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Assessing potential Cretaceous source facies within the Orphan Basin using analogue examples from the North Atlantic and 1D basin modelling.

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Project Background/Aims/Objectives

This study aims to build on the assessment of Late Jurassic source rocks recently completed various authors (e.g. Enachescu 2006, Beicip-Franlab,2018) In those studies the petroleum systems that were examined ranged centred on source facies of marginal to open marine. Further rifting in the Early to Mid Cretaceous, probably coupled with Labrador Sea extension and opening, resulted in considerable accumulation of sediments. These Cretaceous sediments are considered to potentially house, mature source facies capable of generating oil and/or gas. The few wells that have been drilled in the basin have targeted fault related structures where the Cretaceous is either condensed or indeed, eroded. As a result, there is very little information pertaining to potential source facies.

One of the aims of this study is to initially examine the known Cretaceous source facies of West Greenland, offshore Labrador, Morocco and those noted in the offshore of the Iberian Peninsula to west of Ireland. There is a considerable amount of source rock and oil geochemistry data available including that of DSDP / ODP programmes, publicly available data from the Natural Resources Canada BASIN Database (http://basin.gdr.nrcan.gc.ca/wells/index_e.php). These source facies have been documented, categorised and compared.

A review of the available tectonic and seismic data both publicly available and that supplied by Nalcor will allow good estimation of the occurrence and extent of Cretaceous sediments. Additionally, this information will also be useful in providing an assessment of areas that could contain source facies. The review of source facies in the conjugate basins, as noted above, will be integrated with the assessment of the most probable locations for Cretaceous source development.

To integrate these data the final part of this project is the generation of a series of 1D basin models. his has been performed using Sirius's Novva modelling package. The modelling has been executed in two parts utilising different heat-flow histories and kerogen kinetics

