

Chapter 4 Seismic Sequence Stratigraphy

4.1 Introduction

This chapter outlines the gross geometry of seismic packages and basin-fill history. All seismic profiles across the Longford Sub-basin were used for interpreting seismic sequences. Lines TB01- SA, SB and PM were studied in greater detail because they contain the most detailed and informative view of Tertiary deposition. Seismic sequence interpretations are based solely on seismic reflection characteristics with very limited data (figure 4.1) used to constrain lithologies and age. Details on integration of well log and seismic stratigraphy are discussed in Chapter 5. Isochron maps (TWT) help to illustrate the geometry of packages defined from seismic profiles.

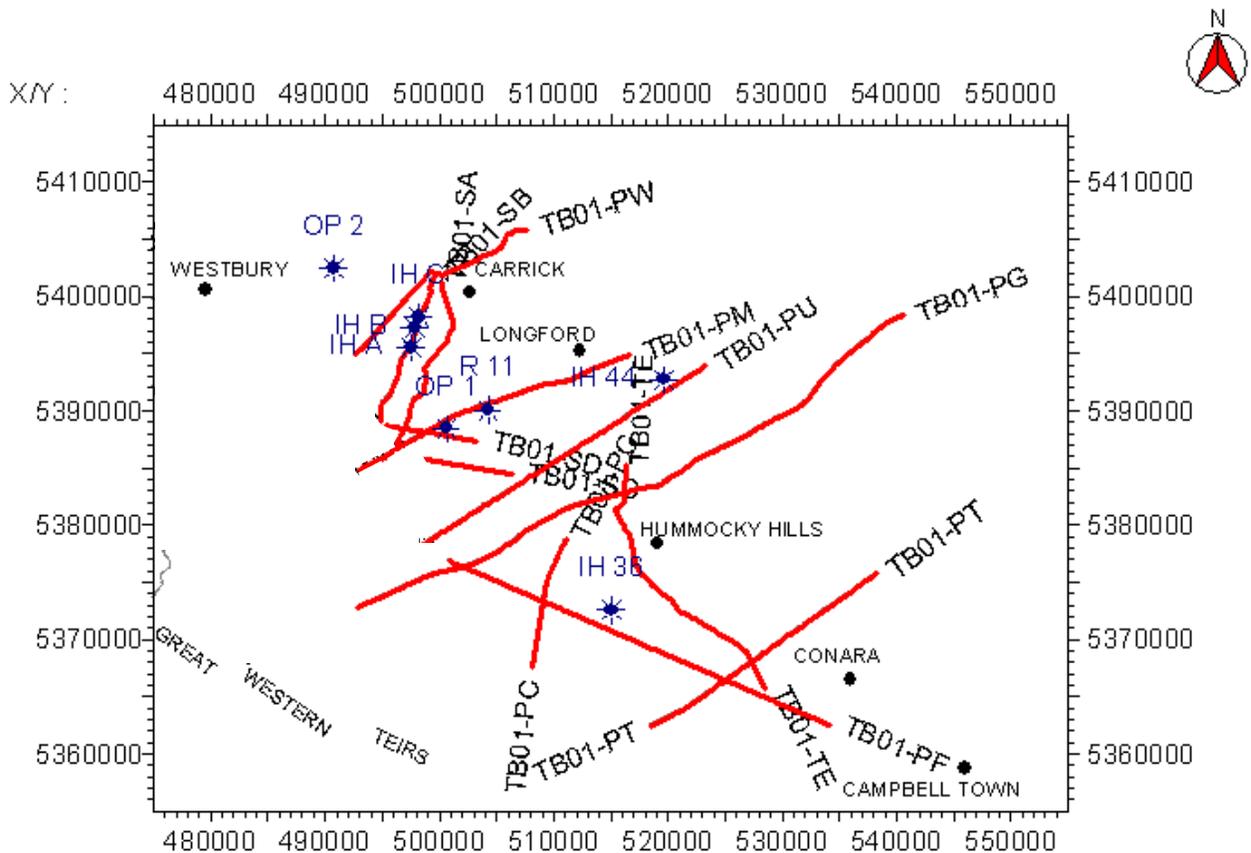


Figure 4.1: Base map of the Longford Sub-basin, with seismic grid and well locations (Coordinates are in meters on the AMG grid, AGD 1966).

Seismic interpretation was carried out to develop a stratigraphic and structural (Chapter 6) framework for the Longford Sub-basin. The first step was to outline seismic facies, by identifying genetically related packages on the basis of reflection patterns. Sequence boundaries were interpreted on the basis of reflection termination. The main termination surfaces (figure 4.2) commonly encountered in seismic reflection data are onlap, downlap, toplap and erosional truncation as outlined by Mitchum et al. (1977). Sequence boundaries for the Longford Sub-basin have been interpreted primarily from onlap and truncational surfaces.

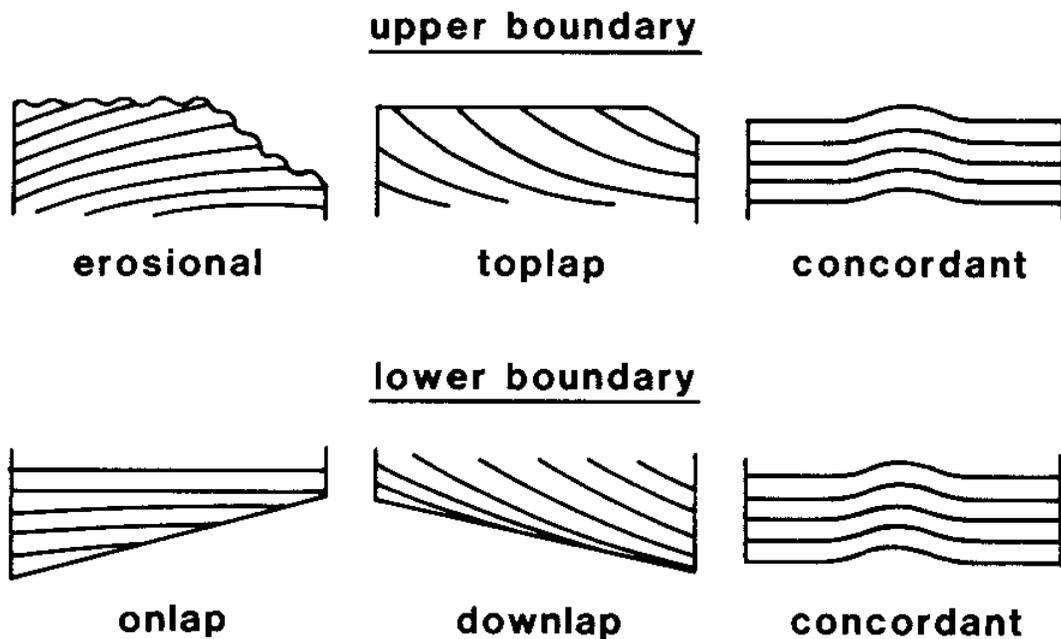


Figure 4.2: Different types of geological boundaries defining seismic sequences (Mitchum et al. 1977).

From the 12 seismic profiles, 8 seismic packages (including basement) have been interpreted for the basin. A summary of the seismic analysis is given in Table 4.1. Representative profiles are shown in figure 4.3a and 4.3b.

Interpretation					
Sequence (S)	Thick. (metres)	AGE	SEISMIC CHARACTERISTICS	BOUNDARIES	EVENT/PHASE
S1	70-160	mid-late Eocene	Low amplitude chaotic reflectors	Truncational surface Lower- unconformity	Uplift/localised transpression
S2	60	<i>Proteacidites pachypolus</i> zone middle Eocene	High amplitude parallel reflectors	Toplapping surface Internal onlap Lower-conformable	Minor faulting
S3	60	middle Eocene	Low amplitude chaotic reflectors	Truncational surface	Sag Phase?
S4	100-350	early to middle Eocene	High amplitude parallel reflectors changing laterally to low amp.	Lower-conformable	Major faulting-eastern sub-basin formation
S5	95	Palaeocene to early Eocene	Consistent high amplitude reflectors- parallel	Upper-conformable Lower-Onlap surface	Fault controlled deposition
S6	30-120	late Palaeocene	High amplitude reflectors Short, highly truncated, high amp. reflectors	Upper-truncational surface Lower-Basal unconformity	Major faulting western sub-basin
S7		late Palaeocene	Prograding reflectors	Upper -truncational surface	Pre-syn- or post-rifting deposition
S8		pre-Jurassic	High amplitude reflectors Uniform chaotic reflectors High amplitude reflectors	upper erosional unconformity	Pre-rift

