Aptian/Albian Reservoir Development in the Jeanne d'Arc Basin, Offshore Eastern Canada*

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Search and Discovery Article #10598 (2014)
Posted May 12, 2014

*Adapted from extended abstract prepared in conjunction with presentation at CSPG/CSEG/CWLS GeoConvention 2012, (Vision) Calgary TELUS Convention Centre & ERCB Core Research Centre, Calgary, AB, Canada, 14-18 May 2012, AAPG/CSPG©2014

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Introduction: The Jeanne d'Arc Basin

The Jeanne d'Arc Basin is one of several fault-bounded Mesozoic rift-basins located within the Grand Banks region of offshore Eastern Canada (Figure1). Formation of the Jeanne d'Arc Basin is attributed to episodic extension associated with Pangean disassembly and the formation of the modern Atlantic Basin (Hiscott et al., 1990). The Jeanne d'Arc itself is also one of Canada's most explored and prolific offshore petroleum basins; providing a significant component of Canadian petroleum production and continued explorative interest. Reservoir intervals present within the Jeanne d'Arc Basin are largely constrained to syn-tectonic siliciclastic formations, ranging in age from Late Jurassic to Early/Middle Cretaceous; the latter of which is considered the most consistently hydrocarbon-bearing interval throughout the basin (Pemberton et al., 2001). As such, the predominantly Aptian/Albian Ben Nevis and Avalon Formations have been identified as key reservoir targets within the Jeanne d'Arc Basin; containing substantial hydrocarbon accumulations within the Hibernia, Hebron, and White Rose fields (Figure 1).

However, relatively little information is available regarding regional evolution and development of Avalon/Ben Nevis reservoir intervals outside of key producing fields. As a result, a regional study was initiated in order to integrate key learnings from individual fields, providing a new regional context. Thus, understanding regional Aptian/Albian reservoir development and distribution may prove to reduce reservoir presence risk in previously untested/unproven areas of the Jeanne d'Arc Basin. Development of regional-scale Avalon/Ben Nevis depositional models may also prove beneficial in unlocking Aptian/Albian prospectivity in other, proximally situated extensional basins.

Stratigraphic Context: Avalon and Ben Nevis Formations

The Lower Cretaceous Avalon Formation was deposited during Barremian-Aptian transitional tectonism; a result of post-rift thermal-subsidence and subsequent rift-initiation (Welsink et al., 1989). The Avalon Formation lies stratigraphically below the Ben Nevis Formation (Figure 2), and is recognized as predominantly progradational shallow-marine facies, associated with large-scale eustatic sea-level fall (forced regression); a direct result of renewed uplift on the Southern Jeanne d'Arc margin (Grant and McAlpine, 1990). The Avalon Formation is stratigraphically bound by the "A Marker" limestone below and the Mid-Aptian Unconformity above; both of which exhibit moderate/good seismic character throughout the basin. However, differential "Mid-Aptian" erosion has resulted in variable preservation of the Avalon

Formation throughout the basin; most notable in Southern regions of the study area (Marshall, 2011). Above the Avalon Formation is the Aptian/Albian Ben Nevis Formation, which is characteristic of syn-tectonic sea-level rise (transgression), associated with the third and final extensional event, separating the Canadian Grand Banks from North-West Europe and Greenland (MacKay and Tankard, 1990). The Ben Nevis Formation is generally thought to be composed of marginal-marine to marine facies, deposited in a restricted marine embayment (Marshall, 2011). The Ben Nevis Formation grades both laterally and vertically into the Nautilus Shale Formation, which is thought to signify rift-cessation and thermal subsidence in the basin. This deep marine shale also acts as a regional seal for most Avalon/Ben Nevis reservoirs in the area, as the Nautilus Shale Formation is characteristic of low permeability/porosity and basin-wide depositional extent. The Ben Nevis and Avalon Formations are also believed to have been sourced from the Avalon Uplift to the south, the Bonavista Platform to the west, and other uplifted margins to the north-east of the study area (as indicated by seismic and attribute analysis).

