GEM Systems, Inc.
135 Spy Court
Markham, ON CANADA L3R 5H6
Ph. 905 752 2202 Fax 905 752 220
info@gemsys.ca www.gemsys.ca

Site Characterization for Monitoring Applications Using Overhauser Magnetometer

Dr. Ivan Hrvoic, Mike Wilson and Francisco Lopez (GEM Systems, Inc., Markham, Ontario)

Magnetometers and gradiometers are being used increasingly in monitoring roles (i.e. to monitor atmospheric magnetic disturbances, volcanoes or earthquakes).

The Overhauser magnetometer, with its unique set of features, represents a pillar of modern magnetometry of the Earth's magnetic field. Its sensitivity matches costlier and less convenient cesium magnetometers, for example. The Overhauser magnetometer also offers superior omnidirectional sensors; no dead zones; no heading errors; or warm-up time prior to surveys; wide temperature range of operation (from –40 to 50 degrees Celsius standard and –55 to 60 degrees Celsius optional); rugged and reliable design; and virtually no maintenance during its lifetime. Other advantages include high absolute accuracy, rapid speed of operation (up to 5 readings per second), and exceptionally low power consumption.

Overhauser magnetometers use proton precession signals to measure the magnetic field – but that's where the similarity with the proton precession magnetometer ends.

Overhauser magnetometers were introduced by GEM Systems, Inc. following R&D in the 80's and 90's, and are the standard for magnetic observatories, long term magnetic field monitoring in volcanology, geophysical ground and vehicle borne exploration, and marine exploration.

Operating Principles

The Overhauser effect takes advantage of a quantum physics effect that applies to the hydrogen atom. This effect occurs when a special liquid (containing free, unpaired electrons) is combined with hydrogen atoms and then exposed to secondary polarization from a radio frequency (RF) magnetic field (i.e. generated from a RF source).

RF magnetic fields measurement are "transparent" to the Earth's "DC" magnetic field and the RF frequency is well out of the bandwidth of the precession signal (i.e. they do not contribute noise to the measuring system).

GEM Systems, Inc.
135 Spy Court
Markham, ON CANADA L3R 5H6
Ph. 905 752 2202 Fax 905 752 220
info@gemsys.ca www.gemsys.ca

The unbound electrons in the special liquid transfer their excited state (i.e. energy) to the hydrogen nuclei (i.e. protons). This transfer of energy alters the spin state populations of the protons and polarizes the liquid – just like a proton precession magnetometer – but with much less power and to much greater extent.

The proportionality of the precession frequency and magnetic flux density is perfectly linear, independent of temperature and only slightly affected by shielding effects of hydrogen orbital electrons. The constant of proportionality, γ_p, is known to a high degree of accuracy.

Overhauser magnetometers achieve some 0.01nT/ √Hz noise levels, depending on particulars of design, and they can operate in either pulsed or continuous mode.

Site characterization

One of the prime goals is to ensure that sensors used for measurements locate in magnetically very quiet zones. This can be done with a magnetometer or gradiometer ground survey. The corresponding data is taken from the site of Oaxaca, Mexico where specialists from GEM Systems and University of Mexico installed a SuperGradiometer for earthquake prediction applications.

