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Eocene Compressive Deformation in Arctic Canada, North Greenland and Svalbard and Its Plate Tectonic Causes

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THEME 6: Eurekan Tectonics in Canada, North Greenland, Spitsbergen: Fold Belts Adjacent to Extensional Ocean Basins

Summary: The compressive deformation in the Eurekan fold belt of Canada as well as in the West-Spitsbergen Fold-and-thrust belt is related to northward movement of the Greenland plate between anomalies 24 and 13. During this period, spreading systems W and E of Greenland, converging at a RRR triple-junction S of Greenland, were active simultaneously. It is proposed that sinistral strike-slip movement in Nares Strait occurred before this period, when spreading occurred in the Baffin Bay system W of Greenland only and the entire Eurasian plate (with Greenland attached) moved to the NE.

The lack of typical features such as syntectonic magmatism and relicts of oceanic crust indicate that the Eocene fold belt extending today from Ellesmere Island through North Greenland into West Spitsbergen was not formed at an active plate margin by subduction or collision. The causes must be sought in the processes related to the stepwise separation of the Eurasian and North American plates. We propose that in the period between magnetic anomalies 24 and 13 (Eocene) characterized by contemporaneous spreading on either side of Greenland, Greenland moved north as an independent microplate. This movement caused compression of the E-W trending fold belt.

Greenland is separated from the North American plate by the Labrador Sea / Baffin Bay system of spreading ridges and from the Eurasian plate by the North Atlantic spreading system (Fig. 1). Two megashears, the sinistral Wegener Fault in Nares Strait at the NW corner of Greenland, and the dextral De Geer Fault in Fram Strait at the NE corner are generally taken to be connected with these spreading systems. Spreading in the Labrador Sea (SRIVASTAVA 1978, HINZ et al., 1979) was active between anomalies 34 (Late Cretaceous) and 13 (Oligocene); the North Atlantic spreading (TALWANI & ELDHOLM 1977) between anomalies 24 (Eocene) and the present (Fig. 2). Therefore contemporaneous spreading occurred on either side of Greenland between anomalies 24 and 13.

Both, west and east of Greenland, the spreading processes have been used to explain:

