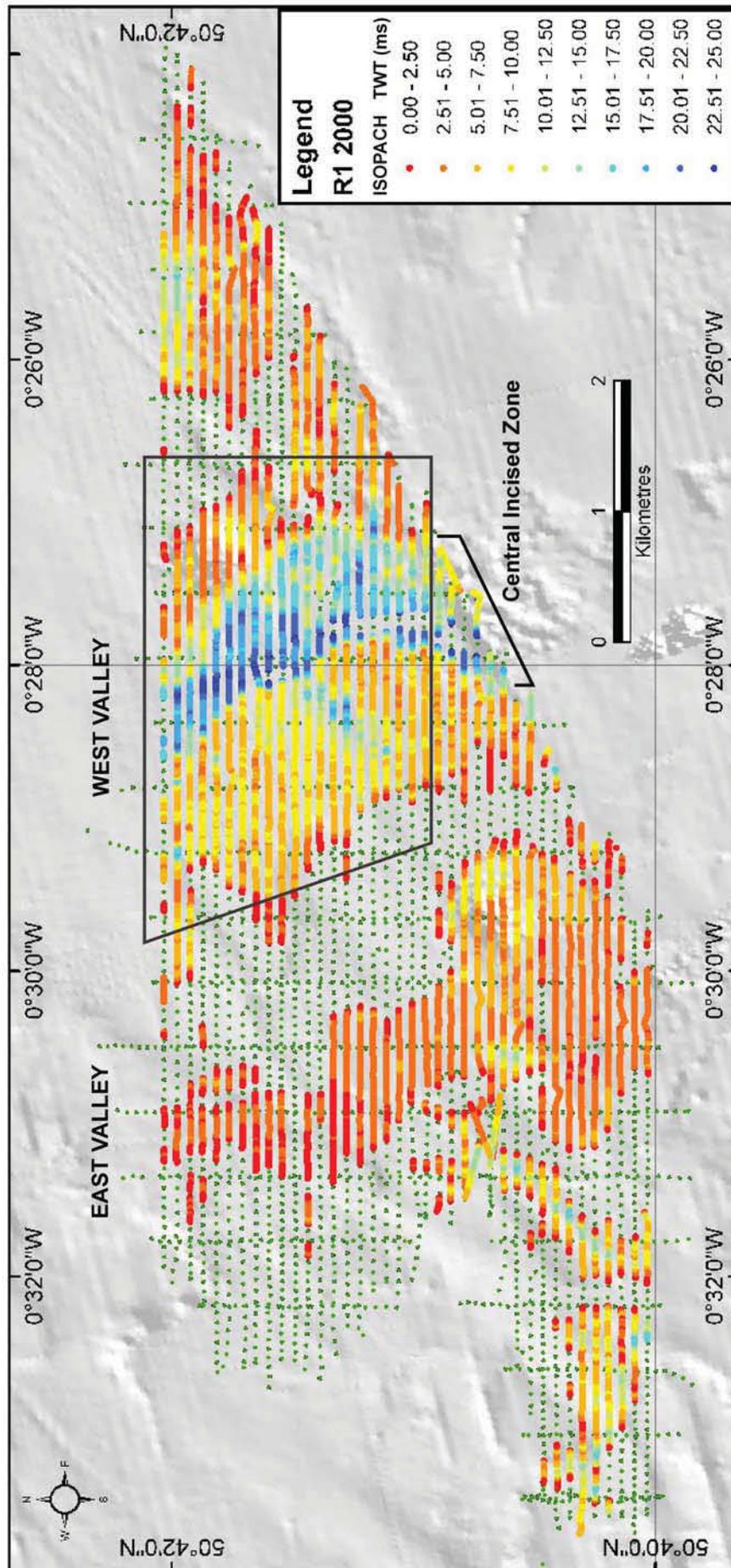


Figure 5.12 Isopach thickness (sea floor to base valley) in TWT(ms) of the digitised 2000 seismic survey data for the middle section of the palaeo-Arun Valley. Two dominant valleys are identified one to the east and the other to the west. It is the west valley that is the focus of this study and forms part of the main palaeo-Arun Valley. The box indicates the area where the internal stratigraphy has been mapped, Figs 5.21 and 5.22.

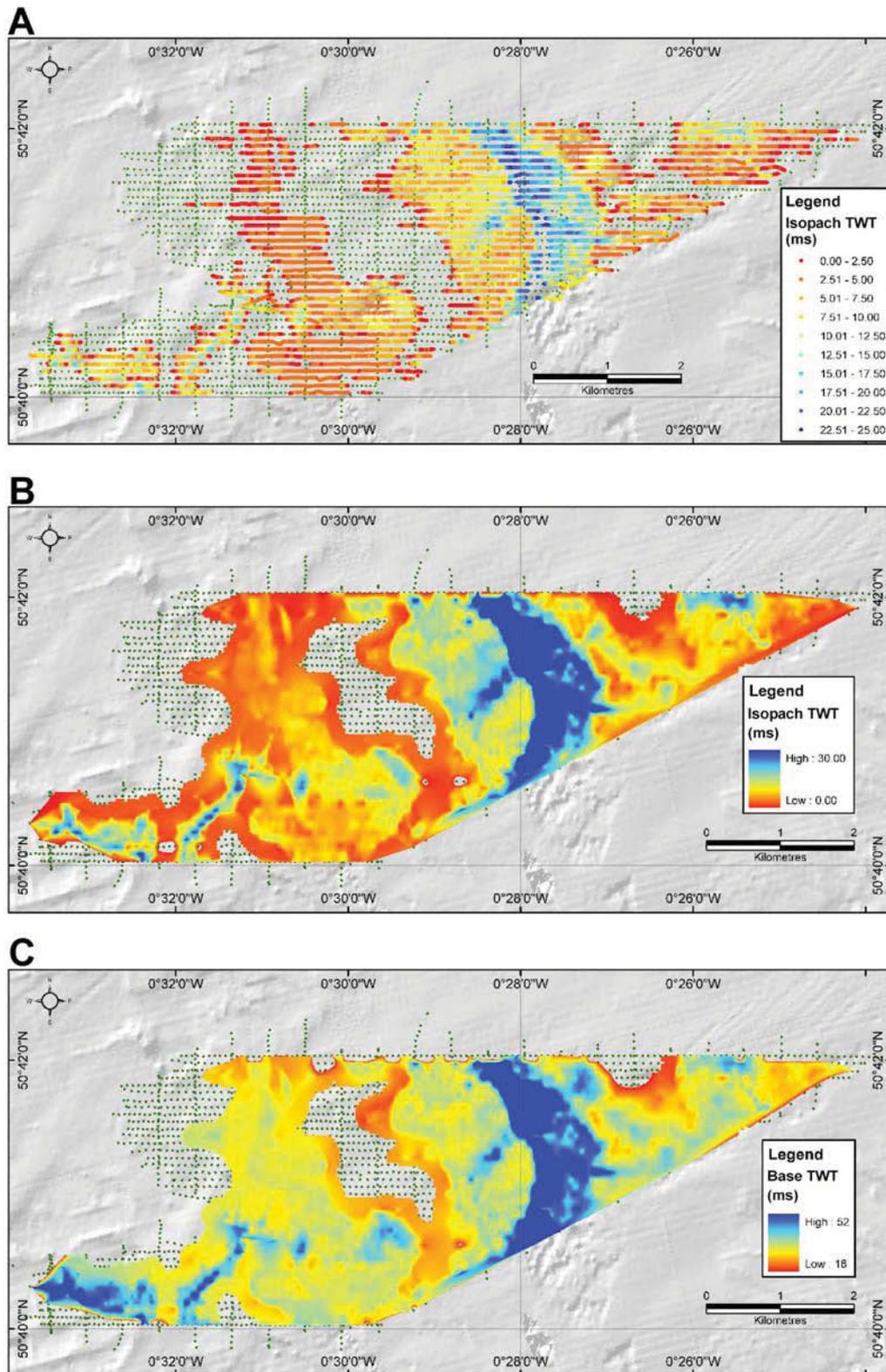


Figure 5.13 Digitised base of valley maps for the middle section (2000 seismic survey) to illustrate the different gridding of the data. **A.** Isopach thickness (sea floor to base of valley in TWT) map of digitised points. **B.** Contoured grid of isopach thickness. **C.** Contoured grid for structure contour surface (base of valley to sea surface in TWT). Note that only the east-west lines have been digitised. The method for gridding of the data is described in Chapter 2.

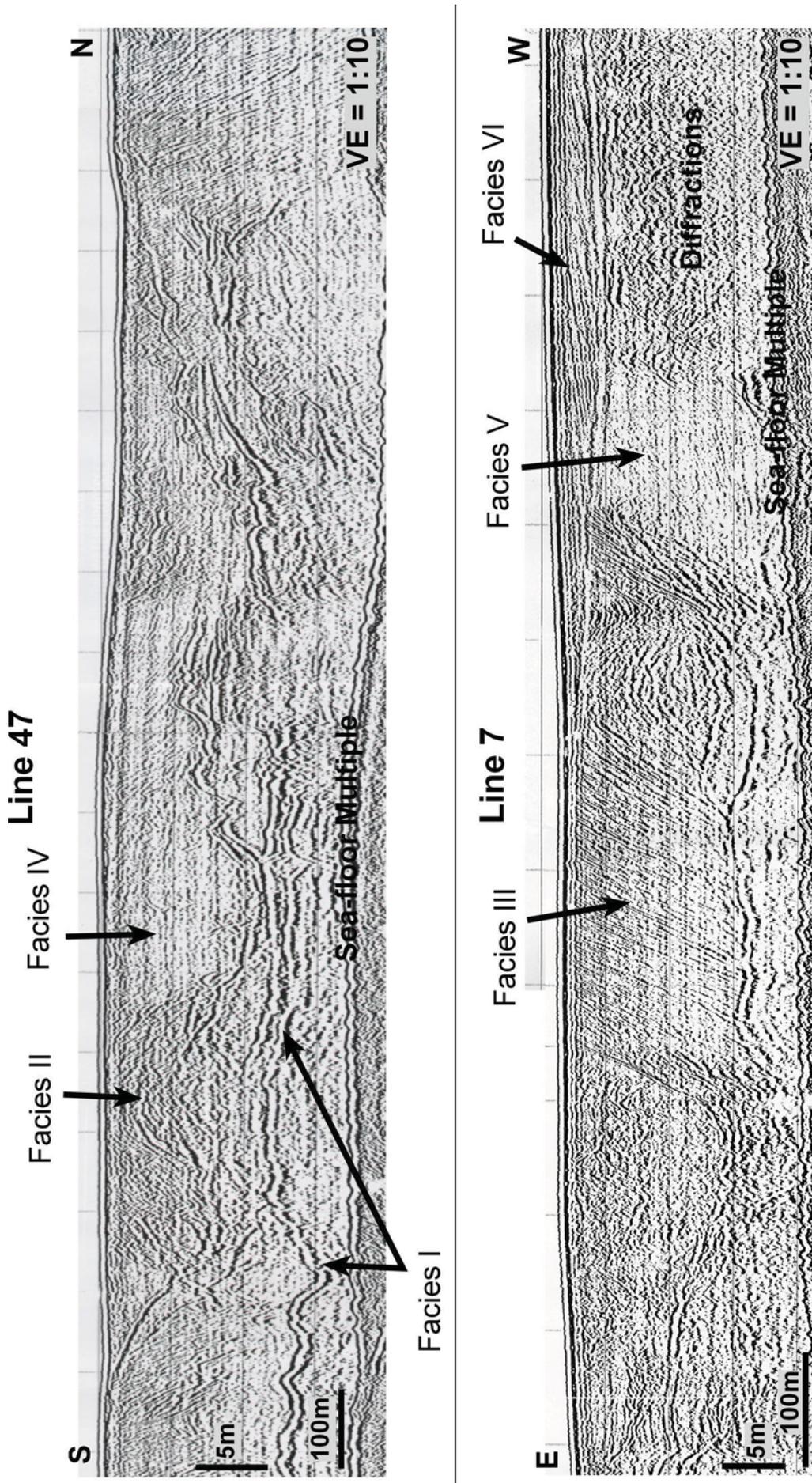


Figure 5.14 Seismic profiles from the 2000 survey to illustrate the different seismic facies identified in the record. Note the common appearance of diffraction beneath chaotic, high-amplitude reflections caused by acoustic variation associated with coarse sediments. See Fig. 5.11 for location of lines.

Table 5.1 Acoustic facies recognised in palaeo-Arun valley

Facies	Reflector characteristics	Lithology	Interpretation
I	Parallel, continuous, high-amplitude	Coarse gravels	Basal gravel lag
II	Discontinuous, irregular, high-amplitude, chaotic reflections	Coarse gravels and sands	Poorly structured coarse-grained gravels and sands, high-energy deposition
III	Parallel to subparallel, continuous, moderate-amplitude, high-angle oblique reflections	Sands and gravels	Lateral accretion surfaces
IV	Parallel to subparallel, low-amplitude reflections, ambient noise	Silts and clays \pm organic material	Fine-grained low-energy infill from suspension,
V	Parallel, continuous to semi-continuous, moderate-amplitude	Silts and sands \pm organic material	Fine-grained low-energy infill from suspension
VI	Parallel, continuous, high and moderated-amplitude, oblique reflectors	Coarse clastics of shelly sands and gravels	Transgressive sediment deposition

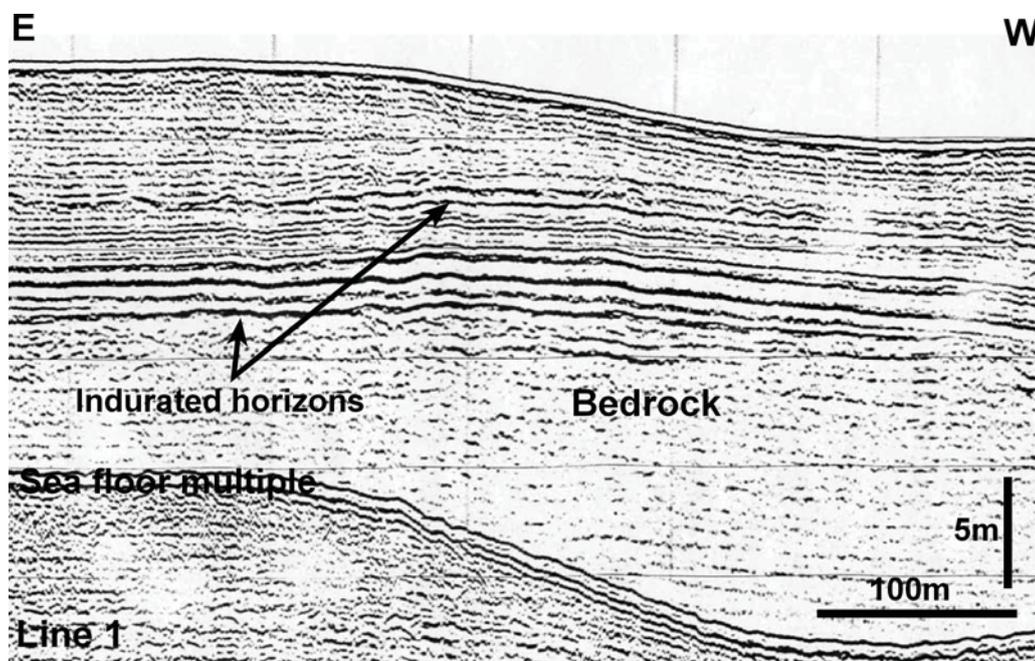


Fig. 5.15 Section of a seismic profile to illustrate the bedrock character evident in the 2000 seismic survey. See Fig. 5.15 for location of the section.

The discontinuous, irregular, high-amplitude reflections of facies II also indicate a major acoustic impedance contrast and the commonly chaotic internal appearance suggests that the facies represents poorly structured coarse-grained sediments deposited in high-energy environments. As with facies I this facies is also commonly beyond the depth of coring, but vibrocore 435-10 intersects the facies near the surface and reveals a succession of gravels and coarse sands (Fig. 5.16).

The oblique reflectors of facies III are interpreted as representing surfaces of lateral accretion. Their moderate-amplitude suggests a coarser lithology of sands and gravels, which is corroborated by cores 435-11A, 435-13 and IC8 (Fig. 5.16), and a high-energy environment. There is no obvious layering evident in the cores to indicate erosional surfaces of deposition as inferred from the seismic. Although, occasional truncation of the internal reflectors suggests that the surfaces are interrupted by erosional events producing a thick aggradation sequence that contains minor sedimentary unconformities (Fig 5.14).

Vibrocore 396-10 and 435-18 penetrate through facies IV and reveal a sequence of sandy silty clay (Fig. 5.17). This in conjunction with the low-amplitude internal reflections, reflector-free zones and high ambient noise, which principally indicates homogeneous fine-grained sediments (clays, silts and sands), suggests that facies IV was deposited from low energy aqueous flows.

The parallel, continuous to semi-continuous, and moderate-amplitude reflections of facies V suggest an interval of vertical aggradation representing drape of underlying elements or filling of depressions and probably records parallel-bedded, low-moderate energy silt and sands deposited from suspension. No cores intersect this facies in this area, but similar facies are cored to the south and show a sequence of fine-medium sand and lenses and clay and organic material.

The internal reflections of facies VI are very similar to facies III, however the amplitude is higher and the oblique reflections better defined. The high amplitude indicates a high impedance and coarse lithology. This is supported by cores (435-22, 435-21A and 435-25A), which produce coarse sandy gravel that commonly includes shell fragments (Fig. 5.17). A marine veneer covers the entire region, which is present at the top of all cores as shelly sandy gravel up to 50 cm thick. The landward direction of aggradation indicated by reflections typical of facies VI and the shell content suggests that this facies represents thicker transgressive deposits on the shelf.

5.6.3 Architectural Elements

Interpretation of the high-resolution boomer seismic-reflection data has resulted in the recognition of six major architectural elements within the fill of the palaeo-Arun valley. These depositional features are defined on the basis of acoustic facies, geometry in cross-section, and bounding surfaces. Bellamy (1994) defined 10 seismic units based on their internal and external characteristics. Although these units are broadly similar to the architectural elements described here, because the 1990 and 1991 seismic surveys used by Bellamy were located further to the south there are differences reflecting changes in the deposition of the valley as it flows to the south.

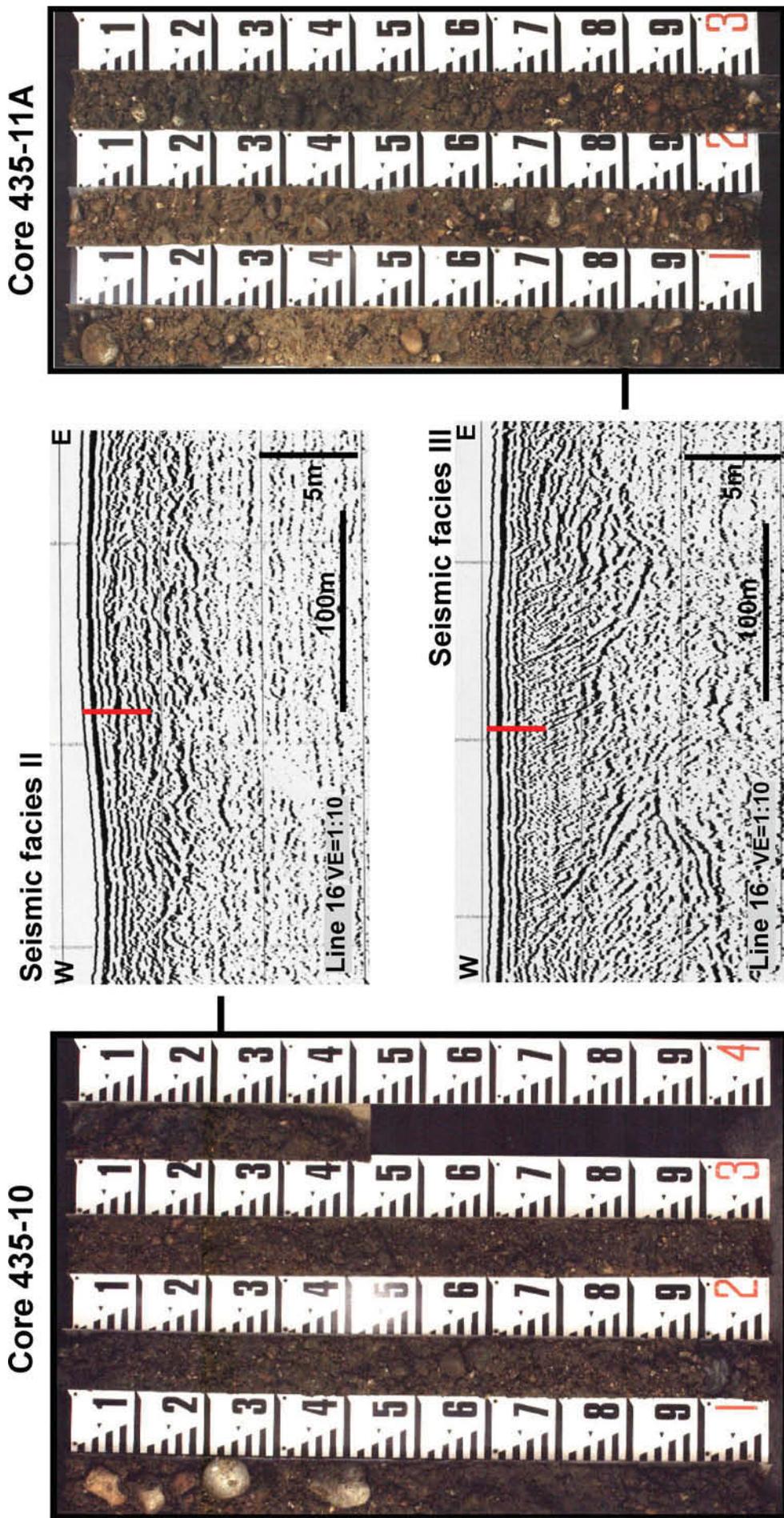


Figure 5.16 Vibrocore characteristics of 2000 survey seismic facies II and III. The higher amplitude facies appear to indicate coarser lithologies. The vertical scale for the cores is in the decimetre. See Fig. 5.11 for the position of the vibrocores.

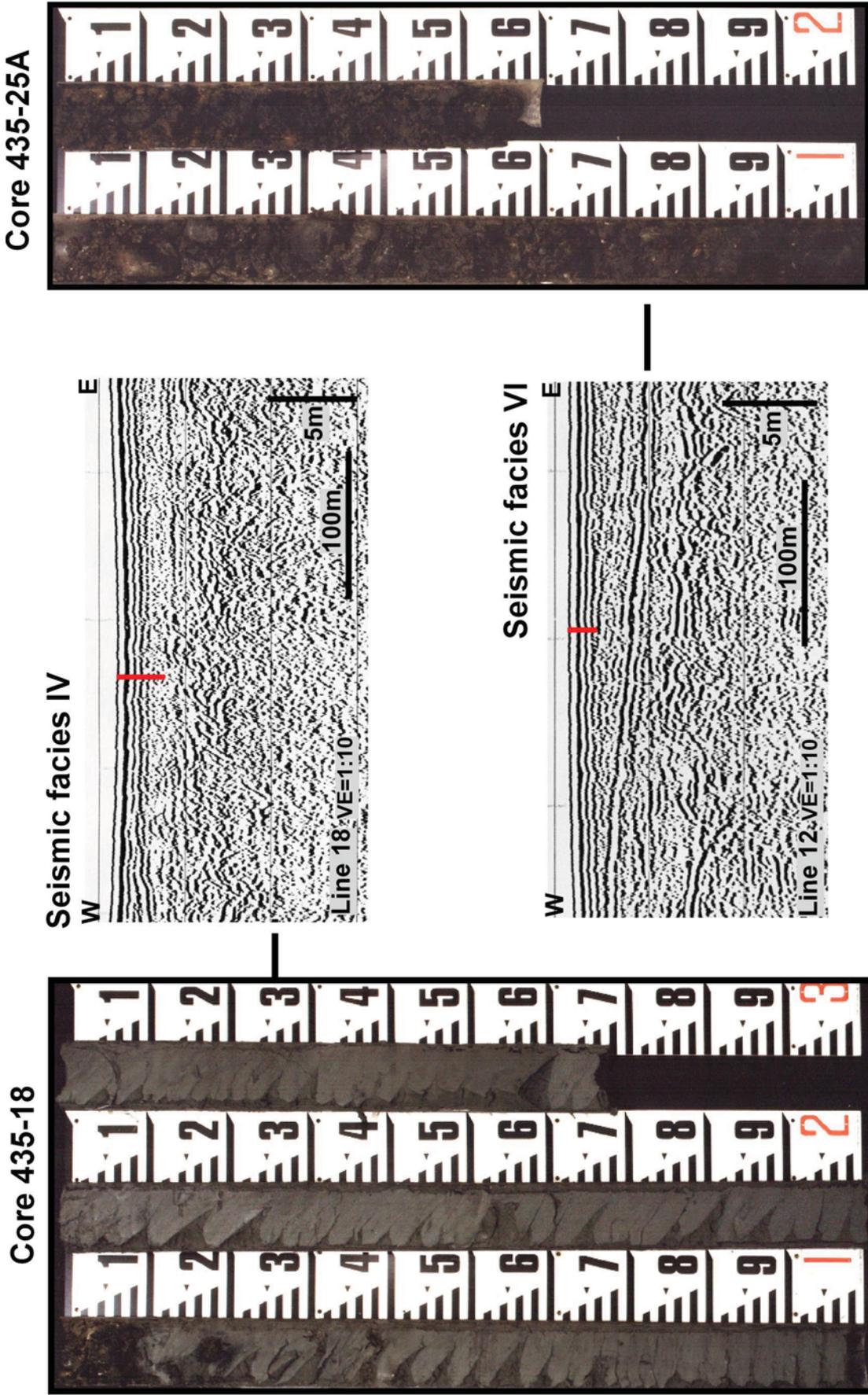


Figure 5.17 Vibrocores characteristics of 2000 survey seismic facies IV and VI. Core 435-18 indicates that the low-amplitude reflectors of facies IV represent a fine-grained lithology. The vertical scale for the cores is in the decimetre. See Fig. 5.11 for the position of the vibrocores.

