AAPG EXPLORER

Geophysical Corner

# Primer: Interpreting Magnetic Data

*(Editor's note: The Geophysical Corner is a regular column in the EXPLORER and is produced by M. Ray Thomasson of the AAPG Geophysical Committee. This month's column is the first of a two-part series on interpreting magnetic data.")*

By DALE BIRD
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Traditionally, magnetic data have been used in early phases of exploration programs to map depth to magnetic basement and define the basin architecture.

Recent improvements in acquisition and processing technology, together with more detailed understanding of structural styles in exploration areas, allows us to now say:

"Magnetic data are not just for the basement anymore."

This month's "Geophysical Corner" describes methods of interpreting magnetic anomalies. Fundamental concepts, or "rules-of-thumb," are also included.

Although there are certainly alternative approaches and/or techniques that may be used, the purpose here is to provide a framework for geoscientists who may be unfamiliar or do not regularly work with magnetic data.

**Rules of Thumb**

p Wavelength.

In general, the wavelength of an anomaly is proportional to the depth of the magnetic source body that produces it (Figure 1). More correctly, depth is related to the horizontal distance of the slope of the anomaly.

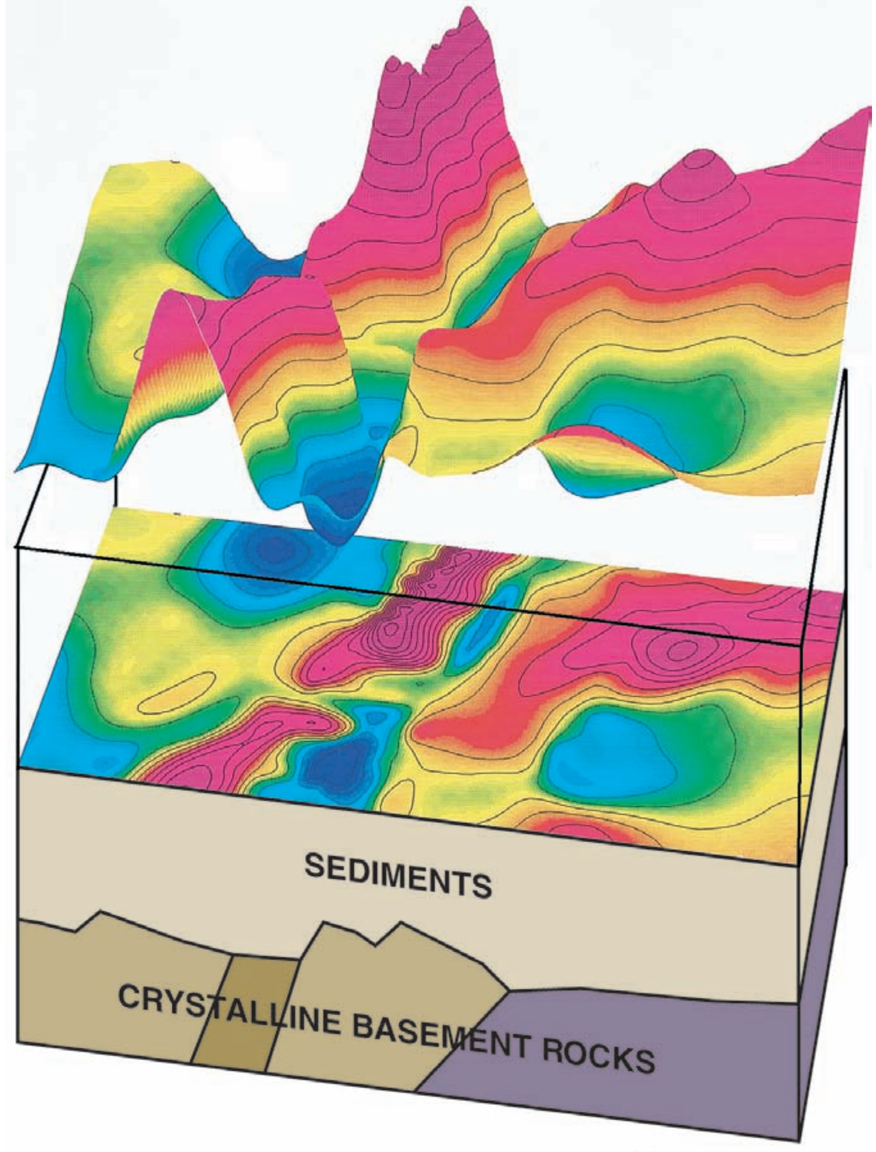
As with other geophysical data, long "wavelengths" are related to deep sources (or events), and short "wavelengths" are related to shallower sources.

Outcrops of the San Juan volcanics in southwestern Colorado have narrow, high frequency anomalies, while the deep basement in the Williston Basin causes relatively broad highs and lows.

