Seepage-Induced Magnetic Anomalies Associated with Oil and Gas Fields: Onshore and Offshore Examples*

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Introduction

The presence of magnetic anomalies over oil and gas fields has been noted for several decades, but it is only in recent years that the phenomenon has been critically examined. Studies of geologically and geographically diverse regions document that:

1. Authigenic magnetic minerals occur in near-surface sediments over many petroleum accumulations,
2. This hydrocarbon-induced mineralization is detectable in high resolution, broad bandwidth magnetic data acquired at low altitude and with closely-spaced flight lines, and in ground magnetic surveys,
3. The magnetic susceptibility analysis of drill cuttings and near-surface sediments confirms the existence of the aeromagnetic anomalies,
4. Sediments with anomalous magnetic susceptibility frequently contain ferromagnetic minerals such as greigite, maghemite, magnetite, and pyrrhotite,
5. Approximately 80% of oil and gas discoveries are associated with hydrocarbon-induced magnetic anomalies.

The association between hydrocarbon seepage and the formation of authigenic magnetic minerals in the near-surface has important applications in hydrocarbon exploration. Application of this methodology can quickly identify the areas or prospects with the greatest petroleum potential. Although the discovery of shallow sedimentary magnetic anomalies does not guarantee the discovery of commercial hydrocarbon accumulations, it does identify areas requiring more detailed evaluation, thereby focusing attention and resources on a relatively small number of high potential sites. More significantly, these seep-induced magnetic anomalies have been documented over many deep-water discoveries in the Gulf of Mexico. Proper integration of near-surface magnetic data with geologic and seismic data can improve exploration success and reduce development costs. This presentation is illustrated with examples from North America (including the deep-water Gulf of Mexico) and Africa.

Methodology

Variation in the measurement of the earth/s magnetic field can result from the following causes:

- Lithologic and magnetic changes associated with basement rocks
- Intrusive igneous bodies, volcanic deposits, shallow salt masses
- Cultural contamination from surface and near-surface iron material
- Solar modulation of the earth's magnetic field
- Authigenic ferromagnetic minerals in near-surface sediments.

Low-terrain-clearance, high- sensitivity cesium vapor aeromagnetic measurements provide a composite of these effects on the magnetic field data. Data reduction techniques that remove the influence of magnetic basement rocks on the total magnetic field and, where possible, the effects of cultural iron contamination allow the identification of sedimentary residual magnetic (SRM) anomalies (Figure 1) as they exist along the flight line. When these SRM anomalies are positioned line-to-line adjacent to one another, they define SRM anomaly clusters. It is these clusters that define the micromagnetic anomaly – also referred to as "Magnetic Bright Spots" (Figure 2) – which provide valuable clues to an underlying oil or gas accumulation.

Selected Exploration Examples

Figures 3 and 4 show several exploration examples. In the Bob West Field example (Figure 3), the shallow sedimentary magnetic anomaly clearly outlined this deep Wilcox field years before that field was discovered and developed. In the Morrow trend example (Figure 4), we see the value of high-resolution airborne magnetic data to map the regional distribution of a highly productive channel sandstone.

The "Summary of Drilling Results" documents (Table 1) that exploration leads and prospects associated with a seep-induced magnetic anomaly is 4 to 6 times more likely to result in a commercial oil or gas discovery than a similar prospect without such an anomaly.

Applications for Deep-Water Exploration

The association between hydrocarbon seepage and the formation of authigenic magnetic minerals in near-surface sediments has important applications in deep-water hydrocarbon exploration. Sepage-induced sedimentary magnetic anomalies can reliably identify areas and prospects with the highest petroleum potential in water depths as great as 9000 feet (2800 m). The high-resolution cesium vapor aeromagnetic data used in this study by Robert Foote and his colleagues were acquired between 1986 and 1992 and extend from East Breaks to Viosca Knoll in the Gulf of Mexico. A comparison of the specially processed and interpreted aeromagnetic data with post-survey drilling results documents that more than 80% of wells drilled on prospects within or adjacent to Magnetic Bright Spots have resulted in commercial discoveries. In contrast, only 40% of wells drilled on prospects located more than 800 m from the MBS have resulted in discoveries. Although the discovery of MBS anomalies does not guarantee the discovery of hydrocarbon accumulations, it does identify areas requiring more detailed evaluation, thereby focusing attention and resources on a relatively small number of high potential sites.