5.6.3.1 Basal Valley-fill Unit

This base of valley element consists of high-amplitude, parallel internal reflectors (Fig. 5.18). These are bounded by high-amplitude, parallel and continuous bounding surfaces. The element is typically observed at the base of the valley incision, where the lower bounding surface rests unconformably on the bedrock at the base of the valley marking an erosional contact. The element forms sheets that extend across the base of valley as a predominately horizontal feature. However, at the margin edges the unit dips at up to 6° , and can be undulating within the centre of the valley indicating topographical relief at the basal valley incision. The unit generally reaches a thickness of 1 m, which in places accumulates up to a maximum of 3 m. The position of these bright reflectors at the base of the channel incision leads to an interpretation of basal lag deposits, consisting of massive fluvial gravels and coarse sands. The unit is formed during intervals of sea level lowstand when the fluvial system was incised and coarse clastic sediments were deposited due to a high-energy regime. The basal lag element is also apparent as the bottom of channels cut within the fill of the valley. Although not as thick (up to a maximum of 1 m) or as extensive the interpretation as coarse basal lag sediments deposited in high-energy environments is the same, but the degree of incision is less.

5.6.3.2 Lateral Accretion Unit

The lower bounding surface of the element has a continuous, high-amplitude and commonly plano-concave character. The surface dips at up to 6° and truncates lower reflectors, forming an erosional and unconformable contact with the underlying units (Fig 5.18B). This element generally occurs at the top of the sequence and so the upper bounding surface is truncated by erosion at the sea floor and deposition of a marine transgressive unit. Where the unit is found lower in the fill sequence the upper bounding surface typically equates to the lower bounding surface of a younger channel, which has eroded the top of the unit by its incision. The cross-section geometry of the element is that of a plano-concave shaped channel. The internal reflectors of the element are characterised by steep dipping reflectors (up to 6°) of moderate-amplitude that are parallel and downlap against, or are concordant with, the lower bounding surface. It is not uncommon for the aggrading reflectors to merge laterally with horizontal reflectors of seismic facies IV. These dipping reflectors are interpreted as representing surfaces of lateral accretion. However, the occasional presence of truncated internal reflectors suggests that these surfaces are also subject to minor erosional events within the overall deposition of the element. The formation of this unit reflects high-energy environments by the presence of coarse sands and gravels in cores and the moderate-amplitude reflectors. This unit can extend hundreds of metres in both transverse and longitudinal sections, with the general trend of aggradation in an upstream direction.

5.6.3.3 Fine-grained Channel-fill

The fine-grained channel-fill element displays a broad U-shaped geometry and is commonly marked by a transition from the lateral accretion unit (seismic facies III) by a lateral merge from dipping to

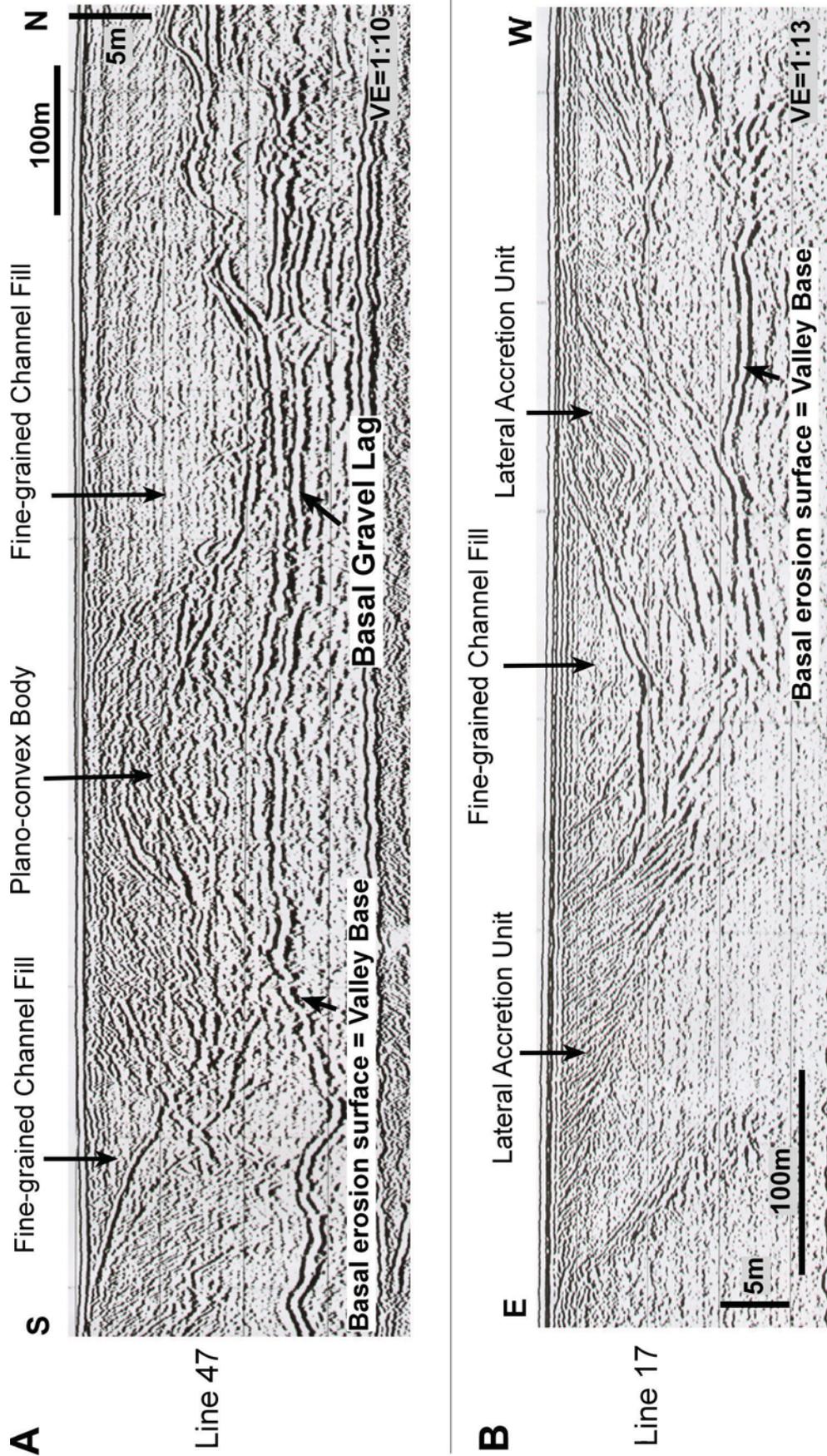


Figure 5.18 Seismic profiles from the 2000 survey to illustrate architectural elements identified in the seismic record. A. A plano-convex body is truncated by channels at its margin. The channels show fine-grained channel fill and lateral accretion units. A thick basal gravel lag marks the base of the valley. B. Lateral accretion units dominate the fill sequence. Note the truncation of the unit by younger channels. See Fig. 5.11 for the location of the seismic lines.

horizontal reflectors of low-amplitude (Fig. 5.18B). The poor seismic signal received for this element makes interpretation difficult. However, the low-amplitude reflectivity indicates massive sediment packages that drape underlying elements or fill depressions, recording parallel-bedded, low-energy, fine sand, silt and clay deposited from suspension (seismic facies IV and V). Cores and weakly identifiable horizontal reflectors confirm this. The packages are up to 10 m thick and hundreds of meters across. The lower boundary lies above a basal lag deposit and appears to be conformable rather than erosional, with the coarse-grained lag deposit marking the base of the channel. The upper bounding surface is either at the sea floor and marked by planation by the overlying transgressive ravinement surface or truncation by a subsequent incision. The latter is not common and this probably reflects fine-grained lithology of this channel-fill making it easier and more prone to removal by younger cut and fill events.

5.6.3.4 *Plano-convex Body*

The plano-convex body element of the valley corresponds to facies III. The lower bounding surface of the element is typically planar and undulating, although it can have a dipping component, and lies upon a basal lag (Fig. 5.18A). The upper bounding surfaces are concave and dip away from the centre of the body on both sides. This upper surface reflects the incision of a channel on either side of the body to form a mound-like geometry. The internal characteristics of the body element are typified by discontinuous, irregular, high-amplitude reflections. They have an overall chaotic appearance and there are many internal truncations of reflectors, which indicate the presence of many erosional surfaces. These features indicate that the reworking of coarse clastic sediment has been the dominant process in forming the body and may represent an accumulation of sediment over some time. The unit can reach a maximum thickness of 5 m and extend for up to 100 m, however it is difficult to determine their true extent, as they appear to be spatially restricted features that are difficult to map out. They typically appear to be smaller features of a few metres thickness and tens of metres extent, occurring within a complex geometry associated with lateral accretion units.

5.6.3.5 *Terrace*

The element combines a number of facies to characterise the setting of deposition. The lower portion consists of reflectors indicative of facies I, where high-amplitude, parallel reflectors form an erosive surface over bedrock. There is a high surface reflectivity associated with this that is attributed to large velocity contrasts and numerous diffractions suggest the presence of large gravel cobbles on which the seismic energy diffracts (Fig 5.19). This makes it difficult to ascertain the true base of the unit, but it is assumed to be not much deeper than ~5 m from the sea floor. The upper portion of the terrace is made up of facies IV, and has low-amplitude internal reflectors. Cores indicate fine-grained silts and clays with the presence of organic material dominating the sediments. The element conforms to a tabular geometry and occurs on either side of the main palaeo-Arun central incised zone along the entire length of the valley. To the west the feature is not well constrained as the overlying

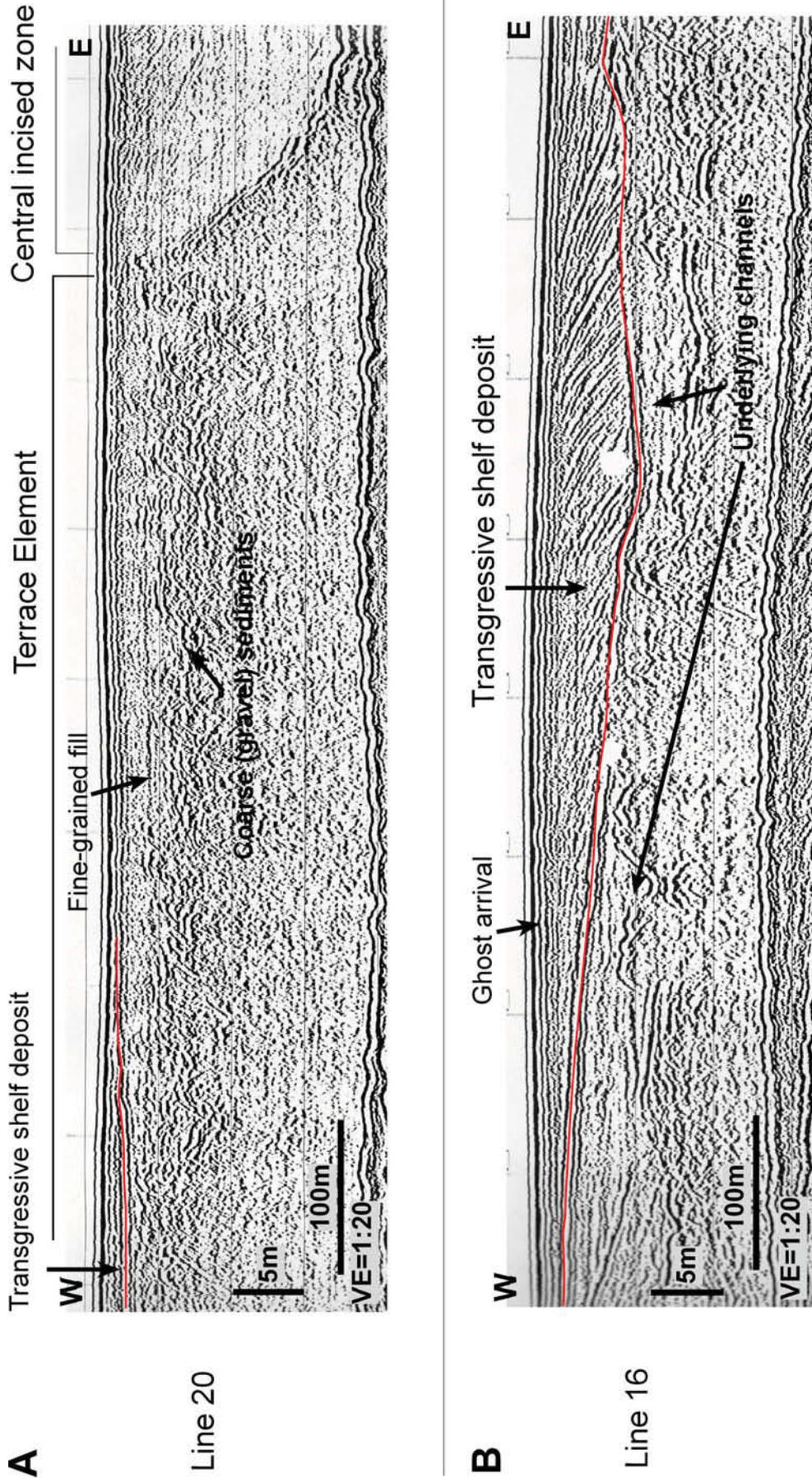


Figure 5.19 Seismic profiles from the 2000 survey to illustrate architectural elements identified in the seismic record. A. A terrace flanks the west of the central incised zone. The transgressive shelf deposit is present to the west and the main valley is present to the east of the profile. B. Transgressive shelf deposit, the base of which is marked by the red line. Note the truncation of the underlying channel. See Fig. 5.11 for the location of the seismic lines.

transgressive deposit truncates it, but to the east it extends away from the channel for hundreds of meters. Truncation of this element by reflectors in the central zone suggests downcutting of the system subsequent to its deposition. This geometry indicates the feature is a terrace of the main valley. The deposition of coarser sediments at the base indicates high-energy environments. Fine-grained deposition above these and the presence of organic material is interpreted to represent temperate phases of the systems evolution and may be associated with estuarine deposition during transgression.

5.6.3.6 *Transgressive Shelf Deposit*

The region has been planed by marine erosion, which has resulted in an extensive marine veneer that is generally up to 0.5 m thick. The deposit is typified by shelly, sandy, coarse gravel sediment, evident at the top of all cores. In the seismic profile the properties of the marine veneer is generally masked by interference in the record, as a result of what is possibly a ghost arrival (Fig. 5.19). However, beneath the veneer in places is a thick transgressive shelf deposit that corresponds to facies VI. The transgressive deposit reaches a maximum thickness of 7 m and extends for hundreds of metres and up to two kilometres. The lower bounding surface truncates the underlying reflectors and forms a sharp, planar erosional surface (transgressive ravinement surface) that forms the base of a very broad U-shaped basin (Fig. 5.19). The upper bounding surface appears in places to be conformable with the overlying veneer, but interference with the signal makes further interpretation difficult. The internal reflectors exhibit alternating moderate to high-amplitude dipping reflectors that are continuous and well defined. The reflectors dip in a landward (northeast) direction, becoming steeper towards the centre of the deposit and are gentler, almost horizontal, at the margins. The deposit is interpreted as having formed by the reworking of coarse sediments on the shelf. This resulted from erosional shoreface retreat during the last transgressive event in the area.

5.6.4 **Stratigraphic Architecture of the Valley Fill**

5.6.4.1 *Stratigraphic Correlation Scheme*

Seismic reflectors have been traced through the 2000 survey grid within the main valley of the palaeo-Arun River. Where possible, correlations have been checked at each trackline intersection to ensure precision. The mapped surfaces represent significant erosion events where a change in the depositional regime can be recognised. The complex and changeable nature of fluvial system means that it is possible to identify many more surfaces within each seismic profile, each of which records a cut and fill event (Fig. 5.20). However, these are minor internal sedimentary erosion surfaces and it is difficult to trace these from one profile to the next. These surfaces represent channel migration on a smaller timescale. The principle reflectors that have been mapped are termed RI-V from oldest to youngest (Fig. 5.21 and Figs 5.21A-D) and each of these major reflectors separates the fill into five depositional sequences (S1-5), which are illustrated in plan view in Figure 5.22 and are discussed in the following sections.

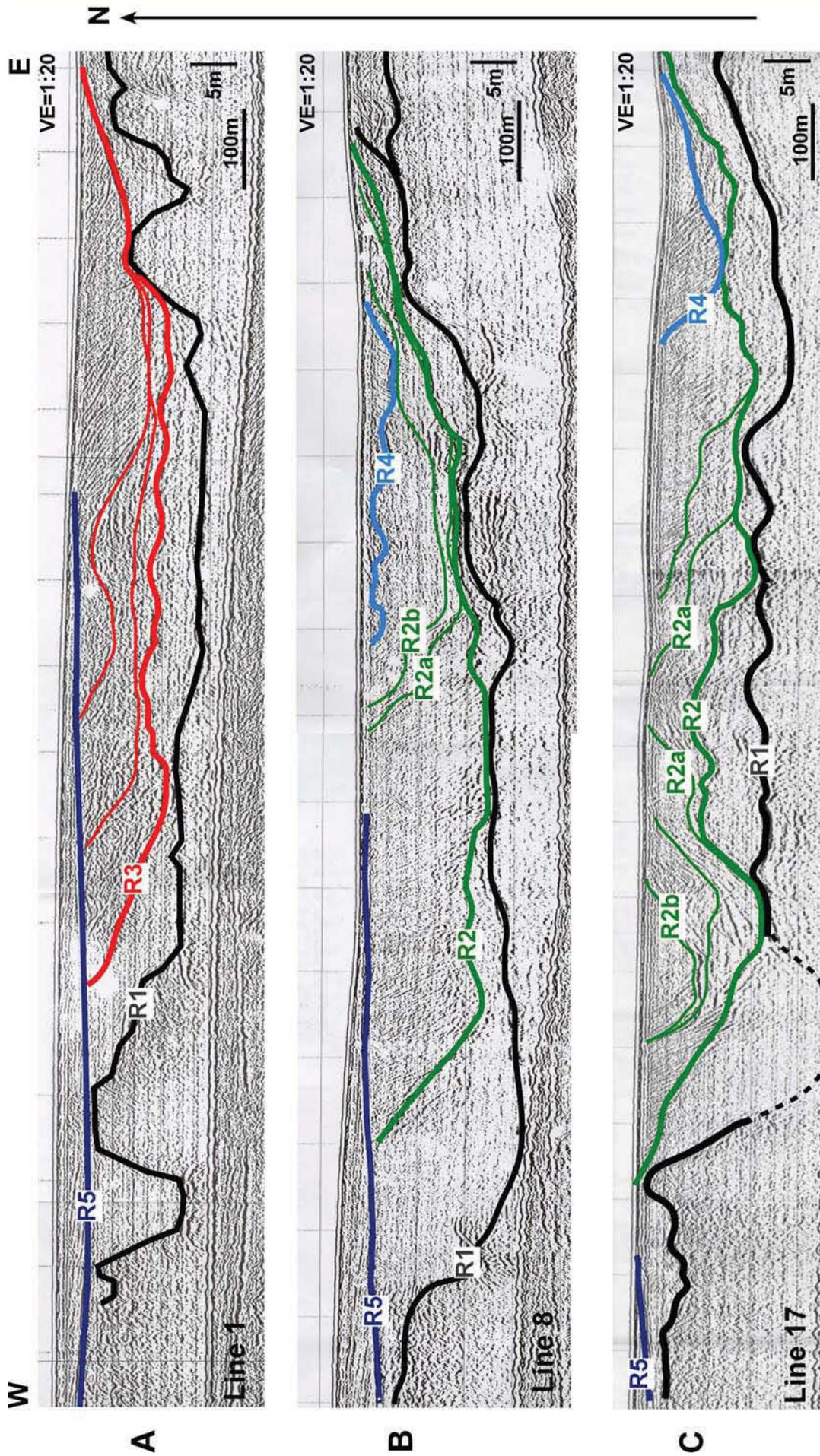


Figure 5.20 2000 seismic profiles to illustrate the seismic appearance of the internal stratigraphy that has been correlated through the middle section. Fig. 5.11 for location of seismic lines.

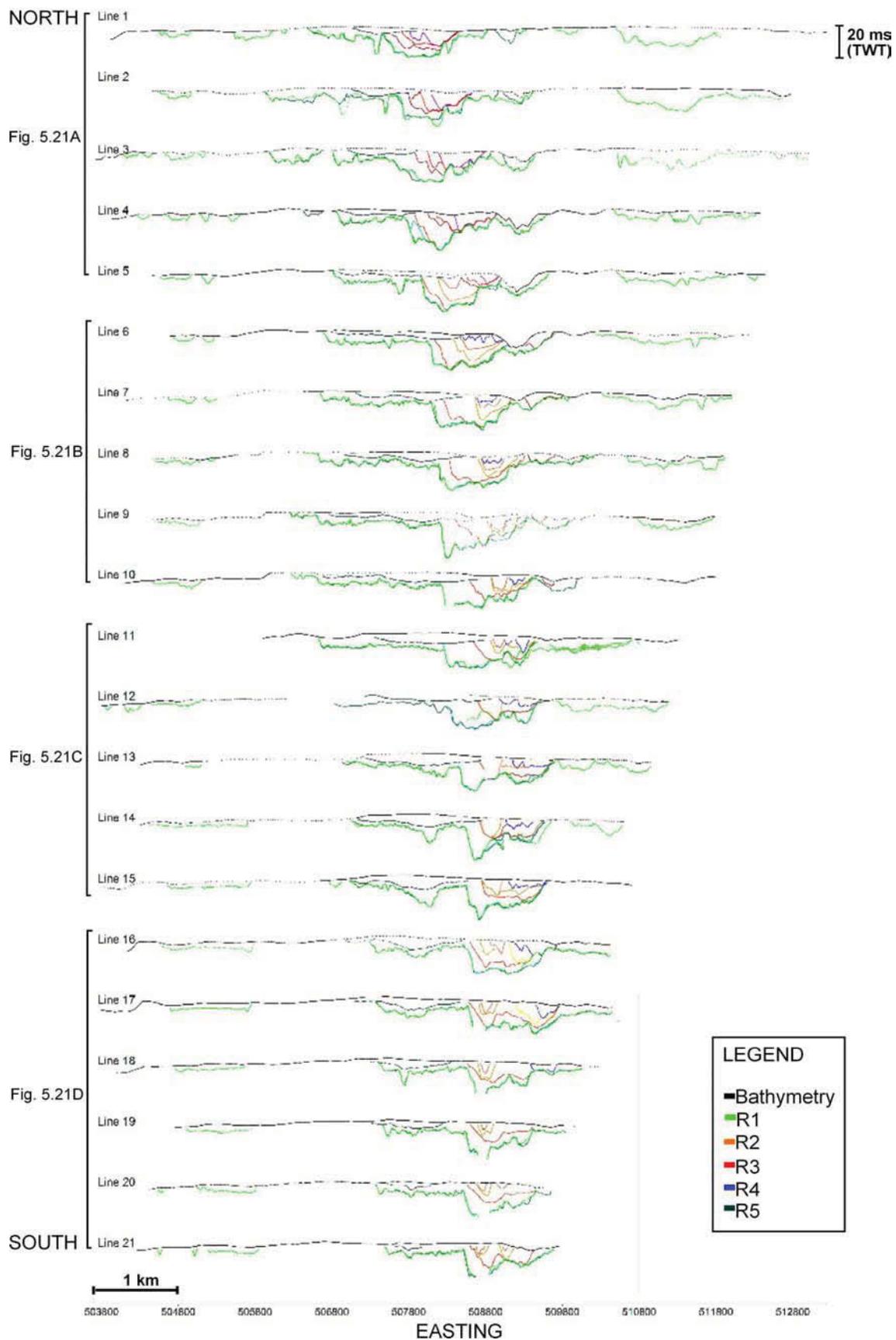


Figure 5.21 Cross-sectional view of interpreted 2000 seismic profiles illustrating the surfaces that have been traced through the survey. The sections are broken up into 5 line blocks so that they can be viewed in detail (Figs 5.21A-5.21D)

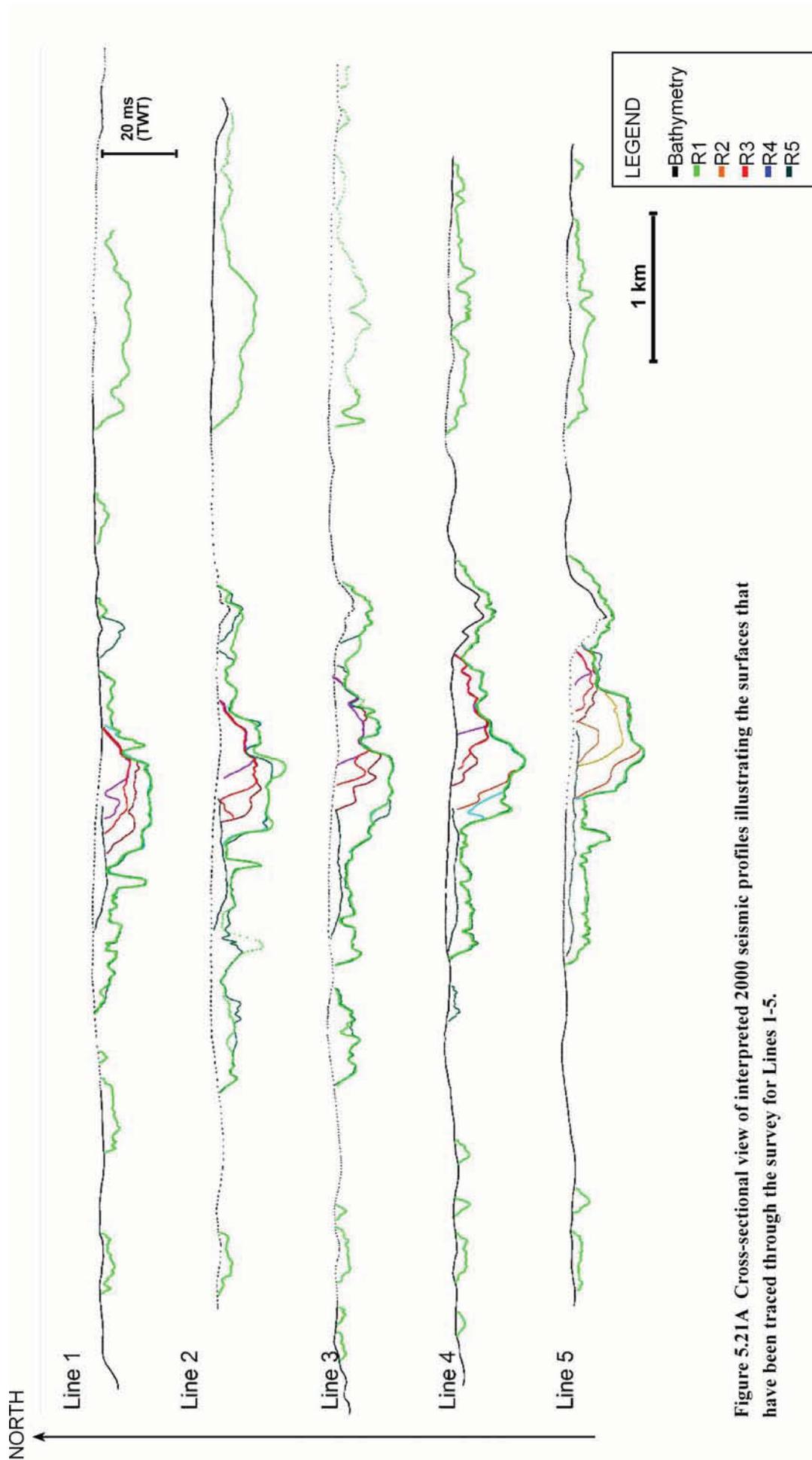


Figure 5.21A Cross-sectional view of interpreted 2000 seismic profiles illustrating the surfaces that have been traced through the survey for Lines 1-5.

