2015 Gussow Conference
Fine-Grained Rocks: Resources to Reserves
October 13-15 | Banff Centre | Banff, Canada

Stratal Architecture of a Fine-grained Carbonate Play: The Regional Swan Hills Platform in West Central Alberta

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The Swan Hills platform is an areally extensive shallow marine carbonate unit that averages around 35 metres in thickness and covers an area of approximately 13,000 km^2 (5000 square miles) along the western margin of the Alberta Basin in west central Alberta (Figure 1). It represents the first transgressive unit of the Upper Devonian and overlies shales of the Watt Mountain and evaporites of the Fort Vermilion Formation (Figure 2).

The main platform evolved through a number of depositional cycles as the transgression proceeded and these control the depositional distribution of the various reservoir facies (Figure 3). However, as the transgression accelerated, the main platform became flooded and upper cycles withdrew in a step-like fashion to form a number of discrete depositional highs (Figure 2). These depositional highs subsequently became the site for nucleation of the first stage of isolate reef growth of the later Swan Hills reefs. As shown by a number of authors, these isolate reefs then continued to grow in a series of stacked depositional cycles in response to continued sea level fluctuations.

Subsequently these buildups too became 'drowned' by rising sea level and a deep water argillaceous limestone (Waterways Formation) infills and covers them (Figure 2).

Reservoir Quality

The entire Swan Hills system is preserved as limestone and as numerous authors have shown, there is a direct relationship of reservoir quality to the energy level of the various depositional facies. The Swan Hills reefs were surrounded by deep water so their high energy margins are very porous and permeable and shelter a muddier low energy lagoon of poorer reservoir quality. So it is, with the underlying much more areally extensive Swan Hills platform. The relatively narrow rim bordering its equivalent shallow basin is the most porous (Figure 3), although somewhat reduced from the reservoir quality of the isolate reefs, due to the shallow nature of its' adjacent basin. Average field porosity is around 6% with permeabilities of 6md. These rims enclose a very broad area of interior platform lagoon of immense scale. Following the discovery of these platform edge fields, vertical wells exploited primarily the platform margin porosity spreading slowly into the adjacent interior. It also became apparent that small 'backsteps' had formed as the platform retreated and constituted additional developments of reservoir quality inboard along the upper surface of the unit (Figure 3).

Because of the relatively low productivity of the vertical wells for many years drill depth set an economic limit on the play. The House Mountain complex, which produces 42^o API oil at an average depth of 2300 metres has no gas cap or underlying aquifer, with primary recovery by solution gas drive estimated to be only 11%. Consequently, the field was put on waterflood with a projected ultimate recovery of around 34% of the OOIP (Cooper, 1990).

With the advent of horizontal drilling, the play was revived and production was not only accelerated but wells exhibited additional reserves capture. Operators are now drilling horizontal wells and using multi-stage fracs to increase access to the untapped reserves and extend inboard into previously undrilled areas of the platform.

The entire Swan Hills system appears hydrocarbon-charged with the isolate Swan Hills reefs being filled beyond spill point and productive wells in the platform exhibiting no discernible oil-water contact (Figure 4).

Hydrocarbon Charge

Following regional tilting (down to the southwest), hydrocarbons derived from the stratigraphically higher Duvernay Formation, to the southwest, migrated updip through the platform progressively filling the downdip reefs and 'spilling' updip into the shallower buried ones in a classic 'Gussow-like' fashion (Figure 4). 'Filling' and 'spilling' continued until it reached the end of the migration pathway, which in this case was the northerly end of the Swan Hills platform. Here the migration pathway was bottom-sealed by the evaporitic Fort Vermilion and sealed above and updip by the Waterways basinal shales. The oil column 'backed up' and formed the main accumulation known as the House Mountain-Deer Mountain fields (Figure 4). Migrating oil accumulated to the point that the entire northern end of the Swan Hills platform became saturated with each of the isolate reefs along this trend 'overfilled' into the underlying platform. As such, the northern end of the Swan Hills platform system exhibits no natural water leg.

