

How Deep is Shallow? Re-evaluation of Depositional Models for the Jurassic Nordegg and Rock Creek Members of the Fernie Group

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Summary

Few sedimentological studies exist of Jurassic strata of the Western Canada Sedimentary Basin (WCSB) that provide detailed bedform and ichnology descriptions. A historical preoccupation with biostratigraphy and lithostratigraphy has led to most members of the Fernie Group being assigned a depositional interpretation in the absence of sedimentological analysis. Lithostratigraphic interpretations have produced a shallow-water paradigm that constrains our interpretation of Jurassic deposition in the WCSB. In almost every case, biostratigraphic unconformities and changes in lithologic character have been attributed to changes in relative (eustatic) base level. Cores from the Rock Creek and Nordegg members will demonstrate how process sedimentology can be used to re-evaluate the existing shallow-water depositional models.

Introduction

The Jurassic succession in the WCSB comprises a single 1st order sequence bounded by the angular, regional sub-Jurassic and sub-Cretaceous unconformities. Hans Frebold (1954) first recognized that within the Jurassic Fernie Group *“there are no visible angular unconformities and the hiatuses can only be recognized on a paleontological basis - by the absence of typical guide fossils.”* Frebold also noted that these depositional hiatuses are often marked by an *“abundance of Gryphaea or the presence of ‘Belemnite battlefields’ and other fossil concentrations, sometimes with pebbles which are characteristic of very shallow water conditions.”* He was one of the first to link omission surfaces in the Jurassic of western Canada to base level driven *“temporary regressions of the sea or at least conditions which hindered the deposition of any appreciable amount of sediment.”* Few subsequent authors have challenged Frebold's basic observations and interpretations.

The Lower-Middle Jurassic succession containing the productive Nordegg and Rock Creek members is generally interpreted as widespread “thin deposits of platform limestones and cherts, and widespread, starved-shelf, phosphatic, organic-rich shales, limestones, and sandstones separated by disconformities” (Poulton et al, 1994). The currently popular shallow water paradigm constraining interpretation of Jurassic strata in the WCSB is captured in the statement by Poulton et al (ibid): “The disconformities that separate many of the Lower and Middle Jurassic units are the result of strandline migrations across a shallow epicontinental platform characterized by relatively low sediment input and low relief.”

The Lower Jurassic Nordegg Member forms the basal unit of the Fernie Group. In much of the subsurface south of Township 54, the Nordegg comprises grey, calcareous chert and cherty limestone characterized by a blocky gamma-ray log signature. It thins gradually northward, westward, and eastward from a maximum thickness of 50 to 60 m into a thinner, more heterolithic distal facies termed the Gordondale Member by Asgar-Deen (2003). The lithological characteristics and relative proportion of chert, limestone and sandstone within the Nordegg Member are laterally quite variable. In addition to recrystallized limestone and chert, the Nordegg Member from T52-59 R7-12 W5 contains sandy phosphatic, fossiliferous packstones and grainstones; laminated microfossiliferous wackestones and mudstones; and fine to medium grained quartz arenites to lithic arenites (Bovell, 1979). The high clastic content led Bovell (ibid) to interpret a well oxygenated, high energy, shallow-water inner shelf depositional setting for the upper Nordegg Member. Toward the SE over T36-40 R2-5 W5, Stroble et al (1993) recognized a similar, but coarser-grained lithological suite within the Nordegg Member that differed in having a lower chert and limestone content and thicker beds of sandstone, bioclastic limestone and coquina. Gibson and Poulton (1994) suggested a 'deeper water' (below wave base) anoxic, outer shelf interpretation for the banded cherts and limestones deposits of the lower Nordegg Member to the west, but retained the platform interpretation for the more massive limestones and cherts.