Table 4.1: Summary of seismic stratigraphy

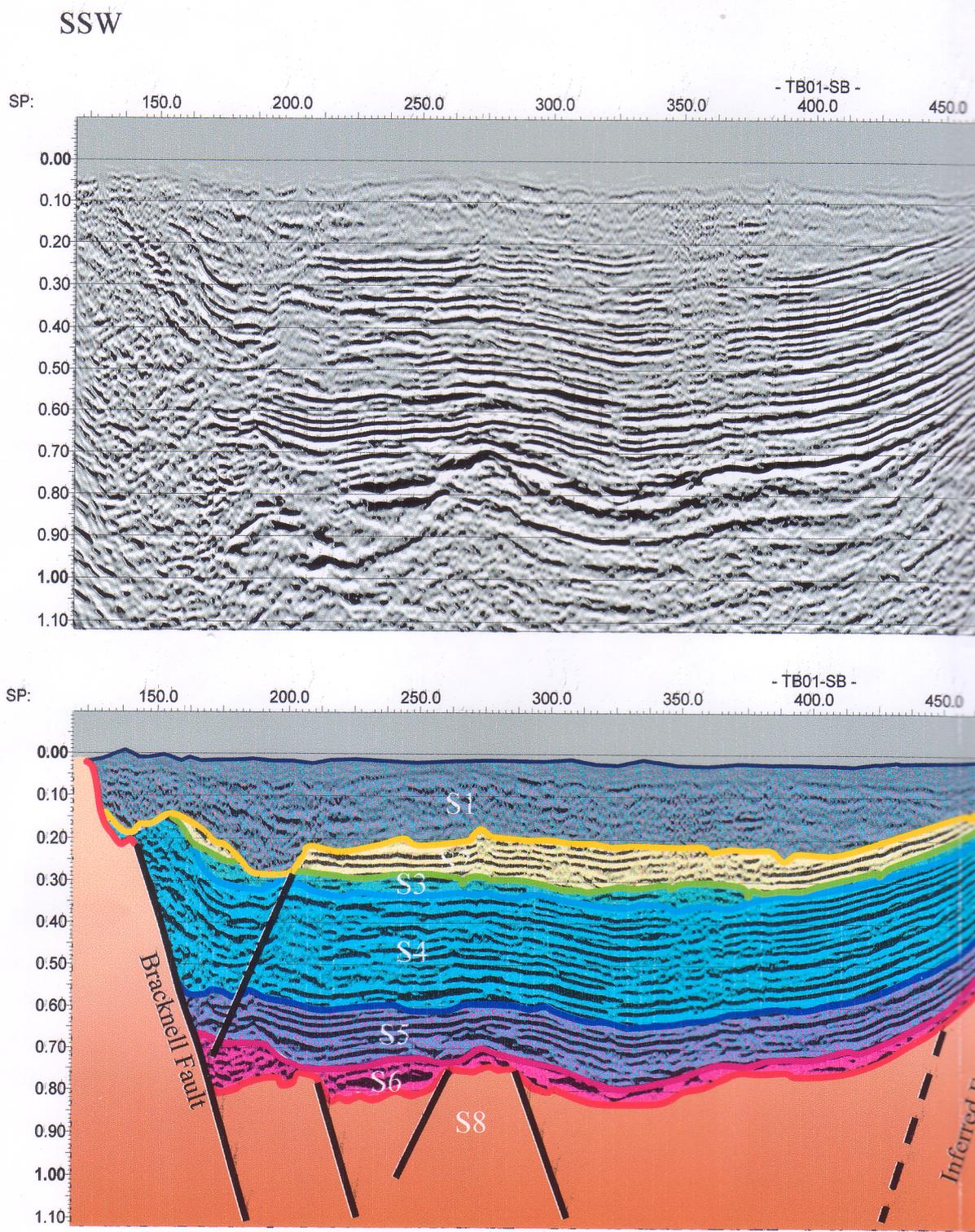
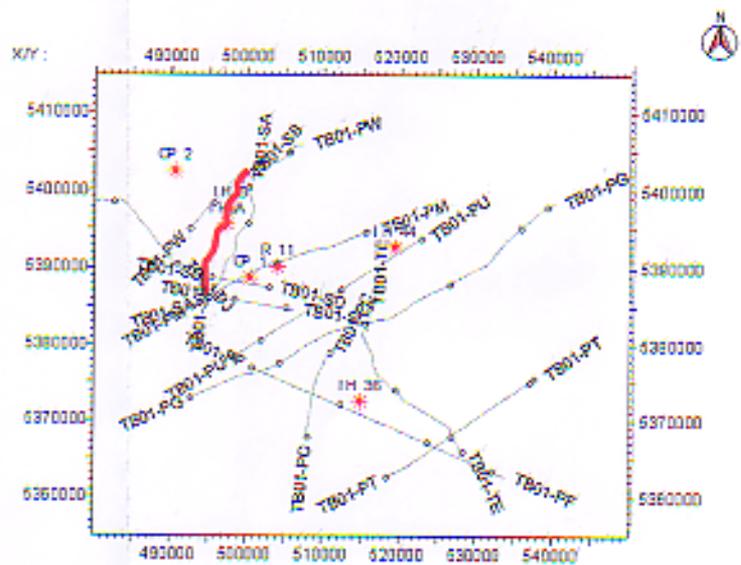
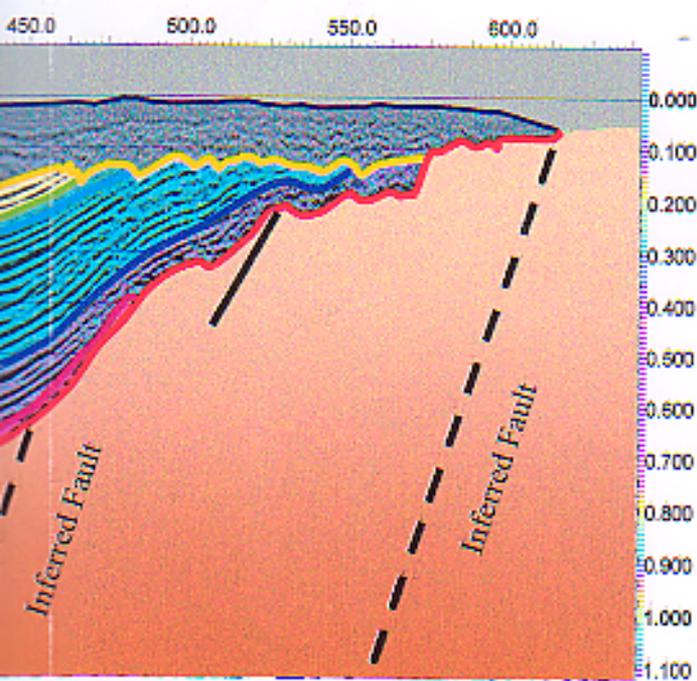
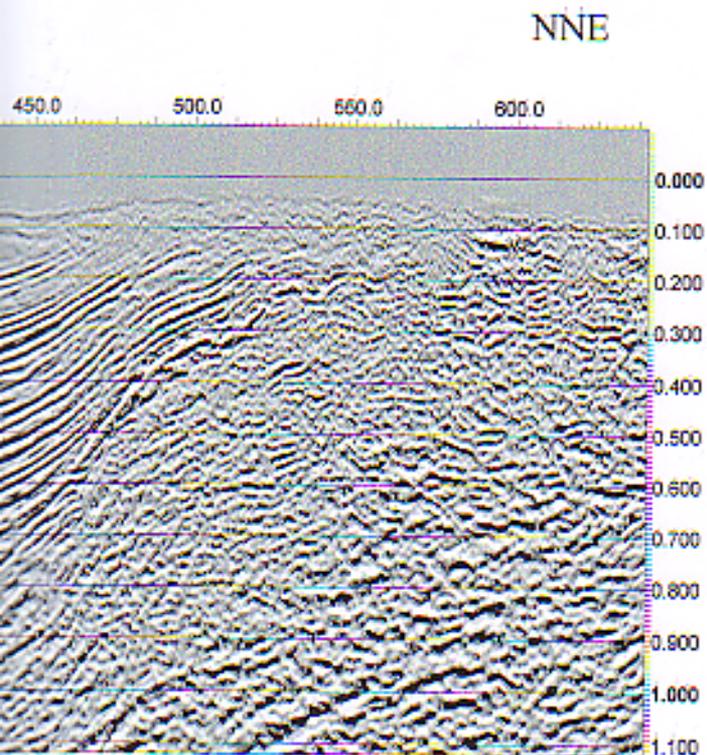


Figure 4.3a: Seismic Line TB01-SB with seismic sequence interpretations. S8 represents the base of the sequence. The colour of the sequence boundary corresponds to the underlying package.



represents basement which in most cases is Jurassic dolerite.
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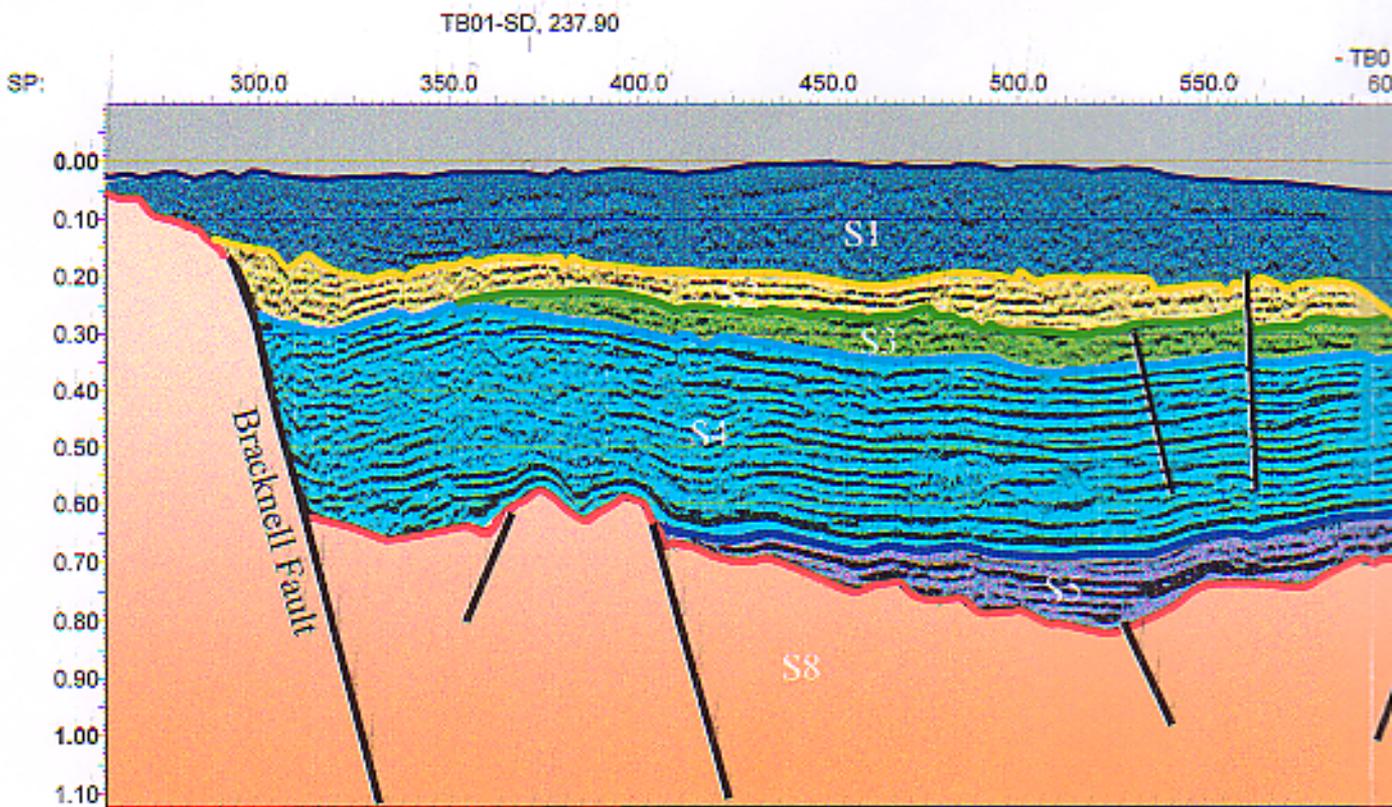
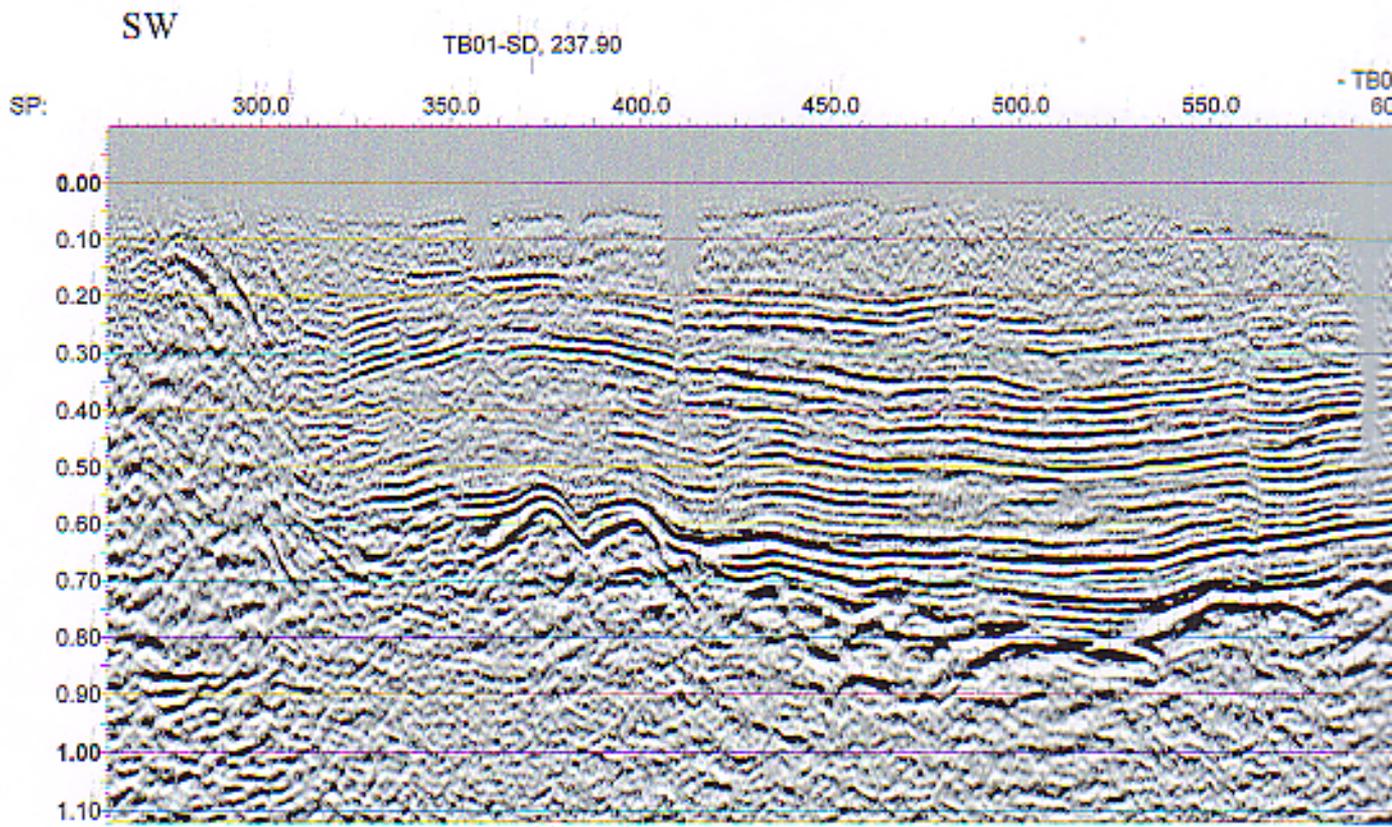


