Geophysics Bright Spots

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The *Bright Spots* of the September-October 2015 issue of Geophysics take us from joint inversion of resistivity and gravity data to improved edge enhancement in magnetic data; from improved finite-difference elastic modeling with topography to Marchenko imaging with both internal and free-surface multiples; from improved reservoir modeling to a thin-bed estimation technique using zero-crossing-time amplitude stratal sections; and to a discussion of the role of body-wave diffraction and backscatter seismic data in tunnel detection.

Zhang and Revil present a "2D joint inversion of geophysical data using petrophysical clustering and facies deformation." The authors pose the geophysical inverse problem in terms of Gaussian random fields with mean functions, in turn controlled by petrophysical relationship and covariance functions controlled by a prior geologic cross section, including the definition of spatial boundaries for the geophysical facies. This approach provides prior information for a Bayesian inversion. The authors present a synthetic example of joint inversion of gravity and galvonometric resistivity for the subsurface density and resistivity from data recorded at stations on the surface of the model.

As a second step, the authors consider the possibility that the facies surfaces are deformable and thus might be a target of inversion. Zhang and Revil use a level set approach to perform the facies boundary inversion such as to preserve the topology of the facies surfaces. With the help of prior facies petrophysical relationships and topological characteristic of each facies, the authors make posterior inference about multiple geophysical tomograms based on their corresponding geophysical data misfits.

The method is applied to a second synthetic case, showing that it is possible to recover heterogeneities inside the facies, the mean values for the petrophysical properties and, to some extent, the facies boundaries using the 2D joint inversion of gravity and galvanometric resistivity data.

Hidalgo-Gato and Barbosa propose a new method of "Edge detection of potential-field sources using scale-space monogenic signal: Fundamental principles." The authors present a new approach for enhancing weak and noisy magnetic anomalies produced by shallow- and deep-seated geologic contacts. The method involves creating a band-pass filter by taking the differences between two Poisson scale-space representations of the data. The Poisson scale-space representation of potential-field data is equivalent to performing an upward continuation of the data. The monogenic signal is defined as the linear combination of a 2D signal with its (first-order) Riesz transform (the generalization of the Hilbert transform to 2D), and thus is a generalization of the 2D analytic signal (Dong and Kuang, 2015). The (first in order) Riesz transform is computed in the wavenumber domain. The authors present several synthetic examples and a real data example of edge sharpening of magnetic data collected over the Pará-Maranhão Basin in Brazil (Figure 1).

Gao et al. present "An immersed free-surface boundary treatment for seismic wave simulation" in finite-difference modeling. The need is for the problem of finite-difference modeling in the presence of complicated free-surface topography. The authors present a strategy to incorporate a free-surface boundary condition that follows the immersed-boundary methods for seismic applications, closely related to an interface

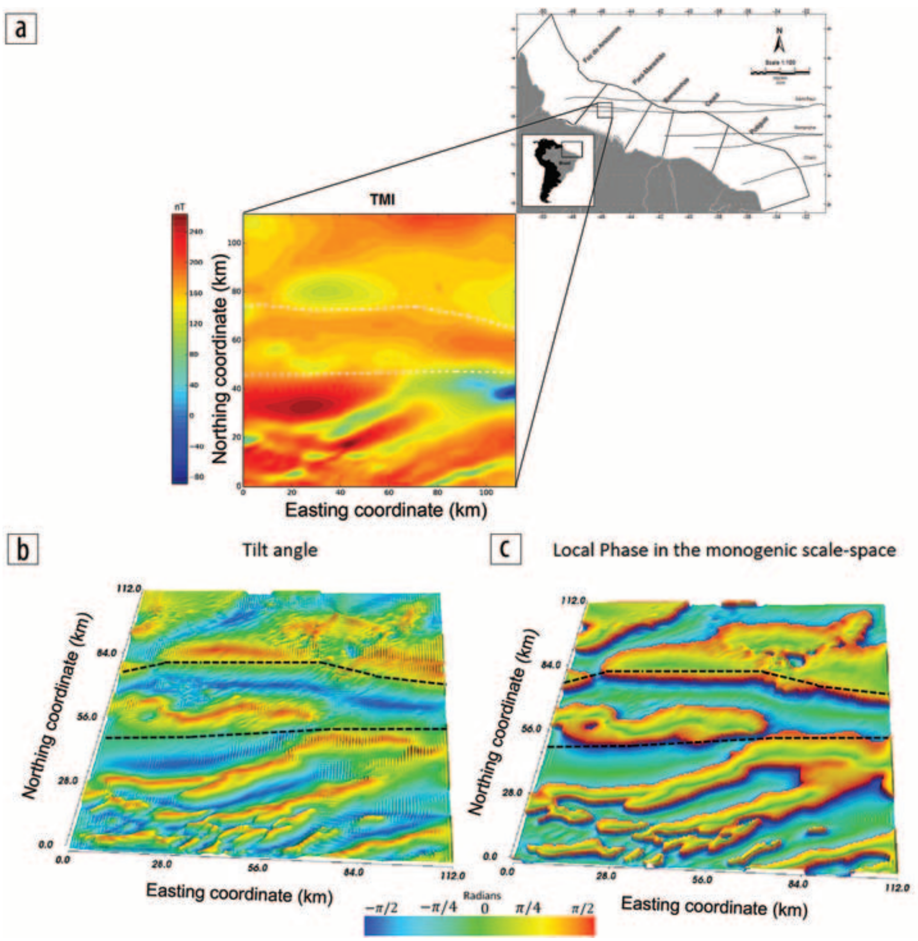

Figure 1. (Figure 9 from Hidalgo-Gato and Barbosa) The enhancements of the total-field anomaly by using (b) the tilt angle (TILT) and (c) the local phase in the scale-space monogenic signal. The dashed black lines in (b) and (c) are correlated with the Saint Paul Fracture Zone shown in part (a), which cuts across the continental margin into the Pará-Maranhão Basin.

method that has been previously investigated by Piraux and Lombard (2001), Lombard and Piraux (2004), and Lombard et al. (2008). Gao et al. develop their method for 2D isotropic elastic models and present several computational examples of simple media with increasingly complicated free surface.