High frequency anomalies are also observed over the Devil's River Uplift in West Texas. Adjacent to the Uplift, anomalies are broader indicating a dramatic deepening of the basin.

When looking at a magnetic map, an anomaly high is not necessarily produced by a structural high. Rather

continued on next page




*Graphics courtesy of Aerodat Inc.*

Figure 1: Three-dimensional perspective of magnetic data and Earth model.

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an area of closely spaced, sharp, short wavelength anomalies implies shallow basement and an area of smooth, broad, long wavelength anomalies implies deep basement.

With a practiced eye an interpreter can quickly pick deeper from shallower areas.

p Amplitude

The amplitude value is proportional to the magnetic susceptibility contrast in the rocks beneath the magnetometer.

"Susceptibility" is a measure of the ease with which a rock can be magnetized. Geologically it can be thought of as a measure of the magnetite content, although a few other minerals may contribute under special circumstances.

Amplitude does decrease with increasing distance from the source, but not to an extent that effects the following concepts.

Amplitudes can generally be divided into categories of hundreds of nanoteslas (nT), tens of nT, and ones of nT. The nanotesla (nT) has been adopted by our industry as the "official" unit of measure for magnetics. It replaces the gamma (y); in other words, 1 nT is equal to 1 gamma (y).

Lithologic variations in magnetic basement, or the presence of igneous rocks within the sedimentary section, generally produce anomalies with the highest amplitudes. For example, the magnetization of intra-basement features may be stronger than surrounding basement rocks.

In this case, large amplitude anomalies would be observed where basement structures are not present.

The East Coast Magnetic Anomaly, with an amplitude of several hundred nT, is related to the contact between oceanic and continental crust and to possible intrusive rocks along it. In the Black Warrior Basin of northwestern Mississippi, an area of low magnetic intensity is bordered by high amplitude anomalies and is, in fact, structurally high.

The basement in this area is, in fact, structurally high – as proven by several exploration wells.

To summarize, high amplitude anomalies typically reflect lithologic contrasts. While anomalies produced by structures are usually more subtle.

Anomalies with amplitudes on the order of:

4 100s nT – are related to lithologic variations in basement or igneous rocks with the sedimentary section.

4 10s nT – are related to basement structures (supra-basement).

4 1s nT – are related to sedimentary magnetization contrasts.

p Methodology

A typical approach for interpreting magnetic data involves geologic research including an assessment of existing geologic and geophysical control, depth-to-magnetic source estimation, 2-D and 3-D forward modeling, data inversion, analyses of anomaly trends (using observed data and its derivatives), and data filtering.

It is not necessary to follow a specific order when applying these elements, but final products usually involve producing geologic map(s) that incorporate information from one or more elements.

p Geologic Concept

The most important element required for interpreting magnetic data is a geologic concept or structural model. We are never blind; that is, even if the only data available in an area are magnetic data, we know the area is in a rift setting, or a foreland basin, or along a passive margin, etc.

We also know the survey's location, hence, we know the attitude of the magnetic field or its inclination and declination and strength.

The poles of the Earth's magnetic field are not aligned exactly with its geographic poles, and therefore inclination, declination and field strength indicate the direction and magnitude of the field relative to geographic position.

When interpreting geophysical data

See **Geophysical Corner**, page 21

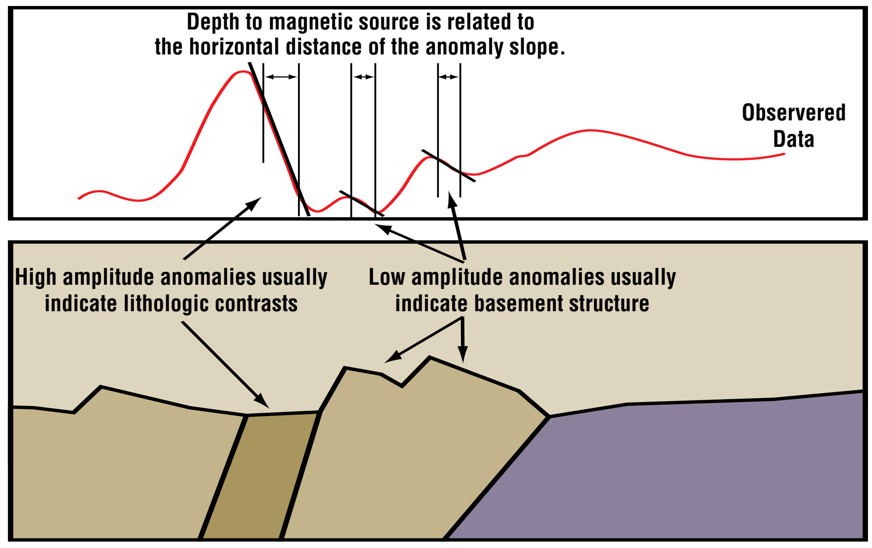


Figure 2: Two-dimensional cross-section

continued from previous page

Techniques for Evaluating Origin and Distribution
Sept. 23-24, Houston

**Structure**

* Continental Wrench-Tectonics and Hydrocarbon Habitat
Sept. 11-12, Vienna, Austria (with the AAPG international meeting)
* Workstation Interpretation of Structural Styles
Oct. 8-10, Houston