Aptian/Albian Analysis

As part of an integrated Aptian/Albian regional study, emphasis has been placed on the development of regional geological, petrophysical, and sequence-stratigraphic models to constrain Aptian/Albian depositional systems throughout the area (e.g., Figure 3). 3D-seismic analysis was utilized to assess the temporal and stratigraphic evolution of the Ben Nevis / Avalon formations and construct regional-scale paleogeographic maps detailing Avalon / Ben Nevis deposition throughout the basin (Figure 4). Seismic truncation on the lower Ben Nevis contact helped define the lower unconformable surface of the Ben Nevis Formation (the Mid-Aptian Unconformity), while onlap and downlap surfaces aided in connecting additional Lower Cretaceous sequence-stratigraphic surfaces (Figure 3).

The Mid-Aptian Unconformity was subsequently identified as a Type 1 sequence boundary; separating retrogradational parasequence sets of the Ben Nevis Formation, with progradational, shallow-marine deposits of the Avalon Formation below. Successive attribute analysis identified many large-scale depositional patterns representing Early Cretaceous sedimentary systems throughout the Jeanne d'Arc Basin, allowing for the first regional look at Ben Nevis / Avalon depositional systems. Sequence stratigraphic models facilitated in the identification of prospective flooding surfaces within these intervals, several of which may have implications on connectivity and heterogeneity within prospective Ben Nevis / Avalon reservoirs. Petrophysical analysis also aided in the identification of facies in non-cored wells distributed throughout the Basin. Implications of this study suggest the presence of potential Mid-Aptian, lowstand deposits basinward in the southern Jeanne d'Arc, which may make for attractive exploration targets. Likewise, reservoir potential exists in barrier bar / island deposits in fault-bounded regions in proximity to the Voyager Fault System of the southern Jeanne d'Arc Basin, and in increasingly distal regions of the Jeanne d'Arc Basin, likely as part of the Avalon Formation. As a result, predicting Avalon / Ben Nevis reservoir presence away from the southern margin of the Jeanne d'Arc Basin may help in identifying potential salt-structured Avalon / Ben Nevis prospects in the northern regions of the basin.

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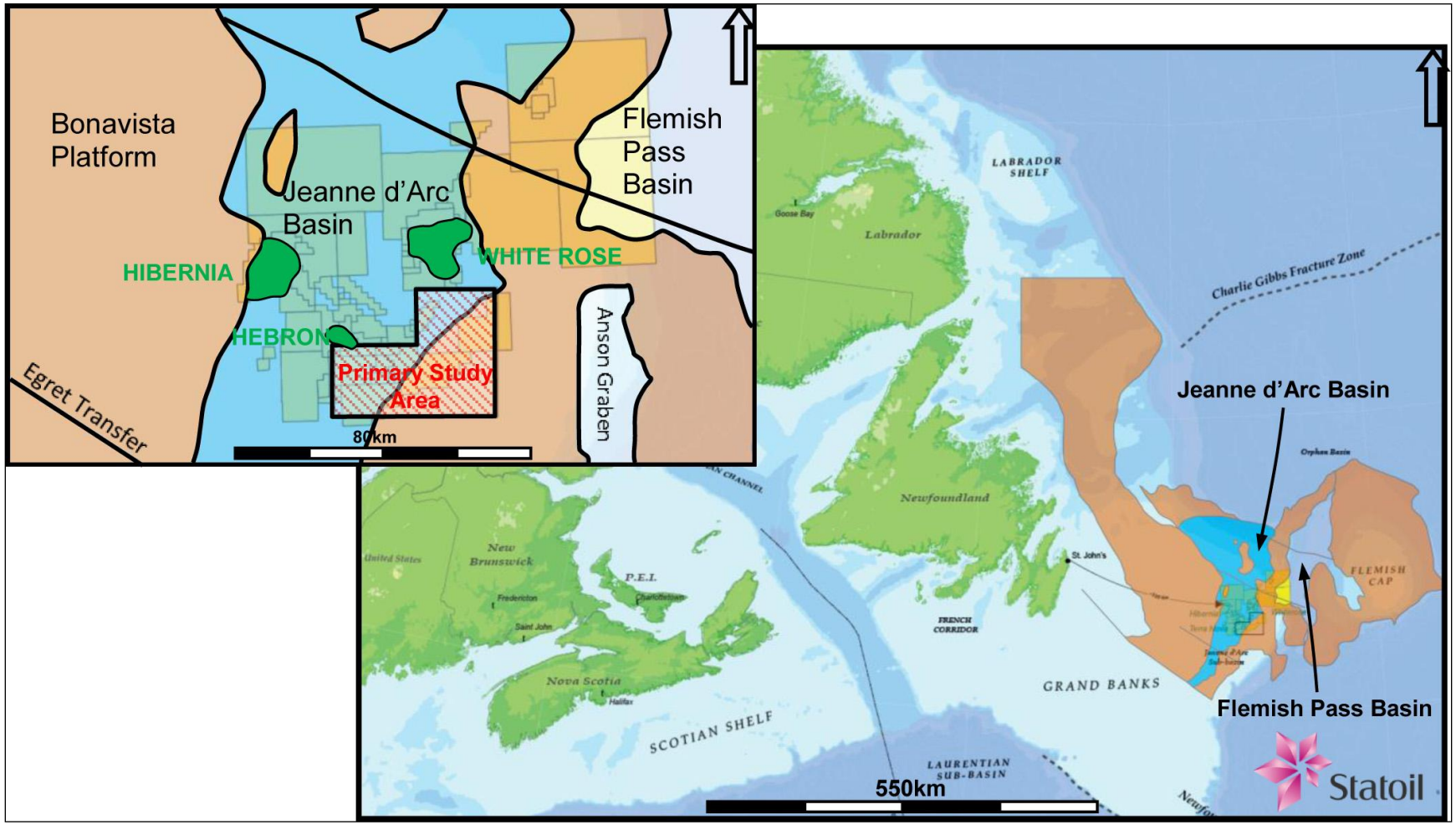

