Core–Log–Seismic Integration—New Scientific and Technological Challenges

by Philippe Gaillot, Hideki Masago, Moe Kyaw Thu, and Hisao Ito

Introduction

"Core-Log-Seismic Integration: New Scientific and Technological Challenges," a technical workshop addressing critical issues in scientific drilling and coring was held in Tokyo, Japan on 3–4 October 2005. The workshop was organized by the Center for Deep Earth Exploration – Japan Agency for Marine-Earth Science and Technology (CDEX-JAMSTEC) and the Japan Drilling Earth-Science Consortium (J-DESC) following an initiative discussed during the February 2005 IODP Scientific Measurements Panel (SciMP) meeting.

One aim of this workshop was to promote discussions between scientists who use core, log, and seismic data to address academic or industrial problems and those who are developing new databases, data handling procedures, and visualization technologies. Goals of the workshop included reviewing and exploring extant methods for processing and analyzing core, log, and seismic data, with significance placed upon problem solving using a variety of methodologies and approaches to core-log-seismic integration. Forty scientists from Asia, North America, and Europe attended the meeting. The topics discussed included (1) the different approaches to core-log and core-log-seismic integration concerning theoretical aspects such as scaling problems, modeling, or petrophysics or technologies such as engineering or IT, (2) the possibilities for testing these methods using individual case studies including marine, coastal, and continental environments, and most important, (3) comparison and exchange of methods and views between researchers working in related or complementary fields. The workshop program, proceedings, and most of the presentations can be accessed at http://www.jamstec.go.jp/chikyu/jp/news/nw_050712.html. The major items from the discussions are summarized as follows.

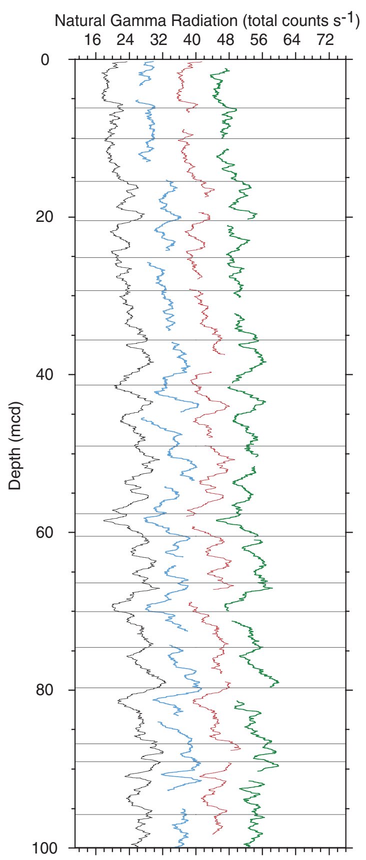

Figure 1. Example of spliced stratigraphic section: Natural gamma radiation data from ODP Site 1146 (black) was compiled by splicing the individual core logs (blue, red, green, Wang et al., 2000).

Information Exchange

Core-log-seismic integration methodology and practice lie intrinsically at the interface between multiple scientific and technical fields of inquiry, thus requiring a major effort (1) to promote better documentation of methods, assumptions, tools, resolution, and limitations inherent in each newly acquired data set and (2) to address better the problems associated with parallel measurements acquired at different scales or resolution, often using different equipment or tools, or relying on different principles and assumptions. A clear example of potential problems associated with these kinds of overlaps is the measurement of porosity. Porosity can be measured or derived from discrete samples (moisture and density measurement vs. Hg or BET porosities), neutron-porosity logs, density logs, resistivity logs or analysis of downhole imagery, and all reported in any database as porosity, in the same units; however, these measurements of porosity can have vastly different values depending on methodology, even within the same core interval. It was proposed that a working group including industry should address a discipline-wide descriptive terminology for standard measurement techniques and results.

Depth Issues

A critical issue in core-log integration is the question of standardizing depth positioning and depth accuracy of collected data sets. This issue generated extensive discussion and debate among the workshop participants, who clearly identified the need for standard definitions and processing procedures to generate depth scales for the geological and geophysical aspects of drilling, coring, and logging.

Geological measurements, including cores, cuttings, and gas or mud logging operations, must be calibrated accurately and efficiently. Specifically, the conversion of incident time (for mud logging, cuttings, and gas logging data) and the conversion of curation depth (for cores and samples) must be undertaken to derive accurate and internally consistent depth values (Fig. 1).

