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Introduction to the 75th Anniversary Special Section

Geophysics is 75 years old this year. To celebrate this milestone, the editors decided to publish a special section in our journal containing a series of specially invited review papers to summarize the current state of the art in exploration geophysics, but with particular emphasis on developments during the past five years. The papers you will find in what follows describe a number of areas in which significant progress has been made. Of course it has not been possible to do justice to all areas of our field, yet the wide range of subjects covered surely indicates the current sound health of our profession. It also behooves us to keep in mind that what appears promising today may turn out to have lost luster a few years from now; time alone will tell. Most invited authors submitted manuscripts; in the end, only a few were unable to do so.

The purely technical portions of this volume are nicely complemented by several short pieces with recollections recorded by past editors, along with listings of past best papers, classic papers published in previous special issues, listings of papers most often cited in the literature, and an article on the impact factor of the journal.

In what follows, we give brief summaries of the papers included in this special section. We believe that our selection is a good, while admittedly incomplete, snapshot of the present state of the art of exploration geophysics. The ordering of papers follows the alphabetical section ordering of Geophysics in 2010.

Amplitude Variation with Offset (AVO)

Amplitude variation with offset (AVO) analysis of seismic reflections has become an important tool for hydrocarbon prospecting. Foster, Keys, and Lane review the development of AVO technology and give guidelines for the interpretation of AVO responses in terms of reservoir properties. They give examples of the use of AVO technology to detect hydrocarbons and distinguish high porosity reservoir sands from low porosity sands and shales.

Anisotropy

The role of anisotropy in seismic prospecting has dramatically increased over the past two decades due to advances in parameter estimation, the transition from poststack imaging to prestack depth migration, the wider offset and azimuthal coverage of 3D surveys, and acquisition of high-quality multicomponent data. Tsvankin, Gaiser, Grechka, van der Baan, and Thomsen present a comprehensive review of seismic modeling, processing, and inversion for anisotropic media. They discuss the foundations of methods operating with both P-waves and multicomponent data, demonstrate the improvements achieved by anisotropic imaging algorithms, and outline the possibilities of applying anisotropy parameters in reservoir characterization.

Borehole Geophysics and Rock Properties

Rock physics provides a link between geologic reservoir parameters (e.g., porosity, clay content, sorting, lithology, saturation) and seismic properties (e.g., acoustic impedance, the V_P/V_S ratio, bulk density, and the elastic moduli). Avseth, Mukerji, Mavko, and Dvorkin review some existing rock physics models and practical work flows, and demonstrate the importance and benefit of linking rock physics to geologic processes. They highlight a hybrid modeling approach applicable to high porosity siliciclastic sediments and rocks.

Electrical and Electromagnetic Methods

Two papers are dedicated to electrical and electromagnetic methods. Zhdanov provides a historical overview of electromagnetic (EM) geophysics with a focus on the major discoveries and some critical turning points of this development. He outlines a framework for the further developments, which should focus on the multitransmitter and multireceiver surveys, analogous to seismic data acquisition systems, and on the multidimensional modeling and inversion methods. In a second paper, Constable provides a review of marine CSEM for hydrocarbon exploration, accessible to the nonspecialist. The paper also contains new material on the sensitivity of the CSEM method to 3D structure and anisotropy, as well as a comparison of time-domain and frequency-domain methods.

Engineering and Environmental Geophysics

Surface wave analysis is nowadays widely adopted for building near surface S-wave velocity models. Socco, Foti, and Boiero provide a comprehensive review of the literature, with particular attention to the historical perspective, methodological issues, applications, and the most promising approaches developed in recent years. They discuss the inclusion of higher modes and the retrieval of lateral variations, and they review the current scientific debate on these topics. The paper concludes with a best practice guideline.

Ground-penetrating Radar

Ground-penetrating radar (GPR) is a geophysical method for obtaining information about the subsurface with extremely high resolution. GPR waves are sensitive to changes in the subsurface. Contrasts in electrical and magnetic properties can be detected, imaged, and characterized from GPR data. Slob, Sato, and Olhoeft review how GPR has developed into a versatile tool used at the ground surface and in boreholes, for subsurface characterization and monitoring changes, in a variety of applications.