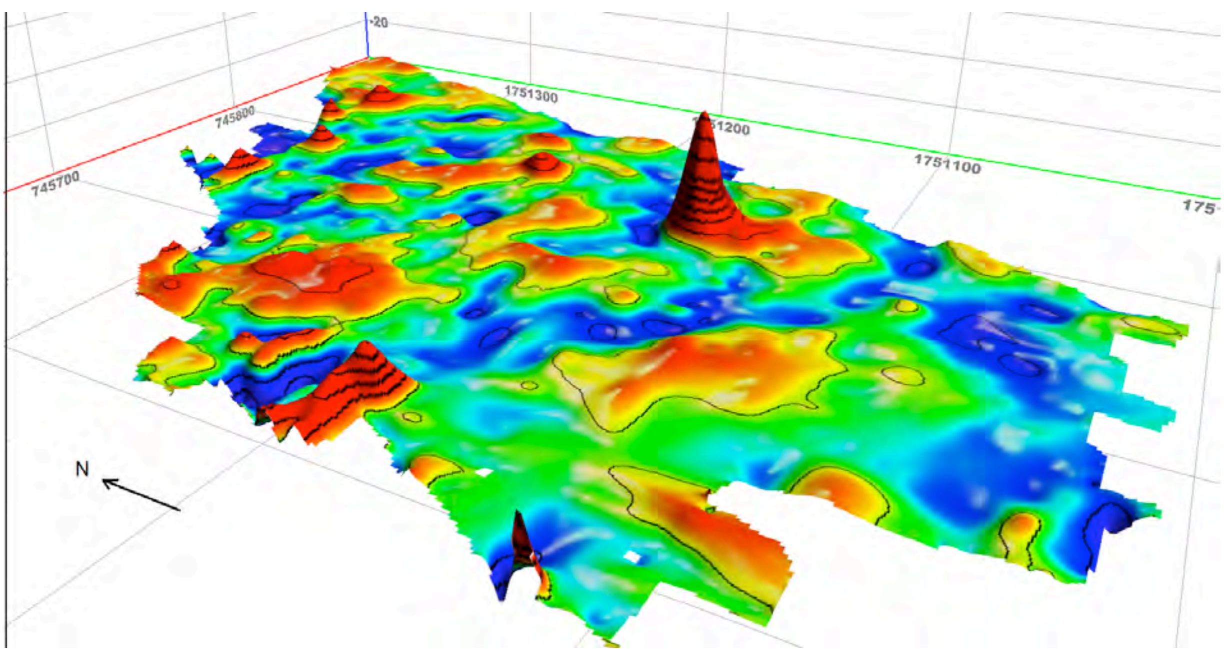
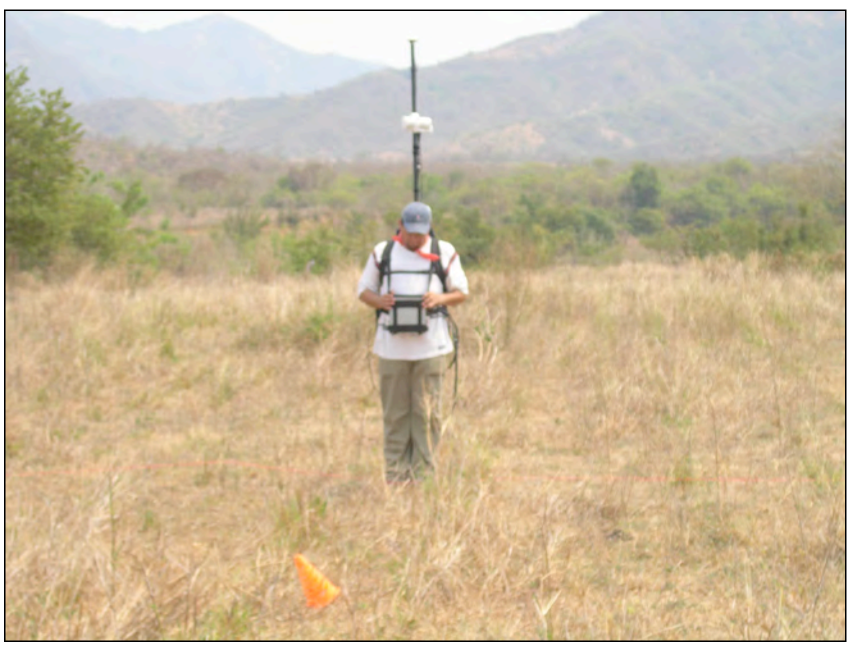


Figure 1: Site characterization map derived from Overhauser gradiometer (0.5 second sampling) for Oaxaca site. The site is characterized by a magnetically active western portion which grades into a peak anomaly to the east. The north-central and southwestern areas are quiet … this is where monitoring sensors were placed.

