Cretaceous Possibilities: Sedimentology and Reservoir Potential of the Lower Cretaceous Isachsen Formation of the Sverdrup Basin, Ellef Ringnes Island, Arctic Canada*

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Summary

The Isachsen Formation is a Valanginian- to Aptian-aged fluvio-deltaic succession ranging in thickness from tens of meters to over 1400 m within the Sverdrup Basin of the Canadian Arctic Archipelago (Figures 1 and 2). The formation exhibits a variety of lithologies, including coarse-grained quartzarenite sandstones, fine-grained ripple-laminated sandstones and siltstones, marine mudstones and coals that were deposited in marginal marine, marine shelf, meandering and braided river depositional environments.

A sedimentological study of the Isachsen Formation on Ellef Ringnes Island based on seven measured stratigraphic sections demonstrates that the formation contains source and reservoir potential. Porous, coarse-grained sandstone and pebble conglomerate successions up to 35 m thick are potential primary reservoirs. These coarse-grained successions display lateral continuity over the study area and occur at two separate intervals in most of the sections measured. These strata are overlain by thick deposits of mudstones that may provide a seal to hydrocarbon migration.

Nearly all hydrocarbon deposits discovered to date within the Canadian Arctic Archipelago occur within Mesozoic strata. Main targets within the Sverdrup Basin have been Triassic and Jurassic units within salt-cored anticlinal traps, specifically the Heiberg Group that includes the Upper Triassic - Lower Jurassic Heiberg Formation, and its lateral equivalents, the King Christian and Skybattle formations. Heiberg Group targets have yielded significant gas field discoveries, including the Drake and Hecla fields on Sabine Peninsula; however, little oil has been discovered within these units.

The largest oil field discovered within the Sverdrup Basin is pooled within the Upper Jurassic Awingak Formation that holds roughly 0.66 billion bbl, more than the combined oil reserves of Heiberg Group reservoirs. The second largest oil field discovered in the Sverdrup Basin is estimated to hold roughly 0.59 billion bbl within the Isachsen Formation in the offshore Balaena D-58 oil and gas well just southwest of Ellef

Ringnes Island. Surface stratigraphic studies on Ellef Ringnes Island confirm reservoir pay zones of comparable magnitude to the 30m, >30% porosity pay zone of Isachsen Formation preserved in the Balaena D-58 well.

The Awingak Formation unconformably underlies the Isachsen Formation at many locations near the southern, western, and eastern margins of the Sverdrup Basin. It is reasonable to assume that fractures and faults influencing oil migration into Awingak reservoirs in these locations may also have influenced accumulation within Isachsen Formation targets. On Ellef Ringnes Island, the Awingak Formation, where present, is separated from the Isachsen Formation by highly fractured mudstones of the Jurassic Deer Bay Formation. Basinward, Awingak Formation sandstones are replaced with mudstones and siltstones of the Ringnes Formation that may also contain intervals with oil-generative potential (Stewart et al., 1992). The fractured mudstones of the overlying Deer Bay Formation may permit hydraulic conductivity between Awingak and Ringnes formations, as well as Isachsen reservoirs.

Although both oil and gas accumulations have been found within the Isachsen Formation in the Sverdrup Basin, the formation has rarely been viewed as a target for resource extraction due to its shallow burial and generally insufficient thermal maturity. Prevalent halokinetic activity associated with salt diapirs, sourced from Carboniferous evaporites in the western portions of the basin, allow for the possibility of significant fracturing and oil migration from deeper source rocks to shallower reservoir units, such as the Isachsen Formation. Salt accumulation in the form of wings and canopies has been interpreted on Ellef Ringnes and Axel Heiberg Island to have been initiated beneath some of the more competent beds within the Isachsen Formation, creating trap potential within this unit (Boutelier et al., 2010; Jackson and Harrison, 2006). It is also possible that marginally mature source rocks, such as the underlying Jameson Bay Formation that contains oil-prone Type II kerogen may increase in maturity locally around salt intrusions due to hot fluid circulation and high geothermal gradients (Issler, 1985; Gentzis and Goodarzi, 1998), thus increasing the likelihood for hydrocarbon generation at these locations.

