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Mud Volcanism and the Origin of Green Shales in the Devonian Swan Hills Formation, Alberta, Canada

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Summary

The repetitive occurrence of terrigenous shale horizons in otherwise prolific carbonate banks, offshore buildups, or isolated platforms is problematic. Despite numerous explanations for the occurrence of such shale in typically healthy carbonate environments, the causal relationship between events that suspended carbonate production and shale deposition remains a subject of ongoing debate. Interpretations often hinge on whether shale actively inhibited carbonate production or merely reflects the background accumulation of terrigenous clay during hiatuses in carbonate production. The Devonian Swan Hills reef complex in west-central Alberta is one such example of a highly productive biogenic carbonate factory interspersed with several fine-grained green shale horizons.

Results, Observations, Conclusions

At the Swan Hills buildup, green-grey calcareous to dolomitic argillaceous shale is observed as massive to mottled beds, however, more commonly presents as sheet cracks, thin stringers, geopetal fillings in primary and secondary solution pores, matrix fills, and as thin irregular layers along stylolites. Hypotheses for green shales are as varied as storm deposits (Wendte and Stoakes, 1982; Wendte, 1992; Wendte and Muir, 1995), eolian deposits (Chow and Wendte, 2011), paleosols and karsts (Murray, 1966; Havard and Oldershaw, 1976; Walls and Burrows, 1985; Packard and Hills, 2001; Wendte and Uneyo, 2005; Chow and Wendte, 2011), sedimentation in remnant ponds (Murray, 1966; Leavitt, 1966; Fischbuch, 1968), residual concentrations along stylolites and dissolution seams. Through core examination, petrography and geochemical analysis, this study proposes a new model which reinterprets green shale from the above processes to a coproduct of dolomitizing and potentially non-dolomitizing fluids.

The terrigenous clays are suggested to be sourced from underlying clastic formations, in particular, the Watt Mountain Formation, and advected upwards alongside a mixture of carbonate mud, organic matter, pyrite and carbonate debris which accumulated onto the reef environment through hydrothermal mud volcanism.

Advection and extrusion of such green shale slurries were associated with NW-SE trending basement faults that initiated buildup nucleation on the widespread platform and acted as an important segment of a large hydrothermal convection cell driven by regional tectonism. In addition to being reducing and toxic, these gaseous slurries were episodic in nature, acting in a fault-valve type manner, and resulted in the diverse depositional spectrum of green shale across various facies, diagenetic environments and stratigraphic intervals. The hydrothermal mud volcanism model thus provides a new and testable explanation for the origin, transportation, sedimentation and diagenetic transformations of green shales in the Devonian succession of the Western Canada Sedimentary Basin.

