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Geochemical Indicators of Shallow Gas in Groundwater in North Dakota

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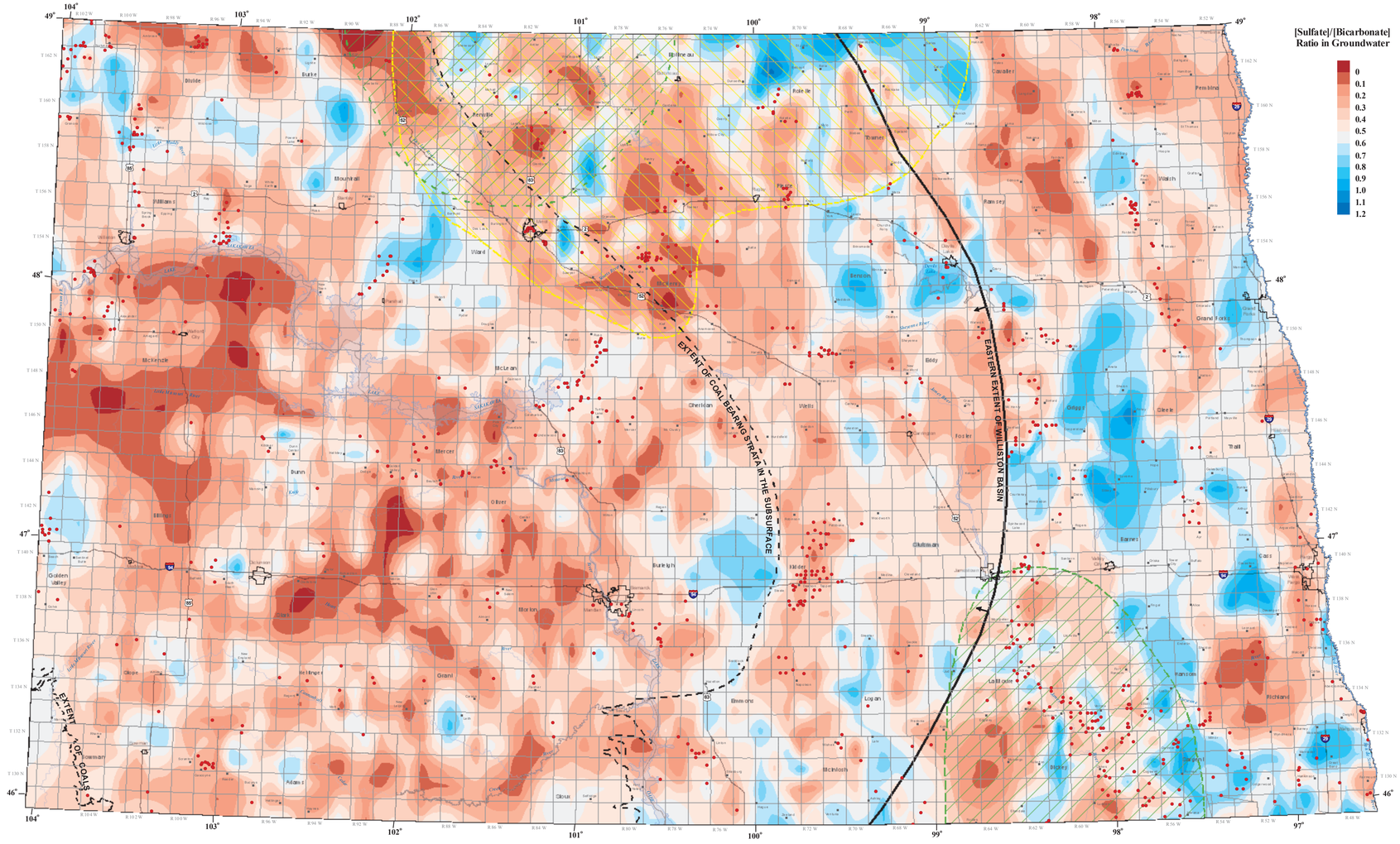

DISCUSSION

The geochemical distribution of ground-water chemistries (in the form of sulfate [SO_4^{-2}] to bicarbonate [HCO_3^-] ion ratio) favorable for the occurrence of methane (CH_4 or C1) is presented on this map. In addition, the locations of ground-water wells (field screened between 2006 to 2010) have been plotted that contain methane. Data from 7,503 wells was extracted, averaged, and interpreted here *as is* from ground-water geochemical databases maintained by the North Dakota State Water Commission (NDSWC). The data used for the geochemical interpolation on the map is from many different individual sampling events and include data from sampling events as far back as 1932. Any well sampled with ground-water ion chemistry meeting previously identified shallow gas exploration criteria has been included. Data reported from all types of wells found across the state, including: domestic, stock, production, municipal, industrial, observation, and irrigation wells, were used in the geostatistical interpolation. Wells described as "unknowns" with reported sulfate and bicarbonate ion concentrations were also included for completeness. Well depths range across all shallow ground-water systems from as shallow as three feet to as deep as 3,277 feet with the majority of wells (>80%) completed to depths less than 300 feet.

