Shallow Gas Wildcat Drilling in the Niobrara Formation in South-Central North Dakota

By **Fred J. Anderson**

Introduction

Since the inception of the ND Geological Survey shallow gas program in early 2005, the NDGS has conducted several investigations related to the shallow gas potential of North Dakota. As a result of investigative activities such as these, the oil & gas industry undertook a shallow gas wildcat drilling project late in 2006. This article will provide a brief overview of the drilling activities conducted and highlight some of the results of the investigation related specifically to the Niobrara Formation of North Dakota.

The exploration program targeted the Late Cretaceous-age Niobrara Formation in south-central North Dakota. The Niobrara Formation in North Dakota is a gray to tan calcareous shale that was deposited in the shallow waters of the Cretaceous Interior Seaway around 80 million years ago. The Niobrara Formation can be found throughout the mid-continent of the U.S. and Canada and was named for exposures near the mouth of the Niobrara River in Knox County, Nebraska. The word *Niobrara* originates from Omaha and Ponca native American languages and means "running" or "spreading water". The formation is often recognized as the "first white specks", referring to the abundant calcareous nanofossils distributed in the upper portions of the formation. The Niobrara Formation extends over 90% of North Dakota, subcropping in eastern Cavalier and western Pembina counties in the northeastern part of the state and Dickey and Sargent counties in the southeast (fig. 1). In general, the formation dips gently to the west/northwest towards the central portion of the Williston Basin. The Niobrara Formation is exposed in outcrops along the Pembina and Turtle Rivers in northeastern North Dakota and along the Sheyenne River south of Valley City in southeastern North Dakota (fig. 2).

The Niobrara Formation is an important shallow gas producer in the Midwest and Rocky Mountain regions. Shallow gas production from the Niobrara Formation occurs in the Nebraska, Kansas, and Colorado portions of the Denver Basin. Often in the search for hydrocarbons, the knowledge gained working in one basin is extrapolated and applied when exploring in another. For example, the exploration and production knowledge gained from exploring the Niobrara Formation in the Denver Basin could aid in the discovery of Niobrara gas in the Williston Basin. On several occasions over the past 110 years, the Niobrara Formation has been investigated in North Dakota as a potential cement rock resource (see NDGS Newsletter Vol. 33, No. 1). Recently, researchers, as wells as industry, have been taking a closer look at the natural gas potential of the Niobrara.

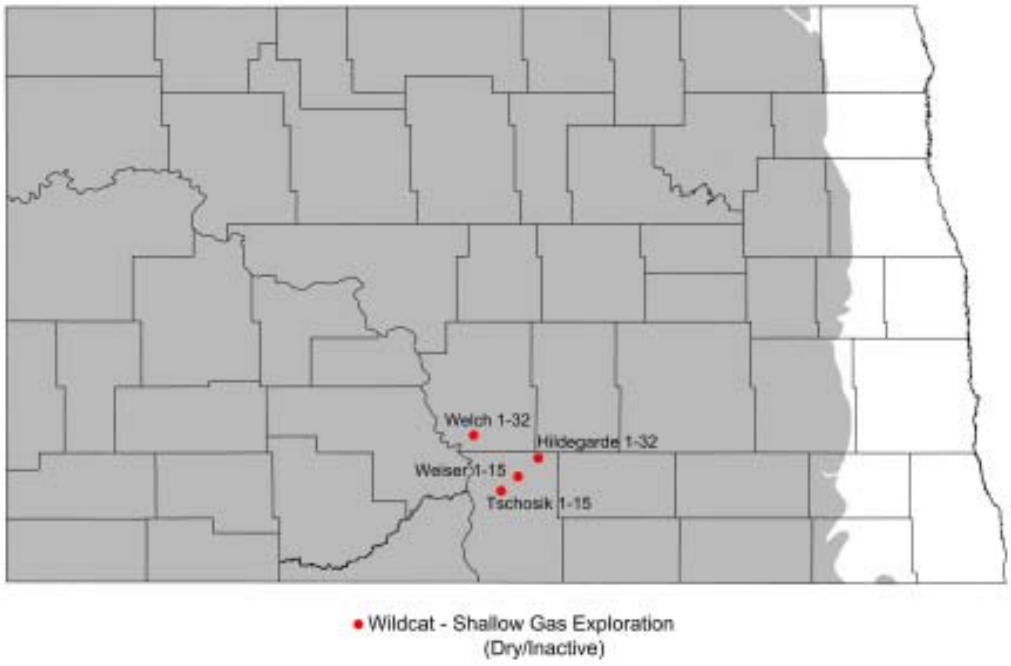

Figure 1. The Niobrara Formation (gray) is present in the shallow sub-surface throughout much of North Dakota. The wells that were recently drilled as wildcat shallow gas wells are shown in Burleigh and Emmons Counties.

Figure 2. The upper portion of the Niobrara Formation is exposed along several drainages in northeastern North Dakota. This Niobrara outcrop consists of tan to white calcareous shales interbedded with tan to buff siltstones. Laminated glaciolacustrine sediments (upper left background) and recent alluvial sediments (right foreground) rest unconformably over eroded Niobrara Formation at the outcrop. High-frequency bedding plane fractures along with systematic vertical to sub-vertical fracture sets are visible at outcrop and, as an outcrop analog to the shallow subsurface, can provide indications of preferential pathways for fluid flow such as shallow gas and groundwater.

