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What's new in exploration

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Underutilized EM technologies become more adaptable, affordable

Electromagnetic (EM) systems are rarely discussed or used for exploration in the US but have been in continuous use elsewhere in the world. EM is excellent for basin reconnaissance, producing accurate depth to basement, which is not always as obvious on seismic. Time-domain EM can be used to provide static corrections for seismic. Magnetotellurics (MT) shows great promise in high-resistivity formations, penetrating basalt to image underlying sedimentary rock, and in reservoir modeling, to monitor a flood front from the surface. If today's electromagnetic technology can be used to better constrain plays, it can reduce exploration risk.

The underlying concepts are not new.Electric borehole logging began in the 1920s, airborne surveys in the 1950s and land-based surface systems in the 1960s.

Commercial marine EM systems were developed in the 1990s. Statoil AG deployed a marine EM system for use off West Africa in 2000. Then, in 2004, ExxonMobil demonstrated in a proven oil field that its new R3M electromagnetic technology could map oil "with unerring preci-sion,"The Wall Street Journal reported.

Applicability. Misconceptions about the applicability of EM in petroleum exploration abound, partly due to the limited coverage in geology and geophysics curricula in the US. EM systems are popular in mineral exploration, geothermal prospecting and engineering site characterization. But these methods are not limited to shallow recognition of ore bodies.

Electromagnetic methods of geophysical exploration are used to study subsurface resistivity. The electrical resistivities of subsurface rocks are controlled by the porosity and pore fluid resistivity. Oil is resistive, conducting electricity poorly, compared with water. Resistivity is measured in ohm-meters; hydrocarbon-bearing reservoir resistivity is generally between 10 Ω-m and 100 Ω-m; water-saturated rock is 1–2 Ω-m, and seawater is 0.3 Ω-m.

EM wave propagation is the basis for many well-logging tools, but is much less common in systems deployed on the surface. The most common land-based exploration method is magnetotellurics (MT); controlled-source EM (CSEM) is rarely used on land. In marine exploration, CSEM and MT are both common. Induced polarization is rarely used on land or in marine settings.

Alphabet soup. TEM, CSAMT, AMT and MT methods require the measurement of one or more components of the magnetic field (or its time derivative) as a function of frequency and/or time.

In transient or time-domain electromagnetics (TEM), the depth of exploration is controlled by the size of the transmitting loop, earth resistivity and decay time. Units are milliseconds for time-decay plots and ohm-meters for calculated resistivities.

In controlled source audio-frequency magnetotellurics (CSAMT), the depth of exploration is controlled by frequency and earth resistivity, and units are ohm-meters for resistivity and milliradians for phase. MT uses naturally occurring or manmade electromagnetic fields to probe the electrical conductivity structure of the Earth.

In frequency-domain electromagnetics (FEM), frequency, earth resistivity and receiver/transmitter separation constrain the depth of exploration. Units are the percentage for in-phase and quadrature components, field strength ratio, tilt angle degrees, etc.

Niche. Electromagnetic techniques are still a niche business, but can be a meaningful supplement to seismic surveys. Dr. Kurt Strack, president of Houston-based KMS Technologies, has spent much of his career studying EM field methods, and believes that there is a big need to integrate EM with seismic, where it requires only a small incremental cost to add a rich source of data. A shared cost base makes EM exploration more economically feasible.

But Strack is realistic about the relative market sizes. In the West (i.e., excluding China and the Former Soviet Union), he estimates that $1.5 billion is spent annually on seismic, compared with $100 million on

airborne exploration, $100 million on marine EM exploration, and $20 million on land-based EM methods.

Breakthroughs. The newest EM advances, according to Strack, are 3D anisotropy induction for borehole logging; airborne TEM; portable, land-based MT systems; marine CSEM; and boreholeto- surface monitoring. Development of smaller, lower-cost hardware has already reduced the cost per site by 50% compared with the bulkier units previously available, Strack says. Microprocessorcontrolled receivers improve portability and deployment.

Magnetotellurics. KMS Technologies recently released a new-generation array acquisition system, KMS-820, which features wireless controllers, six GPSsynchronized channels, 24-bit analog/ digital resolution, and sampling rates up to 100 kHz. The wireless control capability allows a remote control interaction of up to 8 km, or unlimited distance in relay mode, between the data acquisition unit and the monitoring computer. KMS sent new MT land acquisition systems to India and China this spring, designed to work with various EM and seismic sensors.

Road ahead. Reservoir monitoring is on the upswing, and we will probably see increased use of land-based MT arrays. The development of less expensive, portable EM systems with lower power consumption and flexible data processing options should increase industry interest. EM technologies can be used to better define depth to basement, salt edges, statically correct seismic—all of which can reduce exploration risk—making them attractive to operators in tricky plays. WO

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