Figure 1. Map of East-Coast Canada and Newfoundland, showing location of Jeanne d'Arc Basin. Also displayed is the location of several large petroleum fields present in the area, including Hibernia, Whiterose, and Hebron. The Jeanne d'Arc Basin is shown in blue, whereas structural highs are displayed in orange. (Modified map courtesy of Statoil Canada Ltd.)

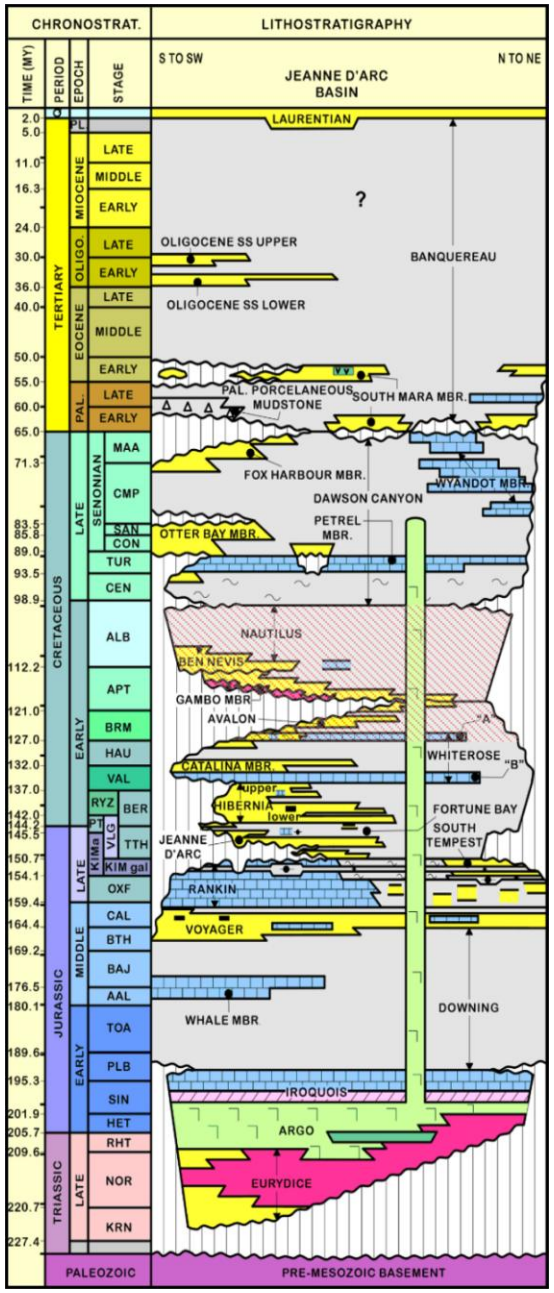

Figure 2. Lithostratigraphy of the Jeanne d'Arc Basin (graphic courtesy of HMDC, modified after Sinclair, 1993.)

