

Imaging oblique reflectors on a 2D line

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ABSTRACT

Seismic data are usually acquired with a 3D geometry for exploration and exploitation purposes. This 3D geometry allows the resolution of dipping or oblique reflectors, and eliminates the concern of sideswipe. However, 2D data is still being acquired and designed to be normal to the geological structures. Some reflector may be oblique to the 2D line and may not be imaged correctly. Raising the velocities during a poststack migration allows the specific oblique reflectors to be imaged correctly. Should the same concept be applied to a prestack time migration?

Prestack time migration is very sensitive to the migration velocities which aids in defining accurate migration velocities. However, small perturbations in velocity can create significant artifacts. Therefore, prestack migration should be used to create one migrated section using the best velocities. This migrated section can be re-migrated which modified velocities to simulate a poststack migration that was designed to focus oblique reflectors.

INTRODUCTION

Raypaths for zero-offset reflections from an oblique reflector are illustrated in Figure 1a. The location of the reflection point moves away from the vertical plane as the source moves away from the intersection point. The offset case (b) shows a source and receiver with the zero offset raypath in blue, the offset raypaths in red, and a normal reflector raypath in green. The oblique raypaths have a shorter traveltime and require a higher velocity to migrate.

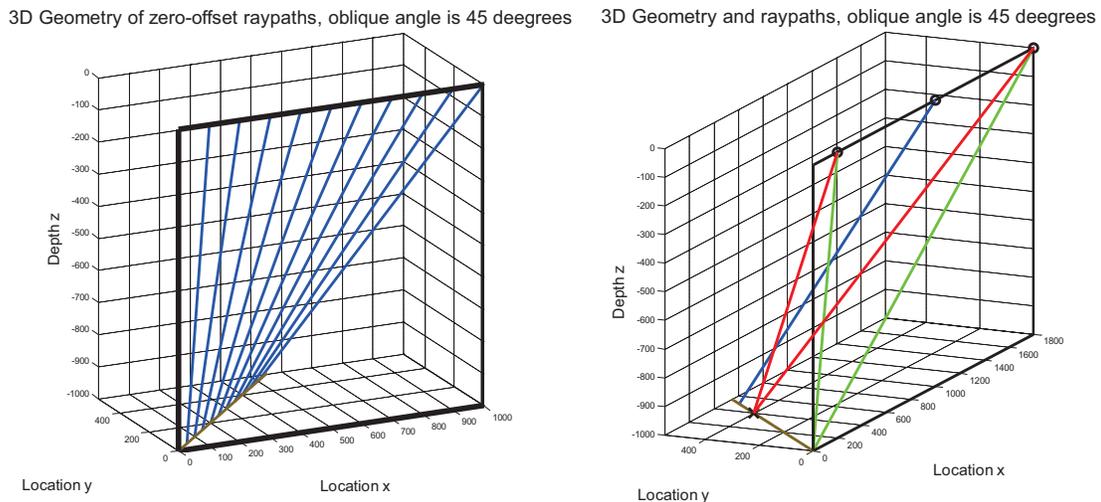


FIG. 1 Perspective view of raypaths, a) for zero offset and b) for an offset case.

Poststack 2D migration for oblique reflectors was described by French (1975). The migration velocity V_{mig} was increased over the RMS velocity V_{rms} using the angle of obliquity, γ , i.e.,

$$V_{mig} = \frac{V_{rms}}{\cos(\gamma)}. \quad (1)$$

An example of the success of this concept is displayed in Figure 1 that shows a conventional poststack migration in (a) whose input was a stacked section, and (b) using the same stacked section as input, but migrated with 130% of the RMS velocities that were used in (a). The 130% migration shows a fault, not evident on the 100% migration. The angle of obliquity, γ , can be estimated from equation (1), and is approximately ± 40 degrees.

