Below are some highlights from the September-October issue of GEOPHYSICS. Topics include prestack inversion, noise suppression by empirical mode decomposition, dependence of seismic velocity on stress, wave propagation in jointed rock, and a new look at microseismic data from Valhall.

Ray-based stochastic inversion of prestack seismic data

Associate Editor: Bob Keyes. A new method for reservoir parameter estimation is introduced by van der Burg, et al. Conventional trace inversion techniques that use the 1D convolutional model and operate on migrated data are affected by wavelet distortion due to reflector dip (Figure 1) and reflection angle. The new method applies a combination of ray tracing and stochastic inversion to estimate reservoir parameters and their uncertainties from prestack seismic data. The use of ray tracing on prestack unmigrated data avoids wavelet-distortion effects due to structural complexity. Results from a Gulf of Mexico field study showed that reservoir thickness and P-wave velocity estimates obtained with the ray-based stochastic method were more accurate than estimates derived from a conventional trace inversion approach.

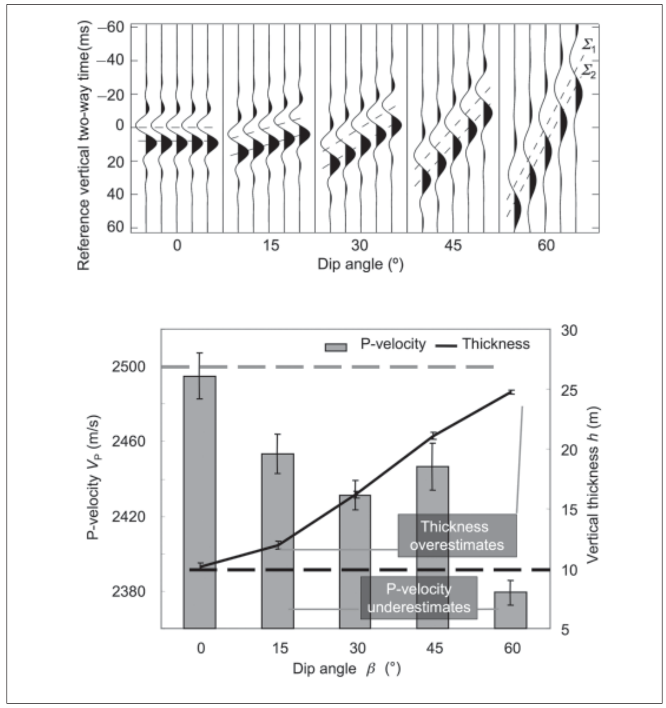


Figure 1. (top) Migration-induced, dip-dependent wavelet stretch. Dashed lines denote layer boundary in two-way traveltime. (bottom) P-wave velocity thickness estimates from standard inversion for dip angles indicated on the horizontal axis. Error bars denote posterior standard deviations. Dashed horizontal lines denote actual values for P-wave velocity (gray) and thickness (black). (From Figures 3 and 4 of "Ray-based stochastic inversion of prestack seismic data for improved reservoir characterization" by van der Burg et al.)

Parameters controlling stress dependency of seismic ultrasonic velocities

Associate Editor: Boris Gurevich. Knowledge of stress-dependence in seismic velocity is important for many geophysical applications, including reservoir characterization, pore pressure prediction, and reservoir monitoring using time-lapse data. Angus et al. perform a systematic statistical analysis of parameters controlling velocity stress dependence through modeling with an isotropic or anisotropic distribution of microcracks representing grain contacts. The key parameters of this model are initial crack density of the unstressed rock, mean microcrack aspect ratio, and characteristic ratio of normal to tangential compliance of microcracks B_N/B_T. The authors estimate these parameters from published measurements on 125 rock samples representing various lithologies, including sandstone, carbonate, and shale. Their analysis focuses on dry rocks, though some samples (notably shales and shaly sands) may not have been dried completely. First, initial crack density and aspect ratio are obtained assuming that microcracks are penny-shaped. This assumption implies that $B_N/B_T = 1 - \nu/2$, where ν is Poisson's ratio of the rock without microcracks. Second, the authors allow the compliance ratio B_N/B_T to be a free parameter, and estimate it directly from the data to obtain a frequency histogram of B_N/B_T values as shown in Figure 2. This implies the compliance ratio can vary widely (between 0 and 2) and is not necessarily close to the value of penny-shaped cracks.

