Depth conversion techniques in the Gippsland Basin

P. J. Birmingham, K. R. A. Grieves and D. E. Spring

In the offshore Gippsland Basin of southeast Australia, the determination of velocities for depth conversion continues to be a perplexing geophysical problem. This paper examines the causes of velocity variations in the basin, describes three techniques currently in use by Esso Australia Ltd to effect depth conversion and presents the case history of the Veilfin prospect to illustrate the use of these three techniques.

Variations in average velocity (VAVG) to the top of the reservoir unit, the Latrobe Group, are related to lateral variations in interval velocity in the overlying section. In the Gippsland Basin this overlying section consists of interbedded limestones and marls of the Oligocene and Miocene Seaspray Group, exhibiting large variations in interval velocity which appear to correspond to large variations in carbonate content. Sea level changes and basin deformation during the Miocene have combined to produce complex channel cutting and reworking of these limestones and marls (Fig. 1). One of these channels overlies the Veilfin prospect (Fig. 2) and has been infilled with material of much higher interval velocity than the underlying sediments, inducing a two-way time pull-up at the top of the Latrobe Group (Fig. 3).

Depth conversion in this environment must accurately compensate for this time distortion. Unfortunately, normal moveout velocity (VNMO) determinations in the vicinity of these high velocity channels are unreliable. The VNMO is distorted by the deviation of ray-paths passing through the high velocity channel, by significant variations in interval velocity within the channel and by anisotropy (differences between horizontal and vertical transmission velocities).

Due to the lack of confidence in stacking velocities, attempts were made to model the effects of these velocity-distorting phenomena, using non-zero offset ray-tracing. The seismic model constructed from velocity data at well locations always predicted VNMO to be slower than that determined from CDP gather records at the same location. In addition the mistie between ray-traced and seismic VNMO is neither constant nor predictable (Fig. 4). Anisotropy in some of the overlying units is thought to be the cause of this effect.

The three depth conversion techniques used to overcome these problems in the Veilfin area were:

THE SMOOTHED VNMO METHOD

With this method maps of smoothed VNMO to the top of the Latrobe Group are multiplied by conversion factor maps to produce the VAVG maps required for depth conversion. The

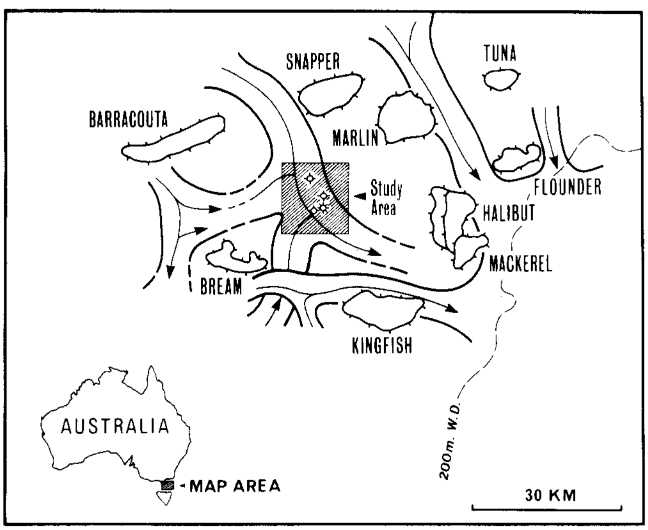


Fig 1 Locality map showing Miocene high velocity channels.

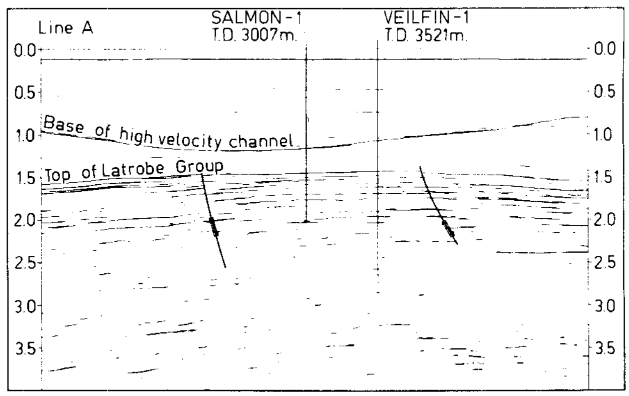


Fig 2 Seismic line A, illustrating the high velocity channel and associated two-way time pull-up at top of Latrobe.