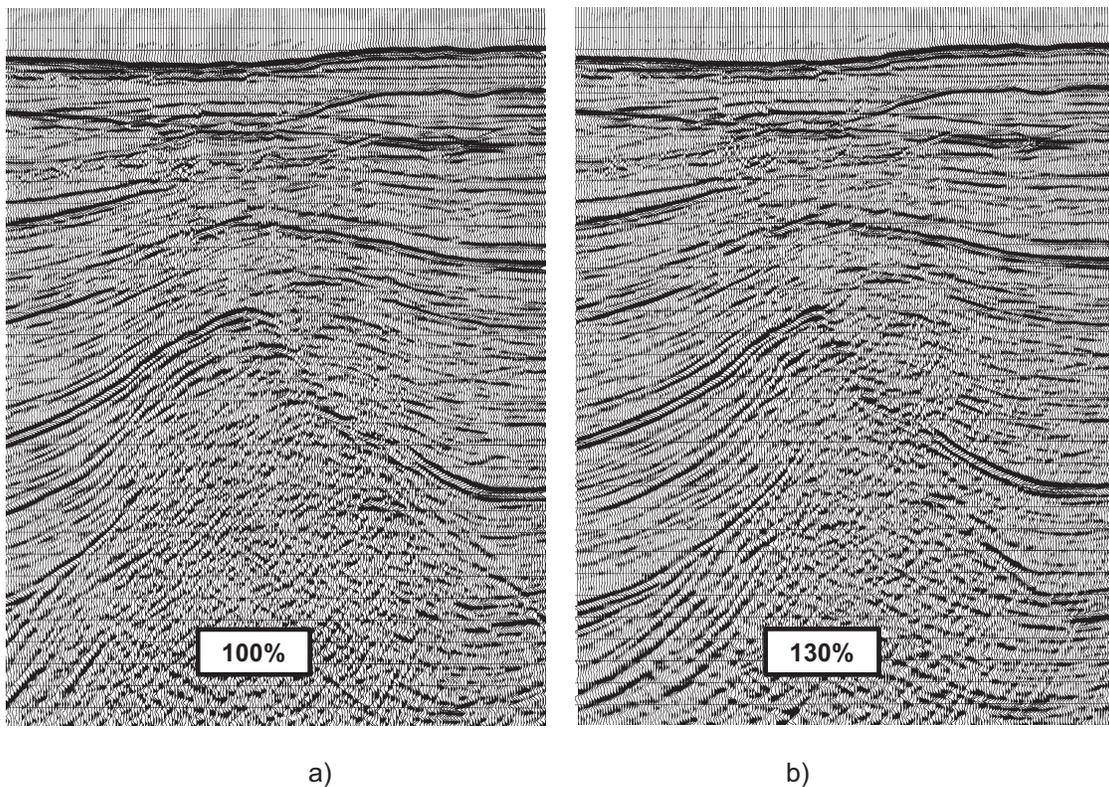


FIG. 2 Two images, migrated with a) 100% V_{rms} and b) 130% V_{rms} .

Prestack method 1

Extending the migration process to use prestack data as the input has been discussed (Bancroft et al. 2000, and Bancroft 2001) with the intent of providing improved imaging. Equation 5 from Bancroft et al. 2000 is

$$T^2 = T_0^2 + \frac{4x^2 \cos^2 \gamma}{V_{rms}^2} + \frac{4h^2}{V_{rms}^2}, \quad (2)$$

and may be written as

$$T^2 = T_0^2 + \frac{4(x^2 \cos^2 \gamma + h^2)}{V_{rms}^2} = T_0^2 + \frac{4\tilde{h}_e^2}{V_{rms}^2}, \quad (3)$$

where \tilde{h}_e is a new equivalent offset

$$\tilde{h}_e^2 = x^2 \cos^2 \gamma + h^2. \quad (4)$$

This equivalent offset was used to form prestack migration gathers similar to the Equivalent Offset migration (EOM) (Bancroft et al. 1996). The new offset is independent of time or velocity and enables rapid gathering of the prestack traces into migration gathers. Tests were conducted on the Hussar data where prestack gathers were formed at various obliquity angles, velocities estimated, and the gathers then stacked to complete the prestack migration. These results were not satisfactory and were very sensitive to velocities. This method was much more time consuming than the following Method 3 as it required a complete EOM prestack migration for every oblique migration. Testing has been delayed until a better data set is available.

Prestack method 2

Conventional EOM produces CSP gathers using no velocity information. Velocity analysis of these gathers provides RMS velocities for moveout, then stacking completes the prestack migration. Different percentages of the RMS velocity could be applied to the CSP gathers in an attempt to focus the energy from an oblique reflector.

This process was also applied to the Hussar data with unsatisfactory results, due to the sensitivity of the velocities. This method is much faster than Method 1 as there is only one run of EOM required to produce the CSP gathers.

