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Kinking of the Subducting Slab by Escalator Normal Faulting beneath the North Island of New Zealand

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1.0 Multichannel Seismic Processing

Table DR1: Multi-channel seismic reprocessing sequence for NIGHT line.

PROCESSING STEPS	COMMENTS
Reformat SEGY data	Anti-alias filter: minimum phase high cut butterworth : 80Hz-90Hz. Resample to 4 ms sample interval
Trace editing	Interactive QC to locate noise and amplitude spikes
Amplitude recovery	Linear gain based on RMS window-based scaling
Swell noise filter	400 ms minimum phase trapezium butterworth: 3-6-80-90 Hz, 8.33 ms/trace FK-filter with a 500ms median AGC wrap
Trace decimation	25m bins with spatial anti-alias filter: minimum phase low cut butterworth: 50-60 Hz. Resample to 8 ms sample interval
Gap deconvolution	Operator length 350 ms, gap is 32 ms, design window is water bottom + 500 ms to water bottom + 3000 ms
Sort to CDP	
Correction for cross-line-offset	The acquisition geometry included a cross-line source-streamer offset of some 130 metres, with the in-line offset of 173 metres. The data was binned to CDP's assuming a simple 2D in-line offset distribution, and then the true (geometric) offset calculated and a bin-centring correction in the NMO domain.
Static correction	Recording lag plus source/streamer difference: -57 ms
First pass radon demultiple using picked multiple velocity field	120-fold, 4xcdp combined super-gathers Transform range: -1300 ms to +300 ms far-offset moveout Remove multiple range: -200 ms to +200 ms far-offset

	moveout 200 slowness-values used; application from 1.5 times water bottom
Remove NMO correction	
Velocity analysis	Pick velocity from semblance gathers derived from every 240th CDP
Second pass radon demultiple using 90% of primary velocity field	
Residual FK Demultiple	
NMO Correction and water-bottom tied inner/outer trace mutes	
Export traces to Paradigm's GeoDepth™ software	Data are exported for pre-stack depth migration
Stack	
Post-Stack Processing	A post-stack gap-deconvolution was tested, to suppress any residual peg-leg or water bottom multiple, particularly in water depths of under 400ms where the parabolic Radon demultiple approach used can be ineffective
Migration	
Output to SEGY and display	

Uninterpreted processed NIGHT seismic profile is shown in Fig. DR1A.

2.0 Pre-stack Depth Migration

In pre-stack depth migration no assumption is made about the location of reflectors and therefore, the migrated image gives an independent check on the geometry of the plate interface. Pre-stack depth migration was undertaken using Paradigm's GeoDepth™ software. We used a macro-velocity layer approach to building an initial velocity model for depth imaging. Subsequent velocity models are updated as a result of residual-moveout analysis (RMO), performed on common-depth-point (CDP) or common-reflection-point (CRP) gathers around reflection events corresponding to the macro-velocity layer boundaries. In RMO analysis, the residual travel-time curvature of an event, after it has been corrected with the current model, is used as the basis for updating the model

The initial velocity model for pre-stack depth migration was derived from ray tracing of wide-angle data (Zelt and Smith, 1992) using records from the six digital OBSs and five onshore-offshore stations (Henrys et al., 2003a). The model was modified to account for normal-incidence reflection times observed in the reflection data. Also in the vicinity of the NIGHT line are two oil exploration wells (Barnes et al., 2002); Hawke Bay-1 (BP Shell Aquitaine Todd Petroleum Developments Ltd, 1976) which cored Paleogene and Neogene strata and had a usable sonic log between 600 ms and 1700 ms TWT, and Opoutama-1 which intersected Cretaceous rocks but for which no sonic data was available. Therefore, along the NIGHT profile conventional stacking velocity analysis was used to constrain the initial velocity model. Stacking velocities were obtained at 125 m intervals for the seabed and six sedimentary layers, including a layer representing Cretaceous and older rocks. Interval velocities for these layers were converted to depth using image ray map migration and a vertical velocity gradient of 0.6 m/s per metre was assigned to each layer with zero velocity gradient below the deepest horizon.

After RMO iterative velocity model updates the final model resulted in eight layers were defined. The upper four layers retained the original 0.6 m/s per metre vertical velocity gradient, with 0.3 m/s per metre being employed for the deeper layers. Below the Top Cretaceous event, there are few clear reflectors and only layers down to approximately 10 km depth could be update through residual moveout analysis. Beneath 10 km depth the initial wide-angle velocity model was retained and used in the pre-stack depth migration.