Selected References

Foote, R.S., 1996, Relationship of near-surface magnetic anomalies to oil and gas-producing areas: AAPG Memoir 66, p. 111-126.

Foote, R.S., 2007, Method helps find hydrocarbon areas; aids optimum seismic survey planning: Oil & Gas Journal, 5 Feb 2007, p. 35-38.

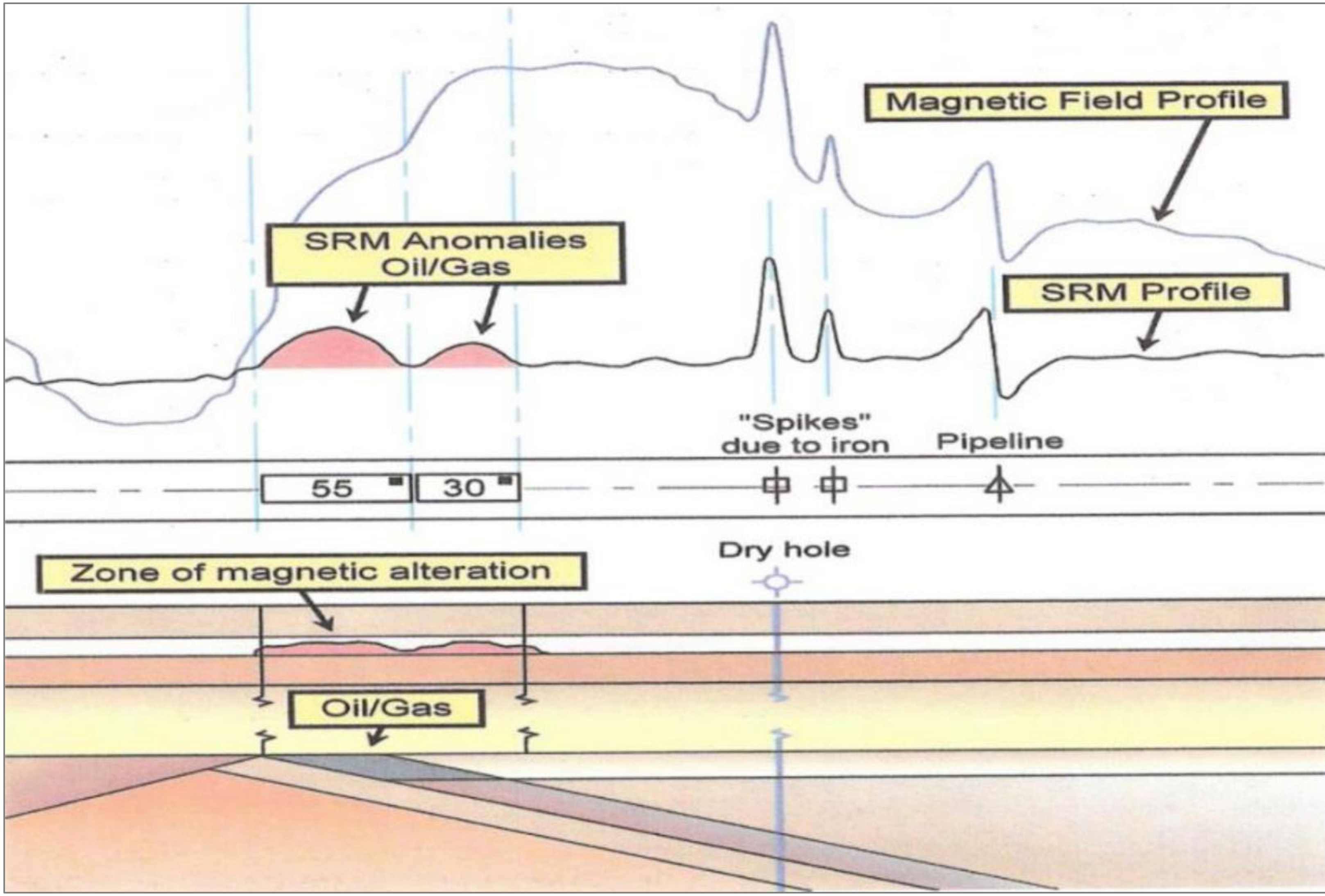

Figure 1. Aeromagnetic SRM data interpretation.