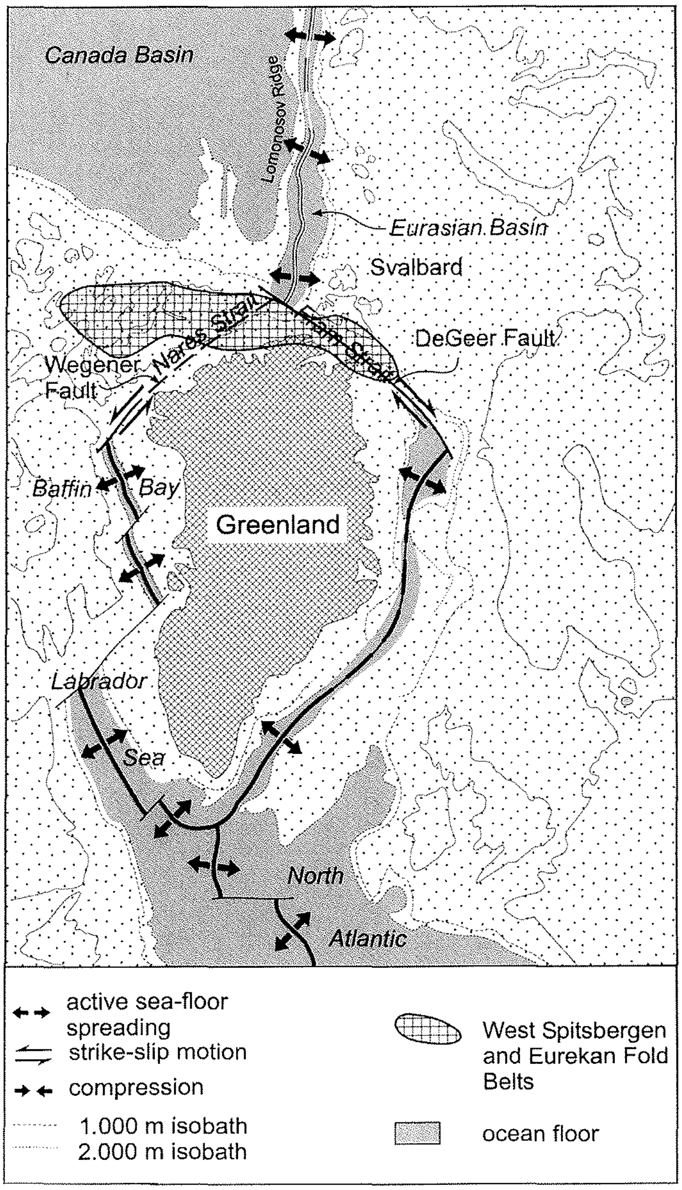

Fig. 1: Plate tectonic setting of Greenland and location of Eocene foldbelt extending from Canada to Svalbard.

a) major strike-slip movements on the megashears and
b) compressional deformation of the Eurekan and West Spitzbergen foldbelts.

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The latter are part of a continuous compressive fold belt system north of Greenland, which stretches from Canada to Svalbard and was formed contemporaneously with the spreading systems, but at roughly right angles. With the exception of HARLAND (1965), SOPER et al. (1982) and LEPVRIER (this volume), this fold belt has generally not been treated as a tectonic entity, but instead rather locally in Canada, North Greenland and Spitsbergen. This treatment resulted in a number of local genetic models some of which contradict each other.

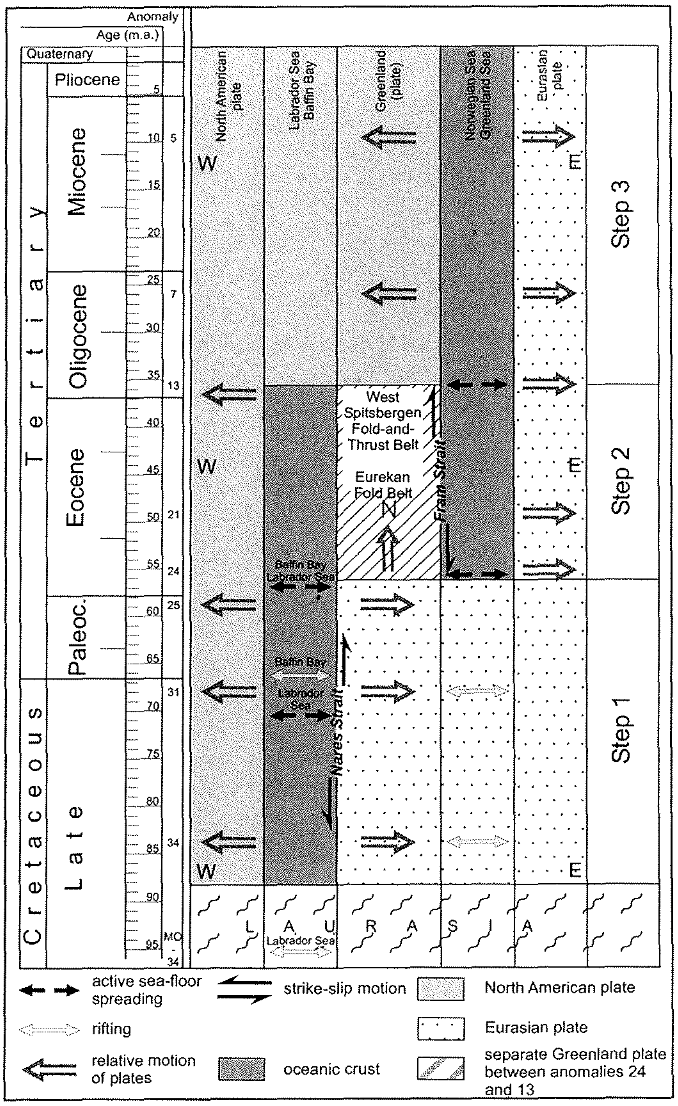

Fig. 2: Synopsis in time of sea-floor spreading events east and west of Greenland during the evolutionary split of the Eurasian plate (right) and the North American plate (left). The formation of the Eurekan+West Spitsbergen foldbelt in our interpretation coincides with the 20 m.y. long phase of contemporaneous spreading west and east of Greenland.