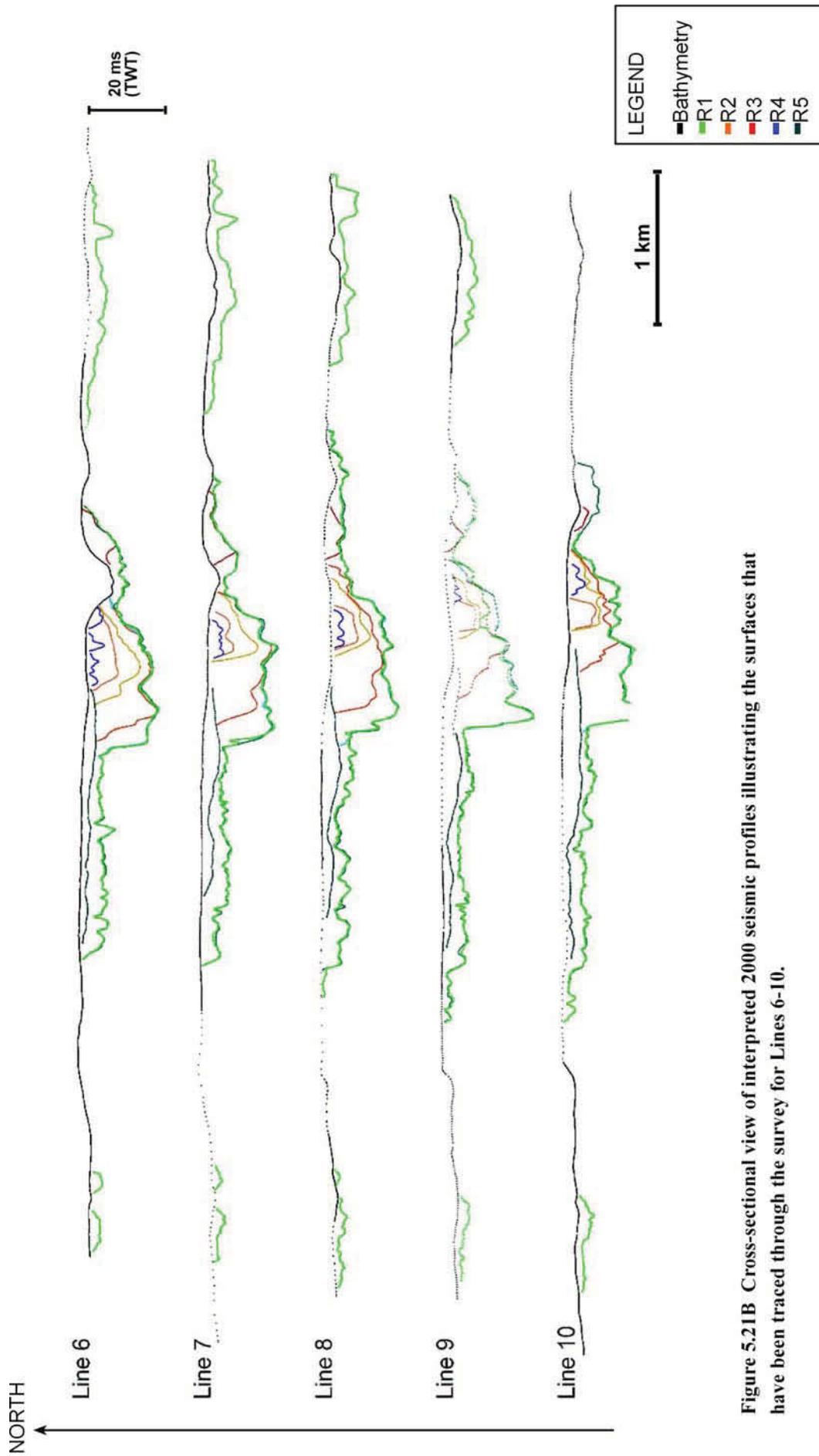


Figure 5.21B Cross-sectional view of interpreted 2000 seismic profiles illustrating the surfaces that have been traced through the survey for Lines 6-10.

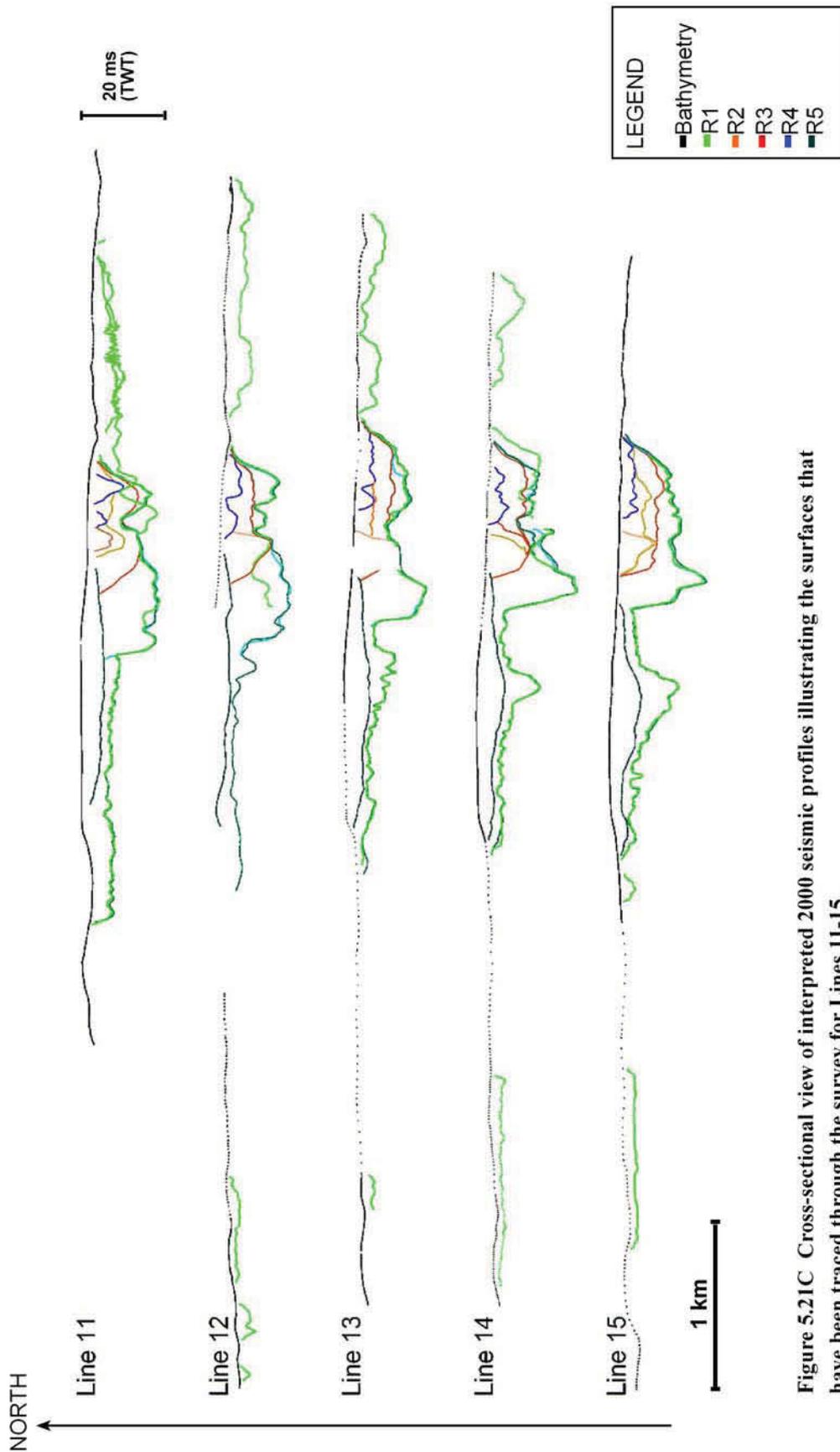


Figure 5.21C Cross-sectional view of interpreted 2000 seismic profiles illustrating the surfaces that have been traced through the survey for Lines 11-15.

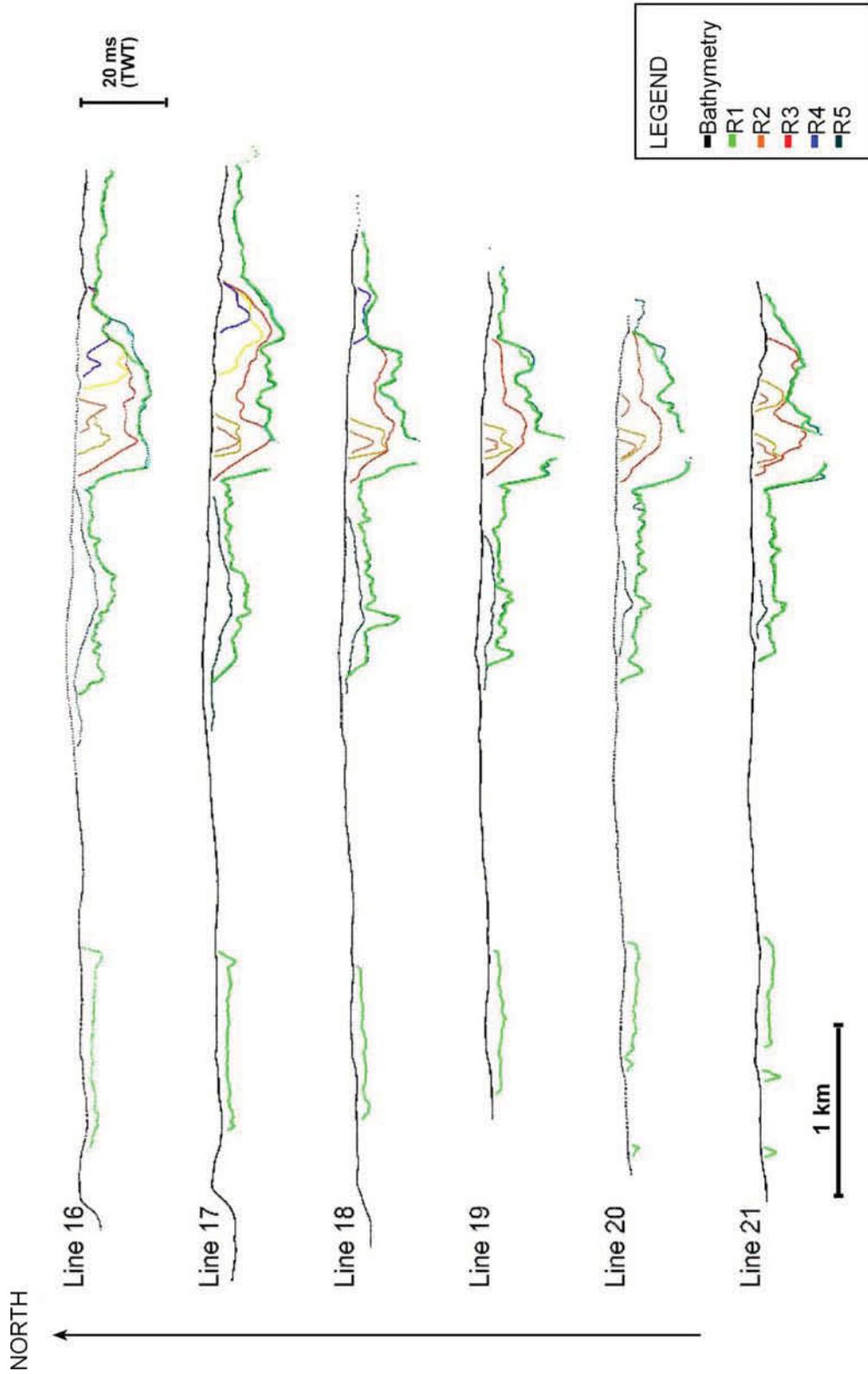


Figure 5.21D Cross-sectional view of interpreted 2000 seismic profiles illustrating the surfaces that have been traced through the survey for Lines 16-21.

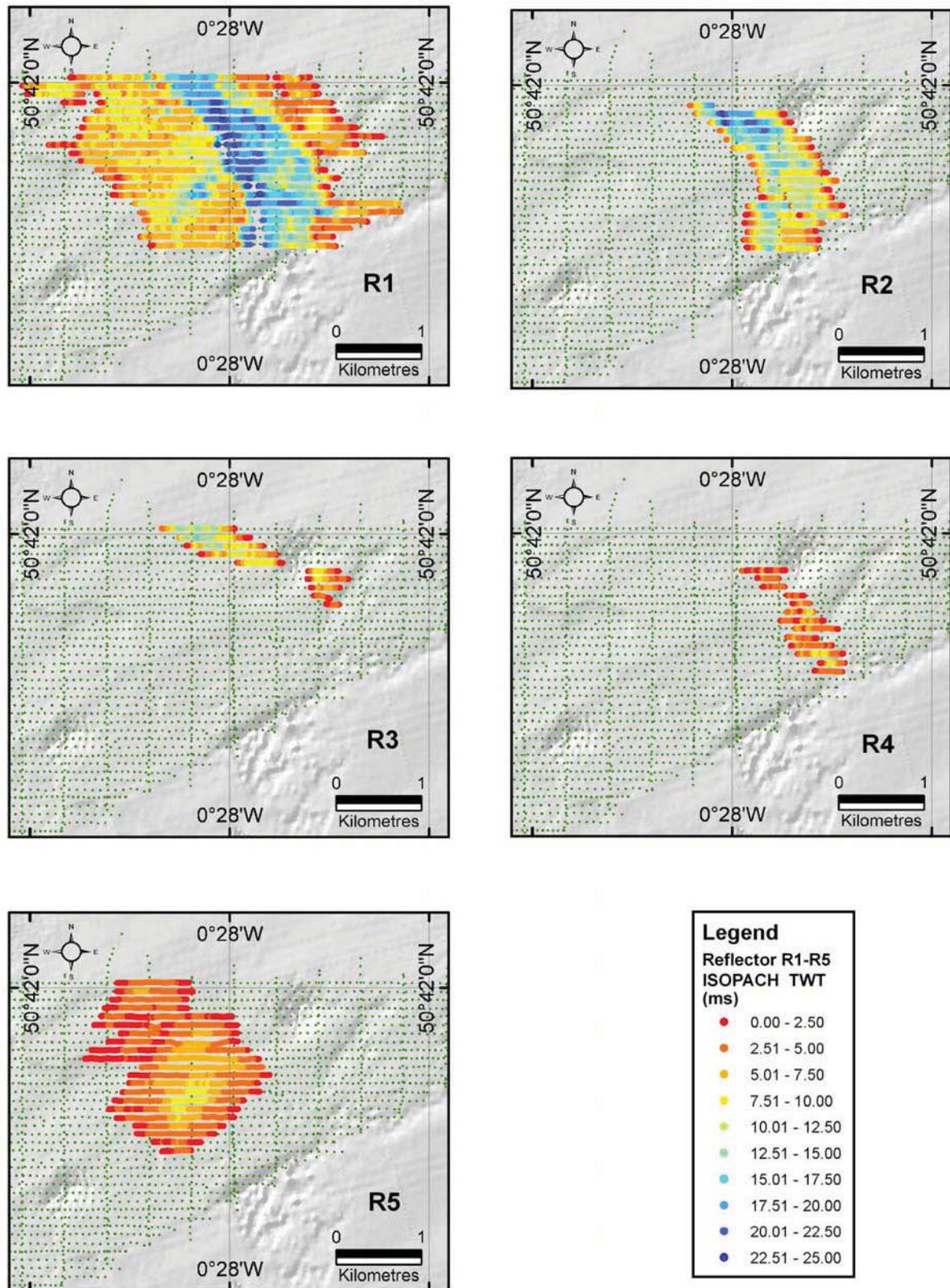


Figure 5.22 Isopach thickness for surfaces R1-R5, from surface to sea floor in TWT (ms). The survey lines are shown behind to indicate the coverage of the data. Note for R5 only the thick shelf deposit has been contoured to show the extent of this, the rest of the surface covers the sea floor in a thin (< 1m veneer).

The correlation of stratigraphic horizons within the fill sequence in the 2000 seismic data was based on the recognition of key erosion events that could be traced from one profile to another. The seismic appearance of those is presented in Figure 5.20. Line 1 (Fig. 5.20A) illustrates the seismic character of the main palaeo-Arun valley in the north of the 2000 seismic survey. The truncation of the western margin by the reflector R5 obscures the relationship between the main valley and a deep channel to the west. However, it is mapped as the same basal erosion surface R1 because the depth of incision is on the same scale. The fill sequence (S3) is dominated by a moderate-high amplitude facies with varying internal characteristics from parallel, continuous and oblique to irregular and chaotic in appearance. These facies are indicative of high-energy depositional environments with a complex cut and fill history. The initiation of this high-energy system above low-amplitude reflectors marks the base of the seismic unit S3.

Line 8 (Fig. 5.20B) illustrates the seismic character of the fill sequence as the system moves to the south. The unit S3 has migrated to the east and the unit S2 dominates the stratigraphy in the central valley. The fill sequence is characterised by moderate-amplitude, steeply dipping reflectors indicative of lateral accretion that merge with low-amplitude, horizontal reflectors. The basal erosion surface of R1 presents a similar geometry with a steep westerly margin that grades to a gentler slope in the east. Reflector R5 also truncates the western margin. The appearance of a near terminal erosion event is evident at the top of the section in the form of reflector R4. The unit is not well developed but the high-amplitude reflectors above the low-amplitude fill of unit S2 suggest a change in depositional regime from low to high energy.

In the southern extent of the 2000 seismic survey Line 17 (Fig. 5.20C) illustrates the development of seismic unit S2 and S4. The basal erosion surface R1 maintains its geometry of a steeper western margin. In places the basal surface appears to extend beneath the sea floor multiple and hence it is difficult to determine the true depth of incision. The stratigraphy above this surface has become more complex. The cross-sectional geometry of unit S2 indicates that the channel has branched to form a braid at this point. A central gravel island has been preserved with filling of the channel on either side. Aggradation by lateral accretion indicated by oblique reflectors still dominates the sequence with a low-amplitude signature typical of fine-grained fill representing final fill phases. The truncation of the western margin by reflector R5 has diminished in the south and it is possible to see the stratigraphic relationship between the central valley and the flanking margin. The sequence within the central valley truncates that of the western margin producing a geometry that is indicative of a fluvial terrace.

5.6.4.2 *Reflector R1*

Reflector R1 marks the base of the valley and the unconformable contact with the underlying Tertiary bedrock (Fig. 5.21). This reflector is mapped over the region to reconstruct the morphology of the palaeovalley system in the study area. Figure 5.12 illustrates the isopach thickness for the surface R1 over the 2000 survey. An isopach thickness and structure contour to base of valley grid was also

produced for reflector R1 (Fig. 5.13). The palaeovalley floor represents an erosive surface that has incised into the regional bedrock of Tertiary sandstones and limestones. The surface indicates that the basal erosion surface for the main valley has a broad U-shaped geometry, with a central incised zone flanked by shallow margins that extend for hundreds of metres (Fig. 5.22). This gives the appearance of a terrace relationship. The surface is characterised by high-amplitude reflectors that truncate the dipping reflectors of the bedrock. Reflector R1 is also taken to include a basal unit, which unconformably overlies the bedrock throughout the palaeo-Arun Valley. The unit extends across the base of the valley as semi-continuous sheets up to 3 m thick. In areas where topography is present at the surface the unit can thicken to fill depressions. The unit displays parallel and continuous, high-amplitude reflectors as its bounding surfaces, the lower of which is undulating and mimics the underlying topography. The internal reflectors typically exhibit a high-amplitude, parallel to chaotic character that exhibits partial lateral continuity. The high-amplitude nature of the reflections is suggestive of a gravel and coarse sand sediment. This and the occurrence at the base of the valley derive an interpretation of a basal lag unit above the incision surface deposited in a high-energy environment. Reflectors of the seismic unit S1 overlie the upper surface of the reflector R1.

5.6.4.3 *Seismic unit S1*

Seismic unit S1 occurs as an interval of low-amplitude reflectors above the basal lag deposit of R1. The basal surface is characterised by the undulating surface of the reflector R1 and younger overlying units truncate the upper surface. Unit S1 is distinguished internally by a low ambient noise that masks any internal stratigraphy, but in some profiles it is possible to resolve a weak seismic record of low-amplitude, flat to slightly wavy, continuous and parallel reflections. The original extent of this unit is poorly constrained due to its extensive erosion. However, it is typically present on the western margin of the central incised valley as a thick (10-15 m) unit that thins to the east due to erosion and becomes a thin (< 1m) basal veneer above the basal lag of the R1 upper surface (Fig. 5.21). The low-amplitude reflectivity suggests that the sequence consists of homogeneous, fine-grained sediment that drapes the surface of R1.

5.6.4.4 *Reflector R2*

Reflector R2 marks the next erosion surface evident above an interval of low-amplitude reflections (S1), which lie over the basal reflector R1 and its associated basal gravel lag (Fig. 5.21). The reflector R2 is an erosive surface within the fill of the main channel and its extent is limited by R1. The surface cannot be correlated in the very north of the valley where reflector R3 incises directly into sequence S1. The surface of R1 is typically high-amplitude suggestive of a coarse (gravel) basal sediment. The internal reflectors of the overlying sequence (S2) appear as oblique reflections that onlap onto R2 and are truncated by the sea floor or R3 in the north and R4 in the south. The oblique reflections indicate a laterally accreting facies and as such the surface R2 represents the erosion and deposition that is the lateral accretion of this unit. This reflector (R2) extends along the western margin of the main

channel, where it has a steep flank. The overall geometry of the surface is a relatively flat, undulating base with a steep margin (up to 6°) on the west and a gentler sloping margin (2-3°) to the east.

5.6.4.5 *Seismic unit S2*

The overlying sequence S2 mirrors this shape with eastward lateral accretion from the west merging into a series of stacked horizontal reflectors that represent vertical aggradation and fine-grained channel fill. The sequence forms an elongate channel (Fig. 5.22) that thickens to the west. No significant braiding or sinuosity is evident in the channel fill. Two internal reflectors, R2a and R2b, separate the internal stratigraphy based on this change in the energy of depositional regime and the associated surfaces. Sequence S2 is dominated by an extensive lateral accretion architecture that accumulates sand and gravel sediments, aggrading to the northeast to a width of several hundred metres. Reflector R2a represents the end of this phase and the position where fill by vertical aggradation dominates. Within the weaker reflections that define the fine-grained infilling are higher-amplitude reflections that indicate intervals of coarser sediment and may mark condensed surfaces. This suggests erosion events occurred during the filling sequence. They are possibly associated with the deposition of the lateral bedding sequence where a coarser lag may have accumulated in the adjacent channel. The final erosion event is mapped as reflector R2b and is concordant with the sequence above and below and marked by a high-amplitude reflector. The final stage of sequence S2 represents continued aggradation of fine-grained sediments.