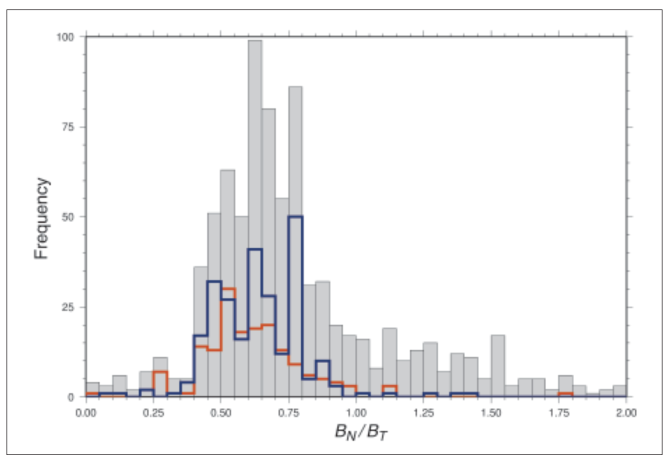
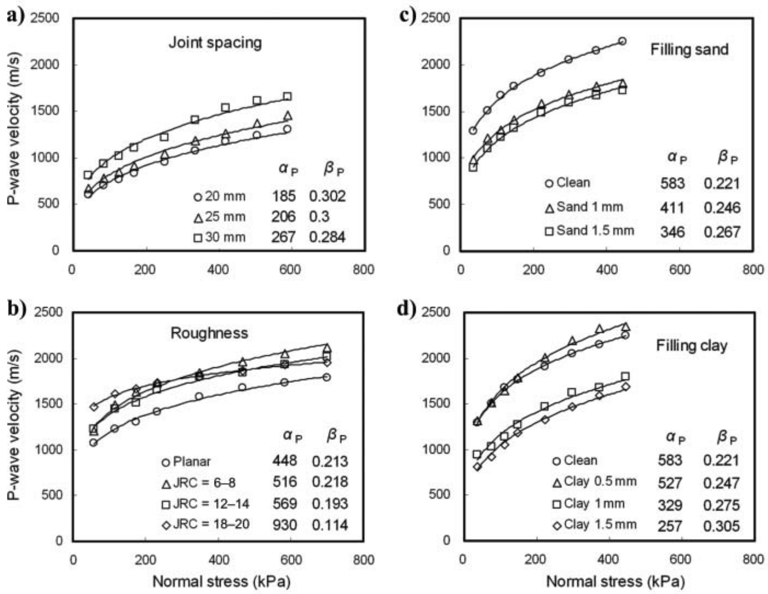


Figure 2. *Frequency histograms of inverted B_N/B_T ratios for all lithologies (gray shaded), sandstone samples (blue outline) and carbonate samples (red outline). (Figure 7 from "Exploring trends in microcrack properties of sedimentary rocks: An audit of dry core velocity-stress measurement" by Angus et al.)*

Long-wave propagation in jointed rock masses

Associate Editor: Deyan Draganov. The presence of joints and their mechanical characteristics influences wavefield propagation in rocks. Using an axially loaded jointed column, Cha et al. study P-wave and S-wave propagation in the long-wavelength regime. In particular, the authors investigate the changes in the P-wave and S-wave velocities (and S-wave attenuation) caused by changes in the normal stress, loading history, joint spacing, matched surface topography, joint cementation, joint opening, and plasticity of joint filling (e.g., Figure 3). The authors find that the V_P/V_S ratio in jointed rock masses is different from the one in homogeneous continua, the concept of Poisson's ratio as a function of V_P/V_S is unwarranted, and V_P/V_S can be interpreted in terms of



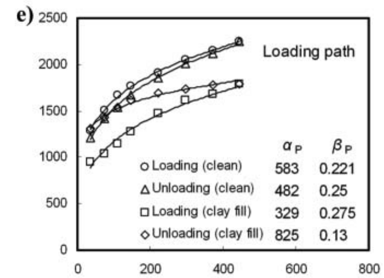


Figure 3. P-wave velocity for different rock mass conditions and stress levels: (a) effect of joint spacing (13 acetal discs with clean joints), (b) effect of joint roughness (15 dental gypsum discs), (c) and (d) effect of joint fillings (15 gneiss discs), and (e) loading and unloading path (15 gneiss discs). The higher JRC value corresponds to rougher surfaces. "Sand 1mm" stands for 1-mm thick sand filling. The parameters α_P and β_P tabulate the values that the authors use in the proposed analytical models to fit the observed data. (Figure 4 from "Long-wavelength P-wave and S-wave propagation in jointed rock masses" by Cha et al.)

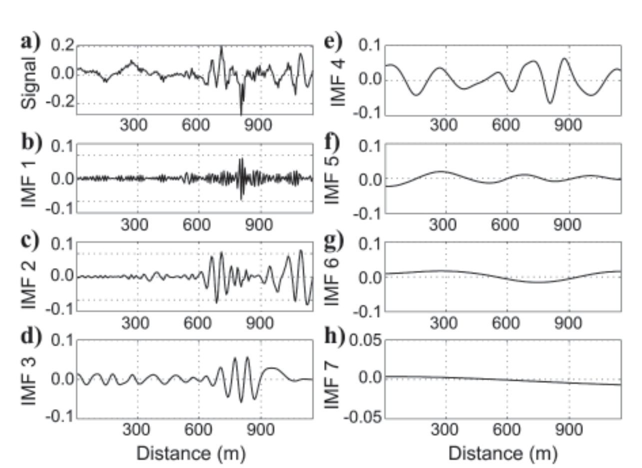


Figure 4. Example of a decomposition signal (a) into seven intrinsic mode functions (IMFs) via the empirical mode decomposition. By removing the IMFs related to the noise, an adaptive noise-removal algorithm is obtained. (Figure 1 from "Random and coherent noise attenuation by empirical mode decomposition" by Bekara and van der Baan).

