Geologic Factors Controlling Natural Gas Distribution Related to the January 2001 Gas Explosions in Hutchinson, Kansas

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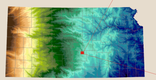
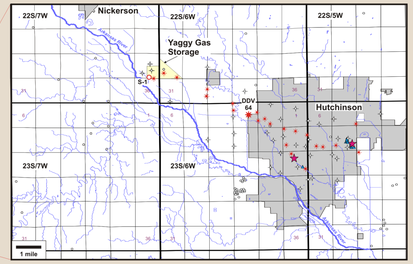
ABSTRACT

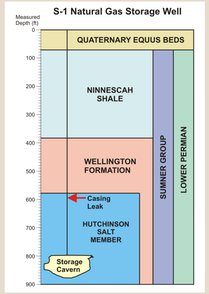
In January 2001, explosions and eruptions of gas geysers occurred in the city of Hutchinson, Kansas. Three days earlier, an estimated 143 million cu ft of natural gas at high pressure escaped from a casing leak at the Yaggy underground gas storage facility, 7 miles to the northwest. At Yaggy, natural gas was stored in solution caverns in the Lower Permian Hutchinson Salt Member. The casing leak was located just below the top of the salt and 184 ft above the top of the storage cavern. Vent and observation wells drilled in the area after the explosions encountered gas over a distance of 9 miles, primarily along a narrow, northwest-southeast-trending corridor between Yaggy and eastern Hutchinson. The widespread distribution of gas warranted further characterization of the surrounding geology to resolve features that provided pathways for the gas. Studies of 116 borehole logs in a 150 mi^2 area, along with seismic lines, core, well logs, and shut-in pressure data, suggest that gas moved through the area within a thin dolomite interval 170 ft above the top of the Hutchinson Salt Member, apparently along a fracture cluster that follows the crest of a low-relief, westerly plunging anticline. High-resolution seismic and stratigraphic analyses revealed deep-seated structural features that appear to have controlled fracture and fault concentrations in the thin, brittle dolomite beds that served as the conduits for the gas. Episodes of focused undersaturated ground-water circulation along associated fractures apparently resulted in evaporite dissolution that enhanced structural relief and tensional forces along the anticline.

BACKGROUND

On January 17 and 18, 2001, explosions and eruptions of gas geysers occurred in the city of Hutchinson, Kansas. Three days earlier, natural gas at high pressure (600+ psi) began escaping from a casing leak in a natural gas storage well, S-1, at the Yaggy underground gas storage facility, 7 miles to the northwest of Hutchinson, with an estimated loss of 143 million cu ft of gas. At Yaggy, natural gas is stored at depths in excess of 600 ft in solution-mined caverns in the Hutchinson Salt Member of the Lower Permian Wellington Formation of the Sumner Group. The casing leak was located just below the top of the salt and 184 ft above the top of the storage cavern.







In response to the explosions, 57 vent wells and five observation wells were drilled in the city of Hutchinson and westward towards the Yaggy storage facility. These wells detected gas over a distance of 9 miles, primarily along a narrow, northwest-southeast-trending corridor between Yaggy and eastern Hutchinson. For all but two of the productive vent wells, the gas was contained within a 30-ft thick interval approximately 170 ft above the top of the Hutchinson Salt Member, which core data show to contain several thin dolomite layers. The natural gas that caused the explosions and gas geysers reached the surface from this interval through abandoned brine wells. On July 7, 2001, DDV #64, in T23S R6W Sec. 3, suddenly vented large amounts of gas at high pressure over several days. This gas originated from a zone 70 ft below the main gas-bearing interval.

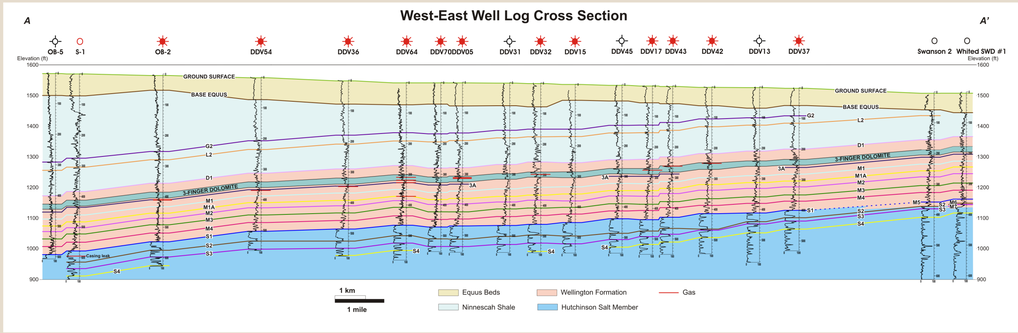
The widespread lateral distribution of gas, along with its apparent narrow vertical distribution, warranted further characterization of the surrounding geology to resolve features that provided pathways for gas movement.