5.6.4.6 *Reflector R3*

In the north of the main palaeo-valley reflector R3 truncates internal reflectors of sequence S1 and as the sequence (S3) it bounds extends to the south, it incises into the sequence S2 (Fig. 5.21). The R3 reflector becomes difficult to trace further to the south as the channel it represents migrates to the west into an area that has historically been dredged. The effect here is two-fold; one, the removal of sediment changes the geometry of the unit and two, disruption of the smooth sea floor by dredging results in diffractions in the seismic data impeding interpretation. Nevertheless the surface has been mapped across the dredged zone but appears to dissipate to the south or may merge into another channel to the east. The reflector R3 is characterised by a planar, undulating, high-amplitude reflector. The surface has a broad flat symmetrical geometry extending across the width of the main palaeo-valley in the north.

5.6.4.7 *Seismic unit S3*

The internal reflectors of seismic unit S3 generally onlap the lower bounding surface but can also be concordant with it. The fill of sequence S3 is typified by high-amplitude reflections that are either steeply dipping indicating lateral accretion or have an irregular, chaotic appearance indicative of a gravel bank feature. Within the sequence there are many cut and fill events representing the products of former channel migration and abandonment. From plan view Figure 5.22 shows that the fill

sequence has an elongate channel form and there is evidence for side chute channels. The internal architecture suggests the seismic unit represents a high-energy system where coarse gravels are mobile. The lack of any evidence for fine-grained aggradation indicates that these must be transported and deposited further downstream. As with seismic unit S2 the internal stratigraphy of the sequence can be divided (reflector S3a and S3b) and show the incision of two younger channels. This however has not been mapped south of the dredged zone.

5.6.4.8 Reflector R4

Reflector R4 marks the base of a channel that incises into sequence S2 (Fig. 5.21). The reflector has not been traced to the northern or southern extent of the palaeo-valley. The inability to trace the horizon to the south reflects again the impact of dredging on the seismic data, which creates diffractions making interpretation difficult. However, where the reflector can be mapped it is characterised by a moderate-amplitude, undulating surface that is onlapped by the overlying fill sequence. The geometry is generally a broad U-shaped channel base.

5.6.4.9 Seismic unit S4

The internal reflectors of the seismic unit S4 are of varying continuation and moderate-amplitude. They are either dipping and onlap onto R4, showing aggradation through lateral accretion and channel migration, or are concordant with the basal reflector, aggrading vertically. The fill of the seismic unit (Fig 5.22) indicates a sinuous channel with evidence for a thalweg meander.

5.6.4.10 Reflector R5

The youngest mapped reflector R5 truncates all other sequences (Fig. 5.21). The surface is a high-amplitude, reflector that generally parallels the sea floor. This reflector represents a planar marine erosion surface upon which a veneer of reworked sediment is deposited. Across the western margin of the palaeo-valley this transgressive surface has a significant relief and is marked by a high-amplitude undulating reflector. The reflector marks a significant surface of erosion upon which coarse gravels and sands occur. It is interpreted as a transgressive ravinement surface.

5.6.4.11 Seismic unit S5

The sequence S5 that lies above reflector R5 is characterised by alternating moderate to high reflectivity dipping internal reflectors that display onlap. The sequence forms a thick package, which has a broadly lobate form (Figs 5.21 and 5.22), of northeast aggrading coarse sediment, deposited in a high-energy environment. It also appears that there are three distinct packages of deposition, which may reflect fluctuations in sea level during its deposition. The position of the seismic unit at the top of the fill stratigraphy, its broad depositional range over the entire region and landward progradation suggest that this thick sediment body represents a transgressive shelf body.

5.6.4.12 Reflector at Base of Valley Margins

Adjacent to the central incised zone of the main Arun palaeo-valley are laterally extensive shallow margins that form a terrace geometry with the central valley (Fig. 5.13). To the west much of the stratigraphy has been removed by erosion due to the transgressive deposit. This makes correlating the stratigraphy with the main valley difficult. To the east the flat channel has an internal stratigraphy of coarse basal gravels overlain by a fine-grained fill. Cores through this indicate the presence of organic matter, which fits with a terrace that has formed adjacent to a fluvial channel. The internal stratigraphy has not been mapped, as there is no significant continuous surface (besides the base) that can be traced along the length of the valley. The incision of the terrace is interpreted as occurring prior to the extensive development of the basal erosion surface R1 in the central incised zone and possibly represents an early phase of incision in the evolution of the palaeo-Arun fluvial system.

5.6.5 Longitudinal v Transverse Facies Distribution

The mapping of surfaces down the valley using the seismic profiles shows a strong dominance in the fluvial architecture for sediment deposition to be preserved as extensive surfaces of lateral accretion. These lateral accretion units truncate other sequences and are merged with fine-grained channel fill facies as the aggradation evolves. The spacing of N-S seismic profiles, which illustrate a longitudinal-section of the valley, is not as close as that of the E-W lines. However, these profiles (Fig. 5.23) illustrate that the same architectural elements are present as what is seen in the transverse-section (Fig. 5.20). The stratigraphy that is evident in the profiles is very much a function of where the survey lines are positioned relative to the channel geometry. However, in the N-S profiles it is evident that the same architectural element is spatially extensive, which suggests that the channel form in any one position is particularly stable. Furthermore, this indicates that the valley system is not dominated by a highly sinuous or meandering channel and that if braiding was widespread then it has not been preserved but rather eroded by subsequent events. The combination of longitudinal and transverse facies distribution indicates that the form of the main palaeo-Arun valley is an entrenched fluvial system that was dominated by a single channel where deposition has been preserved as lateral accretion.

The longitudinal profiles also illustrate the basal profile of the incision by the valley. It is evident that the floor of the valley is generally flat (Fig. 5.23). There is a subtle slope to the south beneath the central incised zone. The shallowing of the basal erosion surface to the north (Line 17, Fig. 5.23) is a function of the profile crossing the margin of the valley. Line 48 (Fig. 5.23) shows the relationship between the central incised zone, the transgressive shelf deposit and the terrace, which occurs along the western margin. In the centre of Line 48 channels within the central incised zone truncate the terrace to the south. At the southern end of this line a down cutting relationship can be seen again and reflects a bend in the valley that is evident in the planform geometry (Fig. 5.13). The transgressive

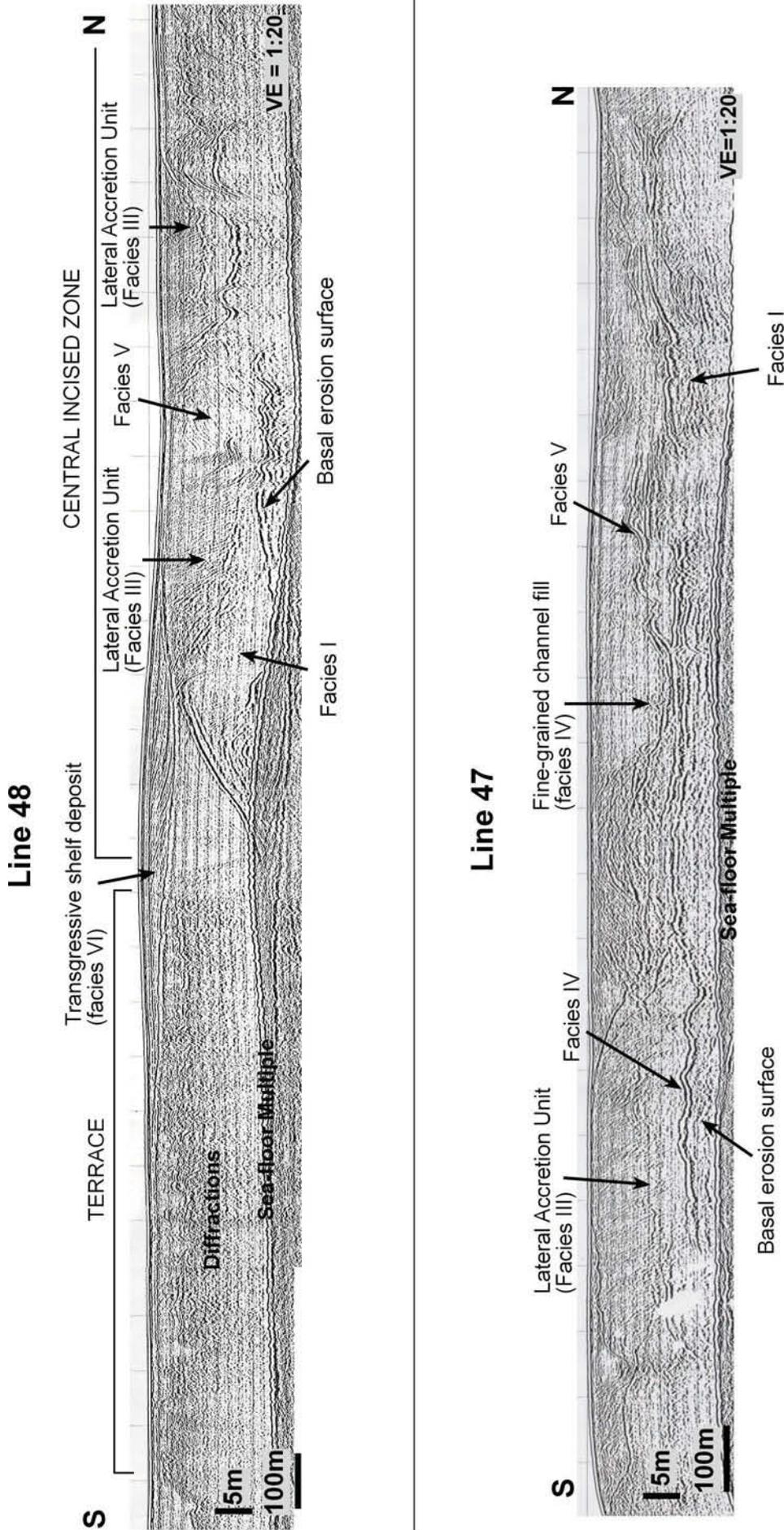


Figure 5.23 Seismic profiles from the 2000 survey orientated N-S to illustrate the longitudinal distribution of seismic facies and architectural elements. See Fig. 5.11 for the location of the profiles.

shelf deposit truncates all units and exhibits a broad, slightly concave ravine surface at its base. The internal reflectors dip to the north suggestive of landward aggradation.

5.7 SEISMIC STRATIGRAPHY OF THE LOWER PALAEO-ARUN SECTION

The stratigraphy for the lower palaeo-Arun has been interpreted from the 1990, 1991, 1995, 1998 and 1999 industry boomer seismic and associated vibrocores, in conjunction with the 2003 seismic survey (Fig. 5.24). As with the stratigraphy of the middle section, mapping of the basal erosion surface though the study area indicates that there is more than one valley (Figs 5.5. and 5.6). In the lower section another valley to the west drains from the middle section to the south. The focus of this section, and the study in general, is on the western valley that drains from the west valley of the middle section and represents the main palaeo-Arun valley (Fig. 5.25). The western valley also flows through the topographic valley imaged by multibeam swath bathymetry data and this allows integration of high-resolution bathymetry, gained from the multibeam, to be integrated with the sub-bottom data. The description and interpretation of the multibeam data is presented in detail in Chapter 3.

Mapping of the basal erosion surface in the lower section indicates that the main palaeo-Arun Valley flows to the south from the middle section and turns to the east continuing to drain through the topographic valley evident in the bathymetry (Fig. 5.25). The southern most extent of the study area shows the valley breaching through a prominent bedrock ridge and continuing to the south. Investigation of the subsurface profiles in the lower section indicates that the stratigraphic valley extends beyond the eastern margin of the topographic valley. However, the structure contour of the base of valley surface to the west indicates that the incision is not as substantial as the central valley (Fig. 5.25), but that the thickness of the sediment preserved is of a similar scale (Fig. 5.26). The stratigraphic valley extends to a width of 3 km. A prominent outcrop of Tertiary bedrock forms the western margin of the stratigraphic valley, whilst an incised terrace that is flanked by outcropping bedrock forms the eastern margin. The depth of incision reaches a maximum of 25 m beneath the sea floor, but this is equal to 45 m of incision in the areas beneath the topographic valley. Although the cross-sectional geometry of the topographic valley is a broad valley, with a flat floor and steep sides up to 20°, the geometry of the stratigraphic valley differs markedly. The western margin is steeply sided up to 20° whilst the eastern margin has a generally gentle slope of a few degrees (Fig. 5.8C). The floor of the valley is flat with a central incised channel that extends through the valley. Gridding of the basal erosional surface shows the extent of this central incised channel, which becomes more developed to the south (Fig. 5.27). The bathymetry of the lower section suggests that the valley narrow to the south prior to draining through the bedrock ridge and that a broad depression is apparent to the east. However, the sub-surface data illustrates that this is not the case and that a broad valley has been incised into the bedrock and subsequently filled with sediment across the width of this area (Fig 5.28 – Line 1). Furthermore, that a valley to the east drains into this area and this broad

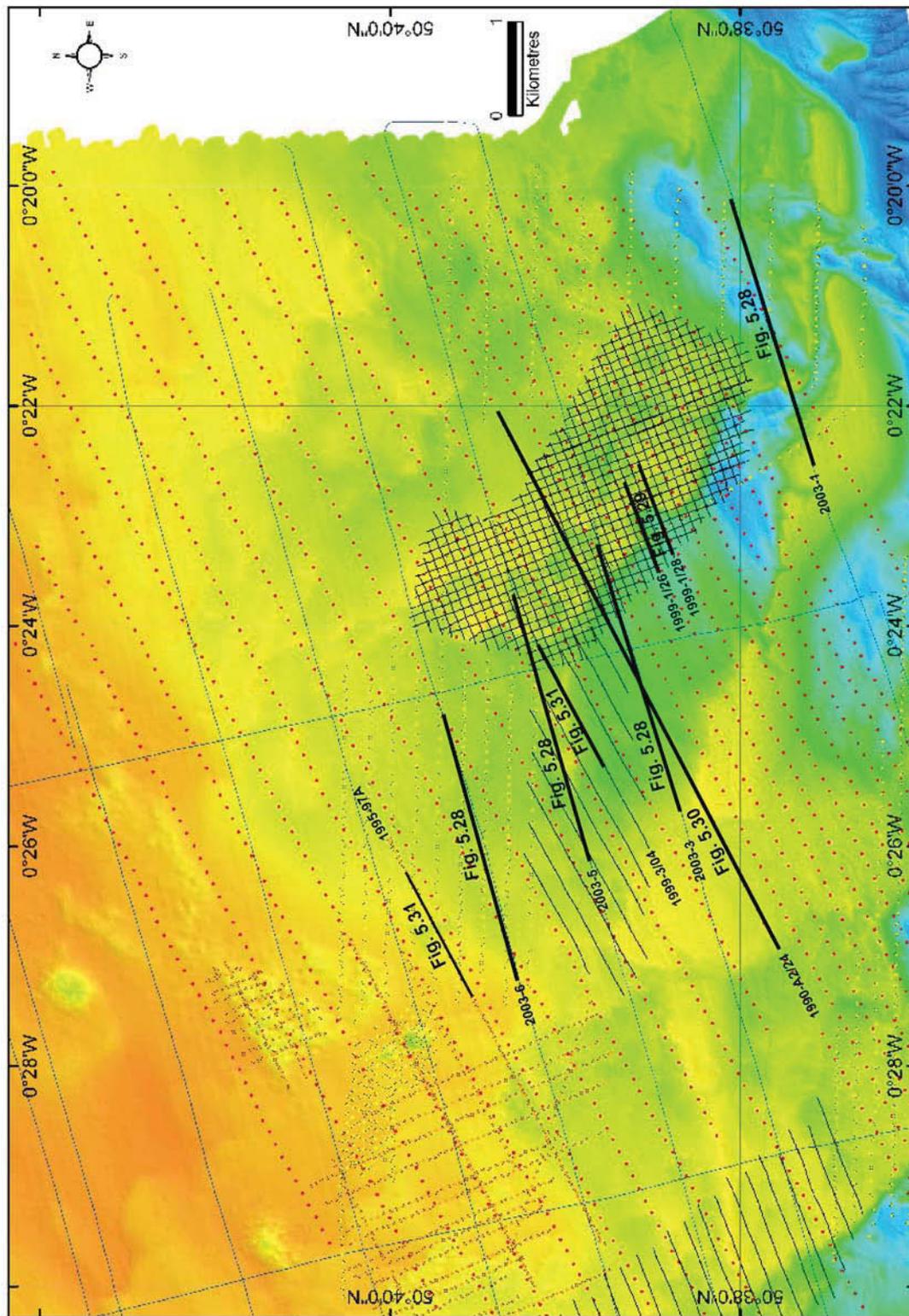


Figure 5.24 Location of seismic lines in the lower section of the palaeo-Arun Valley and the location of figures used to illustrate the stratigraphic relationships discussed in section 5.7. See Fig. 5.2 for the relative position of the area to the coastline.

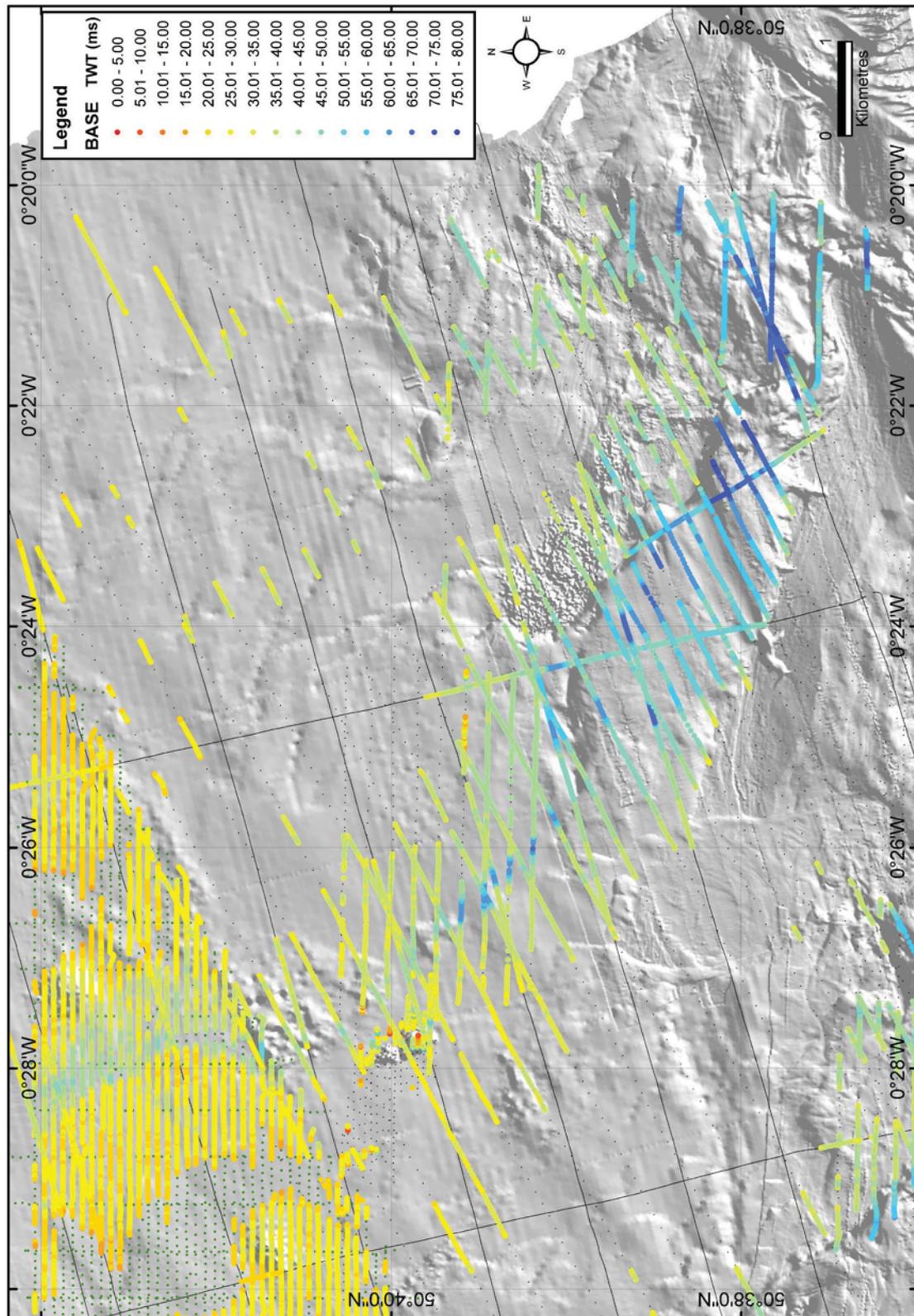


Figure 5.25 Structure contour (sea surface to base of valley in TWT) for the lower section of the palaeo-Arun Valley. The location of the survey lines are shown to indicate the coverage of the digitised 1990, 1998, 2000 and 2003 datasets. See Fig. 5.2 for the relative position of the area to the coastline.

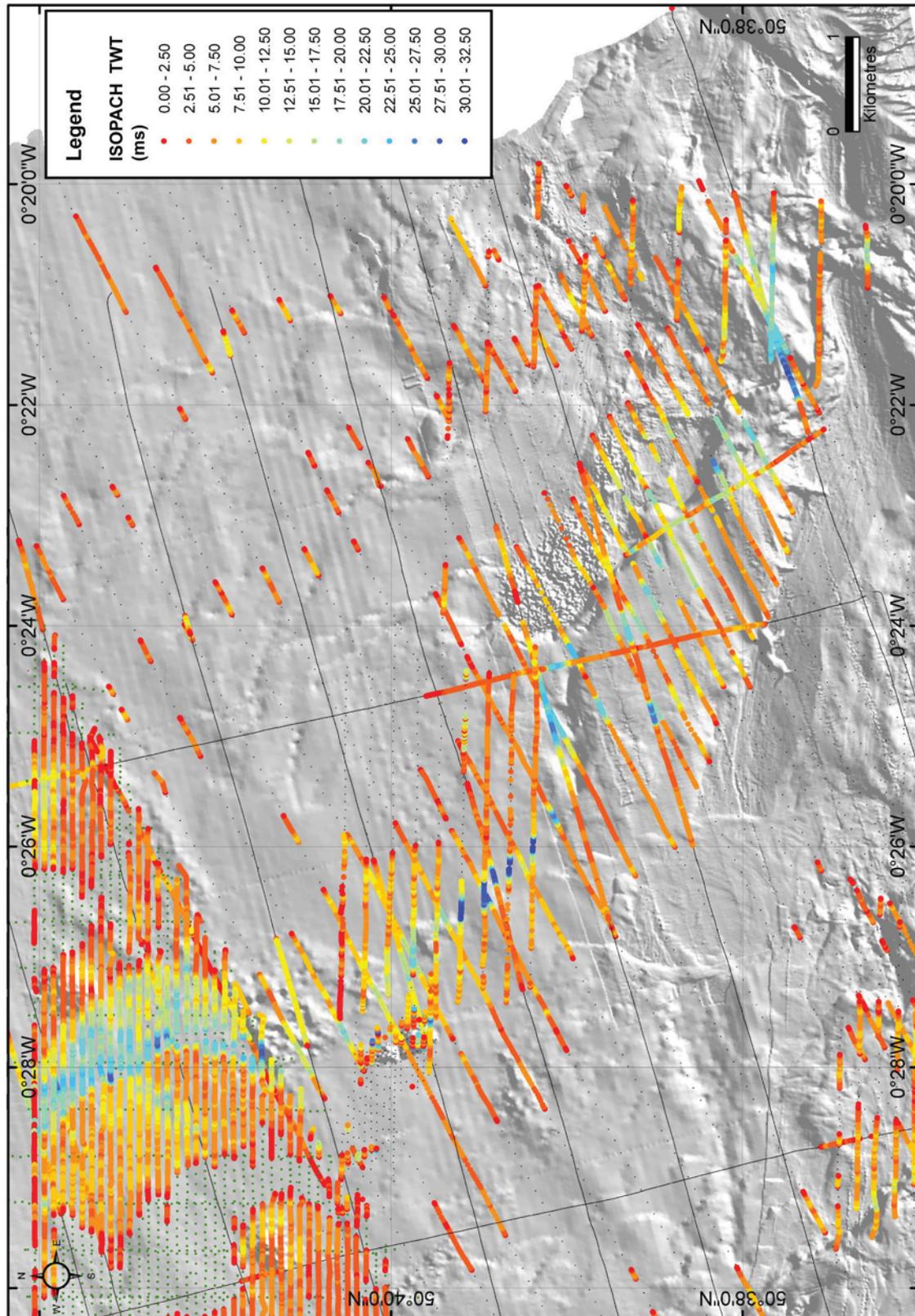


Figure 5.26 Isopach thickness (base of valley to sea floor in TWT) for the lower section of the palaeo-Arun Valley. The position of the survey lines are shown to indicate the coverage of the digitised 1990, 1998, 2000 and 2003 datasets. See Fig. 5.2 for the relative position of the area to the coastline.

