Mesozoic Paleodrainage and Extentional Tectonics of the Grand Banks: Constraints based on Detrital Zircon Provenance of Syn-Rift Sandstones in the Flemish Pass Basin

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(1) Introduction and Regional Geology

Regional Geology

- Atlantic Canadian Mesozoic rift basins associated with opening of North Atlantic Ocean are of particular interest for oil and gas exploration.
- Exploration interests are in deeper water (>500 m) Flemish Pass as well as West and East Orphan basins (FPB, WOB and EOB, respectively). Late Jurassic source rocks and Early Cretaceous reservoir sandstones are known to exist in FPB, and potentially extend into the EOB.

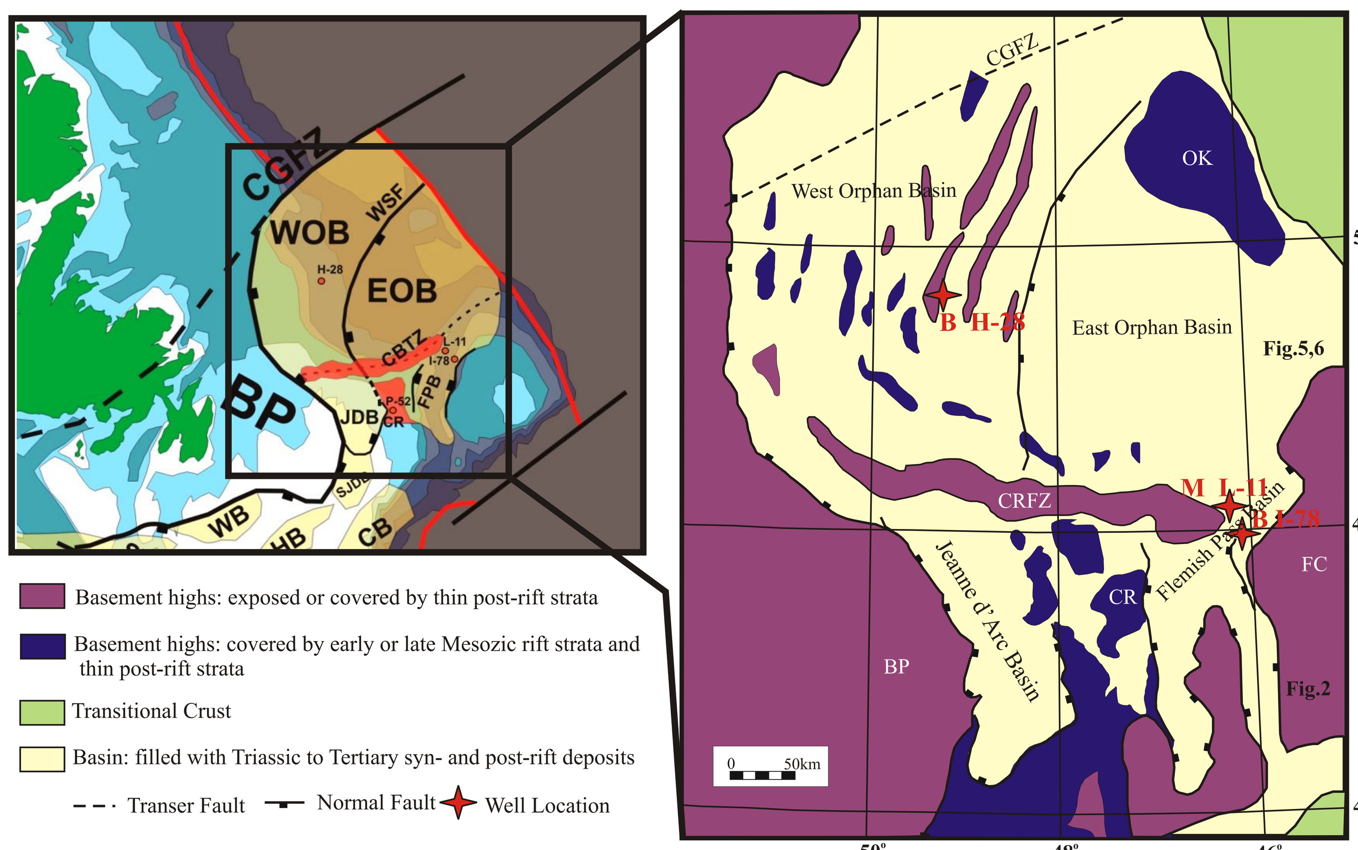


Fig.1:Regional geological and location map of the Mesozoic rift basins on the northern Grand Banks and Northeast Newfoundland Shelf. JDB= Jeanne d'Arc basin; FPB= Flemish Pass basin; EOB= East Orphan basin; WOB= West Orphan basin; CR= Central Ridge; WFS= White Sail fault; FC= Flemish Capl. The three wells studied are Baccalieu I-78 (B I-78), Mizzen L-11 (M L-11) and Blue H-28 (B H-28).

Regional Geologic Evolution

Rifting on this margin was sequential and occurred in 3-4 stages. The most important rifting stage for the studied intervals is the North Atlantic Rifting (Late Jurassic to Early Cretaceous) This rifting stage was focussed between the Grand Banks and Iberia (IB), and ended with seafloor spreading between the Grand Bands and Iberia(IB) at approximately 120 Ma.

