

^{GC}Electromagnetics Help Lower Drilling Risk*

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General Statement

Updated electromagnetic profiling techniques hold promise for evaluating shallow oil and gas plays along basin margins. An electromagnetic (EM) exploration system has been commercialized by Montason Exploration Inc., using recently developed theory combined with computer and measurement instrumentation.

The basic geophysical properties of subsurface reservoirs indicate the range of resistivity variation is much larger than the range of P-wave seismic velocities (Figure 1). By measuring subsurface conductivity, a "virtual" resistivity log can be derived for geological mapping, the company says. Because resistivities of hydrocarbon-filled and wet reservoirs vary significantly, EM resistivity data may define reservoir fluid content without drilling.

Real World Field Tests

Data acquisition consists of an electrical transmitter (Tx) with magnetometer receivers (Rx) positioned up to 1.5 miles away. Data are sampled between the transmitter and receiver (Figure 2). The system records the magnetic induction caused by electrical signals put through a transmitter on the ground. The input signal and the earth's magnetic response are both monitored. Computer processing outputs a conductivity log. Accuracy depends on the thickness-depth ratio, conductivity contrast, and background noise.

Some of the scientific theory has been published in the United States and Russia. Successful lab and field tests have been independently conducted. Testing was done in the shallow Cretaceous Niobrara chinks in the D-J Basin in eastern Colorado, where:

- Niobrara gas pay varies from 25 to 70 feet thick.
- Porosity is 30-40 percent.
- Formation permeability is below a millidarcy.
- Productive wells need fracture stimulation.

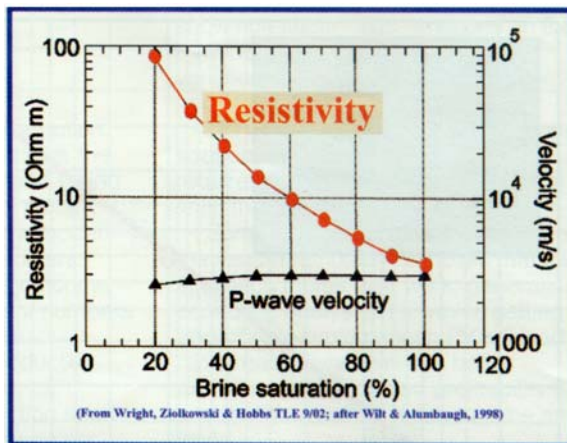


Figure 1. Comparison of resistivity variation in hydrocarbon reservoirs to P-wave seismic velocity. There are large variations in formation resistivity as compared to seismic velocity when water saturations decrease.

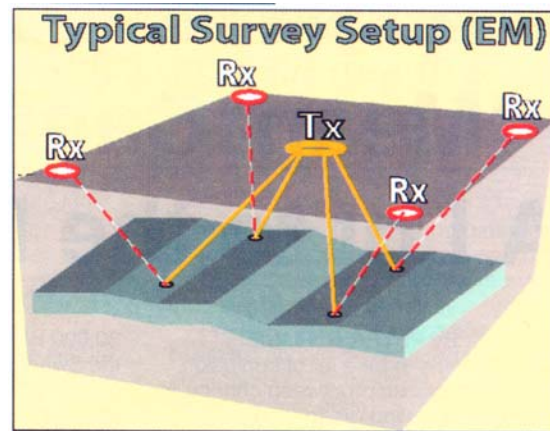


Figure 2. Typical EM survey with a central transmitter and several magnetometer receivers up to 1.5 miles away from the center. Subsurface data are measured halfway between the transmitter and receiver.

Niobrara gas fields are structurally-trapped accumulations. Typical gas wells produce under 500 MCFPD and have reserves averaging from 100-700 MMCF up to 2 BCF per well. Formation resistivity is 1-2 ohm-m in wet wells and 4-25 ohm-m in producers.

Beecher Island Field covers 27 square miles; production is at 1,400 feet, with 200 feet of structural closure. One of the EM tests was done on the field's crest. The results (Figure 3) show that when the Niobrara is gas saturated, EM can measure the depth and resistivity of the pay zone.

A survey also was conducted over the structural lead shown in red (Figure 4) at a depth of 1800 feet. The survey resulted in 29 "virtual" logs being added to existing subsurface data to produce the EM-derived structure map. The lead was verified to the northwest, but it proved to be substantially smaller than expected. EM-verified a structure that was too small to drill because of remote pipeline access. In this case, EM saved thousands of acreage, drilling, completion, and other exploration dollars that otherwise would have been spent on an uneconomic venture.