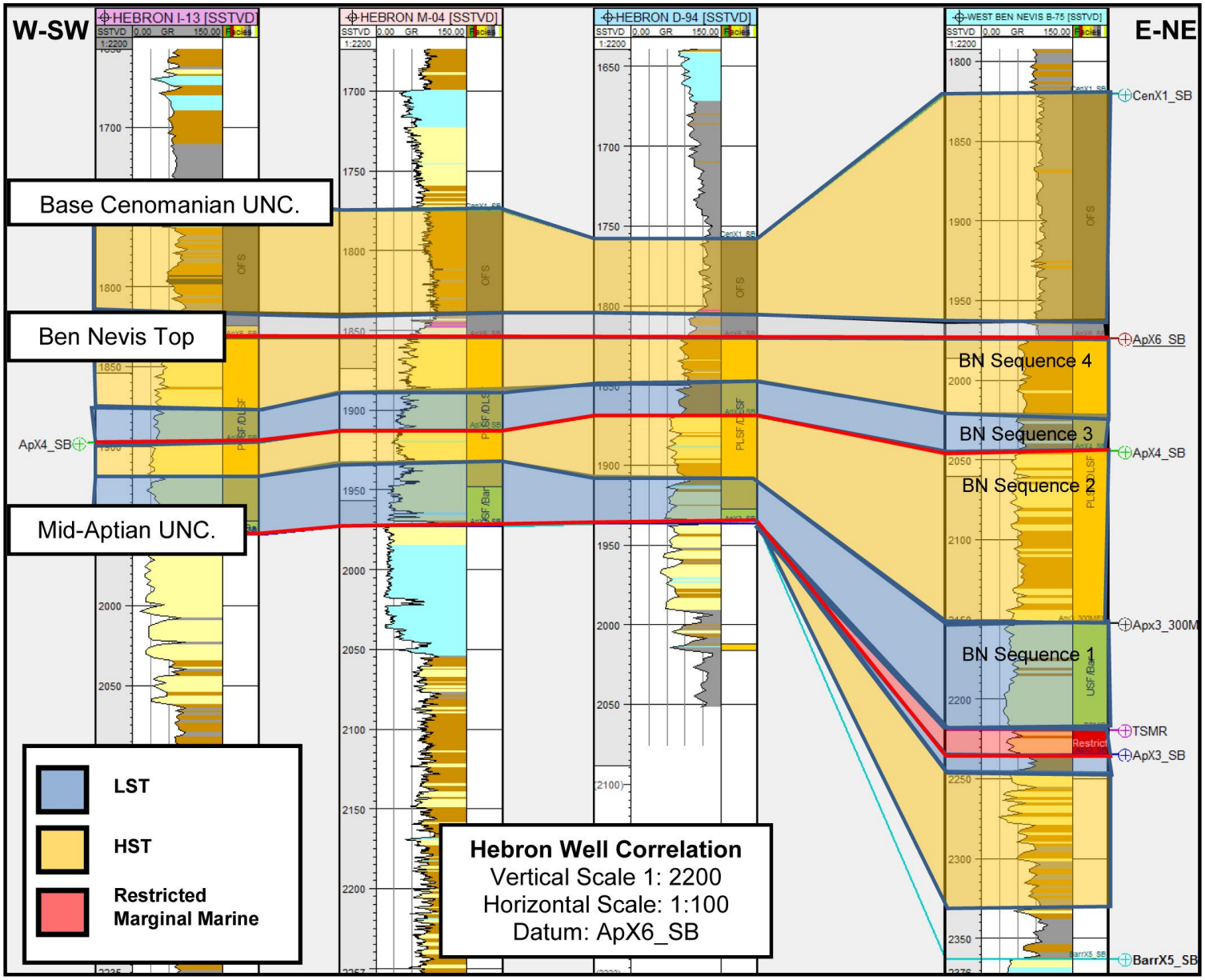

Figure 3. Reservoir correlation through the Hebron Field, Southern Jeanne d'Arc Basin. The location of the Mid Aptian Unconformity, the Top Ben Nevis Formation, and the Base Cenomanian Unconformity are shown in relation to various depositional sequences through the area.