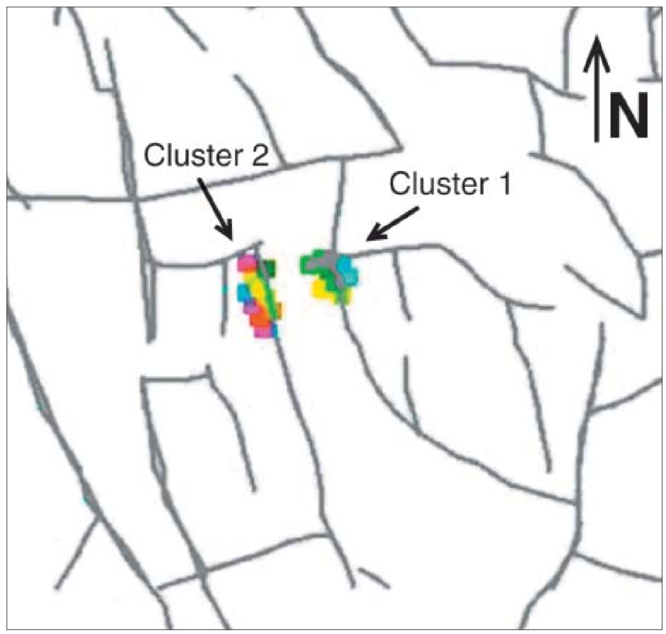


Figure 5. Events from clusters 1 and 2 on a top-reservoir fault map interpreted from 3D surface seismic. Note that the plot colors indicate the source depth rather than multiplet group. (Figure 10 from "The 1998 Valhall microseismicity: an integrated study of relocated sources, seismic multiplets and S-wave splitting," by De Meersman et al.).

jointed characteristics. Cha et al. present analytical models that allow them to properly model the experimental observations and extract joint properties from the test data.

Noise suppression by empirical mode decomposition

Associate Editor: Eric Verschuur. Bekara and van der Baan introduce a new method to remove random and coherent noise from seismic measurements based on the empirical mode decomposition (EMD) operating on constant frequency slices in the *f-x* domain. Whereas many filtering methods assume a regular sampling and stationary noise, EMD can handle irregularly sampled data and is suitable for nonstationary noise. The EMD method decomposes a signal into a limited number of so-called intrinsic mode functions (IMFs). Noise removal simply means removing the IMFs that are related to the noise and then reconstructing the signal. An example of such decomposition is shown in Figure 4, where the input signal is plotted in the upper left corner, along with the first seven IMFs. The authors show several examples on field data, demonstrating that this method is a valuable addition to the processor's toolbox.

New analysis of 1998 Valhall microseismic data

Associate Editor: Sergio Chavez-Perez. De Meersman et al. relocate microseismic events recorded in 1998 by sensors in a single borehole in the North Sea Valhall oil field. They obtain high-resolution absolute and relative event locations, leading to reduced misfit and uncertainty estimates for event locations, and revealing the existence of three additional source clusters. Clusters 1 and 2 are located on the intersection of two fault planes (Figure 5). Short-term variations in seismic anisotropy are observed and measured, as well as reactivation of microseismic source mechanisms over time for the individual events of these clusters. This analysis points to a trigger mechanism of cyclic recharge and dissipation of caprock stress in response to production-driven compaction of the underlying oil reservoir. TLE

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> minimum phase. Well, when this concept was tried on ringing marine data, the results were spectacular. Needless to say GSI moved quickly to patent the process to protect its interests. During this same period, I was reading up on the GAG (Geophysical Analysis Group) reports which I had acquired at MIT. In report No. 7 (I believe), I discovered Enders Robinson's work on predictive filtering which in effect was identical to the aforementioned Burg development. I noted this to Burg and others, but John professed no knowledge of Enders' work or the GAG reports, and I truly believe he independently developed the concept albeit somewhat later. The commercial ramifications of all this were rather exciting as well. Soon after Robinson's public domain work was recognized within GSI, a group lead by Rudy Prince split off to form Digicon and enticed Enders to join them in offering deconvolution processing services to the exploration industry. Not surprisingly, law suits and counter suits were filed and ultimately settled out of court.

It turns out that GSI was a member of the GAG group. Sounds as if there was a "failure to communicate" back then.

Speaking of GAG, Sven Treitel (the Treitel in "Treitel and Robinson" and vice-versa) chimed in with the following:

> While the work by Milo Backus and his colleagues at GSI was indeed seminal, the earliest examples of deconvolution applied to real seismic data, which were provided by the old Magnolia Petroleum Company, are described in a 1953 Geophysics paper by Wadsworth, Robinson, Bryan, and Hurley. This work, done by the MIT Geophysical Analysis Group thus predates GSI's by some ten years!
>
> Analog-to-digital conversion was carried out by eyeball, pencil, and paper by readily available graduate student labor, including that of yours truly. My eyes have never been the same since.

Thanks Sven. These days we say "decon" not deconvolution. There may be some confusion with a bug spray but a geophysicist knows the difference. TLE