Structural Geology and Sedimentology from Dipmeter Data: the Power of Wireline Logging

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Dipmeter logging has recently become an integral part of standard borehole geophysics procedures applied in hydrocarbon exploration and production wells both onshore and offshore. Quality interpretation of numerically processed dipmeter data provides structural, sedimentological and geodynamical data that describe geological aspects of reservoir formations in a much more detailed and informative way than those yielded by other types of wireline logs and by reflection seismics. Of primary importance is the ability of the dipmeter data-based interpretation to locate, recognize and measure size and full orientation (with respect to the north and to a horizontal reference plane) of a variety of tectonic and sedimentary structures. General guidelines of handling the dipmeter raw data, principles of their processing and general rules of geological interpretation are presented in technical manuals issued by manufacturers of geophysical equipment and processing software (e.g. Goetz 1984, 1989; Schlumberger 1986; Halliburton 1992; Adams 1993), though the details of the methods are elaborated and refined in-house by structural geologists and sedimentologists professionally involved in this kind of interpretation, based on their knowledge and field experience in understanding 3D anatomy of the whole spectrum of structures. Detailed geological analysis of data recorded using classical dipmeter or a more sophisticated tool, formation microimager, enables, among others: (1) continuous determination of the attitude of strata along borehole profiles, while monitoring all its changes and variations, (2) identification of unconformities, (3) recognition and determining orientation of faults of various dimensions (down to centimeter-size events), (4) distinguishing fault-related drag zones, (5) analysis of the relative fault block rotations, (6) recognition of brittlely deformed zones, (7) fracture analysis (distinguishing and determining orientation of joint sets, assessment of fracture apertures, distinguishing between water and oil-filled fractures – possible only from formation microimager record), (8) identification and geometrical analysis of folds, (9) orientating drill-cores with respect to the north, (10) distinguishing the types of internal bedding in clastic sediments and assessment of the directions of sediment palaeotransport and of the expected filtration anisotropy, (11) estimating 3D reservoir shapes (expected sandbody elongation and reservoir thickening directions), (12) distinguishing parasequences, sequences and genetically uniform sedimentary complexes in drilled strata, (13) setting up palaeofacies and palaeogeographical models, (14) determining orientations of the present-day around-borehole in situ principal tectonic stress axes and, on this basis, optimizing trajectories of the planned directional and horizontal drilling, estimating potential usefulness of hydraulic fracturing and/or water injection to be undertaken in order to enhance production, as well as setting up optimum configuration of injection wells.

Case examples of applying dipmeter-based structural and sedimentological data in hydrocarbon exploration in a number of geological regions in Poland carried out by a team led by the present author (e.g. Aleksandrowski and Kiersnowski 1998; Jarosiński and Aleksandrowski 1998; Aleksandrowski 2001) and some examples from the Norwegian shelf (Aleksandrowski et al. 1992) are presented, including the Lower Permian redbeds of the fore-Sudetic monocline, Palaeozoic to Miocene platform basement of the Outer Carpathian fold-and-thrust belt and the Miocene to Pliocene succession of the Carpathian foredeep. Running dipmeter and microimager can yield invaluable geological information in any deep drillings, in particular those aimed at scientific targets, at the same time partly replacing and complementing the costly extraction of drill-cores.

References

ADAMS J., 1993. Structural Interpretation Using Dipmeter and Borehole Image Data. In: Dipmeter and Borehole Image Interpretation, Z & S Geology Ltd, Short Course Notes, Aberdeen, 6/1-6/36.

ALEKSANDROWSKI P., 2001. Structural Analysis of Palaeozoic-Triassic Complex in Tarnawa-1 Well (Western Outer Carpathians) Based on *Halliburton SED* Dipmeter Data. *Prace Państwowego Instytutu Geologicznego*, 174, 133-142.

ALEKSANDROWSKI P., INDERHAUG O.H. and KNAPSTAD B., 1992. Tectonic Structures and Well bore Breakout Orientation. In: J.R. TILLERSON and W.R WAWERSIK (Editors), Rock Mechanics. Proceedings of the 33rd U.S. Symposium, Santa Fe (U.S.A.), 29-37. Balkema, Rotterdam.

ALEKSANDROWSKI P. and KIERSNOWSKI H., 1998. On the potential of structural, sedimentological and geodynamical analysis of borehole profiles based on modern dipmeter data. In: Najnowsze Osiągnięcia Metodyczno-Interpretacyjne w Geofizyce Wiertniczej. Materiały VII Krajowej Konferencji Naukowo-Technicznej PGNiG i AGH, Kraków, 9-18.

