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The Methane Time Bomb and the Future of the Biosphere

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Theme: Environment

The extraction and transfer from the earth crust to the atmosphere of every economically available molecule of carbon, including coal,oil, tar sand oil, shale oil, methane gas, coal seam gas and other forms of hydrocarbon, constitutes the most significant shift in composition of the atmosphere since the PETM hyperthermal event about 56 million years ago[i] and the K-T extinction of the dinosaurs some 66 million years ago[ii]. Methane, the most potent common greenhouse gas, billions of tons of which are stored in Arctic permafrost, lakes, shallow seas and sediments, is emitted as the Arctic warms by an average of 3-8 degrees Celsius. This release threatens to melt the large polar ice caps, leading to tens of meters sea level rise and disappearance of species a rate two orders of magnitude faster than they would have without human interference[iii]. Compounding this effect is extensive drilling for coal seam gas, perforating the crust in several parts of the world and releasing commercial and fugitive emissions of methane to the atmosphere. Having sent young generations to kill and die in wars, the powers to be are now presiding over the greatest mass extinction of nature since 66 million years ago.

The accumulation of many hundreds of billions tons of unoxidized methane-rich organic matter in Arctic permafrost and of methane hydrates in shallow Arctic lakes and seas (Figure 1), before and since Arctic glaciation about 2.6 Ma-ago, as well as in tropical bogs, has created a reservoir of carbon whose release to the atmosphere may have catastrophic effects on the biosphere.According to the global carbon project[iv][v] up to 1400 GtC (1400 billion tonnes carbon) on land and ~16,000 GtC in the oceans (Figure 1), much of which may be potentially released upon a significant rise in temperatures, would cause widespread melting and defrosting of the polar ice sheets. This would ensue from major warming feedback effects from further combustion of fossil fuels from recoverable resources,estimated as at least >1100 GtC, and potentially from estimated resources of near 2000 GtC (Figure 2).

Even the release and dissipation of some ~500 to 1000 GtC to the atmosphere as methane, which has 25 to 75 times the greenhouse effect of CO_2[vi], may exceed the atmospheric greenhouse concentration of ~500-700 ppm CO_2e, leading to further extensive melting of the large ice sheets and major sea level rise and to a mass extinction event such as the PETM[vii] (Paleocene-Eocene Thermal Maximum) or even the Permian-Triassic major mass extinction event[viii].