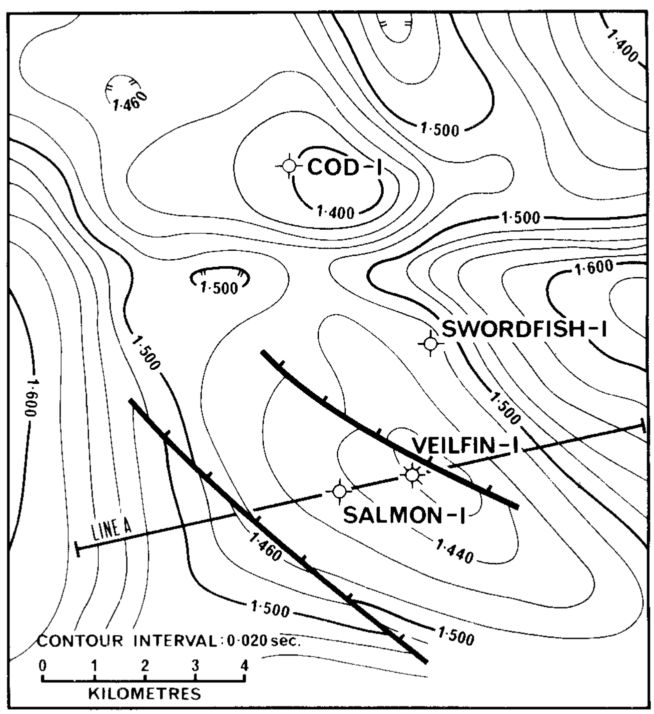


Fig 3 Velifin area. Time structure map, top of Latrobe.

conversion factor provides compensation for the increased refraction of ray-paths passing through the high velocity channel and adjusts the VNMO map so that it ties average velocities determined by well velocity surveys. In this study the trends of the conversion factor map between well control were determined by the structure of the high velocity channel and the form of the VNMO map.

Two highly interpretive steps are involved in this approach, namely the smoothing of VNMO values which are in general highly scattered and the contouring of the conversion factor map away from well control.

THE SMOOTHED INTERVAL VELOCITY (VINT) METHOD

Here the seismic section above the top of Latrobe is divided into a number of intervals, based on significant sonic breaks at nearby wells.

Smoothed interval velocity maps are used to generate isopach maps for each of these time intervals and the isopach maps are then summed to produce depth maps at the top of Latrobe. 'Dix' interval velocities determined from VNMO measurements are used to establish trends in interval velocity between well control. The difficulty with this method is in adequately predicting the lateral variations in interval velocity away from well control, using 'Dix' interval velocities.

THE LINEAR VELOCITY FUNCTION (LVF) METHOD

With this method the interval velocity of significant intervals as determined at well locations are plotted as a function of depth. From these plots functions are generated which assume a linear relationship between depth and velocity for each interval (Fig. 5). Depth conversion is achieved by iterative computation of depth to successive interfaces using these functions.

The disadvantages of this method are firstly that it does not allow for lateral variation in interval velocity which is independent of depth and secondly all units need to be recognized and calibrated in at least one well.

For both interval velocity methods, emphasis was placed on modelling the Miocene channel fill velocities, as these were considered the cause of time distortion at the top of Latrobe.

All three of these methods were applied in the Veilfin area prior to the drilling of the Veilfin-1 well. Although they differed in their predicted heights and areas of closure, all three methods indicated that the structure was a faulted anticline with significant closure updip from the existing well, Salmon-1.

Post Veilfin-1 analysis

When the well was drilled the top of Latrobe was approximately 2% deep to prediction by all three methods.