Geophysical measurements, including wire-line logging, logging-while-drilling, vertical-seismic-profiling (VSP), seismic-while-drilling, and regional 2-D and 3-D seismic surveying, must be converted from either rig-floor depth or seismic two-way traveltime into the final depth reference frame (Fig. 2). The role of VSP in seismic calibration of depth scales was widely emphasized and led to discussions of four issues:

1. The receiver technology (i.e. frequency range)
2. The nature of the source (e.g., borehole, seafloor, sea-level, air gun, vibration, explosion)
3. The coupling between formation and seismic tool in complex environments
4. The role of offset VSPs and multi-component tools in investigation of S-waves and acoustic/seismic anisotropy

These discussions gave rise to a series of complementary proposals for depth-processing procedures dependent on data type and quality that will be reported separately.

New Technology: Initiatives and Needs

In addition to the depth issue, presentations and discussions of new technological developments and challenges focused on data acquisition in extreme environments and integration of a wide array of new data types and formats. Examples of such developments included intensive feasibility testing of logging-while-coring systems potentially equipped with geophones (for check-shot surveys while coring) and development of new downhole probes for microbiological and geochemical investigations of the deep biosphere.

Additional discussion with respect to core-log-seismic integration focused on the problem of *in situ* conditions versus laboratory core or sample measurements. Challenges arose regarding the differences between, for example, acoustic properties like P- and S-wave velocities, Q-factor values, or anisotropy determined from sample or core measurement as opposed to downhole *in situ* seismic velocity or attenuation values.

Depending on scientific objectives, recommendations were devised for a review of available equipment and expertise (specifications vs. needs) and adoption of an optimal strategy (selection of samples, on-site vs. delayed investigations).

Proposal for a Natural Laboratory

A proposal was made to dedicate one or several well-characterized test site(s) encompassing a wide variety of geological settings for educational and methodological uses. At such a site(s), experiments, methods, and tools could be

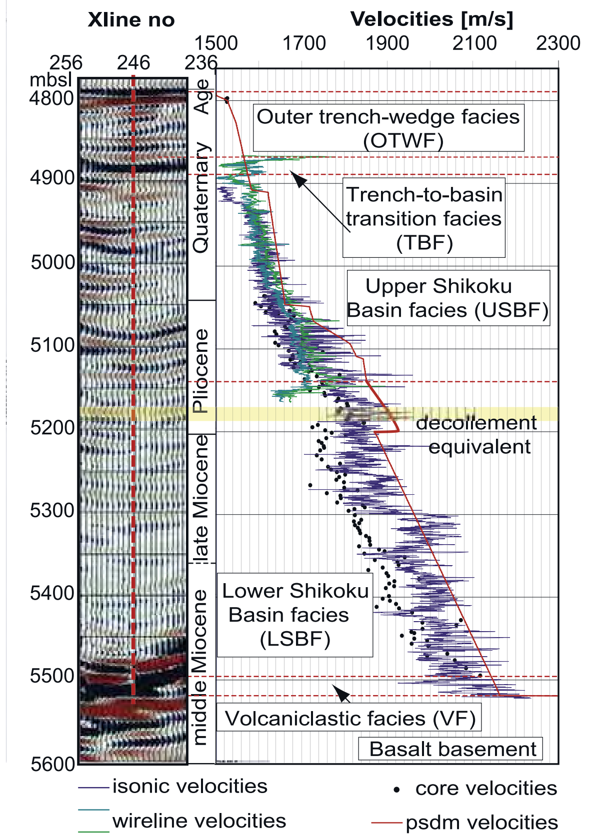

Figure 2. Prestack Depth Migration PSDM depth section across ODP Site 1173 (left); comparison of velocities obtained from PSDM with velocities from cores and logs at Site 1173 (right, from Pisani et al., 2005).

calibrated and tested, providing references for further study and a basis for continued progress. Also, a competence network for consultation, feedback, advice, and interaction was put in place.

Reference

Pisani, P.C., Reshef, M., and Moore, G., 2005. Targeted 3-D prestack depth imaging at Legs 190–196 ODP drill sites (Nankai Trough, Japan). *Geophys. Res. Lett.,* 32. doi:10.1029/2005GL024191

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Authors

Philippe Gaillot, Hideki Masago, Moe Kyaw Thu, and Hisao Ito, CDEX, JAMSTEC, Yokohama Institute for Earth Sciences, 3173-25 Showa-machi, Kanazawa-ku, Yokohama Kanagawa 236-0001 Japan, e-mail: gaillotp@jamstec.go.jp

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