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Pockmark formation in the Witch Ground Basin, central North Sea

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Pockmarks form due to fluid escape from shallow marine sediments that may transport large quantities of e.g. methane to the seafloor. This natural gas emission affects and contributes to the global methane cycle and potentially to climate change. However, the methane budget for natural geological sources, especially in the marine realm, remains poorly constrained. A combination of 3D, 2D seismic, Parasound sediment echosounder, and multibeam bathymetry data from the Witch Ground Basin, central North Sea, show two distinct classes of pockmarks. There are about ten giant pockmarks (i.e. at Scanner, Scotia, Challenger, and Alkor pockmark site) with diameters of 200-400 m and depth of 10-17 m, and numerous smaller pockmarks with diameters of 20-50 m and a depth of about 1-5 m at a density of 1-4 per square kilometer in the Witch Ground Basin. Moreover, Parasound sediment echosounder data show that the small pockmarks also exist in tiers in the subsurface where they are confined to four specific stratigraphic horizons. All small pockmarks are limited to the Witch Ground Formation, show no hydraulic links to deeper strata and there are no observations of present activity. The giant pockmarks are tens of meters deep depressions and form above seismically imaged subsurface chimney structures and all of them show persistent methane gas venting. We propose that giant pockmarks form due to continuous supply of biogenic methane from mid-Pleistocene strata conducted towards the seafloor along vertical fluid conduits, which manifest as chimney structures in seismic data. In contrast, our data suggests episodic formation of the smaller pockmarks. A strong correlation of the thickness of the Witch Ground Formation with pockmark occurrence indicates that biogenic methanogenesis provides a more recent source for methane gas that accumulates in the shallow subsurface, comparable to processes in the Baltic Sea today. We propose that episodic gas releases controls the formation of the small pockmarks. Trigger mechanisms for this gas release and consequently pockmark formation may include warm water inflow, large storms, or pressure changes due to relative sea level change. The different types of pockmarks show that there is a time variant source for methane injection into the ocean in the central North Sea. However, the present day rates of methane release from this system are not a major source for atmospheric methane in the study area.