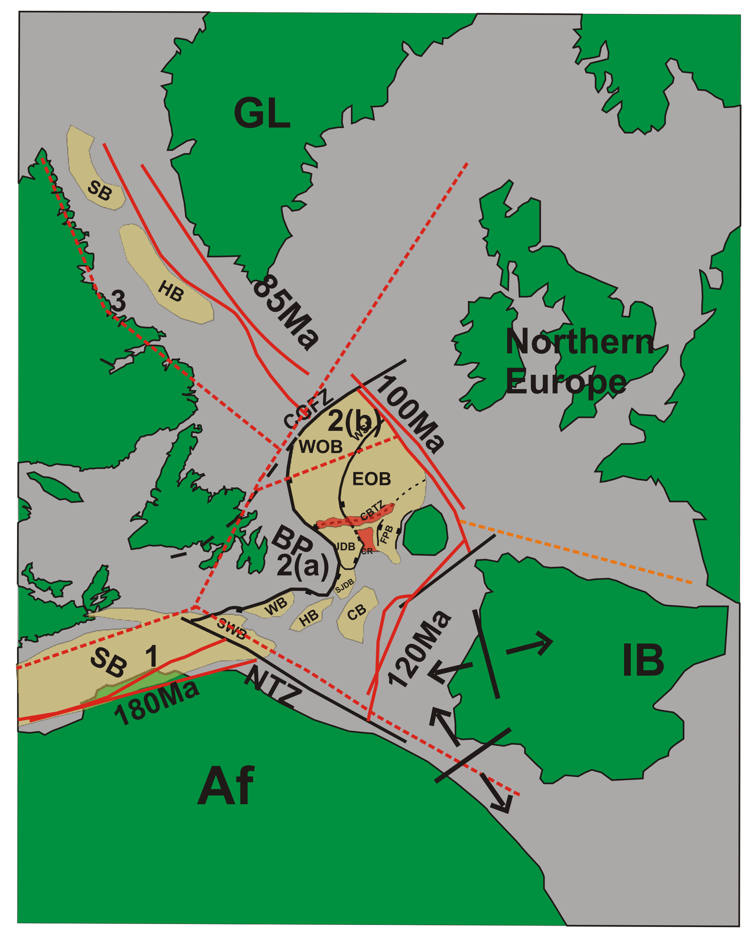


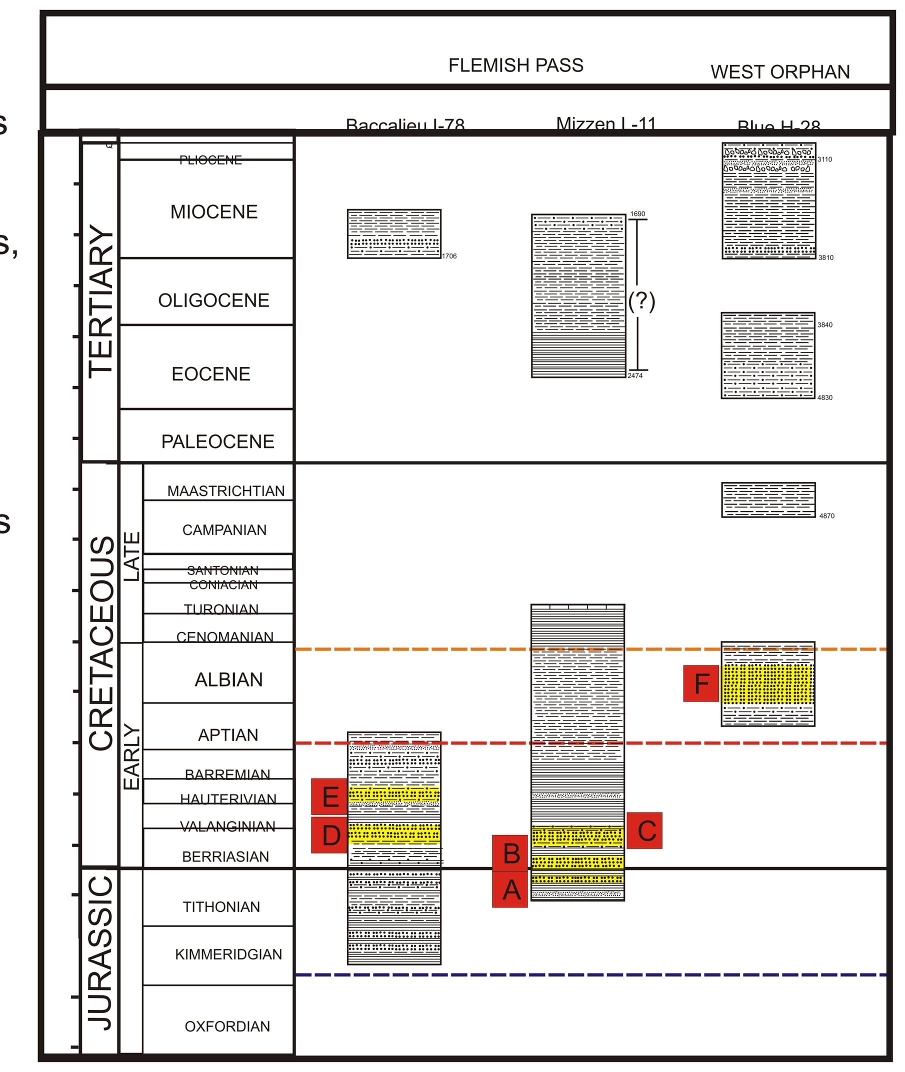
Fig.2: Paleogeographic reconstruction of the North Atlantic region prior to continental rifting and seafloor speading. The approximate ages of incipient seafloor spreading are given. Modified from Ziegler, 1989.

Fig.3: Chronostratigraphic columns showing wells and stratigraphic location/age of sandstone formations used for provenance analysis in this study. The sandstones were intercepted by and gas industry wells, and cuttings samples from these wells were used in this study.

In the Flemish Pass Basin, Late Jurassic to Early Cretaceous sandstones were sampled from the Mizzen L-11 and Baccalieu I-78 wells (M L-11 and B I-78 on Fig.1) These sandstones were deposited during the North Atlantic rifting stage.

In the West Orphan Basin, an Albian sandstone was sampled from the Blue H-28 well (B H-28 in Fig.1).

The table below outlines the names, litholgies, depositonal settings and biostratigraphic and detrital zircon depositional age constraints.



	Unit	Age	Max Depositional age (zircons)	Lithology	Depositional setting
(A)	Jurassic SSt 2	Tithonian	Tithonian-Berriasian	Qtz arenite	Fluvial or gravity flow
(B)	Jurassic SSt 1	Tithonian	Berriasian	Qtz arenite	Fluvial- up. shoreface
(C)	Baccalieu SSt	Neocomian	N/A	Lithic wacke and shales	Turbiditic sst
(D)	Hibernia Fm.	Berriasian	N/A	Sub-litharenite	Fluvial-Deltaic
(E)	Avalon Fm.	Hautervarian-Valanginian	N/A	Biotrub. Qtz wacke	Lower shoreface
(F)	Albian Sandstone	Albian	N/A	Sandstone (?)	Unknown