Figure 4.3b: Seismic Line TB01-PM with seismic sequence interpretations. This

4.2 Stratigraphic Nomenclature

The seismic stratigraphic synthesis of the Longford Sub-basin follows that of Vail et al. (1977) sequence stratigraphy definition. Stratigraphic packages, interpreted on the basis of seismic reflection character, are referred to as “sequences”. By definition a sequence is a “relatively comfortable succession of genetically related strata bounded by unconformities or their correlative conformities”(Mitchum et al. 1977 p.53). Based on palynological dating, basin fill lasted approximately 30m.y (Matthews 1983). Prothero & Schwab (1996) designed a hierarchy of the sequence boundary terms. The 3rd order term “sequence”, is more applicable for the Longford Sub-basin due to the short time frame in which the basin was filled. Seismic data can resolve 1st, 2nd and 3rd order basin events, whereas geophysical logs produce higher resolutions down to 4th and 5th order scales. Stratigraphic units, identified on the basis of well logs and correlated back to seismic reflectors, are referred to here as members (differing from standard lithostratigraphic definition).

Sequence stratigraphic principles, formulated for marine environments, work especially well for lacustrine strata, because sediments are still deposited in layers that are bounded by physical surfaces caused by numerous sedimentary changes and hiatuses (Bohacs 1999).

Sequence 8 (S8) constitutes Parmeener Supergroup sedimentary rocks and Jurassic dolerite. Together, these sediments and rocks form part of the larger Tasmania Basin and do not conform to the 3rd order sequence nomenclature. In this study they form the surface for Tertiary deposition and are referred to as ‘basement’ herein.

4.3 Sequence 8 (S8)

S8 is the oldest sequence identified as pre-rift. This unit largely consists of Jurassic dolerite sills averaging 500m thick that form the immediate base for Tertiary deposition, increasing where preservation of Upper Parmeener above the Jurassic dolerite has occurred. Beneath the dolerite is the 700m thick Parmeener Supergroup. The dolerite appears to contain internal stratification, possible evidence of structuring from successive pulses.

The seismic character of dolerite (figure 4.4) is distinct, with very high amplitude reflectors at the top, followed by a uniform thickness of chaotic reflectors, then finally a high amplitude reflection representing the base of the sill in contact with Parmeener Supergroup sediments.

The very high amplitude reflection is consistent with what is expected when a seismic wave departs unconsolidated sediments and enters a massive coherent igneous body. Similarly, but a less pronounced effect occurs when the signal moves from the igneous body into a consolidated unit.

A major fault scarp bounds the western edge of the Longford Sub-basin with pre-rift basement down thrown to the east.

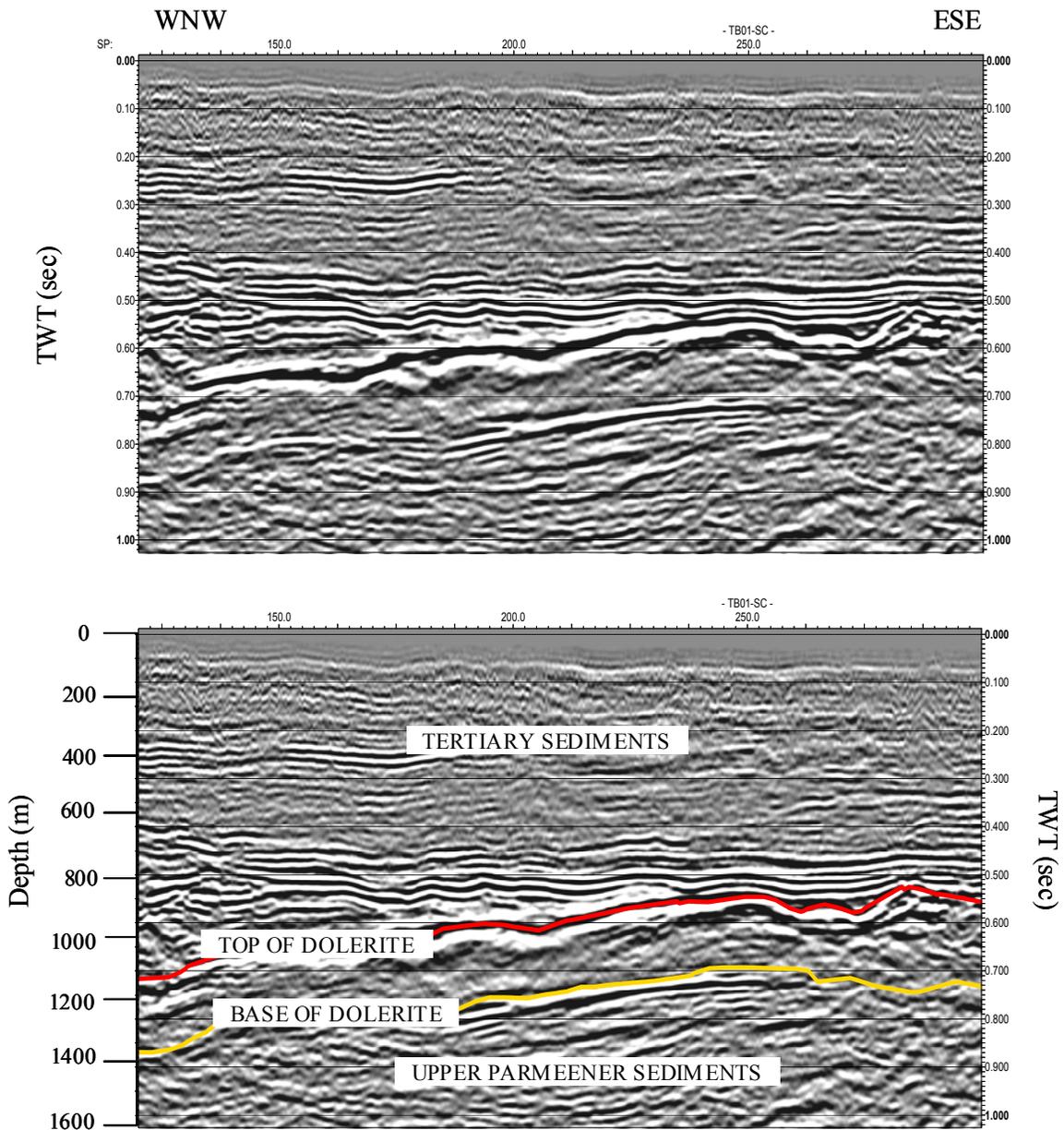


Figure 4.4: A seismic facies interpretation of line TBO1-SC. S8 or basement to the Tertiary sediments is represented by Jurassic dolerite and Upper Parmeener Supergroup. This is one of the best examples of dolerite seismic character beneath the Longford Sub-basin. Depth conversion can be done using the time-depth log.

4.4 Sequence 7 (S7)

S7 is restricted to the eastern margin of the basin and has only been identified on seismic profile TB01-PM. This unconformity bound unit has reflectors of variable amplitude with a distinct prograding character. The upper sequence boundary is an obvious truncational surface, with contrasting planar bedding of S5 overlying prograding strata. There are numerous possibilities for the timing of S7 deposition. They include pre-, syn- or post-rifting by means of mass movement, channeling or deltaic deposition. S7 may well be contemporaneous with S6 because there is no evidence that the later truncates it. It is possible that S7 is a fluvial deposit that connected to a lake deeper in the basin, providing the source of fine grain sedimentation.

