The Stonewall Formation

Timothy O. Nesheim

Introduction

The Stonewall Formation is one of numerous sedimentary strata that have commercially produced oil and gas from North Dakota's subsurface. The Stonewall Formation is also one of many geological formations being overshadowed by the prolific Bakken-Three Forks play. Interestingly, the first successful production test that recovered hydrocarbons (oil and gas) from the Stonewall Formation took place in 1952, less than a year after the discovery of oil in North Dakota. However, sustained commercial production from the Stonewall Formation did not take place for another 27 years until 1979. Since then, the Stonewall Formation has produced approximately 10 million barrels of oil equivalent (MBOE) from 65 vertical wells (fig. 1).

Geology

The Stonewall Formation consists of three carbonate-evaporitic cycles deposited during Late Ordovician through Early Silurian time (fig. 2). The Stonewall Formation is conformably underlain by the Stony Mountain Formation and overlain by the Interlake Formation. Each Stonewall cycle consists of three general lithofacies: 1) bioturbated to laminated carbonate mudstone 2) thin greyish green dolomitic and/or shaley, silty to sandy mudstone, and 3) nodular to laminated anhydrite that is sometimes interlaminated to interbedded with dolomite (fig. 3). Deposition is interpreted to have taken place within a shallow marine (carbonate facies) to hypersaline (anhydrite facies) setting. The shaly sandy mudstone intervals have previously been