The processed pre-stack migrated seismic data are shown in Fig. DR1B

3.0 Thermal Modeling

We have modeled the thermal regime at Hawke Bay-1 (see Fig. 1 for location) using a one-dimensional finite-element method. Basal heat flow is defined at the plate interface and models are limited to considering only the upper plate. The crustal thickness beneath Hawke Bay-1 is taken to be 17 km from Figure 3. To avoid the effect of temperature perturbations at the plate interface we have only modeled the temperature gradient to 15 km depth. Prior to subduction a basal heat flow of 43 mWm-2 is used which is consistent with expected surface heat flow from Cretaceous age (Mortimer and Parkinson, 1996) Pacific Plate (Turcotte and Schubert, 2002), that is, conductive heat flow from the top of the descending slab pre-subduction. Modeled heat productivity within the upper plate contributes 17 mWm^{-2}, hence the pre-sedimentation surface heat flow is 60 mWm^{-2}; a value that is corroborated from BSR derived heat flow at the trench (Henrys et al., 2003b). Since 20 – 25 Ma, the approximate start of subduction (Ballance, 1976), the modeled basal heat flow is varied to fit corrected bore hole temperature data in Hawke Bay-1 using the thermal and physical property parameters given in Figure DR2. The modelling requires the basal heat flow to have decreased to 27-30 mWm^{-2} since 25 Ma due to cooling associated with the subducting Pacific Plate. We have not completed a full sensitivity analysis but a combination of varying conductivity, specific heat capacity, and heat flow gives an estimate of upper and lower limit temperatures at the base of the crust below Hawke Bay-1 at 250ºC and 200ºC respectively.

References

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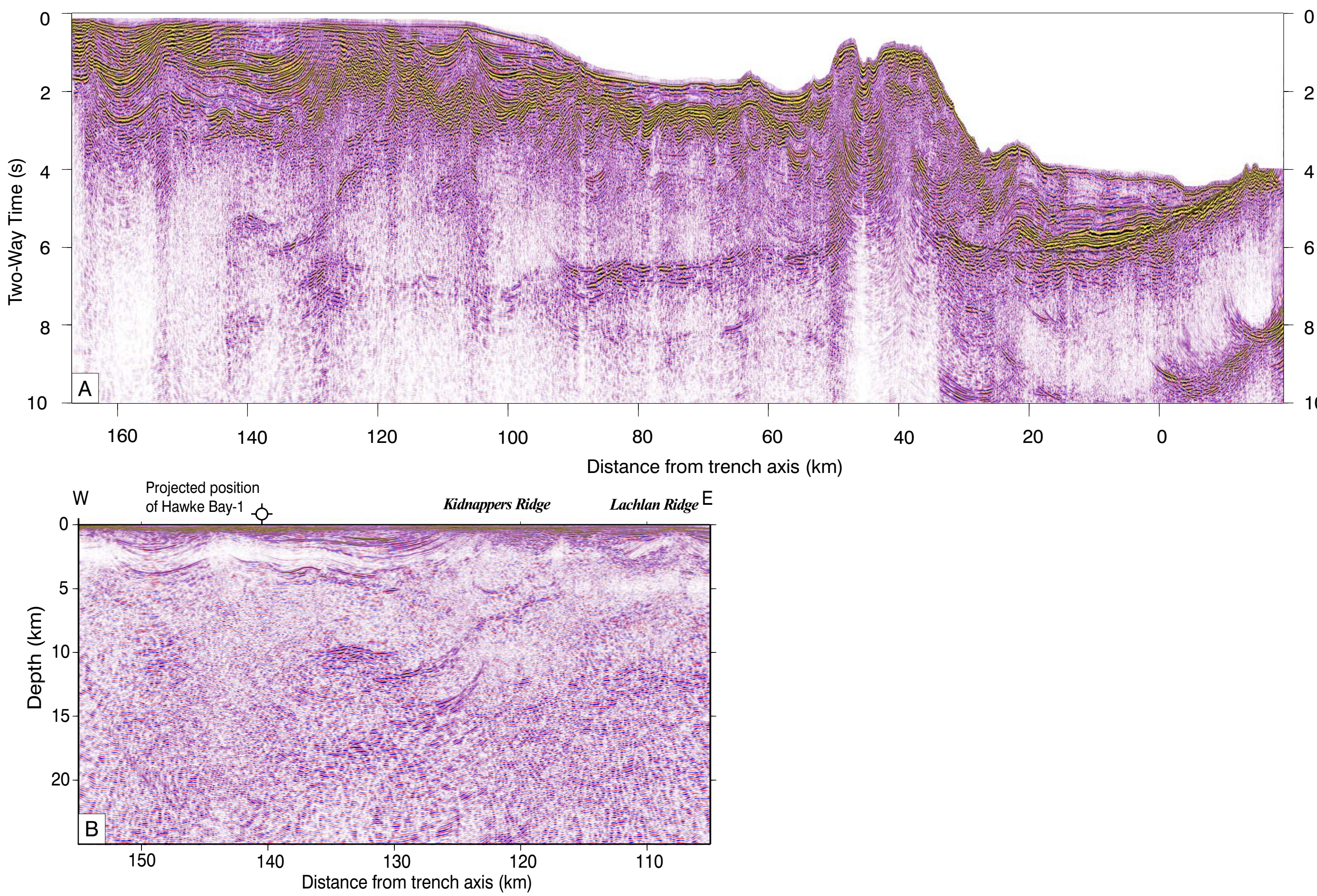
Figure DR1. (A) Uninterpreted time-migrated stack of offshore NIGHT multi-channel seismic line. (B) Pre-stack depth migration for part of the NIGHT seismic reflection line.



