SBGf32699

Enhanced 3D Seismic Surveys Using a New Airborne Pipeline Mapping System

Terence J. McConnell*, Bob Lo and Alastair Ryder-Turner,James A. Musser

* Green Mountain Geophysics, Scintrex Limited

ABSTRACT

The need to accurately locate pipelines and other cultural features is of paramount importance to the safety, planning and quality of 3D seismic data.
With the current industry trend being to maximize production from known reserves, there is an increased practice of shooting 3D seismic surveys over mature and previously abandoned oil and gas fields. In many instances, the infrastructure in the abandoned, and even the active oil and gas fields is poorly documented, and hazard locations are inaccurate.
This lack of knowledge about the location of pipelines, well heads and other oil field infrastructure poses a danger to the seismic crews drilling shot holes within the boundaries of the oil field. It can also cause degradation of the quality of the seismic data; gaps in the shot point positions, created by safety requirements to avoid areas of uncertain pipeline location, result in poor, or zero, seismic fold coverage in the areas of most interest; the oil field itself.
The purpose of this paper is to present a new airborne technology for the detection and mapping of oil field infrastructure, and to review how this technology, when used in conjunction with modern 3D seismic planning software, can result in cost savings, enhanced safety and higher quality 3D seismic surveys.

INTRODUCTION

In many of the areas that 3D seismic is shot, such as in swampy or watery locations, the traditional hazards survey often takes prohibitively long to conduct properly. The high operating costs of a 3D seismic crew means that any down time caused by waiting for a hazards survey to be finished is expensive.
Due to the large areal extent of oil and gas fields and the magnetic nature of the targets, airborne magnetic methods were an obvious, but challenging, choice (Phillips et al, 1995). Scintrex' PDS-3M Pipeline Detection System (hereinafter referred to as PDS) was developed in conjunction with oil pipeline companies to have the ability, under favorable conditions, to detect pipelines as small as two inches in diameter.
The PDS hardware consists of three Scintrex CS-2 cesium vapor sensors mounted in a triangular configuration on a bird towed beneath a helicopter, as shown in Figure 1. With a sampling density of 2.5 meters along line, all three components of the magnetic gradient are measured, yielding excellent near surface resolution of magnetic features. The bird is flown at a 30 meter ground clearance using geodetic quality differential GPS positioning, permitting the spatial resolution of individual magnetic features as close together as 25 meters.
Previous attempts to map pipelines using airborne magnetics have suffered from poor positional accuracy and the ambiguities inherent in measuring only the total magnetic filed. With this system, anomalies are analyzed and classified using all three of the measured magnetic gradients (G_x, G_y and G_z), although the measured total gradient, $G_T = \sqrt{G_x^2+G_y^2+G_z^2}$, also known as the measured analytic signal, appears to be the most robust interpretation tool. The total gradient has a number of advantages over the simple total field and individual gradient measurements. It is independent of normal magnetic diurnal variations, it is independent of sensor orientation errors, it is independent of magnetic latitude variables and of the effect of remnant magnetization. The total gradient is always positive, and always peaks right over top of the causative body, making interpretation and precise positioning a relatively simple process (Gamey et al, 1997)

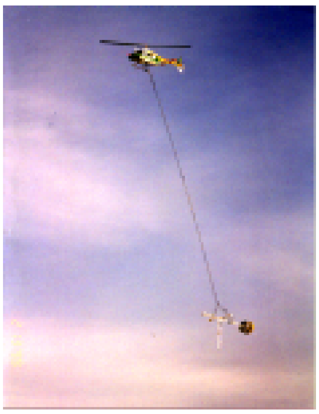

Figure 1: Pipeline Detection System

The magnetic signature of pipes is dependent on many factors, including the presence of cathodic protection current, size of the pipe, and remnant magnetization. Abandoned water pipes as small as four inches in diameter have been located by the system. Active two inch flow lines and their associated well heads are easily detectable. Figure 2 shows a typical profile across an area with multiple magnetic responses.

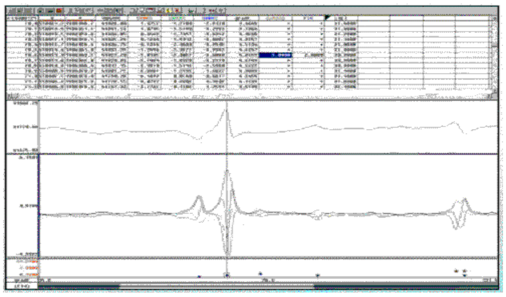

Figure 2: Typical PDS Line Profile

Indices relating to the shape and form of the typical magnetic responses over an oil field were developed. They are used in the interpretation and classification of the anomalies detected.
The result is a digital GIS-type layered database representing the various types of cultural features detected, particularly the oil field infrastructure and pipeline layout. This information is then provided to the 3D seismic survey design geophysicist for use in planning the most effective shot point and receiver layout.
When used in conjunction with surface mapping tools such as aerial photography, the PDS system can provide the most comprehensive analysis database available about both on-surface and sub-surface hazards.

