

Airborne Surveying for

Oil & Gas Exploration



MAGNETICS/ISMAP

GAMMASENSE

GRAVITY

**PASSIVE AIRBORNE
TRANSIENT PULSE EM**

HYPER SPECTRAL

- Detect & characterize offshore oil seeps
- Locate sedimentary basins
- Delineate basin boundaries & structure
- Infer location of thickest sedimentary section
- Detect intrasedimentary "micro-magnetic" anomalies
- Detect characteristic radiation patterns
- Cost effectively place seismic surveys



AIRBORNE GEOPHYSICAL SURVEYS
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AIRBORNE GRAVITY & MAGNETIC SURVEYS

An Airborne Gravity Survey is conducted with a stabilized gravity meter installed on a fixed-wing aircraft, to acquire data over a given area concerning the earth's gravity fields. The data acquired on such a survey may be used to:

- infer the location of the thickest sedimentary section
- delineate basin outlines and boundaries
- define plate tectonic structures
- locate and detail map sedimentary basins for oil and gas
- assisting seismic survey planning, processing and model constraint
- often map structures within the basin

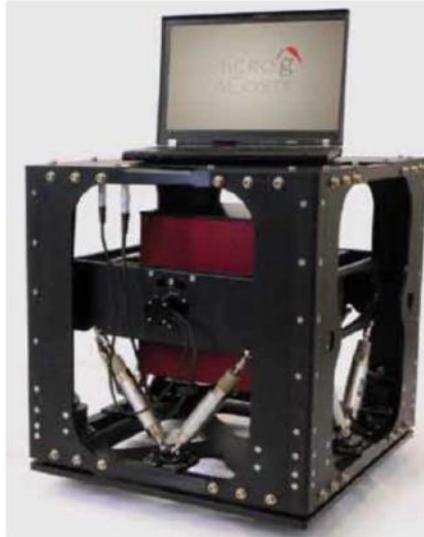
Airborne Gravity surveys are usually conducted in association with a magnetic survey, which provides a very reliable and relatively precise (typically 5 percent or less of the depth below the flight level) method of determining the depth of the sedimentary basin. Geological targets detectable by McPhar's airborne gravity system are in the 2- to 3-km half-wavelength range. Aeromagnetic and gravity data provide information about the main structural trends, including fault patterns and sedimentary basins that may contain a suitable suite of source, reservoir and seal rocks.

An airborne magnetometer, typically a Scintrex CS-3 airborne cesium magnetometer with a real-time digital compensator, is installed on the aircraft in a tail-stinger, providing compensated magnetic data with a resolution of typically 0.001 nT (1pT) at 10 Hz sample rate. Faster sample rates up to 100 Hz are possible.



Scintrex CS-3 cesium magnetometer

A geodetic quality, dual-frequency GPS receiver and GPS base station are used for aircraft navigation and data positioning. An autopilot aids the navigation task. Data acquisition is accomplished using a ruggedized PC-based data acquisition system. Other ancillary instruments include radar and barometric altimeters, power supplies, etc.



TAGS-6 Dynamic Gravity Meter



GT-2A Airborne Gravity Meter

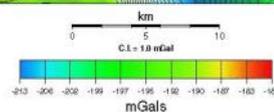
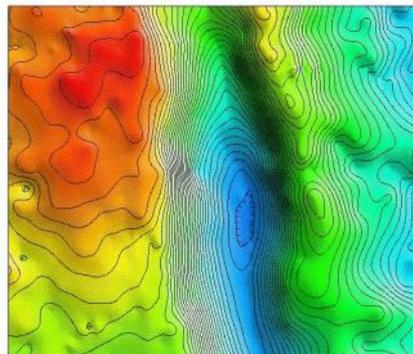
GRAVITY METERS

McPhar uses both the Micro-G Lacoste TAGS-6 dynamic gravity meter and the Canadian Micro Gravity GT-2A airborne gravity meter to undertake airborne gravity surveys. Both of these gravity meters are state-of-the-art, delivering high-quality consistent gravity data when operated under similar climatic and conditions.