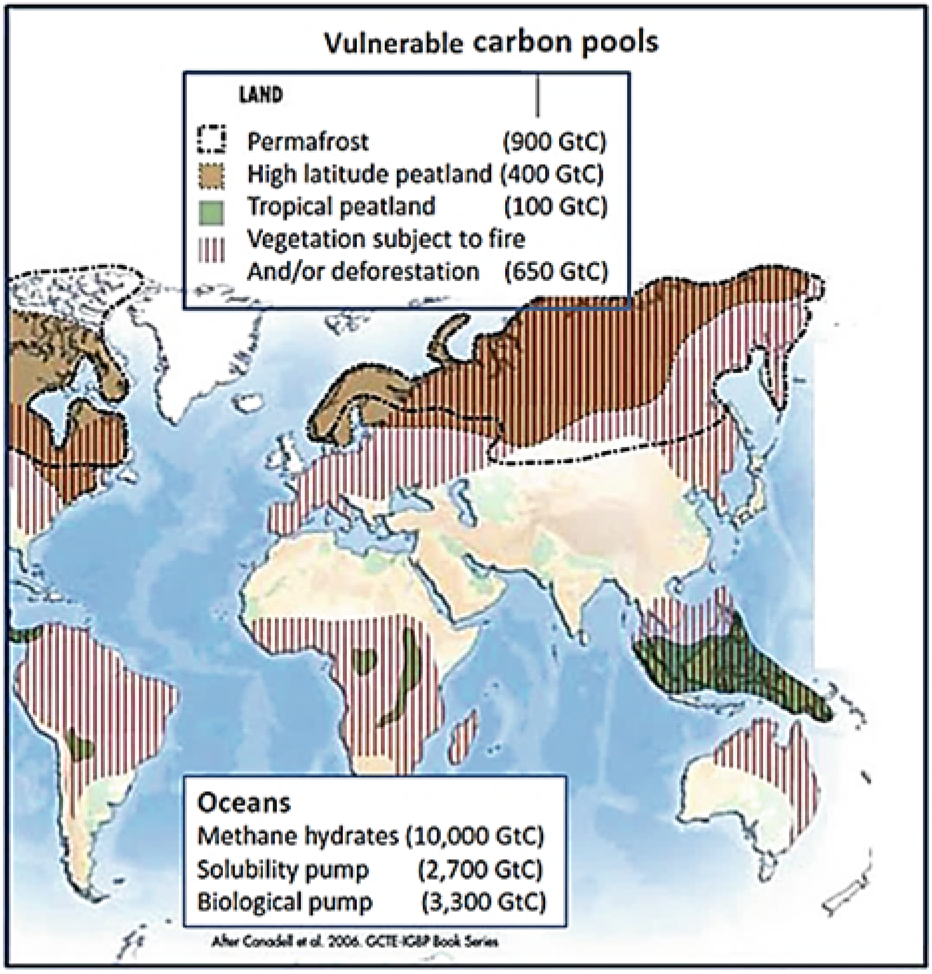

Figure 1.Vulnerable carbon sinks. (a) Land: Permafrost – 600 GtC; High-latitude peatlands – 400 GtC; tropical peatlands – 100 GtC; vegetation subject to fire and/or deforestation – 650 GtC; (b) Oceans: Methane hydrates – 10,000 GtC; Solubility pump – 2700 GtC; Biological pump – 3300 GtC (After Canadell et al. 2007 GCTE-IGBP Book series; The Global carbon cycle; UNESCOSCOPE policy briefs; Vol. 2. Courtesy P. Canadell)

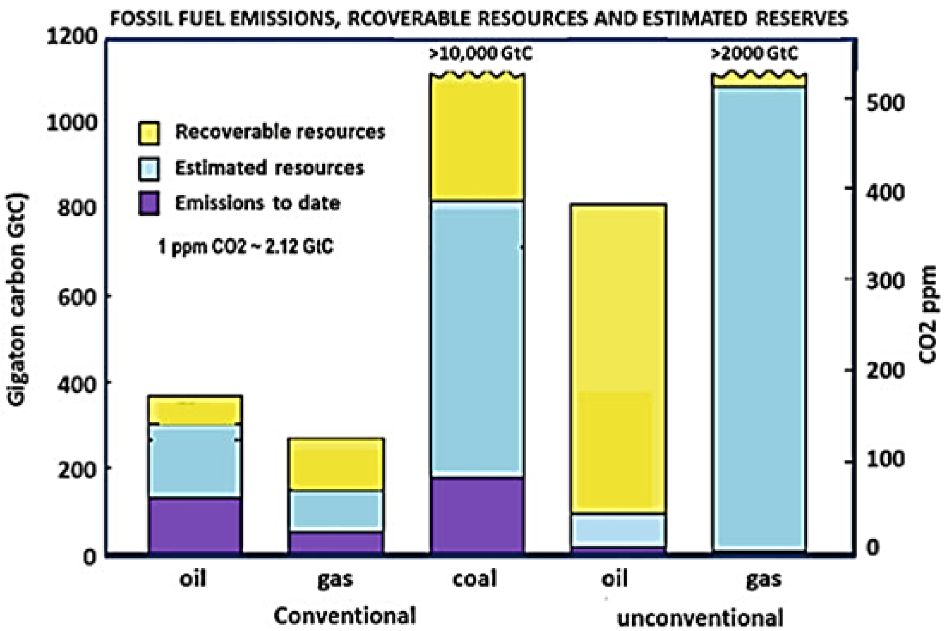

Figure 2 Estimates of fossil fuel resources and equivalent atmospheric CO 2 levels, including (1) emissions to date; (2) estimated reserves, and (3) recoverable resources (1 ppm CO 2 ~ 2.12 GtC)

(Hansen et al. 2012)[ix].

