

Virtues of VSP highlighted at Galperin Readings

Victor Manukov of the Russian company Central Geophysical Expedition reports on the seventh annual Galperin Readings (GR-7) conference on vertical seismic profiling held last year in Moscow.

The Galperin Readings (GR) are devoted to vertical seismic profiling (VSP) issues in commemoration of Prof Yevsey I. Galperin, an outstanding Russian geophysical scientist and inventor of the VSP method. For more than 30 years from the late 1950s to 1990 Prof Galperin devoted himself to developing and field testing the VSP method, as well as applying it in almost all areas of the then USSR where exploration for oil and gas was conducted.

The VSP method is still evolving largely along the lines he initiated, proving that it can be a highly effective exploration tool in most diverse and complex seismic and geologic environments, and it is especially valuable in the development and production of hydrocarbon fields (Galperin, 1955, 1961, 1971, 1977, 1984). Today, VSP is playing a key role in providing oilmen with valuable information not only about near-borehole geology but also subsurface physical properties. VSP has increasingly been in demand especially since refinements, such as polarization VSP and offset VSP have come to be applied in combination with 3D surface seismic surveys, employing advanced computer technologies to process and interpret the acquired data.

In Galperin's time, VSP gained worldwide recognition and started to be used as an indispensable part of surface-downhole seismic exploration for oil and gas. In the USA, Prof Galperin was frequently invited by oil companies to hold VSP workshops, and his monographs were translated into English; experience in VSP was immediately applied and intensely developed on a more advanced technical basis. Publications in professional journals and in papers presented at the EAGE, SEG, and Galperin Readings (GR) conferences witness that VSP is extensively employed in many countries. International attendance at GR conferences has so far primarily consisted of representatives of international companies that are active and have accredited offices or are joint venture companies in Russia such as CGG, Schlumberger, Total, WesternGeco, PetroAliance Services Company, Roy International, VSE, TNK-BP, TGS, P/GSI, and Paradigm Geophysical.

CIS attendees come from Belarus, Kazakhstan, Ukraine, and Azerbaijan. Professionals from faraway countries are fewer in number, apparently due to inadequate awareness of GR activity. The more international professionals attend the GR meeting – the world's only conference on

VSP issues – the more effective the exchange of knowledge and experience in introducing the VSP technology would be, which in turn would facilitate further VSP development and broaden mutually beneficial cooperation. Certain steps have already been taken in this respect. This includes the relationship established with EAGE-PACE that provided sponsorship for convening GR-2006 and GR-2007; active support for these two GR conferences from by Dr Helmut Gaertner, EAGE Board member; and assistance from Pierre Lanfranchi, EAGE technical programme officer, in publishing two articles, one by A. Tabakov and K. Baranov on 'Integrated land seismic and VSP survey geometries offer improved imaging solution' and the other by Julia Zinger and Victor Manukov 'Galperin memory honoured by continuing series of conferences on VSP' in *First Break* in 2007.

The second mentioned article highlighted topics covered at the GR conferences, illustrating the level of VSP theory and practice in implementing today's main exploration objective of enhancing hydrocarbon production. In addition a wide range of geologic problems have been discussed over the years which use latest VSP technologies to extract additional information about petrophysical properties of the subsurface for use in building detailed models of the hydrocarbon deposits and in estimating hydrocarbon reserves.

At the 69th EAGE Conference and Exhibition held in London in 2007, two papers from GR-2006 were presented by geophysicists from Geovers. One more important event is in the pipeline, namely an agreement in which EAGE will be co-organizer of future Galperin Readings conferences together with CGE and Geovers, and *First Break* will carry various announcements in its Calendar of events about future meetings. This initiative is expected to attract the attention of a greater number of VSP enthusiasts to the Galperin Reading conferences. The continuing support from EAGO and from newly set up Moscow EAGE office will also play an important role.

The GR-2007 held last October gathered over 100 specialists from 37 scientific, geophysical, and oil companies, including 13 international companies. Greeting the audience at the GR-2007 opening session, Dr George Gogonenkov, CGE senior deputy general director, Dr Nikolay Savostianov, EAGO president, and Dr Helmut Gaertner, each emphasized the ever-increasing role that VSP sur-

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Dr Helmut Gaertner speaking at the concluding session.

veys play worldwide in efforts to resolve geologic problems of exploration, development, and production of oil and gas. They also spoke of the need to attract greater international attendance to the GR conferences.

At the conference, speakers representing 82 authors delivered about 40 papers, communications, and presentations. The conference proceedings including the paper synopses and Russian/English abstracts were produced with copies handed out to each registered attendee. Overall, GR-2007 was, like preceding GR conferences, focused on discussing theoretical and methodological developments and practical results from deploying combinations of surface/downhole 2D/3D, VSP and well logging surveys.