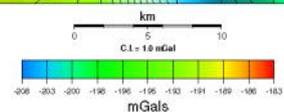
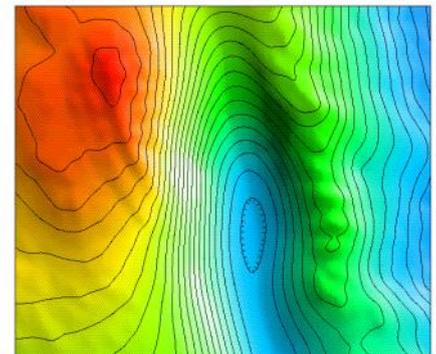
The TAGS-6 is designed specifically for dynamic operations. It incorporates a time-tested, low-drift, zero-length-spring gravity sensor mounted on a gyro-stabilized gimbal platform. The sensor has a dynamic range of $\pm 500,000$ milliGals, a resolution of 0.01 milliGals, static repeatability of 0.02 milliGals and an accuracy of 0.6 milliGals or better. Its data recording rate is 20Hz.

The GT-2A is a vertical sensor, GPS-INS scalar gravimeter with a Schuler-tuned three-axis inertial platform. It is designed specifically for airborne operations. Data is acquired through short periods of accelerometer saturation in extreme turbulence by the automatic application of a reduced-order Kalman filter, enabling platform misalignment to be computed and hence controlled. This feature, combined with the two dynamic ranges, provides an extremely high tolerance to turbulence. The sensor has a dynamic range of 1,000,000 milliGals, a resolution of 0.01 milliGals, and an accuracy of 0.5 milliGals. Its recording rate is 18.5 Hz.

LAND GRAVITY - BOUGUER



AIRBORNE GRAVITY - BOUGUER



The two Bouguer images above show a comparison of land and airborne gravity data acquired over the same survey area - on the left is the land gravity Bouguer map and on the right is the airborne gravity Bouguer map.

HIGH-RESOLUTION AIRBORNE MAGNETIC SURVEYS

A High-Resolution Airborne Magnetic survey (**HRAM**) is an excellent tool for mapping geological structure in a wide range of tectonic settings including new and mature basins in both onshore and offshore environments. **HRAM** involves the use of high-sensitivity, high-resolution airborne magnetics to resolve very low-amplitude (micro-magnetic) anomalies (1nT to 5nT) originating from structures within the essentially non-magnetic sedimentary column, as well as high amplitude features from the crystalline basement.

Some of the units and structures that can cause observable magnetic responses in a sedimentary basin include:

- Pre-existing flood basalts
- Magnetic basement highs formed as a result of intrusion, erosion or structuring
- Detrital or chemically precipitated magnetic minerals in paleo-channels
- Magnetic basements flanking a sedimentary basin
- Mid-basin crustal intrusions
- Magnetic sedimentary units
- Magnetic minerals precipitated in a fault plane
- Intrasedimentary volcanics
- Oceanic crusts
- Igneous sills
- Salt diapirs
- Buried volcanic centres
- Diagenetic magnetite or pyrrhotite formed by hydrocarbon plumes
- Igneous dykes
- Detrital magnetic minerals in bar and fan systems
- Intrabasement magnetic bodies

