Migration in weakly anisotropic medium using approximate quasi-isotropic wavefront construction

Rodrigo S. Portugal, State University of Campinas, Alcides Aggio and Eduardo Filpo, PETROBRAS S/A

Copyright 2003, SBGf - Sociedade Brasileira de Geofísica

This paper was prepared for presentation at the 8th International Congress of The Brazilian Geophysical Society held in Rio de Janeiro, Brazil, 14-18 September 2003.

Contents of this paper was reviewed by The Technical Committee of The 8th International Congress of The Brazilian Geophysical Society and does not necessarily represents any position of the SBGf, its officers or members. Electronic reproduction, or storage of any part of this paper for commercial purposes without the written consent of The Brazilian Geophysical Society is prohibited.

Abstract

When anisotropy is present, even a weak one such as a transverse isotropic (TI) model, the attempt to use isotropic migration often fails. In this work we present a kinematic Kirchhoff migration algorithm which uses the traveltime tables generated by a wavefront construction algorithm corrected to work for quasi-isotropic medium by a velocity perturbation. When the geologic model has a weak anisotropy with some symmetry, such as vertical transverse isotropic (VTI) media, the isotropic wavefront construction method can be corrected giving the expected result of a complete anisotropic ray tracing. Therefore, its output traveltime tables have the correct anisotropic traveltimes and then they can be delivered as input for the Kirchhoff migration. Finally, we present a synthetic example which addresses those important issues.

Introduction

In any Kirchhoff migration method, the velocity model has a great influence on the quality and accuracy of the final migrated image, mainly concerning lateral variations. When the geologic model present some anisotropy, one can impose to an isotropic migration algorithm a velocity model in attempt to simulate the anisotropy effects. This trick, however, works at most for only one offset section at time and, therefore, it has to be done repeatedly.

When the anisotropy is weak, which is the most common case in exploration geophysics, according to Thomsen (1986), it is possible to make a correction on the isotropic ray equations, in order to propagate anisotropic rays. Actually this correction is available for transversely isotropic (TI) models and it employs a first-order perturbation on velocity.

These corrected ray equations can be used in the wavefront construction (WFC) method, which was introduced by Vinje et al. (1993). In this way approximate anisotropic traveltime tables can be delivered to Kirchhoff migration algorithms, producing better images, as if they were produced by a complete anisotropic migration.

In this work, we propose a kinematic migration algorithm which is essentially based on these traveltime tables that are the output of an approximate quasi-Isotropic wavefront construction.

Method

The proposed migration algorithm is basically a kinematic depth migration with full aperture. For each input trace a traveltime table is constructed by means of an interpolation of the wavefronts generated by WFQI method (Portugal *et al*., 2003). Then each trace sample is spread along the isochrons following the migration algorithm.

The approximate quasi-isotropic wavefront construction is achieved by means of a first-order perturbation of the velocity used in ray equations. Therefore the wavefronts are no longer orthogonal to the rays as expected in a weakly anisotropic medium.

Example and discussion

Our comparison is based on two kinematic migration methods: (a) based on the traveltime tables computed with approximate quasi-isotropic wavefront construction (MIGqI) and (b) based on the traveltime tables computed with isotropic wavefront construction (MIGISO).

The chosen geologic model is depicted in Figure 1 and it is a VTI model with Thomsen parameters $\varepsilon = 0.126$ and $\delta = 0.061$. It comprises two homogeneous layers, with P-velocities of 4.18 km/s above and 2.7 km/s below the interface (red line).

The synthetic data were generated by ANRAY software (Gajewski & Pšenčík,1989); that is a 3-D anisotropic ray-tracing package. A sample shot with some reflection rays (in blue) are depicted in Figure 1.

In order to stress the anisotropy effects we have selected as input for migration algorithm three common-offset gathers with: (1) a short offset of 500 m, (2) a medium offset of 1500 m and (3) a large offset of 2500 m.

The vertical axes in the figures represent depth measured in meters, except for Figures 1, 7 and 8, where depth is measured in Kilometers.

