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Managing the Risk of Shallow Drilling Losses in the Permian Basin

Vasudhaven Sudhakar[1], Adam Sallee[1], Hans Dick[1], Alan Morgan[2], Greg Jorgensen[3], Kevin Werth[4], Tom Barnes[5], Salvatore Amico[5], and David Paddock[1]
[1]Schlumberger WesternGeco, [2]Bell GeoSpace, [3]Flatirons Geophysics, [4]Dawson Geophysical, [5]ConocoPhillips

Objectives/Scope
Shallow drilling losses are a significant problem in the Permian basin because of the presence of subsurface karst features. Karst processes dissolve the soluble rock, producing voids and cavern systems that result in drilling losses. An operator drilling in Culberson County, Texas recently experienced total losses drilling four surface holes in a pair of neighboring pads located in bordering leases. Drilling into caverns negatively affected operations by reducing the drilled footage per day, increasing fluid and cementing costs, and increasing the difficulty in performing satisfactory cementing jobs to cover the water table.
This paper will describe the issues faced drilling with losses and explain how to manage risk of losses by improving surface well placement with two different, but complimentary techniques: airborne full tensor gradiometry (FTG) and pad-specific seismic to map subsurface hazards.
Methods/Procedures/Process
Airborne full tensor gradiometry (FTG) measures the directional components of the gravity field. Multiple simultaneously acquired tensor components allow identification of anomalies associated with subsurface voids. For this project, a Basler BT67 aircraft acquired data over the target area with line spacing of 328 ft. The flight took place over 3 days in July 2017.
Feasibility modeling using Castile formation cavern system modern analogs reveals detectability of single caverns larger than 10m diameter with the FTG system, however networks of smaller caverns are also detectable. Polygons created from analysis of negative Tzz anomalies divide the detected cavern systems by tiered risk areas. Curvature analysis further

refines the highest and lowest risk areas.
Pad-specific seismic employs very dense surface seismic over potential well locations, using routine techniques except for the increased density of geophone and seismic sources.
Although yet to be paired together in practice, the two methods have significant synergy. The interpretation of karsts on surface seismic is prone to uncertainty which is reduced when having a gravity measurement to suggest where, laterally, to expect such a feature. On the other side, gravity provides a good indication of the degree of risk areally, but, despite the ability to filter somewhat to focus on specific depths, predicting the exact depth of a cavern is fraught with peril in any gravity method. Seismic provides a better depth estimate. An additional synergy is that the gravity measurement can be used to refine the seismic velocity model, improving both the seismic image and our ability to predict depths.
Results/Observations/Conclusions
For FTG, negative gravity anomalies are highly correlated with drilled cavern network geometry and fracture networks. The most negative portions of the negative maximum along axial traces identify the highest risk for karst penetration. Further refinement was possible by filtering the anomalies for steeper sides, ultimately matching all prior drilling results.
Initial analysis reveals risk at both pads where losses occurred. Extending the analysis to the entire survey area, the drilling events in the drilled offset wells match with the risk interpreted for karst.
FTG data and subsequent interpretation offer strong correlation to known shallow hazards and cavern systems, making it an effective tool for risk assessment. It recommended to locate future drill pads in the identified low-risk areas and that any new wells be located at least 300 ft from highest risk areas derived from curvature analysis.
For pad-specific seismic, feasibility tests showed good promise and were followed up with a field survey over a pad with known drilling losses. The results showed good imaging of the surprisingly large feature which had taken the drilling fluid.
Applications/Significance/Novelty
This is the first application of FTG to classify drilling risk of karst features in the Permian basin. The FTG hazard map improves operational integrity of surface location selection and is a complement to surface topography and

geology considerations. The FTG data and analysis also hold value for fault mapping and for water drilling efforts in the area.
Similarly, pad-specific seismic results were a valid solution.
Both methods are solutions to avoid shallow drilling risks from karsting in the Permian Basin and, as co-measurements of same features, together provide synergies in multiple ways.