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Probabilistic and deterministic seismic hazard results and influence of the sedimentary Møre Basin, NE Atlantic

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Abstract

Seismic hazard assessments have been conducted for the Ormen Lange Gas field in the Norwegian Sea on the flank of the Møre Basin. The study used logic-tree based probabilistic methods combined with semi-deterministic methods for hazard contributions from mapped faults, and the hazard was computed in terms of Peak Ground Acceleration (PGA) and spectral acceleration. The probabilistic seismic hazard results were complemented by deterministic modelling in 1D (wave number integration) and 2D (finite difference) crustal models. The deterministic modelling first of all elucidated the shaking duration problem, indicating that thick offshore sediment structures like the ones in the Møre Basin may significantly extend the shaking duration of an earthquake. The presence of sedimentary layers with large velocity contrasts are responsible for this observation, and a conventional soil amplification analysis would not have revealed this phenomenon. A modelling along similar lines as indicated in the present paper may be recommended in certain vulnerable situations, and in geologic provinces with thick sedimentary layers with significant internal velocity contrasts.

Even though large earthquakes most likely have occurred in the region during the postglacial period, the study could not resolve if the huge Storegga slide, which occurred about 8100 yb, was triggered by an earthquake.

Keywords: Møre region; Ormen Lange; Earthquake hazard; PGA; Spectral acceleration

1. Introduction

The Ormen Lange field (Solheim et al., 2004) is located at the eastern flank of the deep Møre Basin. The deep basin structures are not as well constrained as the Vøring Basin to the north, and only a few intrabasinal highs and associated fault complexes are indicated by the Blystad et al. (1995) map (Fig. 1, left). NE–SW structural trends dominate in most parts of the study area, changing to more northerly trends from the Ormen Lange area and northwards. Large basement reliefs are associated with some of these highs/faults. The main fault activity was in Late Jurassic–Early Cretaceous times, but some of the major faults were later reactivated.

Present-day earthquake activity is more pronounced to the north and to the south of the Møre Basin. This pattern is substantiated both from recent micro-seismicity and from the historical record as shown in Fig. 1. The historical seismicity record includes only the very largest events before the 1880s and a detailed coverage only since the early 1980s. Lindholm and Bungum (2000) have estimated the location uncertainty for the events before 1900 to be at times exceeding 100 km, as compared to a 15–20 km uncertainty for instrumentally located events since 1985. When considering also geological evidences one finds indications that possibly very large earthquakes have occurred in this area. Firstly, the large (34,000 km^2) Storegga subaqeuous slide (Bryn et al., 2004; Solheim et al., 2004) indicated in Fig. 1 may have been triggered by a large earthquake (Bungum et al., 2004; Kvalstad et al., 2004), and secondly the relative concentration of rockfalls in the Møre region may indicate that larger earthquakes

