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GGI Reveals Key Insights In Shale Plays

By Phill Houghton

HOUSTON–The rise of unconventional natural gas resources, particularly shale gas, is starting to change the overall supply-and-demand energy outlook, certainly in North America and perhaps worldwide.

With the U.S. Federal Energy Regulatory Commission estimating that there are 742 trillion cubic feet of technically recoverable shale gas resources in the United States from at least 22 major shale plays, and with Europe, the Middle East, Africa and Asia all beginning to tap into their unconventional resources, the focus has moved to how operators can capture and exploit this resource as efficiently and cost effectively as possible.

While there are a number of significant benefits to shale gas exploration, such as speed to market, accessibility and the relatively low costs compared with other methods, there are a number of specific challenges as well.

Previously the domain of engineers, unconventional exploration increasingly is looking to geophysics and 3-D seismic, particularly in regard to assisting in delineating "sweet spot" areas, providing a greater understanding of the subsurface and helping deliver increased value from the plays.

While 3-D seismic technologies are capable of generating highly-accurate structural models, covering larger areas with expensive 3-D seismic is not always possible, especially in a challenging fiscal climate with lower natural gas prices. Operators still require additional geological data to make informed investment decisions; information such as identifying zones where there is a high probability of structural complexity and other geological features that can impact field development. Therefore, the drivers are high to look at cost-effective technologies such as nonseismic exploration methods as part of an overall exploration strategy.

To maximize each well, operators need to remain in contact with the shale for as long as possible when drilling and carrying out multistage hydraulic fracturing operations. If the operator punches through a fault, he effectively loses the well. Furthermore, if the well breaks out of the shale into bounding sandstone, for example, with increased porosity and connectivity, it is highly likely that the fracture fluid will escape, reducing pressure and ultimately leading to an abandoned well.

Consequently, the need to identify faults–which have the potential to divert hydraulic fracturing–is critical to shale gas exploration and production, with successful fracturing dependent on the ability to inject high-pressure proppant and fluid into the shale unit. It is more important than ever for operators to understand the structural complexity of shale gas fields and the presence of faults, and linked to this, be able to identify which areas of the field are more or less structurally complex than others.

The second key challenge in shale gas fields today is cost and risk. Companies involved in unconventional resources tend to be independent operators who have a lower resource and risk threshold than the majors and need to squeeze every cent out of their exploration and production budgets. Few have the resources to expend vast amounts of money on 3-D seismic over large areas and need to better target their surveys on the key areas identified.

Finally, there is the issue of access. Many shale gas fields are in environmentally sensitive and sometimes even urban areas where deploying large-scale seismic equipment is not always feasible. With the current sensitivities toward exploration, drilling and development technologies, a noninvasive exploration technology is likely to be of significant value.

Gravity Gradiometry Imaging

It is against this challenging backdrop that the industry has been exploring the possible applications of gravity gradiometry imaging (GGI) along with 2-D seismic in shale gas fields. We believe that many of the challenges operators face in exploring and developing these plays can be addressed directly through GGI.

GGI is of significant interest to shale gas operators in two key areas. First, the technology itself and GGI's ability to generate accurate structural models can help identify faults and provide a greater overall understanding of the 3-D earth model. If the resulting information is then married with finite element analysis (FEA), the models can be used to calculate zones where there is higher and lesser probabilities of structural complexity to help determine exploration and production strategies.

Second, GGI can help address the problems of cost and accessibility, where hundreds of miles of shale gas prospects can be surveyed quickly, efficiently and cost effectively without the need for large-scale and invasive seismic equipment. While average exploration costs with GGI come out at about $2.00 an acre, a seismic survey can cost $150 an acre or more.