CASE HISTORY DESCRIPTION

During June and July of 1997, Scintrex flew a detailed airborne pipeline detection survey under contract to COMESA and PEMEX over an active oil field in Mexico. The objective of the survey was to locate and map the oil field pipelines and well heads, as well as other potential hazards, prior to COMESA shooting a large 3D survey over the entire field. The survey was flown in advance of the 3D shoot, and the results were used to ensure seismic crew safety, and to enhance seismic data quality. This was accomplished by the use of the PDS data to relocate shot holes to safer, most advantageous positions.
The entire survey area covered roughly 340 square kilometers. The topography was flat and swamp covered over half of the area, and rolling hills and farmland over the remainder. The PDS system was flown using a flight line spacing of 50 meters over the densest parts of the oil fields, and at 200 meters over the rest of the seismic shoot area. Flight lines were flown using real-time differential GPS so as to exactly overfly the planned seismic shot pattern. The elevation of the PDS sensor was a nominal 30 meters above ground.
The survey was completed in 43 days (including roughly 10 days where flying was not possible due to weather and other factors), using 97 flying hours with a Bell B-206 helicopter. Infrastructure maps were delivered to the client on a progressive basis during the survey. A complete area map was presented fifteen days after all flying was completed.

INTERPRETATION

The interpretation of the PDS data for this survey encompassed several separate but related stages. The general interpretation flow was as follows:
1. The preparation of a symbol map and database reflecting the classification of all magnetic anomalies detected by the system, using an automatic anomaly “picking” routine. This routine examines the relationship of the three measured gradients along a given flight line with respect to magnetic characteristics determined from actual and theoretical studies of “typical” pipeline and well head magnetic responses.
2. The flight line geo-referenced videotapes and operator flight logs were reviewed. The anomaly database from the previous step being revised and expanded based on visible evidence from the geo-referenced videotapes. A revised symbol map and database was then produced.
3. The individual PDS flight line profiles were examined. The interpreter verifying the “auto picks” and adding any additional picks that may have been “missed” or misidentified by the auto picking routine, the review of the flight line videos, or on operator flight logs. A revised symbol map and database was then produced.
4. Any information with respect to known pipelines and well heads in the survey area is then examined in conjunction with the PDS flight line profiles and videotapes. This stage is arguable the most important in the interpretation process. It is at this point that the validity of the supplied information and the interpretation can be assessed with respect to positional accuracy, off flight line detection limits, actual presence of or absence of a detectable feature, detection limits and overall reliability can be assessed.

DISCUSSION OF RESULTS

Data from two adjacent blocks within the larger survey area are presented here. The first example is from an abandoned portion of the field. The client-supplied infrastructure map, as shown in Figure 3 shows almost no hazards for the seismic survey. However, numerous magnetic responses were detected by the PDS survey and the interpreted results,

Sixth International Congress of the Brazilian Geophysical Society

as shown in Figure 4, show that numerous pipelines and well heads are located in the area. These oil field infrastructure components were abandoned close to 30 years ago, and have since been covered over with swamp and undergrowth. Other isolated magnetic responses in the area are due to metallic debris, cattle grates, and other potential seismic hazards in the area.

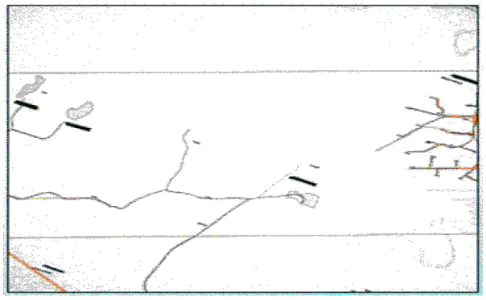

Figure 3: Abandoned Oil Field - Infrastructure Map Before PDS Survey

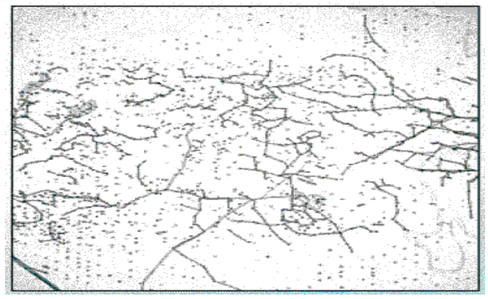

Figure 4: Abandoned Oil Field - Infrastructure Map After PDS Survey

The second example is to the northeast of the first. An infrastructure map existed for this active oil field, and the seismic safety exclusion zones around these pipelines is shown in red in Figure 5. However, the seismic crews operating in the area encountered pipelines in locations different from what was mapped on the original infrastructure map. Due to the resultant uncertainty in the true locations of the pipelines, a large area in the center of this producing oil field (black boundary lines) could not have seismic shot holes due to safety concerns.