However, common features over the whole area are well developed fold and thrust structures and the lack of syntectonic magmatism and of metamorphism as well as the general lack of oceanic material involved. All these features indicate an intraplate rather than a plate-margin development of the fold belt.

Consistent with this interpretation both foreland margins of the belt are exposed in Canada and in the North Greenland /

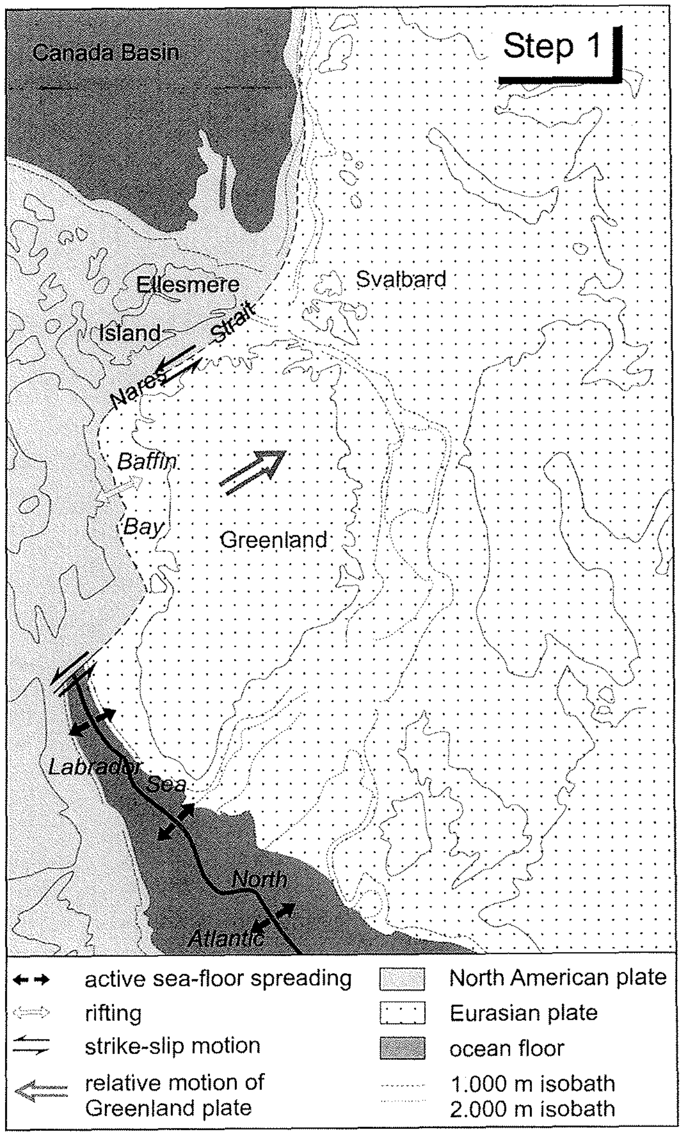

Fig. 3: Reconstruction during anomaly 31 time (68 Ma), modified after SRIVASTAVA & TAPSCOTT (1986). Greenland is part of the Eurasian plate; sea-floor spreading in the North Atlantic Ocean south of Greenland and in the Labrador Sea; rifting in Baffin Bay. The relative motion of Greenland is to the NE with strike-slip along Nares Strait.

Svalbard couple (the two areas having been juxtaposed during the time of deformation). In Canada, the main direction of tectonic transport is cratonwards to the S and SE, but some thrust movements have also occurred in the opposite sense to the N and NW. In Greenland, the main direction of tectonic tranport is to the N as shown particularly well in the Cape Washington area. In Svalbard, the main tectonic transport is to the NE. A rather common feature of the deformational belt is also the partitioning of the deformation into areas with particular strong deformation (along pre-existing lines of weakness) and in intervening areas with less deformation This partitioning is particularly well developed into North Greenland, but is also obvious in the western parts of Spitsbergen.

