The Molo Formation, deposited by coastal progradation on the inner Mid-Norwegian continental shelf, coeval with the Kai Formation to the west and the Utsira Formation in the North Sea

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Eidvin, T., Bugge, T. & Smelror, M.: The Molo Formation, deposited by coastal progradation on the inner Mid-Norwegian continental shelf, coeval with the Kai Formation to the west and the Utsira Formation in the North Sea. *Norwegian Journal of Geology,* Vol. 87, pp. 75-142. Trondheim 2007. ISSN 029-196X.

The Molo Formation represents a characteristic depositional unit on the inner Mid-Norwegian continental shelf and extends along the coast for about 500 km from Møre to Lofoten. It was deposited by coastal progradation in a wave-dominated environment with extensive long-shore drift. The age and stratigraphic relationships have been heavily debated since it was discovered and first described nearly forty years ago. Based on new age information from exploration wells in the Draugen Field on the Trøndelag Platform, the Molo Formation is now determined to be of Late Miocene to Early Pliocene age. It is interpreted to be the proximal equivalent to the deeper marine Kai Formation in the Norwegian Sea and a lateral equivalent to the Utsira Formation in the North Sea. These formations were all deposited as a result of the compression and uplift of mainland Norway in mid Miocene time. In this paper we describe and document the datings and formally define the Molo Formation as a new stratigraphic unit.

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Introduction

The Molo Formation (Figs. 1 and 2) corresponds to the characteristic seismic unit which was informally called the "Delta" by Bugge et al. (1976), IKU Bedrock Unit IX by Bugge et al. (1984) and Rokoengen et al. (1988, 1995) and the "Frøyrygg formation" by Askvik & Rokoengen (1985). The age assignment of the unit has varied from Eocene/Oligocene to Pliocene, thus being a time equivalent to the Brygge, Kai or Naust formations. The formation is nearly exposed on the seabed and forms an approximately 500 km long ridge on the inner shelf from Møre to Lofoten (Fig. 1). Since the unit forms a potential wave breaker and is related to the Naust, Kai or Brygge formations, Gustavson & Bugge (1995) proposed the name "Molo" (Jetty) formation.

In this paper we discuss its stratigraphic relationships and propose a Late Miocene to Early Pliocene age, coeval with most of the Kai Formation in the Norwegian Sea and most of the Utsira Formation in the North Sea. It has long been noted that it has high erosional resistance and therefore is most probably sand dominated. Bugge et al. (1976) proposed that it was deposited as a result of mainland uplift and erosion, and Rokoengen et al. (1995) classified the sediments as delta-like coastal deposits, probably formed in a wave-dominated environment with extensive long-shore drift. Our investigation of exploration wells shows that the proximal part of the unit consists mainly of quartzose and glauconitic sand. The distal part to the west consists mainly of glauconitic sand, silt and clay.

The unit was first described by Eldholm & Nysæther (1969) and Nysæther et al. (1969), and later by Bugge et al. (1976), Skarbø et al. (1983), Bugge et al. (1984), Askvik & Rokoengen (1985), Rokoengen et al. (1988), Sigmond (1992), Poole & Vorren (1993), Eidvin et al. (1995), Gustavson & Bugge (1995), Rokoengen et al. (1995), Henriksen & Vorren (1996), Henriksen & Weimer (1996), Eidvin et al. (1998 and 2000), Brekke (2000) and Bullimore et al. (2005). However, the age of the unit is still disputed. A reason for this is that few wells and boreholes have sampled the sediments with high quality conventional cores or sidewall cores. Another reason is that samples from wells and boreholes from the proximal part of the unit seem to be barren of *in situ* fossils and only contain assemblages which we now interpret to represent caved and reworked material. We therefore made a new effort concentrating on identifying wells that penetrate the outer, more distal and potentially more fine-grained part, although the entire Molo Formation is a proximal deposit. Many of the wells in the Draugen Field on the Trøndelag Platform (Fig. 1) seemed to have optimal locations, and wells 6407/9-1, 6407/9-2 and 6407/9-5 were re-analysed.

The obtained Late Miocene to Early Pliocene age contradicts ages previously given by the biostratigraphic consultants as well as our previous datings of wells and boreholes from proximal parts of the formation. Our new study is based on investigation of ditch cutting samples from wells 6407/9-1, 6407/9-2 and 6407/9-5 by means of foraminiferal, dinoflagellate and strontium isotope