Sedimentology, Biostratigraphy and Diagenesis of Lacustrine Strata, Anguille Group and Equivalents, western Newfoundland.

Lacustrine, marine and marginal marine strata of lower Carboniferous age are widespread across Atlantic Canada and in contiguous locations in NW Europe. In New Brunswick and Nova Scotia, Horton Group and equivalent rocks are being actively explored and developed for hydrocarbons. One of the most prominent units, the Albert Formation, hosts gas and oil fields in sandstone, siltstone and oil shale (e.g. Stoney Creek and McCully). In the Midland Valley of Scotland, strata within the similar aged Strathclyde Group are a well known oil shale resource. Here units such as the Dalmahoy Shale and Pumpherston Shale have been specifically targeted for oil shale extraction. In onshore and offshore Newfoundland, regionally equivalent strata of the Anguille Group also contain prospective targets. However, unlike the Maritime Provinces and the Midland Valley of Scotland, the search for hydrocarbons in Carboniferous strata in Newfoundland is in its infancy; few bore holes have been drilled and no commercial reserves have been currently identified.

For an active petroleum system to exist, several key elements have to come together if commercial reservoirs are to be created in either conventional or unconventional plays. One of the critical components rests with the presence of source rock, its quality, volume, and diagenetic history. Putative Albert Formation equivalent source rocks of the Anguille Group belong to several regionally distinctive formations, each confined to the Bay St George, Deer Lake, and the White Bay sub-basins, and each with their own distinctive characteristics. In Bay St. George, on the Gulf of St. Lawrence, Knight (1983) described the Snakes Bight Formation as nearly 1000 m of thick black shale, grey siltstone, sandstone and dolomite. Farther north in the Deer Lake Basin, Hyde (1983) described the Saltwater Cove formation as more than 2700 m of dark grey siltstone and sandstone, commonly dolomitic, and with black carbonaceous shale. An underlying and intertonguing unit, Forty-five Brook Formation contains at least 500 m of dark grey and black siltstone and carbonaceous shale with sandstone (Hyde, 1983). In Conche, in White Bay on the Atlantic seaboard, the Cape Rouge Formation is about 1200 m of grey and dark grey laminated mudstone with light grey sandstone and thin carbonate beds (Baird, 1966; Hamblin et al., 1995).

In New Brunswick, Albert Formation strata are well dated with palynomorphs. Utting (1987), Utting et al. (1989), and Hamblin et al. (1995) clearly show Albert Formation correlates with the Cape Rouge Formation and with the Tn2-Tn3 Hasterien-Ivorien boundary of the Tournaisian, a maximum flooding event (Gibling, 1995). That said; little definitive information on the palynological age for the Snakes Bight and Saltwater Cove formations exists. Other macrofossils reported by Knight (1983) and Hyde (1983) suggest they are basically the same age. In Scotland the Queensferry Oils Shales are also quite well-dated (Pumperston Marine Band) using ammonoids and asigned as Asbian age and are of broadly similar age to the Anguille Group. Associated volcanics in the Stathclyde Group suggest that main oil shales were deposited during the Tournasian. So while the broad stratigraphy is quite well known high-resolution facies descriptions, that address the specific conditions associated with organic carbon preservation are not

available. This means that geological models designed to predict potential source rock quality and distribution of sweet spots are very vague.

Assuming basic age relations are established there are clearly other fundamental differences between New Brunswick, Scottish and Newfoundland rocks. In New Brunswick, the richest sections of Albert Formation oil shale yield as much as 93 litres/tonne (Macauley and Ball, 1982). In addition, Chowdhury et al. (1991) show Albert Formation (Canadian Occidental Albert Mines #9) shale as excellent Type I source rocks (TOC's 0.88 - 11.29%, with high S2 (avg. 37.68), HI (avg. 650) and a Tmax between 439 and 454. These beds are likely responsible for the oil and gas in the Stoney Creek field. Similarly, in Scotland units such as the Pumpherston Oil Shale are dominated by Type I kerogen and yield up 200 litres/tonne with an average value of 90 litres/tonne (Cameron, 1978). Here the rocks are very organic carbon rich (typically 3.6 to 20% TOC with up to 28% TOC in the Pumpherston Oil Shale) and have high HIs >600. In contrast, Sinclair (1992) reports limited potential (highest TOC's 1.29 - 1.85%), with low values for S2 (<0.04) and HI (<4) indices indicating overmature rock for Snakes Bight strata. So too, and farther north, Hamblin et al (1995) show Cape Rouge Formation strata as a mature and mostly Type 3 source. For these rocks, vitrinite Ro is 1.2, the highest TOC's are 1.61 - 4.59% , and S2 (avg. 1.35) and HI (avg. 110). Cape Rouge values are slightly better than that reported from rocks from the Bay St George Sub-basin. Given these data it appears that there are significant lithofacies variations both between depositional basins and within an individual basin and in addition there is an organic maturation gradient, from mature and overmature gas prone rocks in the Bay St George Sub-basin in the south to mature gas and oil prone rocks in the White Bay Sub-basin in the north.

If exploration of upper Paleozoic rocks of Newfoundland and Labrador is to proceed in both onshore (western Newfoundland) and offshore territory (i.e. the St Anthony and Magdalen basins), it is important to know more about the distribution of sedimentological and diagenetic factors controlling the quantity and quality of source rocks at all scales present in these basins.

Assuming that the mudstones of the Albert Formation and Strathclyde Group rocks directly correlate with Anguille Group rocks in Newfoundland and that they all share similarities is there continuity of this style of deposit across the Gulf of St. Lawrence and eastwards across the Proto-Atlantic? Are maturation and organic gradients constant in the Bay St George and White Bay subbasins, or are there transitions representing regional facies variations? Are the source rock lithofacies the same in these basins and what are the specific controls on organic carbon preservation in these units?

The Anguille Rocks in the Deer Lake and Bay St George Basins have been through a significant deep burial history (Ro ~2.0). This means that they are not optimal for source rock studies because so much of the original mineral material and organic carbon will have been transformed during diagenesis. Preliminary analyses of the Anguille Group strata in the White Bay Sub-basin, however, indicate that their thermal maturitities are much lower (Ro 1.25). This latter succession is therefore a much more promising target

to investigate the fundamental controls on Carboniferous source rock origins in the Newfoundland Basins.

Currently though in spite containing several km of sediment, they have been characterized by relatively few analyses (approximately 20 samples in the Conche region). While these provide some insights into the large scale variability and the age of these rocks they neither allow the high resolution facies to be determined nor provide any detailed insights into the origin of these source rocks at the scale of petroleum system. The first aim of this project therefore is to rectify this position so that the source rock variability in this basin can be characterized within the context of high-resolution biostratigraphy, sedimentology, and source rock lithofacies and geochemistry.

To meet this aim the Tournaisian aged succession exposed at Conche will be mapped and logged, enabling the most promising source rock intervals to be identified and their local architectures and key stratal surfaces determined. Once these intervals are known, the second aim will be to determine the high-resolution palynofacies, lithofacies, and trace element geochemistry of the high TOC intervals within this succession to provide some insights about the controls on source rock formation to provide context for this petroleum system and enable the fundamental physical, chemical and biological controls on its internal variabiltity to be defined.