Publications of the Institute of Geophysics, Polish Academy of Sciences
Geophysical Data Bases, Processing and Instrumentation
vol. 452 (P-4), 2025, pp. 53–57
DOI: 10.25171/InstGeoph_PAS_Publs-2025-006
SVALGEOBASE II: Tectono-thermal evolution of Svalbard, geological workshop, Svalbard 2024

Tectonic Evolution of the Wandel Sea Basin, Eastern North Greenland: Insights from Structural Data, Detrital Zircons Geochronology, Mineralogy, Fluid Inclusions, Vitrinite Reflectance and Conodont Color Alteration Index

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A b s t r a c t

The Wandel Sea Basin (WSB) in eastern North Greenland is represented by a Late Paleozoic-Mesozoic rock succession unconformably overlying Caledonian tectonic units. In Peary Land major NE-dipping normal faults cut through the basin and separate it in two sectors. In the Whyckoff Land sector towards the North-East, the WSB succession unconformably covers Paleoproterozoic quarzites and is folded and metamorphosed up to lower amphibolite facies. In the Herluf Trolle Land sector of the south-western part, the WSB succession is undeformed, non-mature and unconformably onto Silurian flysch and carbonatic rocks. Campanian detrital zircons in the Herlufsholm Strand Formation indicate a possible correlation of this area with the Late Cretaceous volcanism of Kap Washington and constrain the peak metamorphism to the Maastrichtian-Early Paleocene. The Late Paleocene-Early Eocene Thyra Ø Formation post-dates the folding and the paleostress obtained from fault-slip inversion along major normal faults indicates tectonic inversion with compression followed by strike-slip faulting.

Keywords: Eurekan deformation, North Greenland, transpression.

1. INTRODUCTION

The Wandel Sea Basin (WSB) was defined by Dawes and Soper (1973) as a post-Devonian basin unconformably overlying the Silurian flysch-type sequences and the Caledonian tectonic units. The sequence starts with Upper Carboniferous-Lower Permian siliciclastic and calcareous rocks of the Mallemuk Mountain Group followed by Mesozoic sandstones and black shales. The evolution of the basin follows a NE-SW extensional phase separating Greenland from Svalbard since Late Paleozoic time. The pioneering work made after the "Kilen Expedition" in the 1980 (Håkansson et al. 1993) defined the basic geology, stratigraphy, and structural geology of eastern North Greenland and culminated with peer-reviewed papers, reports, and geological maps in the 1990s and later.

The general view of the authors was to relate the tectonic evolution of the area to strike-slip tectonics (Pedersen and Håkansson 1999; Håkansson and Pedersen 2001; 2015). The NW-SE trending faults referred to the Trolle Land Fault System, associated with the rift phases during the development of the WSB were interpreted as strike-slip faults active during the Late Cretaceous-Early Paleocene associated to the Wandel Hav strike-slip Mobile Belt (Håkansson and Pedersen 2001). The authors correlate this fault system with similar fault trends in the Kronprins Christian Land area. In particular, major evidence for strike-slip movements associated with this fault trend was interpreted from the offset of basement rocks that crop out in the Amdrup Land area. Here Carboniferous limestones unconformably rest on basement rocks and metasediments referred to the Independence Fjord Group (Fig. 1). Since similar rocks that crop out along the Caledonian front to the NW are interpreted to be part of the same tectonic unit, the consequence is almost 50 km of right-lateral movement accommodated along the fault.