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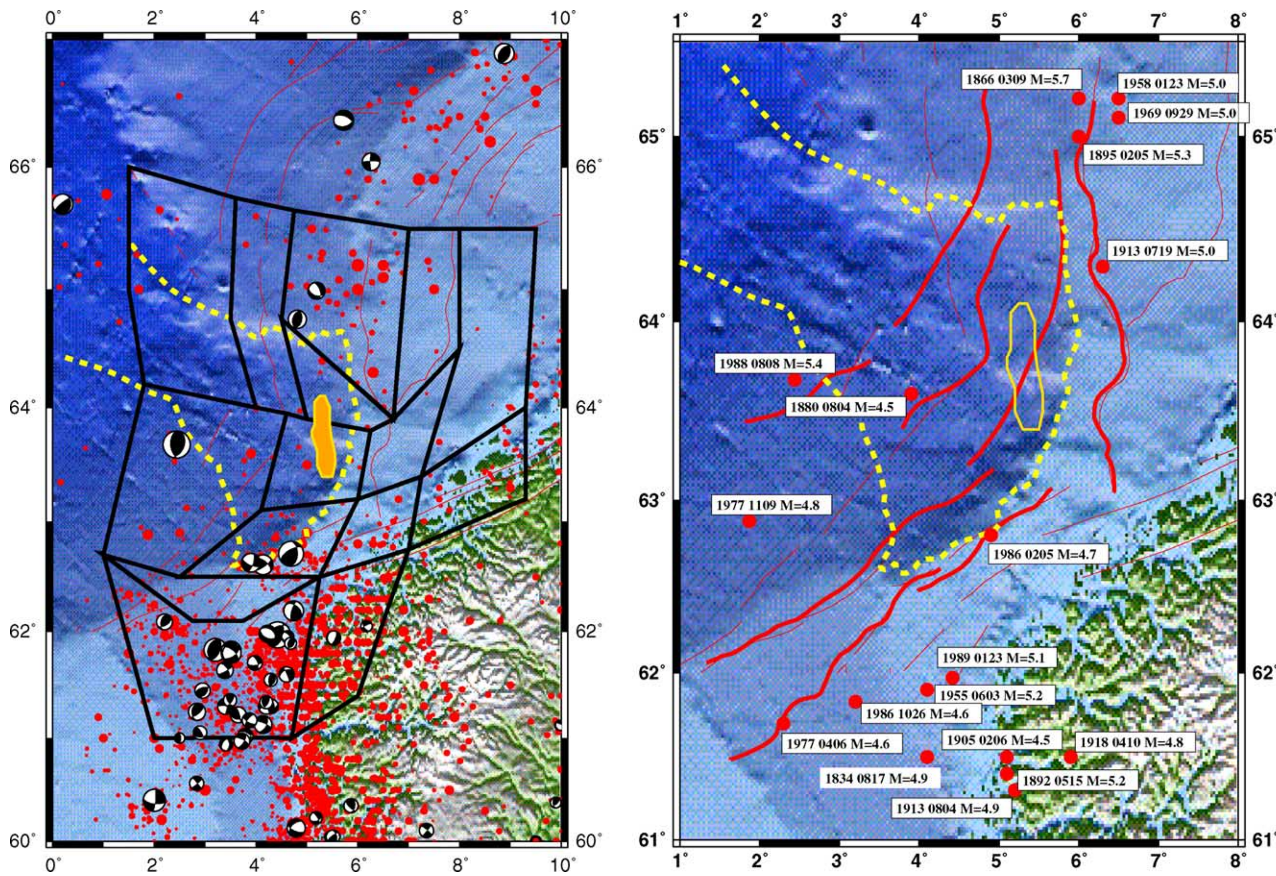

Fig. 1. Left, the historical earthquake record around the Ormen Lange field. Thin lines represent previously mapped deep structures (Blystad et al., 1995). The Ormen Lange reservoir area and the Storegga slide area is also indicated. Black lines indicate zones defined in the PSHA study. Right, historical large earthquakes in the same area. Lines represent major structures mapped in this study (see also Bungum et al., 2002). The Storegga slide scarp and the Ormen Lange field is also indicated on the maps.

have occurred also here. A review by Bungum et al. (2002) makes it clear that large earthquakes would produce ground motions sufficient to trigger landslides and rock falls of the types mapped by Bøe et al. (2002) and Braathen et al. (2004), including the ground failures that have been responsible for the reported turbidite deposits.

Recent studies indicate that the postglacial seismic activity in the larger Møre region can be described in different phases as a function of time (Bungum et al., 2004). In the first phase, immediately following the deglaciation (around 9000 ybp), the seismicity was more intense than today, reflecting the large scale deformations that occurred over a short time span (e.g. Johnston, 1987; Olesen et al., 2004). As the deformation rates have decreased we have today a relatively quiet seismotectonic situation in which global and regional tectonic forces again are of primary importance (Bungum et al., 1991; Byrkjeland et al., 2000; Lindholm et al., 2000).

Nevertheless, the present activity is evaluated as being capable of generating earthquakes larger than magnitude 6, implying significant destructive potentials (Bungum et al., 2004). For the Ormen Lange field, which is located within the upper parts of the giant Storegga slide scar, the proper assessment of seismic hazard and its possible implications for releasing new slides have been of major concern.

The study reported on here focuses on the seismic hazard of the larger Møre basin in general and for the Ormen Lange field in particular. The approaches used were both probabilistic and deterministic, and an assessment of the possibility of reactivating large deep-seated faults in the Møre Basin.

2. Seismicity of the Møre Basin region

The earthquake source catalogue for the larger area around the Ormen Lange field contains thousands of earthquake reports of which many are duplicate reports from different seismological observatories. A significant work was devoted to homogenize the magnitudes and remove the duplicate reports from the original data, thereby reducing the catalogue to about 1700 entries within the area covered by Fig. 1.

As seen from Fig. 1 the micro-seismicity recorded over the last two decades resembles the historical record over the last 100 years in terms of geographical distribution. Even when a one-to-one mapping between earthquakes and causative faults is still to come, it is generally clear that the coseismic deformation predominantly occurs on deep