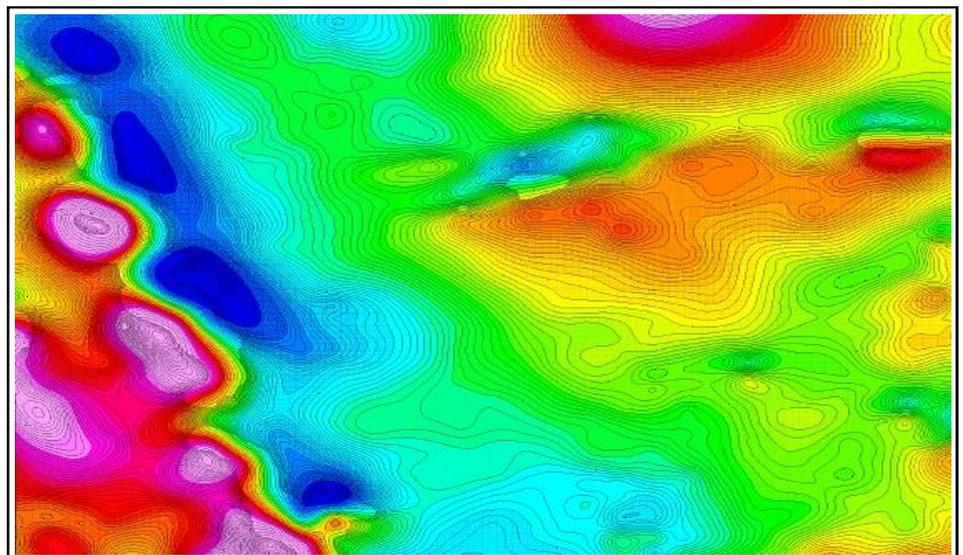
The image to the right is of a HRAM survey conducted in North Africa to map both intrasedimentary anomalies and the basement. The area (approximately 15,000 km² in extent) was flown with a grid of lines 500m x 5km apart, at a survey height of 100 metres draped above the surface.

The benefits of **HRAM** are realized by the most modern instrumentation, highly efficient survey platforms and the state-of-the-art data acquisition and processing techniques we use, which include 3-D drape flying, tie-line leveling, micro-leveling, equivalent source corrections where appropriate, and signal enhancement filtering.

Aircraft manoeuvre noise during a **HRAM** survey, of necessity, is very small. Using the "Figure-of-Merit" (FOM) technique to measure manoeuvre noise, all our aircraft are typically less than 1.0 nT. In addition, the use of differential GPS for navigation and positioning allows micro-magnetic anomalies to be determined to a positional accuracy of about +/- 1 meter.



These aircraft are two of the fleet used by McPhar to acquire airborne geophysical data. The top image is of a Piper PA31 Navajo aircraft featuring an extended tail-boom for the magnetometer and a PAC-750 XSTOL aircraft equipped with an extended tail-boom and wingtip pods for the magnetometers.

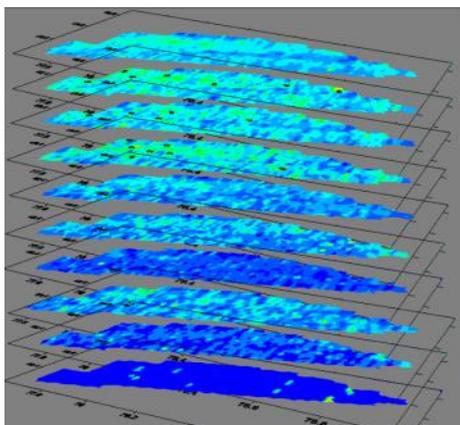


BASEMENT MAGNETIC MAPPING

It is generally assumed that the basement beneath the sediments of interest is generally of crystalline rock. These crystalline rocks have varying amounts of magnetite, generally in greater concentrations than the overlying sediments. This high concentration of magnetite allows the mapping of the basement topography with good accuracy using the magnetic method. Also, because the basement is generally of higher density than the sediments (limestones, marble, some shales and slates, particularly dolomite are an exception) it may be successfully mapped using the airborne magnetics and gravity method.

PASSIVE AIRBORNE TRANSIENT PULSE EM SURVEYS

“Airborne Measurement of Transient Pulses Locates Hydrocarbon Reservoirs” by authors LeSchack & Jackson (Search and Discovery Article #40204 (2006) describes a reliable, cost-effective, environmentally friendly remote sensing tool for finding oil and gas, both on-shore and offshore. Recently, major improvements have been made to the sensing system to automate the efficient collection of these airborne data, enabling us now to make estimates not only of the reservoir’s horizontal location, but also of the depth at which they would likely be encountered.