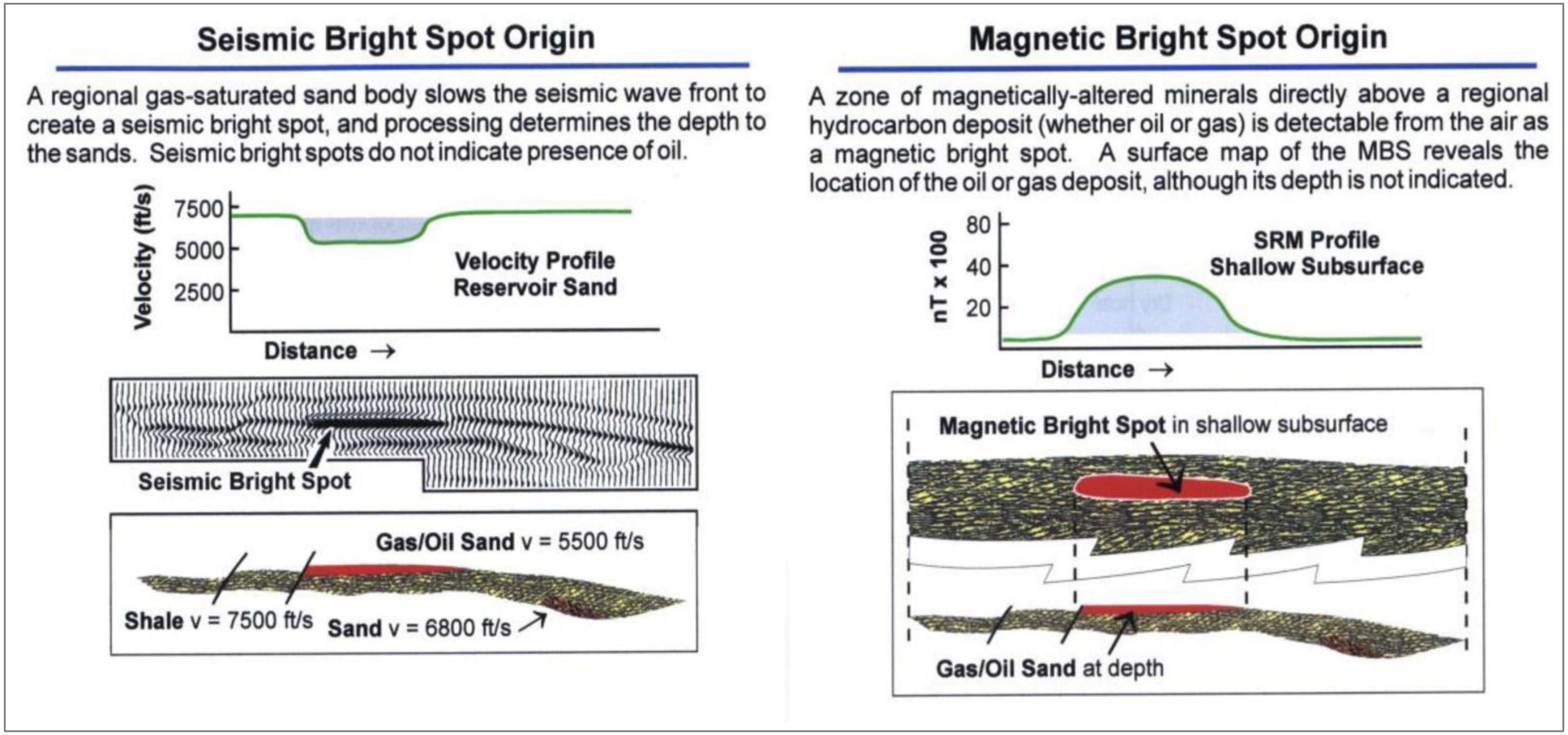

Figure 2. Seismic bright spot origin (left) and magnetic bright spot origin (MBS) (right).