STRATIGRAPHIC ELEMENTS

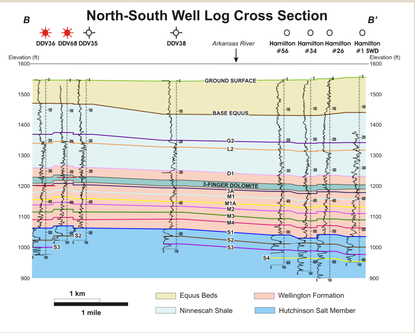
Natural gamma-ray logs from 59 of the vent and observation wells and 57 nearby oil wells and gas-storage wells were used to conduct high-resolution stratigraphic correlation and mapping of 15 closely spaced marker beds within the Lower Permian strata for a 150-mi^2 area encompassing Hutchinson and Yaggy (Nissen and Watney, 2003; Watney et al., 2003). The logs were normalized so that units range from 0 (salt) to 100 (shale).

The main gas-bearing interval generally corresponds to a characteristic pattern of three low natural gamma-ray lobes, informally referred to as the "3-finger dolomite," which can be correlated throughout the Hutchinson area. In several wells, gas is found in an interval approximately 5 to 10 feet below the base of the 3-finger dolomite, corresponding to a fourth low gamma-ray lobe, designated 3A. This lobe appears to be discontinuous and cannot be mapped throughout the Hutchinson area. Deeper gas zones have been reported in two vent wells. The high-pressure gas vented from DDV #64 in July 2001originated from a zone 70 ft below the top of the 3-finger dolomite, corresponding to marker bed M1A. Gas in DDV #09 (approximately 1,000 ft to the north of dry hole DDV #45) was reported from an interval 37 ft below the top of the 3-finger dolomite, corresponding to marker bed M1.

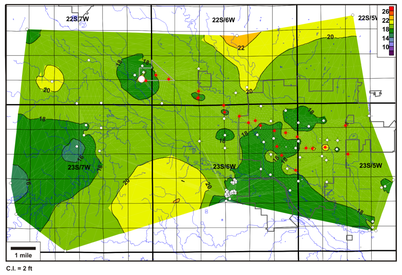
West-East Well Log Cross Section



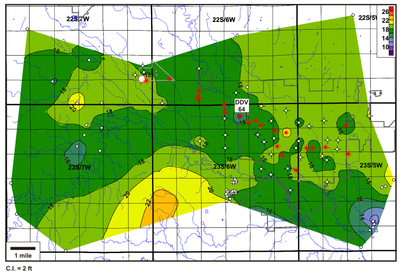
North-South Well Log Cross Section



3-Finger Dolomite Isopach



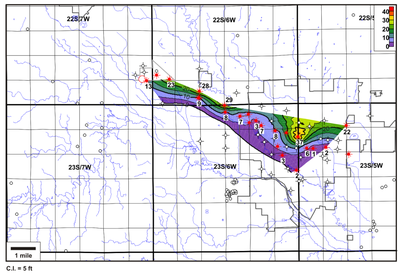
M1A - M2 Isopach



Isopach maps of the 3-finger dolomite and M1A-M2 intervals show that both intervals vary in thickness by less than 4 ft throughout most of the Hutchinson study area.

Subtle localized thinning (by 3-5 ft) of the M1A-M2 isopach occurs at DDV #64, which may by linked in some way to the July 2001 venting of gas from the M1A interval in this well.

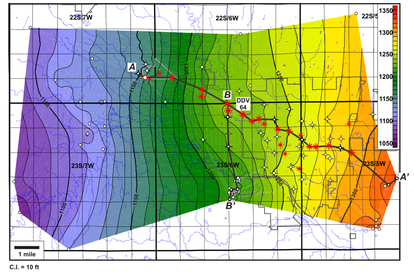
Depth to Gas (feet), Referenced to Top "3-Finger Dolomite"



A map of reported depth to gas referenced to the top of the 3-finger dolomite shows that the gas in the northernmost vent wells resides in a slightly deeper stratigraphic interval (3A) compared to gas in more southerly wells.

The anomalous depth to gas at the eastern edge of T23S R6W Sec. 12 corresponds to the M1 gas zone in DDV #09.

Top 3-Finger Dolomite Structure



A structure map of the top 3-finger dolomite shows a regional westerly structural dip of approximately 20 ft/mi. To the west of Hutchinson, a broad, west-northwest-trending anticline (the Yaggy-Hutchinson anticline) is superimposed on this regional dip. Gas-producing vent wells lie along the northern edge of this anticline. DDV #64 is located on a closed high along the crest of the anticline. This may have made DDV #64 a focus for gas migration.