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Effects of stress changes due to glacial erosion on reservoir excess pressure and fault-zone reactivation

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Rapid, massive erosion is known to alter the stress field in the crust. Such stress changes may affect the excess pressure in fluid-filled reservoirs, such as petroleum reservoirs, and also result in changes in the local stresses around and inside fault zones. The likelihood of fault reactivation and leakage of hydrocarbons from reservoirs has been an issue for the petroleum exploration in areas such as the southwest part of the Barents Sea and in the area off Lofoten, Norway. It is widely accepted that both of these areas have been subject to extensive glacial erosion during the Plio-Pleistocene. Exploration in the southwest part of the Barents Sea have so far resulted mainly in gas discoveries; finding commercial oil deposits has turned out more difficult than expected. The drill cores show rather large amounts of residual oil, so it is likely that hydrocarbons may have leaked out of the systems. It has also been discussed if the potential petroleum exploration off Lofoten may turn out similarly.

Analytical models indicate that a rapid glacial-erosion removal of 900 m thick sediments, similar to the estimated amount of erosion in the Hammerfest basin (the Barents Sea), results in a new upper-crustal stress field where the horizontal compressive stresses may reach a magnitude of about 11 MPa. The erosion-induced compression is simply the result of preserving part of the compressive stress from the original crustal depth of 900m (at the bottom of the subsequently eroded sediments) at the new erosional surface (here the sea bottom).

Analytical models also show that erosion may have influenced the reservoir fluid excess pressure by first leading to increasing excess pressure and reservoir expansion, then to decreasing excess pressure as a consequence of the reservoir expansion and volume increase. Here we present numerical models showing that erosion-induced changes in reservoir excess fluid pressure and horizontal stresses result in stress concentrations at the lateral ends of the reservoir. When the reservoir pressure changes, any fault zone close to its lateral ends is likely to become subject to stress changes.

A fault zone normally consists of several subzones with contrasting mechanical properties which give rise to different local stresses. Depending on the local stresses, the fault zone may be reactivated during glacial erosion and fluid-pressure changes in the associated reservoir. During fault reactivation, the temporary permeability of the fault zone increase greatly, and may thus lead to leakage of hydrocarbons out of the reservoir. This may be an explanation for the lack of oil deposits in the reservoirs of the southwest Barents Sea.