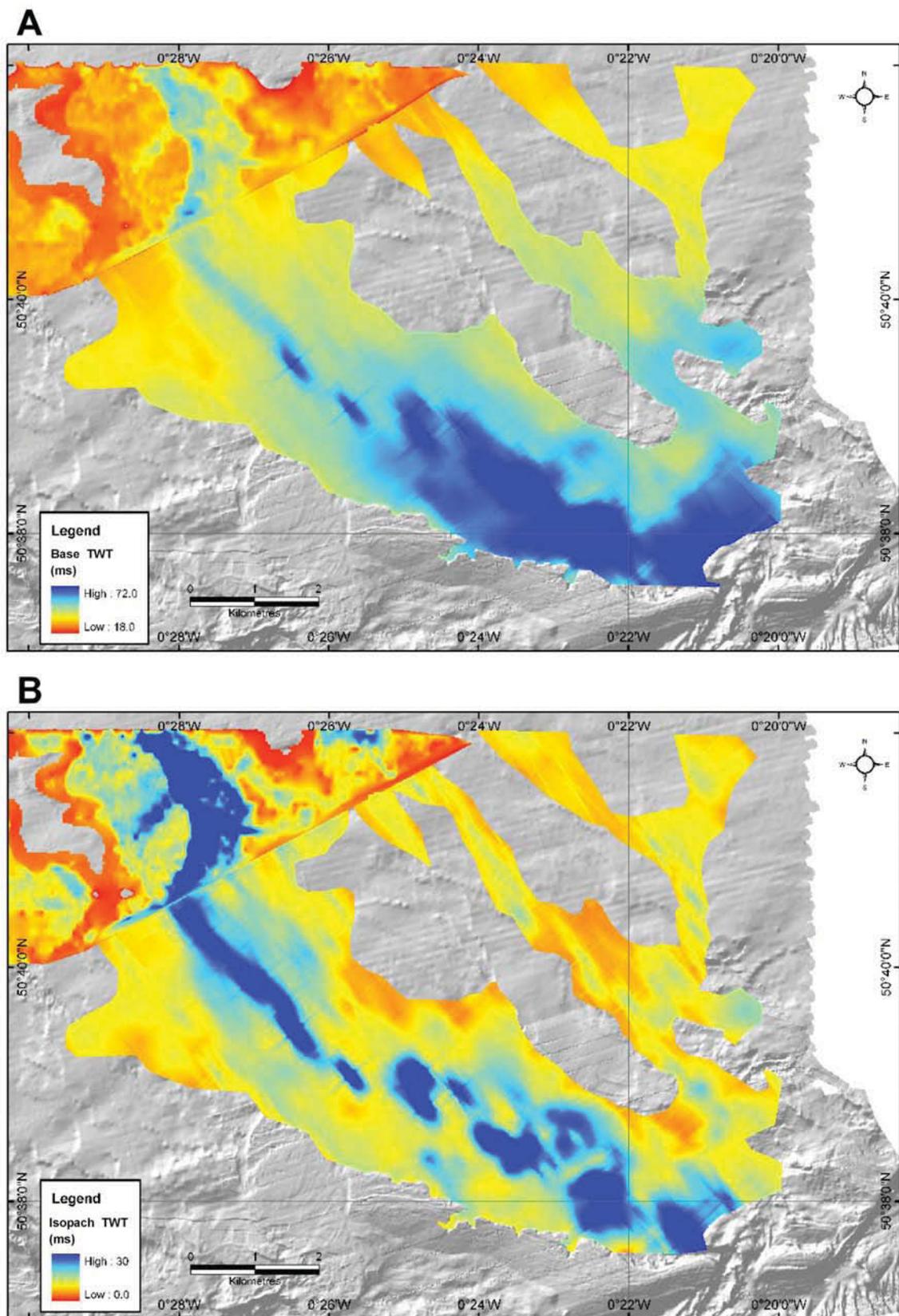


Figure 5.27 Structure contour (sea surface to base of valley - A) and isopach thickness (sea floor to base of valley - B) for the basal erosion surface of the lower palaeo-Arun valley. The data has been grid from the digitised seismic profiles, by the method described in Chapter 2. Lack of continuity in the central channel downstream is an artefact of the gridding due to limited spacing of the seismic lines.

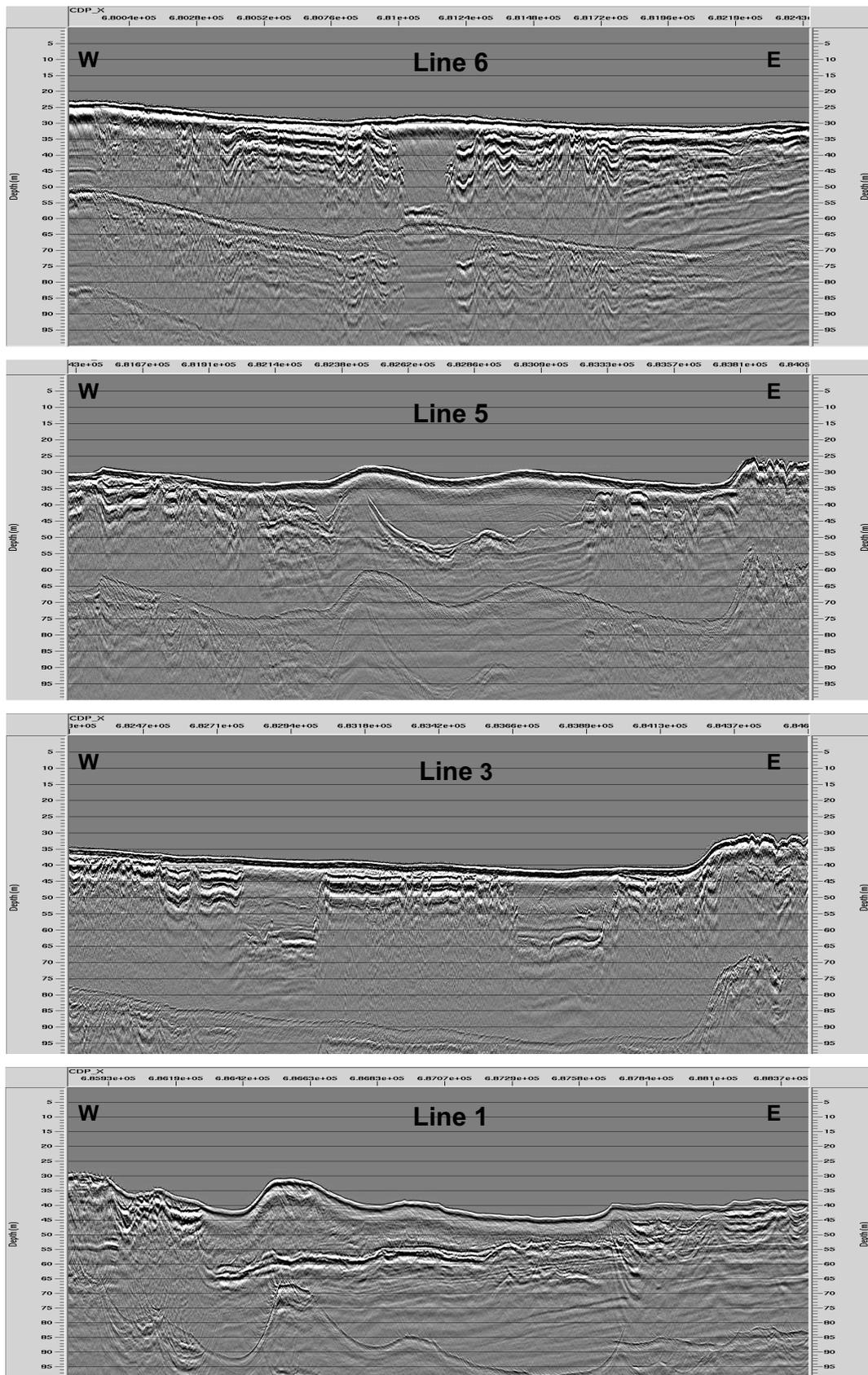


Figure 5.28 Showing lines 1,3,5,6 of the 2003 Boomer seismic survey, from the lower section of the palaeo-Arun Valley. All figures have been processed to stage 3 (see Fig. 4.43). Each line is 2400 m across, with a VE = 24. See Fig. 5.24 for the location of the seismic profiles.

depression forms a confluence connecting it with the main valley. In the lower section the position of the valley is strongly controlled by the bedrock structure. Line 1 of the 2003 seismic survey illustrates how the gently sloping eastern margin follows the dip of the underlying deformed bedrock (Fig 5.28). This is mirrored in the 1999 seismic survey across the eastern margin where it is evident that the base of valley erosion surface is controlled by the bedrock structure (Fig. 5.29A).

5.7.1 Seismic Units

The seismic stratigraphy has been divided into a number of seismic units that are defined based on their internal and external characteristics and mapped through the southern part of the valley. It should be noted that because different seismic datasets have been used there is variation in the relative amplitude of reflectors from one to the other. Here seven seismic units are defined and their spatial relationship is shown in Figure 5.30. Bellamy (1994) defined 10 seismic units for the southern area of this region. These are not directly comparable to those defined here, as a different suite of seismic data has been focused on.

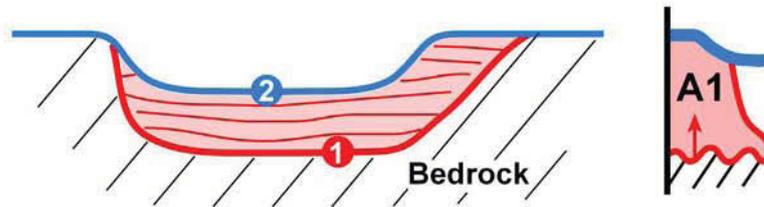
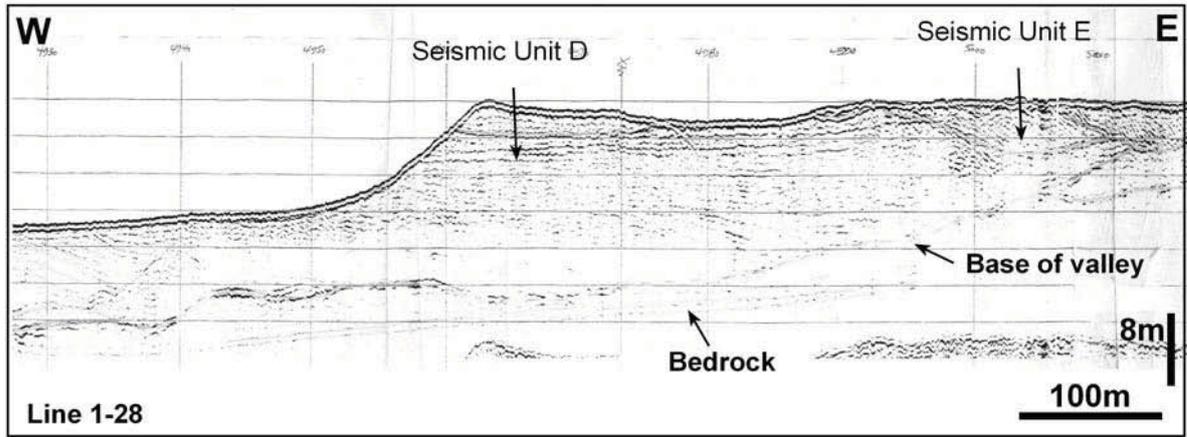
5.7.1.1 Unit A: Tertiary Bedrock

The basal Unit A is present over the entire area. For much of this it outcrops at the sea floor and where Unit A is not present at the sea floor it underlies all other units. The upper bounding surface is marked by the truncation of reflectors either by the overlying units or at the sea floor. The truncation of this unit by overlying units marks the basal erosion surface of the valley. The unit has no basal reflector and extends beyond the vertical extent of the seismic profiles. The internal reflectors are characterised by moderate to high amplitude, parallel, continuous and even reflections (Fig. 5.30). The reflections most commonly exhibit a regional dip to the south. High-amplitude reflectors are interpreted as representing zones of acoustic impedance and are believed to be associated with indurated lithologies (e.g. sandstones) within the bedrock geology. These high-amplitude reflectors are evident in the seismic profiles forming prominent topographic features at the sea floor. The stratigraphic position, extent and structural nature of Unit A determine the strata to be interpreted as representing the Tertiary and Cretaceous strata that form the bedrock in the region.

5.7.1.2 Unit B

Unit B unconformably overlies Unit A throughout the lower palaeo-Arun valley. The unit forms semi-continuous sheets up to 3 m thick across the base of the valley at all levels, but can thicken in areas where it fills topography of the base of valley floor. The unit displays high-amplitude, parallel and continuous reflectors at its upper and lower bounding surfaces. The lower surface is undulating and mimics the underlying topography. It marks the basal erosion surface of the valley that is reflector R1. The internal reflections exhibit a similar high-amplitude, parallel to chaotic reflection character, with partial lateral continuity. The high-amplitude seismic pattern indicates major acoustic impedance

A



B

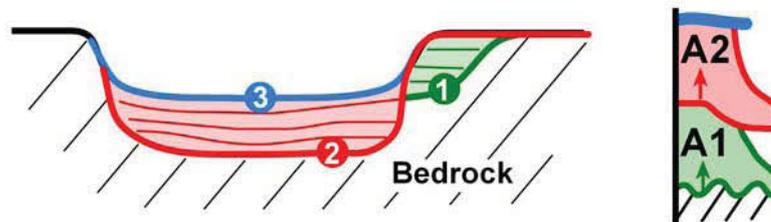
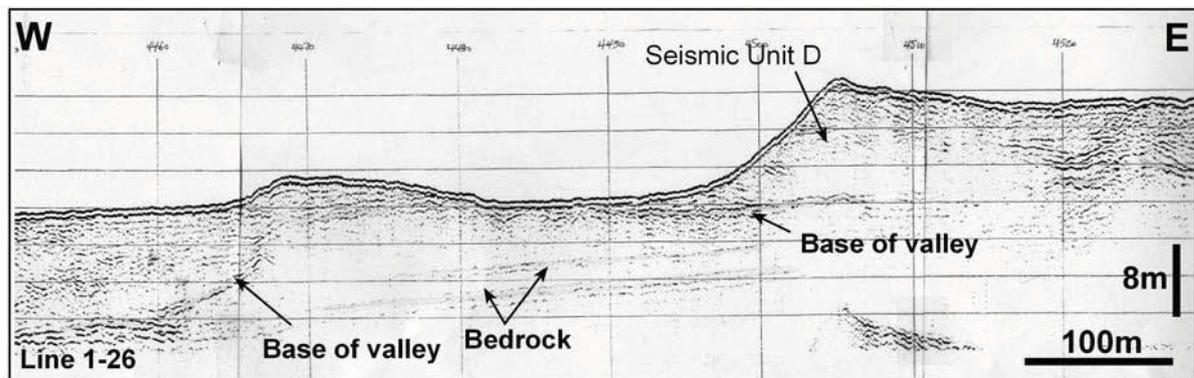


Figure 5.29 Seismic profiles across the eastern margin in the lower section of the palaeo-Arun Valley to illustrate the subsurface stratigraphy and formation of the terrace. The associated cartoons show the stratigraphic formation of the geometry based on the seismic profiles. A. The incision surface beneath the terrace is associated with that of the central valley and so the seismic suggests that the eastern margin is not a terrace. B. The seismic suggests that the eastern margin was formed by a subsequent downcutting event to form a fluvial terrace. See Fig. 5.24 for the location of the seismic lines.

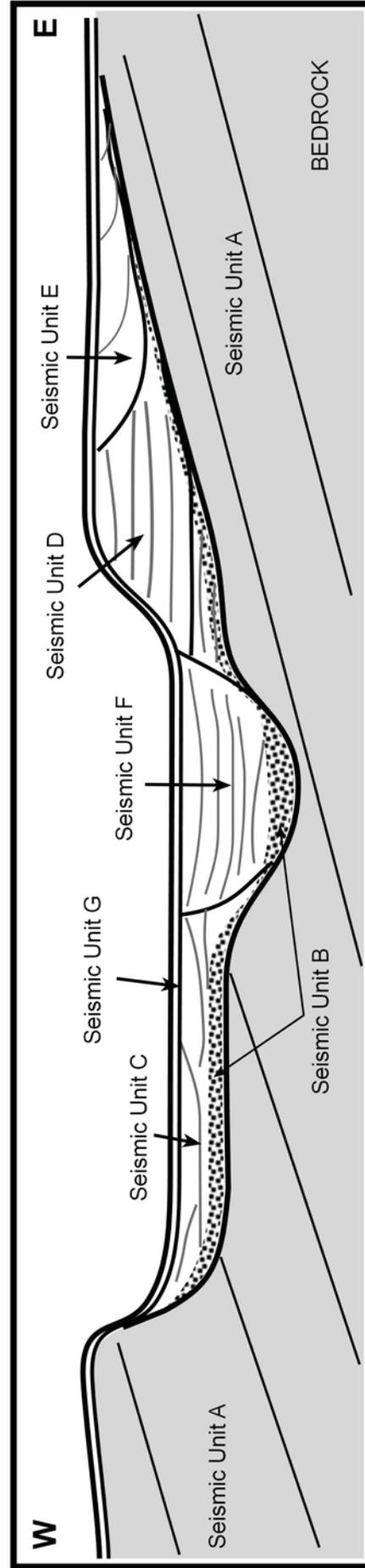
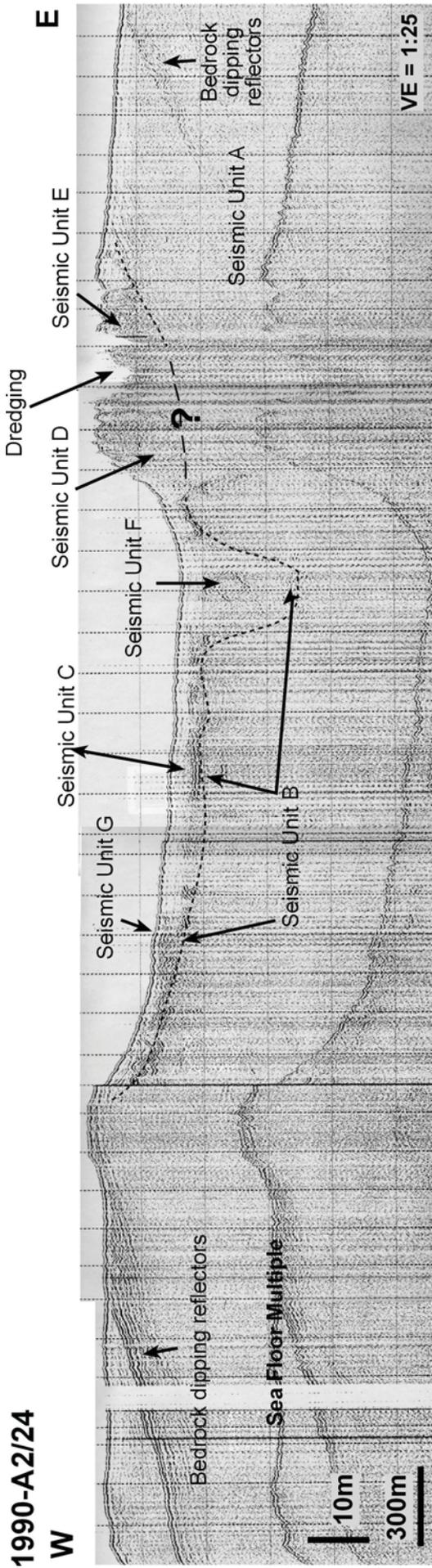


Figure 5.30 Stratigraphic relationship of the seismic units devised for the lower section of the palaeo-Arun Valley. This is shown as a schematic illustration and on a typical seismic profile across the valley. The dashed line on the 1990 seismic profile marks the basal erosion surface. See Fig. 5.24 for the location of the seismic profile.

suggestive of gravels and coarse sand sediments. Consequently, the unit at the base of the valley is interpreted as a fluvial deposit at the base of valley most probably representing a basal gravel lag.

5.7.1.3 Unit C

Unit C comprises the majority of the valley infill and represents a channel fill complex. The lower bounding reflector is a high-amplitude, continuous, and irregular surface, whereas the upper bounding surface is either truncated by Unit F or truncated at the sea floor by Unit G. The internal reflectors are highly variable, but generally they are low-amplitude, parallel to discontinuous, and flat to slightly wavy. They can also exhibit moderate to high-amplitude, parallel to chaotic, semi-continuous and steeply dipping characteristics. Aggrading reflectors downlap against the lower surface and also commonly merge with parallel, horizontally stacked reflectors that are concordant with the lower bounding surface. The dipping reflectors are interpreted as lateral accretion bedding surfaces, which indicates deposition at the margins of coarse-grained barforms. Whilst, the chaotic signature is thought to represent less organised deposition as a barform or island accreting coarse sediments. The unit is interpreted to represent a fluvial channel complex, where channel migration and abandonment has resulted in the deposition of coarse sediments by repeated cycles of cut and fill events. The extent of the fill changes when traced southwards downstream and although units show a similar seismic response it is difficult to determine if the fill in the south is the same age as the fill in the north. There is a substantial variation in the fill thickness from 5-15 m. Whether in the southern area this is due to erosion or non-deposition is uncertain.

5.7.1.4 Unit D

Unit D is present along the terrace that forms the western margin of the southern palaeo-Arun Valley (Fig. 5.1). A low to moderate-amplitude, irregular reflector above Unit A marks the lower bounding reflector. Generally the basal reflector follows a bedding plane of the underlying bedrock, which has an apparent dip to the west. It is difficult to ascertain the stratigraphic relationship of this lower surface with the stratigraphy of the main valley fill due to the resolution of the seismic. Some profiles indicate that it is correlative with the basal incision surface beneath Unit B, whilst others suggest it has been truncated by the incision and deposition of Unit B (Fig. 5.29). This probably reflects the complex nature of downcutting by the river system during its initial formation and incision, combined with the orientation of the seismic profiles across this area. Unit G truncates the upper bounding surface at the sea floor. The internal reflectors display moderate-amplitude, continuous, parallel and horizontal characteristics. They are generally concordant with the basal surface, but exhibit some onlap. The deposition of Unit D is interpreted to represent an older fine-grained channel-fill unit that has subsequently been incised by the main palaeovalley.

5.7.1.5 Unit E

Unit E occurs on the eastern edge of the terrace (Fig. 5.1 and 5.29) along the western margin of the lower section. The base of this unit is incised into the underlying unit D and the Tertiary bedrock of Unit A. The lower bounding reflector is a moderate-amplitude, continuous, and irregular surface, whereas Unit G truncates the upper bounding surface at the sea floor. The internal reflectors are highly variable, but generally they are moderate to high-amplitude, parallel to chaotic, semi-continuous and steeply dipping, they also commonly downlap against the lower surface. The dipping reflectors are interpreted as lateral accretion bedding surfaces and all dip to the northeast. Internal erosion surfaces indicate channel migration. The unit is interpreted to represent a fluvial channel complex, where channel migration and abandonment has resulted in the deposition of coarse sediments by repeated cycles of cut and fill events. The extent of the fill cannot be traced to the northern end of the terrace as substantial dredging has removed the stratigraphy.

5.7.1.6 Unit F

Unit F is present in the valley as a U-shaped channel that is up to 15m deep and up to 300m wide (Fig. 5.31). The lower bounding surface is a moderate-amplitude, continuous reflector that dips up to 6° at the margin of the channel and cuts all earlier deposits. The top of unit F is truncated by the basal surface of unit G. The unit is predominantly present in the south but can be traced to the north and is evident in the lower reaches of the middle section (2000 seismic survey). The internal reflectors are low to moderate -amplitude, with some high-amplitude intervals, parallel, continuous, flat to slightly wavy and gently dipping. The reflectors are concordant with or show slight onlap to the basal surface. A change from lateral to vertical aggradation is evident in some profiles with dipping reflectors becoming horizontal, but generally horizontal reflectors dominate. The internal characteristics of Unit F suggest that the unit formed by deposition of fine-grained sediments from suspension in a lower-energy regime. These sediments completely fill the channel that corresponds to unit ||F.

5.7.1.7 Unit G

Unit G occurs at the seabed as a laterally extensive sheet up to 1 m thick. The lower bounding surface is a high-amplitude reflector that parallels the sea floor. The internal reflectors above are concordant with the surface and mimic its character. The sea-floor reflector is the upper bounding surface of the unit. A major acoustic impedance is indicated by the high-amplitude reflections and reflect the coarse nature of the lithology. The unit only occurs at the top of the sequence and is therefore the youngest. The truncation of underlying beds and the sharp, planar basal contact suggests a high-energy erosive formation to the deposit and is interpreted as a transgressive ravinement surface formed by erosional shoreface retreat.

