Journal of Applied Geophysics 117 (2015) 52–59

Contents lists available at ScienceDirect

Journal of Applied Geophysics

journal homepage: www.elsevier.com/locate/jappgeo

A stochastic approach to uncertainty quantification in residual moveout analysis

T. Johng-Ay [a,b,*], E. Landa [b], S. Dossou-Gbété [a], L. Bordes [a]

[a] Laboratoire de Mathématiques et leurs Applications, Pau, France
[b] OPERA, Applied Geophysical Research Group, France

ARTICLE INFO

Article history:
Received 22 September 2014
Received in revised form 17 February 2015
Accepted 18 February 2015
Available online 26 February 2015

Keywords:
Bayesian approach
Residual moveout analysis
Uncertainty analysis
Common image gathers

ABSTRACT

Oil and gas exploration and production relies usually on the interpretation of a single seismic image, which is obtained from observed data. However, the statistical nature of seismic data and the various approximations and assumptions are sources of uncertainties which may corrupt the evaluation of parameters. The quantification of these uncertainties is a major issue which supposes to help in decisions that have important social and commercial implications. The residual moveout analysis, which is an important step in seismic data processing is usually performed by a deterministic approach. In this paper we discuss a Bayesian approach to the uncertainty analysis.

Contents

1. Introduction

Analysis of the subsurface geology in order to identify and optimize the production of oil and gas deposits relies on the interpretation of seismic images. The seismic images in the depth domain are the result of an imaging tool which is called depth migration. Migration is a procedure in which seismic events are moved to their correct locations in space. This requires an accurate knowledge of seismic velocity model. Usually the so-called Common-Image-Gathers (CIGs) serve as a tool to verify the correctness of the velocity model. Often the CIGs are computed in the surface offset (i.e. distance between shot point and receiver) domain. Their flatness serves as a criterion of the velocity model

* Corresponding author at: LMAP-OPERA, UFR Sciences et Techniques Avenue de l'Université B.P. 1155, 64013 Pau Cedex, France.
E-mail address: tamatorojohng@gmail.com (T. Johng-Ay).

http://dx.doi.org/10.1016/j.jappgeo.2015.02.023
0926-9851/

correctness. Residual moveout (RMO) of the events on CIGs indicates incorrectness of the velocity model and is used to update it. Conventional RMO analysis is based on a simple scan in the CIG panels. A coherency measure (semblance) is used to estimate a residual curvature which matches to the event the best (Deregowski, 1990; Liu and Bleistein, 1995). Unfortunately, this conventional approach does not deal with the uncertainty. At the same time it is well known that structural information is fundamentally uncertain due to errors and inaccuracies in estimated velocity model. Since uncertainty has impacts on decisions that have important social and commercial implications (Bond et al., 2007; Osypov et al., 2011) its quantification is a major issue. The issue of uncertainties in seismic images was discussed previously by Thore et al. (2002), Pon and Lines (2005), Osypov et al. (2013) and Fomel and Landa (2014). To address this issue in this paper we discuss a stochastic approach of the RMO analysis. We suppose that the parameter of the residual curvature is not a deterministic fixed value but rather a random variable of which it is necessary to specify the distribution. The Bayesian approach provides a natural and appropriate framework for uncertainty analysis. This approach accounts for prior knowledge on the model in a justifiable and coherent way. Contrary to the single value of RMO, which is obtained in the conventional approach, the Bayesian approach provides us with the most probable RMO and the uncertainty associated with it. Below in Sections 2 and 3, we introduce Common Image Gather and present the conventional residual moveout analysis. Section 4 presents the Bayesian approach of residual moveout analysis. Examples on synthetic and real data to compare the two approaches are shown in Section 5.

2. Common image gather

Migration produces an image of the three spatial coordinates. Common image gathers exploit the redundancy of seismic data and produce images with more dimensions in the physical space. Usually this is done by imaging the data as a function of their recording offset. For velocity analysis it is useful to measure the differences between the CIG traces (offsets) at a fixed image point. Fig. 1 shows two migrated common offset images using a wrong velocity function. As can be noticed from the figures, the depth position for the same surface location (marked by a black point) is different for zero-offset and the 2500 m offset. We observe that the depth of a point at a fixed surface position is a function of the offset. The panel which allows us to observe the evolution of migrated points according to the offset is called Common Image Gather (Fig. 2). In general, the events (evolution of the depth according to the offset) observed on CIGs can be approximated by a hyperbolic curve given by the following equation (Liu and Bleistein, 1995):