Methane release from permafrost

Early warnings are manifest. Expeditions along the East Siberian Arctic Shelf in 2011 led by the Russian scientists Igor Semiletov and Natalia Shakova identified a large number of km-size sea bed structures from which methane plumes were bubbling[x]. The East Siberian Arctic Shelf (ESAS) is reported to be highly perforated and close to thawing. Reported release of methane from this region estimated as 150 megatons carbon per year[xi] drove atmospheric methane to 2500 ppb. At higher atmospheric altitudes up to ~8 km peak methane values are higher than 2000 ppb and up to a 2241 ppb, while global mean methane levels range from 1768 to 1795 ppb[xii]

Shakova et al. (2014)[xiii]indicate the temperature of submarine permafrost on the ESAS range from −1.8 to 0 °C. Sonar data indicate methane bubbles escaping the partially thawed permafrost inject 100–630 mg methane $m^{-2}\,d^{-1}$ into the overlying water column. Due to storms a significant drop of methane levels occurs in the water column as a consequence of escape of the gas to the overlying atmosphere.

By winter of 2013, satellite measures were showing an increasing overburden of methane in the atmosphere above the Arctic (Figures 3 – 5). By summer of 2013, Peter Wadhams, a polar researcher with more than 30 years of experience studying Arctic sea ice from the vantage of British navy submarines, published in Nature an article titled "*Climate science: Vast costs of Arctic change*"[xiv], projecting the economic costs of a catastrophic 50 GtC methane emission from the ESAS over the coming decades. In reply the climate scientists David Archer and Gavin Schmidt suggested it will take centuries or perhaps thousands of years for a significant volume of methane to be emitted from the Arctic. However, Wadhams suggested that once the ice cover melts water turbulence will warm the underlying sediments by significant amount, up to 7 degrees Celsius. The intense methane bubbling[xv]and caving of permafrost in Siberia[xvi] (Figure 6) hints at a potential catastrophic disintegration of large tracts of Arctic permafrost

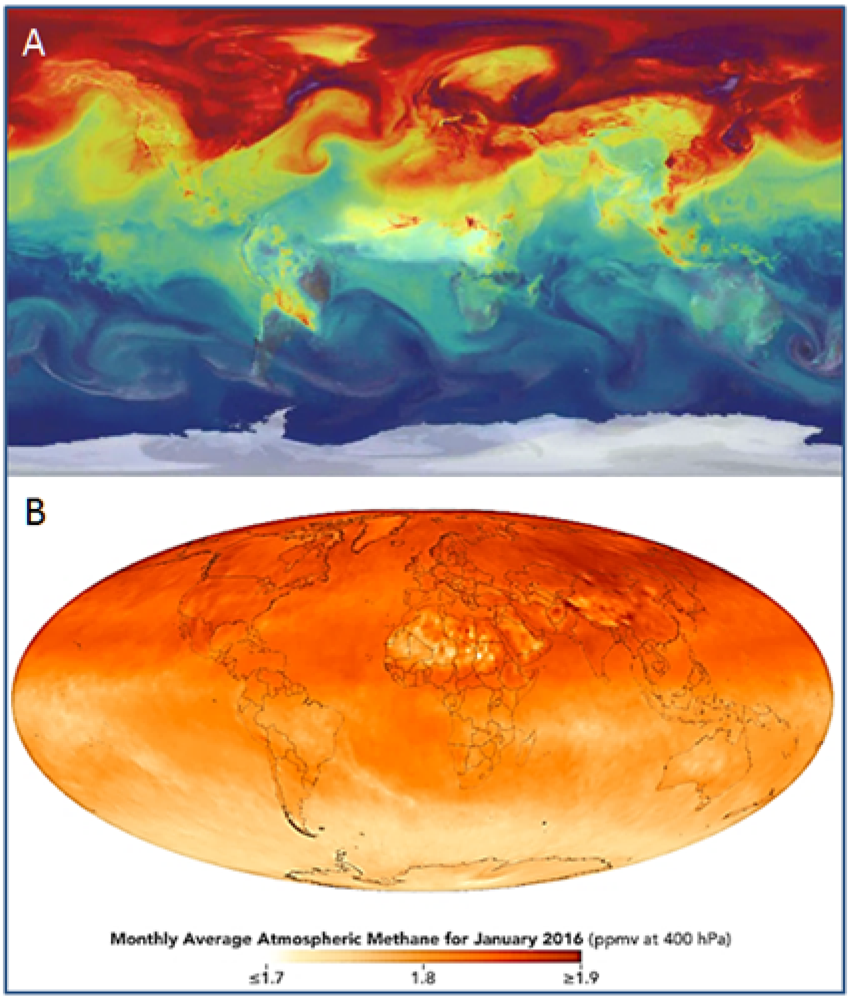

Figure 3a.A. Nov. 18, 2014.NASA ultra-high-resolution computer model displaying the distribution and migration of carbon dioxide in the atmosphere.NASA Goddard Space Flight Center[xvii]. In the NH winter absorption by cold water reduces atmospheric CO_2 while in the NH summer atmospheric CO_2 is reduced by photosynthesis; B. Monthly average atmospheric methane for January 2016 reaching >1900 ppb at pressures of 400 hPa (about 4500 meter height)[xviii].