Looking at the technology in more

FIGURE 1

Density Interface Caused by Baldonnel and Debolt Formations (Montney Shale Play)

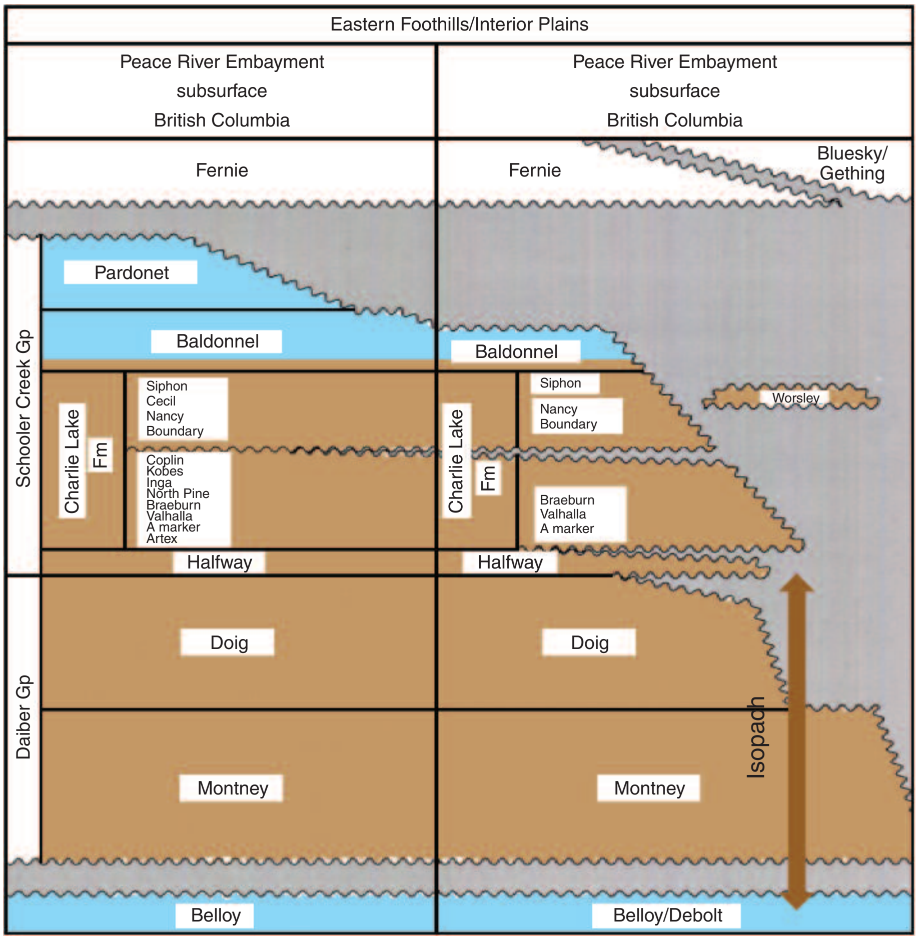
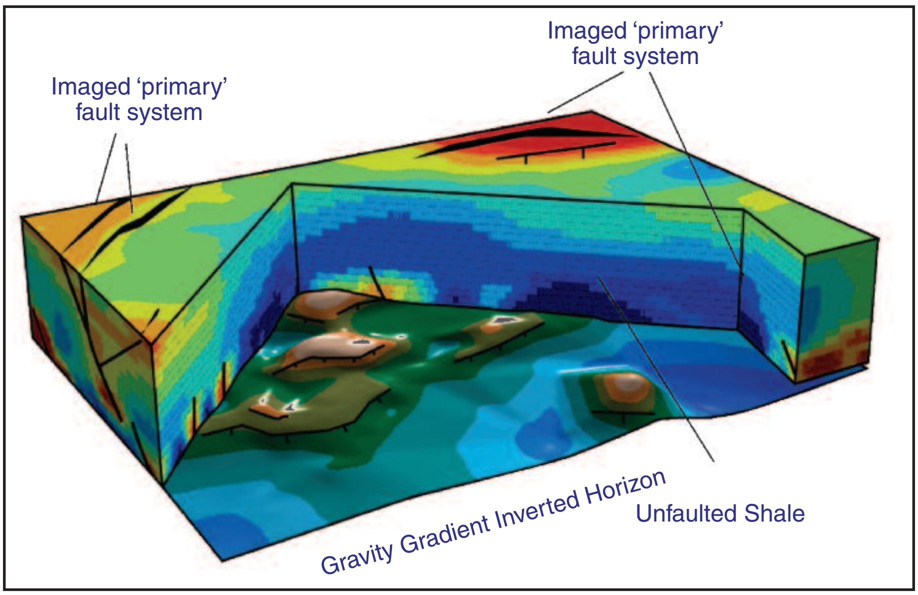


