Where's the Oil?

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Introduction

Discussion abounds in the press about the unconventional resources of the Bakken Formation; the primary question raised is where is the oil stored? In an attempt to answer this question, the geologist has to revisit the conventional reservoir and examine how it works. In dealing with sedimentary rocks not every rock type is a potential reservoir. Some lack any kind of void space such as an evaporite (e.g. salt or an anhydrite). Although these are not reservoir rocks, they commonly help the oil reservoirs by stopping the upward movement of oil. The oil resides within the void space present within the rock. Potential reservoirs are found in sandstones, carbonates and now within the oil source beds themselves. Horizontal drilling with fracture stimulation allows the well to produce from finer-grained rocks with significantly smaller voids.

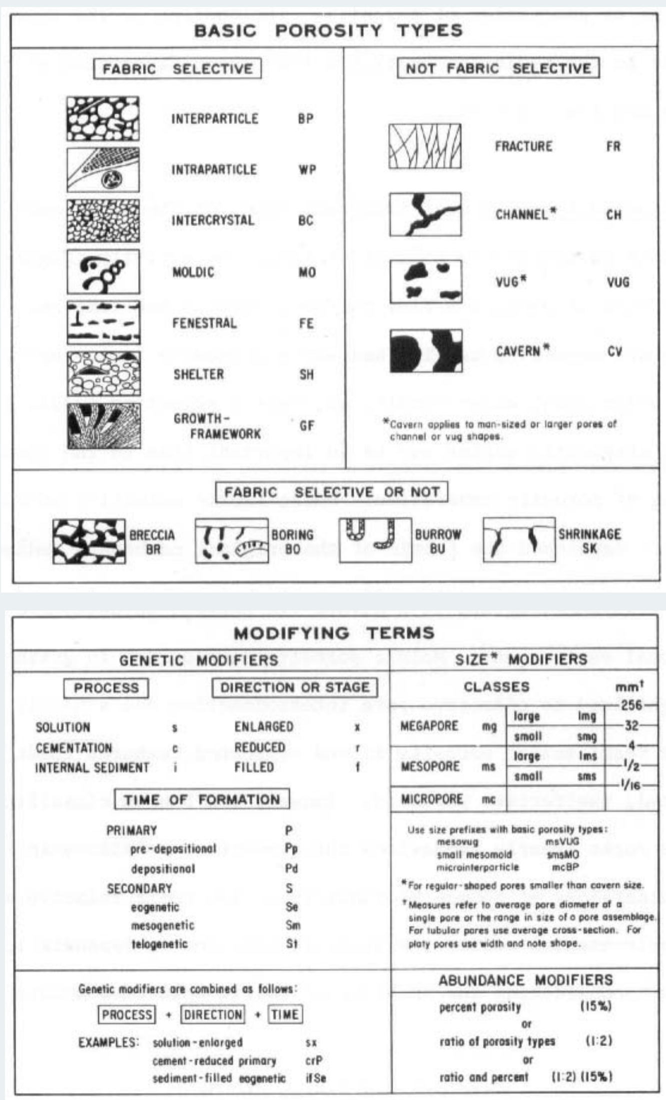


Figure 1. Classification of pore and pore systems in carbonate rocks from Choquette and Pray (1970).

Porosity

Porosity refers to the amount of void space present in a volume of rock. Although the porosity is not the entire story as to whether or not a body of rock will produce oil, it is one of the key components providing the necessary storage for the oil. As we shall see, there are methods to describe the characteristics of the various types of porosity from one rock to another enabling the geologist to more accurately model the oil reservoir. It is also a value that can be measured in the laboratory and used to determine the amount of oil in place.

