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Crestal unconformities on an exposed Jurassic tilted fault block, Wollaston Forland, East Greenland as an analogue for buried hydrocarbon traps

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A B S T R A C T

The stratigraphy of successions exposed in footwall crests of tilted fault blocks is commonly highly complex. Crestal stratigraphy and structure are particularly difficult to unravel in the subsurface due to poor seismic resolution across fault zones, footwall collapse, and coalescing syn- and post-rift unconformities. Crestal ridges are important elements in basin evolution, as they form drainage divides and sediment sources for aprons along footwall scarps and hangingwall deltas. A Middle Jurassic – lowermost Cretaceous footwall crest is exceptionally well exposed in the mountain Stratumbjerg in Wollaston Forland, East Greenland. Rifting and block tilting was initiated in the (?)Bajocian, intensified in the Oxfordian–Kimmeridgian, culminated in latest Jurassic, Volgian, time and faded out in the earliest Cretaceous. The main border faults of the westward tilted blocks trend roughly N–S. The first early syn-rift block was formed in the Middle–Late Jurassic and was 40 km wide. During rift climax in the latest Jurassic it was fragmented into three blocks, each 10–15 km wide. The early syn-rift succession rests on thin Upper Permian evaporites and carbonates or directly on peneplaned crystalline basement. It is composed of the stepwise backstepping marine Pelion, Jakobsstigen and Bernbjerg Formations deposited in progressively deeper water, reflecting the combined effects of increased rifting and long-term eustatic rise. The rift-climax and late syn-rift succession was deposited along the main western basin margin fault scarp. Up to several kilometres thick, it consists of coalesced, mainly conglomeratic, deep-marine–slope-apron fans. Over the block crest this succession unconformably overlies early syn-rift strata, whereas in the deeper parts of the halfgraben, the base of the succession is conformable. A post-rift unconformity was formed in the late Hauterivian, probably during early post-rift emergence and has an irregular, stratigraphically and structurally controlled erosional topography. The eroded early syn-rift, rift-climax and late syn-rift successions were subsequently draped by deep-marine Barremian, and younger post-rift strata. The outcrop example highlights the interplay between large-scale block faulting, minor synthetic intra-block faulting, crestal degradation, and development of rift-climax and post-rift unconformities with pronounced erosional topography. It provides an excellent structural–sedimentological field analogue to deeply buried marine halfgraben settings, which are key elements in many hydrocarbon reservoirs. Its tectonic and stratigraphic development is thus highly similar to a number of large oil fields in the North Sea and the Norwegian shelf.

1. Introduction

The tilted fault block is the basic tectonic element in Mesozoic rift basins in the North Sea – North Atlantic region. Footwall crests contain the main reservoirs in a large number of oil and gas fields, and are particularly important in many prolific oil fields in the North Sea and elsewhere around the northern North Atlantic Ocean (Spencer and Larsen, 1990; Fraser et al., 2003; Husmo et al., 2003).

Mapping of the faults bounding large tilted blocks and of crestal unconformities in the subsurface is commonly hampered by poor seismic resolution across fault zones. Understanding of these features can be aided by the study of good field analogues. A well exposed dip section through a tilted Jurassic fault block occurs in the mountain Stratumbjerg in Wollaston Forland, East Greenland (Figs. 1 and 2; Vischer, 1943; Maync, 1947, 1949; Surlyk, 1977, 1978, 1984, 2003).