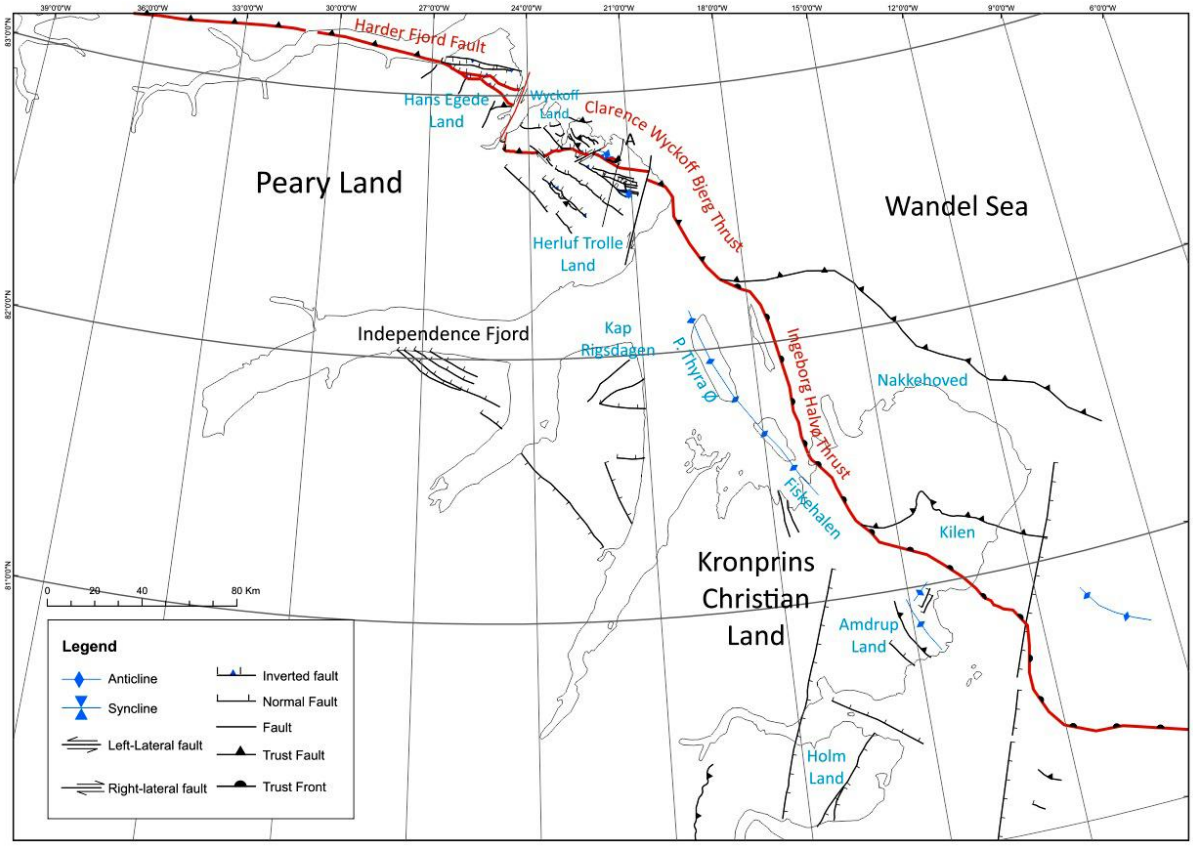

Fig. 1. Structural map of eastern North Greenland from Peary Land to Kronprins Christian Land. The Harder Fjord Fault together with the Clarence Wyckoff Bjerga Thrust and the Ingeborg Halvø Thrust represent the tectonic contact between metamorphic rocks of the Wandel Sea basin and immature rocks of the basin. A-location of the geologic cross-section shown in Fig. 2.

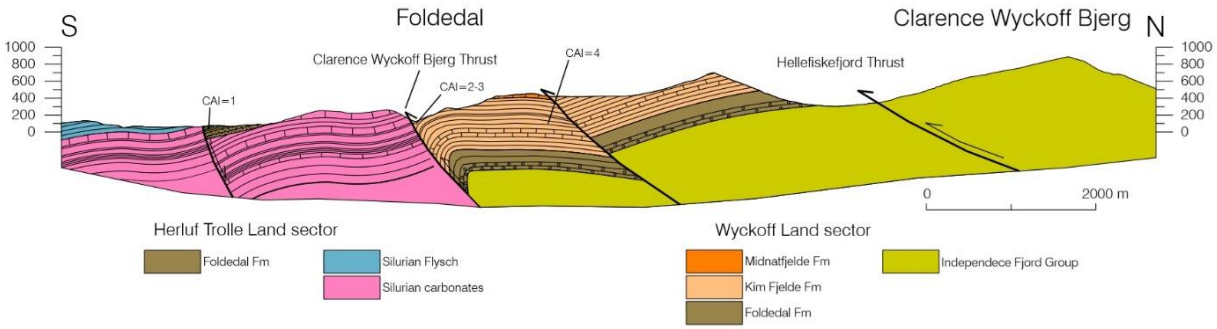

Fig. 2. Geologic cross-section of the northern part of Peary Land (see Fig. 1 for location). Upper Paleozoic rocks of the Wyckoff Land sector show higher thermal maturity compared to the Upper Paleozoic rocks of the Herluf Trolle Land sector as indicated by the Conodont Color Alteration Index (CAI).