Prestack method 3

A third method to improve the focusing of oblique reflectors was tried. It is basically the poststack method using the results of a prestack migration. The method used the prestack migration gathers of EOM corrected for 100% velocities. The migrated section was then re-migrated with different velocities to simulate a poststack migration at various velocities. This is referred to as cascaded migrations.

Cascaded migration (Larner et al. 1987) forms a new migrated section by migrating an initial zero-offset section with velocity V_A , then uses that migrated section as input for a new migration using velocity V_B to produce a new migrated section. The new section is equivalent to migrating the original data with a velocity V_C defined by

$$V_C = (V_A^2 + V_B^2)^{1/2}. \quad (5)$$

If we assume the increment in the velocity V_c is δV_c , i.e. $V_C = (1 + \delta_C)V_A$ and the remigration velocity V_B to be a fraction δ_B of V_A , i.e. $V_B = \delta_B V_A$, then

$$(1 + \delta_C)^2 = 1 + \delta_B^2 \quad (6)$$

or
$$\delta_B = (1 + \delta_C^2)^{1/2} - 1, \tag{7}$$

If we want to simulate a 120% migration, then we need to re migrate the 100% migration with

$$\delta_B = [(1.2)^2 - 1]^{1/2} = 0.6633, \tag{8}$$

or $V_B = 66\%$.

I will now use equation (1) to include the obliquity angle, i.e.,

$$V_C = \frac{V_A}{\cos \gamma}, \tag{9}$$

or
$$1 + \delta_C = \frac{1}{\cos \gamma}, \tag{10}$$

then
$$\delta_B = \left[\frac{1}{\cos^2 \gamma} - 1 \right]^{1/2}. \tag{11}$$

We can now form a table of the velocities required to migrate and re-migrate a section to image an oblique reflector.

Table 1 Migration and remigration velocities V_C and V_B as a function of obliquity angle.

| Obliquity angle (degrees) | Poststack migration velocities V_C | Re-migration velocities % of V_A |
|---------------------------|--------------------------------------|------------------------------------|
| 10 | 102% | 18% |
| 20 | 106% | 36% |
| 30 | 115% | 58% |
| 40 | 131% | 84% |
| 50 | 156% | 119% |
| 60 | 200% | 173% |
| 70 | 292% | 275% |
| 80 | 576% | 567% |

The remigration values may seem extreme, but I have worked with a number of examples where this process has been used successfully for angles up to 70 degrees.

This method is quite fast as it only requires a poststack migration for each obliquity angle, and the images were much more stable than the prestack methods.

EXAMPLES

I will use a line from the Hussar project that is very poor quality. It is a poor example and does not validate the above theory. There may be an oblique reflection around 1,000 ms.

The first three examples use Method 2 with percent velocities of 105%, 110% and 115%.