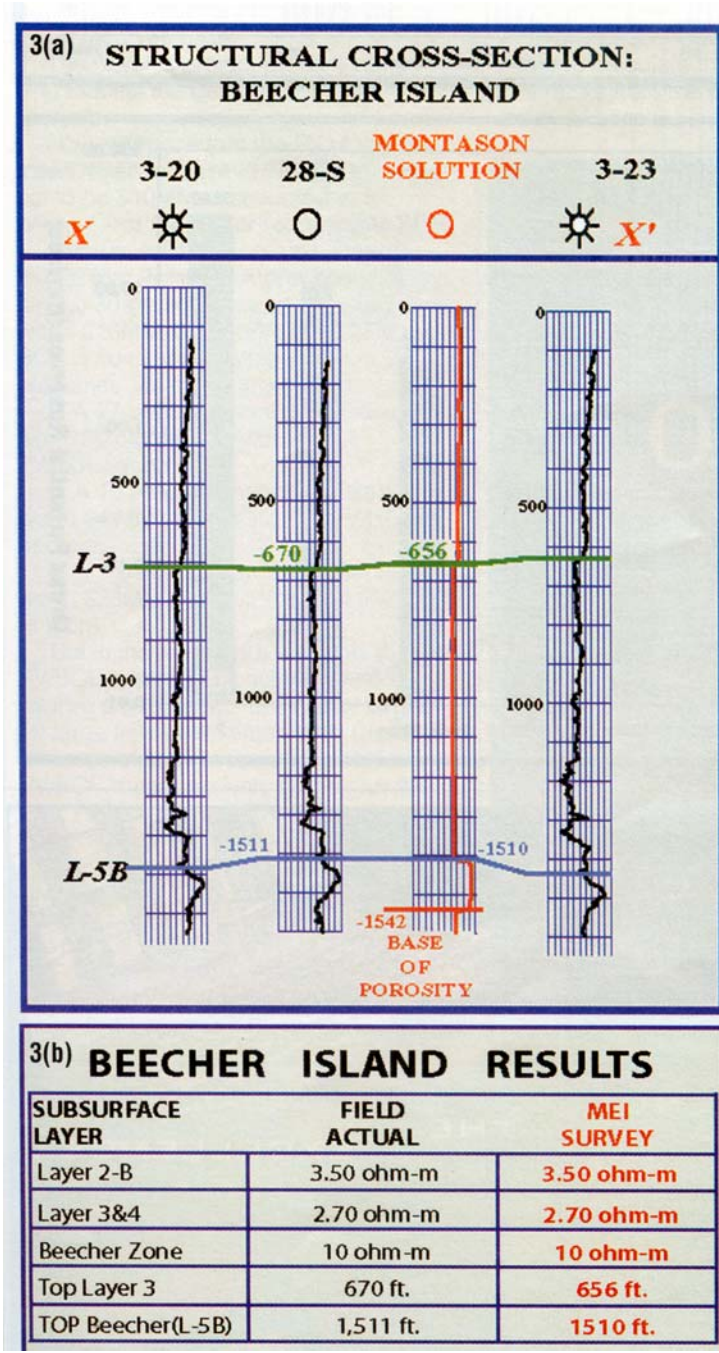


Figure 3. Comparison of Niobrara resistivity logs to an EM profile measured over Beecher Island Field. The table (3(b)) shows a comparison of the EM measurements with actual well measurements.