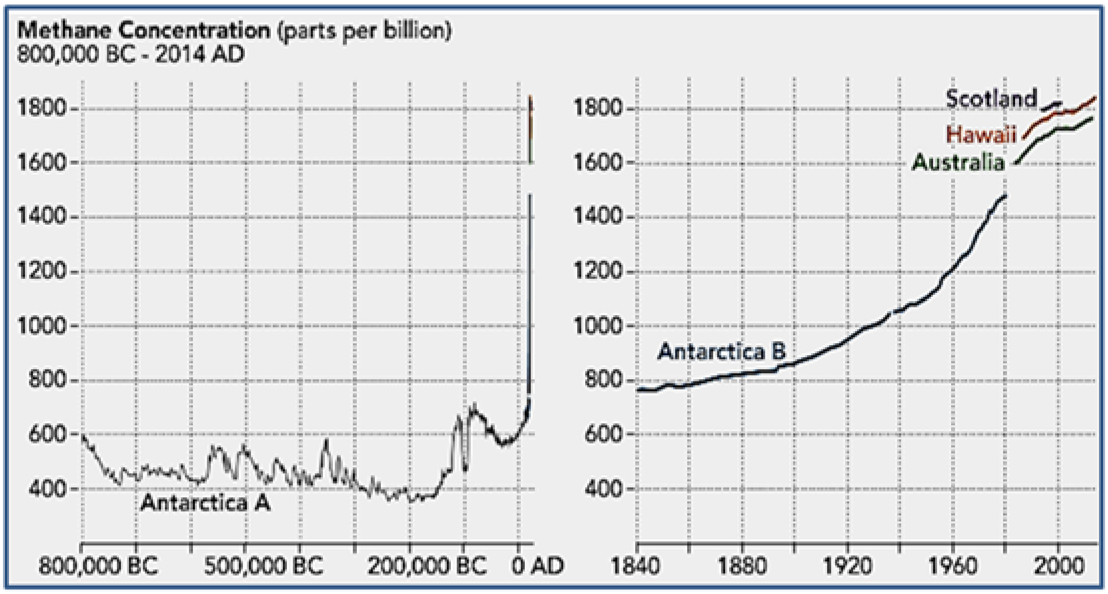

Figure 3b. Variations inconcentrations of atmospheric methane over the last 800,000 years and during

1840-2016, displaying the extreme rise from about 800 ppb to over 1800 ppb CH_4.[xix]

The concentrations of atmospheric methane in the Arctic have been rising sharply during 2009-2013 (Figures 3b and 4), reaching values above >1800 ppb $CH_{4,}$ as compared to values below <800 ppb before 1840 and about 400 ppb during the last glacial period. Hot spots of methane hydrate emissions occur in several parts of the Arctic Ocean (Figure 5). Field evidence for melting of permafrost and methane explosion vents and craters abounds in Siberia (Figure 6).

About one-fifth of the increase in radiative forcing by human-linked greenhouse gas emissions since 1750 is due to methane. The past three decades have seen prolonged periods of increasing atmospheric methane, but the growth rate slowed in the 1990s. From 1999 to 2006 the level of atmospheric methane was nearly constant while strong growth resumed in 2007[xx] (Figure 3b). Between 2000 and 2006 the annual methane peak was about 1740 ppb and since 2007 it has increased by 4-11 ppb per year, peaking at 1803 ppb in September 2015. Since 2007, methane in the atmosphere has steadily increased worldwide[xxi].