4.5 Sequence 6 (S6)

S6 represents the beginning of the Tertiary depositional phase into the depocentre of the western sub-basin. S6 is identifiable on seismic profiles TB01-SA, TB01-SB and TB01-PW and is penetrated by oil prospecting hole (OP2) at Hagley in the extreme north of the basin. The northern-most seismic line within the grid TB01-PW lies to the south of OP2 and has a depth to basement of 752m (0.8sec TWT). OP2 intersects basement at 792.5m. Sequence S6 most likely correlates with the basal package of the Longford Sub-basin in OP2 but the possibility of a lower package cannot be discounted. The interval between 700 and 790m in OP2 is interpreted as equivalent to S6. Lithologies in this interval are sand, shale and wood fragments (Matthews 1983, Appendix 6). Palynological studies on OP2 by S.M Forsyth, give tentative age constraints on S6. He reported a Palaeocene age for samples between 682.8-688.9m and a probable Paleocene age at 749.8m (Matthews, 1983).

Assuming S6 is the basal package, the lower sequence boundary represents the major basal unconformity of the Longford Sub-basin. This unconformity separates the Mesozoic rocks from the Cainozoic basin fill. The unconformity surface exhibits topographic relief up to 250m, an indication that erosional processes dominated during the Cretaceous depositional hiatus. On line TB01-SA, S6 onlaps the basement dolerite, while the overlying sequence truncates the package forming a toplap surface (figure 4.5). Minor faulting at the end of S6 deposition is interpreted.

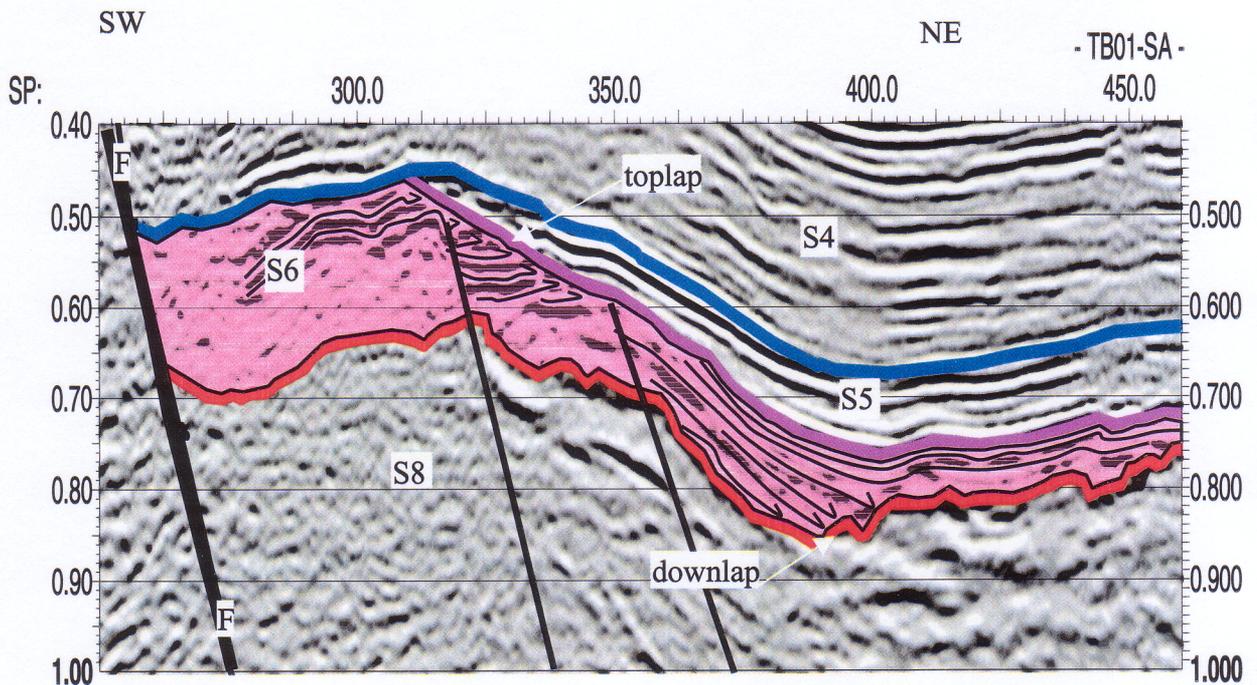


Figure 4.5: Sequence boundary indicators for S6 on seismic line TBO1-SA. The prograding nature of S6 is dissected by normal faulting and has been truncated by overlying S5

S6 shows a progressive thinning from 120m (0.16sec TWT) in the southwest to 30m (0.04sec TWT) in northeast. Most of thinning is due to onlap and truncation by the overlying S5 sequence.

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S6 is characterised by high amplitude reflectors. Reflection geometry depends greatly on the position within the basin. On line TB01-SA, S6 has prograding reflectors over a basement high before onlapping the basement. This unit is interpreted as consisting of deltaic facies with sediment provenance to the west. To the north, on line TB01-SB (figure 4.3a), the basement high is not present and S6 was deposited in excess of 150m lower in the basin. Here, S6 characterised by short, highly truncated, high amplitude reflectors. South of line TB01-PM, S6 is not evident on the seismic profiles.

4.6 Sequence 5 (S5)

S5 is a distinct seismic package, constrained by drill-hole OP1 and Investigation Hole (IH) C. This sequence is characterised by a marked increase in coal (lignite in IH C), interbedded with sand and shales. Palynological dating of samples from the base of OP1 estimates a broad age range of late Tertiary to pre-middle Miocene (Matthews, 1983). Dating of samples from OP2 appears to have tighter age constraints. Correlation of seismic sequences to near OP2 indicate that S5 is probably Palaeocene to early Eocene in age.

S5 lower sequence boundary marks a significant unconformity within the Longford Sub-basin. In the south-southwest, on line TB01-SA, the lower sequence boundary is an onlap surface over topographical highs. Towards the north-northeast the package is largely conformable before onlapping the eastern margin (figure 4.6). South on line TB01-PM, S5 directly onlaps basement in the western sub-basin. Minor faulting at the end of S6 being deposited has ceased before commencement of S5 deposition.

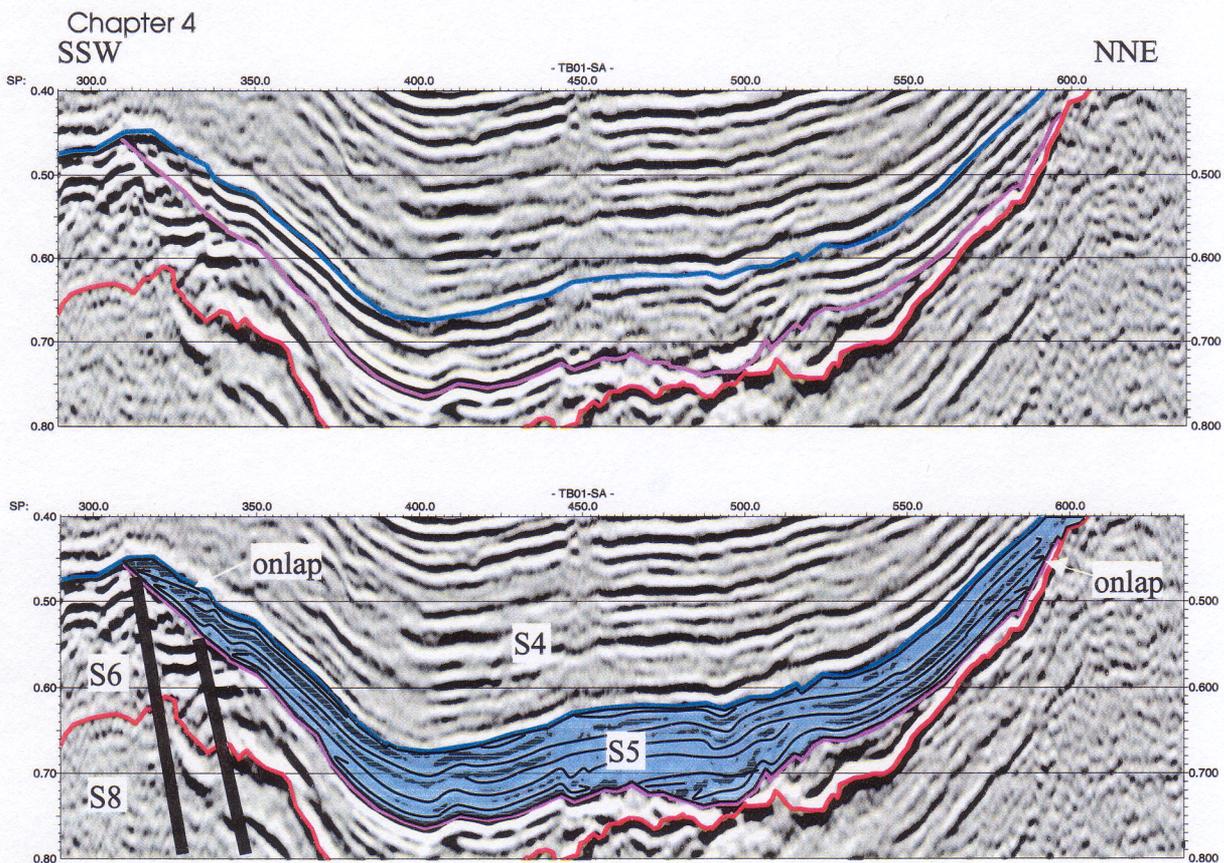


Figure 4.6: Reflection termination surfaces for seismic facies S5, Shows onlap, downlap and truncation of underlying sediments. It appears minor faulting at the south western end of the seismic line has displaced S8 and S6, but not S5.

The maximum thickness of S5 is 95m in the main depocentre in the northern area of the basin. This is a good estimate of the original depositional thickness because truncation or erosion by overlying S4 is minimal. Laterally the package thins towards the basin margin as a consequence of onlap.

S5 is characterised by very high amplitude, continuous, near parallel reflectors. Very high amplitude reflectors are consistent with thick brown coal seams. S5 has consistently continuous reflectors, bringing about an interpreted lacustrine environment flanked by rugged topography. An apparent truncation and onlap surface occurs in the middle of S5. There is no change in seismic character either side of this surface and it is not identifiable in the gamma-ray log from OP1. For these reasons, the surface is not interpreted as a sequence boundary.

