Survey Publishes Drill Stem Test Maps to Aid in Exploration and Assessment of Williston Basin

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Introduction

The earliest commercial drill stem test (DST) was developed by brothers E.C. and M.O. Johnston in 1926 and remained the only method to test formation fluids and pressures until the 1950s when Schlumberger introduced the first wireline conveyed formation testing tool (Lewis, 1961). Drill stem testing thrived against its technological competition for several decades due to superior performance and reliability compared to early versions of the wireline-conveyed formation testing tools. DSTs have become far less common, but results contain valuable subsurface data.

Drill stem tests are conducted via a temporary completion of a targeted zone. The target zone is sealed off from the remainder of the wellbore with temporary packers. Once the packers are in place and the target zone is hydraulically isolated from the remainder of the wellbore, one or more valves are opened in order to produce formation fluids into the drill pipe and this temporary completion is allowed to flow for a period of time (fig. 1). Test duration can be less than an hour or up to several days depending on the objectives of the operator. Data obtained through DSTs, including fluid samples, reservoir pressure, formation property and productivity estimations (e.g. permeability and flow rate, respectively) are used by geologists and reservoir engineers to determine the most efficient way to develop a field (Borah, 1993). In the case of a negative test, operators can use the data to conclude whether their resources are better utilized elsewhere.

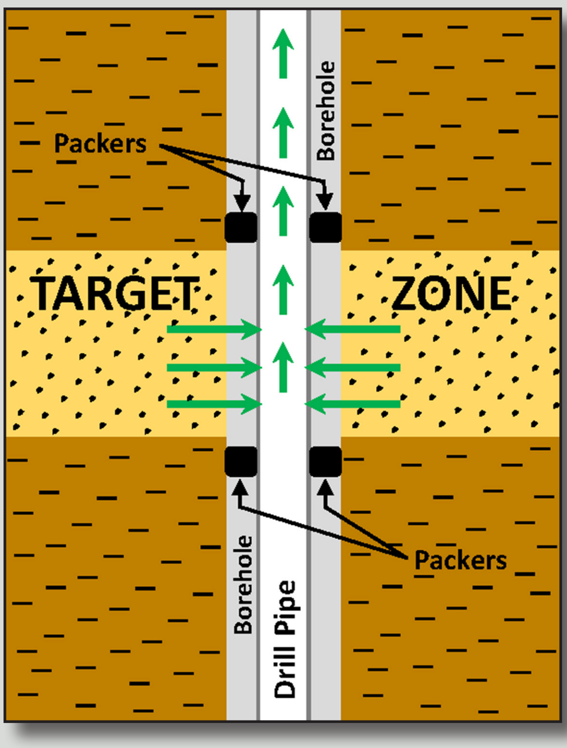


Figure 1. This representation of a drill stem test illustrates the target zone sealed off from the rest of the wellbore using packers, resulting in a temporary completion of the well. Fluid from the target zone (green arrows) is allowed to flow into the drill pipe for a period of time and measured.

Northern Ordinance ran North Dakota's first DST on their Franklin Investment Co. #1 well (API: 330290000100; NDIC: 16) in the summer of 1943 (NDIC O&G, 2020). Unfortunately, after the targeted Deadwood Formation produced only brackish (salty) water, the well was considered dry and later abandoned. Since the Franklin Investment Co. #1, nearly 20,000 DSTs (~13% of which are failed tests) have been run in approximately 8,500 wells across the state of North Dakota. However, over 55% of those wells did not have an associated geologic interval. Addressing the need for more accurate DST results, the North Dakota Geological Survey (NDGS) identified the geologic interval that was tested for over 95% of the wells and recently mapped and published DST results for the hydrocarbon-producing intervals in North Dakota's portion of the Williston Basin (Stolldorf, 2020).