Location Map

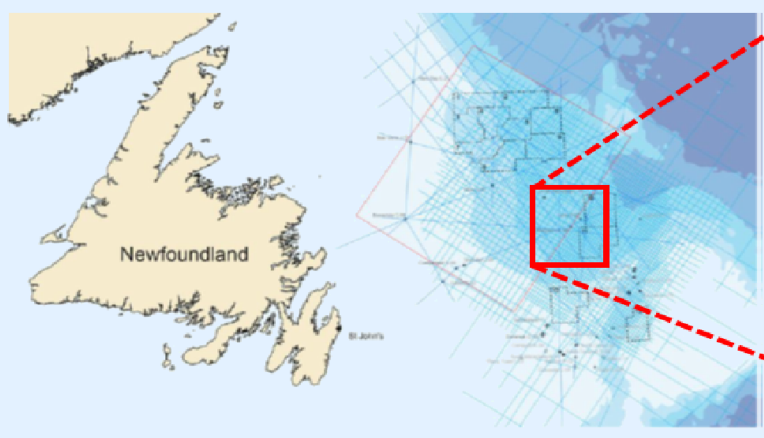

Figure 1a: Broad location of study area within the Orphan Basin

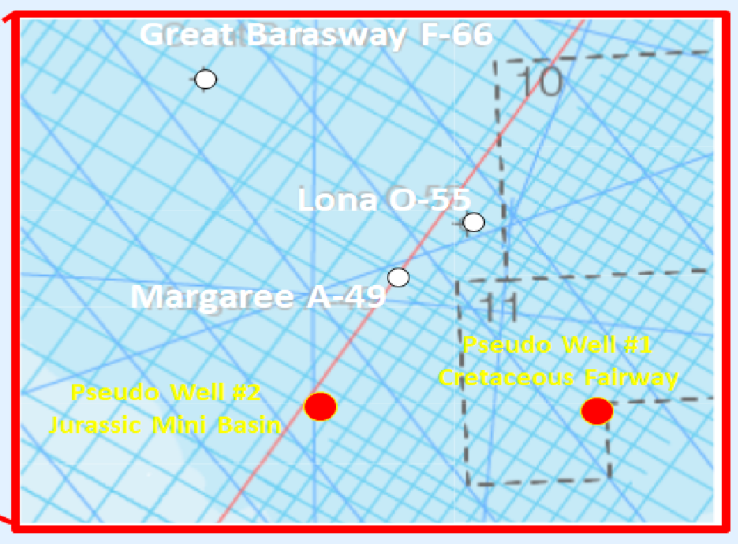

Figure 1b: Detailed location of Pseudo wells #1 and #2 within the Orphan Basin

Database

This study utilises open-file data, compiled and made available by the Canadian government via the Basins database. These datasets contain pyrolysis, organic petrology, well temperature and biostratigraphic data for the majority of the wells within the Orphan Basin and adjacent basins. In addition, geochemical information available for DSDP wells drilled in the North Atlantic have been incorporated into the dataset. Kerogen kinetics for modelling have been taken from Burwood, 1999 assessment of Cretaceous source facies in offshore Angolan basins.

Methodology

The project plan was to:
• To study the tectonics of the Atlantic since rifting began and relate information using analogues from the conjugate margins and surrounding basins such as Jeanne D'Arc.
• Relate the evolution of the basin to the geology and depositional history through a review of palaeo-environment maps and reconstructed environments.
• Use information from Ocean Anoxic Events (OAEs) particularly in the North Atlantic to examine the importance of these.
• In particular, review the arguments as to whether the OAEs were ocean wide or localised phenomena.
• All available data will be used to summarise the Cretaceous source potential.
• 1D basin model to be produced for wells and notional wells determined by Nalcor from their seismic interpretation.
• Use Kerogen kinetics combined with sediment facies maps to determine the potential variability in the former and model the effects of differing kerogen types.

