Frontiers + Innovation
2009 CSPG CSEG CWLS CONVENTION • CALGARY, ALBERTA, CANADA

A Thin Section Petrographic Study Examining Biogenic Porosity Alteration Within the Avalon and Ben Nevis Formations, Whiterose Field, Offshore Newfoundland, Canada

Andrew M. W. Lawfield*, Murray K. Gingras, S. George Pemberton
Department of Earth & Atmospheric Sciences, 1-26 Earth Sciences Building, University of Alberta, Edmonton, Alberta, T6G 2E3, Canada.
Lawfield@ualberta.ca
and
Karl E. Butler
Geology Department, University of New Brunswick, P.O. Box 4400, Fredericton, New Brunswick,
E3B 5A3, Canada.

Summary

The impact of biogenic porosity alteration is being increasingly noted. Within the Whiterose reservoir it is one contributory factor towards the generation of marked local porosity heterogeneities. In addition, the original physical and biogenic signatures have been overprinted by frequently abrupt calcite cementation fronts of variable intensity and extent, as well as concretions. These features locally mask the original sedimentologically and ichnologically derived depositional porosity variation.

Introduction

Awareness of the influence and importance of ichnological activity as an agent of porosity and permeability alteration is becoming increasingly widespread (e.g. Gingras et al, 2004, Pemberton and Gingras, 2005). The expansion of this field of research and consequent greater recognition of localized porosity heterogeneities has considerable potential for the refinement of reservoir models that previously relied on the assumption of uniformly homogenous permeability properties.

The results presented in this study focus on Cretaceous strata from the Avalon (Barremian-Aptian) and Ben Nevis (Aptian-Albian) formations encountered within the Whiterose Field, Jeanne D'Arc Basin, offshore Newfoundland, Canada. These formations have previously been the subject of limited ichnological research focusing on the adjacent Hibernia Field (e.g. Spila 2005) and have also received some petrographic study in the Whiterose field, with Ferry (2005) investigating the relationship of grain size and porosity whilst Norman (2006, and references therein) provides a broader overview of the formation's thin section petrology focusing on the cementation and broader diagenetic history.

Method

Core from nine wells within the Whiterose reservoir was logged, with details of sedimentology, ichnology and both the extent and degree of cementation being recorded. Representative regions of core were then sampled for subsequent petrographic analysis.

Thin sections were prepared with resin impregnation to highlight porosity and examined using a petrographic microscope. Regions of interest were subsequently imaged using a PixeLINK PL-A623 digital camera, mounted on a Nikon “Eclipse, E600 POL” polarizing microscope. The images were taken at a magnification of 40x, providing a field of view of 3 mm. The images were then partitioned according to regions of contrasting porosity, such as burrow mantle, core and surrounding matrix. Porosity values for each region were subsequently derived by point counting using the image analysis software JMicroVision V1.2.7 (Roduit, 2008).

Examples

The activities of infaunal organisms within the nascent Whiterose reservoir led to a number of alterations to the sediments textural properties that could influence reservoir volume and potentially influence tortuosity, flow pathways and strategies for optimal recovery. The textural alteration includes elements of cryptic bioturbation in which primary physical sedimentary structures are largely retained, sediment mixing in otherwise heterolithic strata and also localized partitioning into regions of variably porous silt and/or sand dominated burrow fills that contrast with the adjacent matrix. These correspond to the nonconstrained textural heterogeneities, weakly defined textural heterogeneities and cryptic bioturbation effects outlined in Pemberton and Gingras (2005).

Thin section petrographic analysis reveals that porosity varies both dramatically and abruptly from the millimetre scale upwards. Porosity heterogeneities are observed as a consequence of factors that include bioturbation (Fig 1A-D), with both primary (selective grain emplacement and alignment) and secondary (diagenetic and differential cementation effects) being noted. These properties are particularly apparent amongst burrows that exhibit a zoned fill, where the core and mantle display distinct porosity properties (Fig. 1C and D), as well as in burrows with a simpler burrow lining. Differential cementation is also present independently of any association with biogenic activity, the presence of sharp cementation fronts being locally observed. Thin section analysis of both bioturbated and ichnologically depauperate intervals reveals porosity variation locally exceeding 20% and this variation frequently occurs across abruptly bounded margins (Fig. 1E).