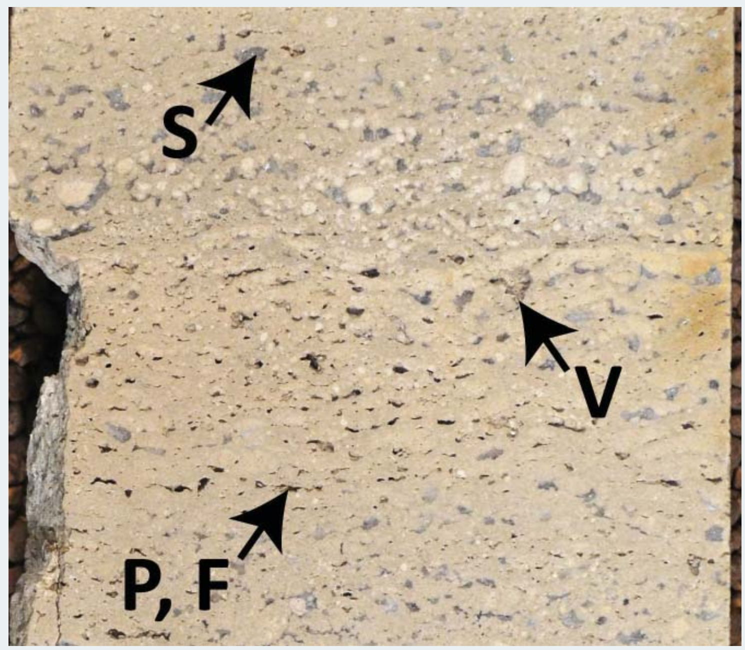


Figure 2. Photograph of a core sample from the Madison Formation in Keldon Oil Company – Cossette Ballantyne #1 (NENE Sec. 9, T161N, R81W) at 4019.5 ft. displaying examples of both "Primary" (P) and "Secondary" (S) porosity. Primary porosity is represented by a connected series of void spaces indicated by the "F." Secondary porosity is enhanced by dissolution and filled by later cement. The Vug (V) is an enhanced but not cemented pore. Width of sample is approximately four inches.

There have been a series of terms used by geologists to describe porosity over the years. "Primary porosity" described void space that was present following deposition. Sandstones are considered to have "primary porosity" with the only changes due to later cementation. However, in some cases porosity may increase when chemically unstable grains dissolve. Carbonate rocks are particularly susceptible to changes in porosity after deposition. When this happens "secondary porosity" develops. "Secondary porosity" is used to describe a rock where the "primary porosity" has been modified after deposition.

Figure 3. Photograph of a core sample from the Madison Formation in CNG Producing Company – Nelson #1-13 (SWSW Sec.13, T159N, R82W) at 4503 ft. showing the relationship of porosity and oil staining. The areas of the rock with abundant pores are heavily stained with oil. The localized areas that show visible pores that are filled with cement (secondary porosity) are not stained with oil. White scale bar represents 1 inch.

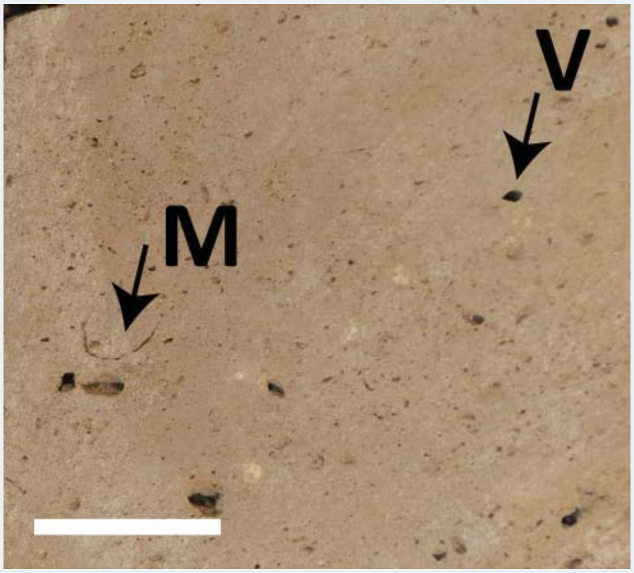


Figure 4. Photograph of a core sample from the Madison Formation in CNG Producing Company – Nelson #1-13 (SWSW Sec.13, T159N, R82W) at 4505.5 ft. displaying numerous pinpoint pores and slightly larger vugs (V) in a tan lime mudstone. Porosity is limited and not interconnected, so oil staining is absent. Note the example of moldic (M) porosity that results from the selective dissolution and removal of a shell fragment. White scale bar represents 1 inch.