Kerogen	Initial HI	A factor	EA Max
Iabe	440	1.20E+15	55

Kerogen	Initial HI	A factor	EA Max
Micrite	600	1.80E+14	54

Kerogen	Initial HI	A factor	EA Max
Chela	400	3.90E+13	51

Kerogen	Initial HI	A factor	EA Max
Teba	360	5.80E+13	54

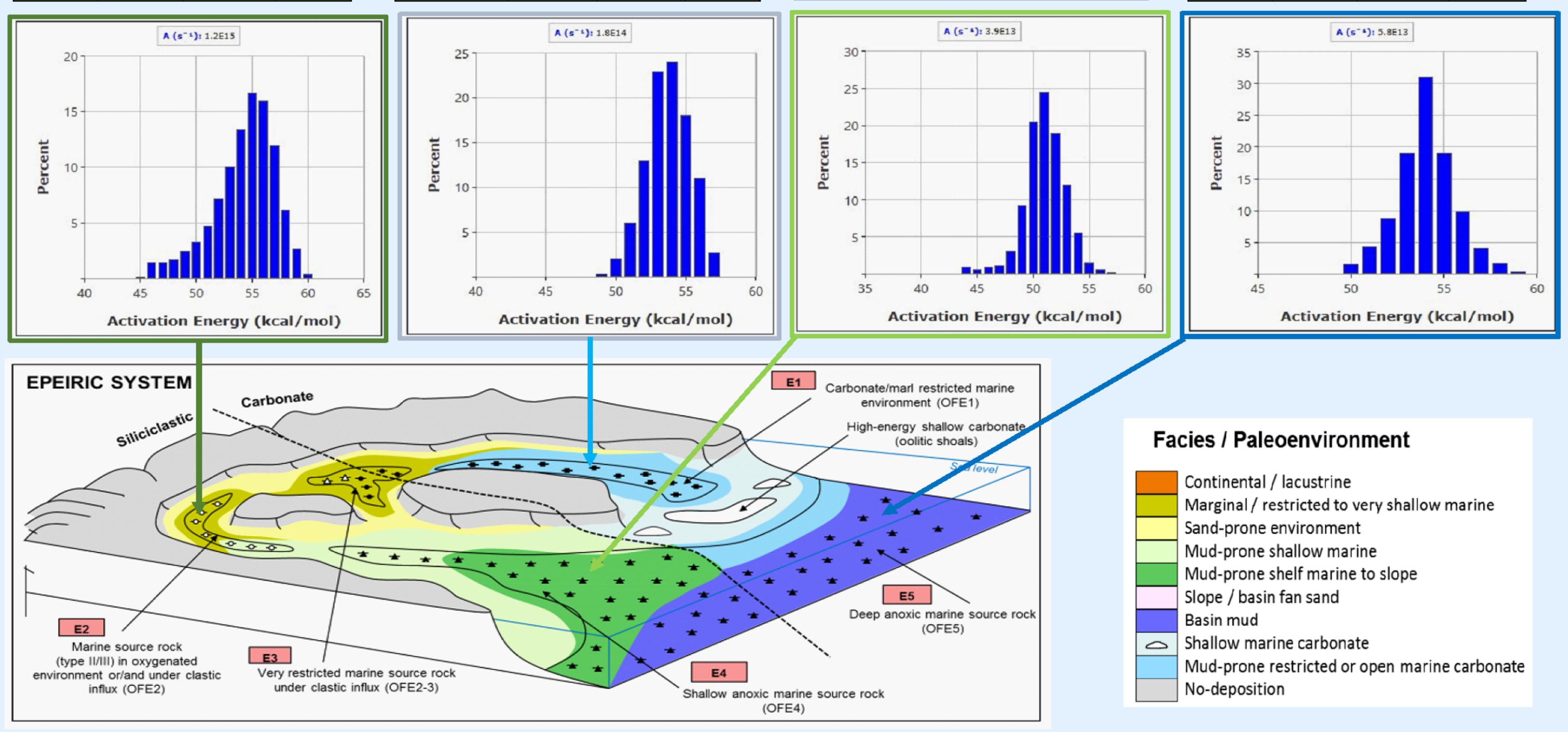

Figure 2: Adopted kerogen kinetics taken from Cretaceous source facies in Angola, Africa (Burwood, 1999). These kerogens have been linked to a facies model produced by Beicip-Franlab report 2017 and as reported in Beicip-Franlab 2018

