Braver and better velocities in the Taranaki Basin, New Zealand

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Abstract

The Institute of Geological and Nuclear Sciences (GNS) recently reprocessed a set of 1991 2D seismic reflection data from the offshore Taranaki Basin for the Spectrum Exploration/Fletcher Challenge Energy Taranaki Joint Venture. A more detailed stacking velocity analysis, incorporating a 40% interval velocity inversion in the Eocene units, resulted in a markedly improved seismic image of Eocene and deeper reflectors. A dense semblance analysis formed the initial part of the velocity analysis sequence. It was followed by interactive constant velocity stack analysis of the velocity inversion, where the weak intra-Eocene reflectors were masked by an overlying strong limestone reflection. A third, automatic, velocity analysis was performed on the final stack using a combination of semblance and digitised horizon times, producing a horizon-based velocity model with data points every 5 traces (63 metres). The combination of these analyses enhanced the reflectors throughout the section, as well as providing relatively accurate interval velocities which are critical in overpressure calculations within basin modelling studies.

Introduction

Spectrum Exploration Ltd, in a joint venture with Fletcher Challenge Energy (Taranaki) Ltd, have undertaken an extensive 2D thermal and fluid-flow modelling study of the northwest offshore Taranaki Basin, New Zealand. The basin contains near-normally pressured Cretaceous and Paleocene reservoirs (Pakawau, Kapuni Groups) beneath overpressured Eocene shales (Moa Group). The degree of overpressuring, a critical input parameter in any fluid migration study, may be estimated from mapping interval velocities.

The Institute of Geological and Nuclear Sciences (GNS) reprocessed five Taranaki seismic reflection sections (originally processed in 1991) for Spectrum Exploration Ltd in mid-1998. The objectives included: a) checking previous processing methodology and parameters to ensure optimised pre-stack processing, b) improving the velocity analysis to enhance the seismic resolution over the entire section, especially in the seismically quiet Eocene interval and in the underlying Paleocene to Late Cretaceous reservoir and source-rock intervals, and c) providing more accurate and detailed velocities to include in overpressure calculations.

In this paper, we describe the general processing parameters of the prestack and poststack data, but will concentrate on the three velocity analyses (semblance, constant velocity stack and horizon-based) applied to the data. The initial semblance analysis provided a densely-sampled stacking velocity map. The interactive constant velocity stack (CVS) analysis greatly improved the reflections within the Eocene interval (Figure 1) and identified a velocity inversion. The horizon-based velocity analysis produced automatically picked stacking velocities along a set of pre-defined horizons.

Seismic data reprocessing

Pre-stack processing and velocity analysis

The raw data originally contained 240 traces per shot record with a 2 ms sampling rate, but were trace summed 2:1 and resampled to 4 ms at the start of the processing sequence.

A number of processes (spherical divergence correction, noisy trace mute, trace balance, deconvolution, bandpass filter, 8 ms bulk shift and refraction arrival mute) were performed on the data, in which the parameters were selected through interactive comparisons. The reflector clarity was improved by the application of a two-pass deconvolution approach, in which a trace-by-trace operator with a 24 ms gap was followed by a shot-averaged spiking deconvolution.

Semblance analysis

The first velocity analysis calculated velocity semblance (a multi-trace coherency measure) maps at 50-CMP (625 m) intervals. Each analysis incorporated four adjacent CMP gathers using side-weights of 0.8 and 0.6 to increase the signal to noise ratio. Stacking velocities (V_{nmo}) were hand-picked from the displayed semblance plot (an example is shown in Figure 2), smoothed and used to create an initial stack as well as a temporary pre- FK-domain Dip Moveout (DMO) NMO correction.