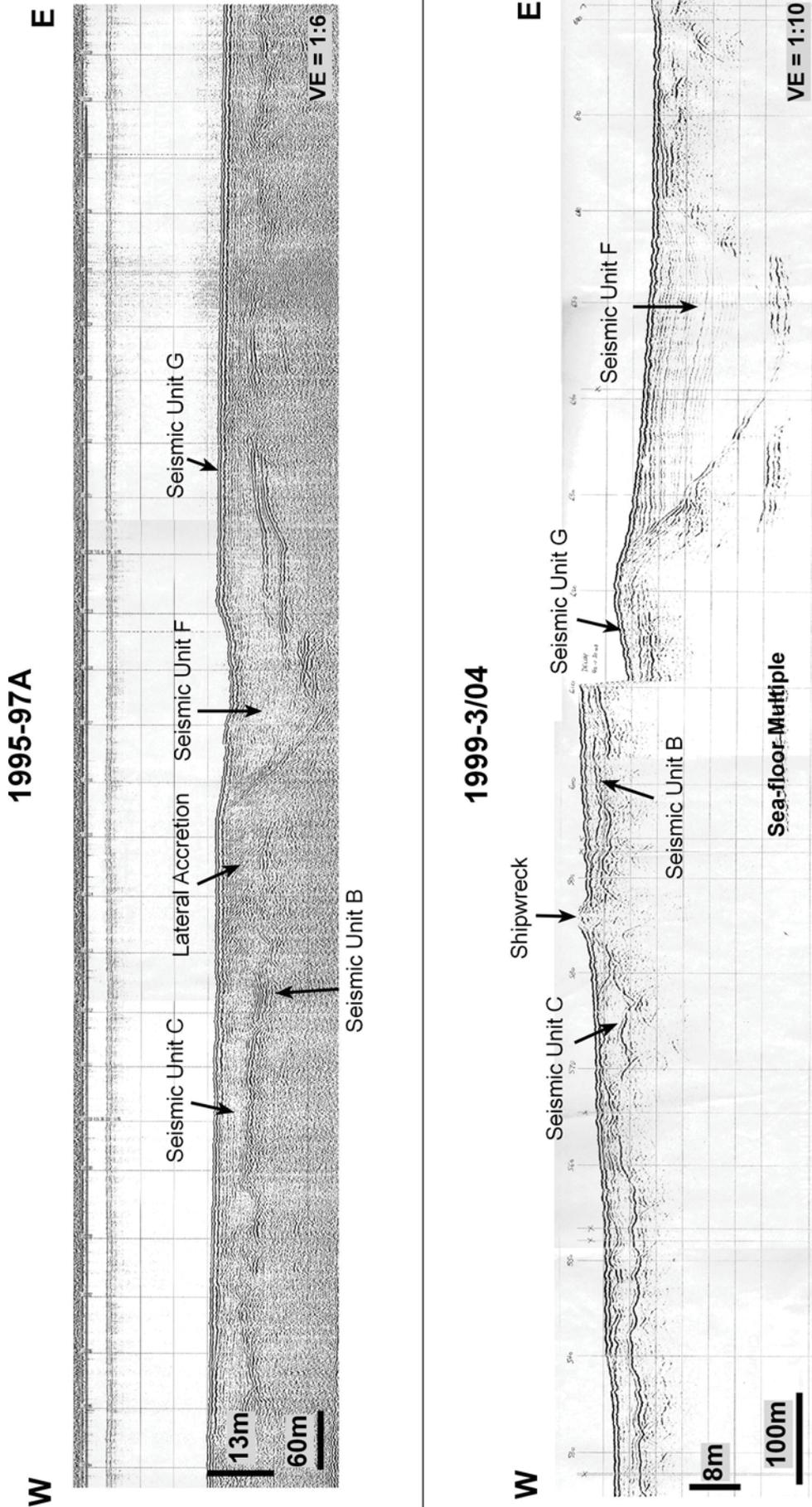


Figure 5.31 Seismic profiles from the lower section of the palaeo-Arun Valley illustrating the seismic units present. See Fig. 5.24 for the location of the seismic lines. Note the position of the shipwreck at the seafloor in profile 1999-3/04. The bedrock (Seismic Unit A) is not imaged due to the resolution of the seismic.

5.8 VIBROCORE SEDIMENTOLOGY

The integration of seismic data with vibrocores provides a means to groundtruth the seismic units. This enables specific lithologies to be assigned and allows the depositional environments and processes responsible for the stratigraphy seen filling the valley to be evaluated. For each of the seismic surveys vibrocores were collected that fall directly on the survey lines and so allow direct correlation with the associated seismic profile. The cores collected all have a maximum sediment retention to 3 m depth. A few cores extend beyond this to 4.5 m, but none penetrate through the entire sequence or reach the base of the valley. More than 100 vibrocores have been collected in the main Arun palaeo-valley (Fig 5.32). From these nine sedimentary facies (Fig 5.33) have been determined based on lithology, composition and sedimentary structures, and are described below.

5.8.1 Sedimentary Facies

5.8.1.1 *Gravel facies:*

G1 - Facies G1 is shelly sandy gravel. It has a sharp erosional base and the top of the core forms the upper contact. The gravel is composed of subangular to rounded, fine to coarse flint and sandstone clasts. Fine to coarse-grained sand can make up to 50% of the unit, and silt is generally present as a minor component (< 5%). Shelly material is usually debris although shells do occur intact. The facies is generally a grey to brown colour, indicating varied levels of oxidation. The coarse nature of the gravel clast and the presence of shell material derive an interpretation of deposition in a high-energy marine environment. The position of the facies at the top of the sediment column and the sharp erosional base suggests this facies represents a reworked sediment body deposited during transgression on the shelf.

G2 - Facies G2 is sandy gravel. The base of the unit is either a sharp erosional base or extends beyond the end of the core. Typically this facies makes up the entire length of the core in which it is found. The top generally has a sharp erosional surface, but may appear conformable when overlain by facies G1 due to the similar lithology and composition. The sand fraction varies from fine to coarse-grained and makes up to 50% of the units, but generally it is a medium-grained sand of < 20%, occasionally present as cm-scale sand lenses. No shell material is present and silt is a minor component (< 2%). The gravel component is rounded to subangular, fine to medium (occasionally coarse) flint clasts. Colour varies between dark grey, orange and brown, reflecting a varying degree of oxidation. The facies is interpreted as being deposited in a high-energy fluvial environment that has resulted in gravel aggradation. The variation in sand content is thought to represent the winnowing away of finer-grained material by turbulent water that is able to hold it in suspension.

5.8.1.2 *Sand Facies:*

S1 - Facies S1 is shelly gravelly sand. It has a sharp erosional base and the top of the core forms the upper contact. The sand fraction is fine to coarse-grained, and can very occasionally be silty.

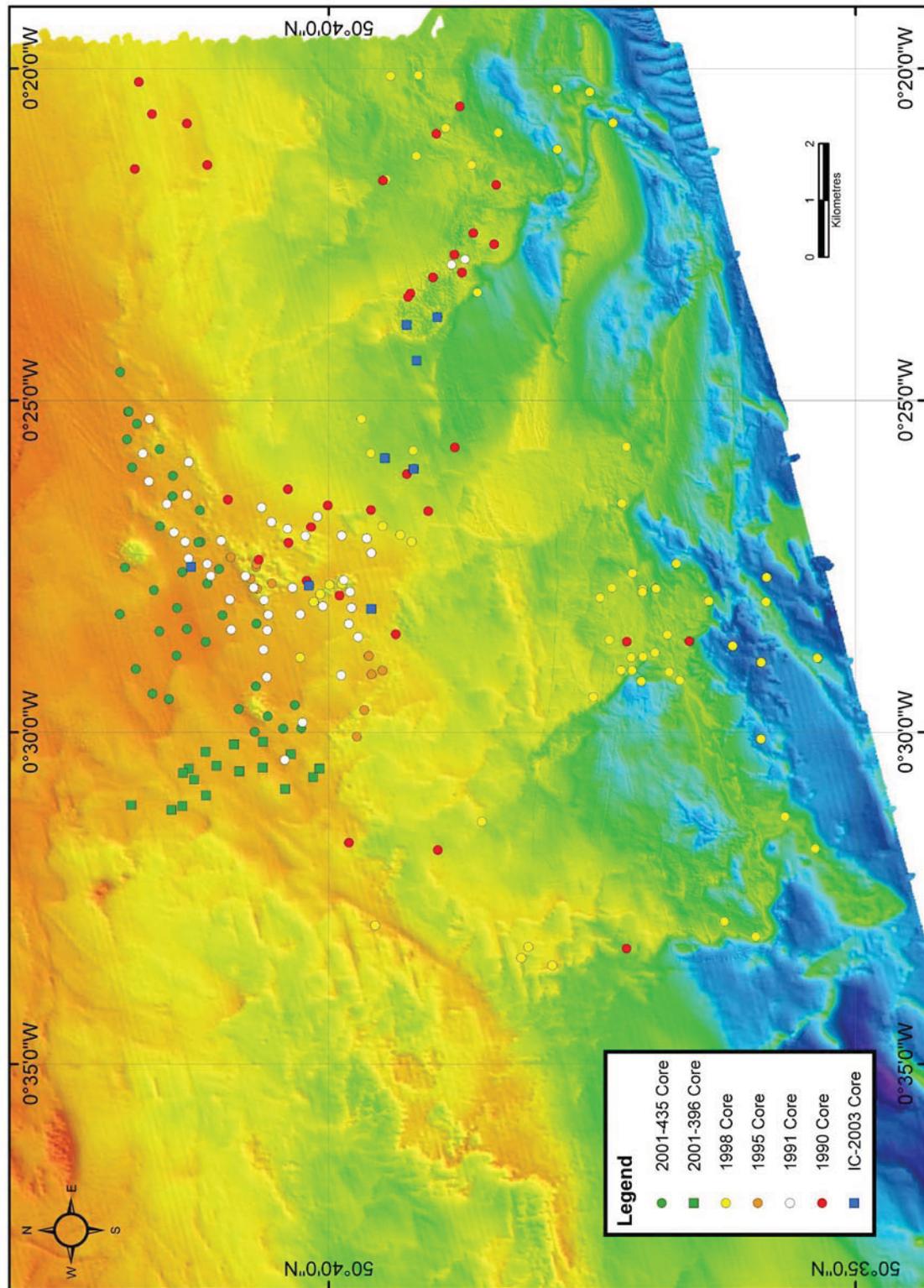


Figure 5.32 Position of vibrocores collected in the study area by Hanson Aggregates Marine Ltd, United Marine Dredging Ltd and Imperial College (IC-2003). The basemap is the singlebeam bathymetry for the area.

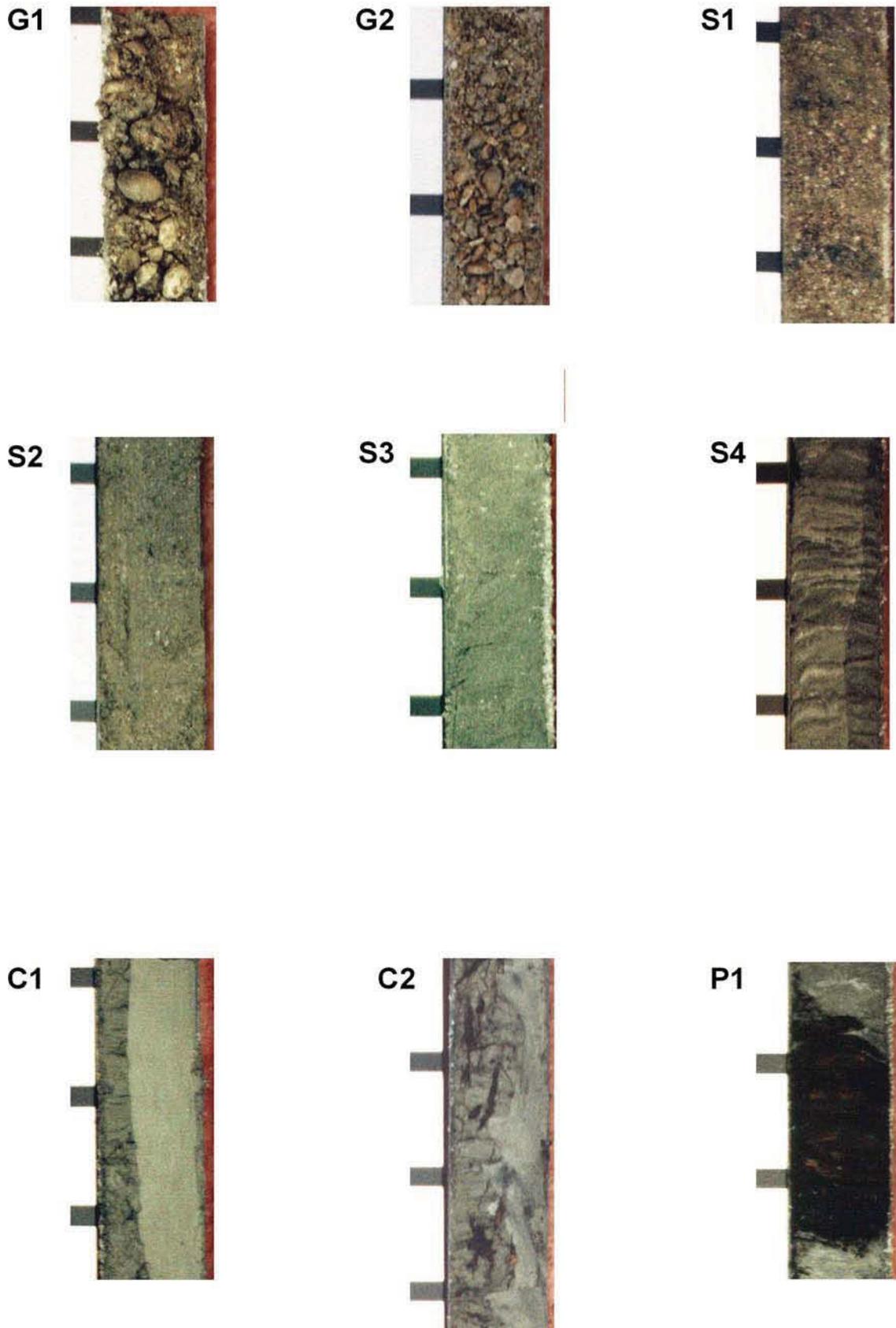


Figure 5.33 Sedimentary facies identified in the palaeo-Arun Valley from vibrocores. The divisions on the vibrocore photographs are equal to 10 cm.

The gravel is composed of subangular to rounded, fine to medium flint and sandstone clasts and makes up to 40% of the unit. Shelly material is usually debris although shells do occur intact. The facies is generally a grey to brown colour, indicating varied levels of oxidation. The coarse nature of the gravel clasts and the presence of shell material derive an interpretation of deposition in a high-energy marine environment. The position of the facies at the top of the sediment column and the sharp erosional base suggests this facies represents a reworked sediment body deposited during transgression on the shelf.

- S2 - Facies S2 is shelly sand. The upper and lower contacts are sharp and planar. The sand is generally fine to medium-grained and commonly silty. The shell component is lenses of broken shell material. Whole shells are rare. The facies is interpreted to be representative of deposition in a moderate-energy environment where marine influenced flows transport shell material. Analysis of ostracoda and foraminifera collected from this facies by Bellamy (1994) produced an assemblage that indicated temperate, open marine shelf habitats. The common position of this facies at the top of the core above facies suggestive of fluvial and tidal environments suggests that this deposit may represent filling of the sequence due to transgression.
- S3 - Facies S3 is grey fine sand. The upper and lower contacts are sharp, planar and erosional. The sand component is fine to coarse grained and it does not contain gravel clasts. Colour generally varies between brown, grey and black. The depositional environment is interpreted to be a moderate-energy aqueous flow. The lack of shell or organic material suggests that the facies formed in a fluvial setting and represents a channel fill deposit.
- S4 - Facies S4 is interbedded sand and clay lenses. Clay is present as (~5mm) thick lenses within sand at few centimetre intervals to produce an interbedded relationship. The upper and lower boundaries are conformable with the surrounding units. Burrows are present extending from the sand into the clay. Some organic matter is present as debris, rootlets and very thin organic drapes. Shell material is also present as lenses of debris hash. Clay colour varies from grey to dark grey. The interbedded sand and clay lenses are interpreted to represent a tidal depositional environment such as an estuary.

5.8.1.3 Clay Facies:

- C1 - Facies C1 is grey silty clay. The top and basal surfaces of this unit is a sharp planar horizon. The clay can be variably sandy (<20%), with thin (cm-scale) sand lenses not uncommon. Shell material is also present as lenses (cm-scale thickness) of shell hash, but these are not common. Gravel clasts are rare, but where present they occur as a singular features rather than as a bed within the clay. The facies is representative of a low-energy depositional regime where clay particles have settled out of suspension. The presence of shell material indicates a marine influence and the facies may represent a marginal marine, estuarine setting.
- C2 - Facies C2 is grey organic-rich clay, typically associated with peat facies P1. The base of the unit is a sharp planar boundary, generally overlying facies P1, and the top has a similar character

with facies G1 the associated facies. Black organic staining, organic debris and roots (3-20 cm length), which are generally well preserved, are common throughout. Very thin (<1mm) organic drapes are also present. Sand and silt are limited but may be present as lenses (cm-scale) or as part of the matrix of the unit. The clay unit also contains shell material as thin lenses of hash or individual shells including bivalves and gastropods. The fine-grained organic nature of this facies indicates a low-energy environment, but the presence of shell hash in the sand fraction indicates the regime was able to transport coarser sediments. This suggests a tidal influence such as an estuary or salt marsh.

5.8.1.4 Peat Facies:

P1 - Facies P1 is a brown to black, fibrous peat. The contact of the peat with surrounding beds is typically sharp and planar. Individual peat horizons can accumulate a thickness of up to 20 cm, whilst the peat horizons can also be interbedded with clay and occasionally sand layers (cm-scale), over a zone of 20 cm. This facies is typically associated with facies C2. The accumulation of peat is interpreted to occur on terraces during subaerial exposure and represent a low-energy depositional environment.

5.9 SEDIMENT DATING

No dates have previously been derived for the Quaternary deposits of the palaeo-Arun valley buried in the English Channel. Consequently, samples have been collected from vibrocores in an attempt to determine some constrain on when the system was active. Organic material was sampled for radiocarbon ^{14}C dating to ascertain when the area was subaerially exposed. Optically stimulated luminescence dating was undertaken on fine-quartz sand deposited within the fluvial channels to determine when the channels were active.

5.9.1 Radiocarbon

Radiocarbon ^{14}C values were analysed from peat horizons within vibrocores collected from the palaeo-Arun Valley (Fig. 5.34). The ages derived from the ^{14}C dating range from 9740 to 11290 cal yr BP (Table 5.2). The age of the peats all fall within an interval after the last glacial maximum dated at 20kyr (Siddal et al., 2003), during the subsequent transgression. The peat horizons are interpreted to represent intervals of subaerial exposure when organic material was accumulating. Analysis of pollen present within an organic horizon in core OVC75 (collected 1991) from the central Arun palaeo-valley indicated a temperate, subaerial, mature woodland environment existed on the shelf at the time of deposition (Bellamy, 1994). It is assumed that the deposition of this peat is correlative with the peat dates here because of the similar stratigraphic position. Consequently, the dates indicate that the palaeo-Arun was still subaerially exposed at least 9.8kyr and at this time the sea had yet to flood this area. Furthermore, there is a strong correlation between the age of the sample and the depth at which

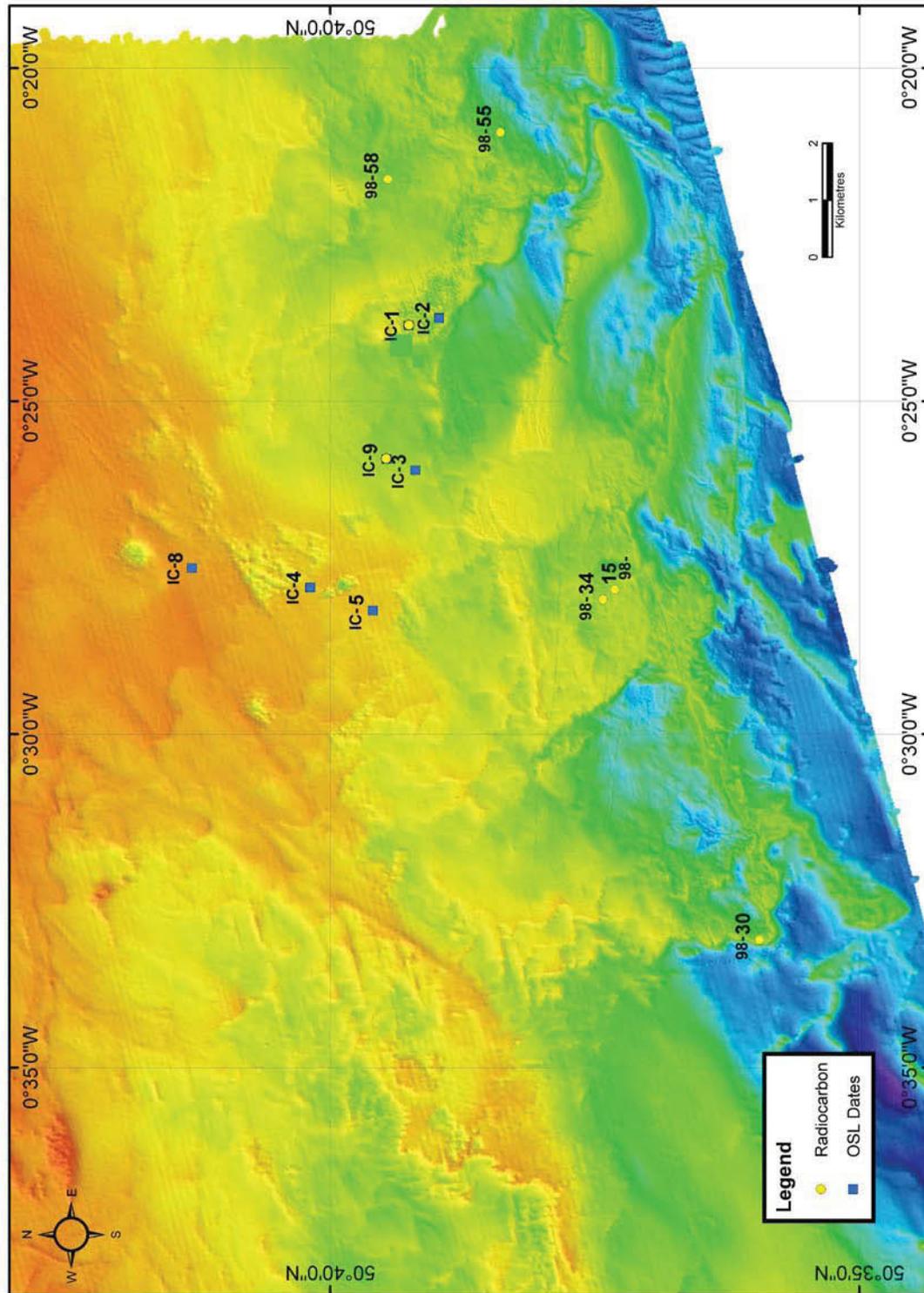


Figure 5.34 Location of vibrocores sampled for radiocarbon and optically stimulated luminescence (OSL) dating in the study area. IC- denotes Imperial College vibrocores and 98- denotes vibrocores collected in 1998. The basemap is the singlebeam bathymetry for the area.

it was collected beneath the ordnance datum (Fig. 5.35), such that the greater the depth of peat beneath OD, the older the deposition. This possibly reflects the influence of the advancing sea, with environments appropriate for peat accumulation retreating landward resulting in peat deposition at a higher stratigraphic position.

Table 5.2 Radiocarbon data for organic material collected from palaeo-Arun vibrocores

Laboratory Code ^a	Sample ^b (depths relative to OD)	Material	$\delta^{13}\text{C}$ (‰)	^{14}C Age BP	Calibrated Date (95% confidence) Cal year BP
GrA-23799	VC30 – 4m (-38.4m)	Leaf fragments	-27.47	9300±60	10730-10290
GrA-23802	VC34 – 2.15m (-32.1m)	Plant stem	-26.89	8870±60	10240-9740
GrA-23803	VC55 – 2.34m (-41.8m)	Leaf fragments	-28.78	9770±60	11290-11160
GrN-28212	VC15 – 1.48m (-31.9m)	Peat	-26.72	9100±110	10610-9960
GrN-28213	VC58 – 2.9m (-38.2m)	Peat	-27.92	9550±60	11220-10650
GrN-24658	IC1 – 3.07m (-28.6m)	Herbaceous	-26.22	8870±60	10240-9740
GrN-24569	IC1 – 4.41m (-32.1m)	Monocot leaf fragment	-28.58	9200±60	10610-10270
OxA-12976	IC9 – 1.46m (-32.5m)	Herbaceous plant fragments	-29.5	8820±70	10240-9600
OxA-12976	IC9 – 3.88m (-34.9m)	Herbaceous plant fragments	-27.6	9340±50	10740-10360

a – GrA denotes analysis conducted at Centre for Isotope Research, University of Groningen, OxA denotes analysis conducted at Oxford Radiation Accelerator Unit, University of Oxford.

b – samples labelled VC were collected during the 1998 Owers Bank survey for Hanson Marine Aggregates Ltd. Samples labelled IC are those cores collected during 2003 for this study.