FIGURE 2

Example of Structural Complexity Volume



detail, gravity gradiometry imaging has significant applications in unconventional resources. First are the traditional benefits of GGI. These include the high-resolution data and wider bandwidth compared with conventional gravity data, which coupled with a strong signal-to-noise ratio, make GGI highly effective in modeling structural geologies. By precisely positioning subsurface density contrasts, gravity gradiometry imaging can target geological settings accurately, derive basement structure maps, and provide input to the structural definition of overlying sedimentary sections/horizons.

In addition, the ability for GGI to act as an intelligent 3-D geologic interpolator allows the interpreter to develop structural models outside the plane of 2-D seismic acquisition. This is a significant benefit in early-stage shale gas exploration and where 3-D seismic access is restricted. Here, seismic lines–often several miles apart–can be integrated, leading to the improved interpretation of faults. GGI's ability to accurately track faults and look at the geology "sideways" when developing its structural models is of high value to shale gas operators.

Finally, the relatively low density of salt in comparison with typical host material is also an ideal target for high-resolution gravity gradiometry imaging, where the density contrast between salt and the surrounding rock can be mapped accurately.

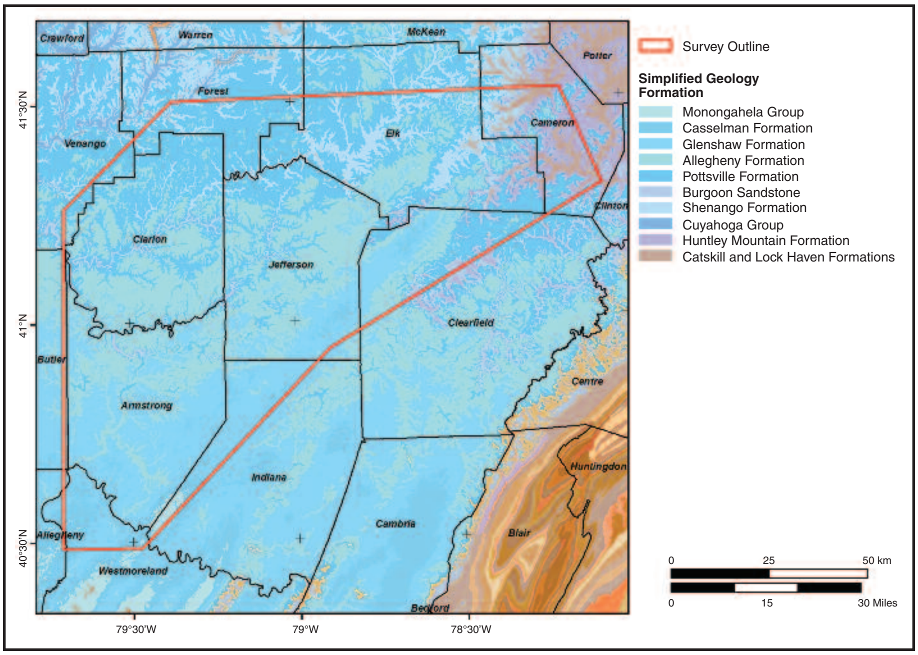
Montney Shale Example

A GGI survey was conducted in North East British Columbia in 2005-06 targeting a Mississippian gas play. At the time the data were acquired, the Montney Shale was not a primary drilling target, and as such, the survey design was not optimized for this type of play. However, the survey did cover part of the Montney and the data have subsequently been used to help develop an improved geologic understanding of the formation.