Figure 5. Thin section photomicrograph of the Middle Member of the Bakken Formation from the EOG Resources - #2-36H Parshall (NWNW Sec. 36, T153N, R90W) at 9291.5 ft. The light blue color represents micro-intercrystalline porosity in an otherwise tight (non-porous) rock. Porosity present is measured analytically to be 7.6%. This is representative of an unconventional reservoir. This is in contrast to that of a conventional reservoir where the porosity is able to be viewed in a core sample without the aid of a microscope. (Scale bar = 100 microns, plane light, 10x).

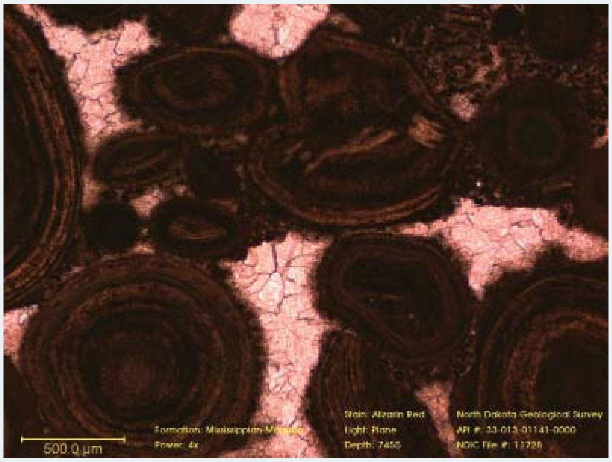


Figure 6. Photomicrograph showing well-developed interparticle porosity in the Madison Formation from the Meridian Oil Inc. – #13-13 Nordloef (NWSW Sec. 13, T159N, R91E) at 7455.0 ft. The well-developed primary porosity has since been filled with a late stage, "secondary," sparry calcite cement indicated by the pale pink Alizarin Red stain. (Scale bar = 500 microns, plane light, 4x).

Common terms in the literature describing porosity include interparticle (between particles), intercrystalline (between crystals) and interfragmental (between fragments). These terms become more descriptive with the use of modifiers such as pinpoint, moldic and vuggy or a size designation. A classification scheme was proposed by Choquette and Pray (1970) for the classification of porosity in carbonates. Because porosity can be created and destroyed multiple times within a carbonate, their classification system was designed to reflect the history of the rock. It provides the geologist with an excellent view of the processes that have affected the rock. The classification scheme was proposed for use with hand samples but has been expanded to include microscope and field studies.

A typical description of porosity within a rock or thin-section would include the time of origin, size and shape of the pore, one of the 15 basic pore types, and pore abundance (fig. 1). Seven of the 15 porosity types are dependent on rock type whereas the others may occur anywhere. The bulk of the pore space found is formed by interparticle (between), intraparticle (within), intercrystal, moldic, fenestral, and vug types (examples are shown in figs. 2-5). Other types are less abundant (figs. 6 and 7), and some are only useful in