The AEM-PTP system spectrally decomposes recorded transient energy to provide an indication of anomaly depth

Passive Airborne Transient Pulse Electromagnetic (AEM-PTP) surveys are based on the following theory: an inherent passive electromagnetic field is present in the earth that can be sensed at the earth’s surface and from low-flying aircraft. Vertical components of this field contain transient random impulses of energy varying across a wide frequency range, including in the audio range.

It is widely believed that the impulses are related to a combination of the effects of solar plasmas, lightning activity around the world that produces electronic disturbances called “sprites” and “whistlers,” seismo-electric potentials within the earth, and REDOX cells generated by vertical hydrocarbon micro-seepage from reservoirs into the surrounding lithology (Boissonnas and Leonardon, 1948; Cummer, 1997; Garcia and Jones, 2002; Labson, et al., 1985; Pirson, 1969; Vozoff, 1972; Ward, 1959).

Although a “unifying theory” has yet to be postulated, empirical evidence points to Airborne Transient Pulse Surveys as being a most valuable recon-

The current AEM-PTP system was developed in 2009, fully digitized, largely based upon the methods described by Mr. Helms, US Patent 5,148,110. This method closely resembles the AFMAG method of SH Ward 1959. This survey tool measures disturbances in the earth’s passive low-frequency EM fields resulting from discontinuities within the earth such as high concentrations of minerals and oil & gas reservoirs at depth, where depth is believed to be a function of the frequency.

Typical AEM-PTP surveys are flown at an altitude of 100m to 120m above ground or water surface, and at a speed of between 90 and 100 knots. Both light planes and helicopters are used as survey platforms. The light-weight portable sensing equipment and antenna are carried entirely within the aircraft. It does not matter if the airframe is made of aluminum or not; transient pulse signals are not attenuated either way.



The AEM-PTP system hardware

The passive EM measurement uses a single, compact E-field antenna, carried on board the aircraft, to receive the transient field. It uses a built-in type analog to digital digitizer. The digitized signal is filtered into (10) 200 Hz low frequency bands in the time domain, using a digital signal processing software package developed for use on a portable windows based computer.

Recent drilling results in Kentucky, USA using the AEM-PTP technology resulted in 8 productive wells out of the 11 wells drilled.

Cultural artifacts on the ground, wells, pipelines, utility lines, etc., have no effect on data quality. Flight line spacing is determined based on the size of the expected reservoirs.

The AEM-PTP survey technology works not only onshore but offshore also. Surveys have been flown over offshore areas of New Zealand’s Tasman Sea, and the North Sea, which was ice covered at the northern extremity of the survey area. Ice cover on the water did not affect the data quality.

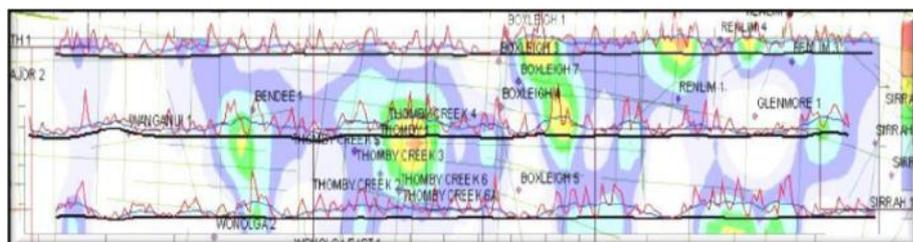


Image above shows high-levels of transient activity associated with hydrocarbon accumulations

WHAT ARE TRANSIENT PULSES?