The data do not directly detect the Montney Shale unit. However, from the structural models developed, we are able to image the base of the Baldonnel and the top of the Debolt formations, which bound the Montney (Figure 1). The resulting isopach map clearly shows the sedimentary structure within the Montney rifted section and the faults that were believed to control fluid distribution. The derivation of the surfaces was achieved

FIGURE 3

Marcellus GGI Survey Outline



using minimal constraint from third-party data sets, such as wells and 2-D seismic data, with the isopach showing thickening toward the northwest and rifted faulting within the Montney itself.

Having interpreted the resulting Montney isopach, the structural data were input into finite element analysis. This combination of high-resolution GGI data with a 2-D seismic-guided 3-D earth model and FEA generates a 3-D volume of the structural complexity of shale gas interval.

While GGI is very good at mapping and determining fault offsets for primary structures, it is FEA that can take GGI to the next level in shale plays through a patented workflow where the finite element modeling of tensile stress and strain relationships identifies secondary faults and "zones of influence" in regard to structural complexity.

In the case of the Montney Shale, the GGI data set and FEA-based approach were able to highlight zones where there was an increased probability of faulting and where the operator might want to shoot additional 3-D seismic. Figure 2 shows an FEA-derived model in which the red color indentifies the more structurally complex areas where there is a high probability of encountering faults, while blue represents less complex areas where there is a low probability of encountering faults.

Through FEA, conjugate fault sets also were identified that led to significantly refining the structural 2-D seismic interpretation. In addition, faults that were believed to control fluid distribution were imaged. This is obviously crucial information for operators when making exploration decisions on shale gas plays and targeting future 3-D seismic surveys.

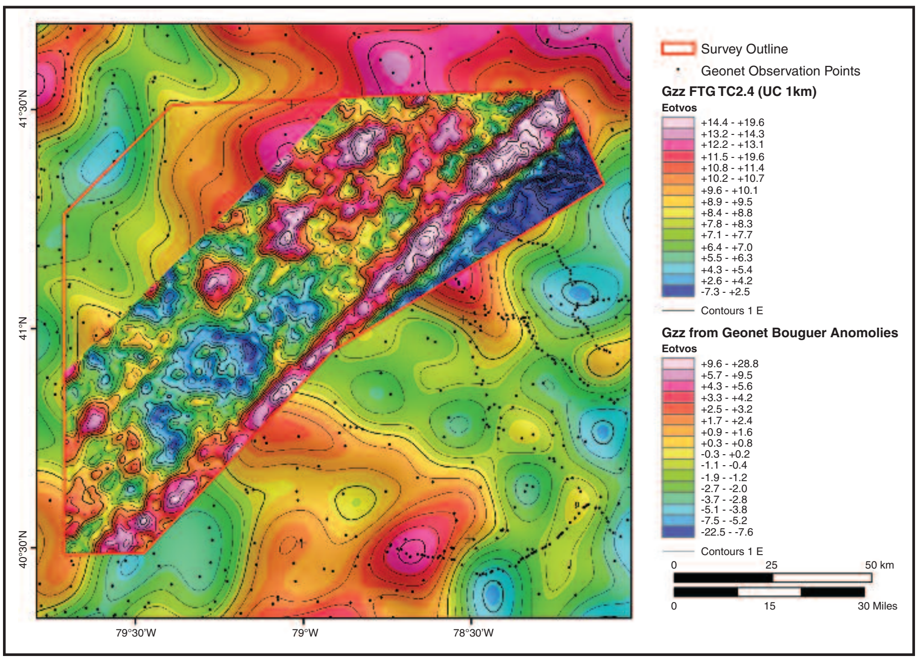
Survey Cost, Access

A second key benefit of GGI in shale gas relates to accessibility and cost. Airborne GGI surveys can explore vast regions quickly and efficiently with its passive technology having minimal adverse environmental impact and inevitable cost savings, as was the case with the Montney survey.

