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Geological and seismic modelling of near-vertical fluid flow structures observed on the Vestnesa Ridge, offshore W-Svalbard

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The Vestnesa Ridge is located at approx. 1200 m water depth on the W-Svalbard Margin, and is a 100-km long sediment drift deposited on young (< 20 Ma) oceanic crust. Seismic and bathymetry data reveal several focused fluid flow pathways, commonly called gas chimneys, underlying seafloor pockmarks ranging from 200-500 m in diameter. Authigenic carbonate concentrations, gas hydrates and active gas seepage characterize the pockmarks.

Gas composition from gas hydrate and gravity-core pore fluid samples inside pockmarks show thermogenic sources, suggesting that chimneys have worked as pathways for gas migrating from deeper reservoirs. Free gas is trapped below the gas hydrate stability zone, but is released episodically through gas chimneys. Despite the facts that gas migrates to the seafloor by pressure and buoyancy forces, the external mechanisms leading to the formation and evolution of gas chimneys remain poorly understood.

Here we perform geological and seismic (forward) modelling to predict the seismic response using a number of geological models of assumed chimney structures. We integrate 3D seismic data, ocean bottom seismometer and petrophysical data to constrain a background geological model, including the necessary elastic parameters for seismic modelling. Gas chimneys are added to our models and the complexity of their structures is subsequently increased. We then use a 3D ray-based prestack-depth migration (PSDM) simulator for a rapid and flexible synthetic seismic imaging of the geological chimney models, including diffraction energy. The sensitivity of the models is thus tested through variation of reservoir characteristics and rock properties, as well as survey geometries and configurations. By varying workflow parameters, we can study reservoir and acquisition parameters that might affect the resolution and illumination of the chimney structure on the seismic data. Such modelling will also allow us to test hypothesis concerning the internal structure development of gas chimneys and the presence of anomalous seismic velocity material (e.g., gas hydrates, free gas, authigenic carbonates). The research is part of the Centre for Arctic Gas Hydrate, Environment and Climate (CAGE) and is supported by the Research Council of Norway through its Centres of Excellence funding scheme grant No. 223259 and UiT.