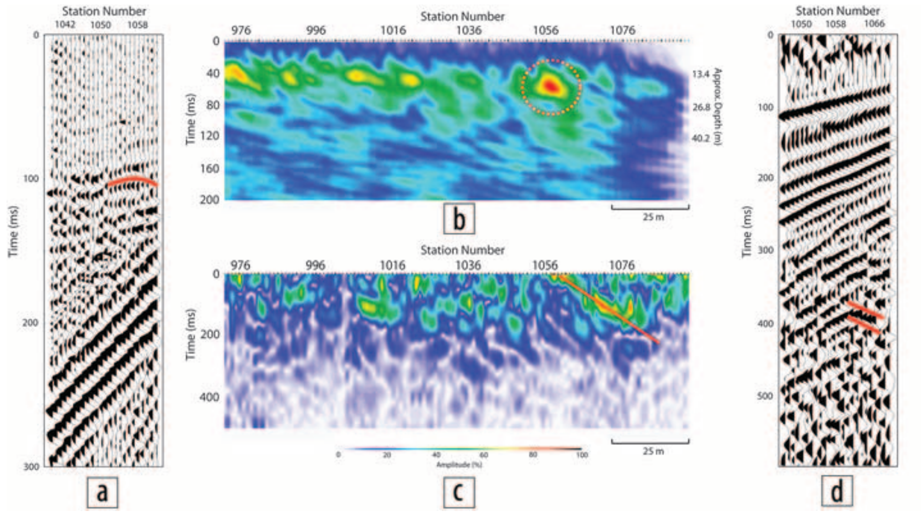

Figure 2. (Figure 4 from Sloan et al.) Data plots for line 1 in example #1: (a) shot gather acquired with 40-Hz geophones and a diffraction marked by the curved red line; (b) processed diffraction section with the interpreted tunnel anomaly marked by the red dashed circle; (c) processed BASW section displayed in instantaneous amplitude with the interpreted tunnel location indicated by the intersection of the red line with t_0; (d) shot gather collected with 4.5-Hz geophones and backscatter highlighted by sloping red lines prior to processing. The shot gather in (a) is displayed with a 610–1035 m/s *f-k* filter and 60-Hz low-cut filter for display purposes to emphasize the diffraction. The depth to the roof of the tunnel is 9.1 m.

"Marchenko imaging: Imaging with primaries, internal multiples and free-surface multiples," as presented by Singh et al., advances the focusing scheme of Broggini et al. (2012), Broggini and Snieder (2012), and Wapenaar et al. (2013), who extend an iterative scheme of Rose (2002a, 2002b) that solves the Marchenko equation for wavefield focusing in one dimension. Generalizing to higher dimensions, Broggini et al. (2014) extended the work of Behura et al. (2012) by using multidimensional deconvolution (MDD) as the imaging condition in place of conventional crosscorrelation or deconvolution. The method operates by estimating the Green's function at every point in the model, permitting a focusing function to be computed that will annihilate internal multiples by focusing them onto the reflectors of origin. Singh et al. present an extension of the 1D method that includes focusing of free-surface multiples. Several 1D examples are presented.

In "Simultaneous optimization of multiple objective functions for reservoir modeling," Niri and Lumley present a new method of constructing reservoir models as well as a synthetic validity test of these models. The authors present a field data demonstration of their method, which simultaneously matches available seismic, borehole, and geologic data in an optimal sense. The authors' method combines geostatistical simulation with simultaneous nonlinear stochastic optimization of multiple objective functions and does not require the selection of weighting schemes or multiple optimization computational runs. Niri and Lumley present a field data example from the Stybarrow Field offshore Western Australia.

Guofa et al. present a new method of the "Characterization of interbedded thin beds using zero-crossing-time amplitude stratal slices." The authors exploit the fact that although it is generally virtually impossible to resolve thin beds because of reflection interferences and wavelet overlap, a given thin bed does not always interfere with other thin beds at all times. At its zero-crossing time (ZCT), a given thin bed's reflection makes no contribution to the composite response. Thus, the ZCT stratal slice of each thin bed can be identified from consecutive amplitude slices, permitting the determination of the thickness, depth, and lateral distribution of each thin bed, as well as the vertical spacing between them. Guofa et al. present a synthetic example as well as a real data example for a 3D data block acquired in Kazakhstan.

Sloan et al. discuss the issue of "Detecting clandestine tunnels using near-surface seismic techniques." The method presented is an analysis of body-wave diffracted waves compared with backscattered wave energy. Three examples are discussed. The first is the analysis of seismic data collected over a test tunnel in Arizona intended as a model of tunnels discovered along the U. S.-Mexico border (Figure 2). The second is seismic data collected over the Sarposa Prison escape tunnel near Kandahar, Afghanistan. The third case is an analysis of seismic data over a second clandestine tunnel at an undisclosed location in Afghanistan. TLE

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