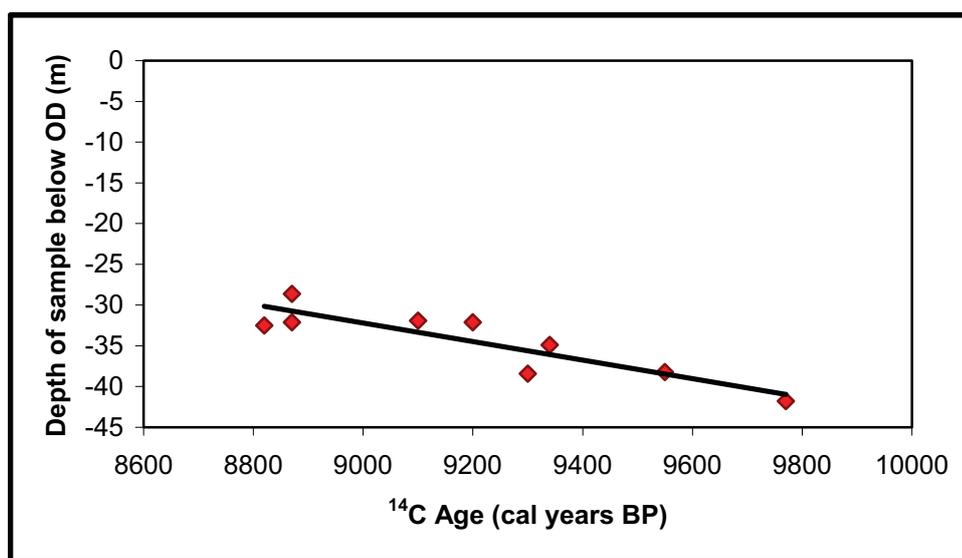


Figure 5.35 Correlation of radiocarbon age of sample to depth below ordnance datum.

5.9.2 Optically Stimulated Luminescence

Sediment rich in fine-grained quartz sand was collected from cores for optically stimulated luminescence (OSL) dating. Optical stimulation of quartz aliquots resulted in predictable, rapidly bleachable OSL signal reduction with exposure time, indicating the samples responded well to the analysis. The dates derived ranged from 6.11 to 29.6 Ka (Table 5.3) from sediments derived in the upper 4 m of the sediment column. The samples were collected from sediment that is assumed to have accumulated within channels by fluvial depositional processes. The range of dates shows that the upper sediments of the fluvial channel were generally filled after the last glacial maximum at an interval of time that was concurrent to peat accumulation.

Table 5.3 Summary of optically stimulated luminescence dating results.

Core	Sample		K	Th	U	Dose rate	D _e	Age (ka)
	depth	WF						
	(m) BSS		(%)error	(ppm)error	(ppm)error	(Gy/ka)	(Gy)	
VC2	0.47	0.4	0.15±0.01	1.06±0.03	0.49±0.02	0.24±0.01	1.45±0.48	6.11±2.05
VC2	1.09	0.4	0.26±0.02	1.08±0.04	0.56±0.01	0.32±0.02	5.83±0.15	18.08±1.23
VC2	1.47	0.4	0.39±0.03	1.40±0.04	0.61±0.04	0.43±0.03	5.34±0.06	12.31±0.95
VC3	0.70	0.4	0.67±0.05	3.44±0.09	1.15±0.06	0.82±0.06	8.84±0.68	10.82±1.12
VC3	1.60	0.4	0.50±0.04	4.68±0.18	1.56±0.07	0.84±0.06	10.94±0.52	13.06±1.12
VC3	2.75	0.4	0.60±0.05	3.28±0.10	1.12±0.04	0.76±0.05	9.11±0.30	12.03±0.92
VC3	3.88	0.4	0.61±0.04	3.12±0.13	0.97±0.04	0.73±0.05	21.64±3.72	29.64±5.43
VC4	3.30	0.4	0.15±0.02	1.10±0.03	0.51±0.02	0.24±0.02	3.59±0.24	14.81±1.80
VC8	0.90	0.4	0.33±0.03	1.40±0.05	0.66±0.02	0.40±0.03	3.92±0.30	9.74±1.05
VC8	1.97	0.4	0.25±0.02	0.97±0.05	0.39±0.03	0.28±0.03	3.47±0.21	12.31±1.33

WF = estimated field moisture content; K = Potassium (percentage); Th = Thorium (parts per million); U = Uranium (parts per million); Gy = Grays; D_e = Dose equivalent; BSS = below sea surface.

5.10 CORRELATION OF STRATIGRAPHIC UNITS

The interpretation of seismic profiles across the palaeo-Arun Valley has enabled the infill stratigraphy of the main valley to be defined as a number of seismic units and sequences. However, the different resolution of the seismic datasets used between the middle and lower sections has resulted in the middle section being mapped with greater detail than that of the lower section. Consequently, the correlation of the stratigraphy between these two areas is limited and not all sequences of the middle section can be seen in the lower section. Furthermore, the lower valley does not have the same thickness of fill as the middle valley, which reflects a different fill history. This section will focus on

discussing the major units that can be mapped down the valley (Fig. 5.36), their distribution, spatial relationship, sedimentology and formation.

5.10.1 Basal erosion surface – R1

The basal erosion surface (R1) is defined as a high-amplitude reflector that truncates the dipping reflectors of the bedrock. In the middle section this has been mapped as R1, which includes a basal unit interpreted as a basal gravel lag. Whilst, in the lower section the surface is defined as the base of Unit B, a basal lag deposit. This basal erosion surface can be mapped through the valley and marks the limit of incision by the depositional system. Although this surface and the basal lag that overlies it has been mapped as one unit their deposition may be unrelated. The incision of the valley marked by the basal surface is related to base level fall associated with sea level cycles, but the deposits above may have been deposited during base level rise.

5.10.2 Basal Lag – Unit B

The basal deposit that overlies the basal erosion surface occurs down the length of the valley. It is beyond the penetration of the vibrocorer so there is no sedimentological data about it. However, the seismic signature is consistently high-amplitude and this in other units that are sampled relates to coarse sediments. It also contrasts with the low-amplitude reflectors typical of fine-grained sediments. In both the middle and lower sections of the valley the unit occurs as a sheet deposit across the valley floor up to 3 m thick, and forms the base of all other deposits. The unit is interpreted as a coarse-grained sediment body, which was deposited concurrently with or soon after erosion of the valley. This erosion is interpreted to be a result of falling base level that created a high-energy environment resulting in the deposition of coarse-grained sediments. It is also possible the unit represents a condensed gravel lag sequence at the base of the valley resulting from several cycles of incision and filling.

5.10.3 Unit C

Unit C represents the majority of the valley fill in the lower section of the valley and overlies the basal lag of Unit B. The unit is characterised by a varied seismic response, but generally the internal reflectors are moderate amplitude, irregular to semi-continuous, parallel to chaotic and occasionally steeply dipping. They also typically exhibit low amplitude characteristics, with some high-amplitude intervals, parallel, continuous, flat to slightly wavy. The unit is sampled by numerous vibrocores, which indicate a predominantly organic-rich clay lithology with fine sand intervals also evident. This corresponds to the sedimentary facies C1, C2, P1 and S3. Sandy lithologies are also present (facies G2). Together the unit is interpreted as a channel fill complex that is dominated by fine-grained lithologies, e.g. peats, muds and sands, with varying proportions of coarser-grained sediments.

The unit extends through the lower section of the valley and is interpreted to correlate with the terrace at the margins of the central incised zone in the middle section. This interpretation is based on

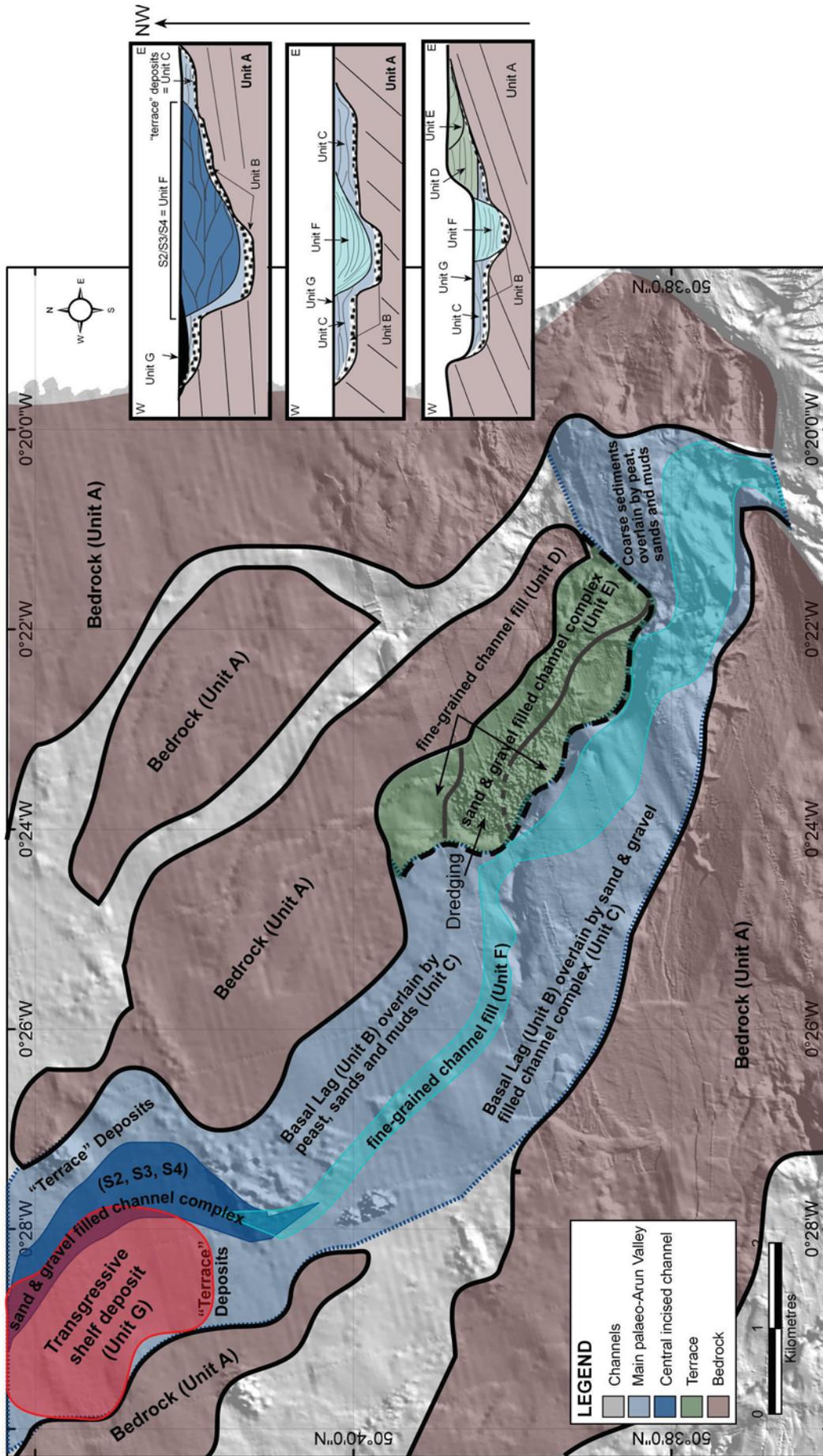


Figure. 5.36 Distribution of seismic units as sub-veener (Unit G) sediment bodies in the lower section of the main palaeo-Arun Valley. The inset shows the cross-sectional relationship of these units upstream. See Fig. 5.37 for the location of the area.

similarities in the seismic response, geometry, stratigraphic position and lithologies of the sequences. The level of basal incision for the terrace and unit C is appropriate for a downstream association. It is not feasible that any of the sequences identified in the central incised zone of the middle section to become topographically higher downstream. However, unit B marks the basal incision and incision does not necessarily equate to the subsequent filling of the channel. Radiocarbon dating of cores that penetrate Unit C derive a depositional age of the lower peat sampled (IC-9) of 10.5 kyr. This indicates that deposition of the organics was prior to flooding of the area during the last transgression. Consequently, the deposition of unit C in the lower section is thought to represent estuarine or peat-land/marsh deposition in temperate conditions prior to flooding of the shelf. It is difficult to determine an age for the terrace fill in the middle section but it is interpreted to be a similar relationship.

5.10.4 Terrace Deposits – Unit D/Unit E

The stratigraphy of the terrace that extends along the eastern margin of the lower section can be divided into two units, D and E. Both units are constrained to the terrace and cannot be traced beyond this due to erosion of the stratigraphy at the margins and dredging. The two units exhibit different seismic characters and are distinct from each other. However, both units are interpreted to represent an older channel system that has subsequently been incised by the main palaeovalley.

Unit D occurs along the western edge of the terrace and is characterised by internal reflectors that display a moderate-amplitude, continuous, parallel and horizontal seismic response. Vibrocores that penetrate the unit indicate a fine-grained lithology composed entirely of peats and clays with varying organic content. Unit D is truncated to the east of the terrace by unit E. The internal reflectors of unit E are highly variable, but generally they are moderate to high-amplitude, parallel to chaotic, semi-continuous, steeply dipping and also commonly downlap against the lower surface. The dipping reflectors are interpreted as lateral accretion bedding surfaces and all dip to the northeast. Internal erosion surfaces indicate channel migration. Samples of the unit are limited but always indicate coarse-grained sands and gravels (facies G2 and S3). The unit is interpreted to represent a fluvial channel complex, where channel migration and abandonment has resulted in the deposition of coarse sediments by repeated cycles of cut and fill events.

5.10.5 Central Channel – Unit F=S2,S3,S4

Unit F is mappable through the lower section of the valley as a channel (up to 15 m deep and 300 m wide), which has been infilled by fine-grained sediments. This is derived from the low-amplitude parallel, continuous, flat to slightly wavy and gently dipping characteristics of the internal reflectors in the seismic record and also the dominance of facies S2 and S3 in vibrocores (IC-3 and 98-61) that penetrate the channel. The extent of Unit F diminishes to the north and is only confidently identified in the lower section, but is thought to occur in the southern extent of the middle section as a much smaller channel. In comparison the sequences S2, S3 and S4 are units that represent extensive channel fill complexes that are mapped through the middle section of the palaeovalley. They are dominated by

coarse-grained sand and gravel sediments and are characterised by highly variable, but generally moderate to high-amplitude parallel to chaotic, semi-continuous and steeply dipping internal reflectors.

Unit F truncates all other units and represents the youngest fill sequence in the valley. Although it cannot be mapped in the middle section of the valley it is believed to be a lateral equivalent of the sequence S2. The correlation between the two units reflects the confinement of the units to occur within the central incised channel of the valley. The significant changes in fill lithology and geometry suggests that the units are laterally equivalent and represent a change in the depositional regime downstream. An interpretation of a tidal channel is derived for at least the upper portion of Unit F based on the presence of shell hash and organic-rich horizons through the predominantly fine sandy silt lithology. The change downstream may reflect the evolution of the fluvial system from broad gravel river to single channel. The dominance of estuarine sedimentation in the lower section of the valley suggests the change in fluvial behaviour be due to a tidal influx and the presence of the coastline near the southern extent of the valley.

5.10.6 Transgressive Deposit – Unit G=Sequence S5

A marine veneer that equates to sequence S5 in the middle section and Unit G in the lower section overlies all other unit in the valley. The basal surface of this deposit is referred to as reflector R5 in the middle section and represents the transgressive ravinement surface. This surface equates to the base of Unit G in the lower section. Due to the location of the unit at the top of the stratigraphic sequence it is well constrained by vibrocores, but it is commonly beyond the resolution of the seismic as it is only a thin (0.5 m) deposit. Only in the middle section does the unit become thick enough to be imaged by the seismic. The deposit consists of shell flint-rich gravels with varying proportions of sands and silts, equating to sedimentary facies G1 and S1. The deposits formed during high-energy marine conditions when the sea floor was above wavebase. The transgression would have resulted in shoreface retreat and the erosion of features with relief (e.g. bar forms) producing marine planation. The reworking and winnowing of the underlying units during this erosion would result in the coarse-grained sediments seen here. The presence of shell material reflects the marine conditions and incorporation of seabed sediments.

5.11 EVOLUTION OF THE PALAEO-ARUN VALLEY

Reconstruction of the palaeo-Arun system has determined the presence of numerous valleys that extend across the English Channel shelf and drain to the southeast (Fig. 5.37). Although the location of other valleys has been mapped the focus of reconstructing the internal stratigraphy has been on the main valley and it is the evolution of this valley that will be discussed.

The age of the initial incision of the palaeo-Arun Valley or how long the system has been active is difficult to constrain as no samples have been retrieved from the base of the valley. However, the

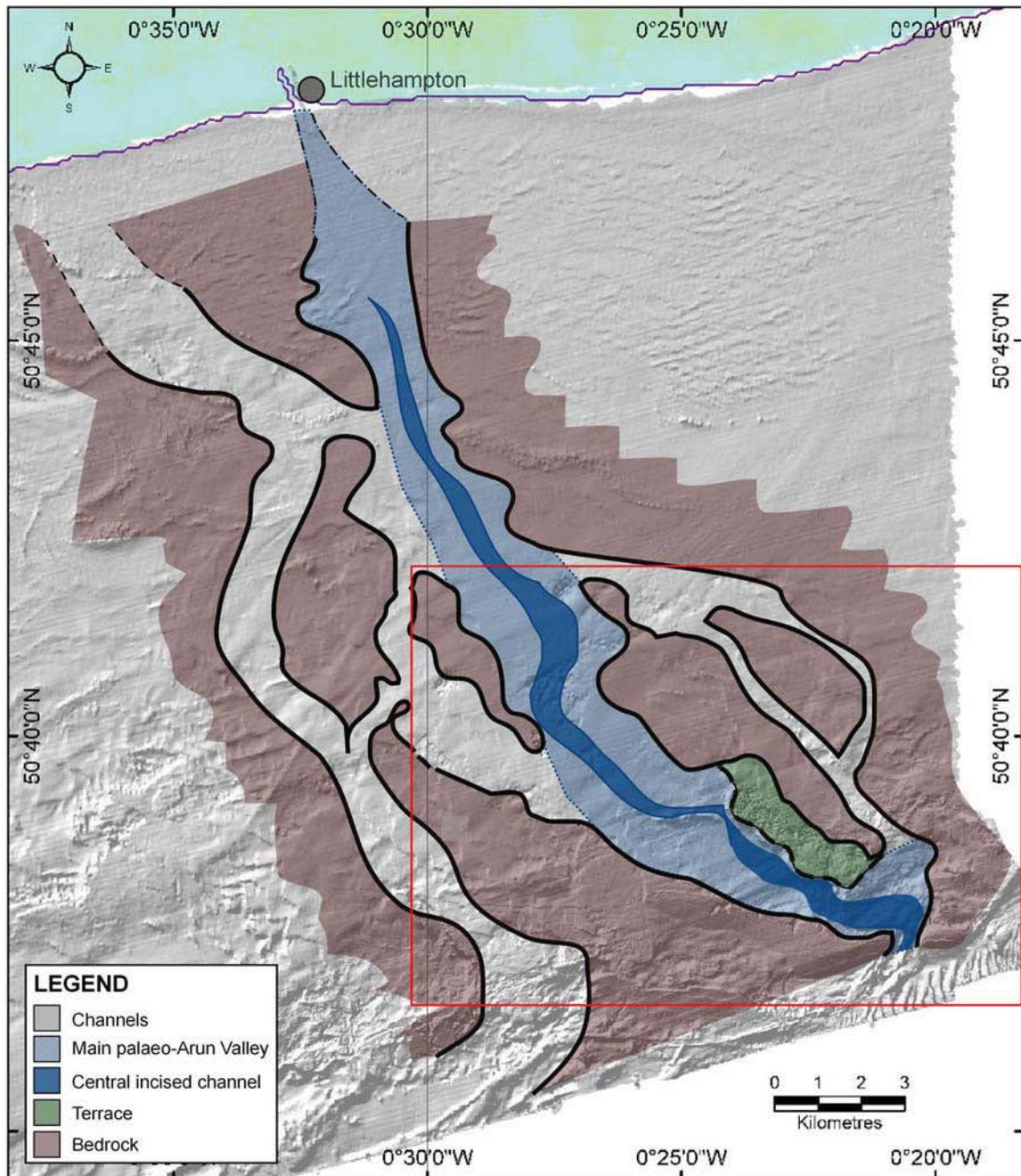


Figure 5.37 Reconstruction of the palaeo-Arun valley derived from the digitised seismic datasets. The red box indicates the position of Figs 5.36 and 5.40.

dating of fluvial terraces of the Arun Valley onshore and raised beaches along the Sussex-Hampshire coastal plain indicate the coast in this area has been influenced by changes in sea level back to at least oxygen isotope stage (OIS) 9 (Fig. 5.38A; Bates et al., 2003). Consequently, it is likely that the offshore palaeo-Arun Valley has equally been influenced by the same fluctuations. The sea level curve for the last 500kyr (Fig. 5.38A) indicates that there have been numerous intervals when sea level would have been beyond the southern extent of the study area (~50 m) and so the whole area would have been subaerially exposed. It is likely that with each of these regressions the fluvial systems that extended across the exposed shelf would have returned to the same valleys. Although, other valleys are present to the east and west of the main valley and these may reflect younger or older systems and the switching of fluvial deposition from one valley to another over time. It is not however possible from the data currently available to determine this, but the prominence of the main palaeo-Arun Valley and extent of its incision suggests that this system has been a dominant feature of the landscape through the Quaternary. Furthermore, that the basal erosion surface, which marks the limit of incision, is probably at least a 500,000-year-old surface.

The stratigraphy above this basal erosion surface of the main palaeo-Arun Valley is characterised by a complex cut and fill history. The stratigraphy that is preserved is determined to represent at least one cycle of deposition since the area has become subaerially exposed, but possibly two or more. The simulated flooding of the study area gives some indication of where the coastline would have been at different bathymetric intervals relating to points on the sea level curve (Fig. 5.39) and hence the dominant processes acting on the valley. Although the actual topography of the area is not known it is assumed that it is similar to the present day as the crustal deformation is determined to be minimal for this area in recent times (Lambeck, 1995). The flooding shows that for the areas to be completely exposed sea level must be less than -45 m (Fig. 5.39), but at -20 m although the lower section would be flooded the middle section would still be exposed. The sea level curve for the last 125 kyr (Fig. 5.38B) indicates that for much of this time the shelf would have been exposed to some degree. It is here suggested that it is this last 125 kyr that have played a defining role on the stratigraphy evident in the palaeo-Arun.

Following the last sea level high (OIS 5e) at 125kyr there was a fall in sea level to ~ -50 m and then for the next 40kyr sea level fluctuated between this and -20 m, commonly sitting at around -30 m to -40 m. This interval on the sea level curve (OIS 5) has significant implications for the palaeo-Arun Valley. At -40 m (Fig. 5.39) the sea would have been flooding the lower reaches of the valley in the study area. The English Channel currently has a tidal range of 7m and it is assumed that this would have been the same through the late Quaternary (Anthony, 2000). Consequently, at -40 m the influence of the tidal range would most likely have extended to around the limits of the -35 m coastline (Fig. 5.39). The flooding of the area to the -30 m bathymetry would have resulted in the complete inundation of the lower reaches by the sea. Consequently, it is determined that when relative sea level was between -40 m to -30 m the lower section was dominated by tidal and marine conditions rather than fluvial environments. Furthermore, that the topographic valley would have formed a tidal

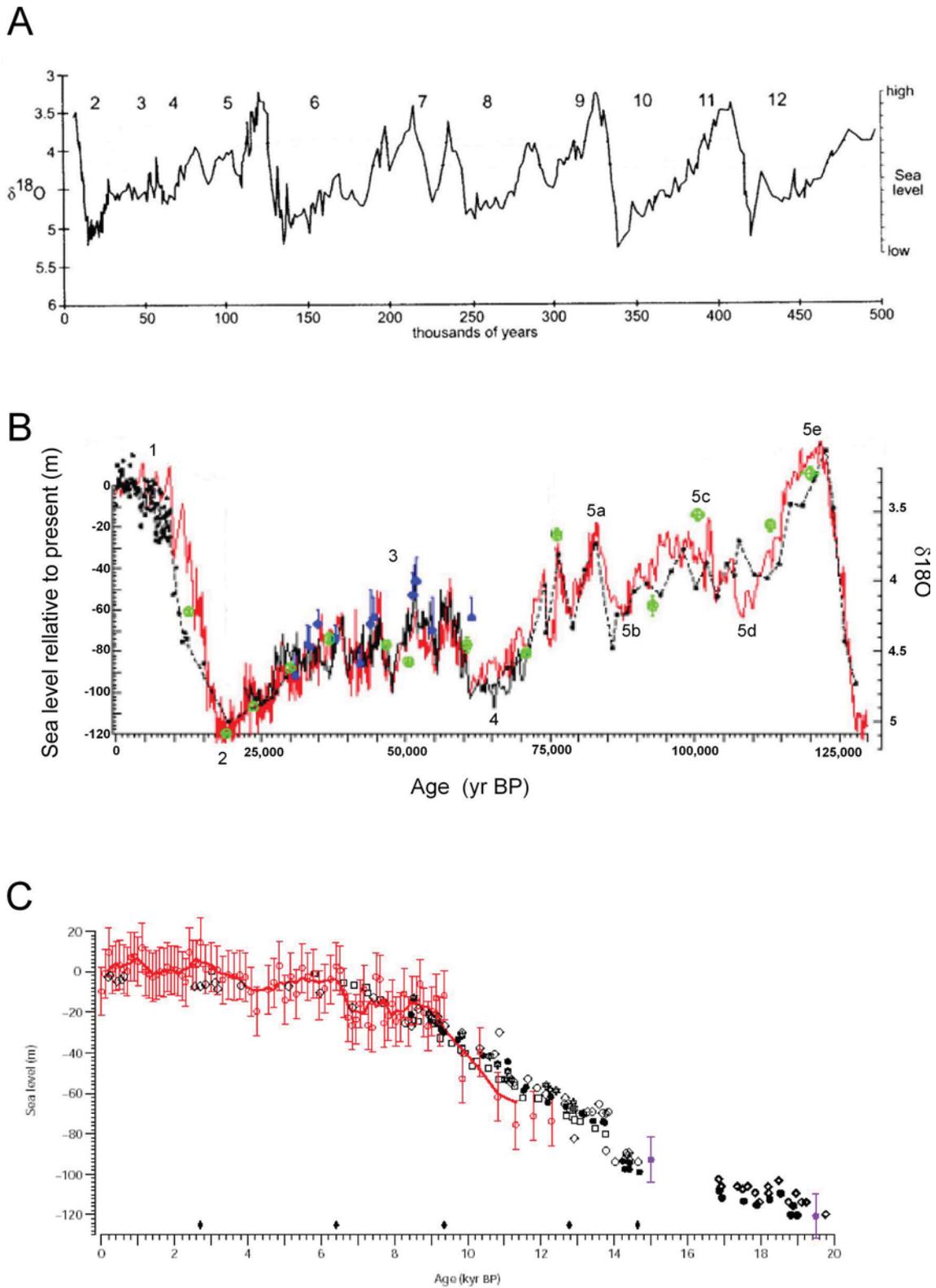


Figure 5.38 Sea level curves through the Quaternary showing differing scales for (A) the last 500kyr after Aston & Lewis, 2003, (B) the last sea level cycle over the last 125kyr (Siddal et al., 2003), and (C) the period of the last transgression (Siddal et al., 2003). The oxygen isotope stages are shown in A and B relative to the sea level curve.