(2) Detrital zircon analysis and geochronology

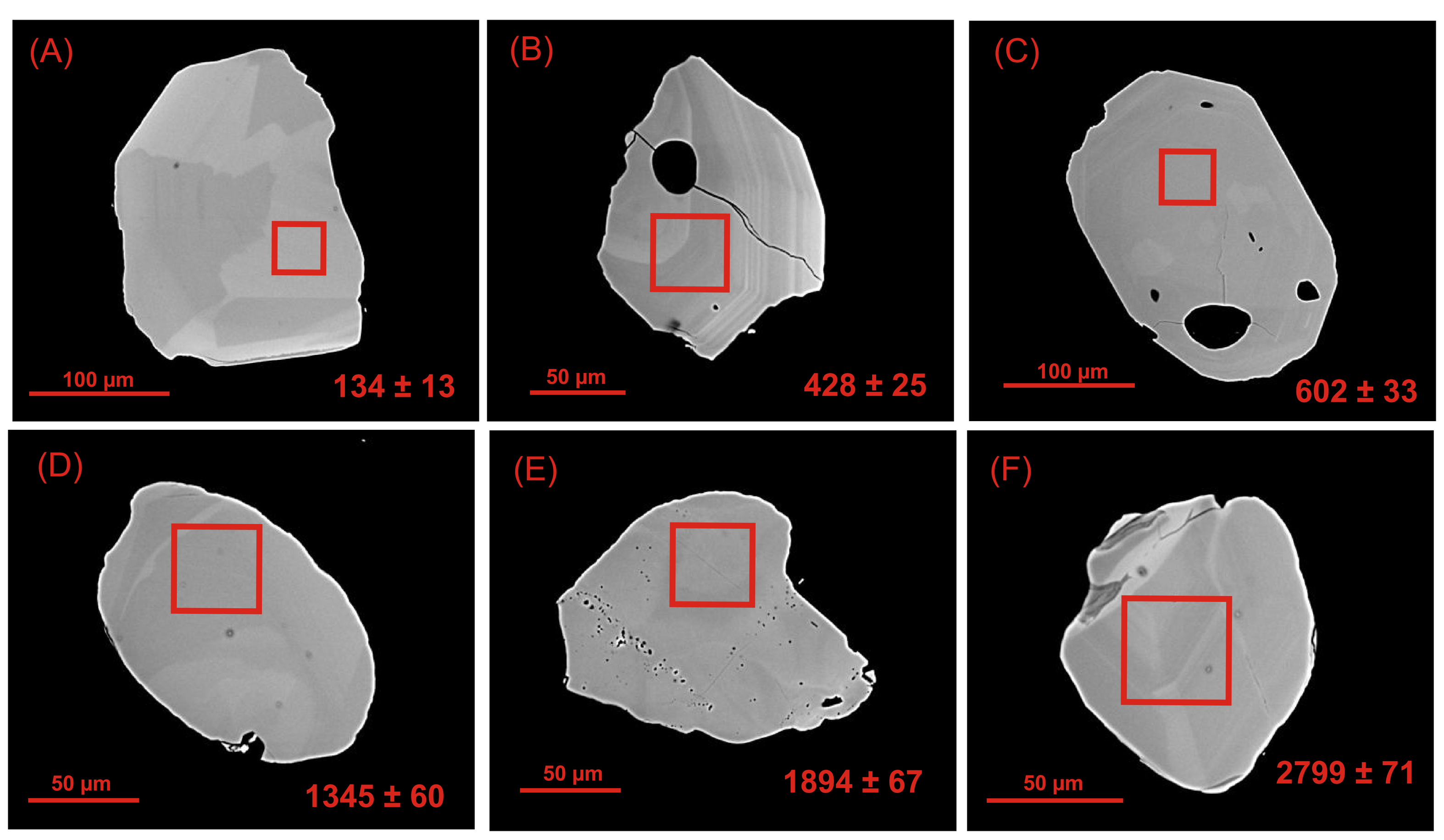


Fig.4: Detrital zircon grains were mounted in epoxy and imaged using an SEM in back scattered electron mode to obtain qualitative data such as zoning, morphology, aspect ratio and size. U, Pb and Th isotopes were measured using LA-ICPMS, also at Memorial University. Th/U ratios were also used in this study as qualitative grain data. Shown here are BSE images of detrital zircons with locations of 40*40 µm laser raster pits from "Jurassic Sandstone #1":