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Tectonic History

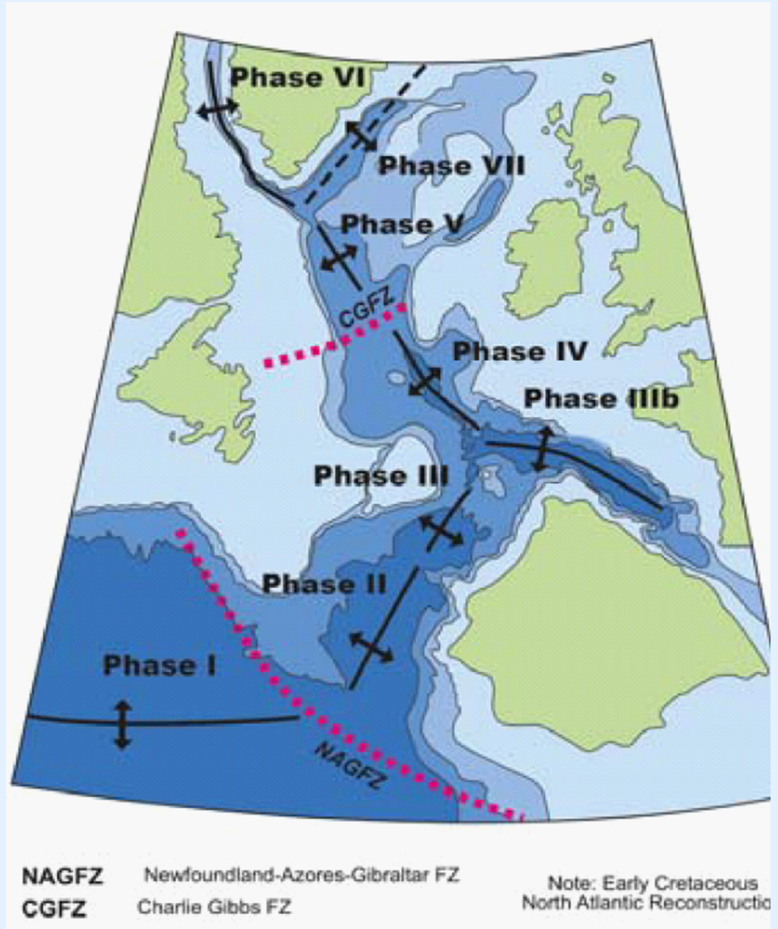

Figure 3: Opening of the North Atlantic (after Masson and Miles, 1986, modified in Petroleum Affairs Division (Ireland) Special Publication 3/06, 2006.)

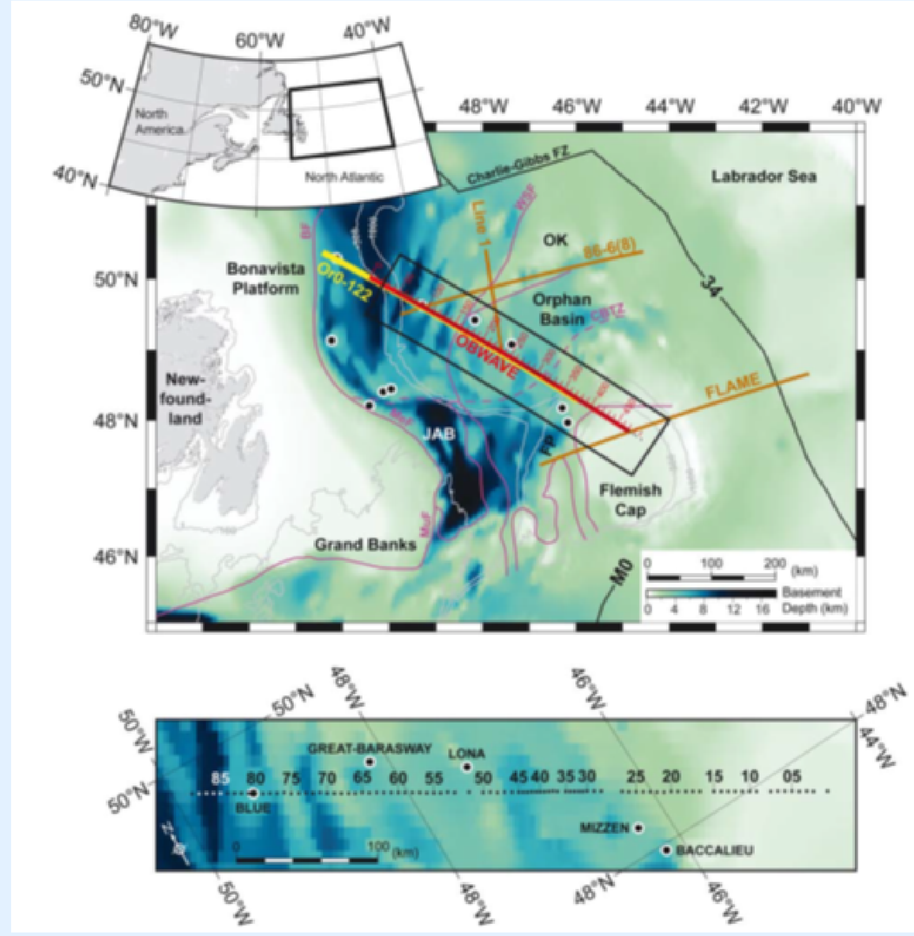

Figure 4: Location of the OBWAVE and Or0–122 profiles in the Orphan Basin (Lau et al, 2015)