From the variety of discussion issues, two investigation directions were of special focus. One direction is the improvement and selection of optimal systems combining 3D seismic and downhole VSP (in its various modifications) in order to establish advantages, limitations, and fitness of such systems for use in examining the structural framework around the borehole, and in enhancing the VSP resolution and imaging accuracy, for noise attenuation and other purposes. The other direction is the multi-component recording of various type waves (direct, incident, P-, S-, PP-, PS-events, etc.) for use in determining petrophysical parameters such as porosity, density, permeability, Poisson ratio, P- and S-wave relationships, fracturing, anisotropy, and finally in evaluating predictable resources and in estimating reserves of hydrocarbons. The waves can be selected by types for fast and effective processing using special procedures. The majority of theoretical and methodology developments are, as a rule, validated by testing them on models and on real data. One paper may discuss more than one issue of interest and their investigation results. It is also important to note that quite a few papers were authored jointly by scientists and regular-production workers.

Geovers presented six papers on new software developments. The paper entitled 'On advantages and disadvantages of surface and downhole surveys' continues discussion of investigations along this most important line of seismic studies, i.e. limitations of the surface seismic in obtaining dependable information about true velocities and true wavelet shape. This limitation prevents attaining desirable levels of recorded data resolution, and accounting for and using converted waves. The paper shows that this is possible with VSP data, but diminishes away from the well location. Surface seismic is compared in this paper with walkaway VSP. Walkaway VSP acquisition system is asymmetric, and as a result boundary points are highlighted at different angles. In addition, strong noise occurs as head waves and multiples, thus degrading deconvolution effectiveness due to signal shape determination errors. Processed data from a VSP+3D combination show that this combination improves surface seismic effectiveness, because it enables utilization of signal shape and a VSP-based velocity model.

Geophysicists of the Krakow Oil and Gas Institute showed in their paper the way they improve surface seismic resolution by incorporating VSP high frequencies into seismic traces on a section through simple and inverse Fourier transform. This transform is also an indispensable tool for detecting hydrocarbons. VimSeis Technologies Co of Moscow and Seismic Technologies Co of Tver city applied a non-linear transform of seismic data, followed by bandpass filtering in order to enhance resolution of both time and depth offset VSP sections, demonstrating improvement of structural imaging on the same offset VSP sections. The applied procedures also made it possible to run dynamic analysis of reflection amplitudes, thanks to the signal amplitude character staying preserved.

Another paper, presented by Geovers and CGE, showed examples of applying model-based auto selection of waves to both model and real VSP and 2D/3D data, thus facilitating a speedier processing of data selected from the original wavefield. Four more papers, authored among others by experts from CGE, Geovers, and Moscow Lomonosov State University, investigated further improvements in geophysical software and data acquisition technology. For example, a method is described for restoring reflection characteristics from traces of PP- and PS-primaries set off by several energy sources and recorded on a vertical profile model. Another solution is offered for optimizing the energy source in the process of finite-difference modelling for a wavefield, whereby the initial error is alleviated.

Wavefield studies were also presented by NIIMorgeofizika Institute of Murmansk demonstrating a VSP wavefield separation into incident and upgoing waves using two adjacent traces. Reservoir Geology Co of Tyumen presented its work summarizing the processing of 3C VSP data acquired from 10 wells in Sakha Republic in East Siberia.

Of particular interest here are direct incident SS-type shear waves recorded by Y-component of geophones. These waves were used to generate migrated depth sections and analyze the velocity section. Also, certain regularities were established, e.g., stratigraphy-consistent velocity characteristics, and a number of good results were obtained from shear wave data. Two of the six Geovers papers assessed velocity model parameters, one by optimally inverting curves of direct, reflected, and converted waves generated by multiple sources in Walkaway and 3D VSP surveys, while the other paper highlighted wavefield modelling technology using ray-path method for non-parallel-layered subsurface.

Among the theory and methodology topics, the Novosibirsk-based Oil and Gas Geology and Geophysics Institute under the Siberian branch of the Russian Academy of Sciences in collaboration with Moscow-based and Japan-based Schlumberger Science Centres presented three papers. Of these two papers considered methods to produce seismic images of near-borehole subsurface from VSP data and images that would help see structural faults and at the same time eliminate migration artifacts using Gaussian beams. Of interest also was a method used to image complex geology of the near-borehole subsurface, using a specifically modified offset VSP data migration algorithm, in situations where the near surface section is unknown or for sections below the well bottomhole. This method can equally be applied to PP- and PS-reflections and transmitted-converted PS-waves. The third paper presented stringent mathematic analysis of methods used to predict the subsurface structure below the well bottomhole from the offset VSP data in order to detect abnormal pressure zones.

Many papers focused on migration procedures. Thus, KrasnoyarskGeofizika Co has developed and successfully applied a depth migration method, advanced by Academician S. V. Goldin, that focuses on wavefield continuation implemented with integral operators for the purpose of producing migrated sections and for determining velocity properties of the medium. IrkutskGeofizika Co has analyzed and generalized the data (well velocity survey, VSP, acoustic logs, and other well logs) acquired from 350 wells scattered over the vast territory of East Siberia, and applied various methods of refining velocity characteristics. This has permitted improvement of migration accuracy in addition to a no less important accuracy improvement in seismic-geologic models of the sedimentary cover for predicting reservoir properties of productive intervals, etc. VNIIGeofizika Institute in collaboration with the Moscow-based unit of ION Geophysical has run an interesting comparison between model wavefields derived from offset VSP data and from changeable source location VSP data in the study of buried reefs. The latter VSP modification proves to be advantageous in providing more distinct images of reef surfaces and of deeper boundaries on sections produced by migration of converted reflections.

