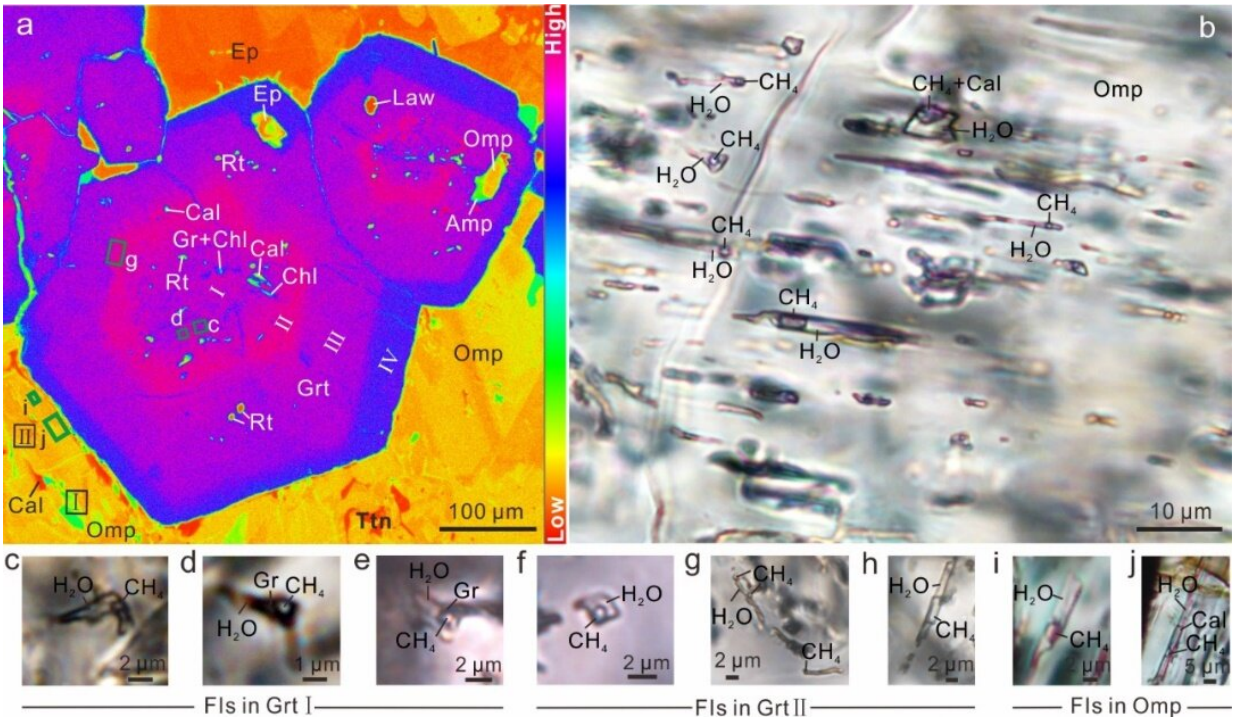
What may be the largest source of abiotic methane gas on Earth