- Transient pulses can be described as large pulses of energy that rise well above the long-term average of the background energy.
- Transient pulses occur naturally in the Earth’s atmosphere and within the subsurface.
- NASA researchers for the space shuttle program demonstrated that lightning discharges are occurring globally at a rate of 80 to 100 strikes per second. The energy from a lightning discharge is about 200 kWh and can be measured over very long distances.
- Transients from both the atmosphere and subsurface excite portions of the REDOX cell, creating a measurable and localized increase in electromagnetic (EM) transient energy
- More than 130 surveys have been flown worldwide and so far, have contributed to 40 known wells drilled with 80% of these encountering hydrocarbons.

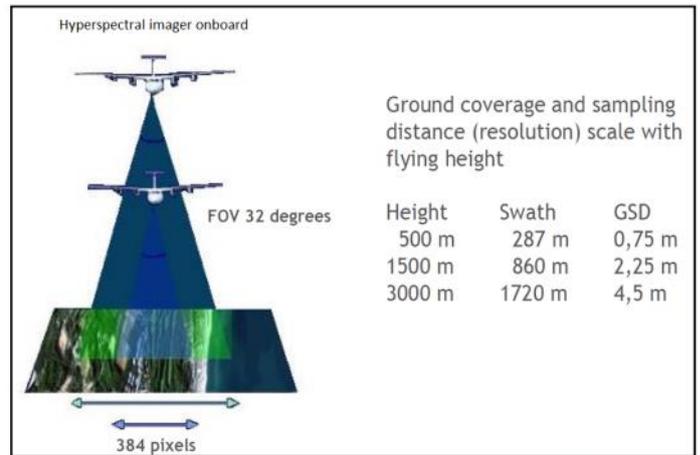
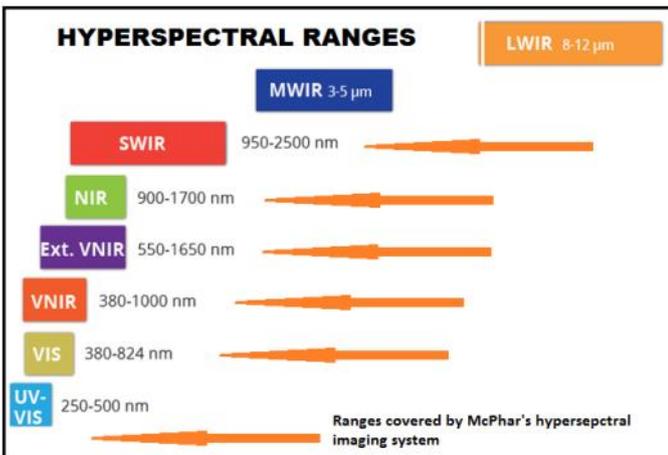
HYPERSENSPECTRAL IMAGING SURVEYS

Airborne Hyperspectral Imaging is a very helpful tool complementing established oil & gas exploration techniques. It delivers high-resolution data and facilitates the identification and classification of offshore oil seeps and the detection of micro-seepage through hydrocarbon-induced surface manifestations. Airborne hyperspectral imaging is being used by major oil companies and governments for exploration and reconnaissance worldwide.

McPhar's hyperspectral sensor is an airborne system capable of recording up to 620 individually selected channels of spectral data in the range of 380nm to 2,500nm (Optical Bands). This is equivalent to having 620 cameras simultaneously recording different parts of the visual, near infra-red and short-wave parts of the spectrum.

Hyperspectral measurements make it possible to derive a continuous spectrum for each image cell. Hyperspectral sensors collect information as a set of 'images'. These 'images' are then combined and formed into a three-dimensional hyperspectral data cube for processing and analysis. These complex sensors were developed based on the convergence of two related technologies - spectroscopy and the remote imaging.

