

Forensic Analysis - Devonian “Blue Hole”, Mayogiak J-17, Tuk Peninsula, NWT, Canada.

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Summary:

The “Blue Hole” is one of the most intriguing phenomena in the carbonate realm. In the modern world “Blue Holes” occur worldwide in the thousands so they are a more common feature than subsurface geoscientists might expect. It is for this reason that it is surprising that none have been recorded in the subsurface – but perhaps they have gone unrecognized! This study documents the penetration of a “Blue Hole” in the Devonian of the Tuktoyaktuk Peninsula, NWT – the IOL Mayogiak J-17 drilled in 1971.

Introduction:

A “Blue Hole” is first an indication of cave formation during a relative sea level drop, followed by flooding of the cave system during sea level rise. Seen from the air the “Blue Hole” is a dark blue deep hole in an azure sea, hence its name. Some features on land have also been termed “Blue Holes” because they are water-filled cave openings which have broken to the surface. These land features are also referred to as “Black Holes”, Cenotes and Sinkholes. True marine “Blue Holes” may have modern reef coral biota near to their hole margins. Tidal exchange in such locations can be quite strong, thereby providing the nutrient supply and oxygenation needed by the corals in an otherwise quieter shelf environment. Storms and tides result in muds, sands and skeletal remains being washed into the “Blue Hole” and incorporated in the cave fill. Recognition of cave breccias in association with extant biologic remains in the fill are significant parameters to assist identification of a “Blue Hole”. Most recently a new criterion has been added to the list of identifiers. It has been documented in the Bahamas (National Geographic, 2013) (Illiffe, 2013) that where marine water is overlain by freshwater in some terrestrial “Blue Holes”, a significant interval of hydrogen sulphide-rich water occurs at the transition. This interval is termed a halocline. Associated with the halocline can be hydrogen sulphide-compatible bacteria in such density that little light passes through the interval, and visibility in the interval is greatly diminished. In addition microbial mats of as much as 2.5 cm. thickness have been observed to line the walls and breccia blocks. The mats can be peeled off in large sheets. These relationships identify very meaningful criteria for ancient “Blue Hole” halocline occurrence, especially in combination with other cave criteria.

Mayogiak Data and Analysis:

This Mayogiak J-17 example is the first documentation of pyritized microbial mats in a Devonian cave system which can be related to the former existence of a halocline within that system followed by full marine flooding and occurrence of a “Blue Hole” at the sea floor.

The Mayogiak core was initially logged by H. Wielens (GSC, 1988) and it was his work that drew my attention to the core. The published descriptions did not seem to be consistent with the core. The core occurs over an interval of 331 ft. (100.91 m.) within the Landry Formation. 107 ft. (32.62 m.) of the interval (9490 – 9383 ft, 2893.29 – 2860.67 m.) returned no samples. This missing interval, on logs and in the few samples recorded, appears to consist of clay and carbonate blocks or chips consistent with the history of the in-fill. Oil shows in the well have been significant (CanStrat log). They begin in the core at 9638 -9594 ft (2938.41- 2925 m.) ft. as "...dead oil..." overlying a "...gassy, muddy, water..."- bearing interval. Upsection from 9586 ft. (2922.56 m.) to 9565 ft. (2916.16 m.) "...oil stain..." is common. From 9523 – 9490 ft. (2903.35 – 2893.29 m) "...good oil shows..." are indicated. Strong oil on DST came from 9582 – 9395 ft. (2921.34 – 2864.33 m.) in the interval of no sample returns. 9300 ft. of "...oil and gas ..." are reported. Subsequent calculations of oil occurrence have indicated potential flow rates of 4000 bo/d. AANDC (1995) estimates reserves at less than 10 Million barrels.

The upper portion of the interval of dead oil coincides with the pyritized mats coating the breccia surfaces. It was my interpretation initially that this could represent a "tar mat" at the base of the oil-filled reservoir. I considered the base of the "tar mat" to record an early oil–water contact and the present transition from the dead oil to the oil shows to be a current oil-water contact. The pyritized zone was interpreted to have been the result of sulphide precipitation within that "tar mat" interval. However, because of the fabric and texture of the pyritized zone this interpretation was deemed to be a less than satisfactory one. With the recent discovery of microbial mats in the hydrogen sulphide-rich halocline of the Bahaman "Blue Holes" the data observed in Mayogiak are now understandable.

Utilizing the high-quality core, CanStrat log and the well files the following generalized description is presented from interval base to top. The Devonian Emsian/Eifelian Landry Formation, being essentially limestone, overlies and is laterally equivalent to the Arnica Formation dolomite (top 11510 ft, 3509.15 m) of similar age. Arnica Formation dolomites at the base represent dominantly supratidal carbonates (sabkha) and the Landry represents those laterally equivalent intertidal and shallow subtidal carbonates. The Landry (top 9375 ft, 2858.23 m) consists of numerous cycles of shallowing upward deposits in a progressively deepening setting, followed later in the mid-Landry (11510 ft - 10460 ft, 3509.15 - 3189.02 m) by overall shallowing and increasing energy conditions. Amphipora, trace stromatoporoid debris, brachiopods and pelletal muds are the most common in the early cycles. This mid-section shallowing is associated with bulbous stromatoporoids, isolated solitary corals, amphipora, crinoids, and brachiopods becoming more common. In addition the carbonates become interbedded with dolomitic and dolomite lithologies characteristic of intertidal and supratidal deposits. The section above 10460 ft (3189.02 m) then deepens again to pelletal mudstones which are followed by shallowing cycles incorporating an increasingly diversified assemblage of biota: Amphipora, Thamnopora, Stromatoporoid debris, bulbous Stromatoporoids, Stachyodes, crinoids, brachiopods, and both tabulate and septate corals. Supratidal sediments top the sequence (9375 ft, 2858.23 m). A thin capping layer of transgressive conglomeratic carbonate and clays (8 ft, 2.44 m) are overlain by the ultimate Cretaceous shales.