4.7 Sequence 4 (S4)

S4 is the largest seismic package of the Longford Sub-basin, but still poorly constrained in consideration to its thickness and proximity to the surface. S4 is contained by wells OP1 and OP2. Wells IH B, IH C and IH 44 near the eastern margin, provide the only other place that S4 is penetrated. The lithology is coarse to fine sandstone, siltstones, shale and minor lignite beds. S4 is early to middle Eocene from palynological dating by M.Dettmann on IH B and, Esso on OP2 and IH 44 (Matthews 1983).

S4 is conformable to underlying S5. Reflectors appear to onlap the western boundary fault and eastern margins. The overlying S3 sequence truncates these packages especially over high relief areas (figure 4.7a). Within S4, reflectors downlap internal unconformity surfaces, which are then onlapped by overlying sediments (figure 4.7b).

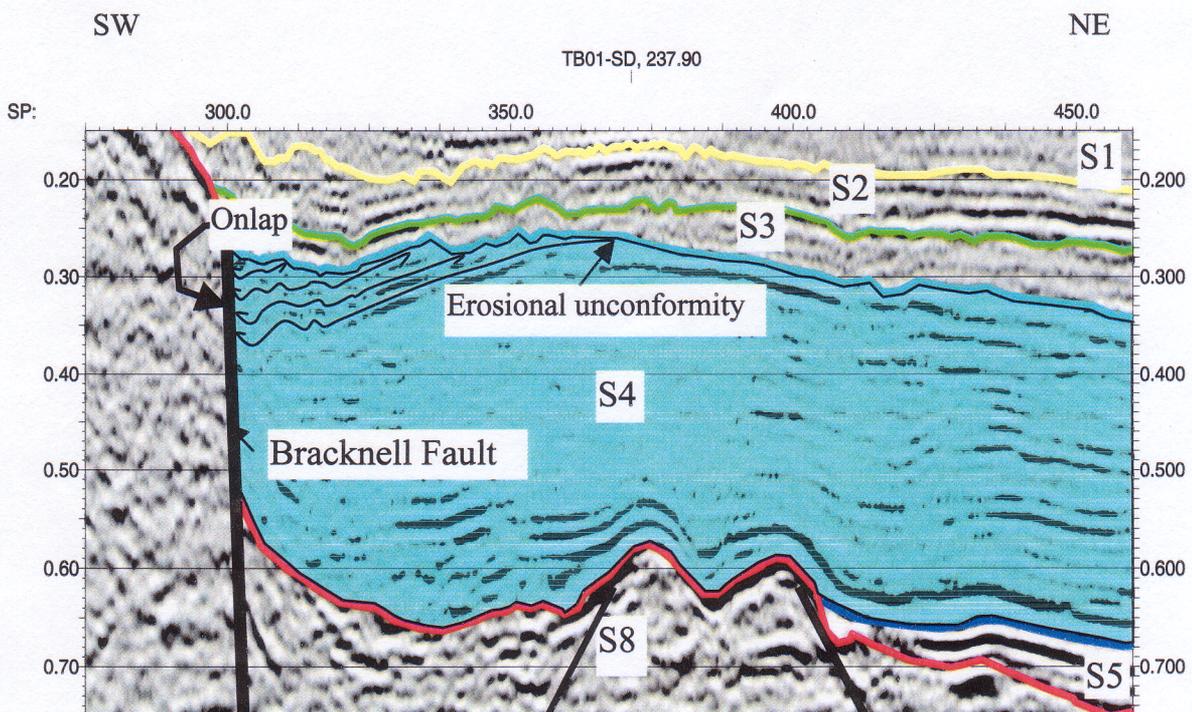


Figure 4.7a: Upper sequence boundary indicators for S4. Reflectors onlap the Bracknell Fault (western margin) and are truncated by overlying S3.

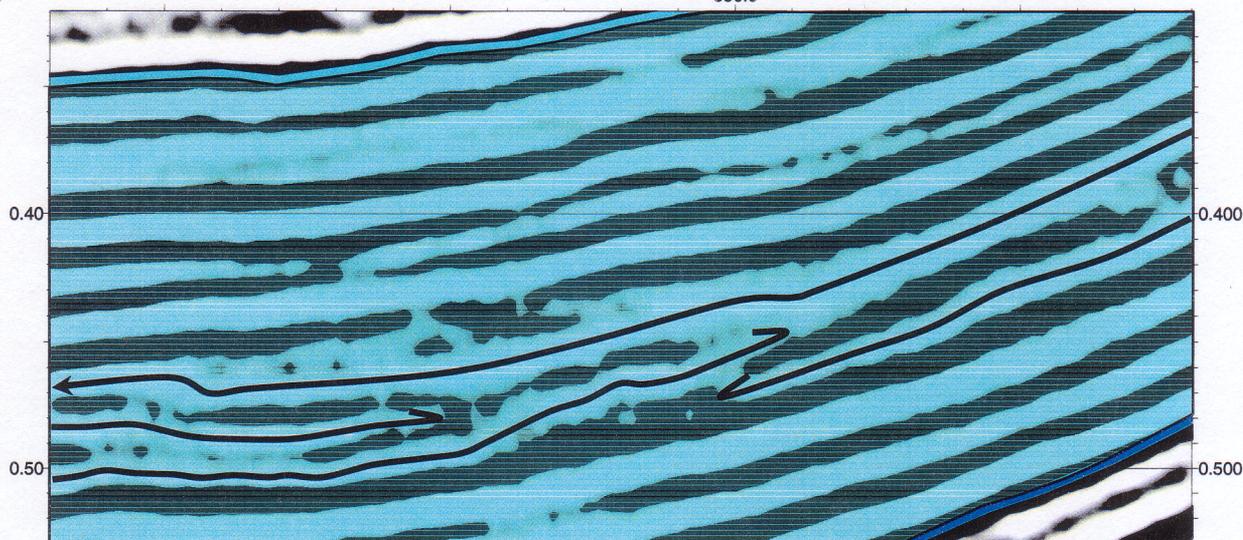


Figure 4.7b: Seismic line TB01-PM showing the changing pattern of sediment supply. The first unit overlies an internal sequence boundary, that is in turn overlapped. The upper continuous units may represent a shoreline transgression caused by an increased base level of the lake.

Representing changes in direction of sediment supply within S4 are surfaces inferred as minor sequence boundaries, and where possible, were tied throughout the seismic grid. A higher resolution breakdown of these surfaces is achieved through the gamma-ray log of OP1 (Chapter 5).

In the north of the basin, S4 has a relatively uniform thickness of 350m (0.3 sec TWT) that thins to 240m (0.2 sec TWT) at the eastern periphery. Thinning appears to be the result of internal onlap of strata. The original depositional thickness may not be preserved, with at least 50m of sediment stripped by the overlying erosional unconformity S3 (figure 5.7a) and uppermost package S1. S4 is interpreted to occur as far south as line TB01-PG with a thickness ranging from 100m (0.11 sec TWT) to the west of Hummocky Hills and 250m (0.21 sec TWT) to the east. The uniform thickness of S4 (figure 4.8) suggests comparable rates of deposition and subsidence along the Bracknell Fault. S4 represents the beginning of deposition into the eastern sub-basin. The package thins and thickens above tilt blocks, suggesting deposition is largely fault controlled (see Section 6.3.2).

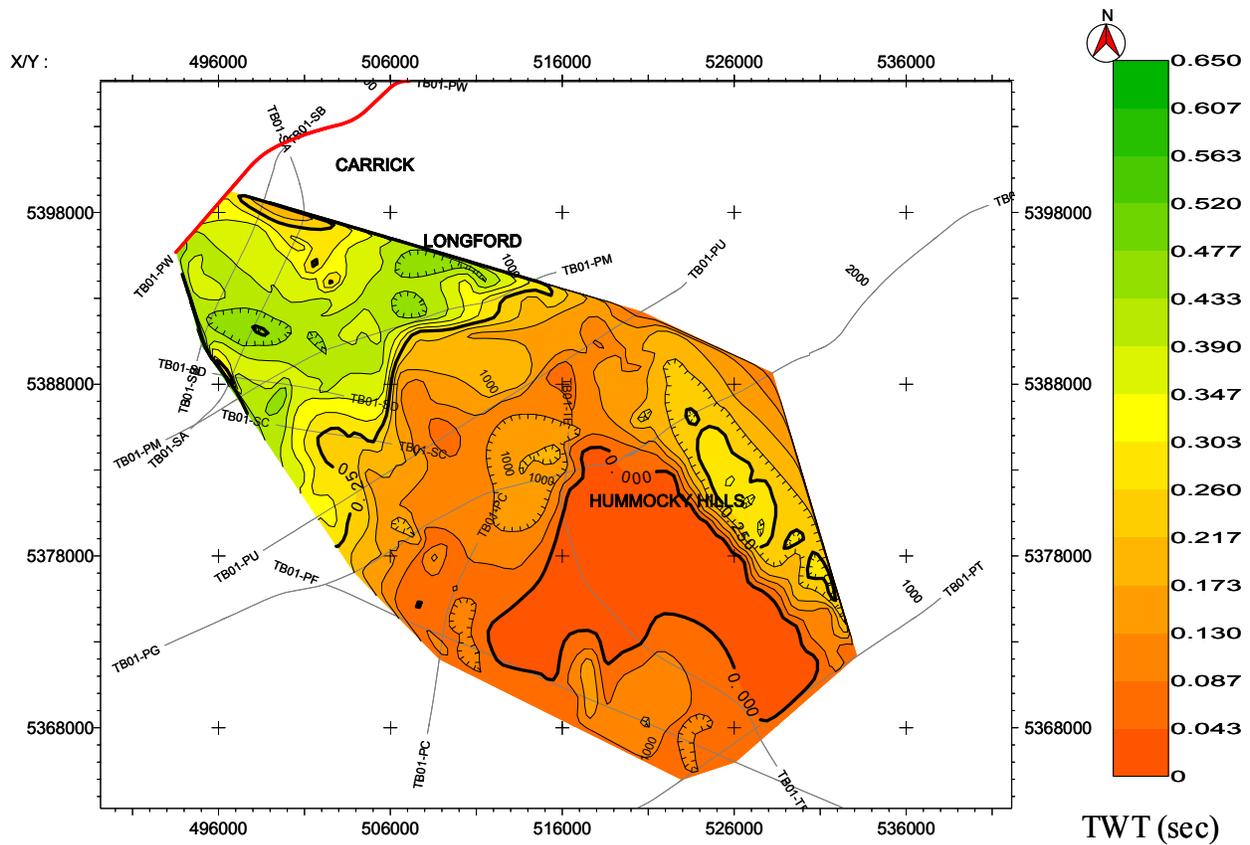


Figure 4.8: Isochron map of S4 to basement. The thickest section occurs to the north, however there is S5 and S6 below S4 in this area. The basement is shown to be dipping towards the NW and S4 overlies this dipping surface.

