Geol. Soc. Malaysia, Bulletin 28, November 1991; pp. 151 - 164

A time migration before stack

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Abstract: The 1970's saw the introduction and development of post-stack migration algorithms to the extent that migrated stacks were routinely produced as part of the basic processing sequence. Today it is common to incorporate a Dip Moveout (DMO) correction into the processing sequence prior to stacking. In this paper we present a processing technique which cascades Dip Moveout with zero-offset time migration before stack. The method overcomes the limitations of DMO in the presence of lateral and vertical velocity gradients, symptomatic in areas of complex geology. A velocity analysis is inherent in the process producing a more accurate velocity field for migration and depth conversion. The robust nature of the method allows its application to routine data processing and we foresee that such migration strategies will be as commonly employed in the future as DMO is today.

INTRODUCTION

Migration is used to reconstruct the true picture of the earth's subsurface from a recorded wavefield. The accuracy of the reconstruction is heavily dependent on the input migration velocity field. The conventional approach to seismic data processing is to analyse for velocity prior to migration, i.e. prestack velocity analysis, stack then post stack migration. This paper presents a technique known as MOVES (Marcoux, 1987) which applies Dip Moveout, prestack time migration, velocity analysis, stack and a final residual migration. The technique is illustrated by a series of synthetic data and actual data examples from offshore Peninsular Malaysia.

THE ROLE OF VELOCITY IN SEISMIC DATA PROCESSING

Velocity plays dual roles in seismic data processing.

1. Normal Moveout Corrections

RMS velocity is used to define space-time (x,t) normal moveout curves along which reflection energy can be constructively stacked onto the zero-offset. Normally the velocity field is derived by analysing the stack response associated with a series of trial time variant hyperbolic moveout corrections.

Presented at GSM Petroleum Geology Seminar 1990

$$Tx = \sqrt{\left(\frac{x}{V}\right)^2 + To}$$

where,

x = shot to receiver distance

V = RMS velocity down to reflector

To = reflector two-way-time at zero offset

Tx = reflector two-way-time at x offset

The optimum RMS stacking velocity function is given by the normal moveout curves which maximizes the stack response.

2. Migration operator design

A velocity field is also necessary to correctly image the stack data during the migration process. The migration velocity field is used in the design of the migration operators, so the migration velocity model should relate directly to the earth's geology. Ideally the interval velocities derived from the stacking velocities should be comparable to the vertical velocities of each layer in the subsurface. As we know the RMS velocity of a reflector will be increased by the cosine of the reflector dip angle, thus in areas of complex geology deriving the interval velocities from the optimum RMS stacking velocities using the Dix equation will produce incorrect results.

Dix equation

$$V_i = \sqrt{\frac{(V_n^2 \cdot t_n - V_{n-1}^2 \cdot t_{n-1})}{(t_n - t_{n-1})}}$$

Where,

V_i = interval velcity between t_n and t_{n-1}

V_n = RMS velocity

t_n = zero offset arrival time

THE ROLE OF MIGRATION

Migration is used to correctly focus the recorded data and correctly position both reflection and diffraction energy to its correct spatial and temporal origin. The application of a migration algorithm prior to estimation of velocity appears at first sight to demand a prior knowledge of the true migration velocity field. When we migrate the data with the correct velocity field the diffractions collapse to their apex, however if we were to migrate with a lower velocity field the resulting data would be under migrated. Too high a velocity field would overcorrect the data causing migration “smiles”. In the case of complex structure some migration prior to velocity analysis could simplify the structural picture.

MOVES

In areas of complex geology the estimation of velocity by means of trial normal moveout scans is often obscured by the presence of diffraction energy and complicated by the temporal and spatial dispersion of dipping events. This paper describes a procedure referred to as MOVES (Marcoux, 1987) which cascades common-offset partial prestack migration (Dip Moveout) and prestack zero offset migration prior to analysing the data for velocity. The velocity field derived is a key output product of the technique. The prestack migration step removes some of the overlapping events as diffraction energy is partially collapsed and dipping events are moved closer to their correct position. The multi-valued velocity-time picks associated with dispersed reflection energy are effectively removed on the prestack migrated gathers. The velocity field derived can be used to correct for normal moveout and provides an ideal velocity field for migration.

MOVES is an acronym for Migration for Optimum Velocity and Stacking. The processing flow chart in Fig. 1 illustrates the difference in the MOVES processing flow by comparison to the conventional sequence. The major difference between the two processing flows is the DMO plus zero-offset time migration step prior to velocity analysis for the MOVES sequence. Note that the DMO and migration are implemented in the common offset domain. In this way the operators are not being applied across dissimilar offsets maintaining the offset-moveout relationship intact for future velocity analysis.

SYNTHETIC DATA EXAMPLE

We can illustrate the MOVES process using a series of simple synthetic data examples. A synthetic stack section (Fig. 2) was simulated over a simple synclinal model (Fig. l) with dips of 15, 30, 45 and 60 degrees in a 2000m/second constant velocity medium with a common-depth-point spacing of 12.5m. It is clear that the results of scanning for velocity (Fig. 3) are difficult to interpret due to the diffraction energy obscuring the true reflection information. If we were able to analyse velocity on the correctly migrated data (Fig. 4) there would be no ambiguity in selecting the correct velocity of 2000m/second. The raypath diagrams (Fig. 6a and b) demonstrate the results of DMO and migration before stack for a zero and far offset. The DMO operator will give the nonzero offset reflections their zero-offset response thus eliminating common-depth-point smear. Although the energy is better focussed for stacking of reflection and diffraction energy with the same velocity the position of the events are unchanged from the conventional stack. Any velocity analysis performed at this stage is along normal rays which are perpendicular to the reflection surface. In the case of dipping events the information sampled at the surface does not originate directly below the location of the velocity analysis. For this reason the RMS velocity derived will not be related to the true vertical velocity