Historically, producing fields relied on original reservoir quality along the margin of this platform system. Poorer reservoir quality in the interior deterred drilling except in the 'backstepped' platform edges forming the 'apron' around individual reefs (Figure 2).

As the various operators drilled further and further into the platform interior, added stratigraphic complexity in the form of elongate embayments became apparent, bisecting and further subdividing the platform interior. These embayments contained even finer-grained carbonate sediments than the platform interior lagoon and in some cases exhibited localized 'perched' oil-water contacts along their southerly edges.

Additional drilling has once again added another degree of stratal complexity to the play, dissecting a fine-grained platform interior with embayments containing yet tighter fill. The two facies appear identical on wireline logs, requiring core to unwind the specific depositional environment.

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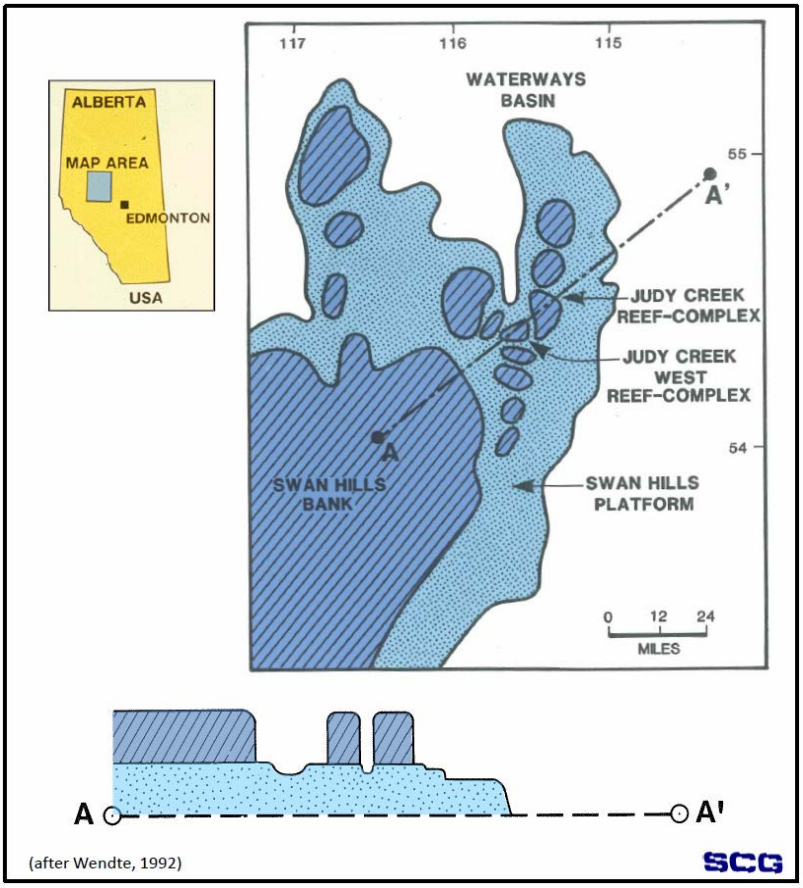

Figure 1. Location of the Swan Hills area and diagrammatic topographic profile.