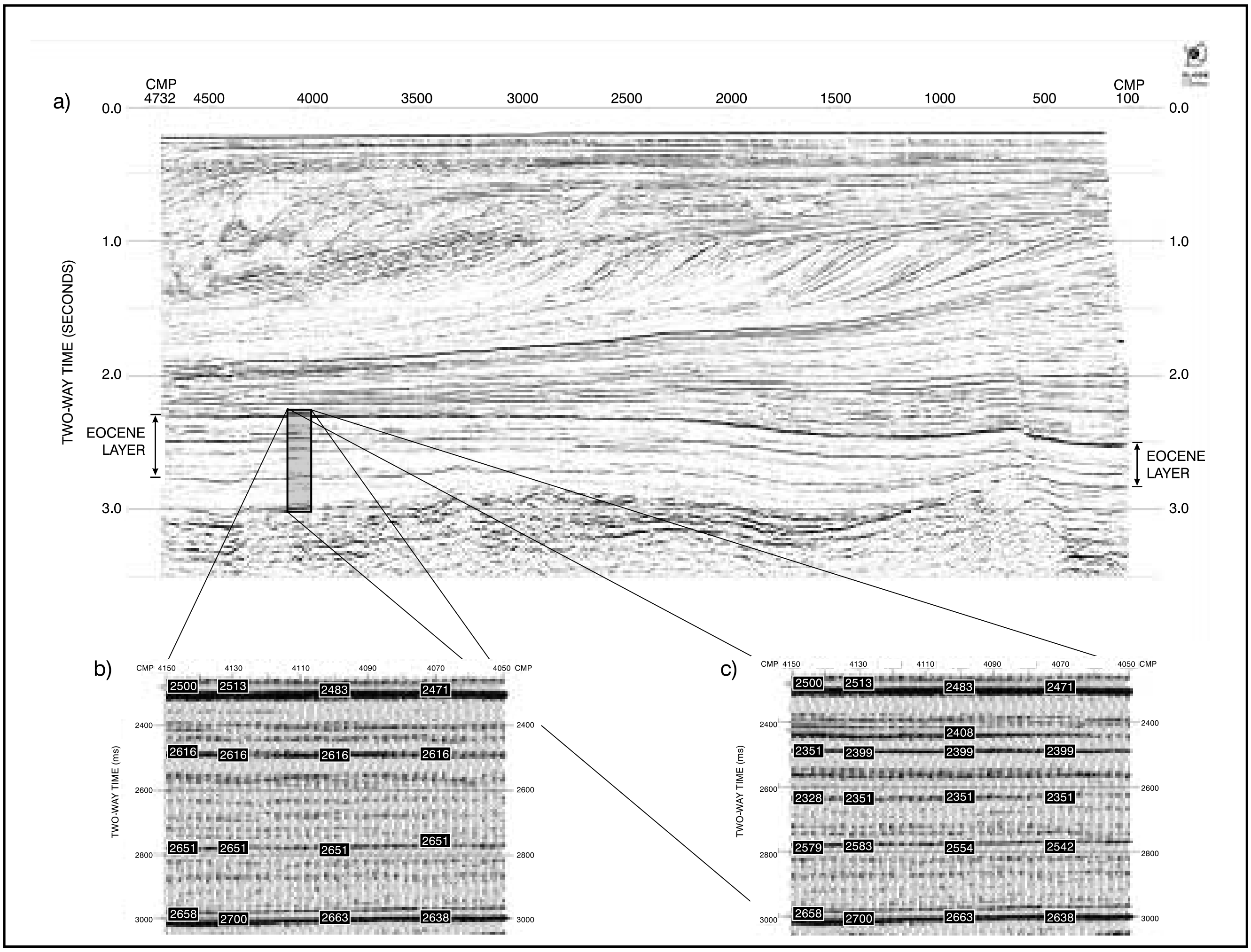

Figure 1: Northwest Taranaki reflection section a) final unmigrated stack, b) stack with semblance- derived stacking velocities only and c) stack with stacking velocities picked using interactive CVS.

After the DMO was applied, the semblance analysis was repeated on the post-DMO CMP gathers, but at a 5 CMP spacing which is more dense than normally used. The output semblance maps were required at this spacing for the final horizon-based velocity analysis. Velocity functions were picked either if a variation from the previous semblance map was apparent, or at roughly every third analysis. A new stack was created using the updated stacking velocities and compared to the initial stack with hard copies and interactive screen comparisons for quality control.

Constant velocity stack

The focus of the Spectrum Exploration Ltd overpressure study is within the Eocene sand and shale layer. It lies between about 2400 and 2800 ms (Figure 1), and underlies a high velocity limestone layer. Reflections from below the limestone are characterised by weak amplitudes and are of limited spatial continuity. The strong limestone reflection creates a bright peak on the semblance profile which has the effect of masking the lower amplitude velocity semblance peaks below it, thus rendering the semblance velocity analysis technique ineffective within the Eocene layer.

To counter this problem, an interactive constant velocity stack (CVS) analysis was performed within the Eocene layer. A facility available with this analysis is to create CVS comparison panels for any velocity range and on any part of the data set. Choice of stacking velocity can then be made on the basis of event character and continuity, rather than purely reflector strength. The stacks (between 4050 and 4150 CMP in Figures 1b and 1c) were created using the previous semblance and the new CVS velocities. In this example, two 'new' sharp reflectors at ~2450 ms and ~2650 ms, which did not appear in the pre-CVS stack, are clearly apparent. The consistent reflector wavelets gave the confidence to pick a significant velocity inversion (i.e. V_{nmo} velocity decrease with depth, solid line Figure 2) in the Eocene interval. This is geologically justifiable on the basis of well data in the region (mudweights, d-Exponent, sonic logs and checkshot velocities). This inversion was not previously picked (dotted line Figure 2) because, without the benefit of evidence to the contrary, it was interpreted as multiple energy. A new stack was created using the post-CVS velocities and is shown in Figure 1a.