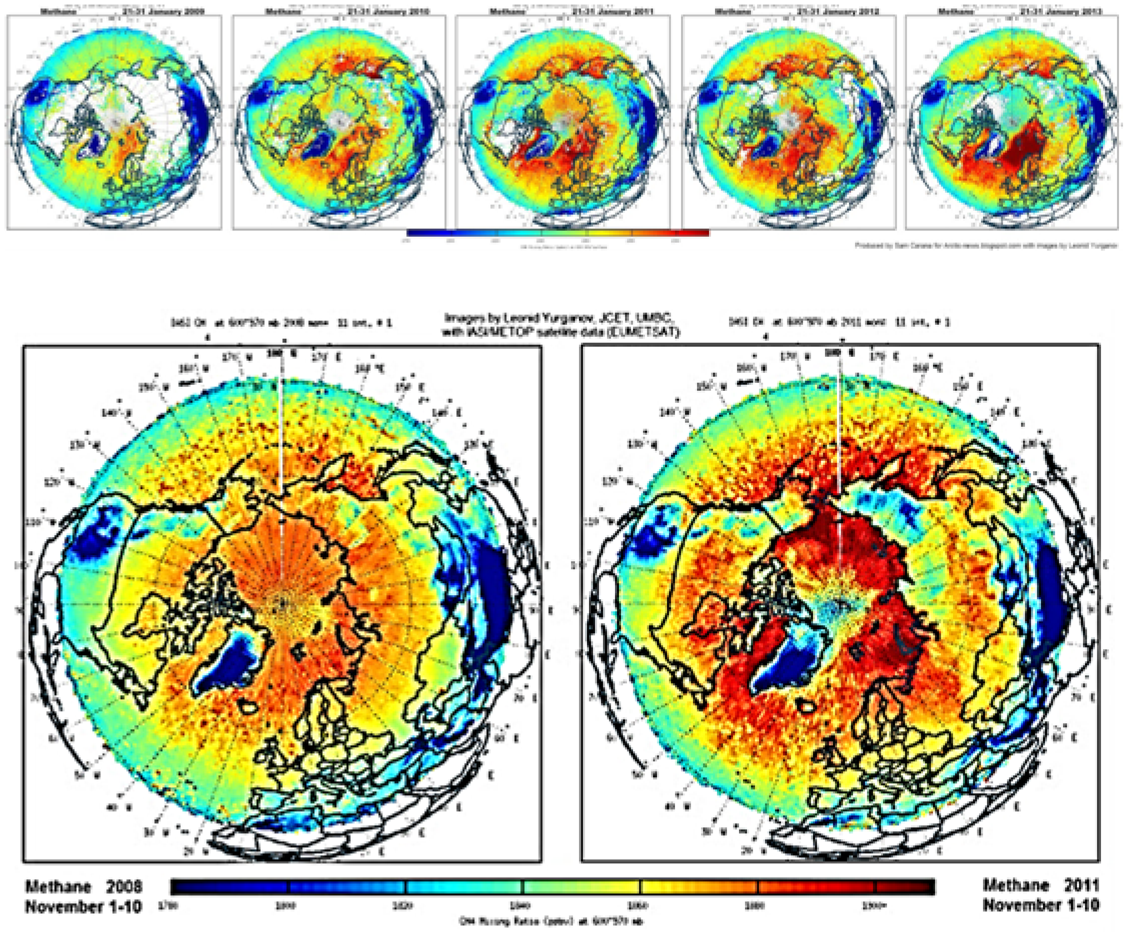

Figure 4.Variations in atmospheric methane concentrations during 2008 – 2013 mapped by Leonid Yurganov, Senior Research Scientist, JCET, UMBC, and member of AMEG, using IASI/METOP satellite data (EUMETSAT)[xxii].