The Middle Jurassic Rock Creek Member (Rock Creek Member) overlies and is separated from the Lower Jurassic Nordegg member by a relatively thin mudstone unit termed the Poker Chip Shale. The Rock Creek Member can be mapped into the disturbed belt >220 km west of its subcrop edge, and >380 km in an N-S direction. The northern limit of the continuous Rock Creek Member coincides with the Nordegg limit and the Snowbird Tectonic Zone (Fig.1). Within the Rock Creek Member there is no unequivocal evidence for subaerial exposure or shallow water deposition across the entire area. In the subsurface, the Rock Creek Member (Rock Creek Member) forms locally prolific reservoirs that are stratigraphically trapped against the sub-Cretaceous subcrop edge to the east. Productive facies of the Rock Creek Member appears to be restricted to the Nordegg 'platform' area. Most Rock Creek Member reservoir units can be classified as sandy coquinas, bioclastic-rich sandstones or quartz arenites. The Rock Creek Member is typified by high lateral continuity and a marine ichnology that have led an interpretation open marine shelf deposits subjected to tidal and storm reworking (Marion, 1984; Putnam and Moore, 1993). Across T37-40 R3-5 W5, Collar (1990) described at least three sequences within the Rock Creek Member, each bounded above and below by a surface of subaerial exposure and erosion. Based upon a diverse ichnology suite and high lithological variability, they interpreted the Rock Creek Member as a shallow, wave dominated delta and strandplain that graded seaward to a high energy carbonate-dominated shelf. Toward the north in the Edson area (T48-T60 R12-19W5), Losert (1990) described a gradational contact between the Rock Creek Member and the adjacent mudstone/siltstone-rich Poker Chip and Fernie shales. They interpreted two units within the Rock Creek Member as a single, coarsening-upward sequence with no intervening unconformity. They suggested that local channeling during Rock Creek deposition was responsible for local removal of the Poker Chip Shale. Taking a contrarian view to all previous authors, Cant (2007) interpreted a much higher degree of channel scouring and incision during Rock Creek deposition, and interpreted the Rock Creek sands as tidally influenced estuarine channel deposits within a laterally extensive, amalgamated complex comprising up to four individual lowstand incised valleys.