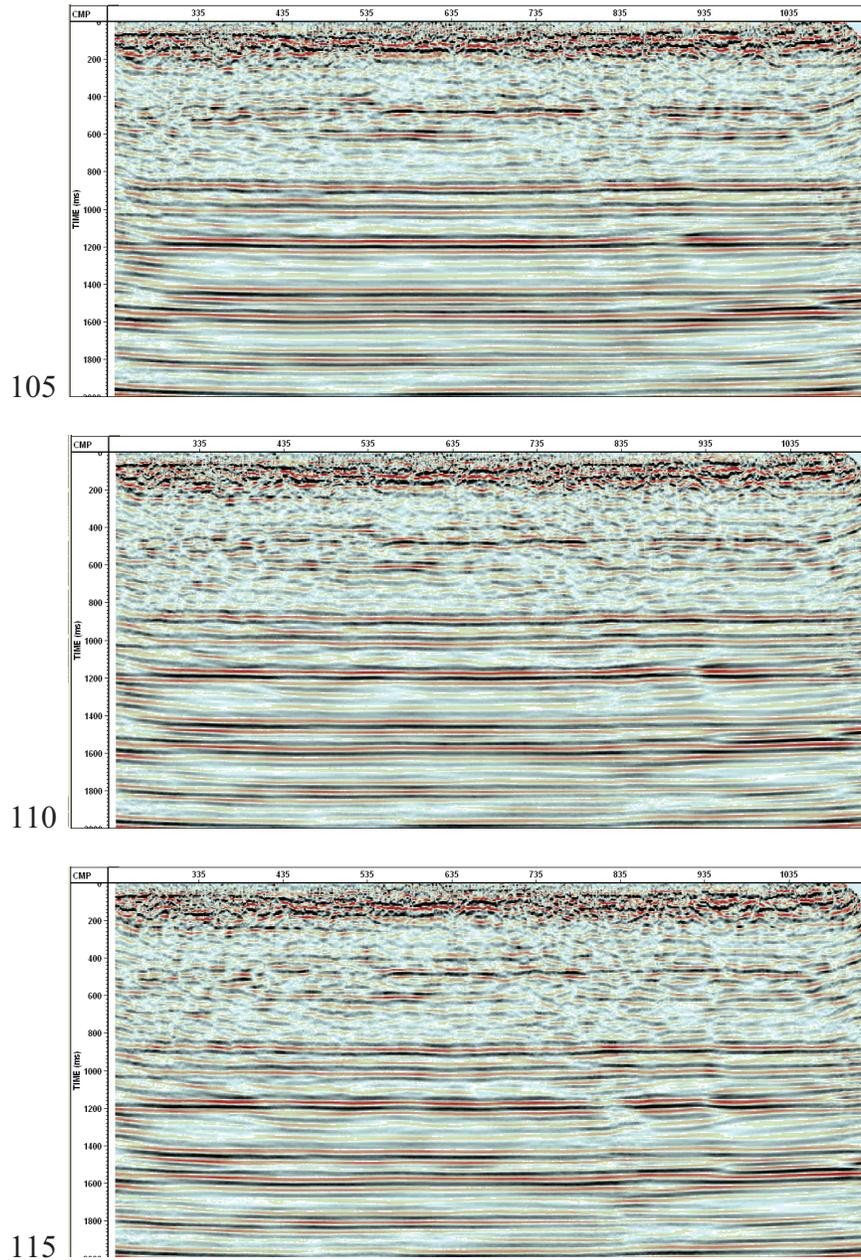
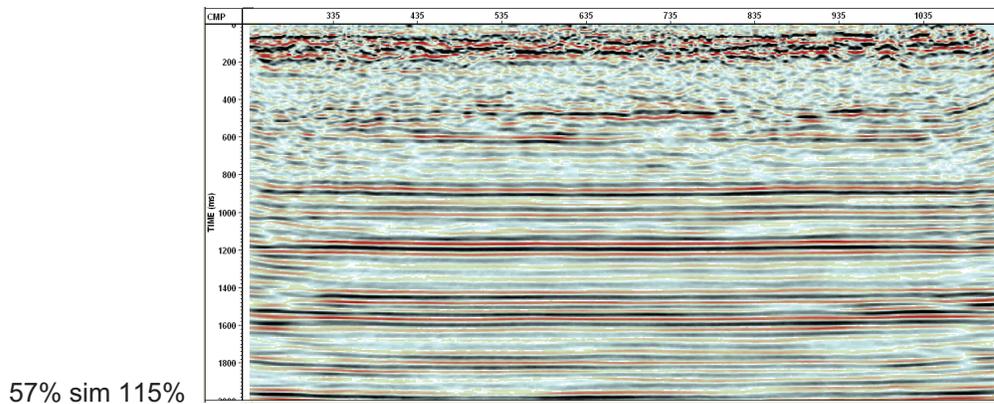
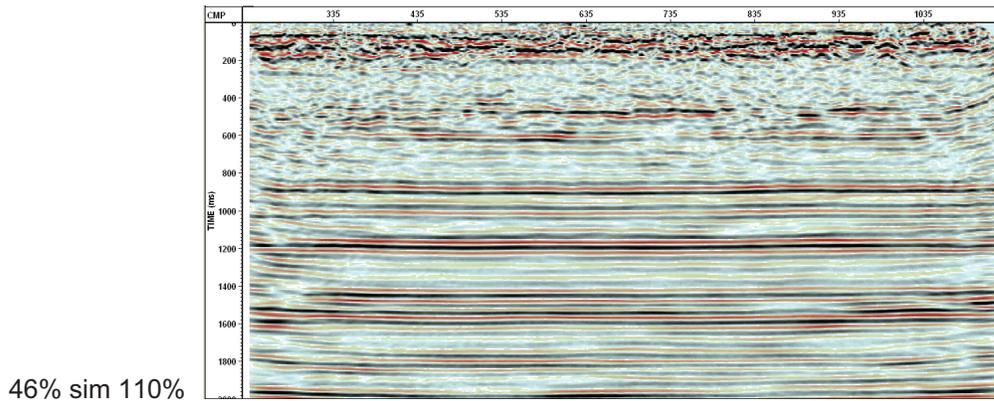
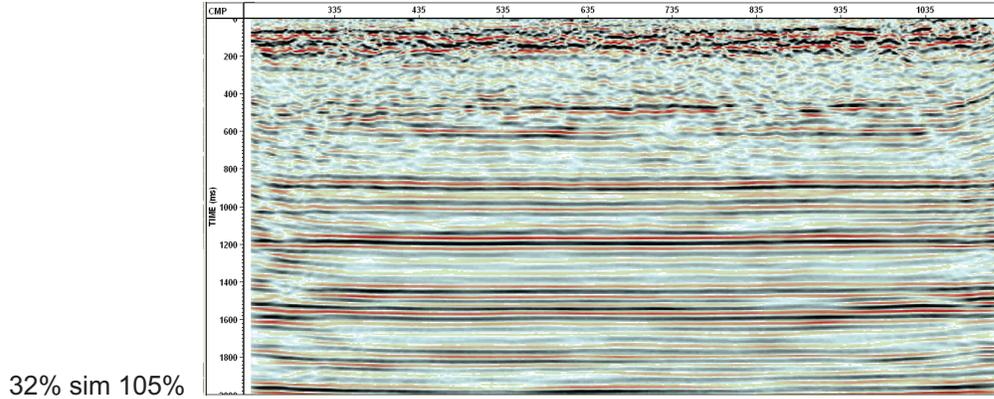
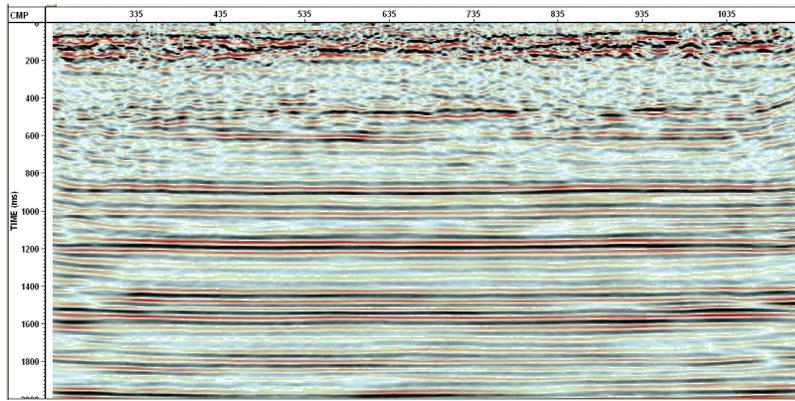