The reconstructed Atlantic opening map (Figure 3) details a mix of depositional environments from continental to deep marine associated with rifting. The Western part of the Orphan Basin has been considered to be younger but the stratigraphic studies reveals the area was on continental shelf resulting in more alluvial deposits. As a basis of understanding the differences within the Orphan Basin using the reconstructed tectonic maps, the Orphan Basin East and West were not connected until the Tithonian but the West Orphan Basin was connected to the Porcupine Basin which is located offshore Ireland from the inception of the main basin forming events.

Lau et al (2015) used a multichannel seismic (MCS) reflection profile, the 500-km long 2-D Or0–122 line that crosses the Orphan Basin along the direction of main extension (Figure 4). This line passes through 3 deep-water wells (Blue H-28, Great Barasway F-66 and Lona O-55) that were used to constrain the interpretation of the main horizons within the penetrated sediments of Tertiary and Mesozoic ages. This line was further supplemented by the OBWAVE (Orphan Basin Wide Angle Velocity Experiment) programme profile that was located to be coincident with MCS profile Or0–122. In Figure 4 the location of both the Or0–122 and OBWAVE profiles are depicted along with their relationship to the three wells noted above.

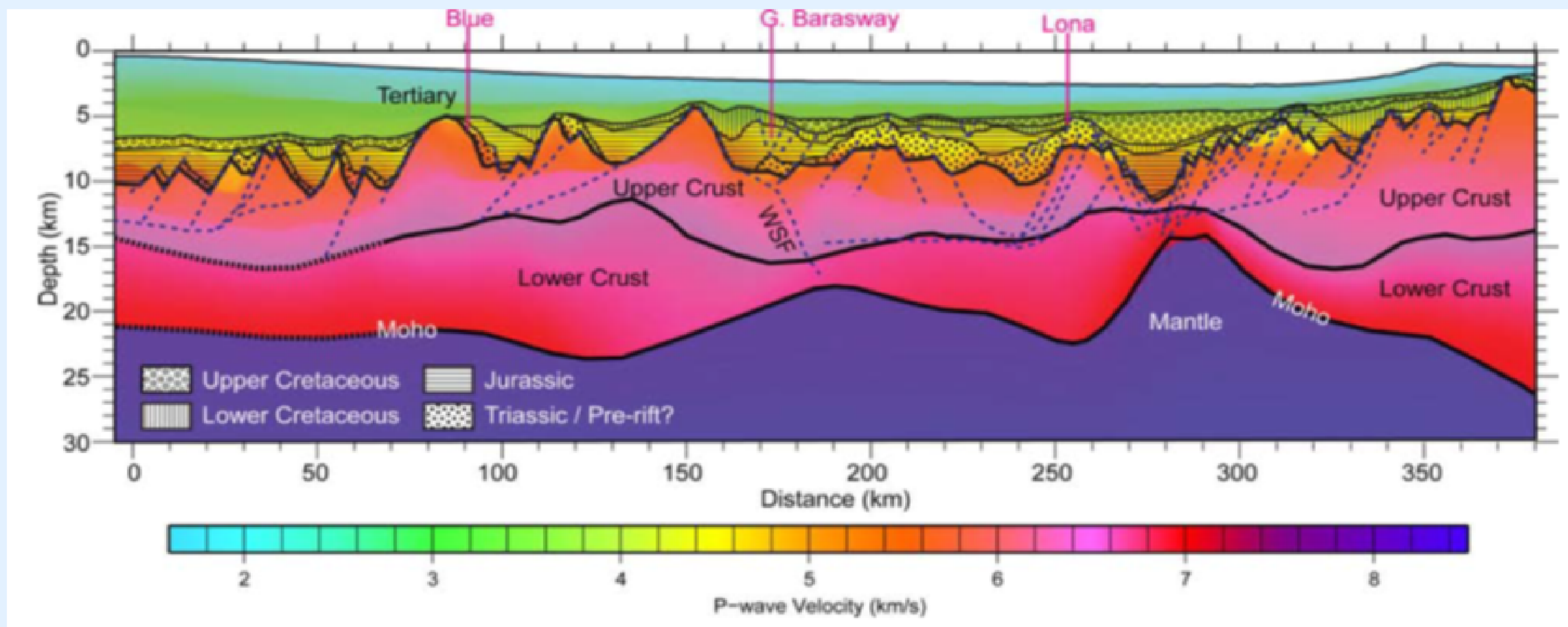

Figure 5: Geological interpretation of Or0–122 OBWAVE showing depth to Mantle across the section. Dashed blue lines are interpreted faults responsible for upper crustal thinning. (Lau et al, 2015)

From the interpretation the depth to Mantle, Lower and Upper Crust sedimentary cover has been calculated along the whole of the line (Figure 5). This also gives a good picture of the amount of stretching (figure 6), for example there is very little or no crustal stretching on the extreme right (easternmost margin) of the interpreted line (Figure 5). Here there is over 25km of Crust before the Mantle is reached. This can be contrasted with the section immediately to the west of the Lona O-55 well on the interpreted section where crustal thickness is no more than 15km as the result of basin extension. This latter locality is of particular importance in the 1D pseudo-well modelling.