Horizon-based velocity analysis

The horizon-based velocity analysis was the final velocity picking method prior to converting to interval velocities, as it provides more objective, high-resolution velocity picks. The input consists of the semblance spectra (every 5 CMP, 63 metres), the best V_{nmo} picks from CVS and the digitised unmigrated seismic horizons.

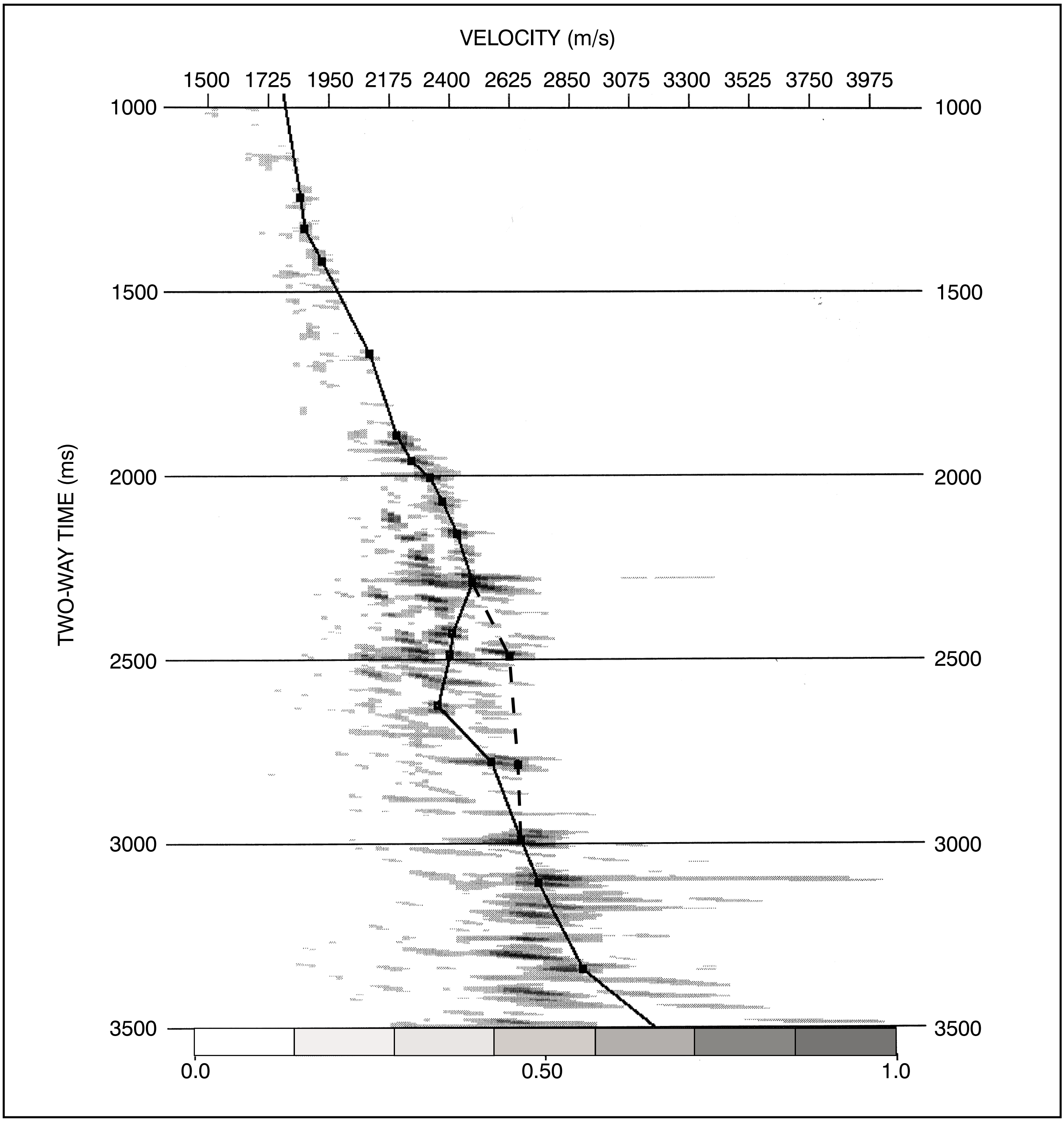

Figure 2: Semblance map for CMP 4100. The dotted line represents the velocity profile picked with semblance only; the solid line demonstrates the stacking velocity inversion (between 2250 ms and 2750 ms) picked using CVS.