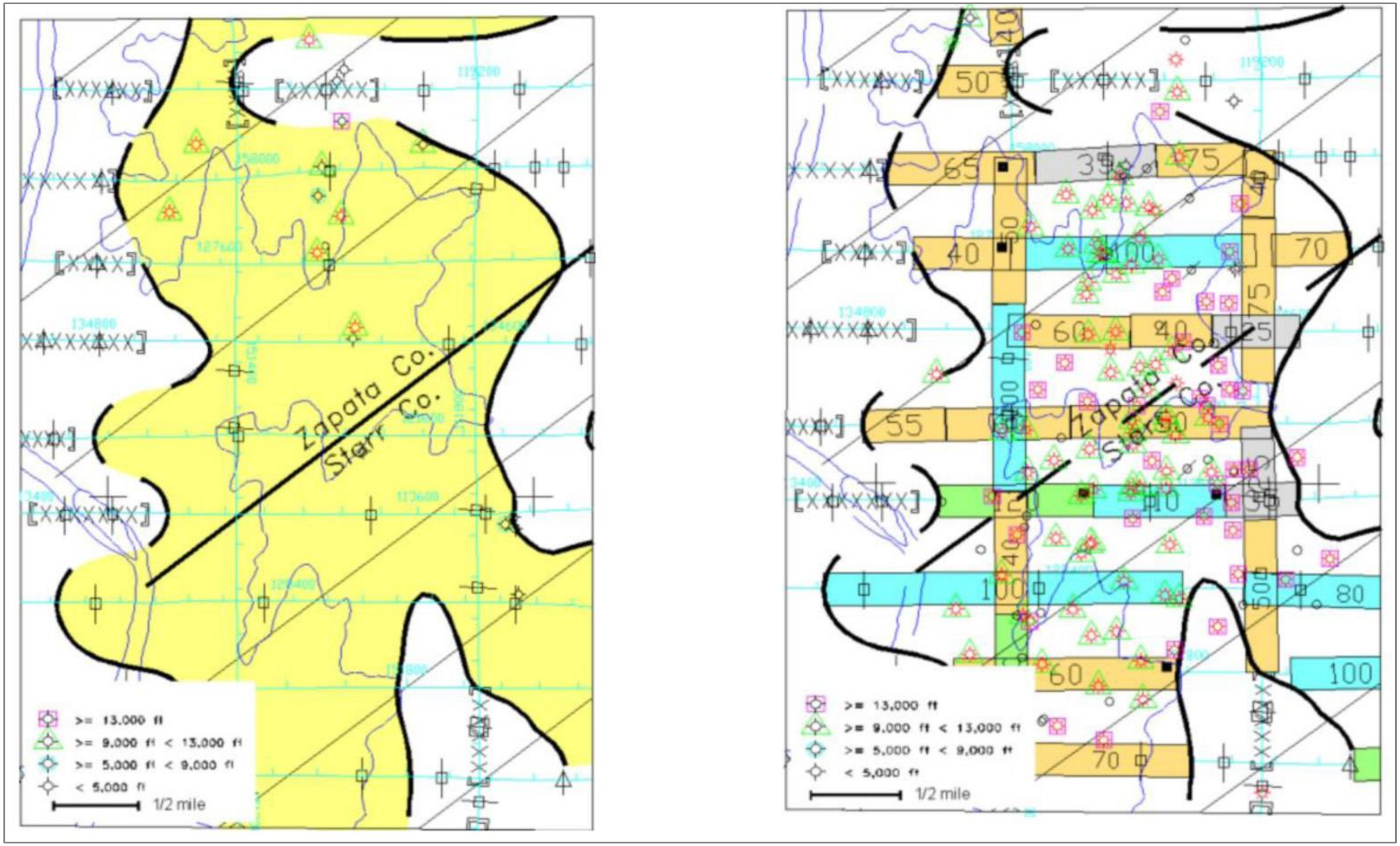

Figure 3. (left) Bob West Field area, December 1985, showing drilling status and magnetic bright spot outline; (right) Bob West Deep Wilcox Gas Field (1990), December 1986 to April 1997, showing SRM and MBS anomalies from 1985 aeromagnetic data.