JAROSIŃSKI M. and ALEKSANDROWSKI P., 1998. Integrated Geodynamic and Structural Investigations of

Fractured Reservoirs Based on Borehole Data. In: Materiały Konferencji Najnowsze Osiągnięcia Metodyczne w Światowej Geologii Naftowej i Ich Wykorzystanie w Polskim Górnictwie Naftowym i Gazownictwie, PGNiG i Geonafta, Warszawa, 57-60.
GOETZ J.F., 1984. Dipmeter Interpretation: the Science and the Art. Gearhart Industries, Inc. Fort Worth, 51 pp.
GOETZ J.F., 1989. Dipmeter Interpretation: Pitfalls and Preferred Practices. In: Halliburton Technical Papers, 1-16.
HALLIBURTON, 1992. Introduction to the Six-Arm Dipmeter and SHIVA Processing.
SCHLUMBERGER, 1986. Dipmeter Interpretation. Fundamentals. Schlumberger Ltd, New York, 76 pp.

Projects ALP 2002 and SUDETES 2003 – Continuation of 3D Refraction Seismic Experiments in Central Europe

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Two large-scale seismic refraction experiments performed recently were aimed at the investigation of lithospheric structure in Central Europe. Experiment POLONAISE'97 targeted the structure and evolution of the prominent European suture zone – TESZ and adjacent units. CELEBRATION 2000 experiment covered namely East European Craton and Paleozoic Platform, Western Carpathians, Panonian basin and partly also the neighbouring units including the Bohemian Massif. Both projetcs benefited from the new generation of small, portable, programmable seismic instruments TEXAN developed in the USA. This fact enabled their massive deployment in the field (1,200 stations during the CELEBRATION 2000 experiment) resulting in a dense coverage of the investigated area. Such methodology offers a possibility of 3-D modelling of seismic wave velocity distribution in the lithosphere in the advanced stage of interpretation. Both experiments were iniciated and realised as an international co-operation of ca. 30 institutes from Europe and North America (Guterch et al., 1999, 2000).

To cover sufficiently the remaining areas of Central Europe, two new seismic refraction projects have been proposed – project ALP2002 and project SUDETES 2003.

Project ALP 2002, scheduled for summer 2002, will cover the Eastern Alps, the Europe's most prominent and complex mountain belt, and adjacent parts of Austria, Hungary, Italy, Czech Republic, Slovenia, and Croatia. The longest Trans-Alpian line of this experiment extending from Adriatic Sea will continue up to the northern part of the Bohemian Massif (Bílina in the Eger Graben region). University of Vienna (group of prof. Ewald Brueckl) is responsible for the project.

The experiment SUDETES 2003 is scheduled for summer 2003 and will cover the northern part of the Czech Republic, southwestern Poland and southeastern Germany. The overall scientific objective of the project is to investigate the deep crustal structure and geodynamics of the northern part of the Bohemian Massif, the largest outcrop of the Late Paleozoic Variscan orogen in Central Europe. In addition to targeting this massif, its relationships with the adjacent Caledonides and TESZ will also be investigated. The project will also focus on Elbe Zone and Eger Graben regions and an unsolved question of the Late-Paleozoic through Recent history of their reactivation. The NW-SE oriented Elbe Zone has for most of its history been active as an important strike-slip zone, parallel to the TESZ. The Elbe Zone produced a juxtaposition of terranes with different geodynamic histories, compositions, and geophysical properties. The WSW-ENE trending Eger Graben has been interpreted as a Neogene rift, characterized by significant Oligo-Miocene volcanism (Kopecký, 1986). At a deep crustal level, the rift axis is generally associated with the southeast-dipping boundary between the Saxothuringian and Moldanubian terranes. This boundary might be (?) associated with a major subduction zone within the Variscan belt that formed during the Middle-Late Paleozoic. The actual spatial characteristics of this boundary, its relationship with the intersecting Elbe Zone structures, as well as the history of its numerous reactivations at shallow crustal levels, remain a challenge to unraveling the geodynamic history of Central Europe.

The layout of the SUDETES 2003 project is suggested to consist of two orthogonal systems of recording profiles oriented perpendicular to and parallel with two main tectonic features of the region, the Elbe Zone and Eger Graben. To obtain dense ray coverage, not only in-line shots but also off-line ones are planned. The network of profile measurements together with the fan records of off-line shots should provide a sufficient 3-D coverage for 3-D modeling in the interpretation stages of the project.

The SUDETES 2003 and the ALP 2002 projects are designed to merge not only with CELEBRATION 2000 and