# Geophysical Corner

from page 19

it is most important to apply known geologic control to constrain the interpretation.

p Depth-to-Magnetic Source

Depths determined from magnetic data can be confidently estimated to about ±7 percent. When an entire data set is interpreted by consistent methods, the interpretation map will show structural highs and lows which are relative to each other. Although depths are not known exactly, the horizontal positions of anomalies are directly related to locations of interpreted sources, so there is no ambiguity with regard to geographic position (Figure 2).

There are many depth-to-magnetic source estimation techniques, manual and automated. The important thing to remember when applying these techniques is to be consistent. The end product will then be a map of posted values that are all relative to each other.

It is helpful to generate hypothetical 2-D models, incorporating the appropriate magnetic field attitude and strength in order to see relationships between structures and the position of anomalies over them (Figure 2, page 19).

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Next month: Two-D modeling, data inversion, trend and lineament analysis and filtering.

*(Editor's note: Dale Bird is general manager of Aerodat Inc., in Houston.)*

**1997 FIELD SEMINARS**

**Carbonates**

Paleokarst Reservoirs and Modern Analogs – Origin and Geometry of Cave Pore-Network Systems
May 5-8
Begins in Little Rock, Ark.
Ends in Austin, Texas
Florida-Bahamas Modern Carbonates
June 8-15
Begins, ends in Miami, Fla.
Carbonate Facies Architecture and High-Resolution Sequence Stratigraphy of the Florida Keys
Sept. 28-Oct. 5
Begins in Miami, Fla.
Ends in Key West, Fla.
Carbonate Sequence Stratigraphy, as Illustrated by Lower Cretaceous Platform Carbonates, Central Texas
Oct. 6-10
Begins in San Antonio
Ends in Austin, Texas
Arid Coastline Depositional Environments
Nov. 2-7
Begins, ends in Abu Dhabi, U.A.E.

**Clastics-Ancient**

Clastic Reservoir Facies and Sequence Stratigraphic Analysis of Alluvial-Plain, Shoreface, Deltaic and Shelf Depositional Systems
May 4-10
Begins, ends in Salt Lake City,Utah
Turbidite Systems and Facies and Their Relations to Depositional Sequences
June 2-9
Begins, ends in Barcelona, Spain
Sequence Stratigraphic Influence on Sandstone Reservoir Characteristics of Cretaceous Foreland Basin Deposits
June 8-14
Begins in Rock Springs, Wyo.
Ends in Steamboat Springs, Colo.
Wave-Dominated Shoreline Deposits and Shelf Sandstones: Depositional Models for Hydrocarbon Exploration
June 16-24; July 21-29
Begins, ends in Grand Junction, Colo.
Petroleum Geology of Deep-Water Clastic Depositional Systems
Oct. 7-11
Begins, ends in Little Rock, Ark.

**Clastics-Modern**

Modern Clastic Depositional Environments
Sept. 13-19; Oct. 12-18
Begins in Columbia, S.C.
Ends in Charleston, S.C.
Modern Deltas
Sept. 15-19
Begins in Baton Rouge, La.
Ends in New Orleans

**Tectonics and Sedimentation**

Grand Canyon Geology via the Colorado River, Arizona
(An AAPG "Geotour")
June 1-8
Begins at Marble Canyon, Ariz.
Ends Marble Canyon or South Rim, Ariz., or Las Vegas, Nev.
* Exploration and Production in Thrusted Terrains: Practical Issues of Exploration and the Environment in the Montana/Alberta Overthrust Belt
July 14-19
Begins, ends in Great Falls, Mont.
* Reservoir Development of Lowstand and Transgressive System Tract Valley-Fill/Estuarine Reservoirs
July 26-Aug. 1
Begins, ends Casper, Wyo.
Rift Tectonics and Carbonate Facies Response: Exploration Models from the Jurassic of the High Atlas, Morocco
Sept. 13-20
Begins in Rabat, Morocco
Ends in Fez, Morocco
Submarine Fan and Canyon Reservoirs, California
Oct. 13-17
Begins, ends in San Francisco
Sequence Stratigraphy Field Seminar: Sequences and Facies on an Active Margin
Nov. 9-14
Begins, ends in La Jolla, Calif.

*Asterisk denotes new AAPG offering.*