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Interpretation of Drilling Gas Geochemistry in Air-Drilled Wells

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Air drilling offers significant speed and cost advantages over conventional water- or oil-based mud drilling. Many unstable formations such as gas shales or tight gas sandstones can only be drilled horizontally on air, especially in low pore pressure or earth stress environments. Horizontal air drilling technology is rapidly coming into use in many basins. EQT Production Company (formerly Equitable Production) is the world leader in horizontal air drilling. Since 2006 no company in the world has drilled more feet of reservoir on air alone. In 2009 alone EQT will drill over 350 horizontal wells on dry air. All of these wells are in the Appalachian basin, with the vast majority in gas shales and tight gas sandstones. Interpretation of quadrupole mass spectrometer drilling gas data from air-drilled wells differs from interpretation of such data from holes drilled with water- or oil-based muds. Air drilling provides unique opportunities for drilling gas logging because the drilling fluid is not recycled, the lag time is short, samples can be lagged accurately, and a calibration standard is continuously provided with the reservoir gas. Air drilling also provides challenges for interpretation because of oxidation and perhaps other reactions at the hot drillbit and variations of drilling gas geochemistry resulting from oxygen scrubbing to prevent downhole fires. Although downhole fires do not pose a safety risk to personnel and equipment on the surface, downhole fires can damage or destroy bottomhole assemblies, damage the wellbore, and require sidetracking of the well. Continuous drilling gas analysis can contribute to the safety and efficiency of drilling operations by providing an early warning system for downhole fire risk.

Calibration

Air drilling uses normal atmosphere as the drilling fluid. Normal atmosphere is almost entirely composed of , and Ar, in fixed abundance, so ratios of these values to the sum of the three should remain constant regardless of the ratio of air to produced gas. These ratios serve as a constant check on the stability, precision, and accuracy of the mass spectrometer throughout the drilling process. Similarly, the ratio of (++Ar) to formation gases can be used as a measure of productivity while drilling. This is useful because air drilling systems typically monitor the volume of injected air but not the volume of produced air + gases.

Correction

The presence of a continuous calibration standard (air) allows mass spectrometer calibration errors to be corrected after the data is collected. An example will be provided in which a mass spectrometer that developed an electrical malfunction was replaced by a spectrometer that was stable but slightly miscalibrated. The data set was corrected using , and Ar ratios.

Depth control

An argon lagging method developed by EQT Production and King Canyon Buffalo (a mass spectrometer service provider) allows accurate lagging of gas samples. Drilling air is not reused, it is injected and then vented directly to the atmosphere. Chemical species therefore do not accumulate in drilling air. The circulation time of drilling air is rapid - typically one to a few minutes depending on the measured depth of the hole. For these reasons a unit of drilling air represents a fresh, uncontaminated sample. With accurate lagging, gas profiles from air drilled holes can offer precise and accurate chemical profiles of the well.

Formation gas oxidation

Some formations that produce without stimulation, such as tight gas sandstones, present a downhole fire risk during air drilling. To prevent downhole fires, scrubbers based on selectively permeable membrane technology are used to deplete the drilling air of oxygen. Scrubbing typically decreases the oxygen content of drilling air to about 5% . Scrubbing efficiency can vary slightly during drilling. Scrubbing is initiated a few hundred feet before high-risk zones are encountered. Distinctive changes in chemical spectra are observed after scrubbing is initiated even in homogeneous formations. These changes indicate that formation gas geochemistry is altered by reactions at the hot drillbit and that those changes are suppressed or eliminated when the oxygen content is dropped. We will explore the effects of such oxidation on the interpretation of mass spectrometer gas analysis in normal and oxygen-depleted air.

Downhole fire detection

Renting oxygen scrubbers adds meaningfully to the cost of drilling wells. Consequently, scrubbers are only used when needed. Downhole fires produce a unique chemical signature that is rapidly detected by quadrupole mass spectrometer analysis of produced drilling air. Such analysis can provide an early warning system for fire risk, because chemical changes indicative of minor fires can start to appear well before known dangerous formations are reached. Such minor fires probably represent brief flares of puffs of gas. Although they do not damage the well or bottom hole assembly or interrupt drilling operations, they can indicate the need for oxygen scrubbers sooner than expected.