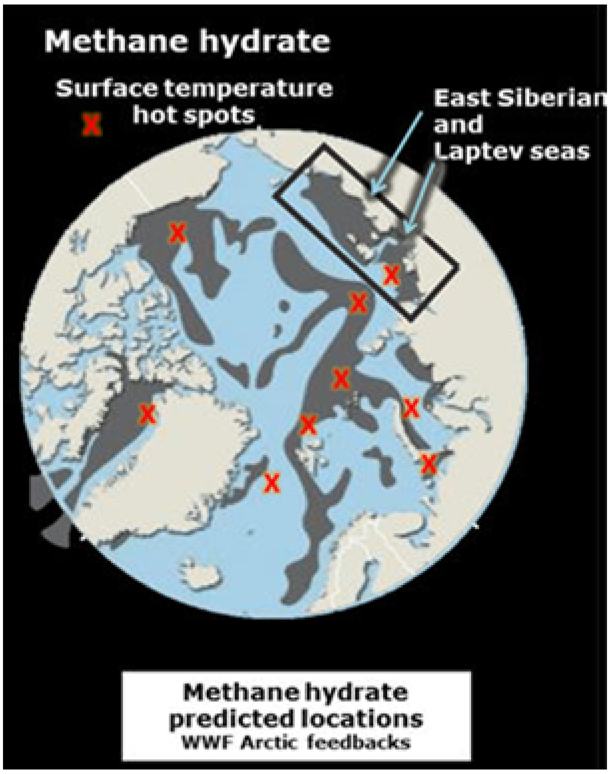

Figure 5.Methane hydrates release locations. WWF Arctic feedbacks[xxiii].

Figure 6.A. Permafrost thaw ponds on peatland in Hudson Bay, Canada in 2008. Wikipedia commons[xxiv]; B. Methane explosion crater northern Siberia[xxv]

CSG fugitive emissions

As if the release of hundreds of GtC carbon from the Arctic permafrost and shallow water bodies would not be disastrous enough, drilling for hydrocarbons in the Arctic Sea has commenced and drilling for coal seam gas is spreading over the continents (Figure 7). The techniques used to extract natural gas trapped in coal seams, tight sandstone or shale formations, may allow significant methane leakage and in 2012 it was reported emissions associated with unconventional gas production in the US were thought to exceed those previously believed[xxvi]. A paper "*Enrichment of Radon and Carbon Dioxide in the Open Atmosphere of an Australian Coal Seam Gas Field*" reported that in 2013 fugitive emissions over Australian coal seam gas (CSG) field (Surat Basin, Tara region, Queensland) yielded atmospheric CO_2 concentrations of ~390 to ~467 ppm, the latter near the centre of the gas field, and a~3 fold increase in maximum of radon (^{222}Rn), used as a tracer for fugitive emissions[xxvii].

Venting of methane from underground coal mines in the Hunter region of New South Wales has reached an atmospheric level of 3000 ppb, with levels of 2000 ppb extending to some 50 km away from the mines[xxviii]. Thus the paper "*Fugitive methane emissions from natural, urban, agricultural, and energy-production landscapes of eastern Australia*" (Kelly et al., 2015)[xxix] states:

> "In the Hunter Valley, New South Wales, open-cut coal mining district we mapped a continuous 50 km interval where the concentration of methane exceeded 1800 ppb. The median concentration in this interval was 2020 ppb. Peak readings were beyond the range of the reliable measurement (in excess of 3000 ppb). This extended plume is an amalgamation of plumes from 17 major pits 1 to 10 km in length. Adjacent to CSG developments in the Surat Basin, southeast Queensland, only small anomalies were detected near the well-heads. Throughout the vast majority of the gas fields the concentration of methane was below 1800 ppb. The largest source of fugitive methane associated with CSG was off-gassing methane from the co-produced water holding ponds. At one location the downwind plume had a cross section of approximately 1 km where the concentration of methane was above 1800 ppb. The median concentration within this section was 1820 ppb, with a peak reading of 2110 ppb."