Hyperspectral imaging does not just measure each pixel in the image, but also measures the reflection, emission and absorption of electromagnetic radiation. It provides a unique spectral signature for every pixel, which can be used by processing techniques to identify and discriminate materials



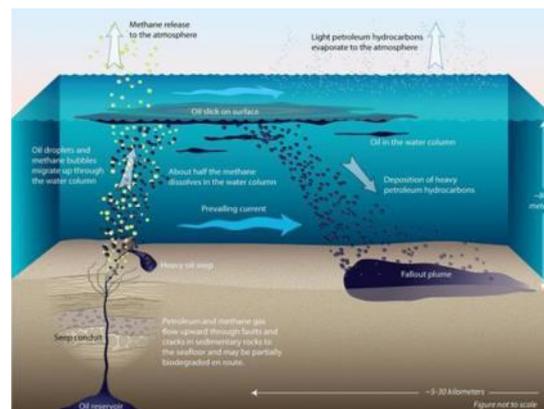
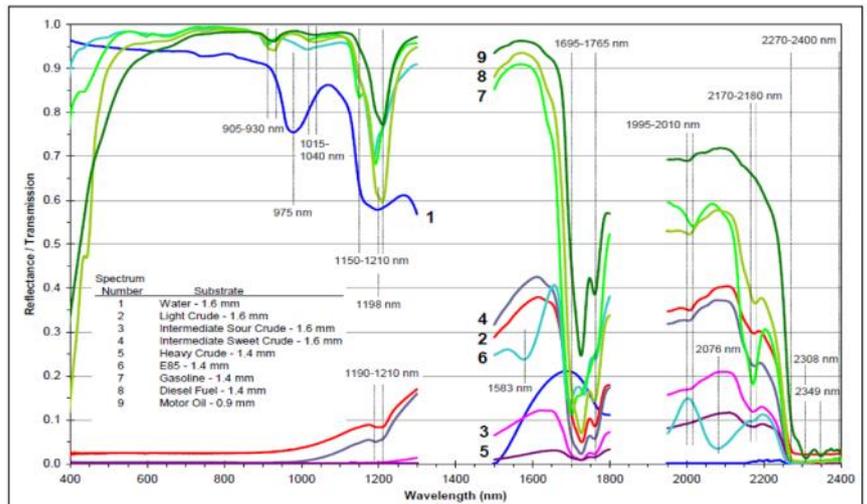
MAPPING OFFSHORE OIL SEEPS

Crude oil seeps naturally from geologic strata beneath the seafloor into water. They contribute the highest amount of oil to the marine environment, accounting for 46 per cent of the annual load to the world's oceans (NRC 2003).

There are four main oil characteristics that should be remotely retrieved for operational purposes: oil seep position, volume of oil contained in the seep, the oil type and a forecast of the drift trajectory.

Hyperspectral sensors can detect the seep position, retrieve information on the nature of the seep, give indications on oil type (crude/light) and thickness, detect submerged oil seeps, emulsions and oil-impacted soils as a consequence of beaching.

To acquire data, the Hyperspectral sensor will be flown in profile mode in conjunction with the other sensors on board the aircraft and at the same line spacing (2 to 4 Km) at straight and level flight at 100 to 200 metres above the sea. The altitude at which the survey will be flown will be determined after the survey aircraft arrives at the base of operations and performs several weather test flights over the survey area.



Above: Hyperspectral sensors have the potential to detect the seep position, to retrieve information on the nature of the seep, to give indications on oil type (crude/light) and thickness

Left: Crude oil seeps naturally from geologic strata beneath the seafloor into water.

AIRBORNE GAMMASENSE SURVEYS

The objective of surveying with a multi-channel, gamma-ray spectrometer system and a large volume gamma-ray sensor is to detect subtle characteristic radiation patterns as indicators of subsurface hydrocarbon accumulations over petroliferous terrane. ISMAP and GammaSense techniques may be applied independently of each other, however, it is practical and cost effective to combine them in one multi-sensor, multi-method survey.