GEM Systems, Inc.
135 Spy Court
Markham, ON CANADA L3R 5H6
Ph. 905 752 2202 Fax 905 752 220
info@gemsys.ca www.gemsys.ca

Figures 2 and 3: Acquisition of gradiometer data on site in south eastern Mexico.



GEM Systems, Inc.
135 Spy Court
Markham, ON CANADA L3R 5H6
Ph. 905 752 2202 Fax 905 752 220
info@gemsys.ca www.gemsys.ca

Survey Data and Methodology

The survey data represent gradiometer data obtained using a GPS and “Walking” survey mode. The operator simply walked roughly N/S lines for as much of the grid as possible. Where there were obstacles or areas that needed detailing, the operator took a zig-zag route, mostly comprising E/W lines. The image below shows the gradiometer survey path.

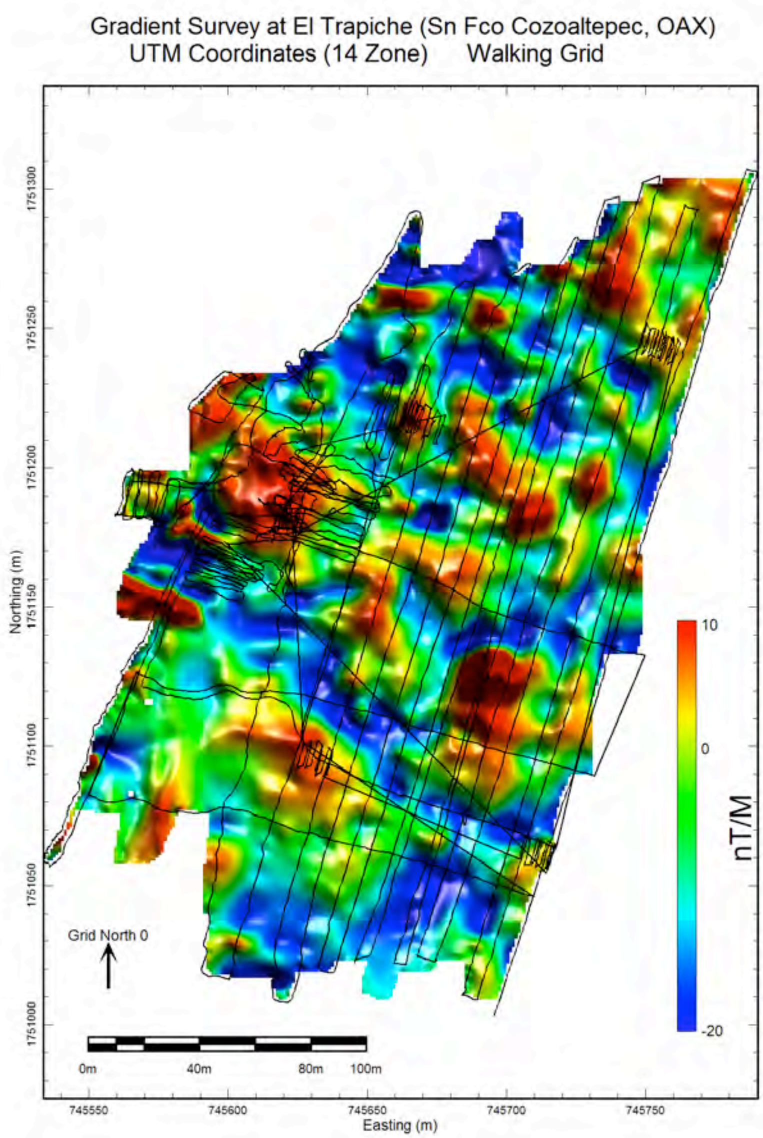


Figure 4. GPS survey path showing extent of coverage and detail areas.