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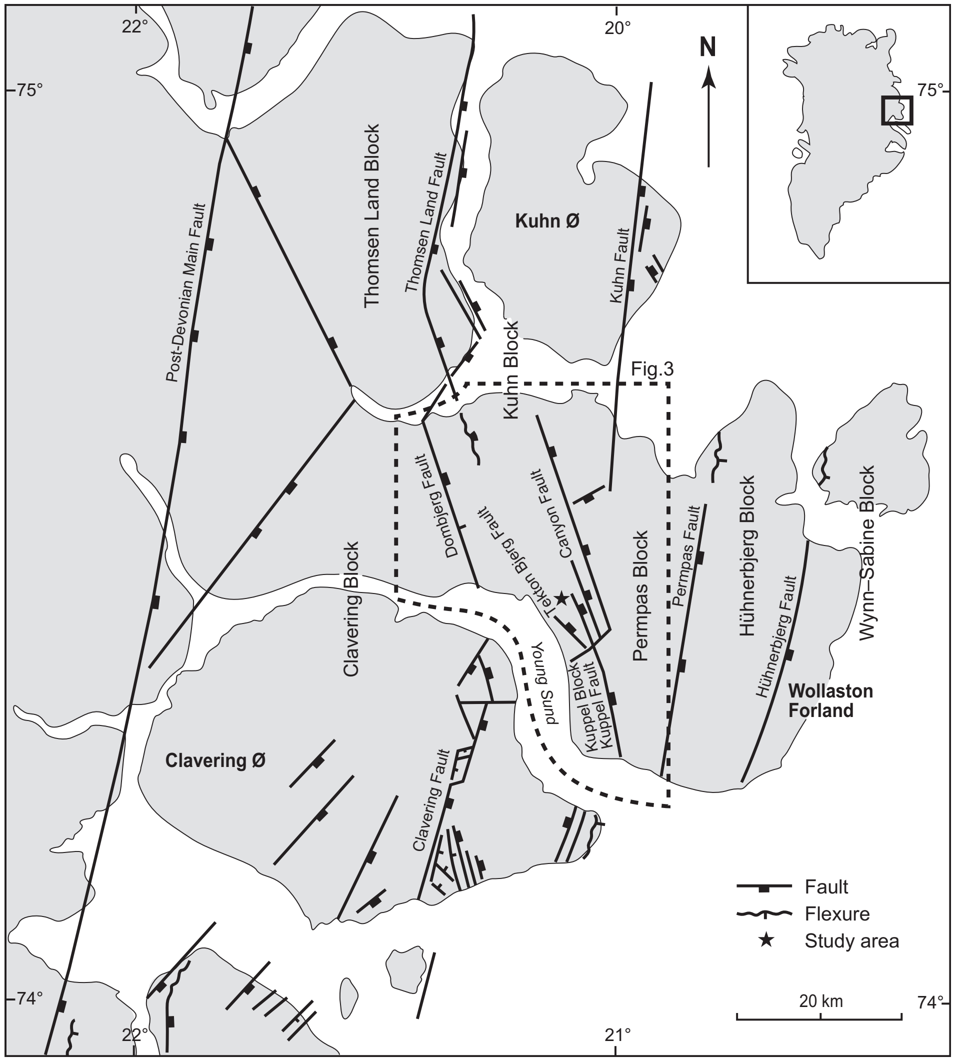

Figure 1. Map of the Wollaston Forland area, East Greenland, showing the main structural features, place names used in the text, and position of the studied locality marked with an asterisk. After Vischer (1943), Maync (1947, 1949), and Surlyk (1978).

The aim of this study is to describe and interpret the interplay between fault geometry, syn-rift deposition, late syn-rift fragmentation of the wide initial block, smaller scale synthetic intra-block faulting, formation of footwall terraces, post-rift erosion and subsequent infilling and draping of the erosional topography. Special emphasis is placed on illustrating the complex nature of the crestal area of a tilted fault block, which may serve as an excellent field analogue for similar deeply buried combined structural–stratigraphic hydrocarbon traps.

2. Geological setting and stratigraphy

The Late Palaeozoic – Mesozoic rift basin of East Greenland underwent major regional uplift of the order of several kilometres during late Cenozoic times (e.g. Christiansen et al., 1992). Remarkably well exposed and little deformed, the basin has received extensive stratigraphic, tectonic and especially sedimentological studies (Surlyk, 1990, 2003, and references therein). The tectonic style and stratigraphy of Jurassic tilted fault blocks in Wollaston Forland, northern East Greenland, were first unravelled in the classic studies of Vischer (1943) and Maync (1947, 1949). The basin evolution, sedimentary environments, lithostratigraphy and sequence stratigraphy of the early syn-rift succession were described by Surlyk (1977, 2003), Surlyk and Clemmensen (1983), Vosgerau et al. (2000), and Alsgaard et al. (2003). The rift-climax deposits were studied by Surlyk (1978, 1984, 1989, 2003) and Alsen (2006). A palynostratigraphic zonation of the Lower Cretaceous post-rift succession was presented by Nøhr-Hansen (1993). Recently, the Jurassic lithostratigraphic scheme has been revised (Surlyk, 2003; Surlyk et al., submitted for publication), and the new scheme is used here.

Major rifting and block tilting in the region took place in the Carboniferous, followed by rift events in Late Permian – earliest Triassic, late Early Triassic, and especially in Middle Jurassic – earliest Cretaceous times. The regional Late Permian transgression reached its northernmost onshore extent in southern Wollaston Forland where thin dolomites, carbonate collapse breccias, and anhydrites of the Foldvik Creek Group were deposited on the peneplaned and tilted surface of the crystalline basement (Fig. 2; Maync, 1942; Vischer, 1943; Surlyk et al., 1986). The sea withdrew from the area during the latest Permian and Triassic, and Lower Jurassic deposits appear to be primarily absent.

The Wollaston Forland area was transgressed again in the Middle Jurassic, but the onset of transgression is poorly dated. Farther south in East Greenland it took place in the late Bajocian (Surlyk, 2003). The (?)Bajocian – Kimmeridgian early syn-rift succession is up to