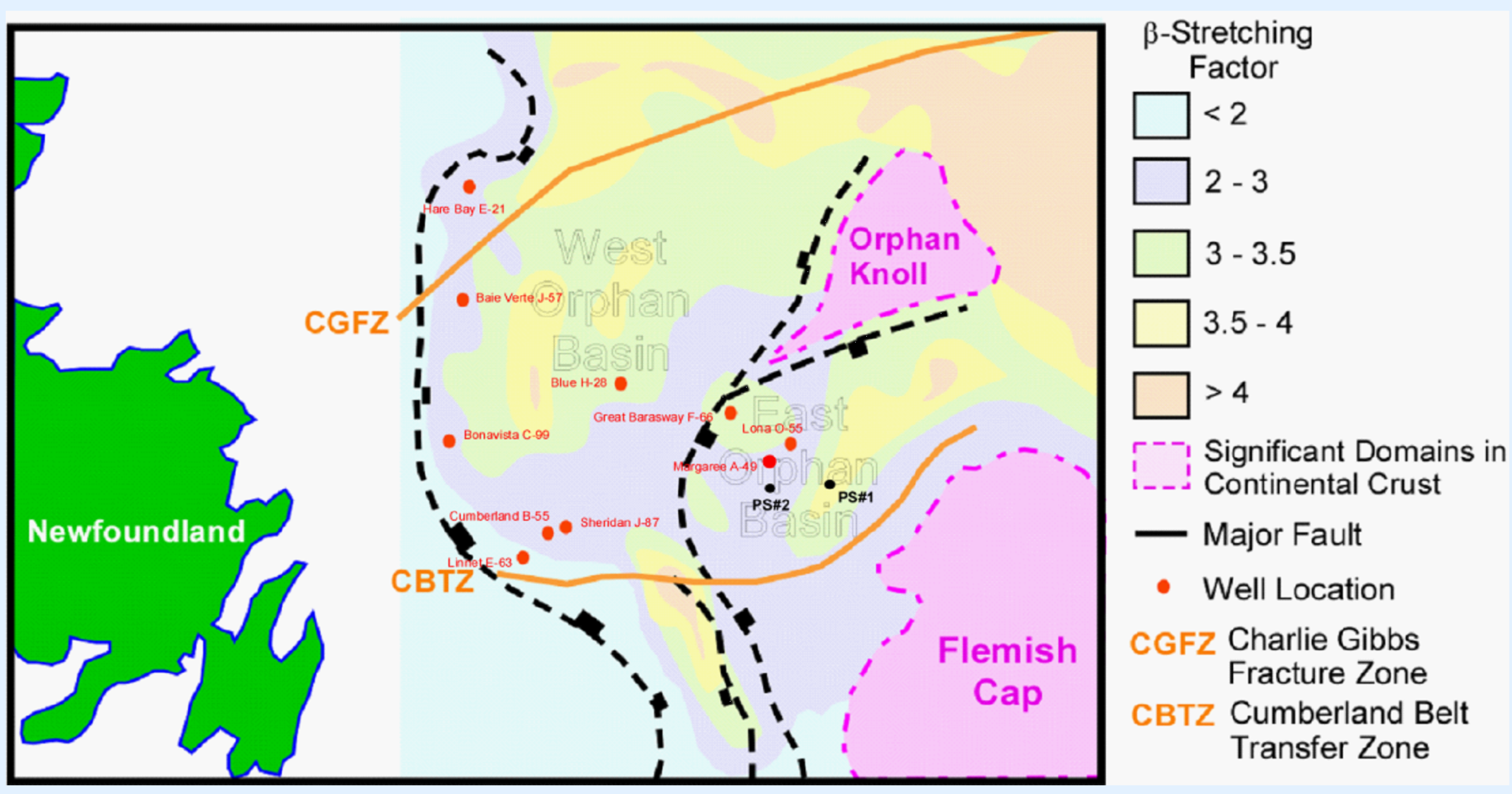

Figure 6: Stretching factor, β, at the initiation of sea-floor spreading within the general Orphan Basin area (adapted from Welford et al, 2012 by Knowles and Armstrong, 2018).

Heat-flow is initially calculated the stretch factor using a simple McKenzie type model (figure 7). The amount of stretching for a particular point has been calculated using the work of Welford et al (2012) (see Figure 6). The Novva software used in this study calibrates heat flow history against measured vitrinite and temperatures from the study wells. The findings of this part of the study are then applied to the pseudo wells as