The seismic character of S4 is very distinct throughout the northern area of the seismic grid (Lines TB01-PW, TB01-SB, TB01-SA and TB01-PM) where it is characterised by high amplitude, continuous (basin wide), parallel reflectors changing laterally to low amplitude appearance. This change in seismic facies (figure 4.9) distinguishes S4 from the surrounding packages. The facies change may represent a transition from shallow water lacustrine environment (high amplitude reflectors) to sub aerial marginal deposit (low amplitude reflectors). Alternatively, an association with a local basement high could suggest a fault-activated relationship (Section 6.4).

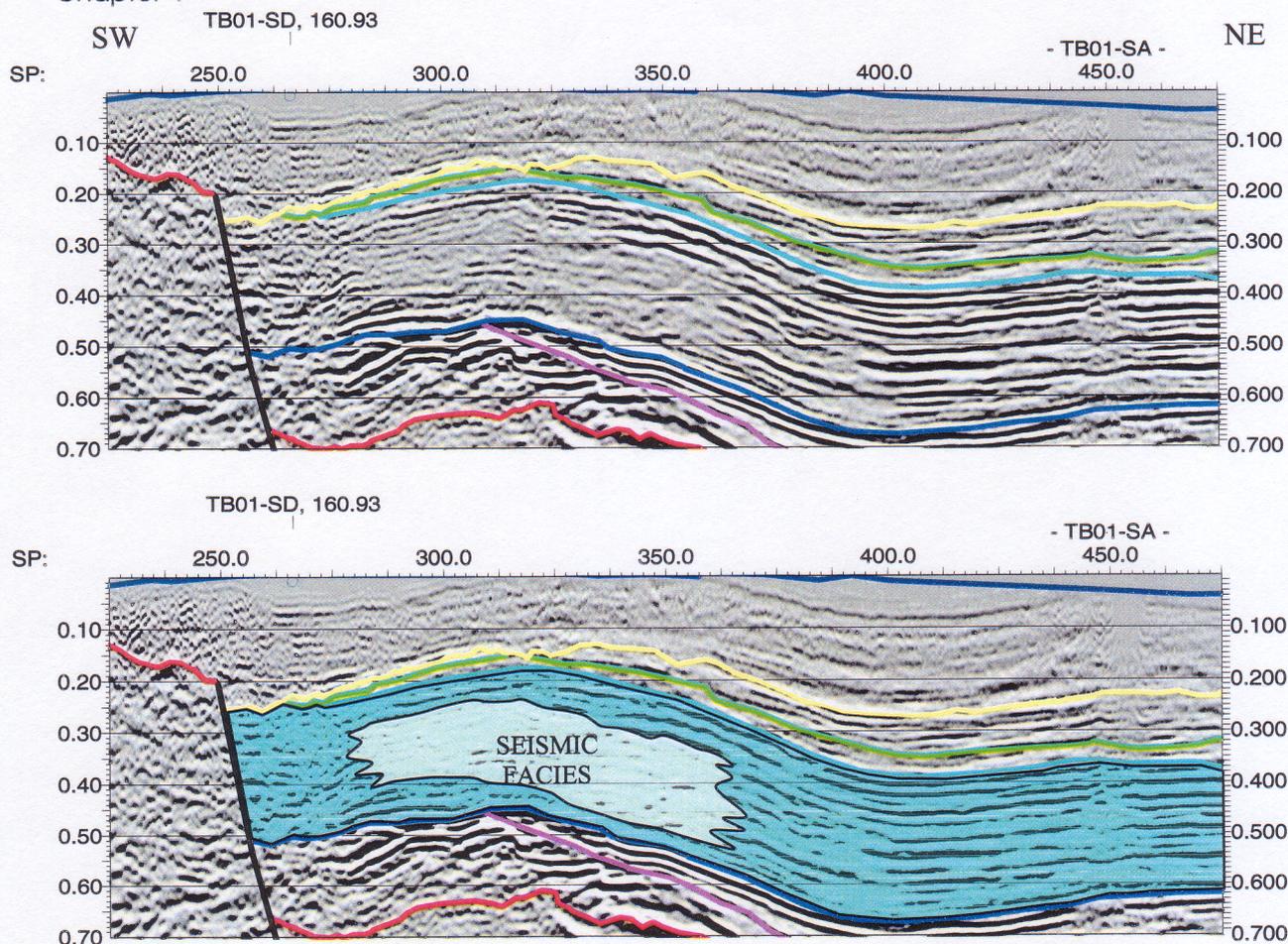


Figure 4.9: Seismic profile TB01-PM, with interpreted seismic facies change occurring within S4, above a local basement high. This facies change may be in response to fault readjustment or changing depositional environment.

In the eastern sub-basin on lines TB01-PU and TB01-PG, the seismic character of S4 is retained. This indicates that the eastern and western sub-basins were connected during their evolutionary history. The tabular zone of chaotic reflectors on line TB01-PU over the eastern sub-basin is possibly basalt (figure 4.10). Matthews (1974) 1:100,000 Longford Sub-basin geology map displays an increase in surface basalt to the north and infers continuation at depth in a southeasterly direction beneath line TB01-PU.

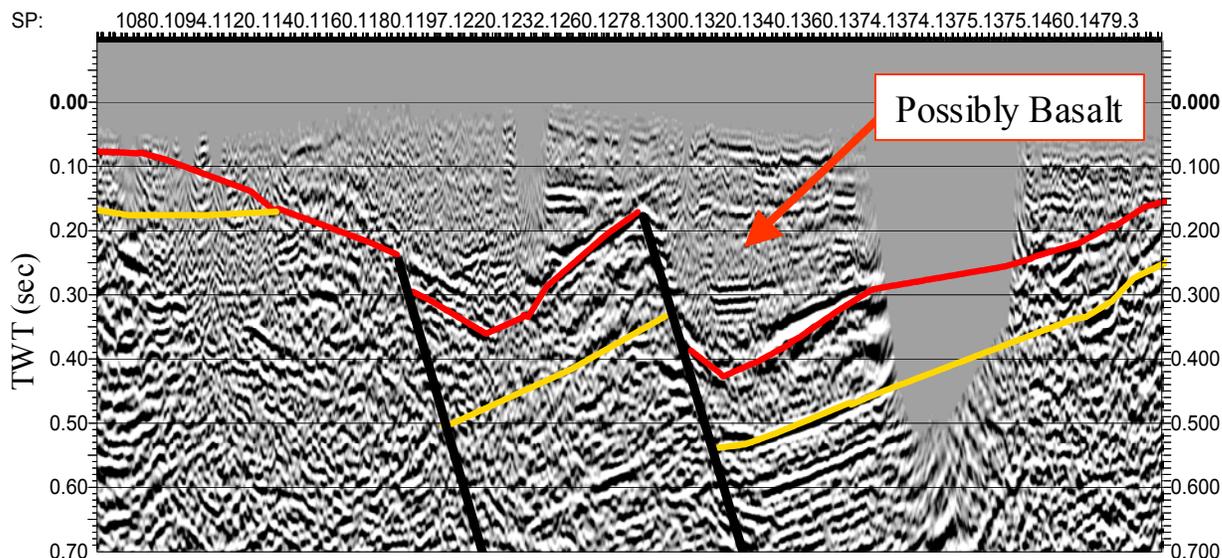


Figure 4.10: Possible basalt at depth on line TB01-PU. This interpretation is based on chaotic reflectors of a tabular nature, coinciding within an area of known occurrence. Processing velocities have remained consistent.

4.8 Sequence 3 (S3)

This seismic package is recognisable because it typically separates two well-imaged packages, S4 and S2. S3 is poorly constrained by wells, with OP1 and OP2 the only holes that intersect this succession.

The OP1 lithology log presented in Matthews (1983) provides no insight in constraining S3, as no sample descriptions were given for the entire package. Based on SP and gamma-ray readings, S3 is probably dominated by an impermeable fine grain lithology. Sequence S3 is probably mid-Eocene based upon similar ages given to rocks well above and below the equivalent depth on OP2 (Matthews 1983).

S3 unconformably overlies S4. S3 lower sequence boundary is an erosional truncation surface that represents a hiatus during the early Eocene.

In the north of the basin, S3 reaches a maximum thickness of 60m (0.08sec TWT) in the main depocentre and pinches out towards the western margin (figure 4.11). The package appears to be confined within a small depression, indicating low energy deposition.

S3 represents a marked change in seismic facies from the underlying S4 and overlying S2 packages. Low amplitude chaotic reflectors characterize S3. Laterally and vertically, there is little variation in seismic character. This suggests a homogenous package, an interpretation supported by lack of variation in gamma-ray and SP logs of OP1.

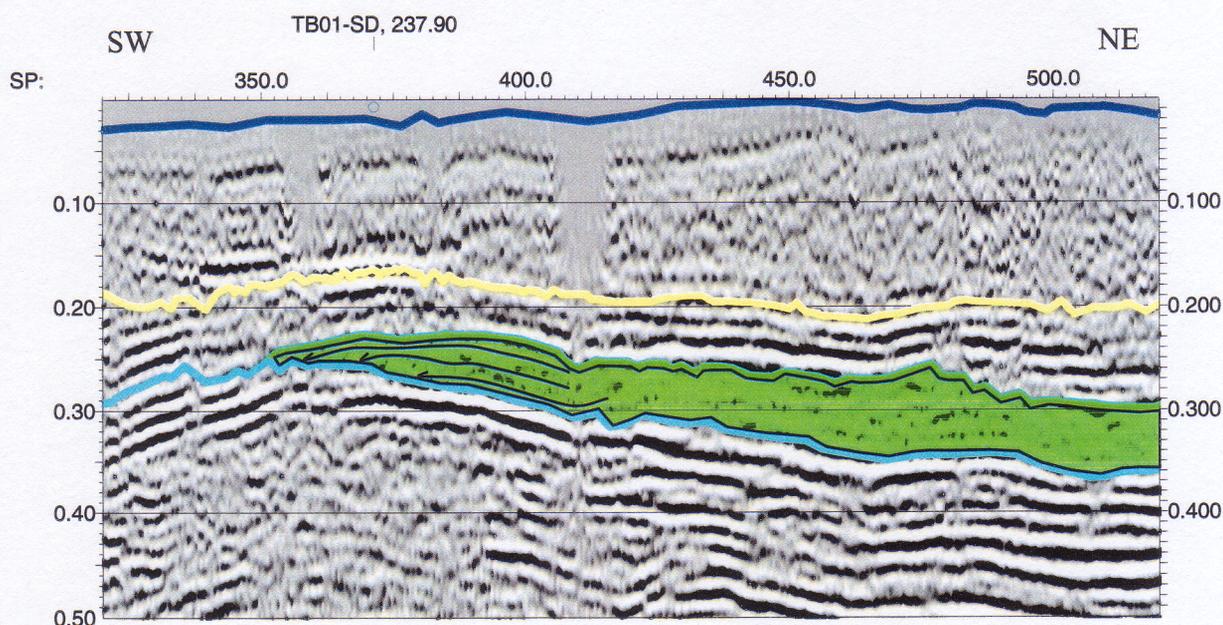


Figure 4.11: Sequence boundaries of S3. The package pinches out towards the margins on line TB01-PM.