November 28 2022



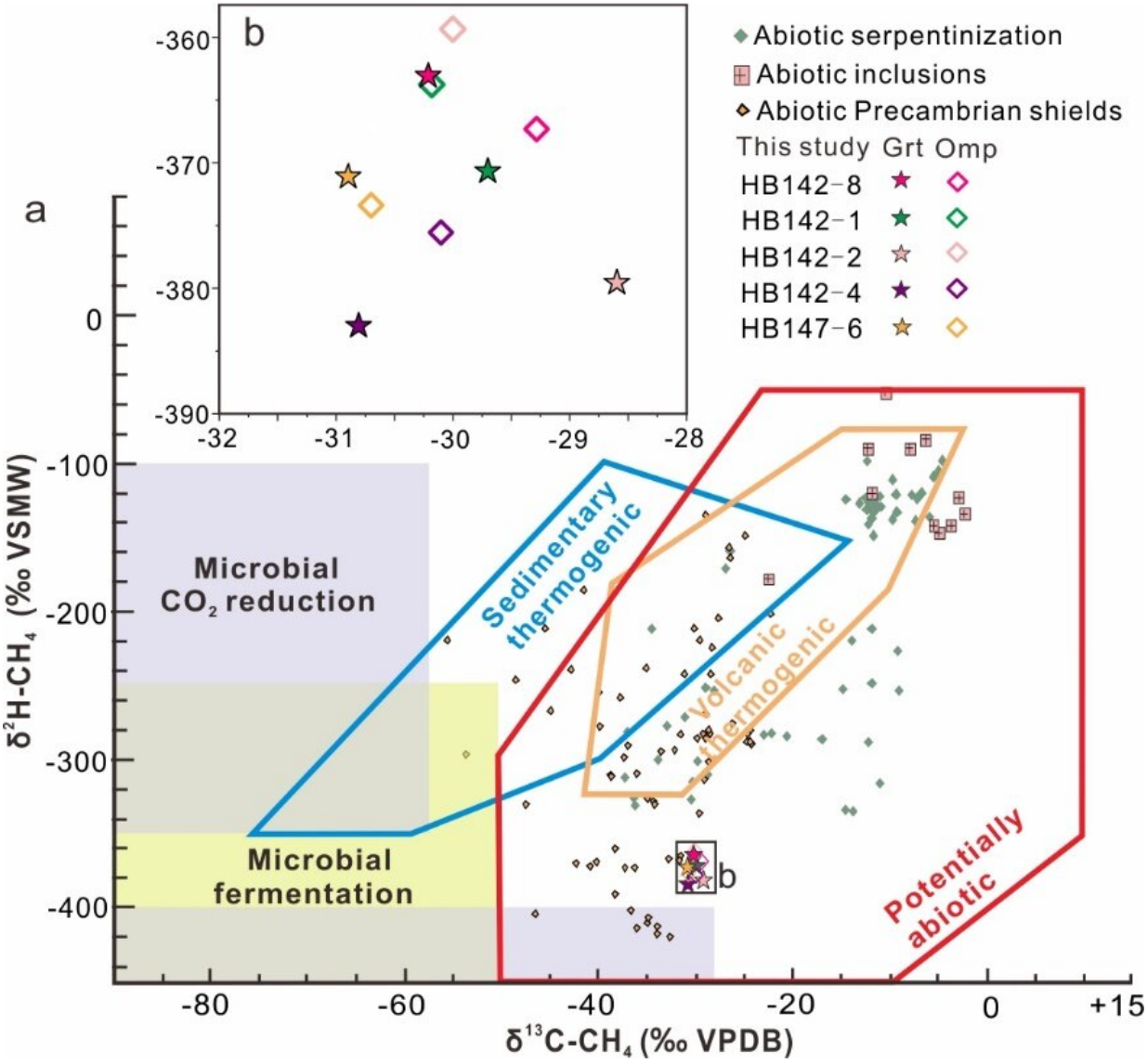
CH_4-rich fluid inclusions in eclogite from the WesternTianshan subduction zone. Credit: Science China Press

Methane (CH_4), the chief constituent of natural gas, is one of the most widely used "clean" fuels. Although methane is usually considered to originate from organic matter, recently, more and more evidence shows that methane can be produced by abiotic processes.

In a recent paper published in *National Science Review* (*NSR*), Professor Lifei Zhang's team from Peking University demonstrated that large amounts of methane gas can form during prograde metamorphism in a cold subduction zone, evidenced by the massive CH_4-rich fluid inclusions in eclogites from Western Tianshan, China.

Based on their calculation, the potential CH_4 flux from worldwide modern subduction zones is estimated to be as much as ~10.8 Mt/y. Consequently, the subducted cold oceanic crust may produce the largest amount of abiotic methane, along with other abiotic methane sources such as that from mid-ocean ridges or that from by high-pressure serpentinization.