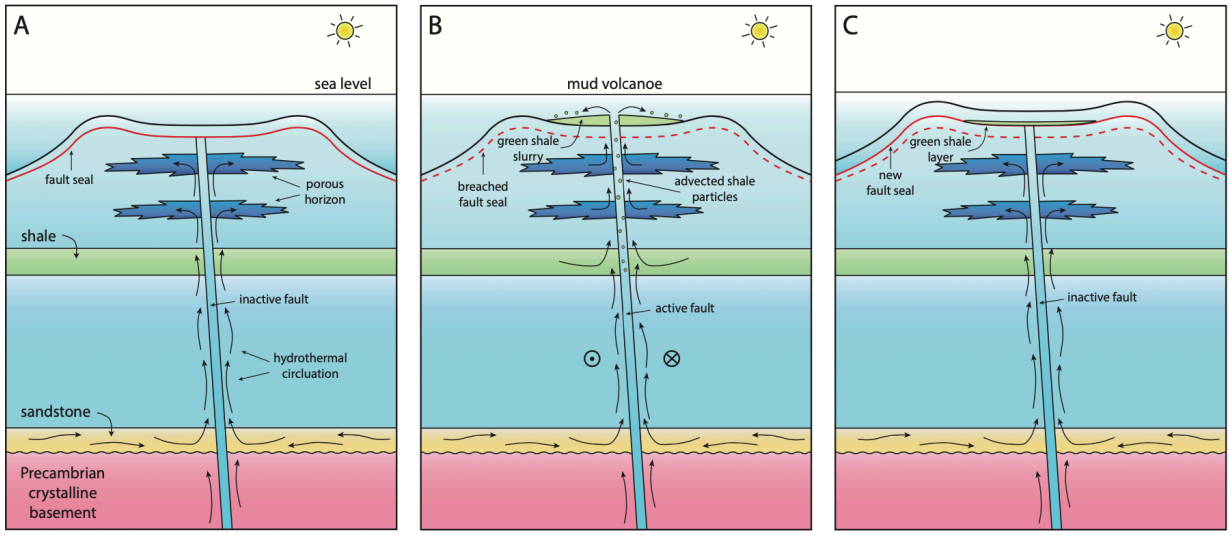

Figure 1. Hydrothermal mud volcanism model for advection of green shale and other material from subsurface sources along fault conduits and extrusion onto the sea floor via mud volcanoes. A) sealed fault conduit during tectonic quiescence. B) Breached fault conduit during tectonic disturbance. C) Sealed fault conduit during renewed tectonic quiescence.

References

Chow, N. and Wendte, J. 2011. Paleosols and paleokarst beneath subaerial unconformities in an Upper Devonian isolated reef complex (Judy Creek), Swan Hills Formation, west-central Alberta, Canada. Sedimentology (2011), v. 58, p. 960-993.

Fischbuch, N.R. 1968. Stratigraphy, Devonian Swan Hills reef complexes of Central Alberta. Bulletin of Canadian Petroleum Geology. V. 16, no. 4 (December 1968), p. 446-587.

Havard, C.J. and Oldershaw, A. 1976. Early diagenesis in back-reef sedimentary cycles, Snipe Lake reef complex, Alberta. Bulletin of Canadian Petroleum Geology, v. 24, p. 27-69.

Leavitt, F.M. 1966. The petrology, paleontology, and geochemistry of the Carson Creek North reef complex, Alberta. Unpublished, Ph.D. Thesis, University of Alberta, 153 pp.

Murray, J.W. 1996. An oil producing reef-fringed carbonate bank in the Upper Devonian Swan Hills Member, Judy Creek, Alberta. Bulletin of Canadian Petroleum Geology, v. 14, p.1-103.

Oldale, H.S., and Munday, R.J. 1994. Devonian Beaverhill Lake Group of the Western Canadian Sedimentary Basin. In: Geological Atlas of the Western Canadian Sedimentary Basin. G.D. Mossip and I. Shetsen (comps.). Canadian Society of Petroleum Geologists and Alberta Research Council, Calgary, p. 149-164.

Packard, J.J. and Hills, D. 2001. The importance of early (penecontemporaneous) meteoric diagenesis in the development of limestone porosity in the “platform” of the Devonian Swan Hills Formation. Rock the Foundations Convention, Calgary, Alberta, Canadian Society of Petroleum Geologists, p. 27-127.

Viau, C.A. 1986. Diagenesis, sedimentology and structure of the Swan Hills Formation, Swan Hills field, central Alberta, Canada: Ph.D. thesis. University of Calgary, Alberta Canada, 574 p.

Wendte, J.C. 1992. Overview of the Devonian of the Western Canada Sedimentary Basin: A Sequence Stratigraphic Framework. J.C. Wendte, F.A. Stoakes, and C.V. Campbell. Society for Sedimentary Geology, Short Course Book 28, p.1-24

Wendte, J.C. and Muir, I. 1995. Recognition and significance of an intraformational unconformity in the late Devonian Swan Hills reef complexes, Alberta. In: Unconformities and Porosity in Carbonate Strata. D.A. Budd, A.H. Saller, and P.M Harris (eds). American Association of Petroleum Geologists, Memoir 63, p. 259-278.

Wendte, J.C. and Stoakes, F.A, 1982. Evolution and corresponding porosity distribution of the Judy Creek reef complex, Upper Devonian, central Alberta. In: Canada’s Giant Hydrocarbon Reservoirs, Core Conference Manual. W.G. Cutler (ed.). Canadian Society of Petroleum Geologists, p. 63-81.

Wendte, J.C. and Uyeno, T. 2005. Sequence stratigraphy and evolution of Middle to Upper Devonian Beaverhill Lake strata, south-central Alberta. Bulletin of Canadian Petroleum Geology, v. 52, p. 250-354.