appropriate. In Figure 7, the area "a" is known to have the greatest stretching so, consequently the thinnest crust and has the highest initial heat-flow at the time of basin opening. Over time the amount of heat-flow decreases from a high of approximately 78mw/m^2 in locality "a" to a Present Day value of around 42mw/m^2. In the case of locality "d" which is on the basin margin and where stretching is minimal the maximum heat-flow does not exceed 47mw/m^2 decreasing to a low 30mw/m^2 Present Day .

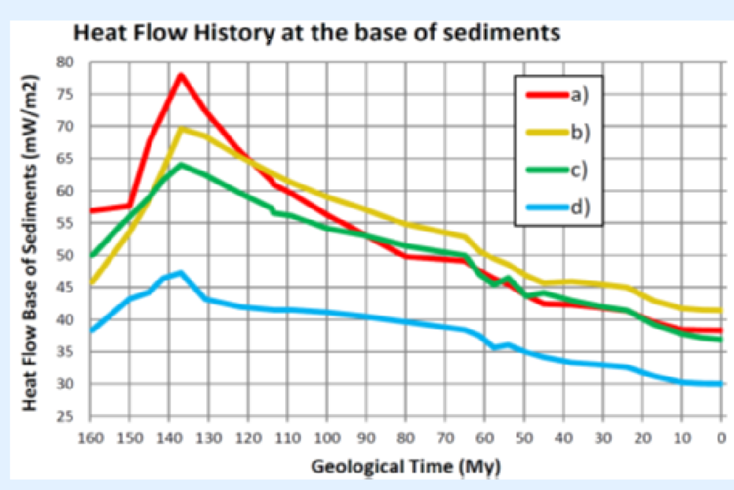

Figure 7: Heat flow history for different settings in the Orphan Basin across geological time (Beicip-Franlab 2018).