VELOCITY ANALYSIS BY
ITERATIVE PROFILE MIGRATION

A DISSERTATION
SUBMITTED TO THE DEPARTMENT OF GEOPHYSICS
AND THE COMMITTEE ON GRADUATE STUDIES
OF STANFORD UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

By
Kamal Mansour Al-Yahya
August 1987

printed as Stanford Exploration Project No. 53
by permission of the author

Velocity analysis by iterative profile migration

Kamal M. Al-Yahya, Ph.D.
Stanford University, 1987

ABSTRACT

In conventional seismic processing, the normal moveout (NMO) equation is used for velocity analysis. The NMO equation is based on the assumption of flat, horizontal reflectors, so the NMO analysis gives erroneous velocities when the subsurface does not consist of flat and horizontal layers. Imaging by migration (either after or before stack) is done in a subsequent step using these velocities.

In this thesis, velocity analysis and imaging are combined in one step, since they are complementary processes in the first place. Velocity analysis gives low-wavenumber information about the subsurface (the velocity) while migration gives the high-wavenumber information (the reflectivity). In this scheme, migration itself is used as a velocity indicator. Because migration is not based on the flat-layer assumption and can be formulated for any velocity function, velocity analysis methods which are based on migration are capable of handling arbitrary structures.

Several schemes can be developed to do velocity analysis using migration. Here, I migrate the data with an initial velocity model and then estimate the velocity error. The initial velocity model is updated next, then the process is repeated until convergence is achieved.

I use the principle that after migration with the correct velocity model, an image in a common-receiver gather (CRG) is aligned horizontally regardless of structure. The deviation from horizontal alignment, namely the curvature, is therefore a measure of the error in velocity. If the migration velocity is lower than the velocity of the medium, events curve upward, where if the migration velocity is higher than the velocity of the medium, events curve downward. In relating the curvature to the error in velocity, kinematic arguments which approximate the error estimation are used.

The iterative method is applied to a field data set and to a synthetic data set. The field data set does not appear to have significant lateral velocity variation; however, the

example shows that prestack migration can be used for velocity analysis. The synthetic example has lateral velocity variations, caused by anticlines and a wedge. It shows that this method detects lateral velocity variation.

Approved for publication:

By ______________________

For Major Department

By ______________________

Dean of Graduate Studies & Research

Acknowledgments

It is my pleasure to take this opportunity to thank those who helped me through my graduate studies and made writing this thesis possible.

My advisors, Jon Claerbout and Francis Muir, provided guidance. I thank Jon for giving me the chance to work in the Stanford Exploration Project—what I believe is the best academic research environment for exploration geophysics. Jon's critical review to the thesis made significant improvements. I also thank him for all the pomegranates he brought me from his garden. I thank Francis for initiating my research and suggesting all the ideas that helped me complete it. I very much enjoyed my discussions with him.

My colleagues at the Stanford Exploration Project helped by providing frequent and useful comments. I would especially like to thank Pete Mora for his review of this thesis and the numerous improvements he suggested. Thanks also to my fellow velocity analyzer, Paul Fowler, for many illuminating discussions, and to Einar Kjartansson for his help during his summer visit to Stanford.

I am grateful to the sponsors of the Stanford Exploration Project. During my stay at Stanford, I benefited from all the facilities provided by their sponsorship. The field data that I used in this thesis was kindly provided by Chevron. I am also grateful to the Exploration Department at ARAMCO for sponsoring my graduate study. I owe many thanks to Mojahid Al-Husseini who supported my sponsorship. His continuous encouragement was extremely valuable to me.

This thesis is a culmination of a long education process. I would like to take this opportunity to thank the many excellent teachers I have had in all the schools I attended. I will never forget their kindness and sincerity.

The arrival of my daughter, Basma, served as the greatest incentive for me to graduate. Thanks to her and to my wife, Maha, for their love and inspiration. Finally, thanks go to my brother, Fawzy, who took care of our family while I was away. I wouldn't have been able to come to Stanford had it not been for him.

Table of Contents

List of Figures