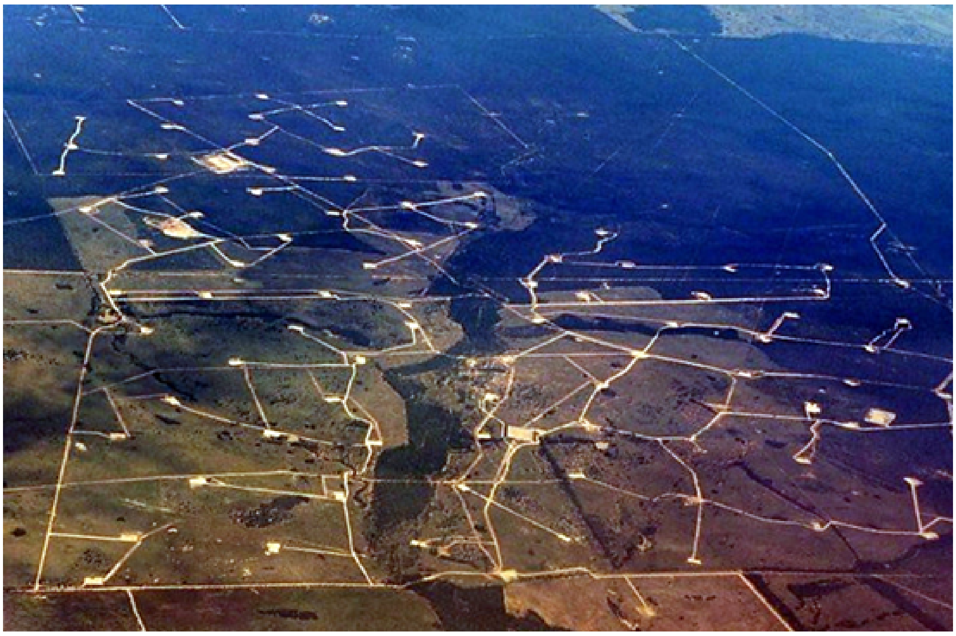

Figure 7.[xxx] Coal seam gas field, Chinchilla, Qld. Wikipedia commons.

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Notes

[i] https://www.britannica.com/science/Paleocene-Eocene-Thermal-Maximum

[ii] http://science.sciencemag.org/content/208/4448/1095

[iii] https://www.populationmatters.org/about/campaigns-and-projects/welcome-to-the-anthropocene/?gclid=EAIaIQobChMIj7y7j7nc2gIVyky9Ch1wKgXPEAAYASAAEgJJevD_BwE

[iv] http://www.globalcarbonproject.org/

[v] https://www.earth-syst-sci-data-discuss.net/essd-2017-123/essd-2017-123.pdf

[vi] https://robertscribbler.com/2013/12/12/arctic-methane-monster-shortens-tail-shakova-semiletov-study-shows-esas-emitting-methane-at-twice-expected-rate/

[vii] https://www.britannica.com/science/Paleocene-Eocene-Thermal-Maximum

[viii] https://www.nationalgeographic.com/science/prehistoric-world/permian-extinction/#close

[ix] http://www.pnas.org/content/109/37/E2415/1

[x] https://robertscribbler.com/2013/12/12/arctic-methane-monster-shortens-tail-shakova-semiletov-study-shows-esas-emitting-methane-at-twice-expected-rate/

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[xii] http://arctic-news.blogspot.com.au/2013/02/dramatic-increase-in-methane-in-the-arctic-in-january-2013.html

[xiii] http://www.nature.com/articles/ngeo2007

[xiv] https://www.nature.com/articles/499401a#supplementary-information

[xv] https://robertscribbler.com/2013/12/12/arctic-methane-monster-shortens-tail-shakova-semiletov-study-shows-esas-emitting-methane-at-twice-expected-rate/

[xvi] https://www.scientificamerican.com/article/siberian-caves-reveal-permafrost-thaw/

[xvii] https://video.nationalgeographic.com/video/news/141119-global-co2-nasa-vin?source=relatedvideo

[xviii] https://earthobservatory.nasa.gov/IOTD/view.php?id=87681

[xix] https://earthobservatory.nasa.gov/IOTD/view.php?id=87681

[xx] http://science.sciencemag.org/content/343/6170/493

[xxi] https://theconversation.com/australias-coal-mines-are-pouring-methane-gas-into-the-atmosphere-55394

[xxii] https://arctic-news.blogspot.com.au/2012/05/striking-increase-of-methane-in-arctic.html?m=1

[xxiii] https://arctic-news.blogspot.com.au/2012/05/striking-increase-of-methane-in-arctic.html?m=1

[xxiv] https://commons.wikimedia.org/wiki/File:Permafrost_thaw_ponds_in_Hudson_Bay_Canada_near_Greenland.jpg

[xxv] http://arctic-news.blogspot.com.au/2015/04/north-siberian-arctic-permafrost-methane-eruption-vents.html

[xxvi] http://www.climateinstitute.org.au/verve/_resources/TCI_CSG_DiscussionPaper_September2012.pdf

[xxvii] https://pubs.acs.org/doi/pdfplus/10.1021/es304538g

[xxviii] https://theconversation.com/australias-coal-mines-are-pouring-methane-gas-into-the-atmosphere-55394

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