4.9 Sequence 2 (S2)

S2 is effectively intersected by wells OP1, OP2, R11 and IH A. In wells R11 and IH A sequence 2 consists predominantly of coarse sandstone with abundant palynomorphs. Gamma-ray values from OP1 support a coarse-grained lithology. S2 can be confidently dated to the *Proteacidites pachypolus* Zone of middle Eocene age at the base of IH A (Matthews 1983).

S2 conformably overlies S3 throughout and S4 at the western margin. There is no evidence of truncation of underlying S3 or onlap onto the sequence boundary. However, internal onlap and truncation occurs locally on lines TB01-SA and TB01-SB. These surfaces are not distinguishable on well logs. On the eastern flanks, toplapping of S2 against overlying S1 is clearly observed (figure 4.12) on seismic profiles TB01-SA, TB01-SB and TB01-PM.

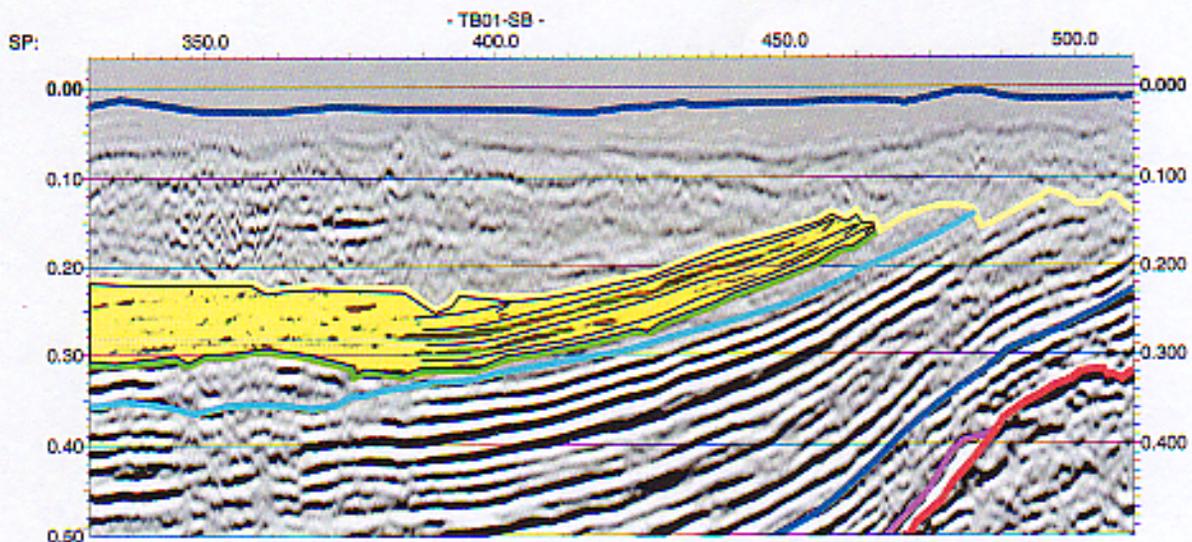


Figure 4.12: Seismic facies interpretation of line TB01-SB. The upper sequence boundary of S2 (yellow) is an extensive erosional surface or angular unconformity. It is the most clearly defined sequence boundary due to the well-imaged toplap of S2 and S4 (cyan).

Further south on line TB01-PG, the basin-fill architecture significantly changes and the toplapping feature does not occur. S2 is another minor package within the Longford Sub-basin. It has a relatively uniform thickness of approximately 60m (0.08 sec TWT). S2 is characterised by high amplitude, continuous, parallel reflectors similar to that of S4 and this is well illustrated where the two packages converge (figure 4.13).

a.

b.

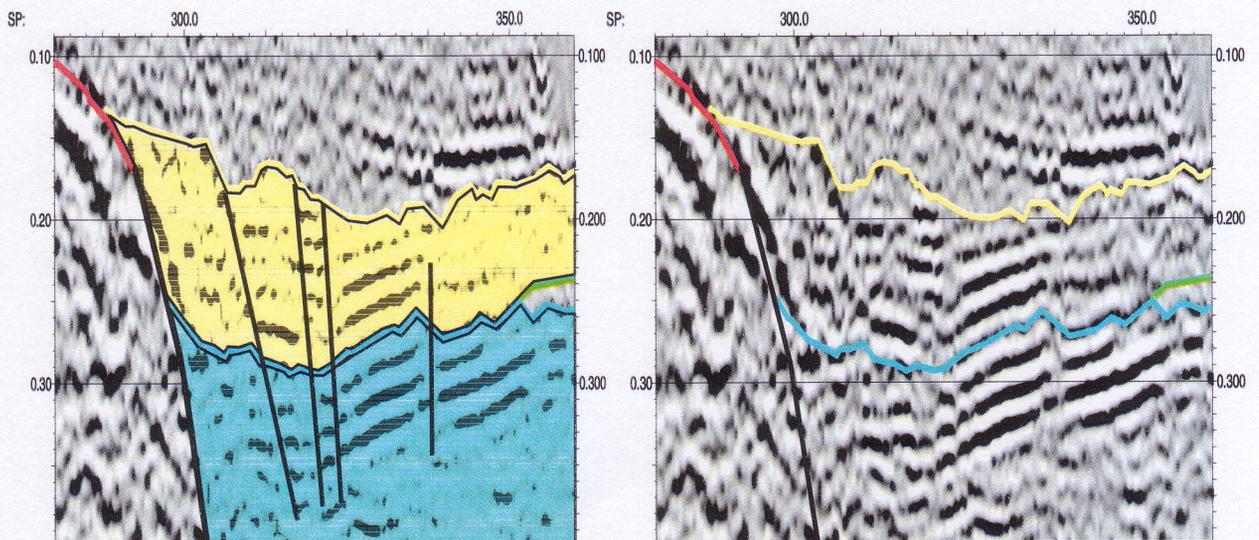


Figure 4.13: a) Seismic facies interpretation of line TB01-PM, S4 (cyan) and S2 (yellow). Minor late Tertiary faulting is interpreted as the reason for reflector offsets.
b) Similar high amplitude, continuous reflector characteristics of S2 and S4.

4.10 Sequence I (S1)

The S1 package is an extensive, basin wide package, well imaged on all seismic lines. The lithology of S1 is well constrained by wells, drill holes and outcrop. Rock types present include conglomerates, coarse-fine sandstone, siltstone, shale, lignite, carbonates and basalt. Direen (1995) has demonstrated the difficulty of correlating S1 lithologies between drill holes. Palynological studies on IH 36 and IH 44 indicate an age of mid-late Eocene for S1 package.

S1 is characterised by a distinct blanket of low amplitude chaotic reflectors. The lack of reflector continuity supports a range of depositional facies, as suggested by Direen (1995).

The S1 lower sequence boundary is a significant unconformity in the northern area of the basin (figure 4.12), becoming conformable south of Hummocky Hills (figure 4.14). In the north, the boundary is a major erosional and truncation surface especially near basin margins. This suggests the tectonics producing the unconformity, i.e. uplift, were more pronounced in the north of the western sub-basin compared to the south and eastern sub-basins.

In the north, S1 thins from 160m (0.2sec TWT) to as little as 70m (0.10 sec TWT). The average thickness of S1 across the entire basin is approximately 110m (0.15sec TWT). Figure 4.15 depicts a relative uniform thickness over the entire basin.