A thermal event was recognized in the Wandel Sea Basin sediments (Pedersen and Håkansson 1999). It was well described by organic metamorphism from Vitrinite Reflectance (VR) and Conodont Color Alteration Index (CAI) (Rasmussen and Håkansson 1996) and from Fluid Inclusion (FI) analyses. Due to the absence of dykes and sill intrusions and to the size of the area overprinted by the metamorphism, the interpretation relates this thermal event to tectonic activity along faults belonging to the Wandel Hav Strike-Slip Mobile Belt (Pedersen and Håkansson 1999). Manby and Lyberis (2000), described the deformation in Trolle Land and Kronprins Christian Land as related to a NE-SW oriented compressional event pre-dating the opening of the Atlantic Ocean. The authors suggested a compression orthogonal to the continental boundary between Greenland and Svalbard. Later, von Gosen and Piepjohn (2003) interpreted the structures in Peary Land and Kronpins Christian Land as related to the Eocene Eurekan deformation suggesting transpressive tectonics along NW-SE trending faults like what was suggested by Håkansson and Pedersen (1982).

The structural interpretation and the tectonic model describing the evolution of the Wandel Sea Basin seem, however, inadequate. The current interpretation is unable to explain the most important thermal overprint observed. Both, Manby and Lyberis (2000) and von Gosen and Piepjohn (2003) did not consider the high thermal maturity of the Wandel Sea Basin sequence. In fact, strike-slip movement along faults described by previous authors pre-dates the Paleocene Thyra Ø Formation that in turn was interpreted as post-orogenic sequence.

2. DATA

The data presented in this study are based on fieldwork in North Greenland in 2012 and 2013 along with collection of oblique photos taken from a helicopter. The interpretation of structural data and the kinematics along major faults together with structural mapping are supported by a dataset of new analyses for Fluid Inclusions, Vitrinite Reflectance, Conodont Colour Alteration Index, mineralogy, and U-Pb age from detrital zircons. Structural analysis along major faults provides a new kinematic model that differs from published models and, together with the analytical data, could explain the strong thermal overprint affecting the Upper Paleozoic-Upper Cretaceous sediments of the Wandel Sea Basin.

3. RESULTS

During two field seasons in North Greenland (2012 and 2013) it was possible to observe folds and thrust faults clearly related to a compressive event involving Late Cretaceous sediments (e.g. Herlufsholm Strand Fm in Peary Land and the Kilen Group) (Guarnieri 2015; Svennevig et al. 2016). Tectonic activity along strike-slip faults and their offset are observed to be a minor event in the general deformation of the area and, in some places, not recognised or even absent.

Moreover, the absence of intrusions in the area, the size of the thermal overprint and the general increasing of maturity from SW to NE together with the style of the deformation, suggest an alternative tectonic setting. The thermal overprint should be considered as regional metamorphic event, and the understanding of this metamorphism seems to be crucial for the tectonic evolution of this area and its conjugate margin, Svalbard and the western Barents Sea.

Deformation in the Wandel Sea is considered Eurekan as in the West Spitsbergen and in North Greenland and it is related to the opening of the North Atlantic and Arctic oceans. Plate tectonics reconstruction established a major convergence stage in the Paleocene followed by strike-slip stage in the Eocene (Guarnieri 2015; Svennevig et al. 2016). The thermal overprint highlighted by Håkansson et al. (1993) is now more constrained by new data. In particular the paleotemperature shows that maximum temperatures and the distribution of metamorphic rocks are not related to local sources, but they follow structural trends as major normal faults that were re-activated as thrust faults during basin inversion before the Eurekan (Fig. 1). The peak of temperature was reached in the latest Cretaceous-Paleocene as a combination of sedimentary and tectonic burial. Folds and thrusts represent the main structural style of deformation affecting the Wandel Sea Basin with minor strike-slip faults and the estimated shortening due to compression varies across the area with a maximum of 50–70 km in the southern sector.

4. CONCLUSIONS

The main deformation style in eastern North Greenland is associated to compressive structures. Strike-slip faults post-date compressive structures in the Wandel Sea Basin and this evidence could be interpreted as strain partitioning during transpression with compressive structures landwards with thrusting and basin inversion locally overprinted by strike-slip faults.

The main conclusions can be summarized as follows:

- Middle Paleocene–earliest Eocene (pre-Eurekan) compression with SSW to SW-ward directed thrusts and basin inversion bringing metamorphic rocks of the Wandel Sea Basin against immature sediments;
- Eocene strike-slip tectonics (Eurekan) with NW-SE trending faults locally offset compressive structures.

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Received 9 February 2025
Accepted 12 February 2025