Figure 2, 3 and 4 show the common offset migrated sections for offsets of 500 m, 1500 m and 2500 m, respectivelly. In Figure 5 we can observe that the picked isotropic migrated interfaces (red lines) become increasingly misplaced as the offset increases. This problem has a direct effect in the stacked section, as the energy is not well aligned (Figure 6). Also it can be observed that the quasi-isotripic migration provides a better energy coherency along the interface, as well as a better vertical positioning than the isotropic migration.

In Figure 7 are depicted all amplitude peaks of Figures 2, 3 and 4. We can see that while the peaks from isotropic migration have greater vertical error as the offset increases, all the peaks from quasi-isotropic migration remain on the reflector. This is also observed in Figure 8, where is depicted the amplitude peaks of the coherency section shown in Figure 6.

Summary and Conclusions

We presented a kinematic mgration method which uses quasi-isotropic traveltime tables generated by a wavefront construction method corrected to work in quasi-isotropic media. As expected, when the medium possess some weak anisotropy with symmetry, as the VTI medium, the quasi-isotropic migration provides a correctly positioned migrated reflector, contrary to the isotropic migration, which produces migrated reflectors with vertical displacement, depending on the offset. As a final remark, we stress that the quasi-isotropic and isotropic traveltime tables were built with regular and corrected WFC methods, respectively, therefore both migration procedures have the same computational cost.

Acknowledgements

The authors wish to thank PETROBRAS for supporting and granting permission to publish this work. Particularly R. S. Portugal also thanks National Agency of Petroleum (ANP-PV/PRH15) for financial support.

References

Ettrich, N. and Gajewski, D., 1996, Wavefront construction in smooth media for pre-stack depth migration. PAGEOPH, **148**, n. 3-4, p. 481-502.

Gajewski,D. and Pšenčík I. , 1989, Ray synthetic seismograms in 3-D laterally inhomogeneous anisotropic structures – Internal Report Centre for Computational Seismology, LBL, Berkeley.

Thomsen, L., 1986, Weak elastic anisotropy. Geophysics, **51**, n. 10, p. 1954-1966

Vinje, V., Iversen, E., and Gjoystdal, H., 1993, Traveltime and amplitude estimation using wavefront construction. Geophysics, **58**, 1157-1166.

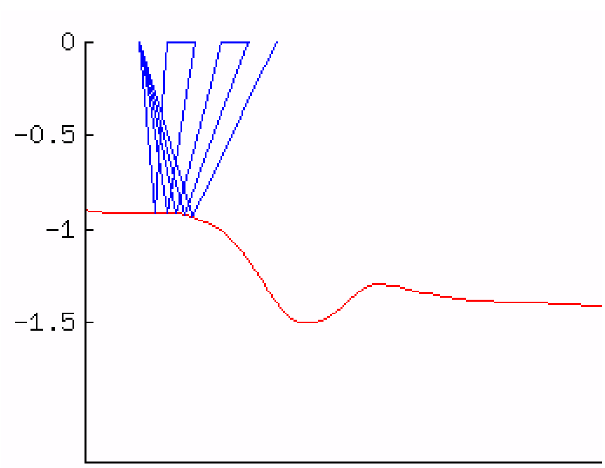

Figure 1: Homogeneous VTI model overburden the reflector (red line). The distances are measured in Km.

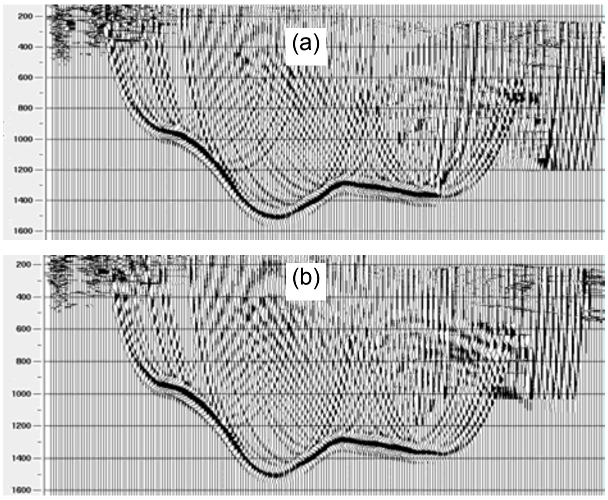

Figure 2: Common offset migration (500 m) using: (a) anisotropic and (b) isotropic traveltime tables.