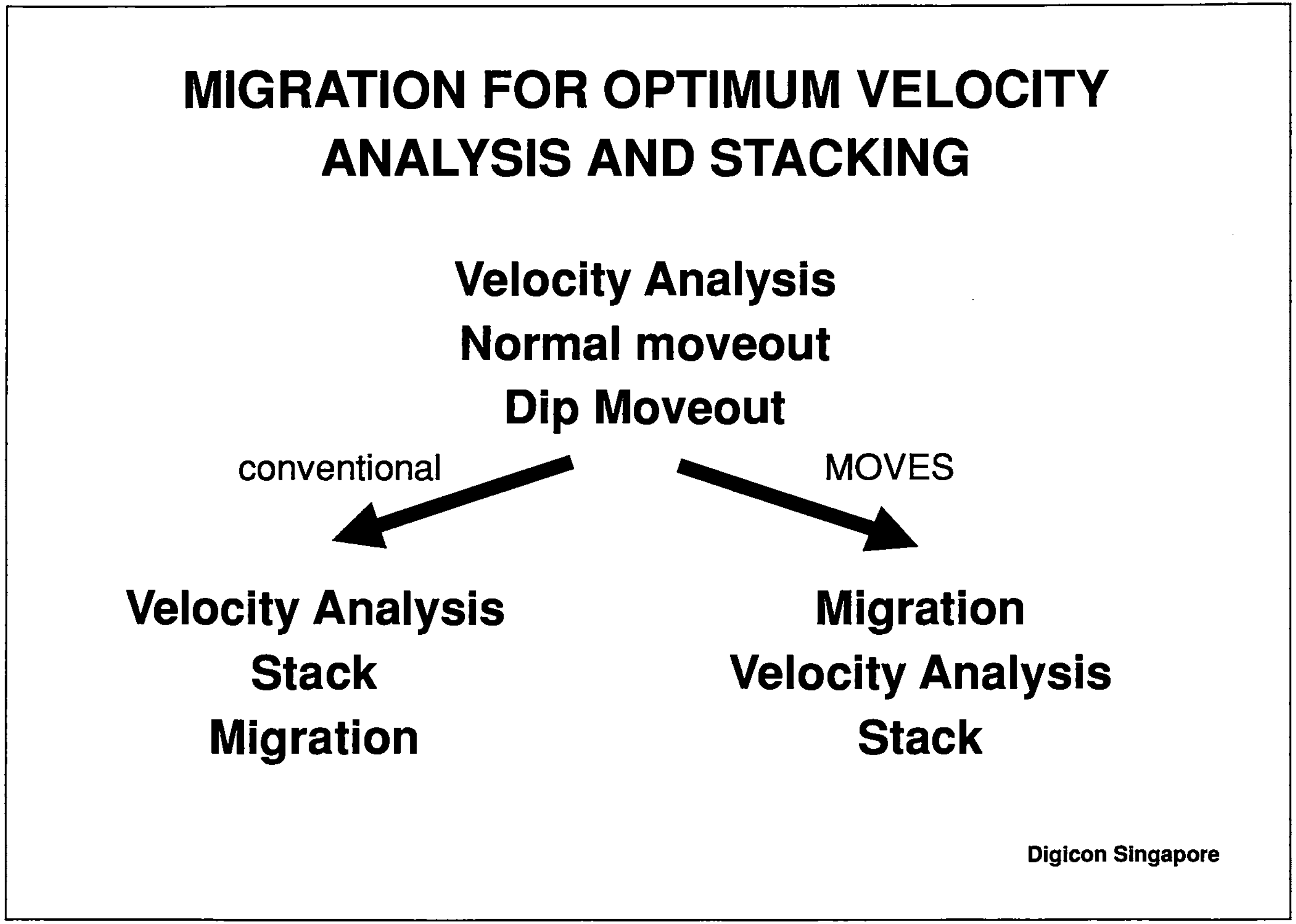

Figure 1: Moves versus conventional processing sequence

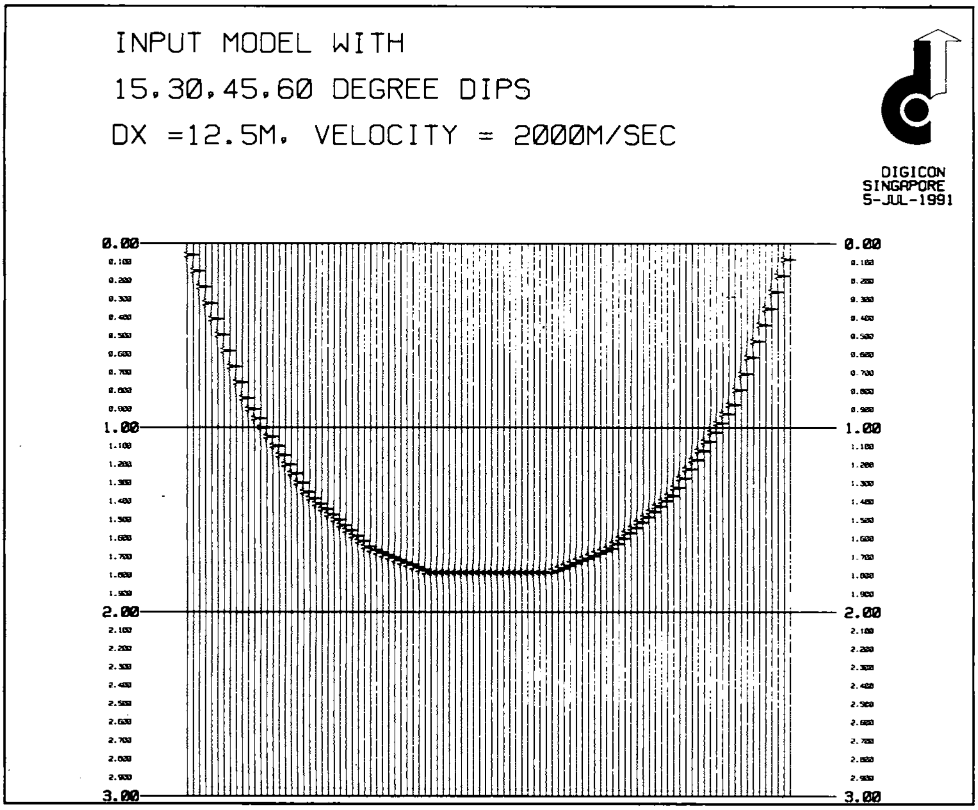

Figure 2: Structural model

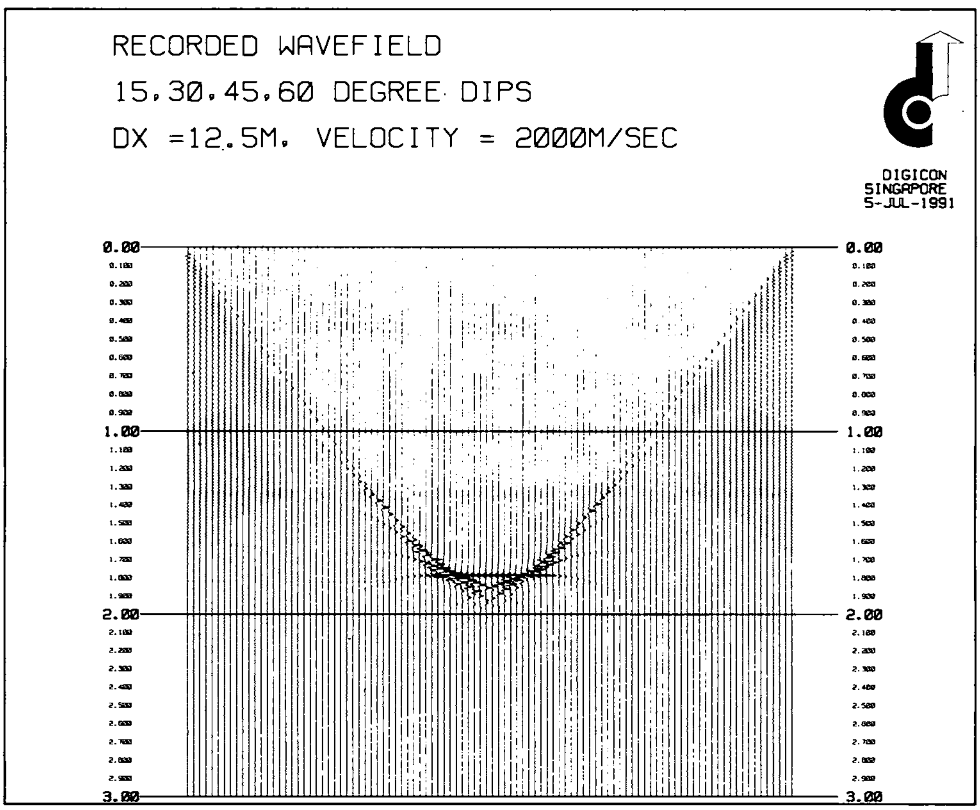

Figure 3: Synthetic stack data

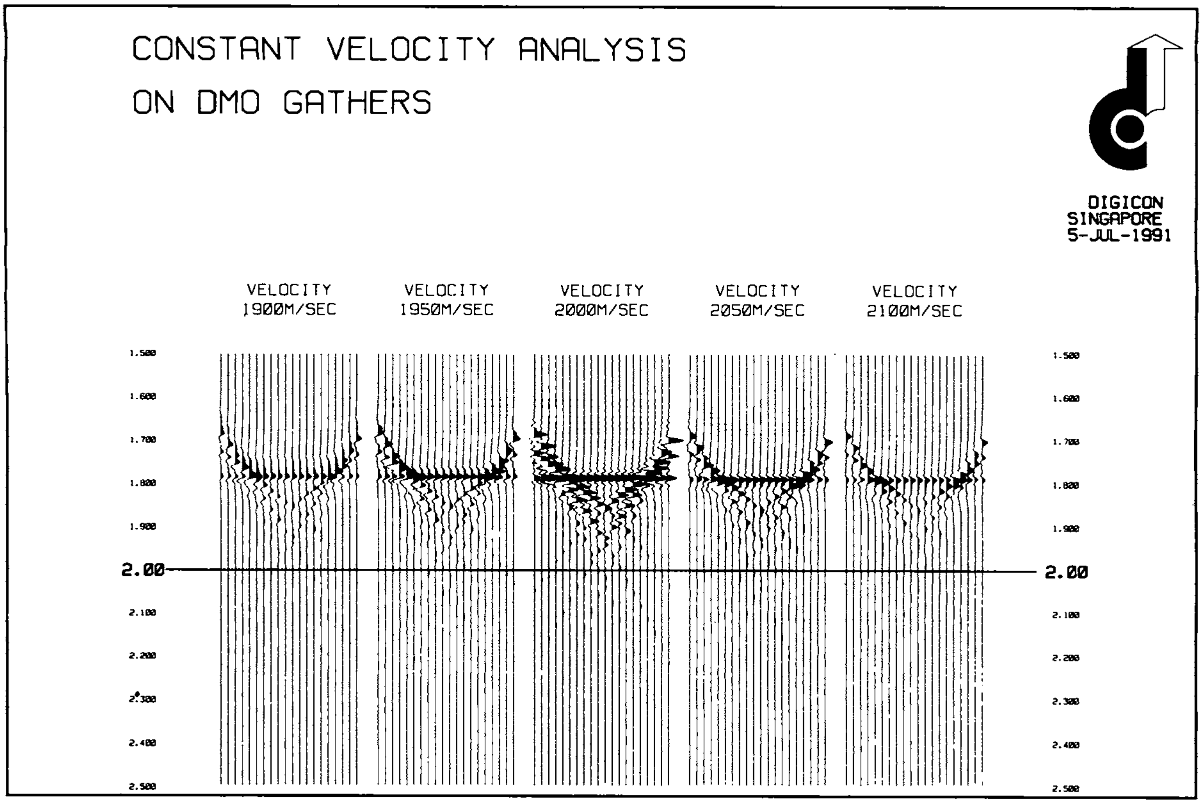

Figure 4: Velocity analysis on structural DMO gathers

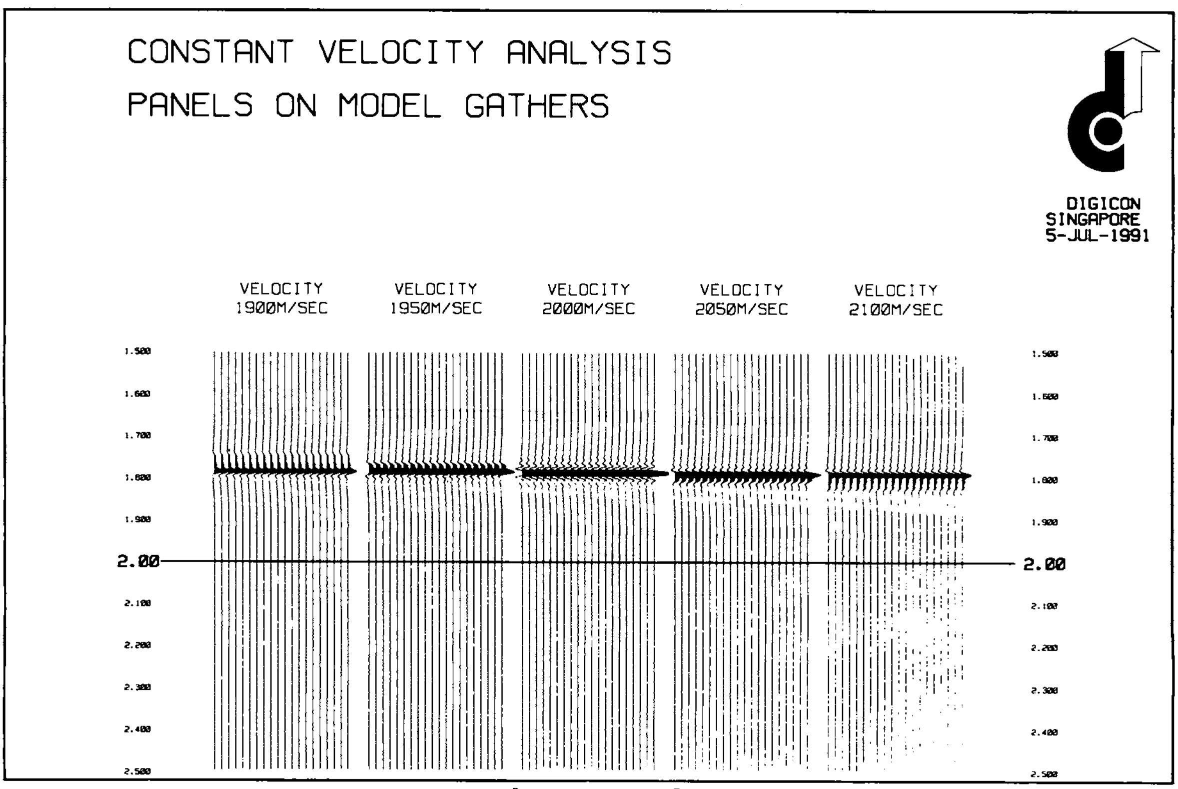

Figure 5: Velocity analysis on structural model