Hydrocarbon anomalies can be qualitatively and directly identified from airborne radiometric measurements. It has been repeatedly observed that the subtle anomalous patterns of radiation flux detected over petroleum basins exists over subsurface hydrocarbon accumulations.

HOW DOES GAMMASENSE WORK?

The earth's crust contains uranium, thorium, and potassium. These primordial radionuclides were randomly laid down during the planet's formation. They and their progeny emit highly energetic gamma-rays in the course of radioactive decay. As their half-lives approximate the age of the earth, it is to be expected that all three elements contribute measurably to our natural radiation background.

Hundreds of millions of years after the laying down of the radionuclides, hydrocarbon deposits formed. Uranium is the most mobile of the three radionuclides. Subsurface hydrocarbons, however, through recognized geochemical processes, alters uranium's mobility above hydrocarbon deposits (in its fully oxidized state, the uranium ion is water-soluble, highly mobile, and easily transported by ground water, however, on entering an environment containing organic matter, the ion is reduced becoming insoluble and immobile).

Potassium also shows similar characteristic mobility changes. As a consequence, the gamma radiation flux detected over hydrocarbon deposits is noticeably altered by the contributions from uranium and potassium. In addition, the random radiation pattern normally observed has now changed into a characteristic radiation pattern, thereby creating a readily identifiable pathfinder in potentially productive basins.

If you wish to know more about the GammaSense method, please contact us. A bibliography of Technical Papers and Case Histories is available (in some instances we can provide a copy of some papers).



An airborne Gammaseense system, comprised of 33.6 litres of NaI(Tl) detectors installed in a survey aircraft.

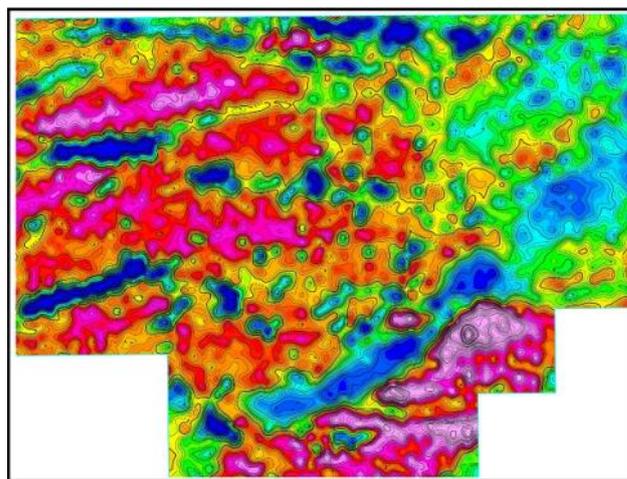


Image of Gammaseense data acquired from a survey in USA.

Q.C, DATA PROCESSING & INTERPRETATION

McPhar undertakes QC and preliminary data processing in the field at the survey base. For this purpose all our airborne systems are mobilized with a geophysicist and a PC-based data processing system to support them. The Field Data Verification Workstation (FWS), as this system is known, can process airborne gravity, EM, magnetic and radiometric data, and produce plots and maps in full-colour, often within hours of the survey flight ending.

Final data processing is undertaken at our Data Processing Centre in Mossel Bay, South Africa, which is staffed by very experienced geoscientists and equipped with a state-of-the-art network of computers, scanners, plotters and other hardware. Processing software that we use includes Geosoft's MONTAJ, INTREPID airborne data processing software and in-house developed programs and routines.

The interpretation of geophysical results into meaningful geological parameters is the prime function of any of our interpreters. The manipulation of geophysical data is only a means to an end, and the final product of the interpretation is the compilation of a series of maps showing interpreted geological parameters. We bring many techniques to bear on the an interpretation project in order to determine depths to causative sources, to delineate discontinuities and boundaries and to draw conclusions regarding the geological structure beneath the survey.



Our facility in Mossel Bay, South Africa. It includes hangarage for up to 5 aircraft as well as administration offices, engineering and aircraft maintenance workshops and a data processing centre