West of Greenland, the opening of the Labrador Sea / Baffin Bay system requires a NE-ward movement of Greenland in the order of 125 km (PEIRCE 1982, SRIVASTAVA 1982). This spreading system was employed to explain both,

a) the sinistral shearing in Nares Strait (Srivastava et al. 1981, Dawes & Kerr 1982), and
b) the Eurekan compressive deformation in Canada (Harland 1963), considered to be due to counterclockwise rotation of Greenland (Kerr 1967, Okulitch & Trettin 1991, Trettin 1991).
Both, shear and compression, are thus explained independently by the same plate tectonic process.

There are, however, a number of inconsistencies in the arguments:

• An isolated anticlockwise rotation of Greenland was hardly possible, when the latter was still attached to Eurasia (Fig. 3), or else it would require a different pole of rotation.
• The problem how both, strike-slip and compressional movements, can be at the same time the effects of Baffin Bay spreading, is unexplained. The time and space relation between these two tectonic products has not been discussed in any detail.
• There is a time problem between the Eurekan and the Baffin Bay opening as pointed out by Okulitch & Trettin (1991): "the onset of inferred spreading and rotation is much older than any known compression in the Eurekan orogen". Even if one assumes a later start of the Baffin Bay opening (Chalmers 1991) there remains a certain time gap.

East of Greenland, the transform movements between the opening of the ocean basins of the northernmost Atlantic and the Eurasian Arctic Ocean basin are considered as the cause for dextral shear and compressional fold belt deformation in Svalbard. But distinct from the Canadian side, both processes were supposed to be linked as dextral transpression (Harland 1969, Lowell 1972). However, also for this hypothesis some problems are obvious:

• The direction of the transform fault between the Eurasian and North Atlantic spreading axes is not at right angles to the spreading directions and thus would in principle lead to transtension rather than transpression (Fig. 5, inset).
• Strike-slip effects are hard to find in the field, the deformation consists mainly of orthogonal foreland thrusting (Bergh et al. 1989, Bergh 1990, Bergh et al. 1997, Tessensohn (ed.) in press).
• There is a similar time problem: Whereas deformation on Svalbard is supposed to have occurred in the Eocene, plate tectonic transform shear lasted much longer, from Eocene to the Oligocene opening of Fram Strait (Schlüter & Hinz 1978).