The image below shows the resulting data that were obtained with three crosses indicating the desired location for monitoring sensors (i.e. based on the data). The objective of the survey was to locate sensors in areas with approximately zero gradient; this result shows that the objective was achieved.

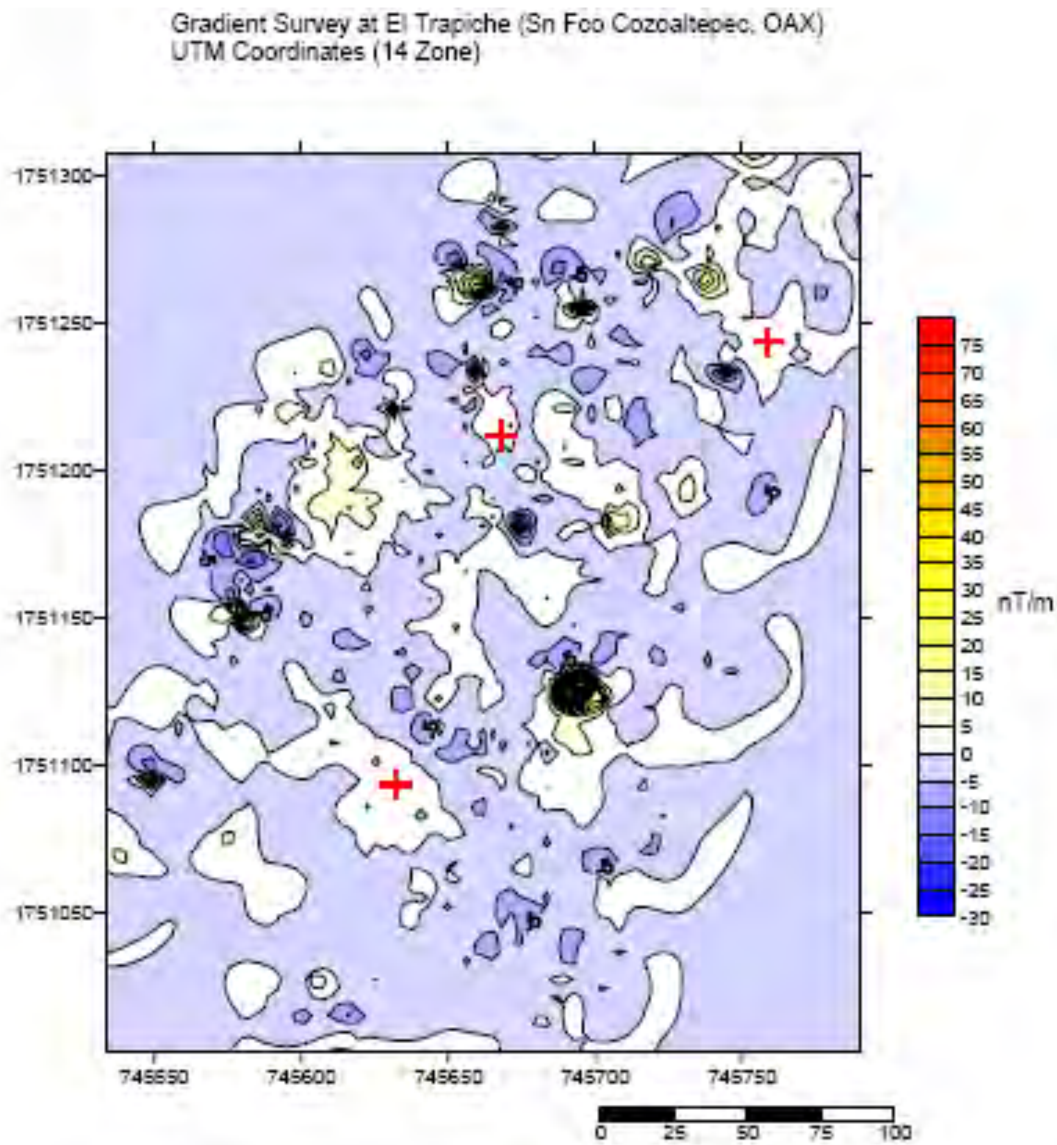


Figure 5: Sensor placement locations. Monitoring sensors were placed at each of the crosses in the figure above.