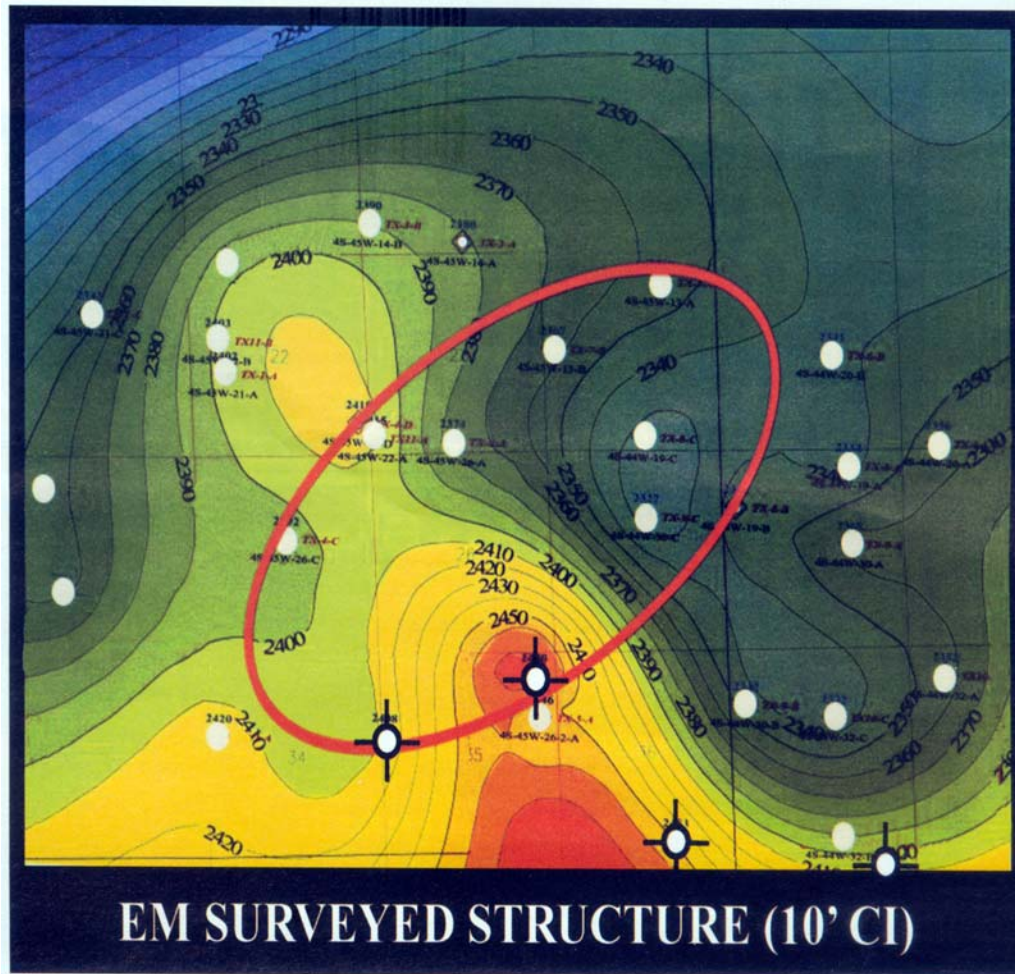


Figure 4. EM-derived structure map from 29 "virtual" logs gathered adjacent to existing wells. The map indicated a prospect lead to be too small to support the cost of drilling and development.

Applications

Reconnaissance work can be done as well as prospect evaluation, because the method is fast, adaptable, and relatively inexpensive.

- Because lateral facies boundaries can cause resistivity changes, the system can be used for stratigraphic exploration.
- Reservoir work, such as gas storage projects, can use EM for field boundary delineation. Reservoirs like the Eagle Sandstone in Montana, shallow gas in California and the Trenton, Clinton, and other shallow formations in the eastern United States can be mapped.
- EM can map shallow coal beds because they have strong resistivity contrast with surrounding rocks.
- Local conductivity variations in coal beds also can be mapped.
- Other areas that can benefit are minerals and groundwater exploration, archeological, and environmental work.

The current EM system's depth limit is about 2500 feet, but signal penetration is area-dependent, and some areas allow deeper penetration. Advanced system designs will soon permit recording well below 5000 feet.

A conductivity contrast is necessary for the tool to work. In the examples presented, productive Niobrara generally has a 100 percent or greater contrast, but EM detects much lower contrasts. Mineralized zones are identifiable because they generally show very high contrasts.

Effective analysis of EM profiles requires calibration to known subsurface conditions. Cultural problems affecting use are electric transmission lines, pumps, pipelines with cathodic protection, and high traffic areas.

EM surveys are highly efficient -- analysis is completed in a few days, allowing for great acquisition versatility. Because of this, the crew can be redirected to sample an anomaly on a tighter grid before moving. EM also is easy on the environment, lowering permitting costs due to negligible surface disturbance.

The Bottom Line

The main advantage of an EM survey is its low cost compared to 3-D seismic designed for high frequency at shallow depths. This is especially true when the cost of three-component data necessary for subsurface fluid detection is added to the basic 3-D cost.

Reference

Wright, D.A., Ziolkowski, A., and Hobbs, B.A., 2001, Hydrocarbon detection with a multi-channel transient electromagnetic survey (Expanded Abstracts): 71st SEG Meeting, 9-14 September, San Antonio, p 1435-1438.