Figure 6 is the modified infrastructure map as created by the PDS survey. Note that the seismic safety exclusion zones are represented by the wide blue lines, the center of which is the actual location of the detected pipelines. Note also the presence of the shot points (boxes) and the receiver points (x's). The data collected during the PDS survey over this active oil field showed that:

- some pipes and wells shown on existing infrastructure maps have been misplaced by hundreds of meters, or do not exist at all;
- there are typically a lot more cultural features present than indicated on existing maps;
- pipes going from wells to collection points have often taken the path of least resistance instead of the originally planned path;
- multiple pipes in a corridor, thought to be parallel, wave and separate by as much as 25 meters;

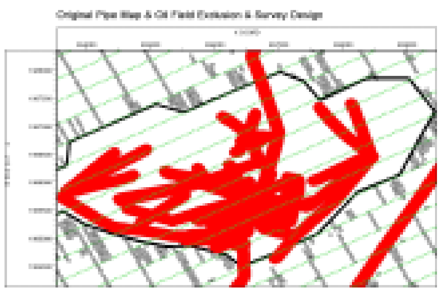

Figure 5: Active Oil field - Infrastructure Map Before PDS Survey

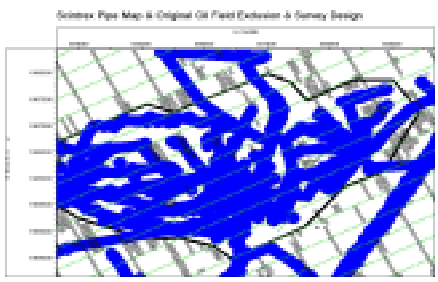

Figure 6: Active Oil field - Infrastructure Map After PDS Survey

EFFECT ON SEISMIC PLANNING / CONCLUSIONS

Using 3D seismic planning software (in this case, the Green Mountain Geophysics MESA program), we can show that the ability to safely place new shot points in areas previously thought to be inaccessible can significantly enhance the

Sexto Congresso Internacional da Sociedade Brasileira De Geofisica

final quality of the entire project.

Figure 7 shows the seismic fold coverage for the area of the active oil field displayed in Figure 5 above, at offsets of 1000 and 2000 meters. The shot point layout excluded most of the active oil field due to safety considerations. Notice that the seismic fold coverage is poor, with large holes in the data set. These holes in the fold coverage are larger for shallow offsets, and smaller for wider offsets where seismic undershooting of the oil field is possible. The result on the 3D seismic data cube is a conical hole directly over the producing geologic structure of the oil field.

With the information from the PDS survey, major revisions to the infrastructure map were made, and the seismic shot hole layout was re-done. With increased confidence in the pipeline and hazard locations, the seismic acquisition geophysicist placed a total of 126 additional shot points within the boundaries of the oil field, significantly in-filling the existing hole in the seismic fold coverage. Figure 8 is the seismic fold coverage at the same offsets as in Figure 7, and after the information from the PDS survey was used to determine safe areas for shooting. The difference between the fold coverage that the seismic company was able to obtain after the PDS survey, and what they had before, is remarkable.

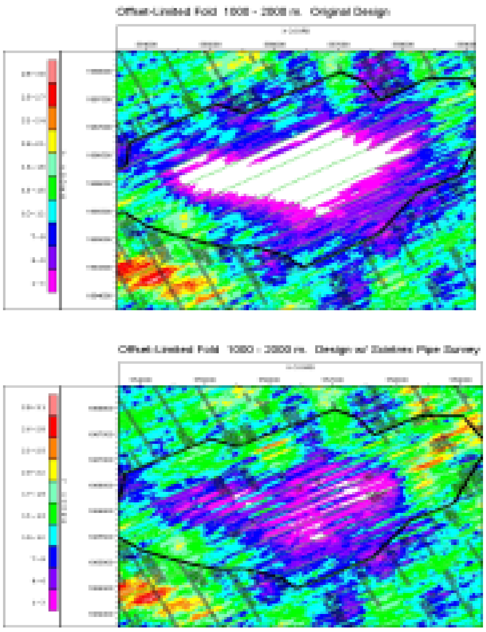

Figure 8: Seismic Fold coverage
After PDS Survey 1000 to 2000 meter Offsets

The case history described within this paper is typical of many other surveys completed using this new airborne pipeline detection technology. The capability to provide a more comprehensive sub-surface infrastructure map results in an enhancement to the safety of the 3D seismic shoot, adds to the final quality of the 3D seismic data cube, and saves money by avoiding unnecessary delays and costly accidents

ACKNOWLEDGMENTS:

The permission of both PEMEX and COMESA in allowing Scintrex to show the data presented is greatly appreciated. Also, the authors wish to acknowledge the support of Scintrex Ltd. and Green Mountain Geophysics during the preparation of this paper.

References:

Gamey, T.J. et. Al, 1997, Airborne Measured Analytic signal for UXO Detection: SAGEEP Proceeding, p.853.

Grant, F. S., and West, G. F., 1976, Interpretation theory in applied geophysics: McGraw-Hill Inc.

Nabighian, M. N., 1972, The analytic signal of two-dimensional magnetic bodies with polygonal cross-section: Its properties and use for automated anomaly interpretation: Geophysics, 37, 507-517.

Phillips, J.D. et. Al, 1995, High Sensitivity Aeromagnetic surveys for Environmental Hazard Detection in South Texas: SAGEEP Proceedings,