(A) Relatively large, subhedral sector + oscillatory zoned Mesozoic aged (Early Cretaceous) detrital zircon; probable first-cycle igneous plutonic origin.
(B) Subhedral/ broken or angular and oscillatory zoned Silurian aged detrital zircon; probable first-cycle igneous plutonic or volcanic origin.
(C) Large, subhedral and sector + oscillatory zoned Late Neoproterozoic zircon; probably first-cycle igneous plutonic origin.
(D) Sub-round and irregularly zoned Mesoproterozoic detrital zircon; probably second- or multi-order metamorphic origin.
(E) Sub-angular to sub-round, irregularly zoned Paleoproterozoic detrital zircon; probable first- or muli-order metamorphic origin.
(F) Sub-rounded, sector + oscillatory and partially irregulalry zoned Archean detrital zircon; probable multi-order (metamorphosed?) igneous plutonic or volcanic origin.

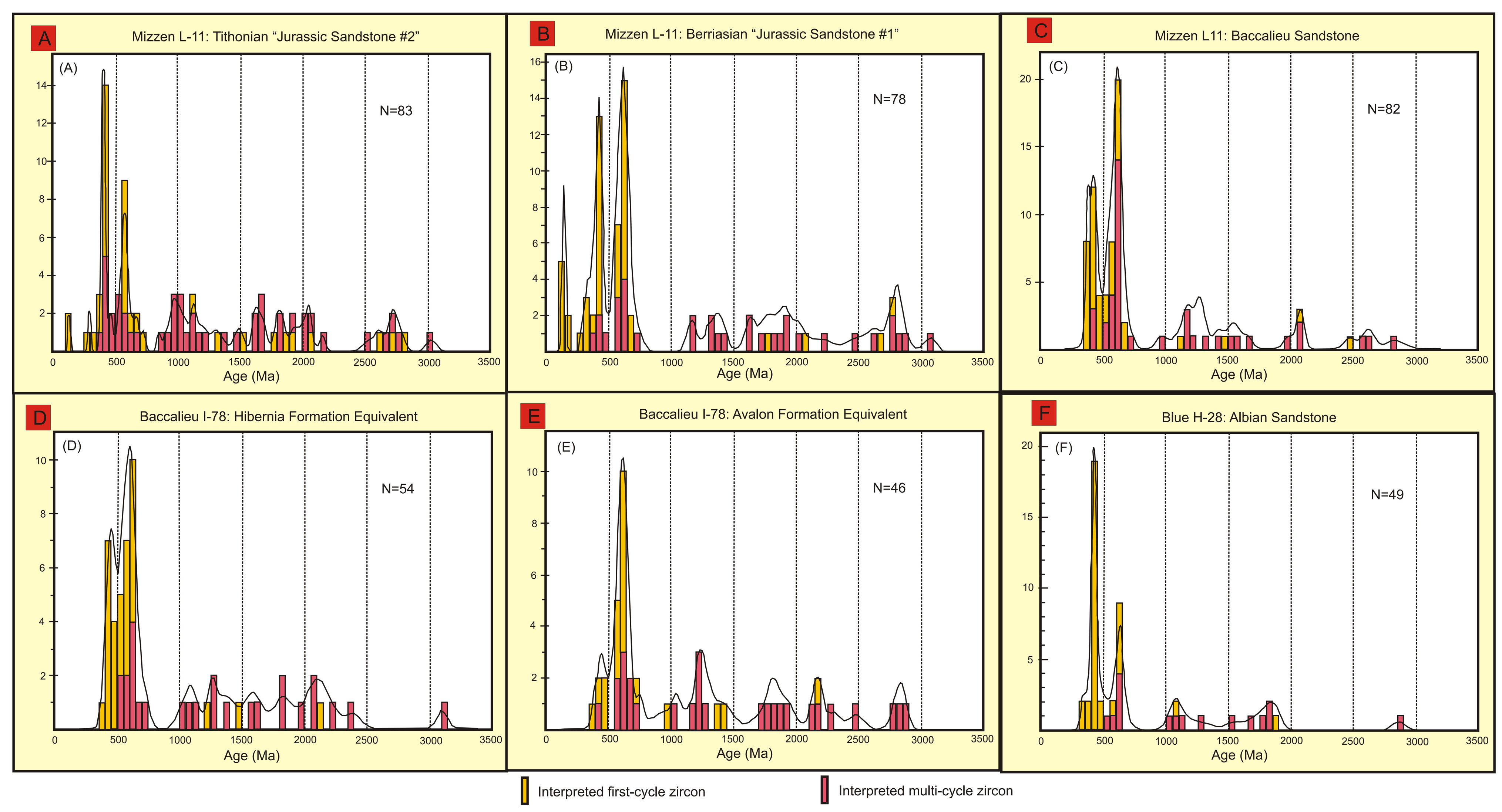


Fig.5: Histograms and cumulative probability plots of concordant ages of detrital zircons from each sample. Only concordant grain analyses with a probability of concordances greater than 1% were used. The most common age peaks encountered are Late Neoproterozoic (610-620 Ma), and Silurian to Early Devonian (400-430 Ma). Less common age peaks and groupings include Jurassic-Cretaceous (130-150Ma), Ordovician (450-480 Ma) and Late Devonian (360-380 Ma) sub-populations. Lesser amounts fo the dated grains were Meosproterozoic and older, and minor age peaks at 1.0-1.3 Ga, 1.6-1.8 Ga, 2.0-2.2 Ga and 2.6-2.7 Ga. The grains were also interpreted as probable first-cycle or recycled based on grain morphology analysis, and this information was used to further identify the origin of detrital grain populations. Most >1Ga detrital zircons are interpreted to have been recycled.

(3) Provenance Interpretations