FIG. 3 Three examples of Method 2 for 105, 110, and 115%.

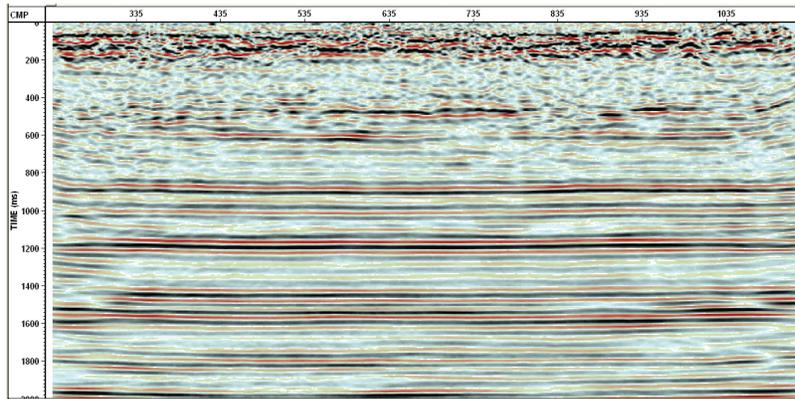
The following set of examples used Method 3 by re-migrating one prestack migration with a percentage to simulate a poststack migration with a given velocity. The remigration velocities were chosen to match post stack migration velocities of 105%, 110%, 115%, etc. The notation on the left of the figure indicated the percentage of the remigration velocity followed by the simulated poststack migration velocity.