0
2
4
6
8
10
Two-Way Time (s)
A
160
140
120
100
80
60
40
20
0
Distance from trench axis (km)
W
Projected position
of Hawke Bay-1
Kidnappers Ridge
Lachlan Ridge
E
0
5
10
15
20
Depth (km)
B
150
140
130
120
110
Distance from trench axis (km)

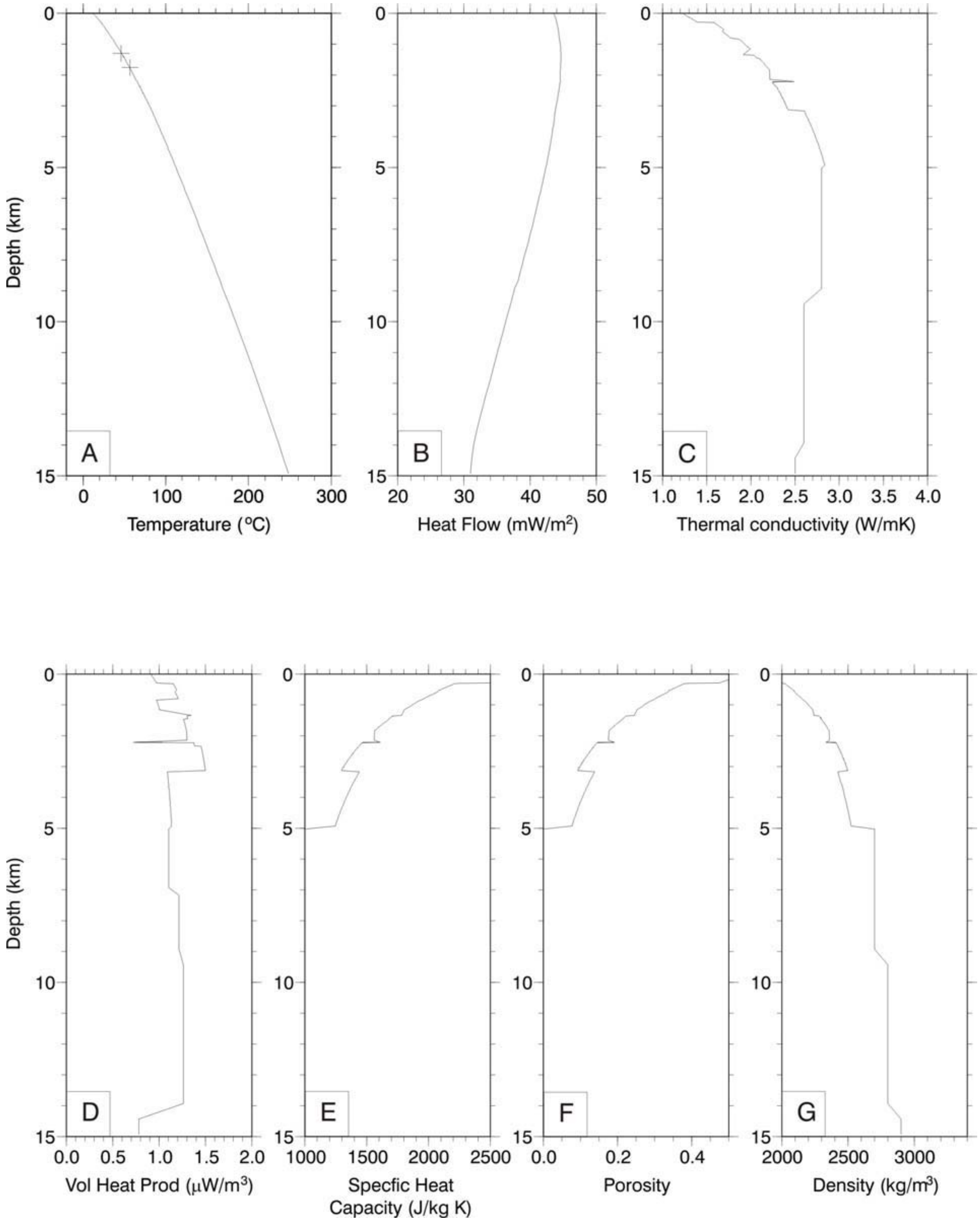


Figure DR2. Depth distribution of (A) measured, shown with plus symbol, and modelled temperature curve in Hawke Bay-1 using thermal and physical property measurements (B-G) derived from a compilation of well log data for Hawke Bay-1 (BP Shell Aquitaine Todd Petroleum Developments Ltd, 1976) and from New Zealand sedimentary basins (Funnell et al., 1996).