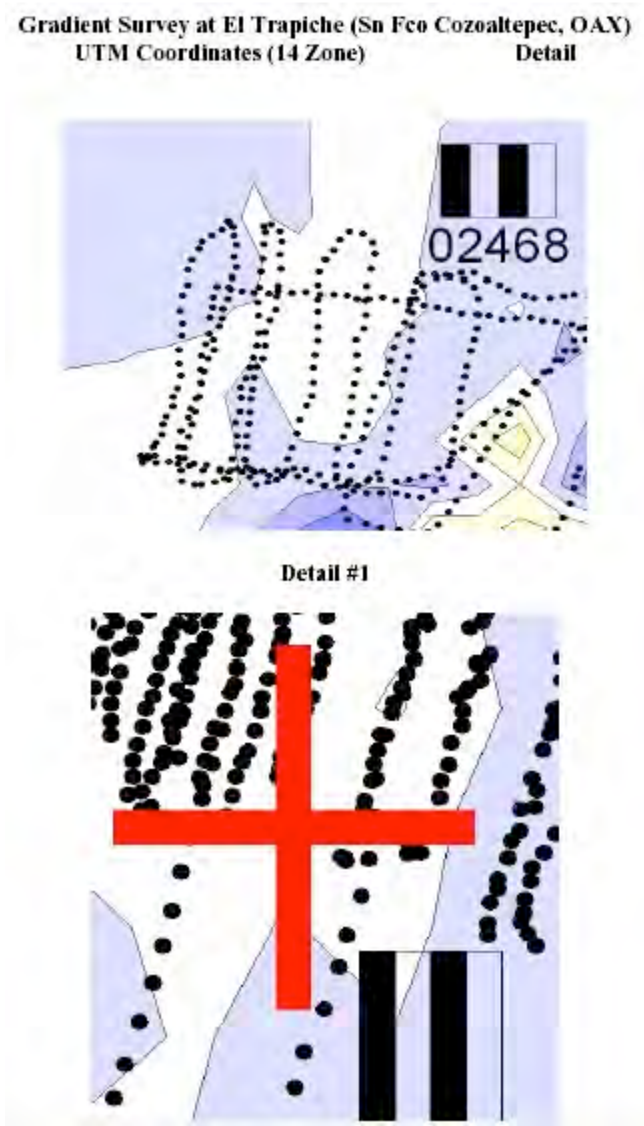


Figure 6: Detail survey path superimposed over gradiometer anomalies.

As shown in Figure 4, detailed data were acquired at several locations in the Oaxaca field site. These detail areas were defined after plotting the main data ... detail areas were to follow up on areas that looked to be magnetically quiet and suitable for installation of monitoring sensors.

Interpretation

There were many anomalies in the area; particularly to the west and central areas of the survey coverage. The general geology is a sedimentary basin with much transported presumably magnetic material (i.e. boulders which are evident at surface). Therefore, it is thought that the magnetic highs are mapping near surface boulders (potentially granite from nearby provenance areas).

All sensors were placed in the quietest areas feasible away from obvious boulders … both visible at surface and from the gradiometer data.

Conclusions

Gradiometric mapping represents an important step in preparing sites for monitoring functions (observatory, volcanoes and earthquakes). With the Overhauser gradiometer, this type of application can be performed very quickly and accurately using GPS functions available to the operator. Ultimately, this mapping led to ideal positioning of sensors within the area of operation determined by the customer on this project.