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Airborne Full Tensor Gradiometry: A Method for Defining the Base and Geometry of Salt Bodies in relation to hydrocarbon storage

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Abstract

Salt caverns are becoming increasingly popular to store natural gas and for waste disposal. It is important to fully understand the geology surrounding the salt body in question and the geometry of the salt body itself to maximize capacity and to minimize potential for seeps and product loss. Increasing pressure from both regulatory and environmental groups makes it imperative that storage facility planners and operators use all scientific data available to them to ensure efficient and safe containment of the product in the facility. Most salt bodies considered for storage have some existing seismic data and well data collected over them. Interpretation of salt body geometry and sub-salt structures can be extremely difficult. Factors affecting salt imaging are steep dips of the edges of salt bodies and rugose top of salt, which absorb or redirect seismic energy, resulting in poor seismic imaging. Other difficulties include salt structures with embedded sediments, as well as multiples and velocity insensitivity. Sediment velocity floods, salt velocity floods and Pre Stack Depth Migrations (PSDM's) are used in an attempt to overcome the salt ambiguity. The use of Full Tensor Gradient (FTG) data in conjunction with seismic data has proven to be an extremely effective and cost efficient method of determining salt body geometry as well as salt overhangs and the base of detached salt bodies. Until 2002, gradiometry data was collected via a ship-borne system and thus available only in offshore areas. In 2002 an airborne system was successfully tested and data has been commercially collected over onshore areas in the US, Canada, and Africa.

Full Tensor Gradient data represents the first derivative of the gravity (vector) field, and describes the spatial rate of change (of the vector field components) in all three dimensions. Gradiometer data differs in many aspects from conventional high-resolution gravity data because of increased

bandwidth and retention of high frequency short wavelength signal (generated by shallow to intermediate geologic features), which results in much greater resolution. A geologic model is constructed comprised of depth layers and associated density grids. A 3-D forward gravity gradient model is then calculated and its response subtracted from the measured FTG data. The resulting difference maps show residual anomalies; areas where mass (density X volume) needs to be increased (positive anomaly) or decreased (negative anomaly) within the geologic model. The horizon is modified in an iterative process until the difference between the calculated and measured data is no more than 5 Eötvös (1 Eötvös = 0.1 milligal per kilometer).

In two recent Green Canyon projects, the bases and geometry of the salt bodies could not be determined by seismic data alone. In the first example, FTG data was able to determine an accurate base of salt, denote suture zones and salt keels as well as define a sub-salt sand fairway, which was subsequently verified via seismic and well data. The FTG interpretation helped drive the PSDM resulting in the need for fewer iterations. In the second example, FTG-enhanced seismic analysis indicated a salt thickness three times the original seismic interpretation. The well was drilled and confirmed the FTG-enhanced interpretation to within 400ft (122m).

Keywords: Gravity, Gradiometry, Seismic, Salt, Models, Methods