Recent Gas Wells

In the past 10 years, there have been 3 wildcat wells drilled in central and eastern North Dakota: the Kodiak (Peterson-1), the Duncan (Graves 1-24), and the Jordan (Williams 1-25), that tested for gas in Cretaceous shales.

In 2006, four new shallow gas wildcat wells were drilled in south-central North Dakota targeting shallow gas in the Cretaceous Niobrara Formation (fig. 1). The Welch 1-32, Tschosik 1-15 (fig. 3), Weiser 1-15, and Hildegarde 1-13 were drilled to depths of about 1,700 feet, During well completion, production casing was run to the bottom of each well and perforated along a 10-foot zone at a depth of approximately 1,400 feet. The Welch, Tschosik, and Weiser wells were all perforated within the Niobrara Formation. In addition, the Tschosik well had a second set of perforations into the underlying Carlile Formation. The Hildegarde well was never perforated. The perforated wells were shut in and later stimulated via hydraulic fracturing methods (fig. 4). Hydraulic fracturing of the shales was accomplished with a mixture of nitrogen gas, sand, and gel. The foam frac mixture consisted roughly of 40,000 pounds of sand (premium 12/20), 5,000 gallons of linear gel (20 pound), and 100,000 standard cubic feet of nitrogen gas.

Figure 3. – Drilling on the Tschosik shallow gas wildcat well in northwestern Emmons County, North Dakota.

Figure 4. Stimulating the targeted zone of the Niobrara Formation in the Weiser well using a coiled-tube hydraulic fracturing rig.

Figure 5. Gas flare on the Welch 1-32 shallow gas well completed in the Niobrara Formation during late December of 2006. The well was drilled in southern Burleigh County, North Dakota.

Two of the wells produced gas during a 24-hour test period. The Welch well (fig. 5) produced 1.8 MCF (thousand cubic feet) of gas and 109 barrels of water during the test and the Tschosik well produced 1.4 MCF and 148 barrels of water. The Weiser well produced 976 barrels of water, but no gas.

Core Sampling and Analytical Testing

The "cutting" of rock core is a crucial and fundamental step in any comprehensive investigative drilling program. Cores of the Niobrara Formation were cut during the drilling of these wells using conventional coring techniques and were submitted for laboratory physical and geochemical analysis (fig. 6).

Core from the Weiser well was analyzed for physical properties including density, porosity, permeability, as well as geochemical properties including the overall mineralogical composition and total organic carbon (TOC). Cuttings from the Welch well were also analyzed for TOC and carbon isotopes. Cuttings from both the Welch and Tschosik were analyzed for headspace gas composition.

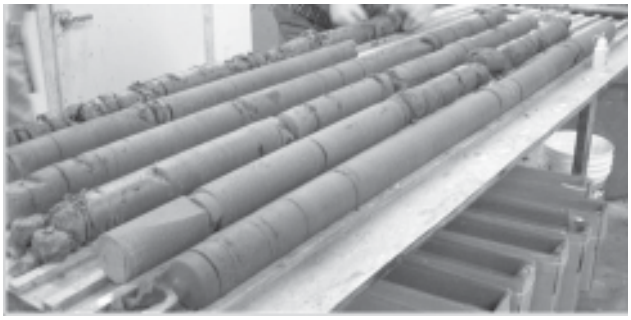

Figure 6. Sections of whole, intact core cut from the Niobrara Formation in south-central North Dakota being prepared and examined in the laboratory prior to sampling for detailed physical properties and geochemical analyses.

Two of the more important reservoir properties are porosity and permeability. An average porosity of approximately 37% was determined for the chalky interval of the Niobrara which is a relatively high value. An average permeability of approximately 0.5 millidarcies was also determined which is a relatively low value. Taken together, these values are consistent for chalk and are comparable to porosities found in other carbonate reservoirs. Gas composition analysis was performed on cuttings collected from the Welch and Tschosik wells and averaged greater than 97% methane with generally 2% or less ethane, propane, butane, pentane, and hexane. These data indicate the gas is of a dry, biogenic character. Total organic carbon (TOC) in the Weiser core and cuttings ranged from 4.23% to 7.28% with an overall average of 5.1%. These values are consistent with published values from Niobrara Formation cores and outcrops in the Northern Plains.

Hot Wire Gas Detection

Gas detection of circulating fluids (i.e. muds) during drilling is done by a "hot wire" total gas detection system coupled with gas chromatographic/mass spectrometry technology. This system allows for the continuous determination of total gas and hydrocarbon speciation contained in the drilling mud. Hot wire lines on these wells showed overall increasing mud-gas contents with depth. Average high mud gas contents of the wells were over three percent. Gas contents were typically highest when drilling in the Niobrara Formation and were found to consist dominantly of methane.

Shallow Gas Production

The initial production tests of the Welch and Tschosik wells had an average shallow gas production of 1.6 MCF/day from Cretaceous shales (Pierre, Niobrara, and Carlile Formations). Typical shallow gas production from wells in similar plays/fields in the Rocky Mountain west are nearly 20 times higher than these rates at around 32 MCF/day (e.g., Beecher Island Field, Co.). However, the results from this investigation suggest that the shallow gas produced during the testing of these wells may be characteristic of a "background" condition that is common throughout the shallow subsurface. More favorable local stratigraphic and structural controls are likely necessary to create gas accumulations "similar" to other shallow gas-producing basins. If this small amount of shallow gas production was sustained over time it might by utilized as a residential, small community, or light industrial natural gas supply. Given that natural gas prices are currently on the rise, the attractiveness of this type of shallow gas play may be increasing in the Northern Plains.