Evidence for sediment compaction and pressure solution is extensive and includes stylolites, as well as concavo-convex and sutured grain contacts that are present in both silicate grains and carbonate allochems (Fig. 1F). Selective dissolution of aragonite fossil material is observed, including complete dissolution of some fully aragonitic bivalves and gastropods (Fig.1G), as well as partial dissolution of serpulid tubes. The dissolution of aragonitic shell material has been invoked by authors including Norman (2006) as a possible source for the subsequently precipitated calcite cementation. Deformation and dissolution of carbonate bioclasts indicates localized compaction, ranging up to as much as 40% for some serpulid material (Fig. 1H).

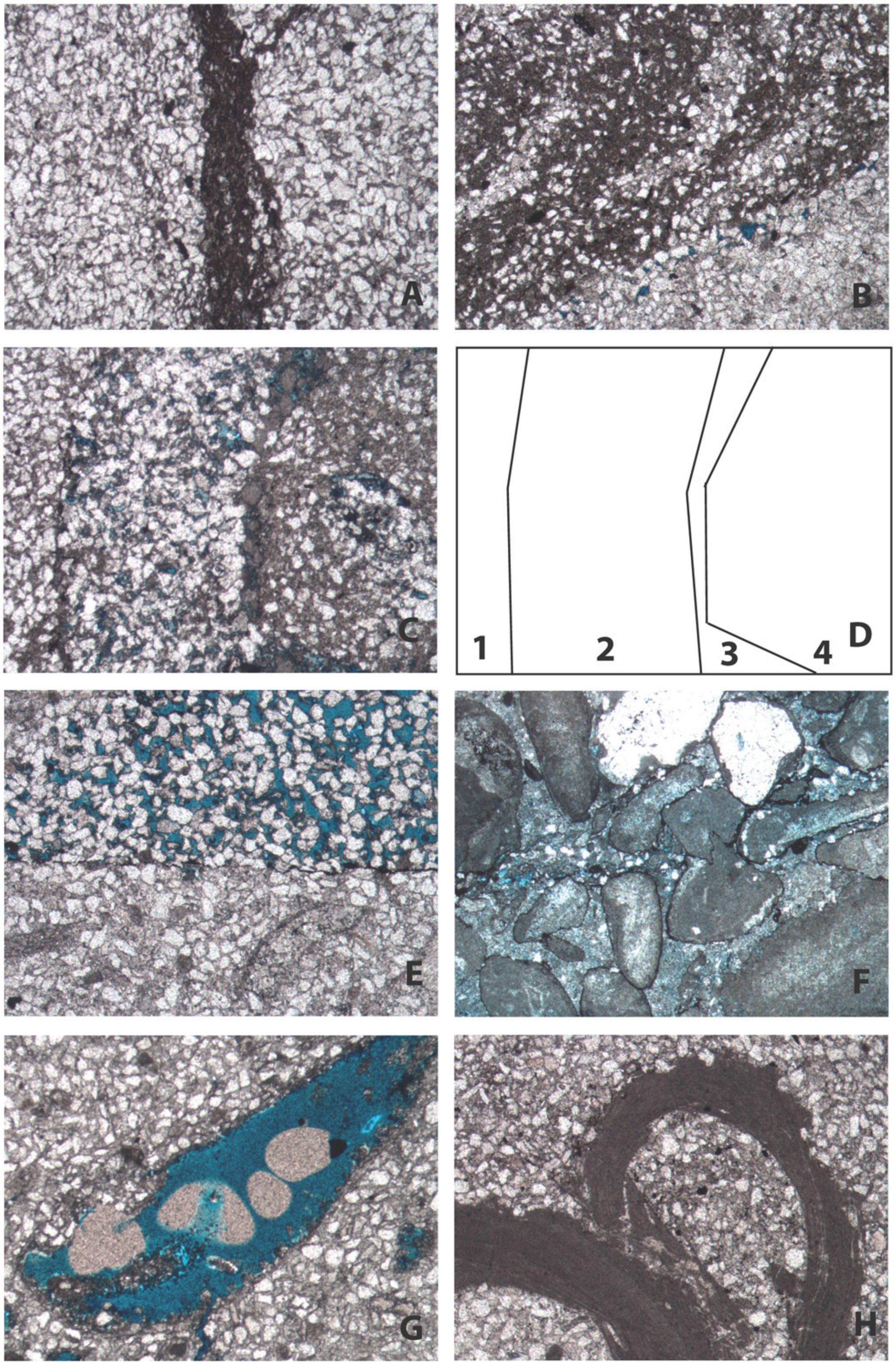
A
B
C
1
2
3
4
D
E
F
G
H

Figure 1: Porosity variation exhibited in thin section. All thin sections are from the Whiterose reservoir, were imaged with transmitted, plane polarized light and have a width of 3mm. Thin sections are unstained, but have been impregnated with blue resin to highlight porosity. A) J-49 3110.70m. Burrow margin, illustrating coarser, more angular sand burrow fill to the right of a mud burrow lining and a finer matrix to the left. B) A-17 2940.85m. Muddy burrow fill exhibiting spreite that are defined by interlayered siltstone and fine-grained, low porosity sandstone layers. Also note increased (5%) porosity along the contact with adjacent sandstone matrix at lower right of image. C and D) J-49 3109.45m. Large burrow cross section (C) and interpreted overlay (D). Illustrating low (0%) porosity matrix (1), high (8%) porosity burrow mantle (2), outer core of 17% porosity (3), and inner core exhibiting a mean porosity of 2.5% (4). E) J-49 3104.35m. Abrupt contact between low and high (23%) porosity sandstone, note the presence of an insoluble stylolitised residue along the boundary, the total occlusion of porosity below this juncture and the high interconnectivity displayed within the porous zone. F) E-18-1 4183.08m. Stylolite cross-cutting a sandstone which is characterized by both concavo-convex and sutured grain contacts. G) B-074 3933.60m. Mouldic porosity after high-spired gastropod, illustrating complete dissolution of original shell material following infilling of chamber with micrite. H) H-20 Core Plug Number 101. Serpulid tubes displaying fracturing associated with compaction of the sandstone matrix and loss of outer margin of shell material by pressure solution.

Conclusions