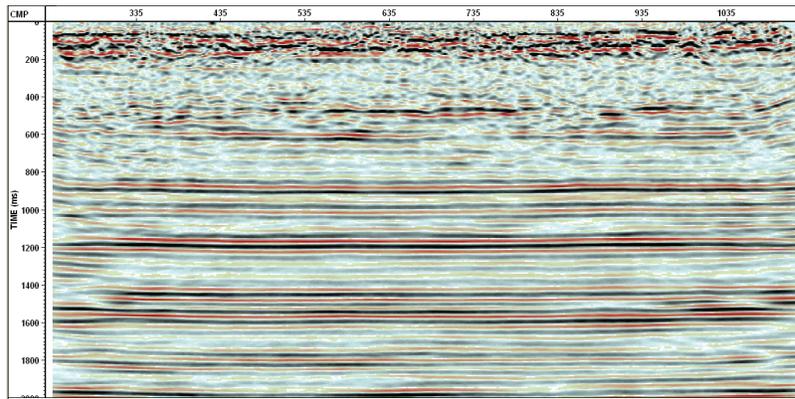
66% sim 120%



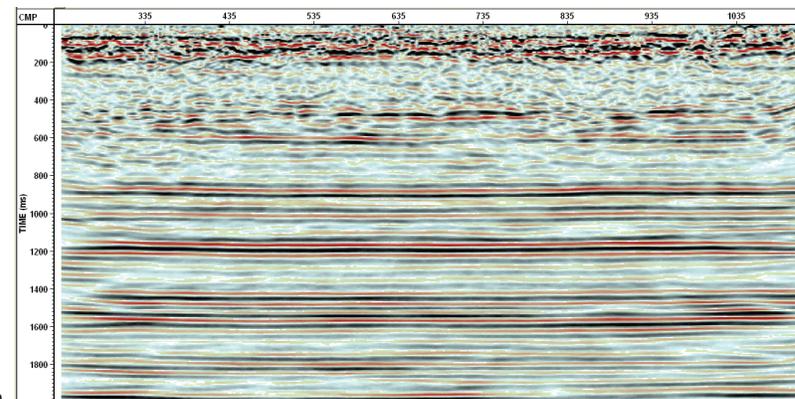
75% sim 125%



83% sim 130%



112% sim 150%



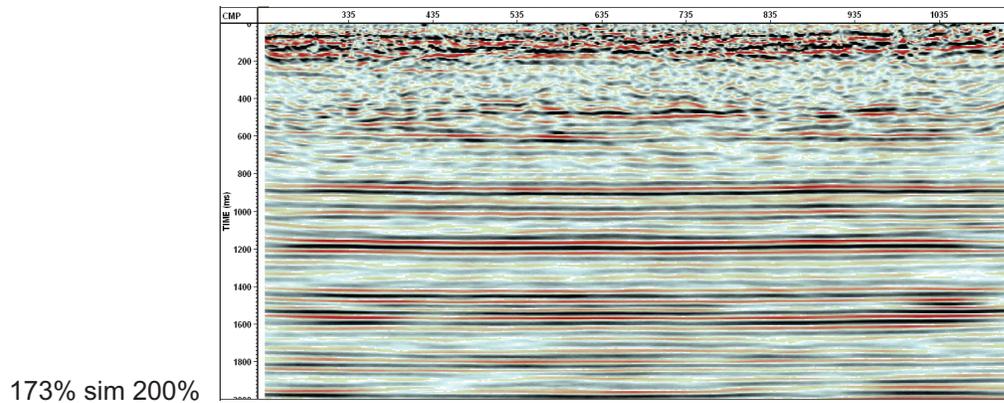


FIG. 4 Various remigrations with the percentages shown on the left.

CONCLUSIONS

Prestack migrations were considered to focus oblique reflectors on a 2D seismic line. Using the angle of obliquity to modify the velocities in a prestack migrations appeared to produce too many artifacts that may obscure an actual oblique reflection. The processes of Cascaded migration and migration for oblique reflectors were combined to produce a migration to focus oblique reflections.

The poor data used produced inconclusive results, but do suggest that the cascaded migration approach is a viable tool for imaging oblique reflectors.

The inclusion of deconvolution after migration may be of value in examining the higher resolution detail of oblique reflectors.

ACKNOWLEDGMENTS

The authors would like to thank all CREWES sponsors, staff and students for their support.

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