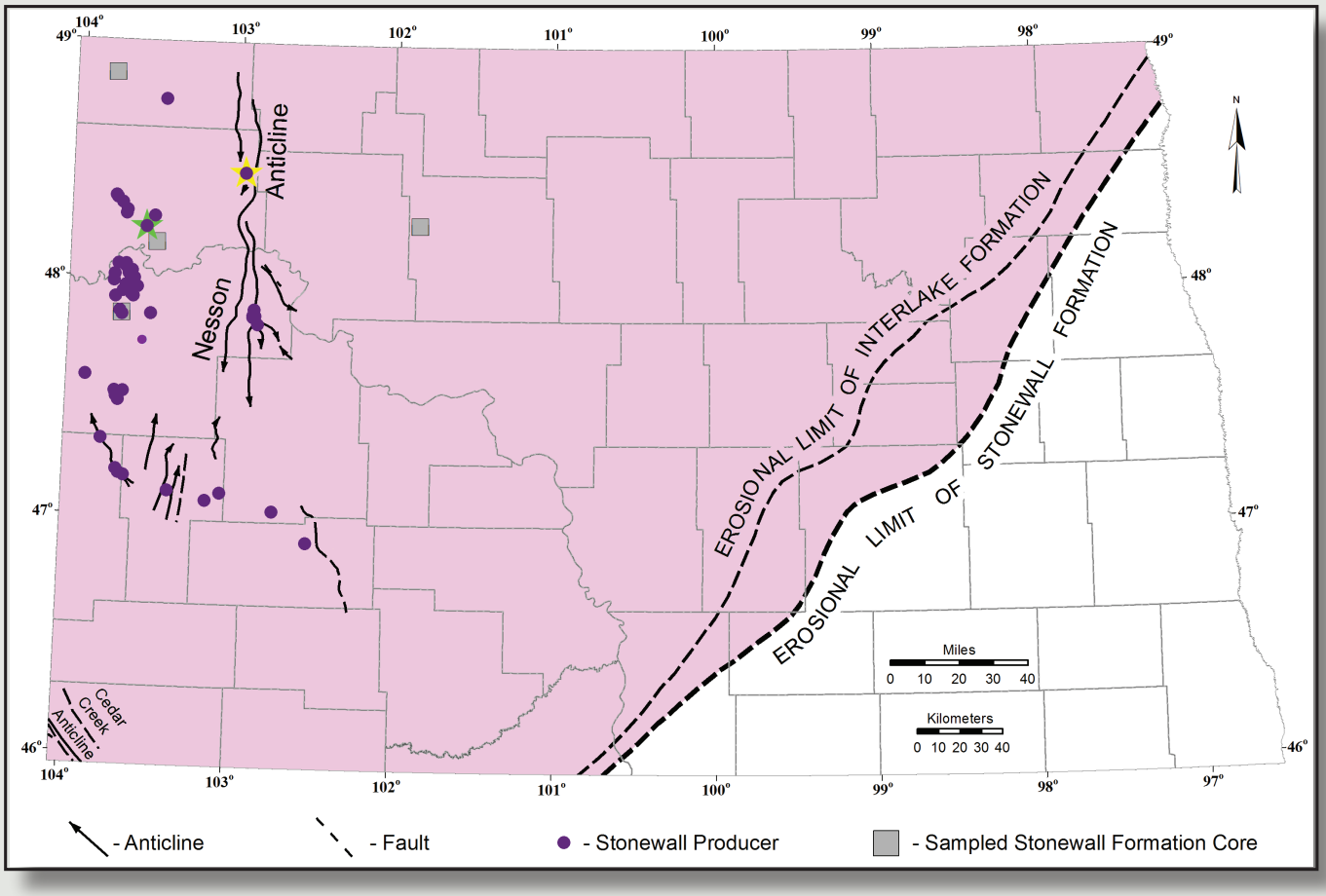

Figure 1. Map depicting the extent of the Stonewall Formation and Stonewall productive wells in North Dakota (Carlson and Eastwood, 1962). For regulatory reasons the Stonewall Formation has been pooled together with the lower Interlake Formation. The map displays only wells with productive perforations in the Stonewall Formation. Grey squares represent Stonewall cores that have been sampled and analyzed for TOC/RockEval. The yellow star depicts the location of the Henry O. Bakken #1, the first well successful in extracting oil and gas from the Stonewall Formation. The green star depicts the location of the Rolfstad #1, the first commercial producer of hydrocarbons from the Stonewall Formation.

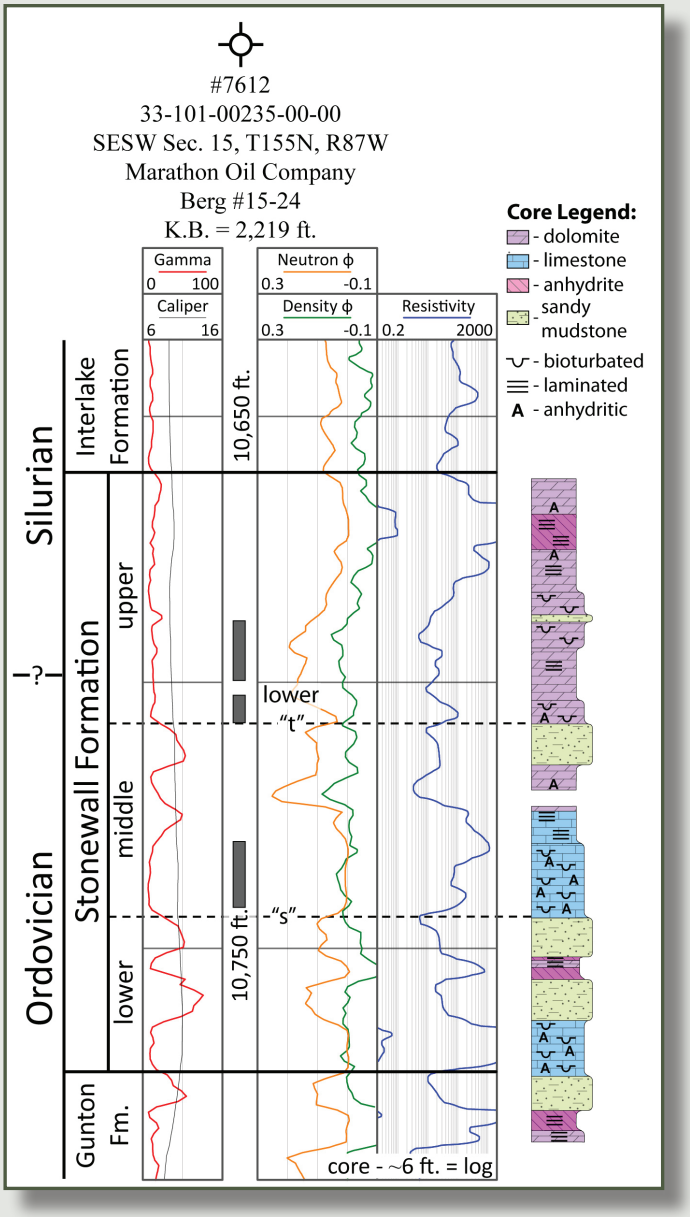

Figure 2. Wireline log and illustrated core example of the Stonewall Formation from Marathon Oil's Berg #15-24 (NDIC: #7612, API: 33-101-00235-00-00, Sec. 15, T155N, R87W). The informal lower, middle, and upper Stonewall intervals represent the three carbonate-evaporitic sequences. Although the Berg #15-24 is located about 50 miles from the nearest Stonewall productive well, this core is the most complete example of the Stonewall Formation to date. The dark gray rectangles in the depth profile represent the typical stratigraphic position of Stonewall pay zones.

described as basin-wide marker beds that represent phases of regression and "interruptions" in carbonate sedimentation (Fuller, 1961; Johnson and Lescinsky, 1986). The Silurian-Ordovician contact has been previously interpreted, based on paleontological data, to occur with close stratigraphic proximity to the upper and lower "t" marker boundaries (fig. 2) (Haidl, 1991). The Stonewall Formation is stratigraphically above the prolific Red River Formation, which is third in cumulative oil production behind the Bakken-Three Forks and Madison oil pools.