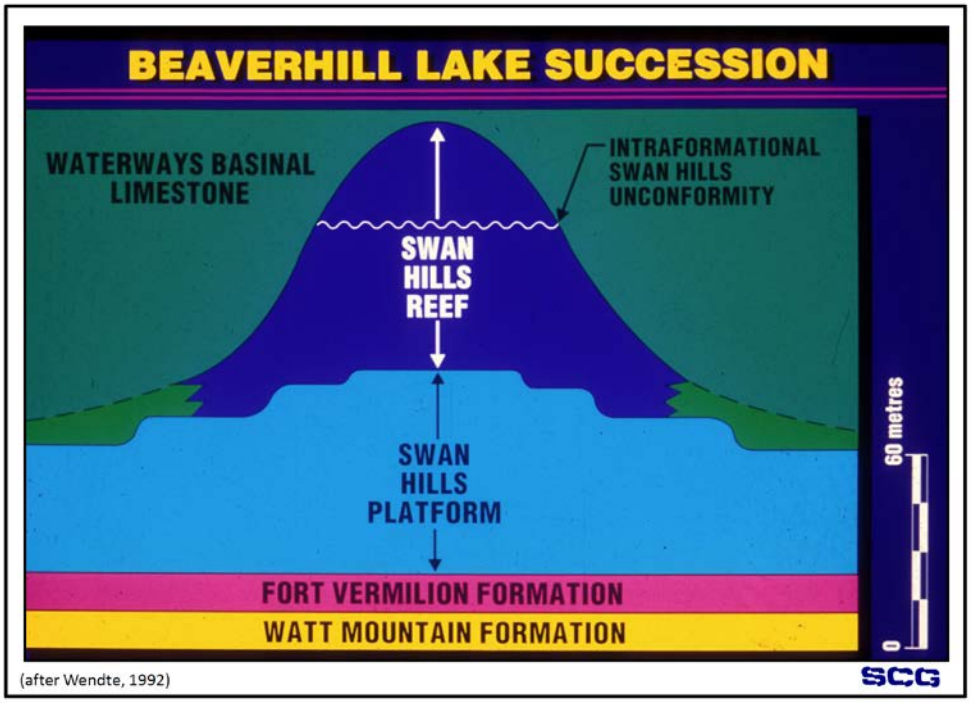

Figure 2. Beaverhill Lake Group stratigraphy.

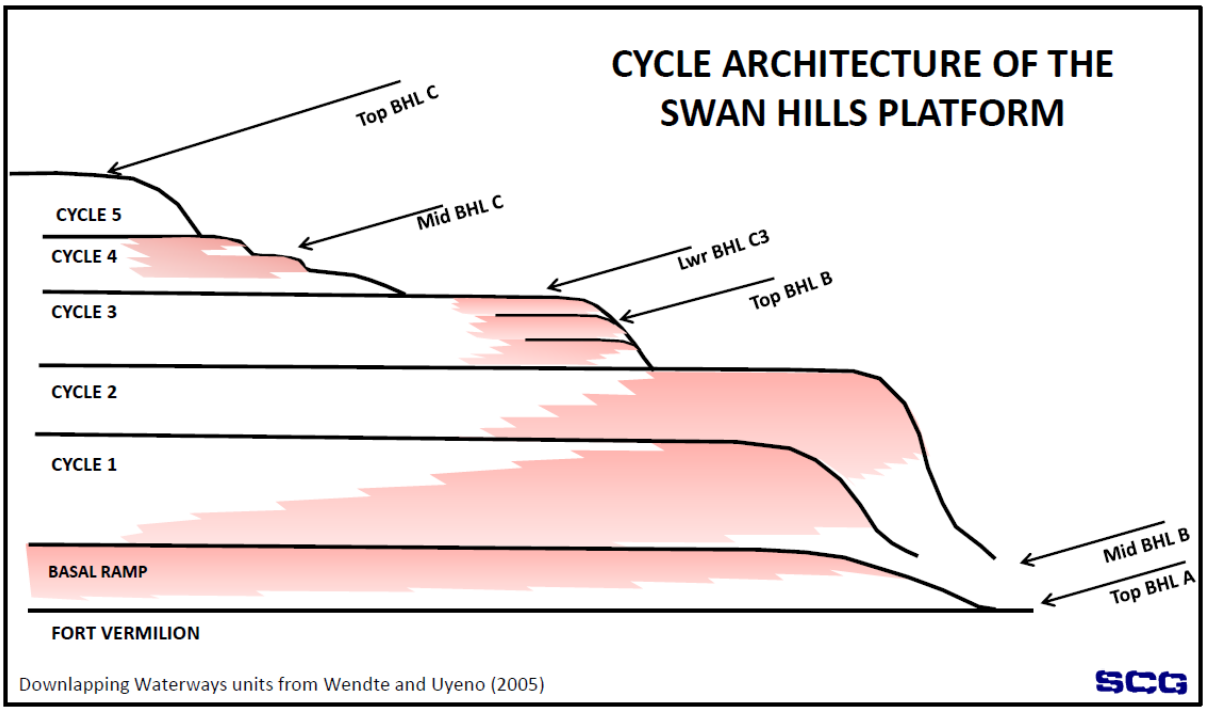

Figure 3. Cycle architecture of the Swan Hills platform.