The cored interval begins at the base in units "1" and "2" fractured country rock. This is overlain upsection at 9620 ft. (2932.93 m) by 18 ft (5.49 m) of unit "3" brecciated in-fill which transitions upwards to units "4" to "7", an interval of strongly pyritized microbial mats lining the breccia blocks and displaying geopetal

relationships relative to those blocks. The section then passes upwards into unit “8” consisting of 8 ft (2.44 m) of breccia debris which includes subtidal and supratidal blocks with calcite-after-anhydrite/gypsum nodules. Units “9” to “11” record 36 ft. (10.98 m) of breccia blocks of all sizes and of typical country rock mixed with in-filling amphipora muds. Toward the top of the interval are found bulbous stromatoporoids. The overlying 46 ft. (14.02 m) of unit “12” consists of brecciated country rock intervals with both open and filled cavities between them. Overlying this interval are 14 ft (4.27 m) of unit “13” and “14” brecciated blocks with distinctive light brown clay fill in the interstices. This brown clay interval is overlain by the 107 ft. (32.62 m) interval (unit “16”) of essentially no recovery. Dark brown, grey and black clays, and carbonate stringers/blocks occur in this interval. Eight ft. (2.44 m) of dolomitized unit “15” supratidal rock and final in-fill of the remaining cavern (unit “16”) caps off the whole sequence, above which are 4 ft (1.22 m) of conglomeratic carbonate (unit “17”) mixed with and overlain by unit “18” dark grey to black clays of deeper water Cretaceous age..

Mayogiak Interpretation:

Significant terrain uplift occurred during later Frasnian and Famennian time in and northwest of the British and Barn Mountains regions to the southeast. This uplift records Ellesmerian Orogeny tectonics which occurred during post-Devonian and pre-Permian time (Wielens, 1988). This Orogeny may account for the uplift, subaerial exposure, and cave formation within the Arnica/Landry sequence. Regardless of “how”, the uplift and cave formation did occur (units “1” and “2”) associated with at least a 245 ft. (74.5 m.) tectono-eustatic sea level fall. Early cave muds and breccia (unit “3”) were deposited on the cave floor. It is not clear how much initial water, or its salinity, was in the cave. Early marine waters began flooding the cave. A hydrogen sulphide-rich halocline analogous to those Bahaman occurrences subsequently formed at the interval of mixing of those marine waters and the overlying fresh waters. Microbial mats formed at that time and became pyritized diagenetically at some later time (units “4” to “7”). Gradually the fresh water lense was replaced by marine waters as tectono-eustatic sea level began to rise. Breccia blocks of supratidal to subtidal origin and country rock accumulated on the cave floor (unit “8”). The occurrence of the calcite-after-anhydrite/gypsum is an interesting twist for discussion. As sea level continued to rise the occurrence of amphipora and bulbous stromatoporoid muds (units “9” to “11”) suggests the formation of shallow reefs at the mouth of the now true “Blue Hole”. Breccia blocks continued to accumulate in the marine water-filled cavern (unit “12”). Units “13” and “14” suggest coastal progradation as the light brown clays were potentially sourced from adjacent and newly eroded subaerial carbonate terrain. At the same time supratidal sediments were forming at the cavern mouth, as unit “15”. The cavern was still not completely filled by this time but that filling was finally accomplished with the dark shales of possible Permian, Jurassic or Cretaceous age. Such age is yet to be determined, if such is even possible. The whole sequence is capped by a conglomeratic interval (unit “17”) and basinal clays (unit “18”) in response to significant sea level rise and basin deepening.

Conclusions:

New data from modern studies have permitted improved closure to the interpretation of the sequence in the Mayogiak well. Recognition of halocline occurrence and microbial mats associated with such hydrogen sulphide-rich zones has permitted interpretation of an unusual occurrence of pyritized “mats” in the Devonian. Cave formation is well recorded. Future exploration models will have to take such interpretations into consideration. A great deal of extremely useful high quality information is available in the files at the Calgary core facility of the Geological Survey of Canada.

One point to note is that the Paleozoic sections in the Tuk Peninsula are overlain by Cretaceous shales according to Geological Survey findings. The related erosional unconformity probably has a composite erosional history. Rift-margin uplift and erosion of the area occurred in association with the Jurassic break-up unconformity related to subsequent rifting and spreading during formation of the present Canada Basin. Such a compound history may play havoc with the historical sequence and might shift the cave formation in time. The process will remain the same.

References

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Pyritized microbial mats lining Devonian breccia blocks, Mayogiak J-17, Tuk Peninsula, NWT



Abaco Blue Hole, Bahamas. Microbial mats on cave walls within halocline zone. National Geographic Daily News, Internet, 2013.