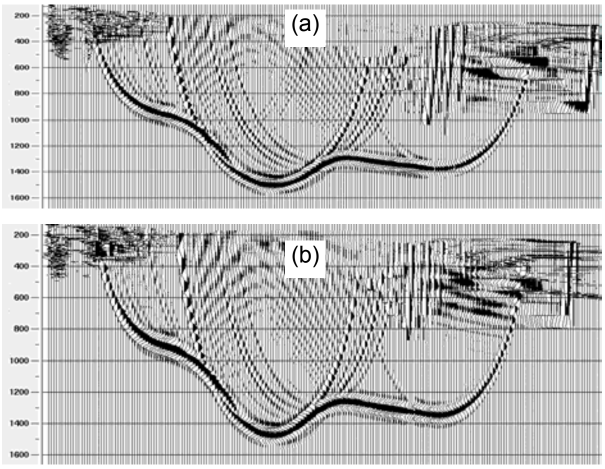

Figure 3: Common-offset migration (1500 m) using: (a) anisotropic and (b) isotropic traveltime tables.

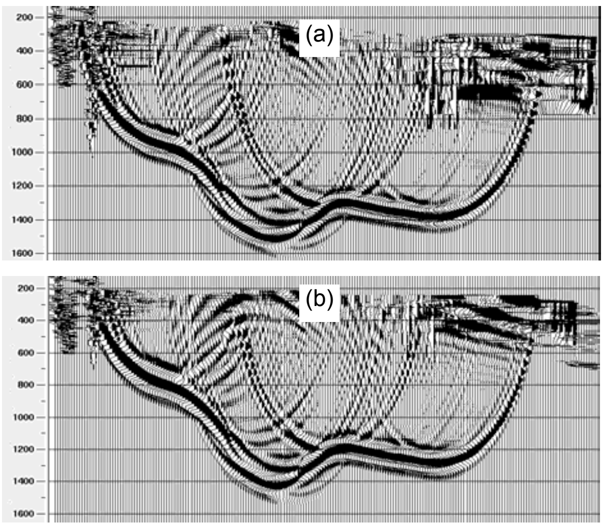

Figure 4: Common offset migration (2500 m) using: (a) anisotropic and (b) isotropic traveltime tables.

