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Hydrocarbon biodegradation in sedimentary rocks linked to atmospheric methane variations during continental deglaciation

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The causes of atmospheric methane variations contributing to climate change remain unresolved. Several mechanisms have been proposed, including increases in emissions due to expansion of wetlands and decomposition of methane chlathrates. Sedimentary rocks may also play a previously unrecognized role in methane release to the atmosphere. Natural gas reserves in which methane of biological origin has been documented are widely distributed around the globe. One example of these is the Late Devonian Antrim Shale of Michigan, USA. At depths between 300 and 500 meters below Earth's surface, this formation hosts an active consortium of fermentative and methanogenic microorganisms, described by both enrichment cultures and 16S rRNA gene sequences. Isotopic characteristics of methane, CO_2 and formation waters recovered from the Antrim indicate that methanogenesis was stimulated in the shale when highly saline basin brines were diluted by meltwaters derived from the overriding Pleistocene ice sheets. Extensive biodegradation has altered the abundance and distribution of hydrocarbons in this OM-rich shale, exhibiting many features common to biodegraded oils. An estimated 1.5 Pg of methane were generated by microorganisms in the Antrim Shale over the past million years, of which approx. 80% escaped subsequent to ice sheet retreat. This flux may thus represent a significant and previously unrecognized source of methane during glacial-interglacial transitions. Given the number of biogenic natural gas reserves found in rocks covered by Pleistocene ice sheets, biodegradation of organic matter in black shales may generate a methane source which, when released to earth's atmosphere, significantly impacts global stocks of greenhouse gases during deglaciation.