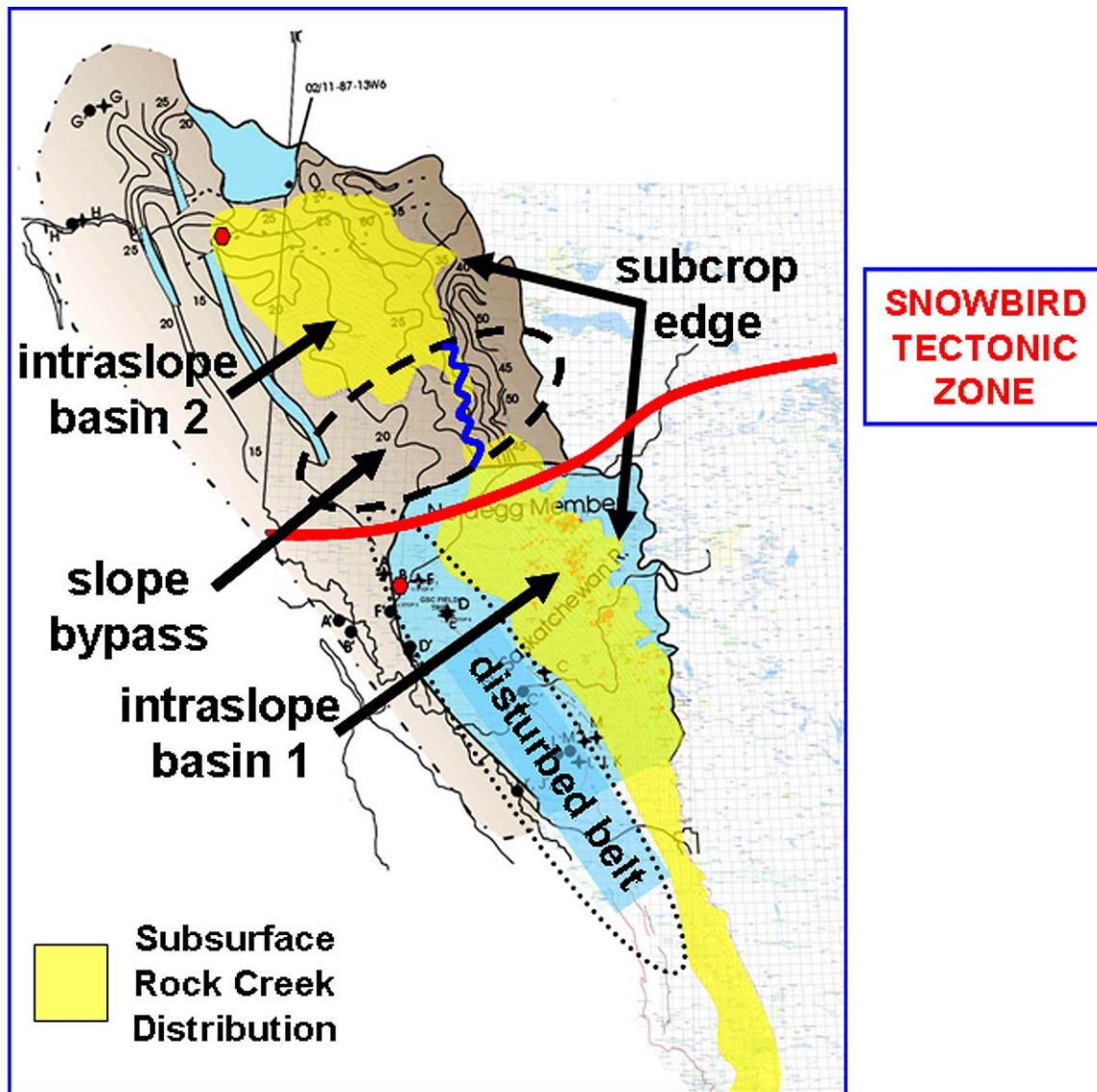


Figure 1: Composite map (modified from Asgar-Deen, 2003) showing distributions of the Rock Creek, Nordegg and Gordondale members. Distribution of the three members can be interpreted as isolated submarine intraslope basins separated laterally by a bypass slope created through differential subsidence across the Snowbird Tectonic Zone.

The Rock Creek Member in core is lithologically complex and exhibits a variety of sedimentary features indicative of flow fluctuations from upper flow regime to suspension deposition. Most noteworthy is the common occurrence of upper flow regime horizontal and antidune stratification interbedded with massive and structureless dm-scale beds. Soft-sediment deformation and slumping is common. Scour surfaces are ubiquitous on both bed and bedset scales. Belemnite- and Gryphea-rich phosphatic hardground omission surfaces occur at the base, in the middle and at the top of the Rock Creek Member. Trace fossils assemblages are generally impoverished, but include suites characteristic of a mixed, substrate-controlled Cruziana and Skolithos ichnofacies indicating marine to restricted marine environments. Individual sand beds tend to show a limited variety of these traces.



Figure 2: Typical current-aligned gryphaea/belemnite rostra/ phosphate nodule traction carpet deposit within the Rock Creek Member (from 14-30-80-9W6). These deposits demarcate an omission surface formed by prolonged sediment bypass. Termed 'Belemnite Battlefields', these are common within deep water deposits of the Jurassic Tethys throughout Europe and can be associated with the loss or non-deposition of up to six ammonite zones.

Bioclastic sandstone of the Rock Creek Member and sandy limestone of the Nordegg Member share some similarity in composition and depositional fabric, and likely share a similar delivery process. The variety of bedforms observed in core, stressed marine ichnology, variability in thickness, vertical and lateral facies changes, and channelized character together with the absence of any subaerial or shallow-water indicators within the rock creek member are best rationalized by deposition from (hyper-) concentrated gravity flows within a deep-water submarine slope-channel system (Fig. 1). A deep-water model for both the Rock Creek Member and underlying Nordegg Member eliminates the need to invoke rapidly fluctuating base levels and large scale ravinement/erosion.

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