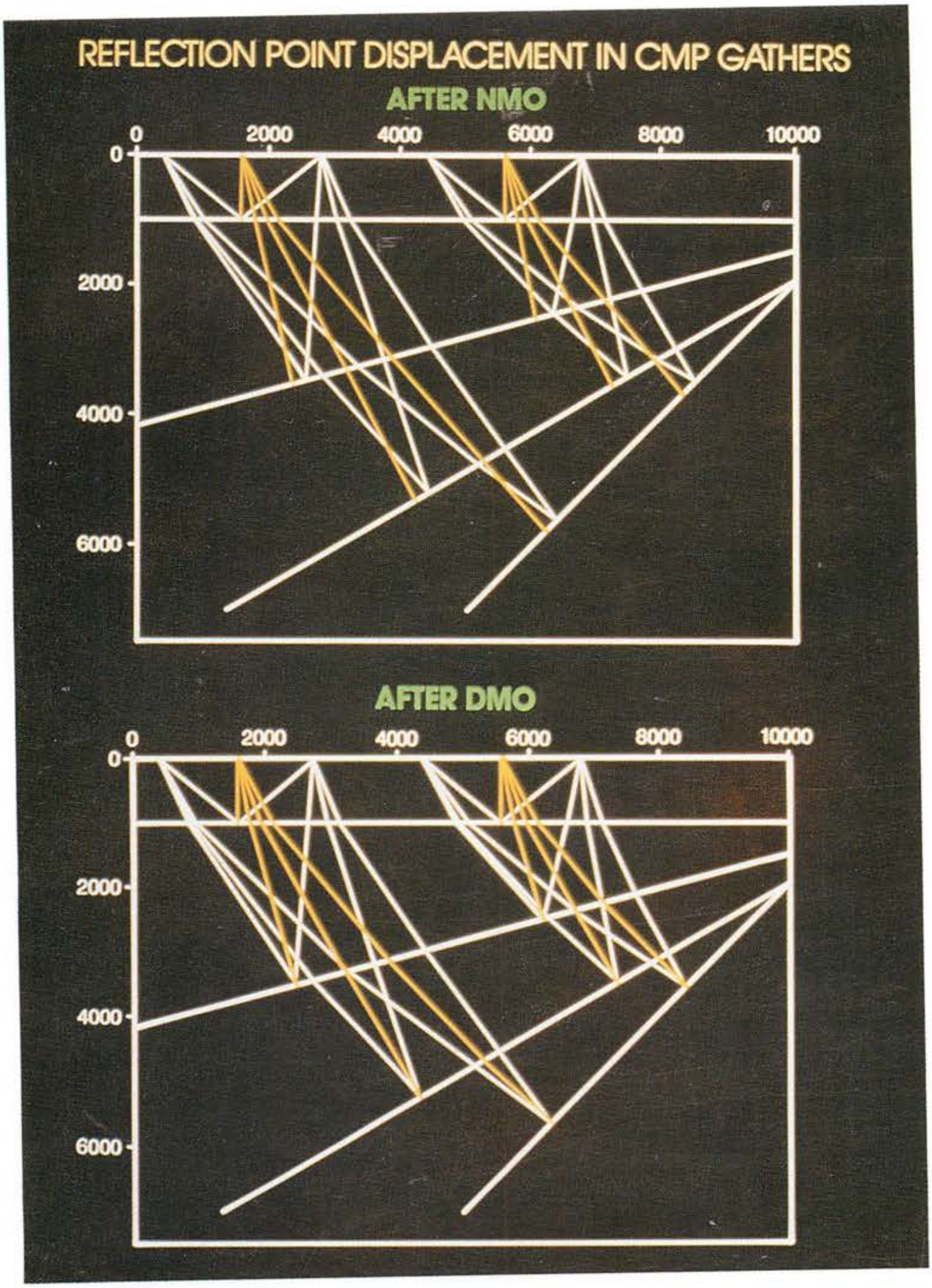

Figure 6a: Raypaths before and after DMO

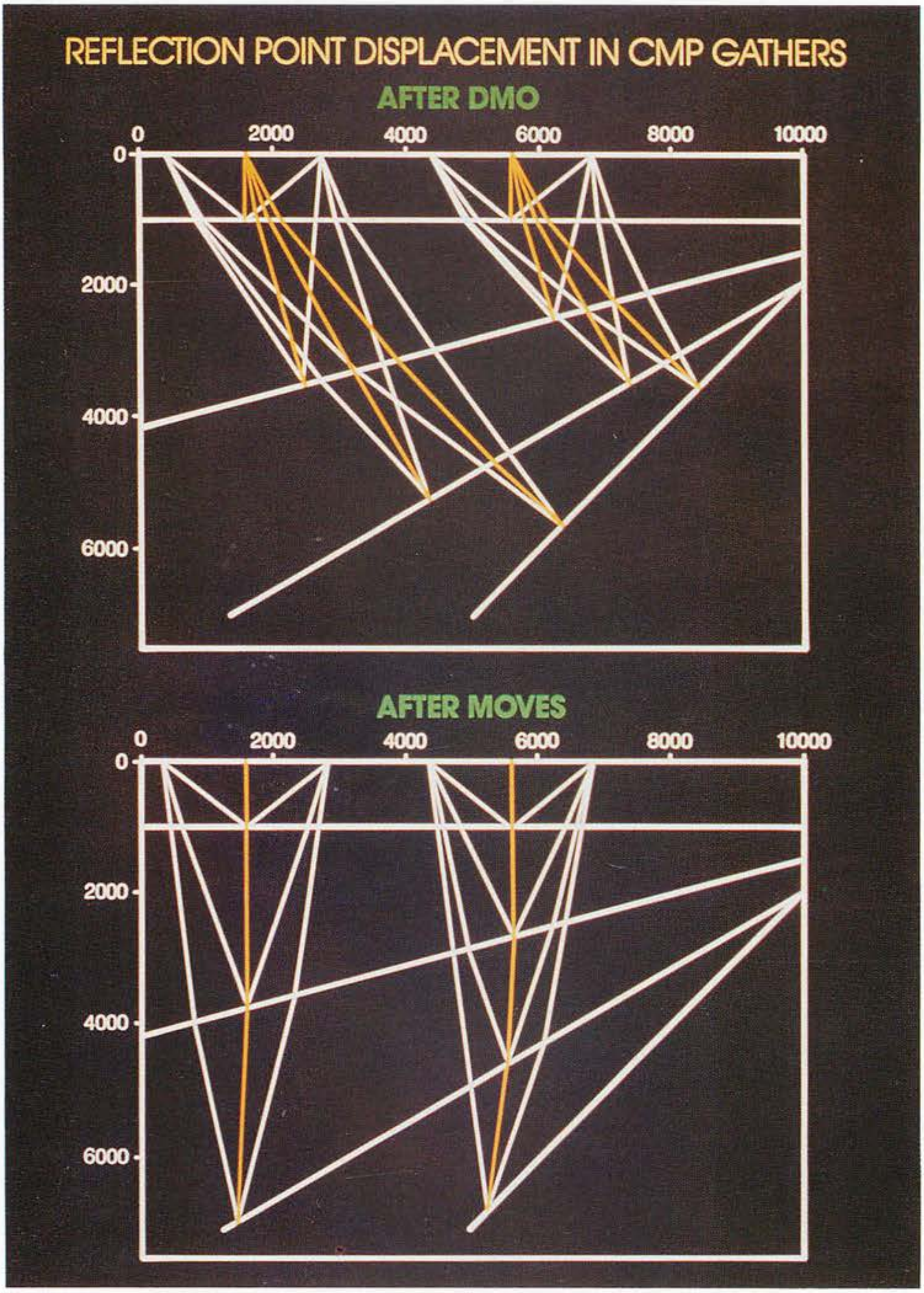

Figure 6b: Raypaths before and after migration

of the underlying sediments. Velocity analysis on fully migrated data would be along image ray-paths which are perpendicular to the recording surface. These velocities would be suitable for depth conversion and post-stack migration, the migration velocity field should be associated with the structures in their actual position and not related to their position on the unmigrated stack section.

We would like to analyse for velocity post migration but migration requires a velocity field. *Ayam atau telor*, which comes first the chicken or the egg, or in this case the migration or the velocity analysis? Some migration may clarify the reflection data as shown in Figure 7, where the data was migrated with a 1700m/second constant velocity field. The synclinal structure is better defined and is approaching the input model. Velocity analysis on these data would lack ambiguity and multi-valued time-velocity choices are removed (Fig. 8). The velocity field would also relate directly to the input model providing an optimum migration velocity field.