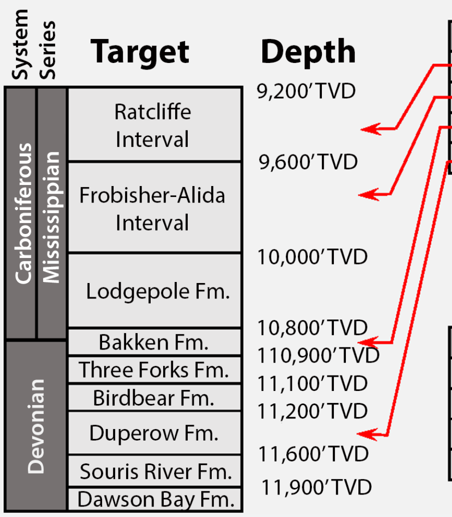
NDGS Bringing Clarity to DST Results

The NDGS utilized a series of filters in Petra® and Microsoft Excel® to unite and consolidate DST results with formation tops. Figure 2 illustrates the products of those filters throughout the three major phases of the project in order to give a high-level understanding of the processes involved. Initially the raw data is culled of misrun or failed tests (2A). Next, using the top and base depths from the test, unknown target intervals are linked to known formation tops to confirm a target interval (2B). Finally test results are interpreted and ranked based on the level of hydrocarbon indicators produced during the test (2C).

Test results were interpreted and separated into three groups. The first group, Positive DSTa, (+ DSTa) contains wells that have recovered oil or gas in either the drill pipe or the sampler (e.g. 12' black oil in pipe), or those that list oil or gas as the primary component of the fluid/gas mixture in the description (e.g. 10' mud cut oil). Wells from the second group, Positive DSTb (+ DSTb), include results where oil or gas was a minor component of the fluid/gas mixture (e.g. 50' gas cut mud). Although + DSTb wells do show signs of hydrocarbons, the hydrocarbon signal is considered weaker than those in the + DSTa group. Lastly, the third group

(A) Remove filed (misrun) tests from raw data to eliminate questionable results

TEST	WELL NAME	TARGET	TOP	BASE	COMMENTS
1	Frost #7	Unknown	9,405	9,491	60' Mud
~~2~~	~~Frost #7~~	~~Unknown~~	~~9,673~~	~~9,785~~	~~** MISRUN **, PACKER FAILED~~
3	Frost #7	Unknown	9,687	9,785	180' gas cut mud
4	Frost #7	Unknown	10,870	10,893	1000' water, 201' oil cut mud
~~5~~	~~Frost #7~~	~~Unknown~~	~~11,500~~	~~11,594~~	~~** MISRUN **, TOOL FAILED TO OPEN~~
6	Frost #7	Unknown	11,598	11,598	1668' BLACK OIL



TEST	WELL NAME	TARGET	TOP	BASE	COMMENTS
1	Frost #7	Unknown	9,405	9,491	60' Mud
3	Frost #7	Unknown	9,687	9,785	180' gas cut mud
4	Frost #7	Unknown	10,870	10,893	1000' water, 201' oil cut mud
6	Frost #7	Unknown	11,521	11,598	1668' BLACK OIL

(B) Join "Unknown" targeted intervals to known formation tops utilizing the top/base depth of tests to confirm target

TEST	WELL NAME	TARGET	TOP	BASE	COMMENTS
1	Frost #7	Ratcliffe	9,405	9,491	60' Mud
3	Frost #7	Frobisher-Alida	9,687	9,785	180' gas cut mud
4	Frost #7	Bakken	10,870	10,893	1000' water, 201' oil cut mud
6	Frost #7	Duperow	11,521	11,598	1668' BLACK OIL

(C) Rank DST results based on test recovery data.
+ DSTa - strong hydrocarbon indicator; **+ DSTb** - weak hydrocarbon indicator; **- DST** - no hydrocarbon indicator

TEST	WELL NAME	FORMATION	TOP	BASE	COMMENTS	RELEVANT RANKING CRITERIA	RANK
1	Frost #7	Ratcliffe	9,405	9,491	60' Mud	No oil or gas reported	- DST
3	Frost #7	Frobisher-Alida	9,687	9,785	180' gas cut mud	Gas as the secondary component of recovered fluids	+ DSTb
4	Frost #7	Bakken	10,870	10,893	1000' water, 201' oil cut mud	Oil as the secondary component of recovered fluids	+ DSTb
6	Frost #7	Duperow	11,521	11,597	1668' BLACK OIL	Oil recovered in drill pipe	+ DSTa

Figure 2. Visual representation of the methodology used in filtering and uniting DST results with recognized geologic intervals. It illustrates failed tests (read: bad data) being removed (A), the remaining data united with geologic intervals (B), and finally ranked (C).

consisted of Negative DST (- DST) wells that have no indication of hydrocarbons.