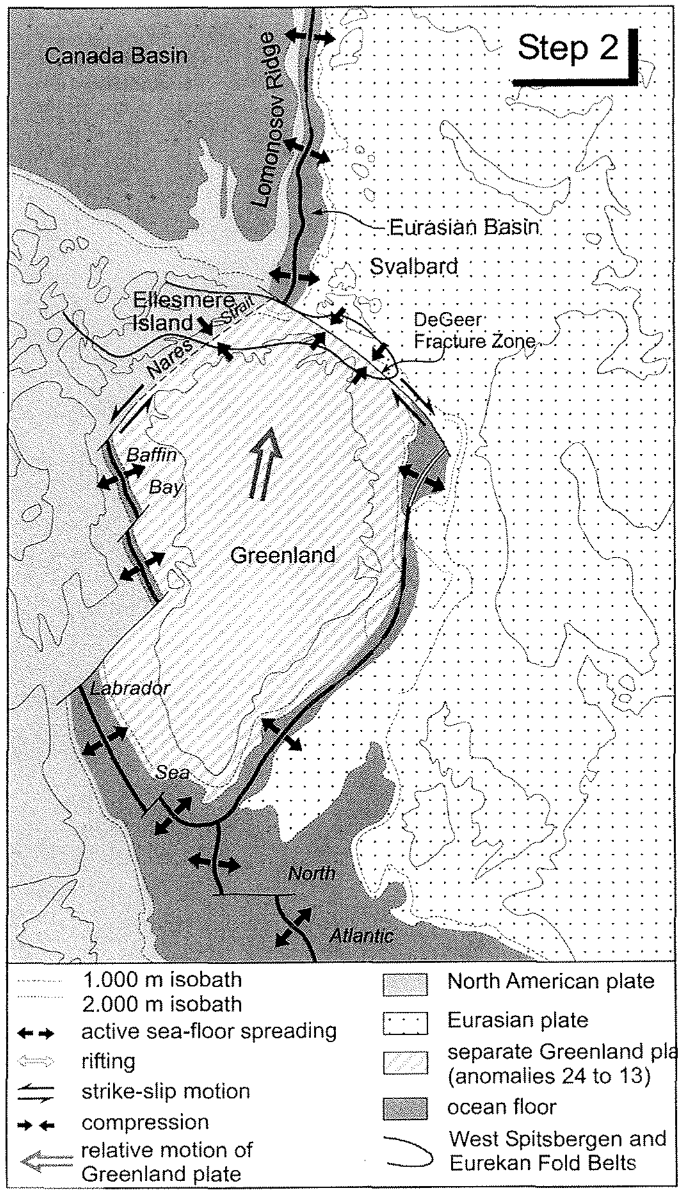

Fig. 4: Reconstruction during anomaly 24 time (55 Ma), modified after Menzies (1982) and Srivastava & Tapscott (1986). Greenland is a separate plate; seafloor spreading in Eurasian Basin, Greenland/Norwegian Seas, North Atlantic Ocean, Labrador Basin and Baffin Bay. Relative movement of Greenland is to the north, causing the main phase of compressive deformation in the Eurekan and West Spitsbergen fold belts.

Based on our analysis of foldbelt structures in Spitsbergen (CASE 1), North-Greenland (CASE 2) and Canada (CASE 4) and on the plate tectonic setting east and west of Greenland as described in the literature, we propose a modified three-step model which can provide solutions to these problems:

Step 1: Seafloor spreading in the Labrador Sea /Baffin Bay system between anomalies 34 and 24 caused NE-ward movement of Greenland *and* Eurasia with strike-slip effects along Nares Strait (Fig. 3).

Step 2: Contemporaneous spreading took place between anomalies 24 and 13 on either side of Greenland in the Labrador Sea and the North Atlantic, the two spreading systems being linked by a RRR triple junction south of Greenland (Fig. 4). This resulted in a northward escape movement of the Greenland plate. This northward movement is made responsible for the compressional deformation of the Eurekan and the West Spitsbergen foldbelts. The onset of this movement at anomaly 24 corresponds well with the assumed Eocene age of for the foldbelt deformation.

Step 3: After ceasing of seafloor spreading W of Greenland and related cessation of the N-drift of Greenland at anomaly 13 time, transtensional opening of the Fram Strait between Greenland and Svalbard (Fig. 5).