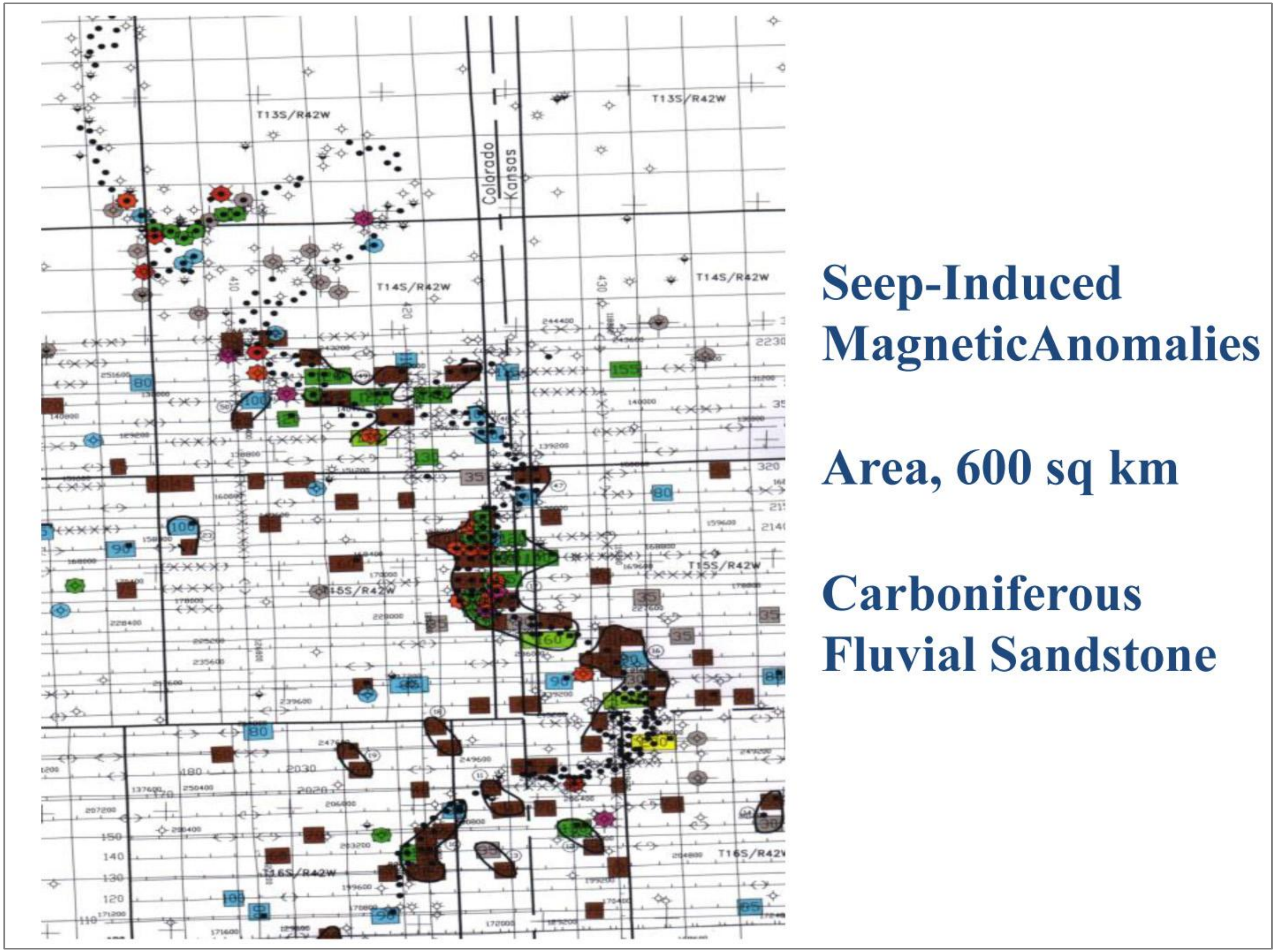

Figure 4. Stateline Morrow trend, Colorado-Kansas.

AREA	WELL INFORMATION	WITHIN MBS	OUTSIDE MBS
Stateline Trend	Total Wells	283	404
Colorado-Kansas	Producers	212 (75%)	51 (13%)
1100 sq miles	Dry Holes	71 (25%)	353 (87%)
Oklahoma	Total Wells	99	146
Caddo/Grady Counties	Producers	88 (89%)	19 (13%)
364 sq miles	Dry Holes	11 (11%)	127 (87%)
Utah	Total Wells	21	21
San Juan County	Producers	19 (90%)	1 (5%)
80 sq miles	Dry Holes	2 (10%)	20 (95%)
Southwest Alabama	Total Wells	67	312
2300 sq miles	Producers	52 (78%)	15 (5%)
	Dry Holes	15 (22%)	297 (95%)
SUM OF ALL 4 AREAS	**Total Wells**	**470**	**883**
3844 sq miles	**Producers**	**371 (79%)**	**86 (10%)**
	Dry Holes	**99 (21%)**	**797 (90%)**

Table 1. Summary of drilling results for onshore MBS Data.