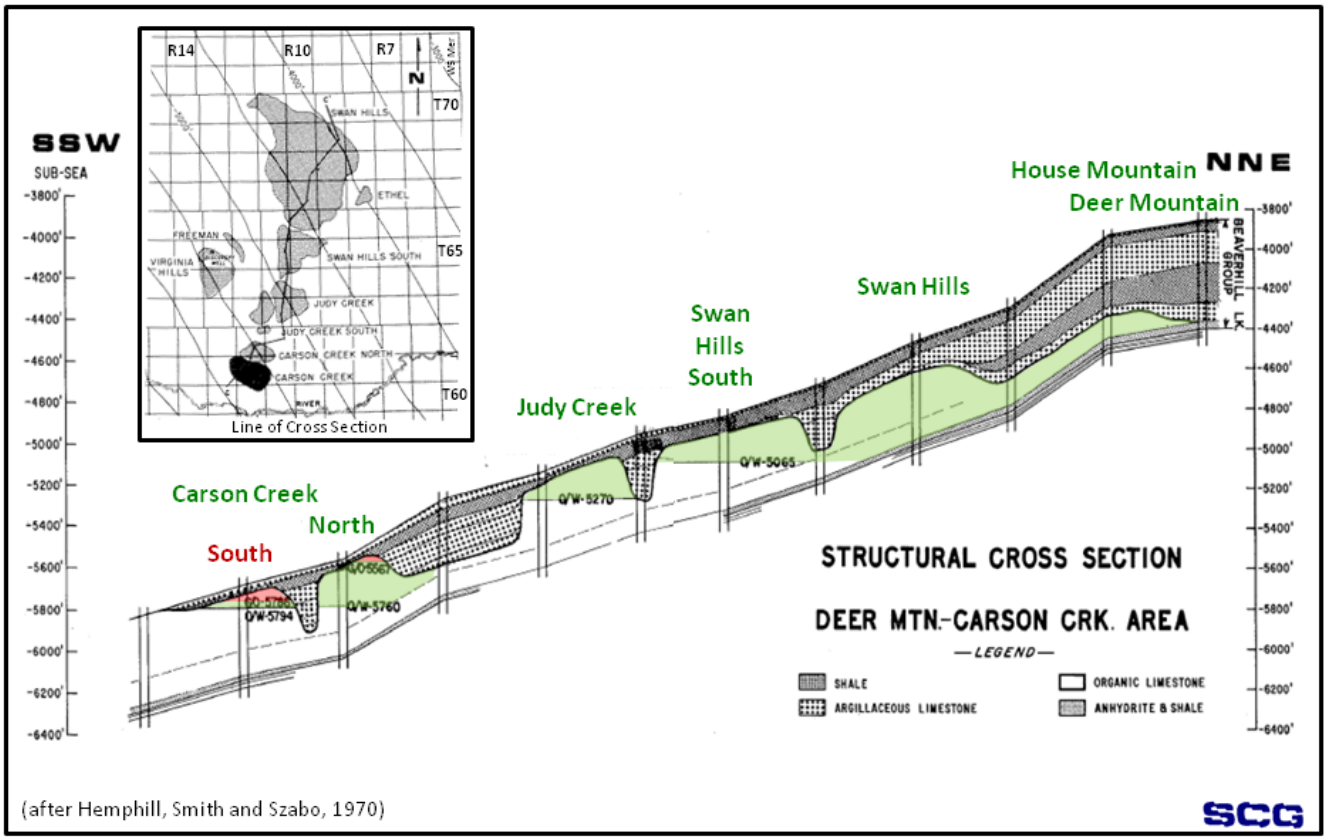

Figure 4. Structural cross section showing spill point updip displacement along the Swan Hills system, in classic 'Gussow-like' fashion.