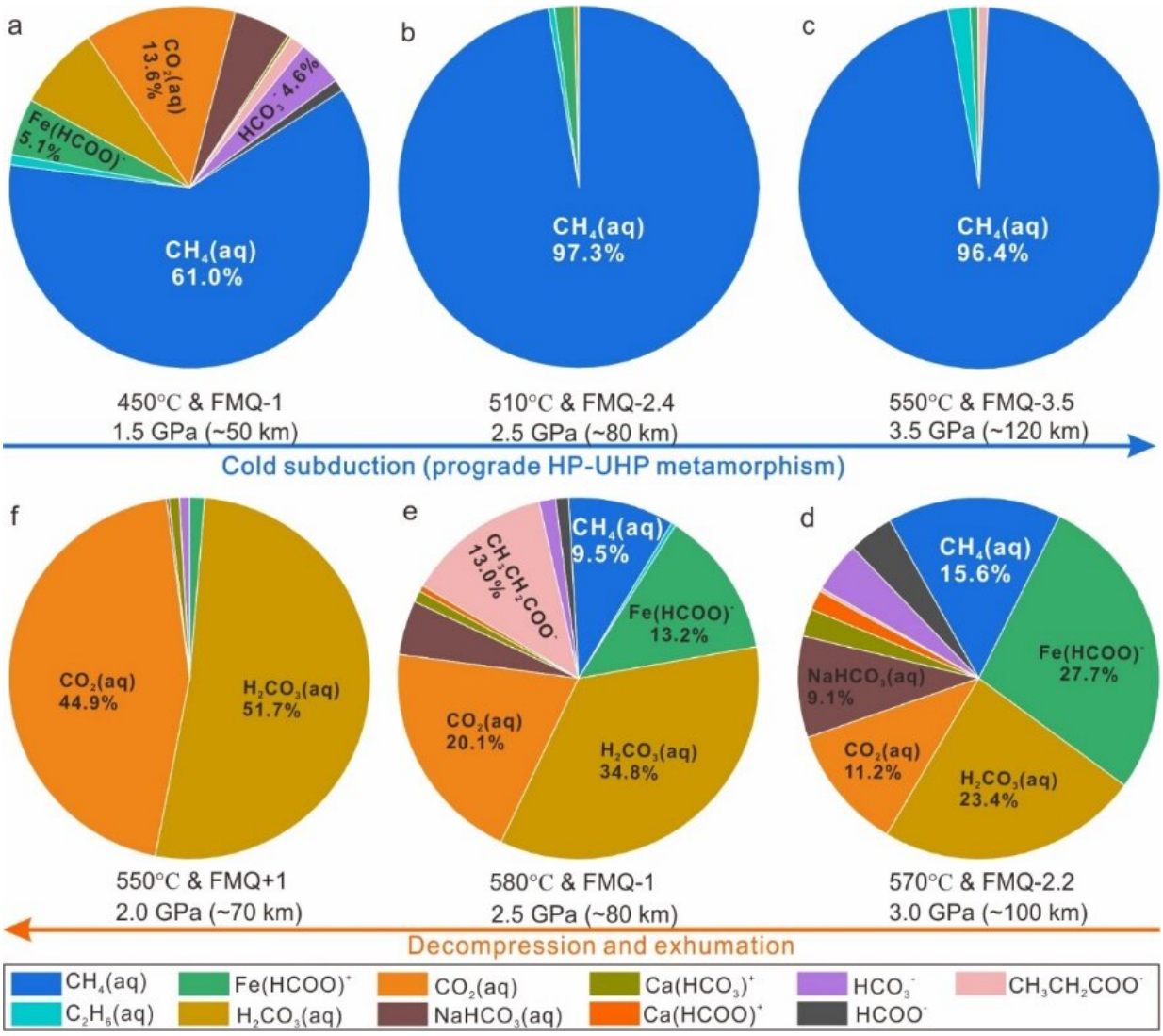
Massive CH_4-rich fluid inclusions have been found in garnet and omphcite, which are the main constituent minerals of eclogite in the West Tianshan subduction zone (eclogite is the most important high grade metamorphic rock during cold subduction). Isotopic analyses and petrological studies both demonstrated that this methane was of abiotic origin and formed by water-rocks reactions during the prograde high-pressure to ultrahigh-pressure metamorphism.