North Dakota's DST Maps Provide Critical Data for USGS Assessment, Future Exploration

In June 2020 the NDGS published a series of Geologic Investigations (GI) containing production-related maps and corresponding datasets (fig. 3). Drill stem tests from the following geologic intervals were mapped: Deadwood-Winnipeg (GI-230); Red River (GI-231); Stonewall, Stony Mountain, and Gunton (GI-232), Interlake (GI-233), Winnepegosis (GI-234), Dawson Bay (GI-235), Duperow (GI-236), Birdbear (GI-237), Bakken Petroleum System (Bakken, Three Forks, Sanish; GI-238), Madison Group (Ratcliffe, Frobisher-Alida, Lodgepole; GI-239), Tyler (GI-240), and Spearfish (GI-241). In conjunction with this project, wells containing hydrogen sulfide (H_2S) were also identified and mapped (GI-242) (Stolldorf, 2020). DST results often contain information about poisonous or corrosive compounds in the fluid mixture, of which H_2S is both. Thus, these data were made available to help facilitate safer operations as additional risk mitigation is required if a well is to be safely drilled and produced in areas containing H_2S.

As evidenced by the example in figure 2, multiple DSTs are often run in the same wellbore. Throughout most of the 20th century operators would drill exploration wells to the deepest target hoping to encounter other hydrocarbon-bearing intervals along the way. They would often test multiple targets to find the reservoir with the highest likelihood of success. Thus, a successful DST doesn't necessarily lead to the well being produced from that interval, as is the case in Figure 2C. A multitude of factors influence whether a well will be produced. Often, it is as simple as another reservoir within the same wellbore appears more productive. Nonetheless, the successful DST shows evidence of hydrocarbons and is valued data for anyone trying to assess the productivity of this interval.

The United States Geological Survey (USGS) is currently reassessing the undiscovered, technically recoverable oil and gas resources within the Williston Basin. In order to accomplish this task, USGS assessment team members use any available data to assess an area of interest (e.g. the Williston Basin). Typically, the data are limited to production and/or geologic data. However, DSTs can offer additional information that neither of the above can provide. DSTs can be mapped in conjunction with production and geologic data to more accurately identify areas where a given interval may be productive. Figure 4A shows an example of an oil play (Target A) where the play boundary is defined using production and geologic data (assume geologic data are the same for both 4A and 4B). In contrast, Figure 4B represents an expanded play boundary generated by incorporating production, geologic and DST data. In this example, an expanded play boundary could mean that there are additional areas for exploration and development in the target interval. Further, it provides a fundamentally more accurate estimate of the play boundary that can be utilized by the public, government agencies or private companies. Accurate estimates of the subsurface are difficult to obtain. Providing easily accessible data will benefit future assessments as well as help to rejuvenate some of North Dakota's less developed plays.