Biogenic activity is one of a number of processes that may impact the porosity and permeability properties of a reservoir. The behaviour of infaunal organisms may result in either sorting or mixing of sediment, the former leading to partitioning by grain size and other physical grain parameters. In the case of the Whiterose reservoir this leads to minor localised textural heterogeneities.

Of greater significance within the studied Ben Nevis and Avalon formations, the original porosity variations created as a consequence of primary depositional fabrics, have been overprinted by a complex and locally variable array of post-depositional diagenetic signatures that include compaction, the dissolution of aragonitic shell material, and subsequent cementation processes that are locally intense and generally of calcitic composition.

Acknowledgements

The authors would like to acknowledge the contribution of the following individuals and thank them for their input to this project. Ian Sinclair and colleagues at Husky Energy. Dave Mills of the Canada-Newfoundland and Labrador Offshore Petroleum Board (CNLOPB). Thin sections were prepared by Ancel Murphy and Calvin Nash at the University of New Brunswick. Initial stages of this research were funded through the Pan-Atlantic Petroleum Systems Consortium (PPSC), endowed by the Atlantic Innovation Fund (AIF) and benefited from the advice of both Ron Pickerill and David Keighley.

References

Ferry, M.P., 2005, An evaluation of the sedimentology and the influence of grain size and facies on permeability for the White Rose A-17 cored interval, White Rose oilfield, offshore eastern Newfoundland. Unpublished M.Sc. thesis. Memorial University, St Johns, Canada 227 pp.

Gingras, M.K., Mendoza, C.A., and Pemberton, S.G., 2004, Fossilized worm burrows influence the resource quality of porous media. AAPG Bulletin, **88**, 875-883.

Norman. L.S., 2006, Origin, distribution and paragenetic sequence of carbonate cements in the Ben Nevis Formation, White Rose Field, Jeanne d'Arc Basin, offshore Newfoundland, Canada. Unpublished M.Sc. thesis. Memorial University, St Johns, Canada 216 pp.

Pemberton, S.G., and Gingras, M.K., 2005, Classification and characterizations of biogenically enhanced permeability: AAPG Bulletin, **89**, 1493-1517.

Roduit, N., 2008, JMicroVision: Image analysis toolbox for measuring and quantifying components of high-definition images. Version 1.2.7. Software available for free download at http://www.jmicrovision.com/ accessed October, 2008.

Spila, M.V., 2005, Application of ichnology in the paleoenvironmental reconstruction and reservoir characterization of the Avalon and Ben Nevis formations, Hibernia Field, Jeanne d'Arc Basin, Grand Banks of Newfoundland. Unpublished Ph.D. dissertation. University of Alberta, Edmonton, Canada 188 pp.