PENINSULAR MALAYSIA EXAMPLE

The results of applying the MOVES sequence to offshore Peninsular Malaysian data are shown in Figures 9 through 11. The application of Dip Moveout (Fig. 9b) allows the diffraction and steep dip energy to be stacked and improves the reflection data by comparison to the stack without Dip Moveout (Fig. 9a). The MOVES stack section, performing the migration step with a spatially invariant and slower velocity field, partially collapses the diffractions and migrates dipping energy updip. The partially migrated reflection events are now approaching their correct location (Fig. 9c). The velocity fields derived from the unmigrated and partially migrated datasets shown in Figure 10 demonstrate that after some migration the velocity field is more closely related to the structural geology.

Migrating the dip moveout corrected stack section (Fig. 9a) with these two velocity fields illustrates how the MOVES process derives a better migration velocity field (Figs. 11a, 11b & 11c)

RESIDUAL MIGRATION

A post stack residual migration using a velocity field calculated using the square root law can be applied to the MOVES stack.

$$V_{resid} = \sqrt{V_{Final}^2 - V_{First}^2}$$

where

V_{resid} = residual migration velocity field

V_{final} = migration velocity field derived from MOVES velocity analysis

V_{first} = Initial prestack migration velocity field used to partially migrated the data prestack.

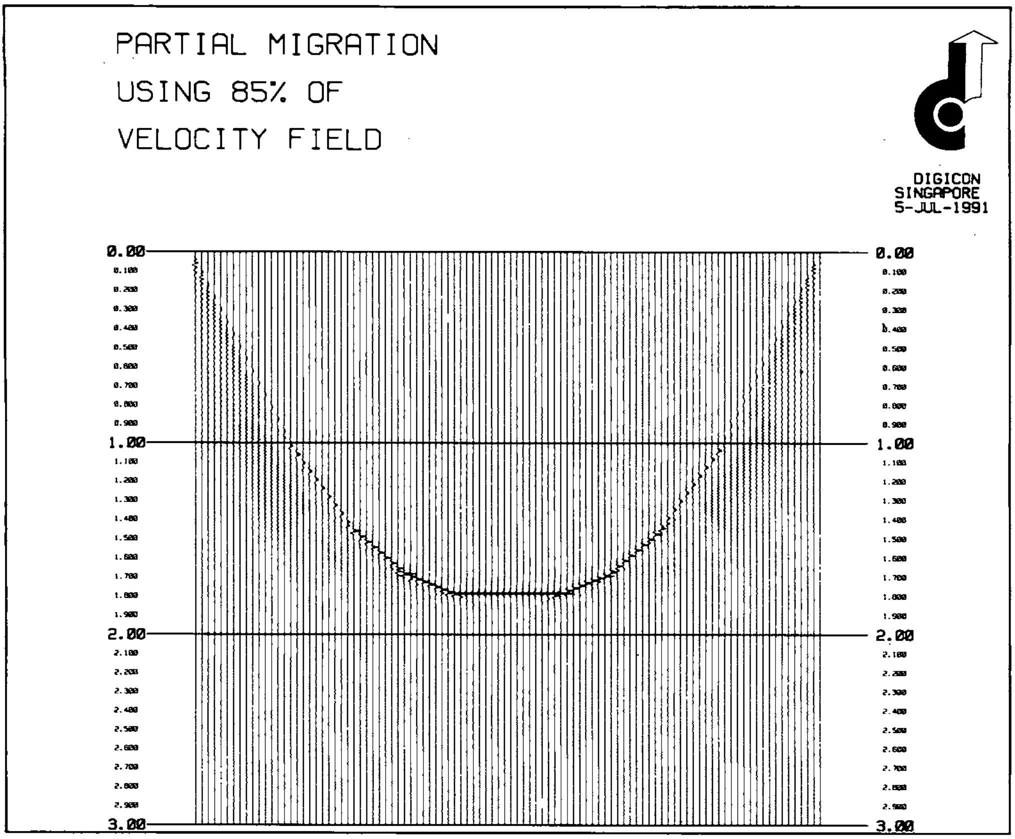

Figure 7: Partial migration of synthetic data

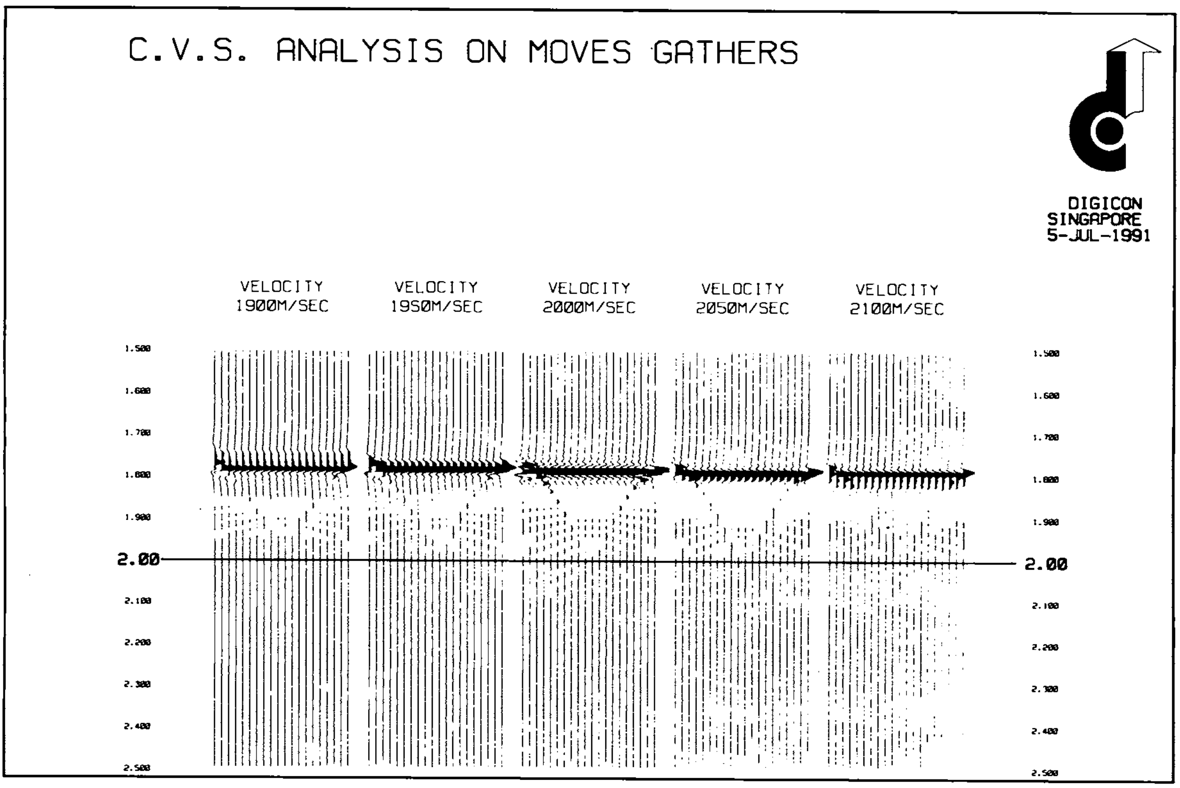

Figure 8: Velocity analysis on partially migrated gathers

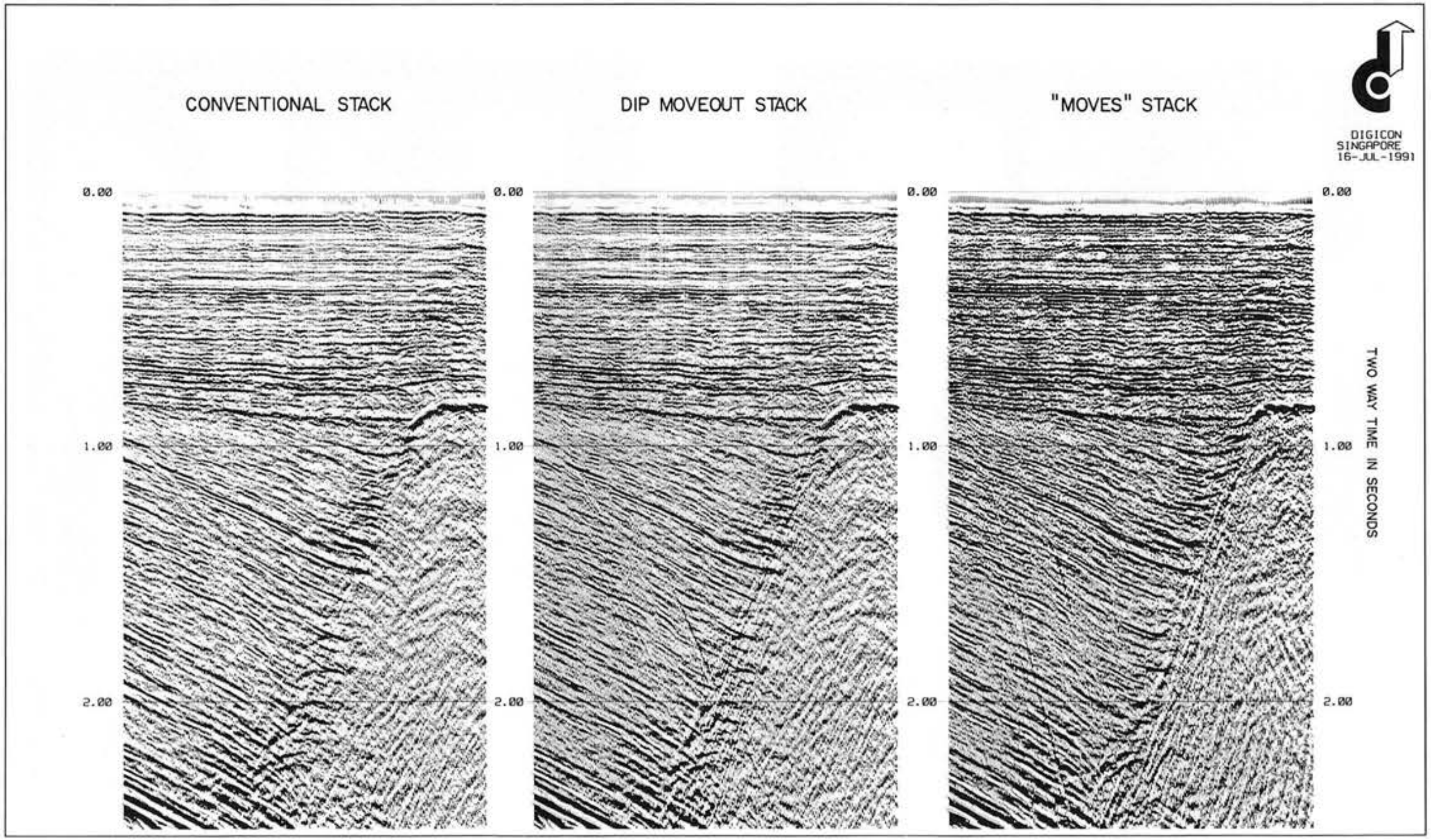

Figure 9a: Conventional final stack

Figure 9b: DMO stack

Figure 9c: MOVES stack

Figure 10a: Conventional derived velocity field

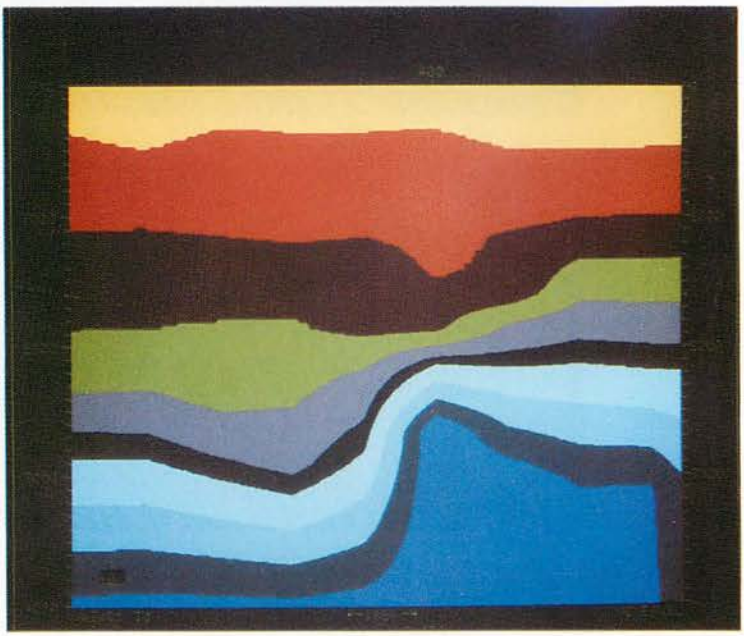