References

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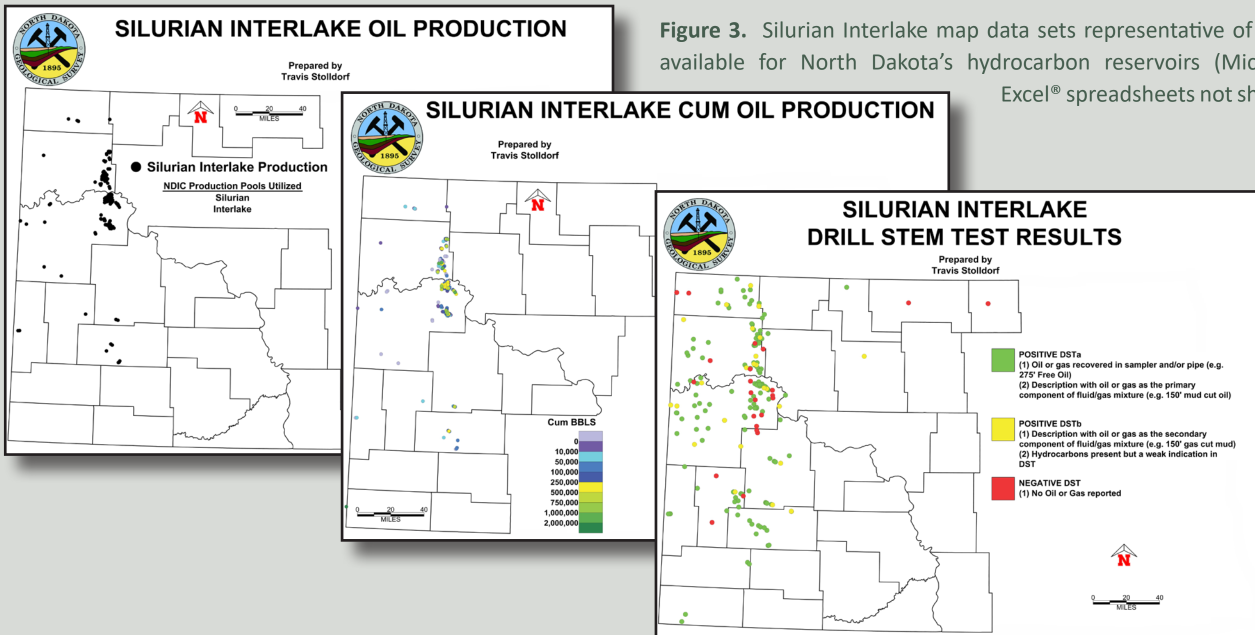

Figure 3. Silurian Interlake map data sets representative of those available for North Dakota's hydrocarbon reservoirs (Microsoft Excel® spreadsheets not shown).

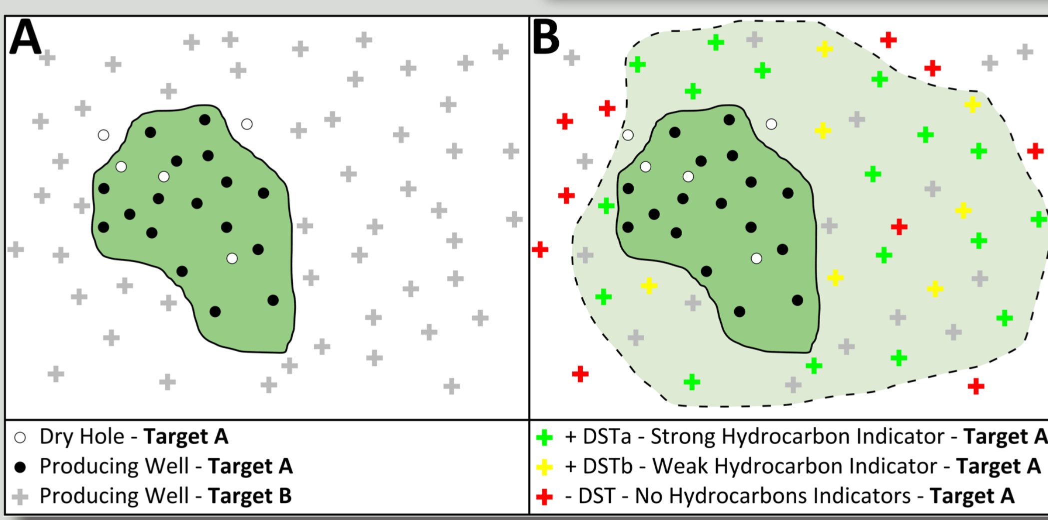

Figure 4. An example oil play with its play boundary defined by production and geologic data (A) compared to the same oil play with a play boundary created by integrating production, geologic and DST data (B). Wells represented by circles indicate wells that produced from Target A (black dot) or that were considered dry in Target A (white dot). Crosses represent wells that targeted a different reservoir for production (Target B). Ranked DST results (only in wells with DSTs from Target A) were added to accurately reflect areas where Target A displayed a strong hydrocarbon signal (+ DSTa = green cross), a weaker hydrocarbon signal (+ DSTb = yellow cross) or no hydrocarbon signal (- DST = red cross).