This method determines where the maximum semblance is found for the specific horizon times within a certain percentage either side of the existing (hand-picked) velocity. In this case, the maximum percent difference allowed was 5%.

The new V_{nmo} velocities were smoothed using two different filters (to judge the impact of the smoothing operator) and converted to interval velocities using the Dix equation and either the horizon times, or a regular time grid at 50 ms intervals. As a final display, the derived interval velocities were underprinted with the unmigrated seismic section (Figure 3). It shows the significant velocity variation within the Eocene layer compared to the rest of the section.

Conclusions

This bolder approach to velocity picking not only produced an enhanced seismic section, but also provided evidence for a significant velocity inversion within the Eocene layer, and relatively accurate interval velocities. These interval velocities are used in overpressure calculations which provide critical constraints for the modelling of fluid flow in basin models (McAlpine, 2000).

The semblance analysis provided an initial stacking velocity profile, but did not discern the velocity inversion in the Eocene layer. The interactive CVS method clarified this velocity inversion and focused two reflectors beneath the limestone

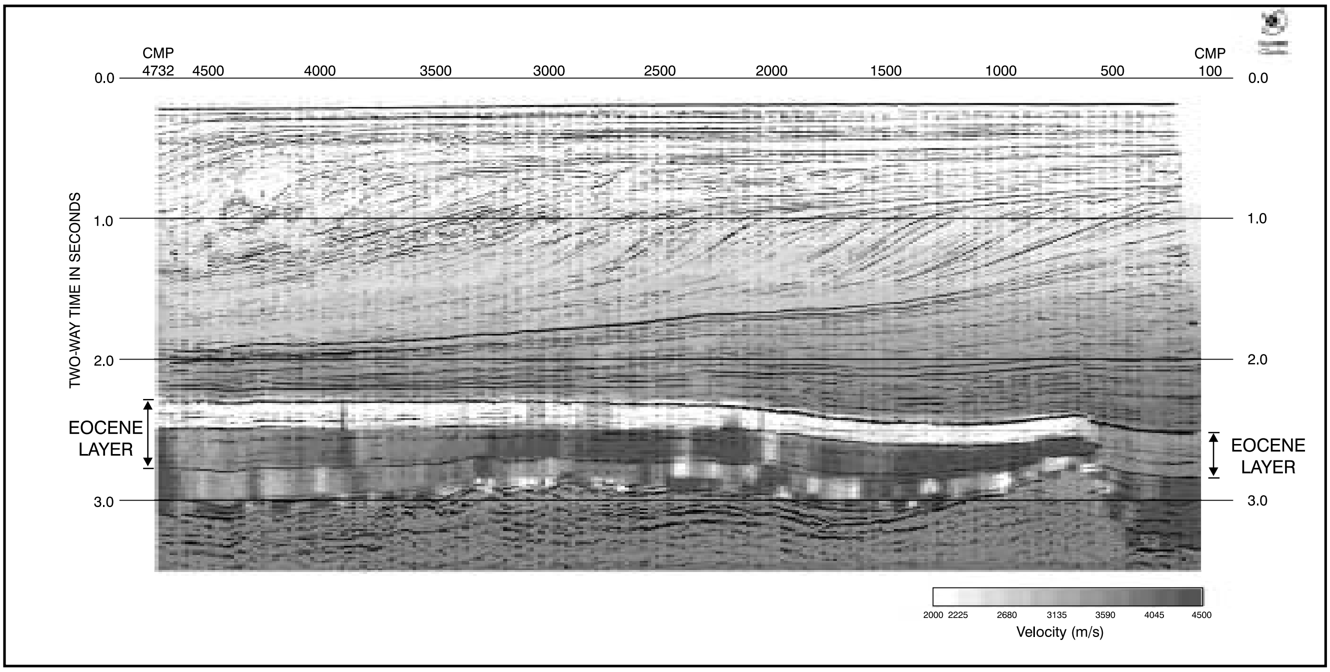

Figure 3: Interval velocity superimposed on final unmigrated stack.

layer that were not distinguished in previous stacked sections. The horizon-based method provided more objective, high-resolution stacking velocities using the CVS picks as a starting point. The picks from the horizon-based analysis were used in the calculation of interval velocities.

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Authors

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JONATHAN RAVENS, MSc in Geophysics at Durham in 1983, has worked for the last 15 years on seismic reflection methods, for GNS and its predecessors. His principal focus is development of the seismic processing software package GLOBE Claritas.