As shale gas moves into other environmentally sensitive or urban areas, such as the Monterey Shale in California and the Utica and other liquid shales in Ohio, the light environmental footprint of GGI is likely to be particularly beneficial in helping target future 3-D seismic surveys. And importantly, this light footprint is

FIGURE 4

GGI Gzz Data Shown with Calculated Geonet Gzz Data



PHILL HOUGHTON

Phill Houghton is vice president of business development and a co-founder of ARKeX, which has partnered with JEBCO Seismic to conduct the airborne geophysical survey in central Utah along the Hingeline, and with ION Geophysical Corporation to acquire GGI data in the transition zone along the Louisiana Coast. Houghton has more than 25 years of worldwide oil and gas industry experience, and has held positions in sales, technical development and gravity surveying with ARK Geophysics, MGAL, Oceonics and the Royal Navy Hydrographic Office. He holds a degree in electrical engineering.

FIGURE 5

Terrain-Corrected Gzz Shown with Pennsylvania Regional Interpretation

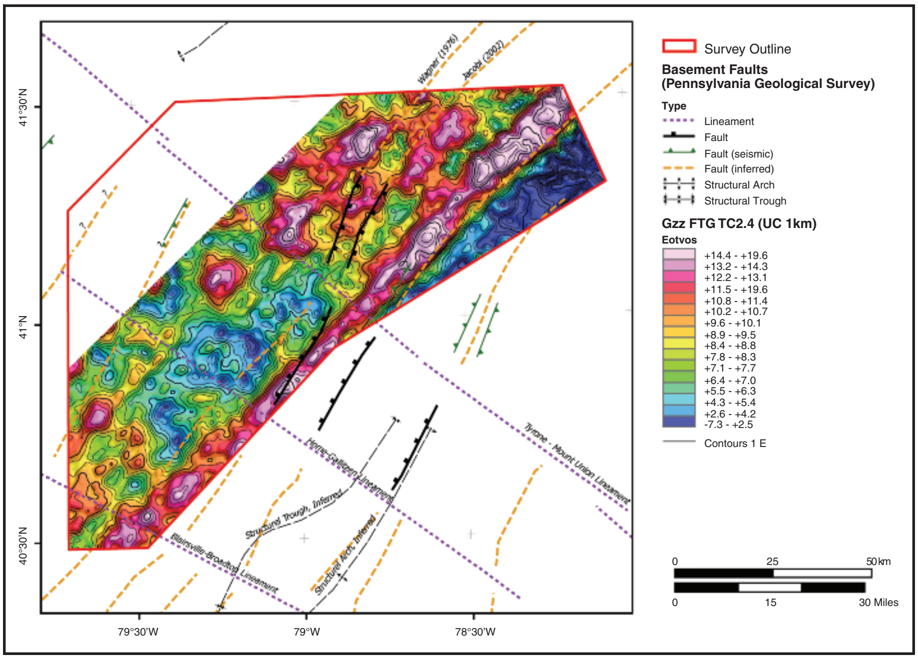
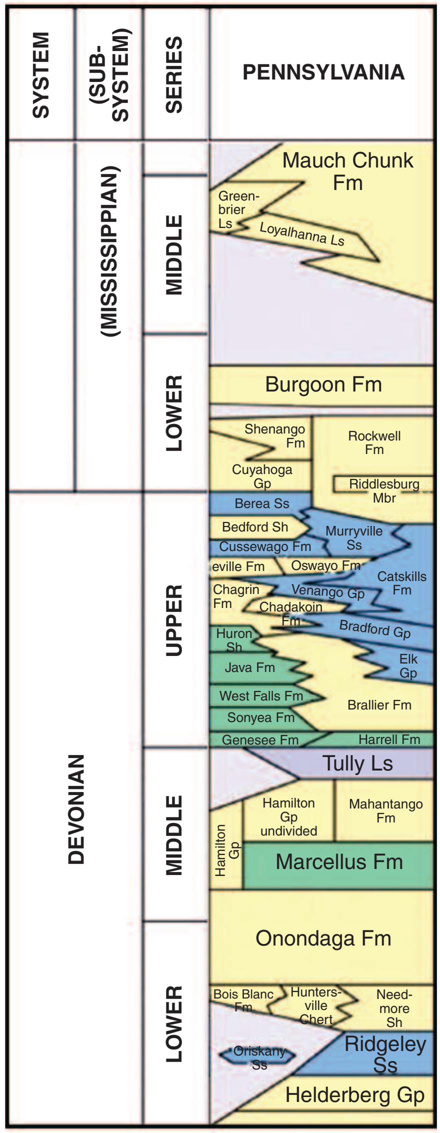


