Geophysical Research Abstracts
Vol. 16, EGU2014-9774, 2014
EGU General Assembly 2014

Seafloor expressions of tectonic structures in Isfjorden, Svalbard: implications for fluid migration

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This study investigates the seafloor expressions of Isfjorden in western Svalbard, interlinked with sub-seafloor structures using a dense grid of 2D multichannel marine seismic and magnetic data integrated with high resolution multibeam bathymetric data. The underlying bedrock structures spans from Paleozoic carbonates and evaporates to Mesozoic and Paleogene sandstones and shales. This 4 to 6 km thick succession is truncated by structures linked to Eocene transpressional deformation that resulted in the formation of the West Spitsbergen Fold-and-Thrust Belt (WSFTB). The WSFTB divides into three major belts : (a) western zone characterized by a basement involved fold-thrust complex, (b) central zone consisting of three thin-skinned fold-thrust sheets with thrusts splaying from décollement layers and, east of a frontal duplex system, (c) eastern zone showing décollement in Mesozoic shales with some thrust splays, and with the décollement interacting with reactivated, steep and basement-rooted faults (Bergh et al., 1997). In the continuation, we discuss combined seafloor and bedrock observations, starting from the west.

In the west, a 6.5 km long and 5 to 9 m high ridge demarcates the eastern boundary of the major basement involved fold complex, with thrusted and folded competent Cretaceous to Paleogene units reaching the seafloor. Three submarine slides originate from this ridge, possibly triggered by tectonic activities. In Central Isfjorden (central zone of the WSFTB), several NNW-SSE striking ridges with a relief of 5 to 25 m have been tied with shallow, steep faults and folds. In addition to the NNW-SSE striking ridges, a set of SW-NE striking ridges with relief of 2 to 5 m are observed in Nordfjorden. Based on the seismic data observations, these ridges can be linked to the surface expression of competent sandstones that are transported on splay-thrusts above a décollement in Triassic shales. Further, seafloor ridges with relief of 5 of 18 m, linked to high amplitude flat reflectors and high magnetic values have been interpreted as Cretaceous dolerite intrusions in Nordfjorden and central Isfjorden. In the eastern Isfjorden (eastern zone of WSFTB), a 10.5 km long N-S striking ridge in Billefjorden corresponds to the deep-seated Billefjorden Fault Zone, extending south across the mouth of Tempelfjorden where it is 8.5 km long. This composite ridge is bound by a steep east-dipping fault, placing competent Carboniferous and Permian carbonates at the seafloor.

Overall, our study shows a distinct pattern of pockmarks concentrated along the identified ridges on the seafloor of Isfjorden. These ridges can be linked to fault-fold systems and dolerite intrusions in the bedrock, thereby suggesting various possible fluid migration pathways towards pockmarks: (i) along fracture networks associated with folds and intrusions, (ii) along décollement zones and faults acting as localized conduits, and (iii) directly from organic rich layers when exposed at the seafloor.

Reference:

Bergh, S. G., Braathen, A., and Andresen, A., 1997, Interaction of basement-involved and thin-skinned tectonism in the Tertiary fold-thrust belt of central Spitsbergen, Svalbard: AAPG Bulletin, v. 81, no. 4, p. 637-661.