Figure 10b: MOVES derived velocity field

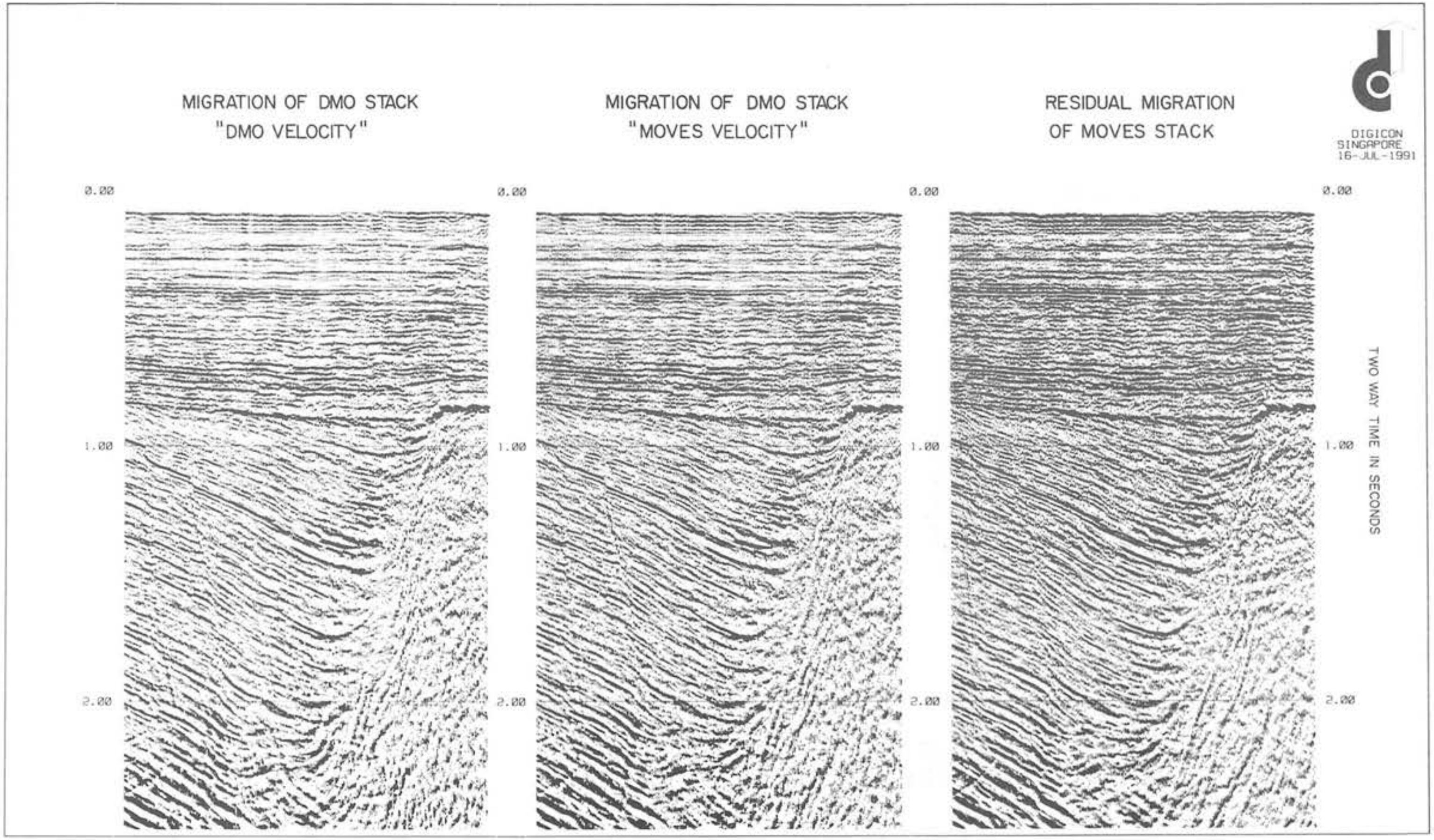

Figure 11a: Migration of DMO with conventional velocity field

Figure 11b: Migration of DMO stack with MOVES velocities

Figure 11c: Residual migration of MOVES stack

Migrating the MOVES stack with the V_{resid} velocity field will fully migrate the data to its correct position.

CONCLUSION

The results of performing common-offset Dip moveout and migration show that favourable results can be achieved over conventional methods in the case of structurally complex data zones. Cascading Dip moveout with migration enables the MOVES process to be economically viable on a production basis; the procedure is employed routinely and yields excellent results.

REFERENCE

MARLOUX, M.O., 1987. Migration for optimum velocity evaluation and stacking. Presented at the 40th Annual Midwest Regional Meeting of the SEG, Dallas.

Manuscript received 5th August 1991