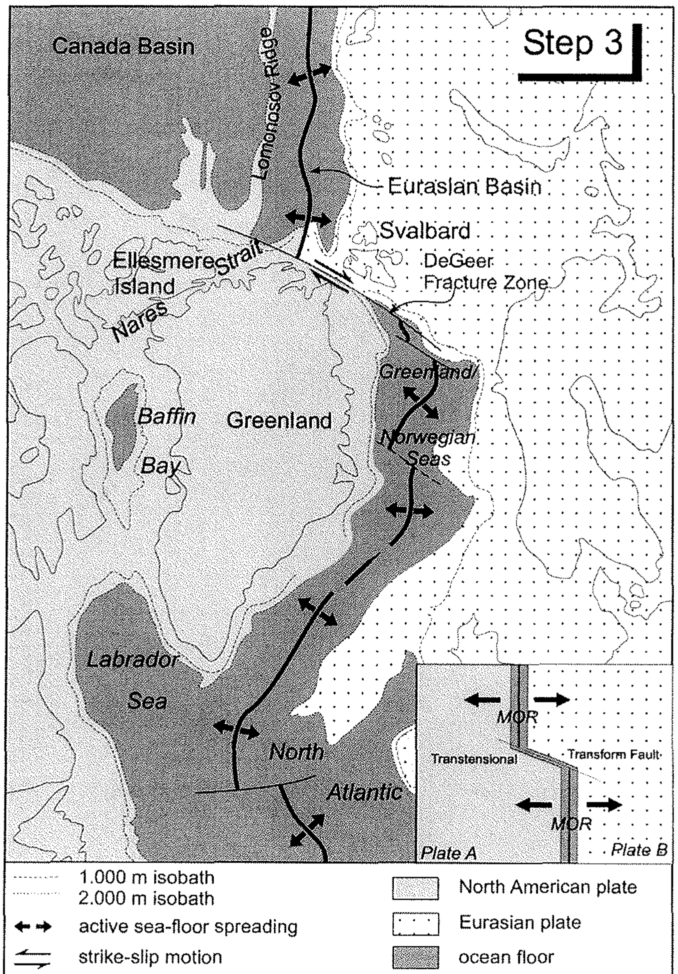

Fig. 5: Reconstruction during anomaly 13 time (36 Ma), modified after SRIVASTAVA & TAPSCOTT (1986). Sea-floor spreading in Labrador Sea and Baffin Bay has ceased. Greenland is part of the North American plate; sea-floor spreading in Eurasian Basin and Greenland/Norwegian Seas; de Geer Fracture Zone becomes transtensional transform fault. Inset: Cartoon illustrating principle of transtensional movement along oblique transform fault between two orthogonally separating plates:

A consequence of this model is the assumption, that strike-slip movements in Nares Strait are older than the Eurekan deformation. This assumption can possibly be tested either onshore by paleomagnetic and structural investigations on the Nares Strait coast of Ellesmere Island, where both features come closest together or offshore by a seismic program in Nares Strait.

References

Bergh, S.G. (1990): Structural development of the Tertiary fold-and-thrust belt in east Oscar II Land, Spitsbergen.- Polar Res. 8: 217-236.

Bergh, S.G., Andresen, A., Bergvik, A. & Hansen, A.I. (1988): Tertiary thin-skinned compressional deformation on Oskar II Land, central Vest-Spitsbergen.- Norsk Polarinst. Rapportser 46: 51-54.

Bergh, S.G., Braathen, A. & Andresen, A. (1997): Interaction of basement-involved and thin-skinned tectonism in the Tertiary Fold-Thrust belt of central Spitsbergen, Svalbard.- Am. Assoc. Petrol. Geol. Bull. 81: 637-661.

Chalmers, J.A. (1991): New evidence on the structure of the Labrador Sea/ Greenland continental margin.- J. Geol. Soc. 148, 499-908.

Dawes, P.R. & Kerr, J.W. ,eds., (1982): Nares Strait and the drift of Greenland: a conflict in plate tectonics.- Medd. om Grønland, Geosciences 8: 1-392.

Harland, W.B. (1965): The tectonic evolution of the Arctic-North Atlantic region.- Phil. Trans. Roy. Soc. 258: 59-75.

Harland, W.B. (1969: Contribution of Svalbard to the evolution of the North Atlantic region.- In: MCKAY (ed.), North Atlantic Geology and Continental Drift. Am. Ass. Petrol. Geol. Mem. 12: 817-857.

Harland, W.B. (1975): Paleogene correlation in and around Svalbard.- Geol. Mag. 112 (4): 421-429.

Harland, W.B. & Horsfield, W.T. (1974): West Spitsbergen Orogen.- In: A.M.SPENCER (ed.): Mesozoic-Cenozoic Orogenic Belts, Data for orogenic studies.- Geol. Soc. London Spec. Publ. 4: 747-755.

Hinz, K., Schlüter, H.-U., Grant, A.C., Srivastava, S.P., Umpleby, D. & Woodside, J. (1979): Geophysical transects of the Labrador Sea: Labrador to Southwest Greenland.- Tectonophysics 59: 151-183.