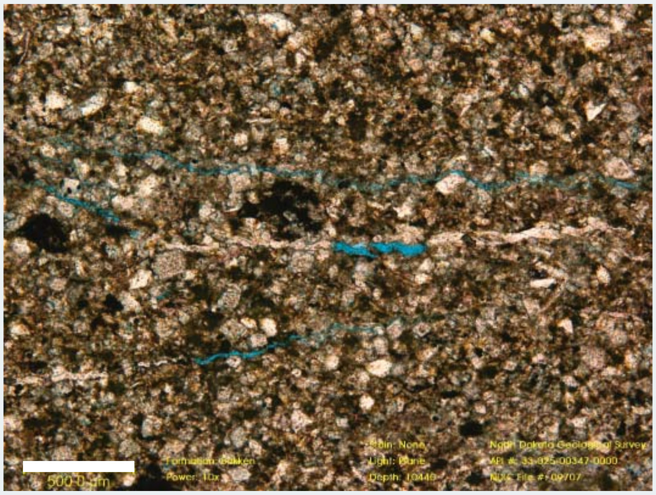


Figure 7. Photomicrograph of the Middle Member of the Bakken Formation from the Shell Oil Company – 32-4 Young Bear (SWNE Sec. 4, T148N, R92W) at 10440 ft. The photograph displays horizontal fracture porosity common to the Bakken Formation. Blue epoxy fills fractures in picture above. Fractures also show cementation along their length. An overall faint blue cast demonstrates the presence of micro-intercrystalline porosity. Measured porosity at this depth is 3.8%. (Scale bar = 500 microns, plane light, 10x).

the interpretation of facies. Some of these can help decipher the history and processes that have changed the rock.

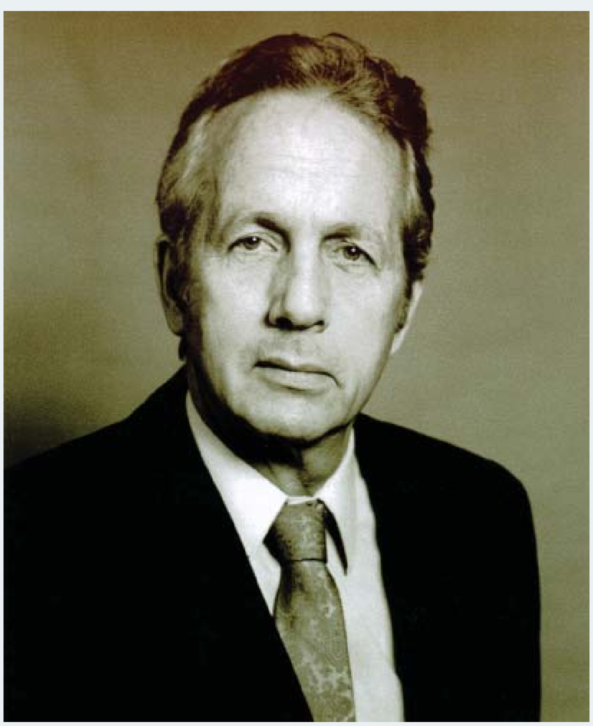
Conventional versus Unconventional

The ability to view and interpret the pore types in a conventional reservoir where data is visible without the use of a microscope prepares a geologist for work with unconventional reservoirs. Although many of the porosity types are the same for both types of reservoirs, the scale is significantly different. Unconventional reservoirs require the use of microscopes and other equipment that allows the geologist to study at the micro-scale. Oil is still stored in the fine-pore network, it is still able to be produced with proper technology, it has just required a change in methods for modeling an oil reservoir.

References Cited:

Choquette, P.W. and Pray, L.C., 1970, Geologic Nomenclature and Classification of Porosity in Sedimentary Carbonates: American Association of Petroleum Geologists Bulletin, v. 54, no. 2, p. 207-250.

Edwin (Ned) Austin Noble



Edwin Austin Noble passed away on January 3, 2013 at the age of 90. Ned was born in Bethel, Vermont on December 15, 1922, to Mary and John Noble. He had a lifelong interest in natural history and sports. While studying at Tufts University he was called to serve in the Army's First Infantry Division during World War II.

He returned to Tufts after the war where he met his wife Polly. He then studied at the University of New Mexico and received his PhD in Geology from the University of Wyoming. He explored for uranium on the Colorado Plateau for the Atomic Energy Commission and later in Argentina as a United Nations advisor to their uranium program.

Ned came to the North Dakota Geological Survey in 1965 and served as Assistant State Geologist from 1965 to 1969 and as State Geologist and Chairman of the Geology Department at the University of North Dakota from 1969 to 1977. After working for the NDGS, Ned went to work for the United States Geological Survey in Reston, VA, and spent five years working in Pakistan on a USAID energy resource program.

Ned is survived by Polly, his wife of 64 years, sons Bill (Colorado) and Jonathan (Tucson), daughter Mary (San Antonio), and granddaughter Andrea Stuen (Idaho).