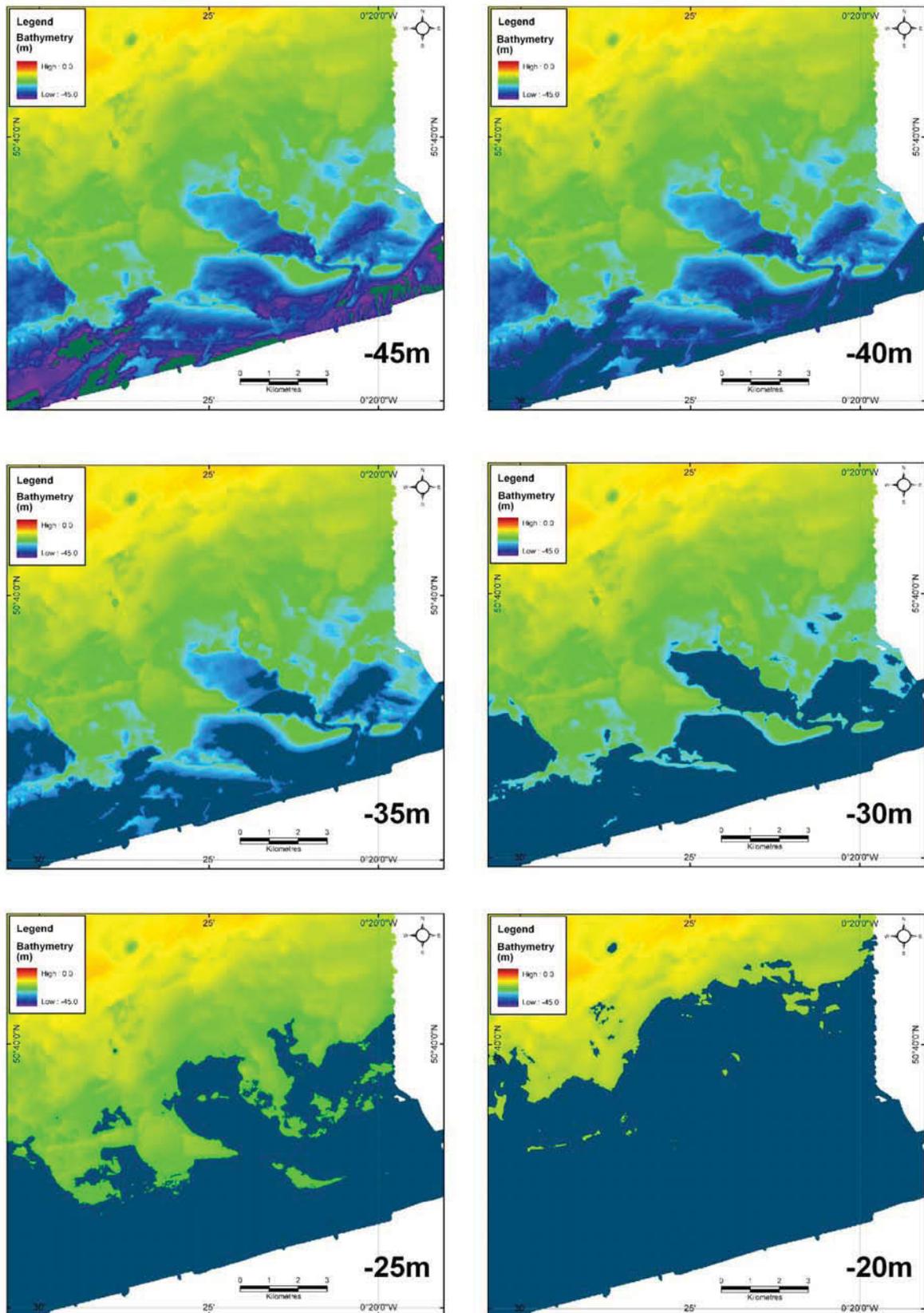


Figure 5.39 Simulated flooding of the lower reaches of the study area from -45m to -20m to determine the position of the coastline in the area at various sea levels. The influence of isostatic rebound during the late Quaternary is assumed to be nominal after the modelling by Lambeck, 1995. The basemap is the singlebeam bathymetry for the area.

embayment or estuary. The influence of a tidal regime is evident in the sediments recovered from the lower section, with the presence of interbedded sand and clay lenses, organic clays including root nodules typical of salt marshes, and shell material. However, throughout this time the middle section would have remained exposed and fluvial processes dominated sedimentation. Even at the maximum sea level of -20 m during OIS 5c the middle section would have remained a fluvial system and only its southern extent would have been within the tidal range. This reconstruction indicates that for a significant interval of the last 125kyr the dominant depositional process occurring in the lower valley was tidally influenced.

The influence of sea level is evident in the mapped stratigraphy of the palaeo-Arun Valley. In the middle section the deposition is wholly fluvial with only the transgressive shelf deposit showing any marine influence, whilst the lower section exhibits the affect of a tidal-marine regime. Furthermore, the central incised zone of the middle section is laterally more developed than the incised channel in the lower section. The central channel becomes substantially narrower to the south and in the lower section peats, clays and muds dominate aggradation in the channel, rather than the extensive lateral accretion units of the middle section. This may also explain the difference in preserved thickness between the middle and lower sections.

Following OIS 5 relative sea level fell to -100 m during OIS 4 and remained beyond the southern extent of the study area until the last transgression following the last glacial maximum at 20 kyr. Throughout this time the palaeo-Arun Valley was completely exposed and fluvial sedimentation dominated. The relatively low sea level implies that the climatic conditions were colder than present. Although the river was situated beyond the limits of the Quaternary ice sheets and associated meltwater drainage, periglacial conditions prevailed across the shelf (Gibbard, 1988). Furthermore, various reconstructions have suggested that permafrost was present to some degree (e.g. Isarin, 1997; Murton and Lautridou, 2003). This implies that the river flow was controlled by seasonal climatic changes, producing high discharge in the spring and summer from snow and ground-ice melt, and negligible discharge during winter months. The lack of coarse-grained deposition in the lower section suggests that the aggradation of the system was influenced by sediment supply resulting from this seasonal climatic change. Consequently, there is a seasonal cycle to the deposition with incision dominating during spring and summer when high discharge has the capacity to transport sediment and aggradation occurring in the low discharge winter period. This relationship is common for modern rivers in periglacial settings (Blum & Tornqvist, 2000; Vandenberghe, 2001). Bellamy (1994) illustrated the sediment dynamics of a river analogous to Quaternary periglacial condition (Sachs River, Canada) to show flow rate variation reflecting seasonal climate change. During high and low stage flows the river was dominated by a single main channel. Braiding only became evident during intermediary stages. The mapping the middle section stratigraphy illustrates this single main channel with limited evidence of braiding.

The last transgression was initiated at 20kyr and resulted in a rise in sea level (Fig. 5.38C). Radiocarbon dates derived from peat horizons in the palaeo-Arun indicated that the area was still

exposed 10.2kyr BP, which by the sea level curve derives a relative sea level of -45 m. A palaeogeographic reconstruction of the lower and middle section of the valley during the initial stages of flooding is presented in Figure 5.40. This shows the influence of a tidal regime in the lower reaches, which would have become more dominant with continued transgression. The infill of the channel in the lower valley is dominated by an estuarine fill onlapping the channel base. The rise in base level would have also resulted in the filling of valley upstream as the change to more temperate conditions signalled a decline in seasonally related high discharge. As the energy to transport sediments wanes so coarser-grained sediments are progressively deposited farther upstream (Schumm, 1993). This is seen in the middle section with the sequence S3, a young unit that is dominated by a coarse-lithology that becomes more extensive upstream and less so downstream. The filling of a valley during base level rise also results in backfilling and landward aggradation, which again is evident in this system by the dominance of northeasterly lateral accretion. The restriction of coarse-sediments upstream allows transportation of fine-grained sediments to be deposited in the tidal zone. The initial sea level rise was rapid but the rate began to slow at about 9kyr BP, by which time relative sea level was at -20 m. During transgressions if there is a rapid base level rise then minimal erosion will occur, but during slow rates erosion is greater (Heward, 1981). It is this rapid transgression that has resulted in the submergence and preservation of the palaeo-Arun landscape. By 8kyr the relative sea level had reached -20 m (Fig. 5.38C). This depth is significant as beyond this point in the stratigraphy the development of a thick transgressive shelf deposit (S5) occurs in the middle section. A decline in the rate of sea level rise at ~ 8 kyr (Fig. 5.38C) resulted in significant transgressive erosion by shoreface retreat. This change in the rate of sea level rise explains the generally thin marine veneer in most places but the extensive formation of a transgressive deposit in the middle section of the valley.

A model for the evolution of the palaeo-Arun Valley is illustrated in Figure 5.41. This depicts the major stages in the formation of the stratigraphy described in this chapter for the middle and lower sections. Six key stages are defined. The timing of the initial stages are relative because it is likely that the incision of the valley may have taken several cycles of sea level change, but the later stages are referred to more specific intervals.

1 – Base level fall results in the extension of the fluvial system across the shelf leading to the incision and subsequent aggradation of coarse-grained sediments (Units D and E of the terrace) during the following rise of sea level.

2 – Another cycle of sea level leads to the return of the fluvial system to the shelf and incision resulting in the formation of a terrace in the lower valley. The increased incision reflects the grading of the valley to the Northern Palaeovalley. A gravel lag is deposited at the base of the valley (Unit B). During the subsequent transgression, aggradation may occur but is not thought to be preserved to any extent in the stratigraphy now observed.

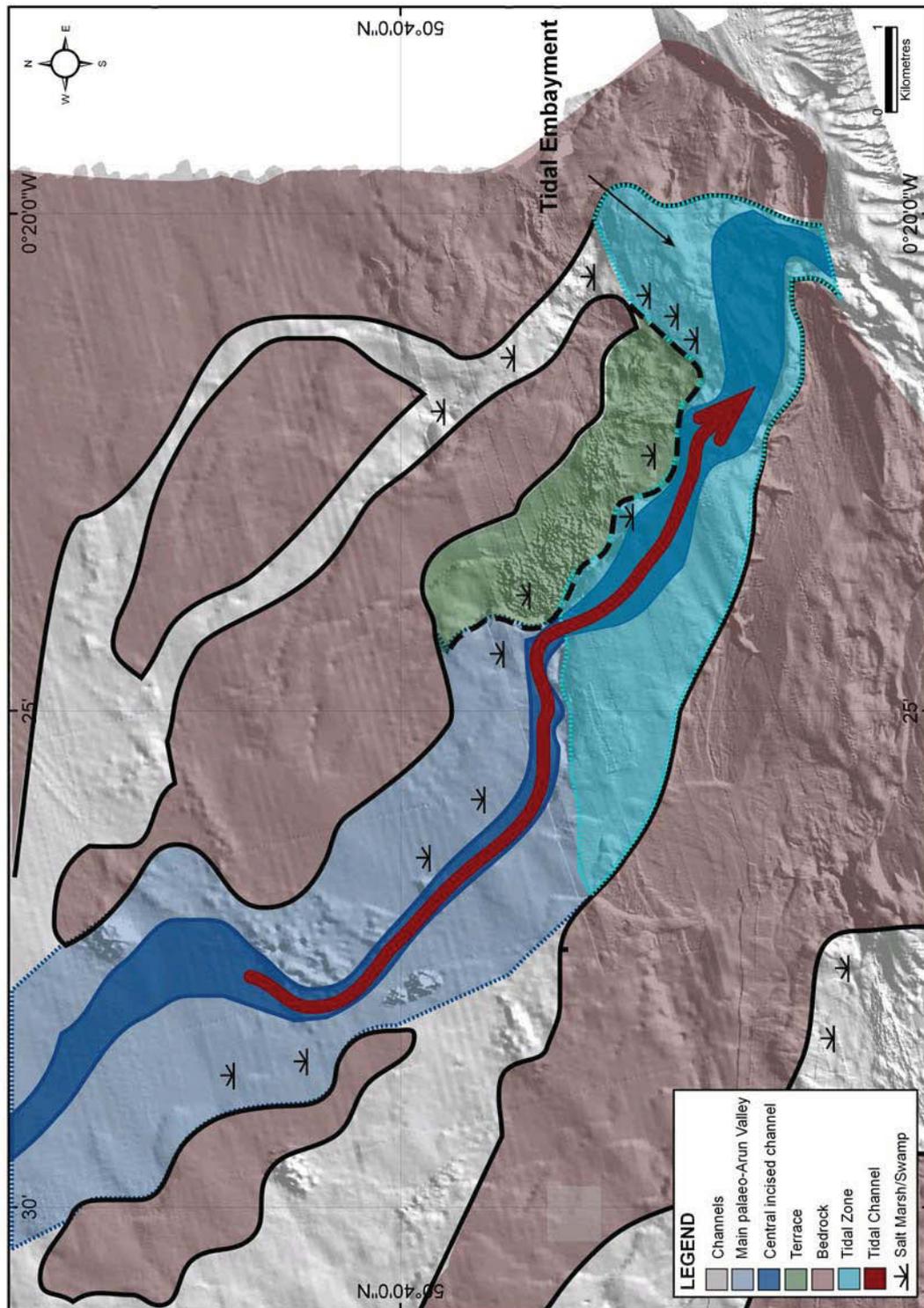


Figure 5.40 Palaeogeographical reconstruction of the middle and lower sections of the main Palaeo-Arun Valley at a time prior to 10,000 BP. Based on data collected from seismic surveys, vibrocore sedimentology and seafloor morphology derived from the multibeam.

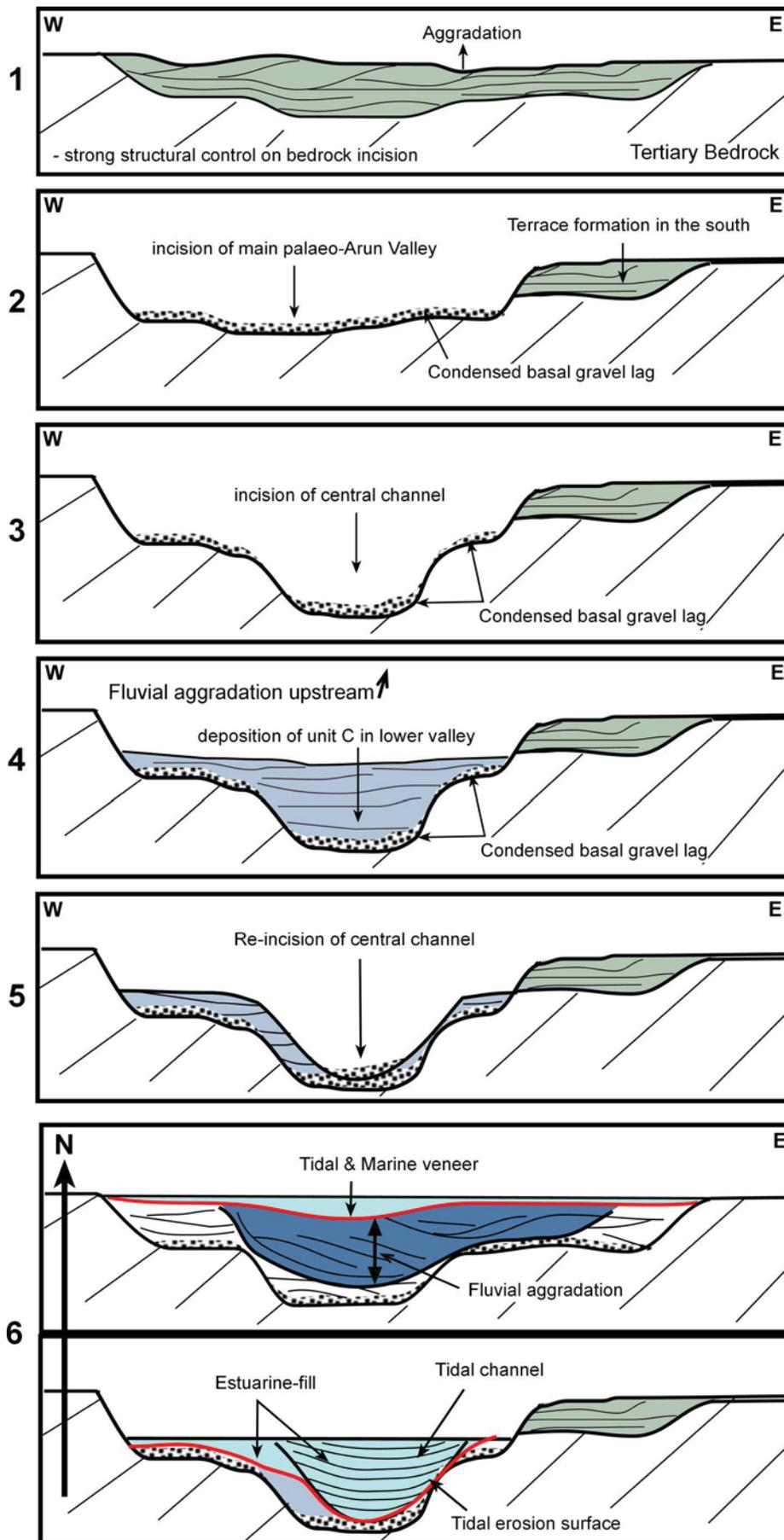


Figure 5.41 Model for the evolution of the palaeo-Arun Valley. The formation of the stratigraphy evident in the valley is illustrated as a series of stages.

3 – Subsequent base level fall relating to a glacial maximum, leads to the incision of the central channel of the valley and the formation of a terrace along the margins of this channel. With each incision a gravel lag (Unit B) is deposited at the base of the valley but no other aggradation occurs. The ultimate downcutting of this surface possibly reflects many cycles of sea level fall.

4 – Transition from cold to temperate stage and the relative rise in sea level (OIS 5). The advancing sea floods the lower reaches of the valley but the coastline does not extend substantially beyond the northern edge of the terrace. During this stage the lower palaeo-Arun would have become a coastal inlet where the depositional regime was influenced by tidal processes. A modern analogy to this on the southern coast would be Portsmouth or Chichester harbours to the west. Deposition of fine-grained sediments (Unit C) representative of marine transgression in fluvial, estuarine and tidal environments fills the valley.

5 – Fall in base level to the last glacial maximum (OIS 2), returns the valley to a fluvial environment. The excavation of the transgressive sediments deposited within the central channel occurs. Their fine-grained lithology would make their removal easy by the coarse sediments and high discharge characterising the periglacial conditions during a glacial maximum. Re-incision dominates the depositional regime of the valley.

6 – Transition from cold to temperate stage and the relative rise in sea level (OIS 1). The lower reaches of the valley are again flooded by the onset of transgression. The decline of cold climates returns the valley to estuarine and tidal sedimentation. Infilling of the channel occurs initially with estuarine sediments that become increasing marine as the transgression continues (Unit F). Further upstream significant fluvial aggradation has occurred, and by the time that the area is flooded only the upper most sediment deposition is marine dominated. The rapid rise in sea level does not allow significant erosion, but the underlying units are reworked and deposited as a marine veneer due to shoreface erosion as the transgression continues.

5.12 FORMATION OF THE TOPOGRAPHIC VALLEY

A dominant feature of the palaeo-Arun Valley is the topographic valley at the southern extent of the study area. The integration of seismic profiles with the high-resolution multibeam has determined the stratigraphic extent of the valley to continue to the east beneath a terrace. The extent of the stratigraphic valley is strongly controlled by the regional dip of the underlying bedrock. This is seen in the sub-bottom data as prominent dipping reflectors and outcropping on the sea floor forming ridges. The majority of the valley has been completely filled by sediment prior to marine planation, but this is not the case for the topographic valley where the sediment thickness is typically only around 5m and there is ~ 15 m of topography in this area. It is difficult to ascertain if the lack of sediment in the lower valley is a result of non-deposition, erosion or a combination of the two. Truncation of the stratigraphy along the eastern margin suggests that downcutting has resulted in the erosion of some stratigraphy. Bellamy (1994) determined the topographic valley to have formed as a result of fluvial

incision during rapidly falling base level that produced the terrace now evident. The investigation of the valley in this study comes to the same conclusion, but would further explain the extensive incision in the study area by a change in the gradient of the valley at this location.

The lower valley is very close to the confluence with the Northern Palaeovalley of the English Channel. The Northern Palaeovalley was a much larger system that flowed from the east and joined the Median Palaeovalley offshore from Cherbourg, France before continuing westward along the Hurd Deep (Antoine et al., 2003). The palaeo-Arun is a tributary of this larger fluvial system. It is inferred from the bathymetry available that the incision of the Northern Palaeovalley was topographically about 10 m lower than that of the palaeo-Arun (Hamblin et al., 1992). The incision of a fluvial valley reflects the need of the system to maintain a stable gradient (Bridge, 2003). Consequently, if there is an increase in the slope downstream the response will be an increase in the incision by knickpoint retreat upstream. The response of a fluvial valley to sea level fall is also strongly controlled by the relative slope of the coastal plain to that of the shelf. When sea level falls the fluvial system will respond by channel extension with incision or aggradation in order to equilibrate the relative slope of the coastal plain to that of the shelf (Blum and Tornqvist, 2000). The prominent bedrock outcrop and the relative topographic height of the Northern Palaeovalley suggest that when the sea level fell to such a depth that the area was exposed the lower palaeo-Arun was in a position where the slope of the upper reaches were less than those downstream. Consequently, the extension of the valley in this area was dominated by incision. Superimposed on this incision is the control of climate on sediment supply, which resulted in coarse-grained sediments deposited upstream during base level rise. The rapid transgression only allowed a relatively thin fine-grained stratigraphy to be preserved before flooding of the area and submergence of the terrace and valley landscape.

5.13 SUMMARY

The complex cut and fill history preserved in the palaeo-Arun Valley reflects a fluvial system that has evolved through the Quaternary due to repeated fluctuations in sea level. Sediments were transported onto the English Channel Shelf by high-energy fluvial processes in response to a significant change in the climate. Mapping of the basal erosion surface across the shelf suggests that the submerged valley is the offshore equivalent of the Arun River and is confluent with the Northern Palaeovalley of the English Channel. This valley is just one of many that occur in the eastern English Channel and represents a good starting model for the investigation of other systems to determine the regional extent of chronostratigraphic horizons preserved in the valley fill. The presence of these channels on the shelf indicates the influence of cold climate, periglacial conditions during ice sheet growth that left the shelf subaerially exposed. The incision of the valley was controlled by a fall in base level due to climatic forcing. The underlying bedrock, which has a strong structural fabric, controlled the actual position of this incision. It is suggested here that the basal erosion surface of the valley reflects many cycles of sea level change and is probably at least OIS 12 (Anglian) in age if not older.

Base level fall during cold stages resulted in downcutting that produced a prominent terrace in the lower valley. The topography of the lower valley formed by this downcutting and its location on the shelf placed this area into a unique bathymetric position. During much of OIS 5a-5e (Ipswichian) the lower valley was subject to marine flooding as sea level fluctuated between -20 and -40 m. Consequently, the lower valley is dominated by fine-grained fill typical of an estuarine setting. However, during this period the middle section, which was situated landward of the coastline, remained in a fluvial environment.

The transition to a temperate climate resulted in base level rise and the accumulation of fine-grained organic-rich sediments in the lower valley. The thin sediment thickness in the lower valley is also due to the position of the lower valley near the confluence with the Northern Palaeovalley. A significant variation in the gradient of the slope produced enhanced incision during cold stage falls when incision was dominant over aggradation. In the upper reaches of the valley aggradation of coarse-grained sediments occurred in response to the climatic change. Aggradation of the valley sequence is typified by backfilling of channels incised and partially filled during base level fall.

Following the last glacial maximum rapid transgression resulted in marine flooding of the area so that the landscape of the palaeo-Arun Valley was submerged and preserved with minimal marine planation. Transgressive deposition is limited to a thin veneer over most of the area, but forms a thick deposit at the point of the shelf where a decrease in the rate of base level rise resulted in erosion during shoreface retreat.

5.14 REFERENCES

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