Kerr, J. (1967): Nares submarine rift valley and the relative motion of North Greenland.- Can. Petrol. Geol. Bull. 15: 483-520.

Kristoffersen, Y. & Talwani, M. (1977): Extinct triple junction south of Greenland and the Tertiary motion of Greenland relative to North America.- Geol. Soc. Am. Bull. 88: 1037-1049.

Lowell, J.D. (1972): Spitsbergen Tertiary Orogenic Belt and the Spitsbergen Fracture Zone.- Geol. Soc. Am. Bull. 83: 3091-3102.

Menzies, A.W. (1982): Crustal History and basin development of Baffin Bay.- In: P.R. DAWES & J.W. KERR (eds.), Nares Strait and the Drift of Greenland: a Conflict in Plate Tectonics. Medd. om Grønland, Geosciences 8: 295-312.

Okulitch, A.V. & Trettin, H. (1991): Late Cretaceous to Early Tertiary deformation, Arctic Islands.- In: H.P. TRETTIN (ed.), Chapter 17, Geology of the Innuitian Orogen and Arctic Platform of Canada and Greenland, Geol. Surv. Canada 3: 469-489.

Peirce, J.W. (1982): The evolution of the Nares Strait lineament and its relation to the Eurekan orogeny.- In: P.R. DAWES & J.W. KERR (eds.), Nares Strait and the Drift of Greenland: a Conflict in Plate Tectonics. Medd. om Grønland, Geosciences 8: 237-252.

Roest, W.R. & Srivastava, S.P. (1989): Sea-floor spreading in the Labrador Sea: A new reconstruction.- Geology 17: 1000-1003.

Schlüter, H.-U. & Hinz, K. (1978): The continental margin of West Spitsbergen.- Polarforschung 48: 151-164.

Soper, N.J., Dawes, P.R. & Higgins, A.K. (1982): Cretaceous - Tertiary magmatic and tectonic events in North Greenland and the history of adjacent ocean basins.- In: P.R. DAWES & J.W. KERR (eds.), Nares Strait and the Drift of Greenland: a conflict in Plate Tectonics. Medd. om Grønland, Geosciences 8: 205-220.

Srivastava, S.P. (1978): Evolution of the Labrador Sea and its bearing on the early evolution of the North Atlantic.- Geophys. J. Roy. Astr. Soc. 52: 313-357.

Srivastava, S.P. (1985): Evolution of the Eurasian Basin and its implications to the motion of Greenland along Nares Strait.- Tectonophysics 114: 29-53.

Srivastava, S.P., Falconer, K.H. & MacLean, B. (1981): Labrador Sea, Davis Strait, Baffin Bay: geology and geophysics - a review.- In: J.W. KERR & A.J. FERGUSSON (eds.), Geology of the North Atlantic borderlands.- Can. Soc. Petrol. Geol. Mem. 7: 333-398.

Srivastava, S.P. & Falconer, K.H. (1982): Nares Strait: a conflict between plate tectonic predictions and geological interpretation.- In: P.R. DAWES & J.W. KERR (eds.), Nares Strait and the Drift of Greenland: a Conflict in Plate Tectonics.- Medd. om Grønland, Geosciences 8: 339-352.

Srivastava, S.P. & Tapscott, C.R. (1986): Plate kinematics of the North Atlantic.- In: P.R.VOGT & B.E.TUCHOLKE (eds.), The Geology of North America, Vol. M, The Western North Atlantic Region, Geol. Soc. Am., 379-405.

Talwani, M. & Eldholm, O. (1977): Evolution of the Norwegian - Greenland Sea.- Geol. Soc. Am. Bull. 88: 969-999.

Tessensohn, F., (ed.), (in press): Intracontinental Fold Belts: CASE 1 - Spitsbergen.- Geol. Jb. B 91, Hannover.

Trettin, H. (1991): Tectonic framework.- In: H.P. Trettin (ed.), Chapter 4 in Geology of the Innuitian Orogen and Arctic Platform of Canada and Greenland, Geol. Surv. Canada 3: 59-68.