- Most of Late Jurassic to early Cretaceous sandstones are interpreted to have had source areas to the west and northwest, including orogenic granites in the Gander and Dunnage Zones and arc-phase magmatics of the Avalon Zone present in western/central Newfoundland, Bonavista platform (BP), northeastern Newfoundland shelf and parts of the Irish conjugate margin (Fig.6). based on predominance of first-cycle grain populations with Silurian-Early Devonian and Neoproterozoic ages. Therefore, regional paleo-drainage into the Flemish Pass/Orphan Basins was predominanlty from the west during the Late Jurassic to Early Cretaceous.
- A group of Late Devonian (380-360 Ma) first-cycle grains are present in the Berriasian aged turbiditic Baccalieu Sandstone, indicative of sourcing from the late orogenic grainites present in the Meguma Zone, which occurs as pre-Mesozoic basement on the Avalon Uplift area (Haworth and Lefort, 1979) (AU, Fig.6). Therefore, the Avalon Uplift is interpreted to have reached its maximum as a regional basement high and source of sediment during the Berriasian, at about the same time as seafloor spreading began between southern Iberia and the Grand Banks (Srivastava et al., 2000).
- The relative scarcity of 1.0 to 1.6 Ga first-cycle detrital zircons as well as detrital chromites in Late Jurassic and Early Cretaceous sandstones in the Flemish Pass Basin indicates that Grenville aged basement and Ordovician ophiolites of the Humber Zone in Western Newfoundland were not sources of sediment at this place and time. This is in contrast to the provenance of Early Cretaceous sandstones in the eastern Scotian Basin, where evidence suggests significant sourcing from the Humber Zone, to the north (Pe-Piper and Mackay, 2006.). Therefore, a drainage divide must have existed somewhere east of the Humber Zone in the Early Cretaceous (Fig.6).
- There is no evidence to support any distal eastern source areas on the Iberian conjugate margin or the Flemish Cap granodiorte, such as Carboniferous or Early Neoproterozoic grains, respectively. The most plausible scenario is that material from the Flemish Cap-Galicia Bank (FC-GB) was instead diverted south, into the incipient Atlantic, or northeast, into the Bay of Biscay during the Late Jurassic to Early Cretaceous (Fig.6).