The error in depth prediction with the VNMO method was due to the pre-drill interpreted axis of high velocity being

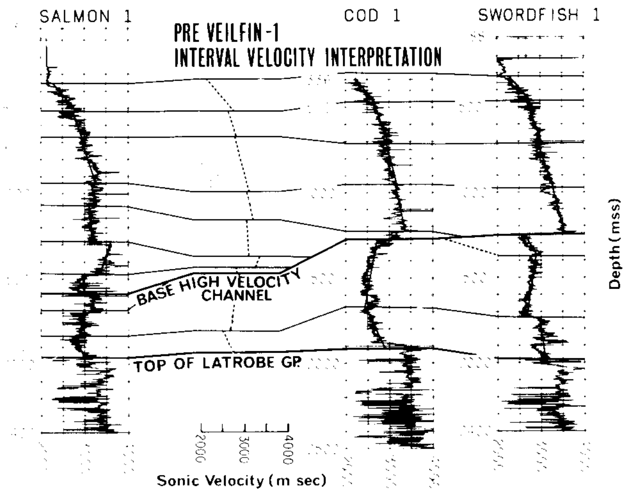


Fig 5 Interpreted linear velocity functions.

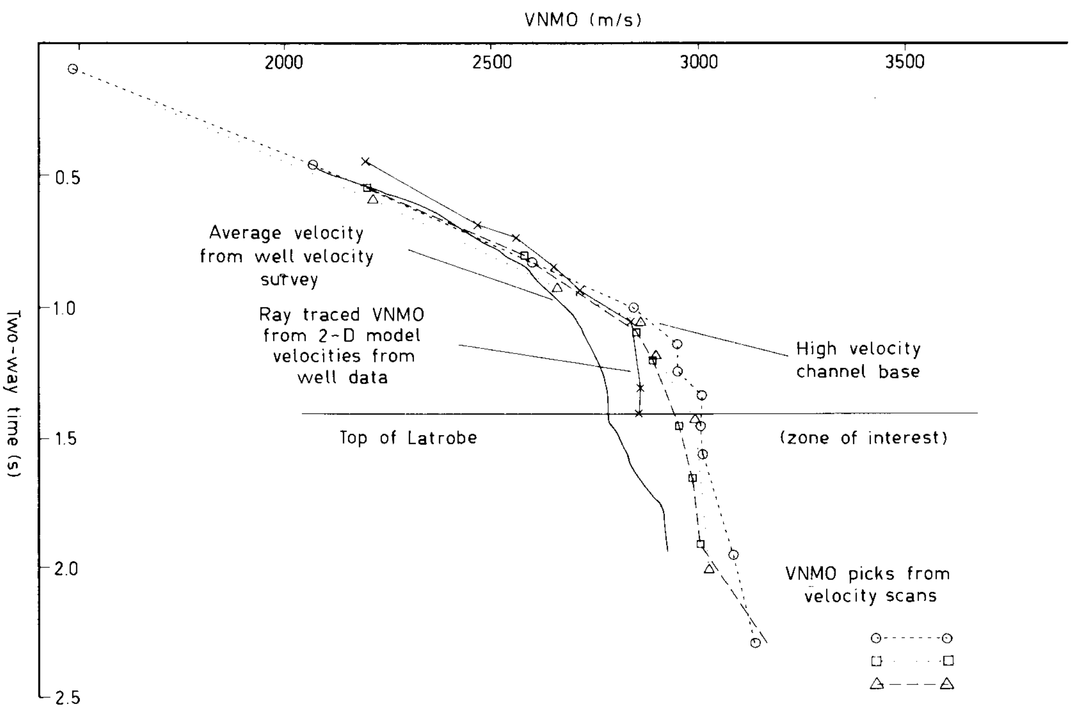


Fig 4 Comparison of well velocity, ray-traced velocity and normal moveout velocity at Salmon-1.

aligned with the two way time axis of the channel. Veilfin-1 was drilled well up on the eastern flank of the channel and the VAVG to the top of Latrobe was found to be higher at Veilfin-1 than at Salmon-1, a well located on the channel axis. It is now believed that the axis of high velocity should be aligned with a high trend apparent on the top of Latrobe time structure map. This high trend runs NW-SE through a point about 0.7 km east of Veilfin-1 and continues northwards passing to the east of the Cod-1 well.