In the absence of methane detection through instrumental or analytical means, sulfate and bicarbonate ion concentrations have been demonstrated as valid proxy indicators for potential occurrences of methane. The ratio of these concentrations are predictive of ground-water chemistry favorable for the presence of methane in the shallow subsurface. Previous workers (Anderson, et. al, 2006, McIntosh and Martini, 2008, Martini, et.al., 2003, Shurr, et.al, 2006, Shurr, 2008, and Van Voast, 2003) have demonstrated empirically that sulfate ion concentrations less than 500 mg/L, coupled with bicarbonate ion concentrations greater than 400 mg/L, are indicative of groundwaters containing detectable concentrations of methane in shallow ground-water systems in the Dakotas. The interpolated sulfate to bicarbonate ratio distribution is plotted on this map for the purposes of shallow gas exploration and comparison with known areas of hydrocarbon resource occurrence and reported historical shallow natural gas occurrence.

Areas where a good correlation exists between known hydrocarbon occurrence and areas shown to be favorable for the occurrence of methane (based on sulfate to bicarbonate ratios) include: 1) the western two-thirds of the state coincident with the existence of the Williston Basin, 2) the areas of measureable coal resources, and 3) areas historically (ca. 1900's) reported to have had shallow gas in the shallow ground-water systems. These historic areas include Bottineau County (north-central North Dakota), and the LaMoure area (southeastern North Dakota). In addition, recent anecdotal reports of shallow gas in water wells have been recorded in north-central North Dakota. Areas recently identified by the NDGS to contain shallow gas through well field screening, sampling, and testing include McKenzie County, western Dickey, northeastern Ransom, and eastern Cavalier counties. Several smaller areas were also identified in Divide and Burke Counties (northwestern North Dakota) as well as Wells, Eddy, Foster, Kidder, Burleigh, and Emmons counties (central North Dakota).

A comparison of shallow gas occurrences with areas of interpolated ground-water geochemistry data further supports the conditions of ground-water geochemistry that are favorable, and potentially predictive of methane occurrence. Comparing sulfate/bicarbonate ratios (i.e. low sulfate/higher bicarbonate concentrations in groundwater) from wells with detected shallow gas indicate that a greater number of wells with relatively higher methane concentrations, occur at the lower end of the sulfate/bicarbonate ratio spectrum (Figure 1). Further, the direct comparison of ground-water geochemistry across the state with wells that contain shallow gas demonstrates occurrences (Figure 2) tend to be found in areas of favorable ground-water geochemistries (i.e. low sulfate/bicarbonate ratio).

It is important to note that this geostatistical interpolation and hydrogeologic interpretation of shallow ground-water geochemistry groups the saturated shallow subsurface into one relatively homogeneous ground-water unit across the state. In actuality this unit consists of several discontinuous systems and aquifers which are most appropriately considered individually and at larger scales for typical hydrogeological studies.

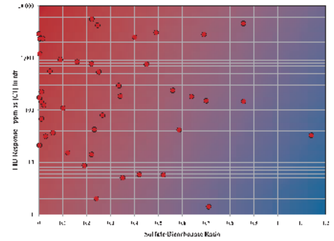

Figure 1. Comparison of sulfate/bicarbonate concentration ratios in groundwater to shallow gas field screening results from *selected* wells across North Dakota. The highest methane concentration (reported in ppm as C1 in air) detected from wells in each county are compared against their respective average sulfate/bicarbonate ratios - as determined from available ground-water geochemical data. The number of shallow gas occurrences is greater, and are also in relatively higher concentrations, as the sulfate/bicarbonate ratio decreases.

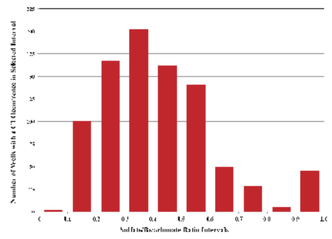

Figure 2. The distribution of shallow gas occurrences detected in groundwaters that are found within respective areas of interpolated sulfate:bicarbonate ratio across North Dakota. The frequency of wells with a shallow gas show is greater in areas delineated as having relatively lower sulfate/bicarbonate ratios.

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Cartographic Compilation: Elroy L. Kadrmas