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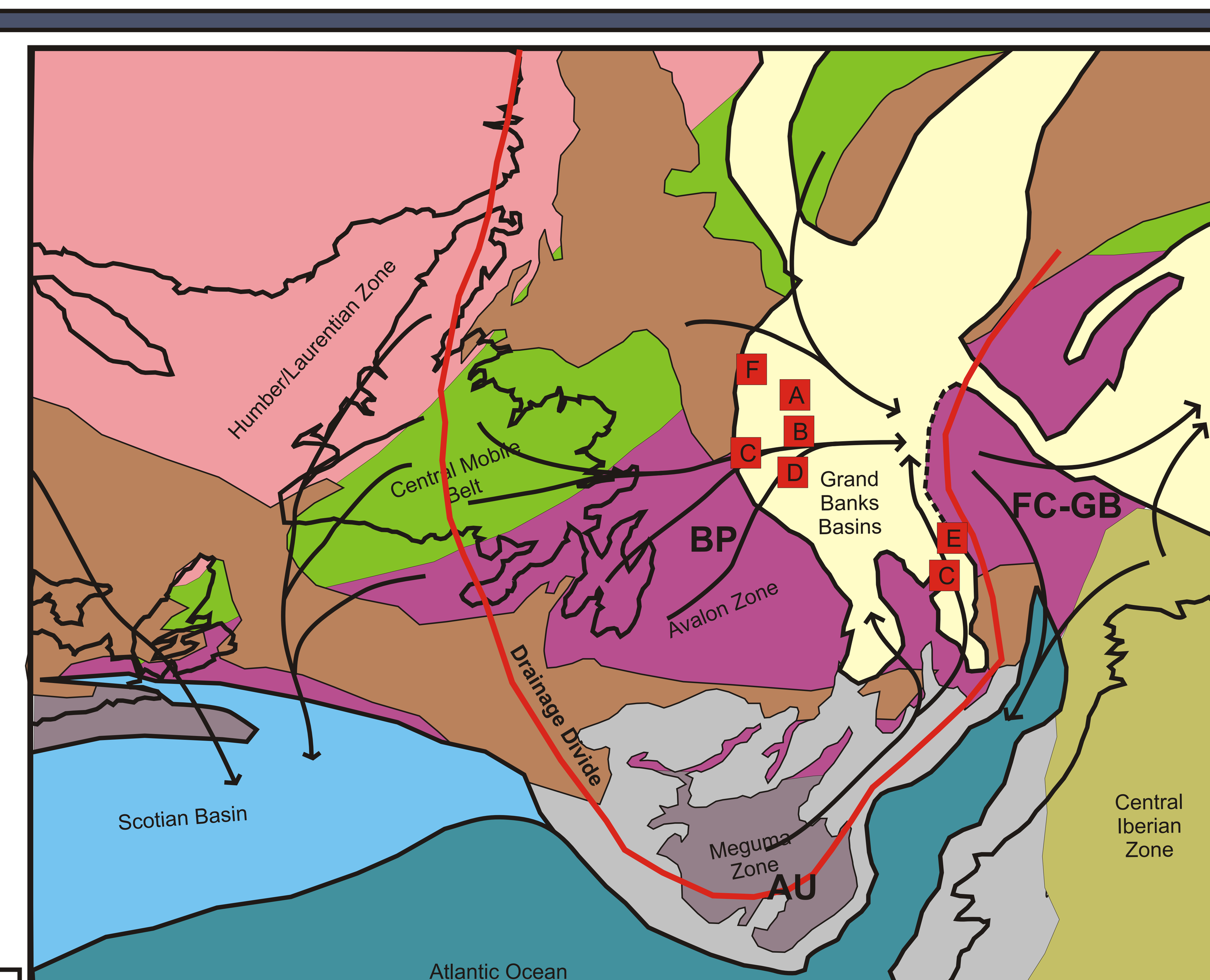

Fig.6: Paleogeographic reconstruction of the Late Jurassic-Early Cretaceous incipient North Atlantic, showing potentially exposed pre-Mesozoic basement and basin areas. The offshore extensions of onland pre-Mesozoic geologic zones are mainly from Lefort (1983), Haworth and Lefort (1979), Johnson et al. (2001) and Capdevila and Mougenot (1988). Paleogeography is mainly from Zeigler (1989) and Srivastava et al. (2001). Scotian Basin provenance from Pe-Piper and Mackay (2006).