V.A. Fok NIIfizika Institute of St Petersburg University in its ongoing studies of the nature of waves propagating through fluid-saturated zones showed a good match between theoretical and experimental spectra in a VSP model wavefield from a fluid-bearing multiple-zone pool. Experimental spectral curves show noticeable resonance frequencies that change away from the well location; this phenomenon can be used to resolve geological problems.

As already noted above, VSP data are play a significant part in a field development and production. Services companies have gained multi-faceted and valuable experience and successfully apply the latest VSP technologies to fields under development and production. TNK-BP, ALTGEO, and COMGEIS in their joint paper proposed a scheme that provides for a successive implementation of all phases – the study of the area geology, acquisition design, quality assurance of field data, data processing, and geological interpretation, using procedures specifically tailored for the particular geologic situation. Successful implementation of the proposed technology was illustrated by a few examples of computing quantitative seismic attributes for productive reservoirs. PetroAlliance Services, a company which traditionally performs large amounts of VSP, in a joint presentation with VimSeis Technology, proposed an interesting conversion of VSP wavefields and offset VSP wavefields – a vector presentation of such wavefields – to enable discrimination of various type events for their subsequent use in computing a good number of petrophysical parameters for building valid models and for interpretation. Another joint paper proposes that, prior to any field operations, offset VSP data undergo integrated full-wave modelling followed by processing and migration of seismogram models in order to produce depth sections, on which basis a proper acquisition technique would be selected or decision as to whether to run field acquisition at all would be considered.



Audience listening to a paper presenter, in the foreground: Dr Alexandre Tabakov (with mike), organizing committee chairman, and Victor Manukov, program committee chairman.

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Greg Ball of Chevron (Australia) and William Hall of Avalon Sciences (UK) at coffee break.

PetroAlliance Services, Lukoil-Komi, and Schlumberger-Logelco in their joint paper showed the results of carbonate fracturing examination from VSP and FMI data (the latter is resistivity measurement on the borehole walls to determine filtration characteristics of reefal buildups). PetroAlliance Services used VSP data to run a study, perhaps unique in the seismic industry, on the dependency of elastic wave propagation velocity vs. temperature in rocks bearing bituminous oil in order to determine the extent of heat-up zone and to decide upon fluid recovery rates and economic feasibility of such recovery.

Two papers from PermNefteGeofizika provided case histories of how downhole VSP and polarization offset VSP can be applied in combination with 3D surface seismic to complex geologic structure producing fields and hence complex wavefields. Interpretation and generation of sections showing P-, S-, and converted events tied to respective horizons confirm the effectiveness of downhole polarization VSP techniques that allow refinement of a detailed 3D survey.

Immense experience gained by BashNefteGeofizika and its affiliated companies in running large-scale VSP surveys of various modifications in Bashkiria, West Siberia, Orenburg Region, and other areas of Russia in over 300 VSP wells under the most diverse geologic conditions integrated with 2D/3D seismic and well logs has served to establish a scientifically and experimentally sound technology referred to as VSP-monitoring for deep exploratory drilling. Apart from standard VSP capabilities such as examination of the wavefield in internal subsurface points and the determination of true velocities, the proposed technology incorporates such downhole seismic functions as pre-

dition of whether hydrocarbon presence is likely or unlikely; correction of previous estimations; spatial monitoring; evaluation of hydrodynamic processes in productive intervals as hydrocarbons are produced, especially in carbonate reservoirs; assessment of vibro-impact on a reservoir aiming to raise oil recovery factor; mitigation of risks in drilling adopted exploratory well patterns; and many other enhanced oil recovery issues.

Emphasizing the need for close interaction with oil company personnel in running a VSP monitoring survey, the paper's authors give a few examples of such interaction in particular with BashNefte oil company who strictly followed BashNefteGeofizika recommendations based on an integrated study. It is easy to imagine that a corrected well drilling pattern would save a good deal of drilling, or more accurately, defined oil pool outline or accurately predicted exploration success ratio would permit oil in place reserves to be estimated more exactly regarding increase in both prospective and producing fields. BashNefteGeofizika has good reason to recommend geophysical service companies to make employ its VSP monitoring system.

Hardware and tools have also been subjects of discussion at GR-2007. Among them, VSP electromagnetic pulse source was presented by Geostr Science and Production Centre of Ufa. Ukrainian geophysicists analyzed parameters of polarization VSP systems operating at large depths and high temperatures and pressures, etc.

At the concluding session, the speakers and presenters underscored the significance and usefulness of the discussion that the participants enjoyed during the GR sessions about the theoretical, methodological, and geologic results achieved in the past year. They also discussed how to progress the development of the VSP method and holding GR meetings with a broader international attendance. Gratitude was expressed to the GR conveners and sponsors PetroAlliance Services, Schlumberger, and EAGE-PACE. The Organizing Committee, in its turn, called upon the participants to come up with papers and presentations highlighting their new achievements at the next GR conference to be held in October this year.

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