Vitrinite reflectance studies from the Hoodoo H-37 well on southern Ellef Ringnes Island indicate mature kerogen within the Patterson Island Member of the Isachsen Formation (Figure 3). This suggests either thermal alteration of indigenous kerogen occurred due to hot fluid circulation and elevated geothermal gradients associated with salt diapirism or represents reworked mature material recycling into the Isachsen Formation. The most promising reservoir potential present within the study on Ellef Ringnes Island lies within coarse-grained and conglomeratic braided stream deposits in the lower Isachsen Formation assigned to the Patterson Island Member. This facies is present at every location viewed within the study area, and in several locations it measured over 40m thick. The extent of these braided stream deposits is documented by identical facies described in early studies on Amund Ringnes, King Christian, Cornwall, Lougheed and lesser islands within the same lower stratigraphic horizon (Balkwill, 1983; Balkwill and Roy, 197; Balkwill et al., 1982; Roy, 1973). These deposits are even documented beyond the limits of the Sverdrup Basin within the Isachsen Formation on Banks Island (Miall, 1979), further confirming the validity of this facies as a laterally extensive reservoir prospect. The economic viability of resource extraction from this region of the globe requires large oil plays for successful projects. With this in mind, Lower Cretaceous reservoirs should not be overlooked in future exploration efforts.

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Figure 1: Map of the Canadian Arctic Archipelago, showing the outline of Sverdrup Basin, basin axis, and the location of Ellef Ringnes Island. Location of the Hoodoo Dome H-37 oil and gas well shown with a red dot, Balaena D-58 oil and gas well shown with a blue dot. (Modified from, Galloway et al., in prep)

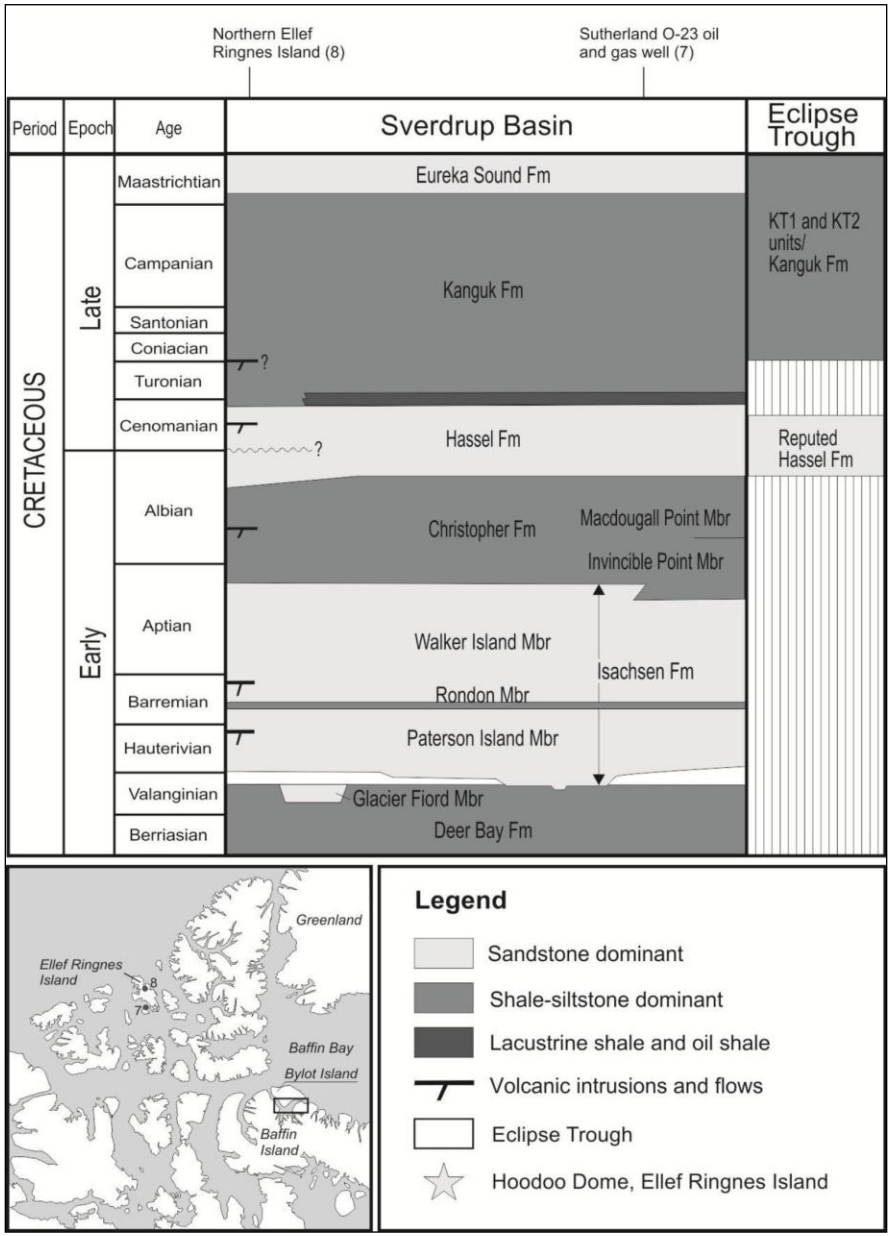

Figure 2: Middle to Upper Mesozoic stratigraphy of Ellef Ringnes Island (compiled from Embry, 1991; Dewing and Embry, 2007; Obermajer et al., 2007; Galloway et al., in prep).