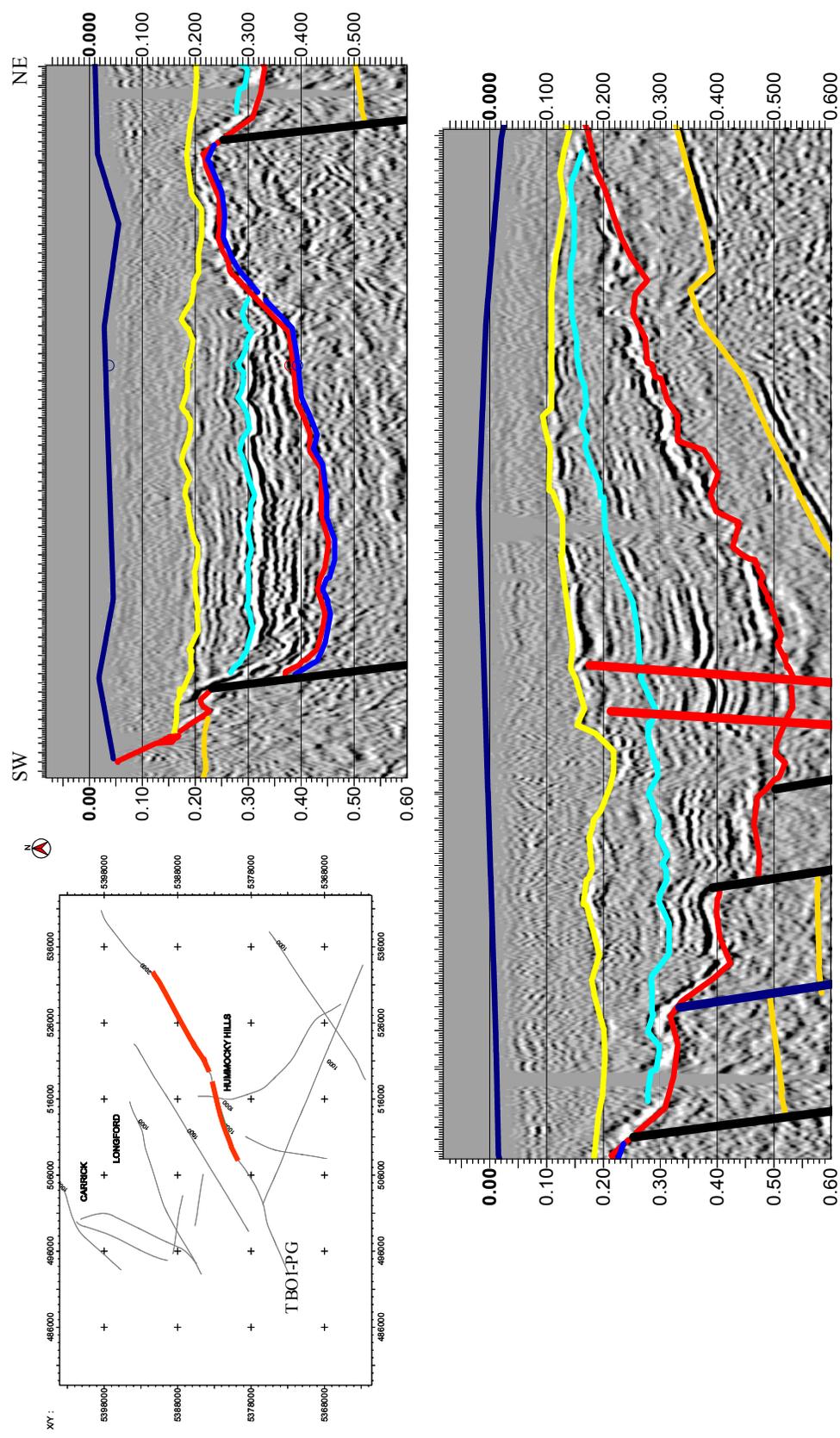


Figure 4.14: Two sections from seismic line TBO1-PG. The S1 conformably overlies S2 here and further south. Erosional truncation of S2 may overlying S1 has not occurred in this part of the basin.

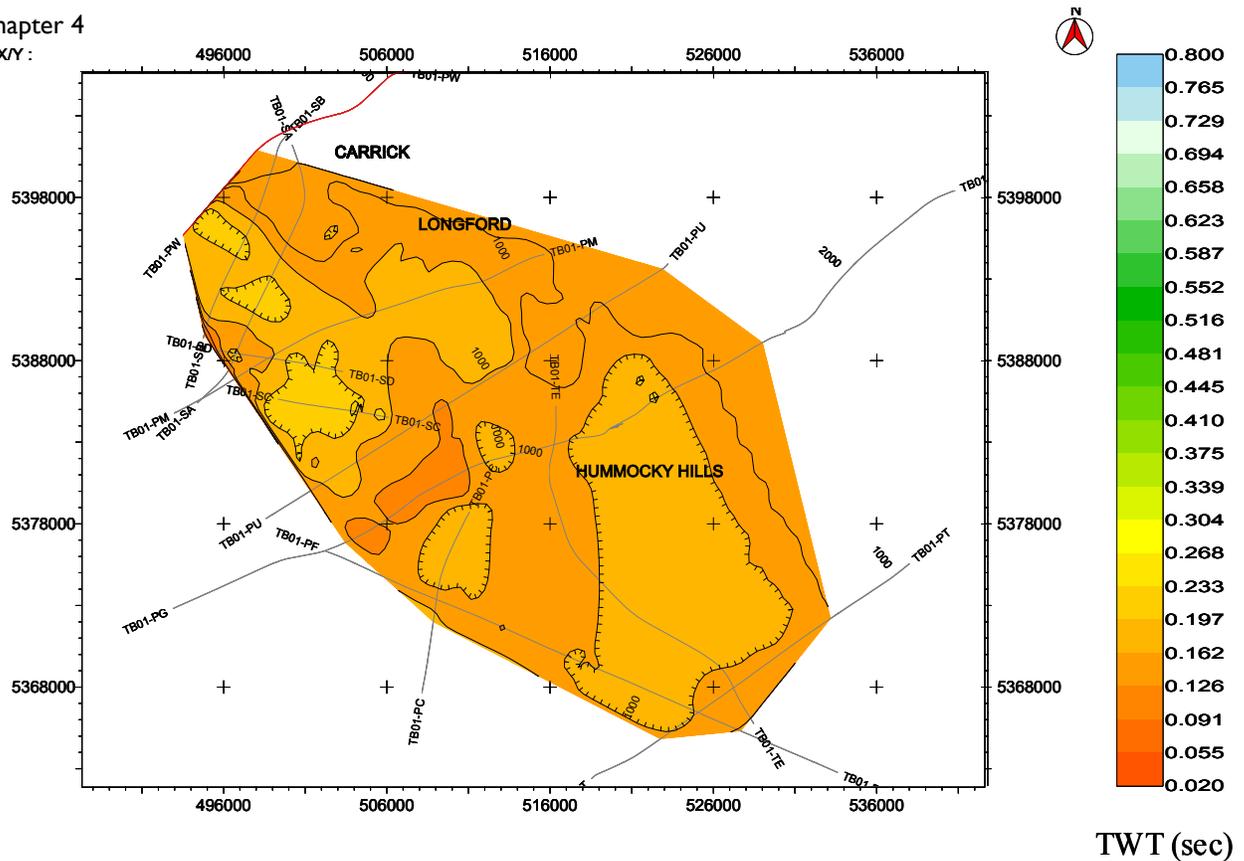


Figure 4.15: Isochron map of S1. The sequence has a relative uniform thickness over both the eastern and western sub-basins.

4.11 Summary

A new stratigraphic framework has been devised based on seismic reflection characteristics and applied across the basin. A simplified model is achievable, but this would involve overlooking sequence boundaries and hiatuses.

Simplified model:

- Palaeocene coal-rich lacustrine facies (S6 & S5)
- late to mid Eocene lacustrine facies (S4, S3 & S2)
- late Eocene fluvio-lacustrine facies (S1)

The basin fill history is shown in figure 4.16. Deposition into the basin commenced with S5 and S6 in the north. The basal unit of S4, also confined to the north, followed. By the time S4 deposition had ceased, the eastern and western sub-basins were connected. This is evident as S4 is occurring east of Hummocky Hills (figure 4.16(b)). S3, S2 and S1 all occur in both sub-basins and show lateral increases in their deposition.

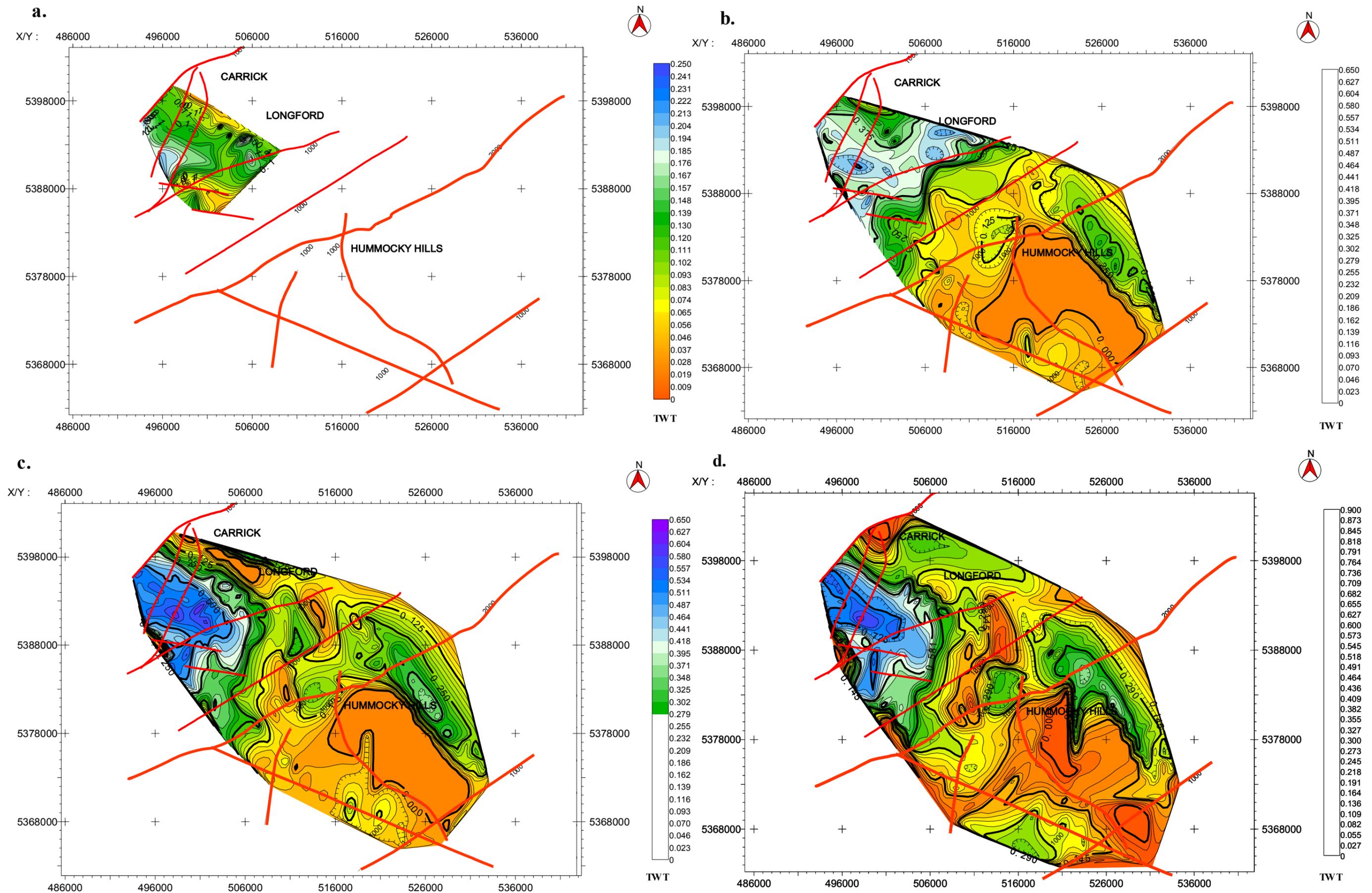


Figure 4.16: Isochron maps of the Longford Sub-basin generated from seismic interpretations (Note: TWT scales are not the same). a) S8 to S5 isochron map, S5 and S6 are relatively thin units confined to the northern end of the western sub-basin. b) S8 to S4 isochron map, the S4 package has an increased area of deposition, occurring above the S5 and S6 in the north, and directly overlying basement in the south and eastern sub-basins. c) S8 to S2 isochron map, S3 and S2 directly overly S4 in most areas, however deposition appears greater in the north. d) S8 to S1 isochron map, similar appearance to c. although laterally the area increased. Coordinates are in meters on the AMG grid, AGD 1966.