AAPG Datapages/Search and Discovery Article #90283 © 2016 SEPM – AAPG Hedberg Research Conference, Mudstone Diagenesis, Santa Fe, New Mexico, October 16-19, 2016

The Ordovician Toyen Shale, and its Eight Steps through diagenesis - an Overview

Sven O. Egenhoff[1] and Neil S. Fishman[2]

[1] Colorado State University, Fort Collins, Colorado, USA
[2] Hess Corporation, Houston, Texas, USA

ABSTRACT

The Lerhamn core, drilled in south-western Scania, southern Sweden, contains an approximately 70 m thick succession of the Early to Middle Ordovician Teyen Shale. The succession was deposited in an outer shelf environment, likely below storm wave base based on a lack of wave-induced sedimentary structures. The unit consists entirely of siliciclastic mudstones with varying amounts of diagenetic carbonate, phosphatic, siliceous, and sulfide cements. Prior to this study, diagenetic phases in this unit and their temporal relationships had not been described even though the Teyen Shale as well as the underlying Alum Shale have the potential to be good source rocks and unconventional reservoirs. In addition, the nature and temporal relationships of diagenetic cements in the Teyen were considered relative to those in the underlying Bjerkasholmen Formation and overlying Huk Formation (both carbonate rocks) to evaluate the role, if any, in interformational fluid flow as it bears on Teyen diagenesis. Seven temporally distinct diagenetic phases have been observed in the Teyen, as determined from petrographic and SEM observations on thin sections (n = 53). Based on paragenetic relations between authigenic phases, the earliest-formed diagenetic mineral was chalcedony that exclusively exists as a cement within roundish organic-shelled microfossils and comprises less than 1 vol% of the rock based on visual estimations. In tum, the chalcedony is variably replaced by the paragenetically earliest generation of calcite observed in the Teyen (Calcite 1). The chalcedony-calcite 1 cemented microfossils are preserved inside of centimeter-scale phosphatic concretions, with phosphate mineralization representing the third diagenetic mineral to have formed in the Teyen. Fractures in the phosphatic concretions are rare, but where present they are filled with a coarsely-crystalline calcite (Calcite II); this generation of calcite clearly post-dates phosphate precipitation. Additionally, small phosphate crystals line the perimeter of presumed primary intergranular pores, and these pores were subsequently filled with coarsely-crystalline calcite (?), which is inferred to also be calcite II. Replacement of calcite II crystals by very fine-grained calcite (Calcite III) has been documented, and calcite III is generally observed adjacent to or within pyrite concretions. The relative timing of calcite III versus concretionary pyrite is unclear, and so is the relationship between-the pyrite to most other cements. Nevertheless, at least two pyrite generations (plus one sphalerite generation?) are recognized. One of the generations of pyrite, here referred to as pyrite I, consists of isolated or multiple euhedral crystals and roundish sub-mm-scale pyrite aggregates or clumps of aggregates in the matrix. A second, texturally distinctive generation of pyrite (pyrite II), are up to mm-scale roundish or elongate masses, and are inferred to have formed as pyrite concretions. The outer margins of these concretionary pyrite masses are either irregularly bulbous or crystal facets.

Even though the Teyen Shale is stratigraphically separated from the underlying high-TOC Alum Shale by the 1 m thick carbonate Bjerkasholmen Formation, diagenesis in the Bjerkasholmen shows significant differences from the Teyen in the number of cement phases, and their relative paragenetic sequence: preliminary results from adjacent outcrops and core sample in Scania show that the Bjerkasholmen Formation contains 3-5 carbonate and one pyrite generations of cement. The pyrite pre-dates the latest carbonate cement. However, the Bj0rkasholmen Formation lacks any quartz or phosphate cements. Our first data from the Huk Formation in Scania, a fine-grained carbonate

unit directly overlying the Teyen, also shows exclusively carbonate cements (3 generations?) and pyrite similar to the Bj0rkasholmen Formation but markedly dissimilar from the Teyen. This study therefore suggests that shale units, even though in close proximity to carbonate units, seem to generally undergo independent diagenetic pathways and thus, interformational fluid flow does not seem to effect shale diagenesis. Therefore, unconventional reservoirs, even though they may be adjacent stratigraphically and regionally, should be expected to show very different diagenesis and geo-mechanical behavior, and behave as entirely separate units when subjected to hydraulic fracturing.