$$z(h) = \sqrt{z_0^2 + (\gamma^2 - 1)h^2} \tag{1}$$

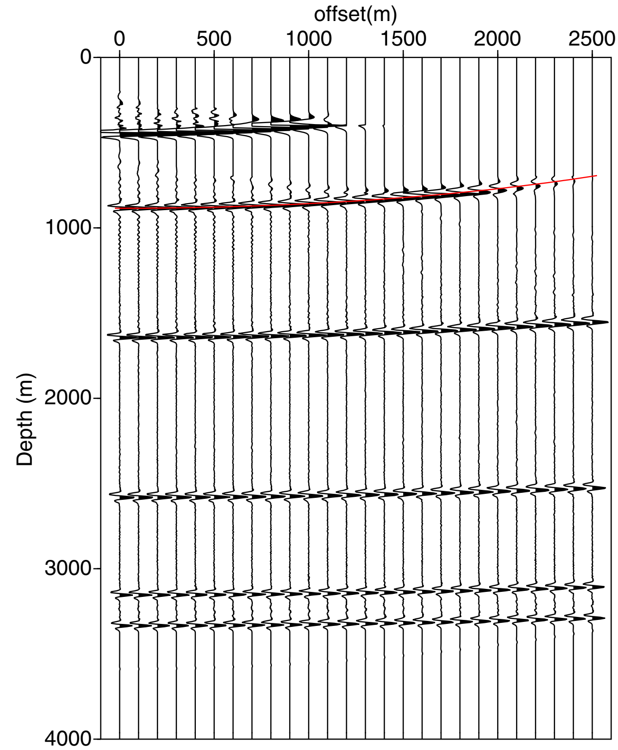

Fig. 2. Offset Domain Common Image Gather at surface position 5425 m. The line in red represents the depth's evolution as a function of the offset. The traces which are forming the CIG serve as data for RMO analysis.

where z_0 is the depth observed at the zero-offset image, $\gamma = \frac{v}{c}$ with v the velocity used for the migration, c is the media velocity and h is the half-offset. The traces which compose the CIG will serve as data for the residual moveout analysis. Those traces are stored as a matrix that we denote by $\mathcal{A} = \left(a_{ij}\right)_{\substack{1 \le i \le N_z \\ 1 \le j \le N_o}}$ where N_z and N_o are the number of depth samples and offsets in the CIG respectively.

3. Conventional residual moveout analysis

For a fixed depth point z_0 indexed by i_{z_0}, the residual moveout curve is fully determined by the parameter $\gamma = \frac{v}{c}$. The conventional residual moveout analysis algorithm defines for each depth z_0 a set of values γ and a corresponding set of residual moveout curves. A coherence

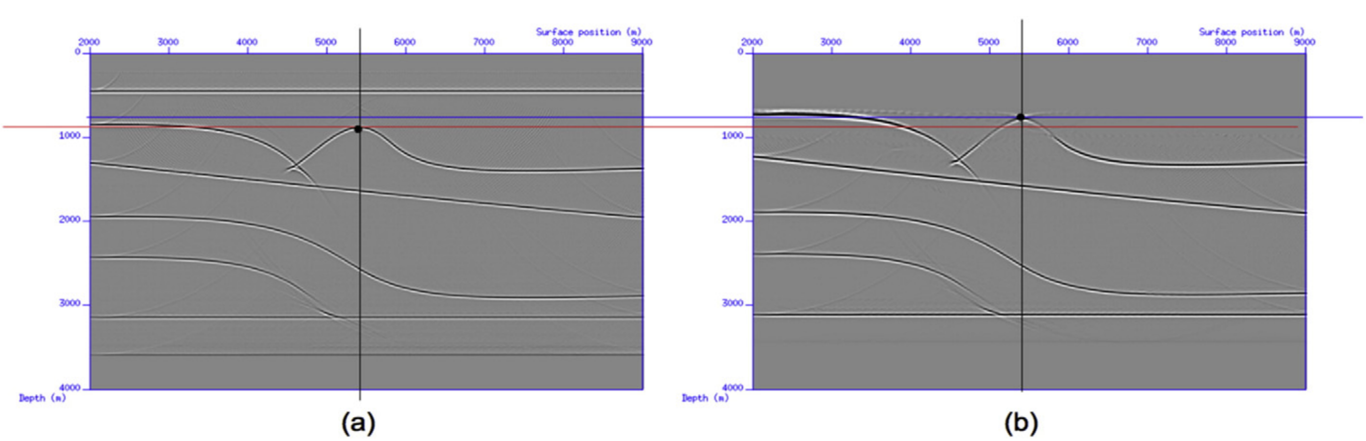

Fig. 1. (a) Image at zero-offset. (b) Image at offset 2500 m of synthetic data. Vertical line represents the surface position at 5425 m.