The source rock and conventional reservoir may be one and the same within the Stonewall Petroleum System. Productive pay zones within the Stonewall Formation are located within the basal, carbonate portions of the upper (89% of productive wells) and/or middle (16% of productive wells) Stonewall (fig. 2). These low gamma-ray carbonate pay zone intervals also contain the highest Total Organic Carbon (TOC) content within the Stonewall section (Nesheim, 2014). The Stonewall contains only moderately organic-rich mudstone (1-3% TOC). However, deep burial depths resulting in high thermal conversion rates of kerogen to hydrocarbons, and the absence of consistent porous and permeable beds to allow for significant migration, appears to have formed substantial hydrocarbon accumulations within the Stonewall Formation.

Production History

The Amerada Petroleum Corporation spudded the Henry O. Bakken #1 (NDIC: 32, API: 33-105-00005-00-00, Sec. 12, T157N, R95W) on July 7th, 1951, just months after Amerada's famous Clarence Iverson #1 discovered the first commercially producible oil within North Dakota. After cutting core samples and finding oil shows within the Stonewall Formation of the Henry O. Bakken #1 well, Amerada ran a drill stem test (DST) on the upper Stonewall and recovered oil and gas cut mud. Following numerous DSTs that tested the production potential of other geologic units both above and below the Stonewall Formation, Amerada set casing and perforated the upper Stonewall for a production test. The Stonewall production test yielded gas along with 64 BBLS oil and 63 BBLS water over a 27-hour test period (57 BOPD = barrels of oil per day and 56 BWPD = barrels of water per day). Had the Stonewall test been the best production test to recover hydrocarbons, the Henry O. Bakken may have remained a Stonewall completion and become the first well to commercially produce from the Stonewall Formation. However, perforations in the Mission Canyon Formation (Madison Group) yielded sustained initial production rates of around 200 BOPD (barrels of oil per day) and the well went on to produce from the Madison Pool until being plugged and abandoned several decades later. While there was not any more reported Stonewall production beyond the 27-hour production test, the Henry O. Bakken was the first well to successfully extract oil and gas from the Stonewall Formation.

Sustained commercial production from the Stonewall Formation did not take place for another 27 years, until the completion of the Rolfstad #1 (NDIC: 6680, API: 33-105-00776-00-00, Sec. 29, T155N, R100W). The Rolfstad #1 was spudded in September 1978 by Lamar Hunt targeting a small structural dome (1-2 miles in diameter) located beneath south-central Williams County (fig. 1). After first testing the underlying Red River Formation, the Rolfstad #1 was completed in the middle Stonewall Formation on January 25th, 1979, a completion that yielded an impressive vertical well IP (initial production) of 628 BOPD with no reported gas or water. After cumulatively producing 119,425 BBLS oil and 233,407 MCF gas, a partial hole collapse occurred above the Stonewall perforations and the well was later recompleted uphole within the Madison Pool.

Following the Rolfstad #1 discovery, Stonewall production primarily spread southward. Between 1979 and 1986, there were 26 wells drilled that were initially completed in, and produced from, the Stonewall Formation, most of which were drilled within northern McKenzie County. Most of these Stonewall producers were drilled into the underlying Red River Formation, suggesting the Stonewall Formation was a secondary target. Following 1986, there have been an additional 38 Stonewall productive wells. Many of these later wells were recompletions of successful Red River producers whose production rates had dropped. A number of these recompletions have been commingled producers, typically extracting oil and gas simultaneously from both the Red River and Stonewall Formations.