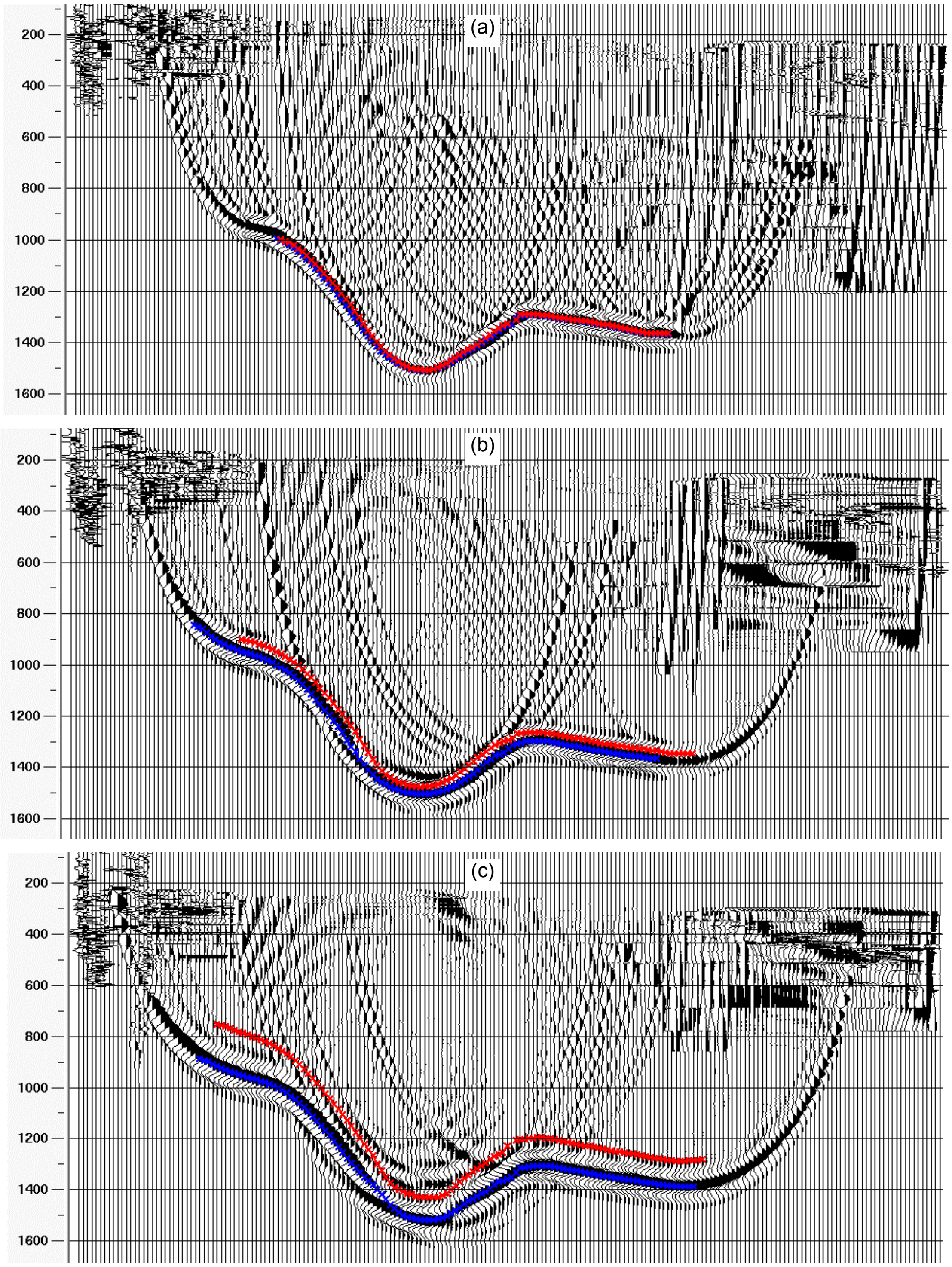

Figure 5: The red line is amplitude peak of the isotropic migration and blue line is the amplitude peak of the quasi-isotropic migration for offsets (a) 500 m, (b) 1500 m and (c) 2500 m..