FIGURE 6

Marcellus Interval Between Tully And Onondaga Formations



not at the expense of the quality and detail of the data generated.

Carrying out these noninvasive surveys also has a significant impact on cost. As noted, multiclient GGI surveys cost about $2.00 an acre–a fraction of the per-acre cost of 3-D seismic. While exploration programs ideally should include 3-D seismic, using GGI (perhaps with 2-D seismic data) can be highly beneficial and cost effective to operators given the low cost and the quality of the stratigraphic data it produces to better target 3-D seismic programs.

Marcellus Shale Survey

The Marcellus Shale is one of the largest sources of domestic natural gas to be discovered to date, with potential recoverable resources estimated to be at least 363 Tcf. The total size of the prospective fairway area is 45,000 square miles, with the north central and southwestern parts of Marcellus the most active for drilling at the moment.

An airborne gradiometry survey has been acquired in the Marcellus to provide an improved understanding of the shale's structural complexity on a regional scale. The airborne survey covered 3,500 square miles and was completed in early October, taking a little more than 100 days to acquire. The results are expected to be available by the end of the year. With parts of the survey covering sensitive areas such as Pennsylvania state forest, conducting a 3-D seismic survey over such a wide area and in the same time frame simply would not have been feasible.

While full-blown modeling has yet to take place, some initial results can be revealed from the survey. The preliminary GGI data have been overlain onto a regional interpretation from Pennsylvania State Geological Survey and U.S. Geological Survey public domain data and show a strong correlation. Figure 3 shows the survey outline, while Figure 4 shows the survey outline with the full-tensor gravity gradiometry data inserted into the public domain (Geonet) data, clearly highlighting the additional bandwidth and signal-to-noise from the GGI data. Figure 5 goes further by displaying the correlation of the regional interpretation with the GGI data.

While GGI does not image the Marcellus Shale itself, it is able to see the density interfaces that influence the Marcellus, particularly the salt on top of which the shale effectively sits, plus the Tully and Onondaga limestone layers that bound the Marcellus interval, as seen in Figure 6.

No Substitute For Seismic

No one would deny that 3-D seismic surveys play a key role in mapping shale gas reservoirs. They define key reservoir properties such as rock brittleness, pore pressure and local stresses; map the thickness and structure of the shale; and identify hazards such as faults. GGI should never be viewed as an alternative to 3-D seismic.

However, initial applications of GGI technology in shale plays clearly do demonstrate the important role GGI fulfils as a complement to seismic, helping identify key structural elements such as faults as well as–through FEA–identifying the more structurally complex zones. A valuable and cost-effective technique, GGI is rapidly becoming an important tool in the explorationist's tool box.

It is also important to stress that GGI should always be used at an early stage in the exploration life cycle, rather than being seen as an add-on to seismic data. The earlier the data can be captured, the more value GGI will have as a prescreening tool and in providing input into designing and targeting future 3-D seismic surveys.

With unconventional resources on the rise in North America as well as in Europe, Africa and the Middle East, GGI coupled with 2-D seismic is likely to have a key role in shale plays for many years to come. ❒