The error in depth prediction for both the VINT and LVF methods was due to the presence of a localized unit of anomalously high velocity below the base of the high velocity channel. Correlation of this unit is not obvious with Cod-1 and Swordfish-2; however, it can be tied to Salmon-1. Significantly, both methods accurately predicted the depth to the base of the high velocity channel. This highlights the fact that greater consideration should be given to the interpretation of sub-channel units when depth converting using interval velocity techniques.

The post-drill Latrobe depth map (Fig. 6) shows that a small, low relief, untested closure may still exist to the northwest of the Veilfin-1 location but that relief in the Salmon-1/Veilfin-1/Swordfish-1 area is essentially low.

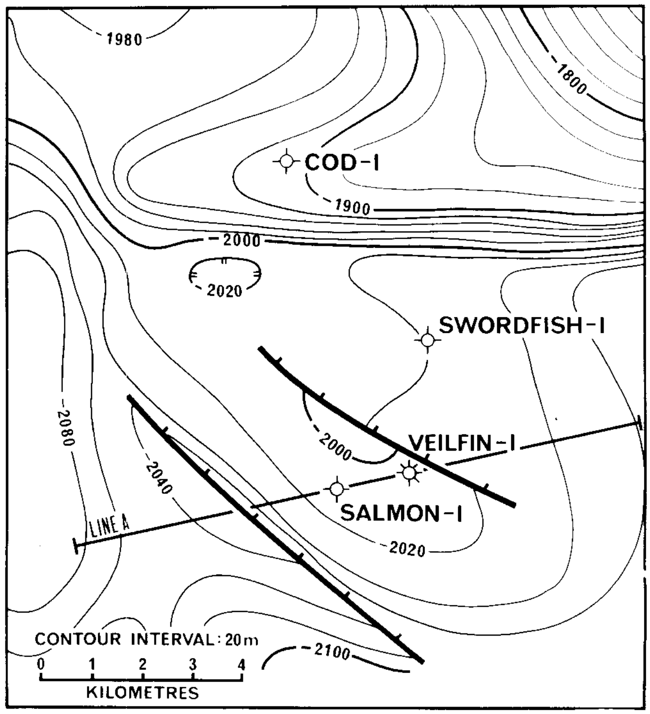
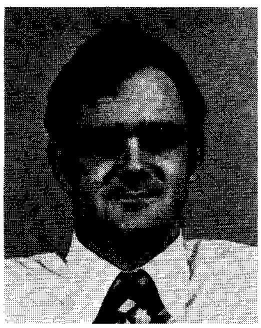


Fig 6 Veilfin area. Post-drill structure map, top of Latrobe.



Peter Birmingham graduated from the University of New England in 1967 with an honours degree in geophysics. His professional career has been with Esso Australia Ltd. where he has held a variety of geophysical positions within the petroleum exploration function. He is currently Esso Australia's Geophysical Applications Supervisor responsible for seismic modelling, velocity analysis and computer applications. He is a member of PESA and ASEG.

P. J. Birmingham, Esso Australia Ltd, GPO Box 4047, Sydney, NSW 2001.

Ken Grieves graduated from the University of Sydney in 1972, majoring in geology and geophysics. From 1972 to 1974 he worked for Geophysical Services International as a processing geophysicist, handling primarily dynamite and vibroseis surveys. After a period away from the industry, he began at Esso Australia Ltd. in 1981, where he is currently employed as a project interpreter, working on the Gippsland Basin. He is a member of AIG, ASEG, and PESA.

K. R. A. Grieves, Esso Australia Ltd, GPO Box 4047, Sydney, NSW 2001.

David Spring graduated from the University of Sydney in 1982, with honours in geophysics. While a student, he worked for the Earth Resources Foundation on seismic and petrophysical research of coal measure sequences in the western coalfield, NSW. Since 1983, he has been employed as a geophysicist with the exploration department of Esso Australia Ltd. He is a member of the ASEG, SEG, GSA, and PESA.

D. E. Spring, Esso Australia Ltd, GPO Box 4047, Sydney, NSW 2001.