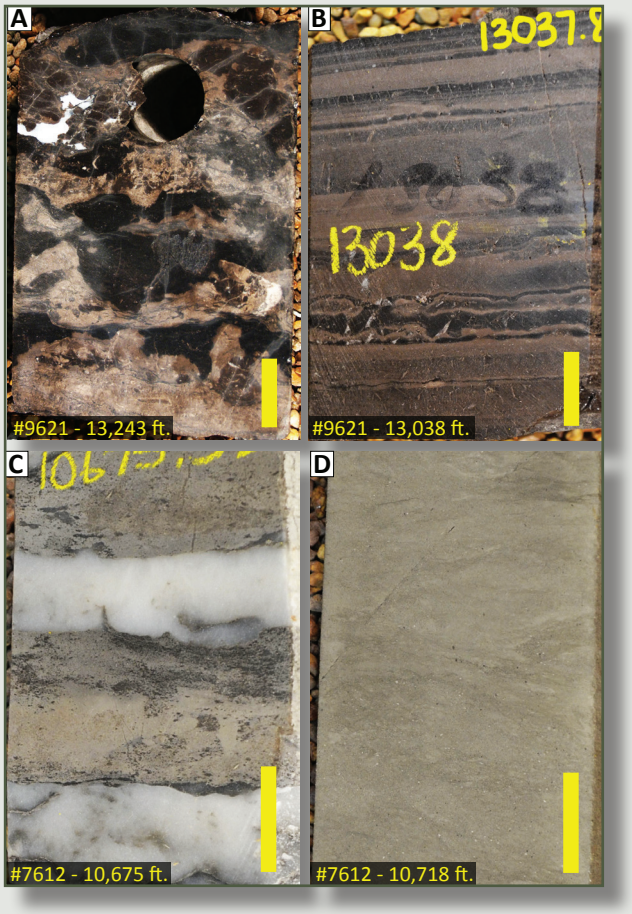

Figure 3. Core photographs of the Stonewall Formation. A) tan to very dark brown bioturbated mudstone, B) tan and dark brown laminated dolomitic mudstone, C) interbedded white anhydrite and greyish tan anhydritic dolomite, and D) greenish grey sandy mudstone. The NDIC well number and approximate core depth is listed in the bottom left hand corner of each photograph. The yellow bar in the bottom right hand corners represent one inch.

Future Exploration Potential

Vertical Stonewall wells completed to date have boasted impressive initial production rates of up to 915 BOPD and cumulative individual well production totals of up to 1.2 MBOE (57% oil). However, roughly two-thirds of all Stonewall producers have cumulatively produced only around 100,000 BOE or less (~70-85% oil), which at depths >12,000 ft. is likely only marginally economic. Reservoir quality and quantity appears to vary substantially over short distances, which makes field development difficult after an initial discovery. As a vertical well play, the Stonewall Formation appears more suited as a secondary exploration target rather than a primary.

Despite the absence of horizontal Stonewall drilling attempts to date, the Stonewall Formation may have a future at some point as an unconventional play. The upper Stonewall Formation may have initially contained moderately organic-rich (1-5% TOC, Hydrogen Index = 400-600) carbonate mudstone which has undergone significant thermal maturation within the central portions of the Williston Basin (e.g. northern McKenzie and southern Williams Counties) (Nesheim, 2014). While the Stonewall Formation does not contain world-class source rock, it does appear to be a self-source petroleum system. Pressure data suggests the upper Stonewall Formation is also slightly overpressured within at least parts of the central basin area, with calculated fluid pressure gradients up to 0.50 psi/ft. Fluid overpressure can be the result of intense hydrocarbon generation and is favorable for unconventional production. Core data from several non-productive Stonewall penetrations within the central basin area also display 8-15 ft. of hydrocarbon-charged dolomite with ≥4% porosity within the upper Stonewall Formation. Although the reservoir quality of the Stonewall may vary enough to make vertical well development difficult, there may be an adequate quality and quantity of hydrocarbon-charged reservoir to warrant horizontal well drilling exploration.

The Stonewall Formation was a late arrival to the Williston Basin in terms of becoming a commercial producer of oil and gas but it has yielded a number of very productive vertical wells. With only a couple dozen core samples collected and a rather limited spatial distribution, our geologic understanding of the Stonewall Formation is still in its infancy in comparison to many other oil and gas productive geologic formations. The Stonewall Formation will probably not become another historic Bakken-like oil play, but there is a good chance it will be one of many geologic formations to see additional exploration activity at some point in the future.

References:

Carlson, C. G., and Eastwood, W. P., 1962, Upper Ordovician and Silurian Rocks of North Dakota: North Dakota Geological Survey, Bulletin 38, 51 p.

Fuller, J. G. C. M., 1961, Ordovician and contiguous formations in North Dakota, South Dakota, Montana, and adjoining areas of Canada and United States: American Association of Petroleum Geologists Bulletin, v. 45, no. 8, p. 1334-1363.

Haidl, F.M., 1991, Note on the Ordovician-Silurian boundary in southeastern Saskatchewan, in Summary of Investigations 1991: Saskatchewan Geological Survey, Saskatchewan Energy Mines, Miscellaneous Report 91-4.

Johnson, M. E., and Lescinsky, H. L., 1986, Depositional Dynamics of Cyclic Carbonates from the Interlake Group (Lower Silurian) of the Williston Basin: Palaios, v. 1, p. 111-121.

Nesheim, T. O., 2014, Preliminary Examination of the Stonewall Formation's Stratigraphy and Organic-richness: North Dakota Geological Survey, Geologic Investigations 181.