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Fault zones as a primary pathways for methane leakage from seabed deposits over the East Siberian Arctic Shelf

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Until recently, the East Siberian Arctic Shelf (ESAS) was not considered a CH4 source due to the impermeability of subsea permafrost, which completely isolated it from modern biogeochemical cycles. The ESAS is home to the world's largest hydrocarbon stocks, mostly as shallow Arctic hydrates, and thus represents an enormous potential CH4 atmospheric source that is sensitive to global warming-triggered permafrost degradation. Increased CH4 fluxes could occur as numerous weak seeps or large areas of strong bubble plumes. Due to the shallow and oligotrophic nature of the ESAS, the majority of aqueous CH4 may avoid biological oxidation and escape to the atmosphere.

ESAS permafrost stability and integrity is key to whether sequestered ancient carbon escapes as the potent greenhouse gas CH4. Recent data suggest the subsea permafrost currently is experiencing significant changes in its thermal regime. For instance, the temperature of subsea permafrost measured in deep boreholes (down to 70 m) 20-km offshore the NW Lena delta was as warm as -1°C, while in the same area terrestrial permafrost had a much lower annual mean temperature (about -12°C) (Rachold et al 2006). At such elevated temperatures, saline permafrost sediments are unfrozen, providing multiple potential CH4 migration pathways.

Available data suggest the ESAS subsea permafrost is leaking substantial CH4. Geophysical data identified numerous gas seeps, mostly in depressions above prominent reflectors, underscoring the likelihood that subsea permafrost is a CH4 source to the overlying water and atmosphere. Numerical models predict permafrost destabilization 5-10 kYr after inundation, depending on the duration of inundation relative to the duration of previous freezing (Soloviev et al 1987), while current predicted open talik (i.e., thawed sediment within permafrost that permit CH¬4 migration) distributions comprise only up to 10% of the ESAS area (Romanovskii et al 2005). Recent observational data go in good agreement with these results as they suggest that ∼10% of the ESAS seabed serves as a strong CH¬4 source, composing plume areas and allowing majority of aqueous CH4 (both dissolved and bubbles) to propagate through the water column and escape to the atmosphere. Emissions from plume areas contribute up to 60% of the total annual methane flux from the ESAS.