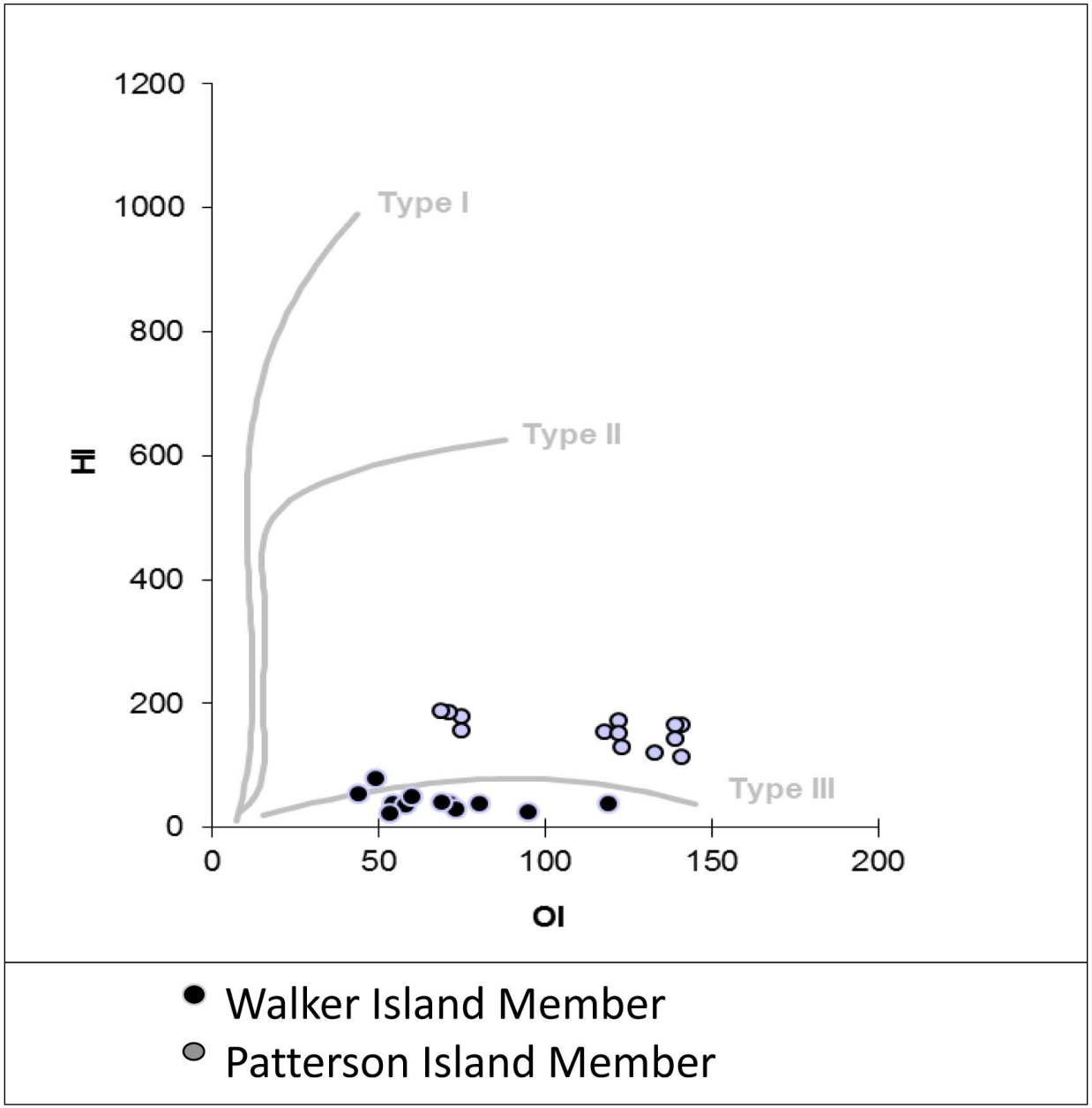

Figure 3: Pseudo-Van Krevelen diagram of organic matter preserved in Isachsen Formation cuttings samples from the Hoodoo Dome H-37 oil and gas well. Patterson Island Member samples contain hydrogen-enriched oil prone Type II kerogen. (Modified from Galloway et al., in prep)