Interpretation Methods

Helbig gives an interesting account of seismic interpretation in the predigital era. Traditionally, the input acquired in the field consisted of the original paper records, and the output submitted to the client consisted of structural sections and depth-contour maps of selected interfaces. Before the introduction of magnetic recording, it was common practice to do the conversion in the field office. Helbig's message is that the techniques of data acquisition and data interpretation have changed considerably, but the underlying principles are still the same. Therefore, many of the new methods are based on ideas formulated in the early times of the industry.

Passive Seismic Methods

Two papers deal with passive seismic methods. Maxwell, Rutledge, Jones, and Fehler review key projects associated with the development of downhole microseismic imaging for hydraulic fracturing and reservoir monitoring over the last 40 years. They describe the evolution of reservoir monitoring projects in North America, the North Sea, and the Middle East and the growth of hydraulic fracture imaging projects from the first known example in 1974, through commercial offerings spawned from the Cotton Valley Sand Project and the first fracture image in the Barnett Shale. In a second paper, Duncan and Eisner review the practice of microseismic reservoir monitoring using surface and near-surface arrays. The history, theory, field techniques, processing approaches, and data interpretation methodologies are described, and opportunities for future developments are suggested.

Poroelasticity

Understanding and quantification of attenuation and dispersion of seismic waves due to wave-induced flow has attracted considerable research interest over the last decades. Numerous models have been developed with varying degrees of rigor and complexity. Though all models predict attenuation and velocity dispersion typical for a relaxation process, there exist differences that can be related to the type of disorder (periodic, random, space dimension) and to the way the local flow is incorporated. Mueller, Gurevich, and Lebedev review recent experimental and theoretical developments in a comparative manner.

Reservoir Geophysics

Reservoir geophysics is treated in a paper by Bosch, Mukerji, and Gonzalez. They review various approaches in seismic inversion and its combination with rock physics and geostatistics for quantitative reservoir characterization. Rock physics plays the important role of linking elastic parameters, such as impedances and velocities, to reservoir properties of interest such as lithologies, porosity, and pore fluids, while geostatistical methods help to add constraints of spatial correlation, and conditioning to different kinds of data and to incorporate subseismic scales of heterogeneities.

Seismic Data Acquisition

Maurer, Curtis, and Boerner discuss seismic data acquisition. They review the history of geophysical experimental design and describe possible extensions to current state-of-the-art methods. Their theoretical models are supported by four experimental design examples which are based on four different geophysical techniques.

Seismic Interferometry

Seismic interferometry is covered in a two-part contribution by Wapenaar, Draganov, Snieder, Campman, Verdel, Slob, and Curtis. Part 1 reviews the basic principles step by step, starting with 1D interferometry for direct waves and ending with 3D interferometry for reflected waves. The authors emphasize that the common aspect of direct and reflected wave interferometry is that virtual sources are created at positions where there are only receivers, without requiring knowledge of the subsurface medium parameters nor of the positions of the actual sources. In part 2, the authors discuss the underlying theory, starting with a review of the relation between time-reversed acoustics and the virtual source method, and ending with exact Green's function representations for seismic interferometry. Next they present many variants and extensions, including unified representations for general diffusion and wave phenomena, variants for virtual receivers and virtual reflectors, modifications for time-lapse interferometry and, last but not least, interferometry by deconvolution.

Seismic Modeling and Wave Propagation

Carcione, Morency, and Santos deal with seismic modeling and wave propagation by introducing the partial differential equations for wave propagation in fluid-saturated rocks. In particular, they discuss finite-difference, pseudospectral, and finite-element methods. The modeling is based on Biot-type theories of dynamic poroelasticity, which constitute a general framework to describe the physics of wave propagation.

Signal Processing

A contribution by Dragoset, Verschuur, Moore, and Bisley is devoted to geophysical signal processing. It gives a fine description of the surface related multiple elimination (SRME) method. SRME is the most successful approach yet found for predicting and attenuating surface multiples. The authors present a brief history of the basic concept, a simple explanation of the method, a discussion of the challenges it faces in practice, and examples of how these challenges can be overcome.