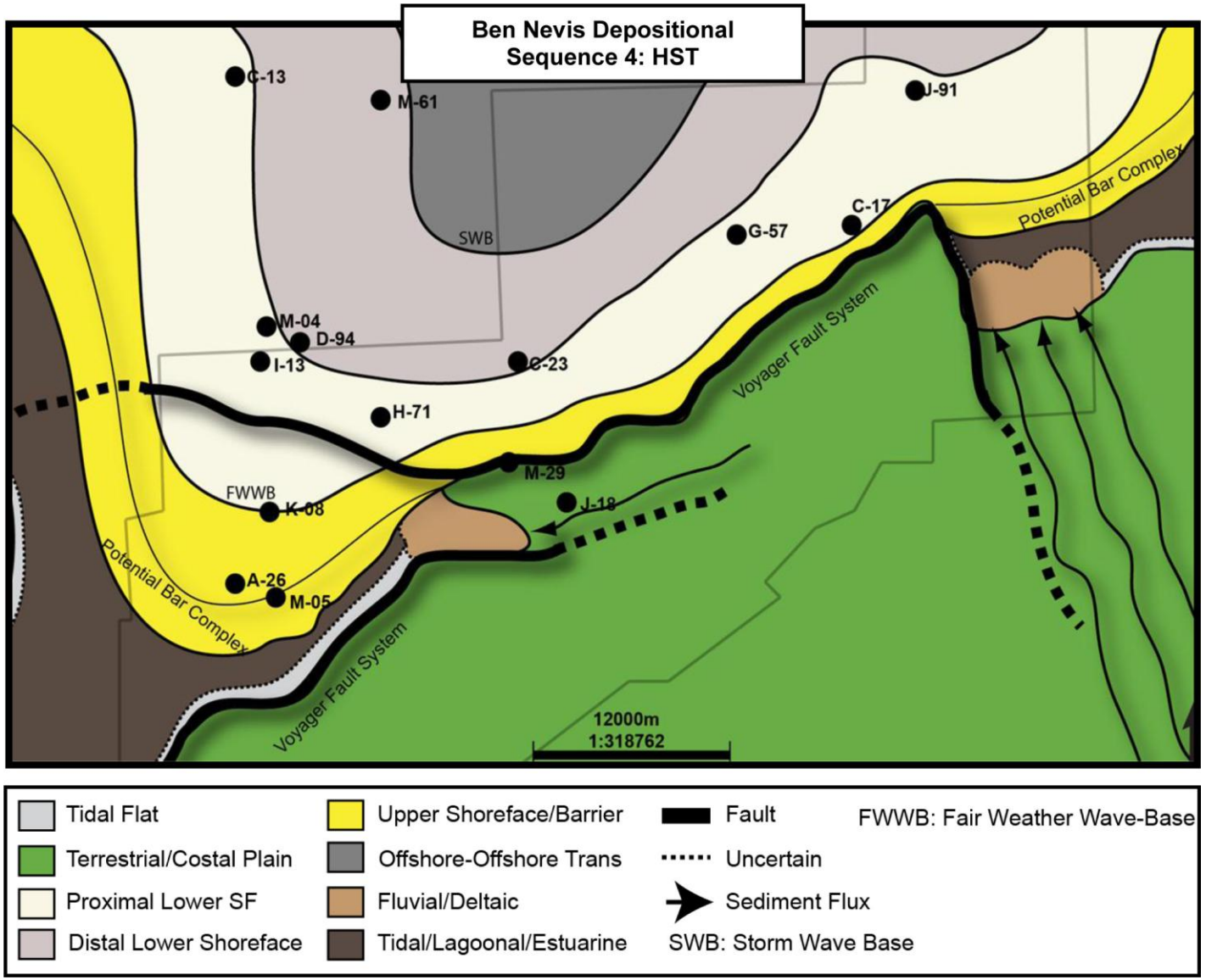

Figure 4. Paleogeographic map detailing various depositional environments through the upper HST of the Ben Nevis Formation. Note that in this case, the southern basin-bounding fault (the Voyager Fault) acts as a topographic barrier, restricting development of marginal and shallow marine facies farther south.