Stable C and H isotope compositions of CH_4 in eclogites from the Western Tianshan subduction zone. Credit: Science China Press

Phase equilibrium and DEW simulations showed that the favorable temperature, pressure and oxygen fugacity conditions for abiotic methane formation were 450-560°C, 1.5-3.5 GPa, and FMQ-1 to FMQ-3.5 respectively. During the cold subduction and exhumation of the oceanic crust:

- When the oceanic crust subducted to ~50 km, the carbon species in the fluids were dominated by reduced CH_4, and its proportion is ~61%;
- When the oceanic crust subducted to ~80 km, CH_4 in the fluids reached the maximum of ~97%;
- When the oceanic crust subducted to 80-120 km, CH_4 in the fluids remained at the maximum of ~97%;
- During the exhumation, CH_4 in the fluids decreases drastically, while oxidized carbon species, such as CO_2 and H_2CO_3, increase gradually.



Compositional variation of aqueous carbon species in eclogitic fluid along the P–T–fO_2-fluid evolution trajectory. Credit: Science China Press

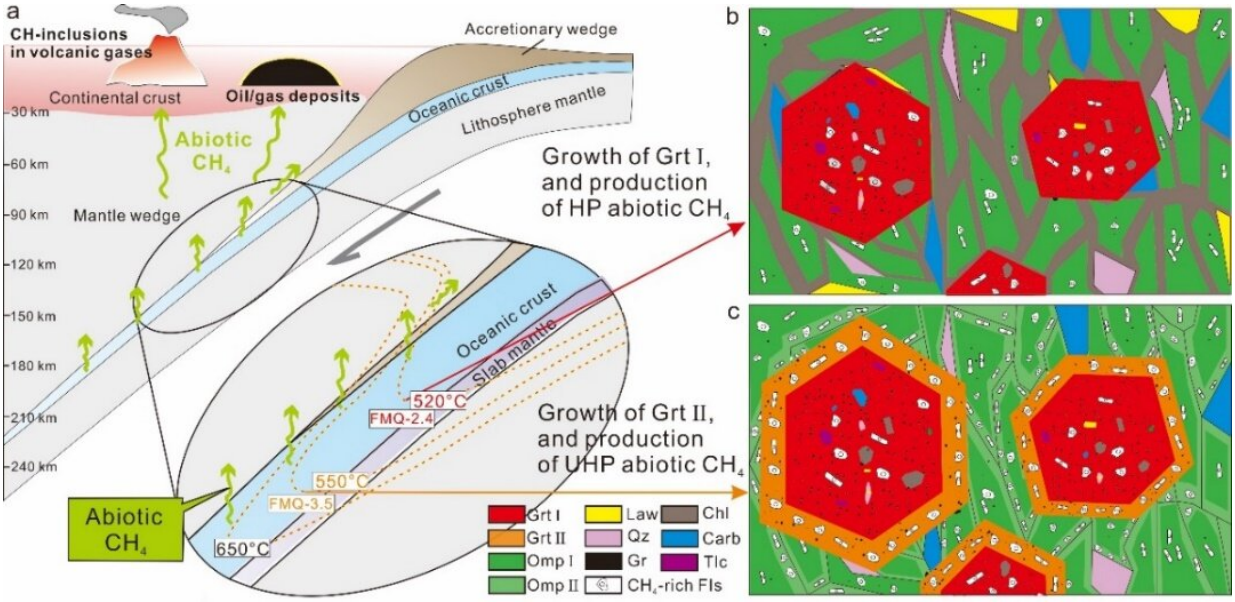


Illustration of the abiotic CH_4 production during prograde HP–UHP metamorphism during cold subduction. Credit: Science China Press

It can be inferred that the cold subduction zone is the factory of abiotic CH_4 gas, which can form enormous methane gas.

"We report a large yet previously overlooked source of methane gas," Prof. Zhang said, "the released abiotic CH_4 might contribute to natural gas deposits at shallow basins. Otherwise, if it goes into the atmosphere by degassing through arc volcanoes, an impact on climate can be expected given its large potential volume."

More information: Lijuan Zhang et al, Massive abiotic methane production in eclogite during cold subduction, *National Science Review* (2022). DOI: 10.1093/nsr/nwac207