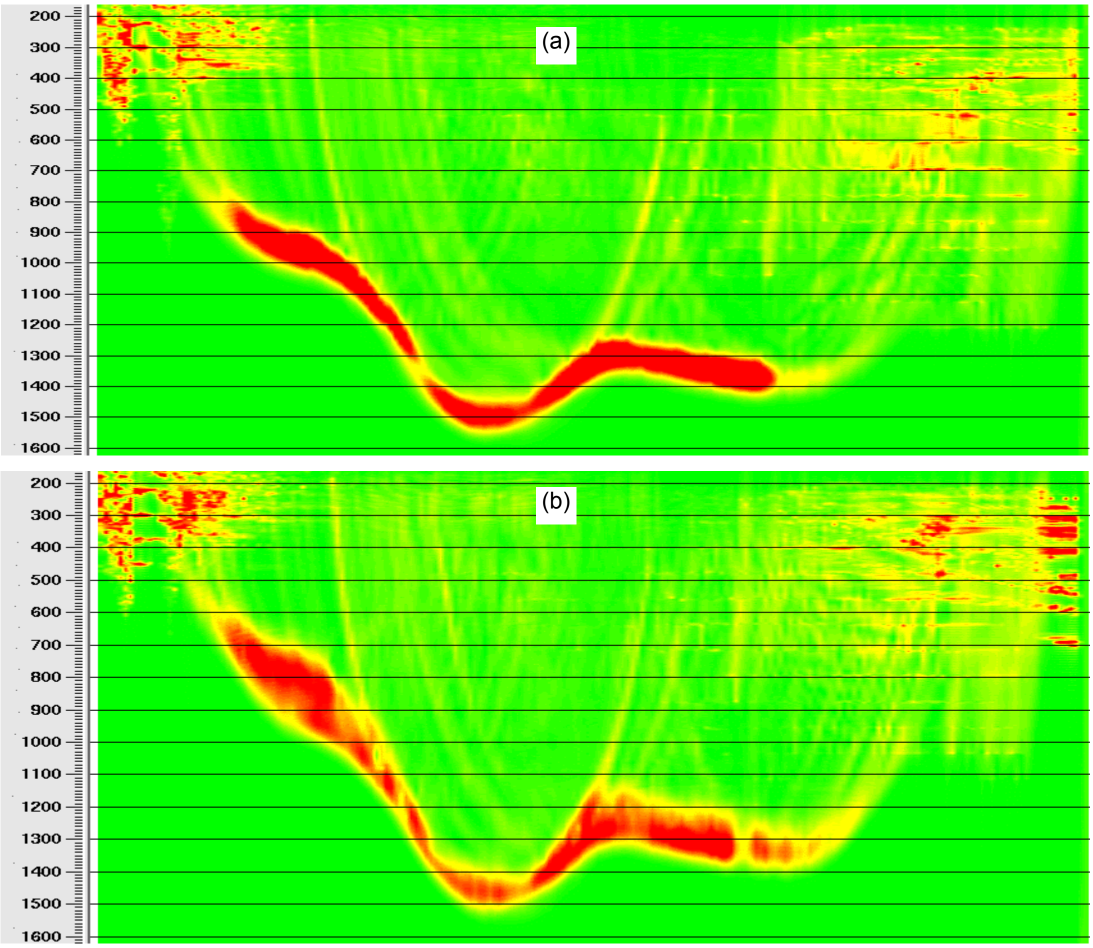

Figure 6: Envelope sections of the stacked migrated sections (500, 1500 and 2500 m) using: (a) quasi-anisotropic traveltimes and (b) isotropic traveltimes.

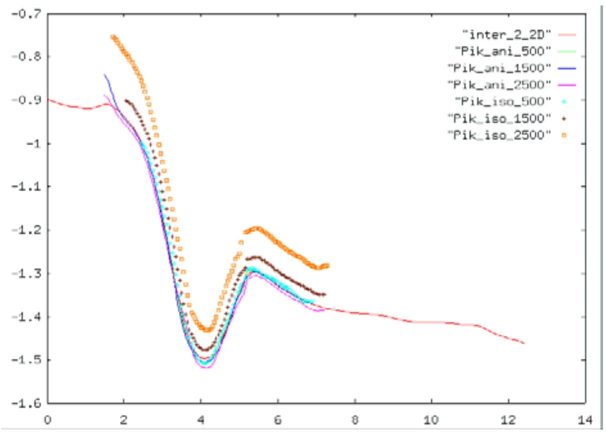

Figure 7: Amplitude peaks both quasi-isotropic and isotropic migrations of 500 m, 1500 m and 2500 m sections shown in Figures. 2, 3 and 4, respectively. The red line is the exact position of reflector. (Distances are measured in Km)

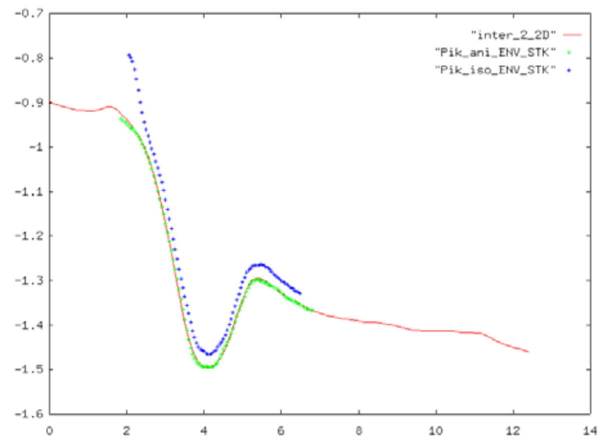

Figure 8 The amplitude peaks of the envelope sections shown in Figure 6. The red line is the reflector, the green squares are the from quasi-isotropic migration and the blue crosses are from isotropic migration. (Distances are measured in Km)