Gravity in the 21st century: Over land, under sea, and through time

By Jennifer Hare, Micro-g LaCoste Inc

The unveiling of the new Lacoste & Romberg – Scintrex (LRS) INO sea-floor gravity meter highlights the significant re-emergence of rapid, reliable, gravimetric methods for exploration in recent years. Across the petroleum industry, gravity is being used for widespread applications in a wealth of environments, including land, sea, air, sea-floor, and borehole, and across both spatial and time dimensions.

The gravity method has been used for many decades to map lateral density changes associated with petroleum and other natural resource accumulations in the earth. It uses the universal, "free", environmentally-friendly energy source (the earth's gravity field), and touts a direct relationship to earth properties (density) which is the exploration goal.

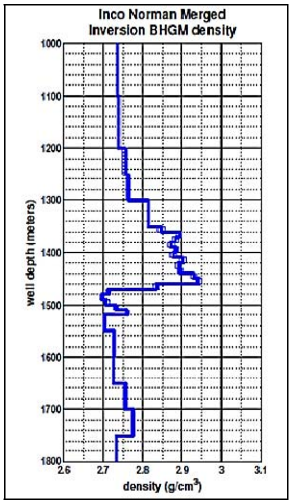
Gravity and seismic data are very complimentary and provide independent constraints on both structure and reservoir properties. While gravity provides limited depth resolution compared to seismic, it has excellent lateral resolution and can now be used in boreholes as well, providing much needed vertical sampling for improved imaging and bulk density estimates.

CG5-Autograv™

The CG-5 Autograv™ is the industry standard in portable, field-ruggedized, relative land gravimeters. It is being used today to collect high-resolution data in a rapid, robust, automated survey mode. Other specialized instruments such as the INO sea-floor gravity meter, Gravilog borehole gravity meter, and the rugged A-10 portable absolute gravity meter can acquire part per billion (microGal) resolution data in environments that were considered inaccessible as recently as ten years ago. These new instruments can be operated in extreme environments - from arctic ice to desert terrains, on the sea-floor in thousands of meters of water, and even in small diameter or significantly deviated boreholes.

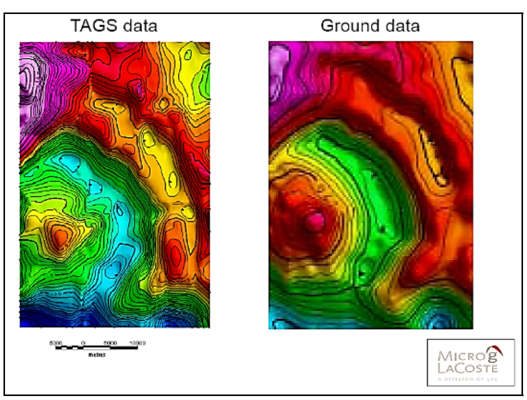
INO Sea-floor Gravity Meter

Gravilog Borehole Gravity Survey



Gravilog Bulk Density Log

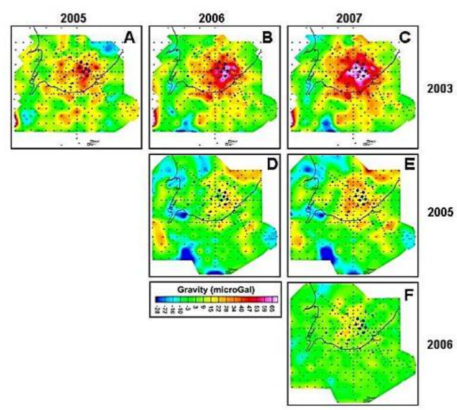
In 1965 LaCoste & Romberg introduced the world's first dynamically stabilized platform gravity meter. These meters revolutionized the geophysics world by making it possible, for the first time, to take highly accurate gravity measurements from a moving ship or aircraft. Since then, hundreds of these instruments have been sailed or flown around the world, logging millions of hours of gravity data. In 2005 LaCoste and Romberg moved from Texas to Colorado and merged with Micro-g Solutions to form Micro-g LaCoste. Developments continued and the Turnkey Airborne Gravity System (TAGS) and the Air/Sea II Gravity System are the upgraded descendants of the original L&R platform systems. Improvements in dynamic compensation and digital data acquisition have resulted in the remarkable ability to resolve sub-milliGal resolution gravity from the total acceleration on these moving platforms.



TAGS airborne gravity data (left) and legacy ground gravity survey data (right)

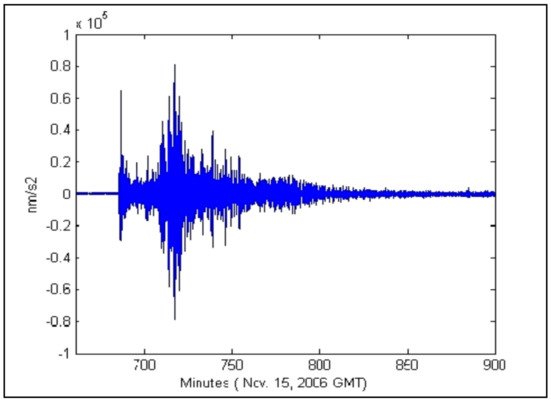
Modern gravity instruments are able to provide accurate measurement of the earth's gravitational field to 1 part per billion, or 1 microGal. Instruments are either based on zero-length spring or fused quartz technologies (*relative* gravimeters) or laser interferometric measurements of a falling mass (*absolute* gravimeters). In fact, the Micro-g LaCoste FG-5 absolute gravity meter has replaced the pendulum as the official standard for gravity measurements worldwide.

The extreme precisions of modern gravity instruments and robust engineering designs have allowed high-resolution gravity methods to migrate from the laboratory to field environments. Consequently, in recent years, the method has been successful for 4-D, or time-lapse, monitoring of extremely subtle reservoir changes through time, for production, gas sequestration (storage), and enhanced hydrocarbon recovery. Comparison of density models from repeated gravity surveys provide map images of subtle, year-to-year changes in reservoir fluids.



Time-difference matrix of gravity signals from Prudhoe Bay, Alaska

Often overlooked is the fact that the gravitational field is time variable with infinite bandwidth. Traditionally, gravity survey methods correct for time-variable factors in order to provide a 2- or 3-D spatial image- essentially providing a 'snapshot in time' of lateral density variations in the earth. However, gravity time-series recordings can also be used for monitoring and other applications. In the past decade, there has been a flurry of research related to ocean waves, earthquakes, volcanic and tectonic tremors, and other sources of small magnitude, naturally-occurring, ambient earth seismicity. Studies of these phenomena, of course, have potentially huge implications to society for natural hazard prediction. Both gravity meters and broadband seismometers are highly sensitive, low-frequency sensors that can record the time signals from these subtle, but consequential phenomena. In the petroleum industry, passive seismic methods utilize time signals recorded on broadband instruments for both exploration and monitoring.



Time-series recording of an earthquake on a gPhone gravity meter

With the resurgence of potential field methods in the past decade, including high-resolution gravimetry with improved instruments and field versatility, petroleum applications for these methods are becoming more and more focused. Higher resolution information is available now for smaller scale problems, in addition to the still extremely cost-effective, traditional capabilities for regional mapping. The challenges will be to find the best methods for integrating data from a variety of different sources which have different parameters, dimensionality, and resolution in order to best image and monitor hydrocarbon resources.

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