Comment on "A note on the relationship between ice core methane concentrations and insolation" by G. A. Schmidt et al.

William F. Ruddiman

Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia, USA

Received 1 February 2005; revised 7 June 2005; accepted 27 June 2005; published 4 August 2005.

Citation: Ruddiman, W. F. (2005), Comment on ''A note on the relationship between ice core methane concentrations and insolation'' by G. A. Schmidt et al., *Geophys. Res. Lett.*, *32*, L15703, doi:10.1029/2005GL022599.

[1] *Schmidt et al.* [2004, hereinafter referred to as SSH04] evaluated the hypothesis that humans caused a large (250 ppb) anomaly in the methane trend of the last 5000 years [*Ruddiman*, 2003] and concluded that "a significant anthropogenic input is not obviously required". Here I respond to and rebut their conclusions.

[2] SSH04 based part of their argument on the report by *EPICA Community Members* [2004] of stable CH_4 values during the early part of isotopic stage 11, the interglaciation regarded as the closest analog to the Holocene. But *Ruddiman* [2005] showed that the timescale of *EPICA Community Members* [2004, Figure 5] contained a critical flaw. It aligned the present-day deuterium value with the stage 11 value from 409,000 years ago, even though 65°N summer insolation is at a minimum value today, but was at a maximum 409,000 years ago. While I fully agree with the idea of looking to stage 11 for the closest insolation analog to the late Holocene, the EPICA alignment of a minimum with a maximum hardly meets that test. In contrast, *Berger and Loutre* [2003] picked the closest insolation analog at ~398,000 years ago, a choice confirmed by the match of insolation minima shown in Figure 1a (revised to correct an error of *Ruddiman* [2005, Figure 3a]). Three independently developed time scales — those of *Petit* [1999], *Shackleton* [2000], and *Bender* [2002] — have placed the location of this closest-analog interval within the same section of the Vostok ice record. At that time, CH_4 concentrations fell by 235 ppb to ~445 ppb (Figure 1b), almost exactly the value proposed by the early anthropogenic hypothesis [*Ruddiman and Thomson*, 2001; *Ruddiman*, 2003]. That CH_4 drop, coming at a time when the climate system was free of measurable human interference, defines the natural CH_4 response to the insolation drop most similar to that of recent millennia. Contrary to SSH04, the comparison confirms the large Holocene CH_4 anomaly proposed in the hypothesis.

[3] SSH04 called on boreal peat lands and permafrost regions as two natural causes of the late Holocene CH_4 increase. In support of this claim, they cited an increase in the extent of peat land and permafrost areas throughout the Holocene [*Smith et al.*, 2004] and an increase in the interhemispheric (Greenland-Antarctic) CH_4 gradient that would indicate increased boreal CH_4 emissions. Yet *Chappellaz et al.* [1997] clearly showed that during the last 4000 years — the interval of the major CH_4 increase — the methane gradient decreased, a trend that indicates a relative decrease in boreal versus tropical emissions. Using a box model with latitudinal diffusion, *Chappellaz et al.* [1997] found that the decrease in CH_4 gradient during the last 4000 years in fact demands an absolute decrease of CH_4 emissions from boreal sources, exactly opposite in sense to the claim made by SSH04. Apparently, the cooler and shorter summer season caused by decreasing northern summer insolation suppressed total CH_4 releases from boreal regions, even though wetlands were still slowly expanding. This evidence rules out two of the three natural sources of the methane increase proposed by SSH04.

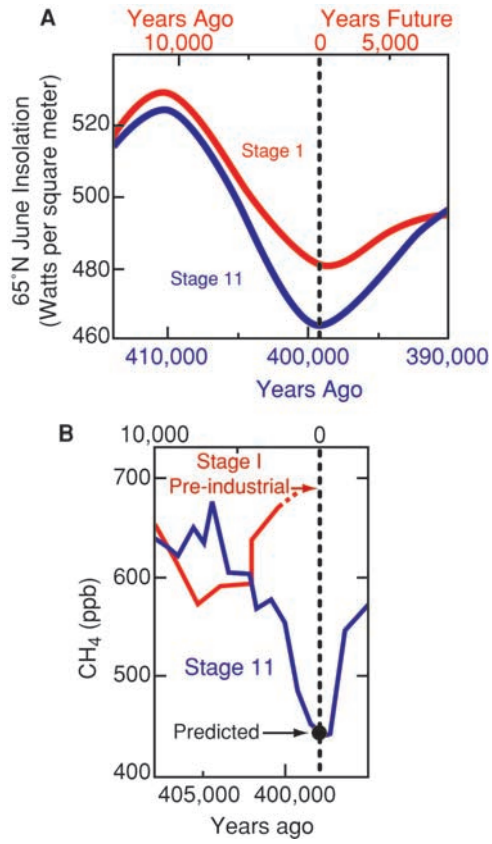

Figure 1. (a) The closest analog to late Holocene insolation trends (June, 65°N) during isotopic stage 11 occurred 398,000 years ago [*Berger and Loutre*, 2003]. (b) At that time, CH_4 values in Vostok ice dropped to the levels predicted by the early anthropogenic hypothesis of *Ruddiman* [2003].

0094-8276/05/2005GL022599$05.00

[4] The only remaining natural methane source SSH04 cited — growth of tropical river deltas and related wetlands — is at best problematic as an explanation of the late-Holocene increase in CH_4 concentrations. Historical ecologists and archeologists have found that clearing of Eurasian forests for agriculture during the last 5000 years was extensive enough to cause widespread erosion of steep terrain, increased sediment loads in rivers, and major enlargement of delta areas [*Roberts*, 1998]. Anthropogenic influences would thus account for a substantial part of any late-Holocene increase in CH_4 fluxes from Eurasian deltas. Moreover, if 'natural' delta growth explains increased methane emissions during the Holocene, then why did CH_4 values fall in stage 11 during the closest analog to the Holocene (Figure 1)?

[5] The attempt by SSH04 to test the link between insolation and methane trends rests on an implicit assumption that CH_4 values respond only to precessional insolation, and do so linearly. Yet such a claim never formed part of my hypothesis. To the contrary, *Ruddiman* [2003] and *Ruddiman and Raymo* [2003] pointed out that the 41,000-year component of the CH_4 signal has the same delayed phase as northern ice sheets, probably because the ice sheets had a downstream temperature impact on boreal wetlands. I also noted that ice sheets influence the shape of the 100,000-year CH_4 signal. In short, the simplistic one-for-one relationship chosen by *Schmidt et al.* [2004] is a 'straw man' assumption that ignores important complexities I have already noted.

[6] In summary, the late-Holocene methane trend is anomalous by 200–250 ppb, the natural causes proposed by *Schmidt et al.* [2004] cannot explain it, and an anthropogenic overprint is required.

References

Bender, M. L. (2002), Orbital tuning chronology for the Vostok climate record supported by trapped gas comparison, *Earth Planet. Sci. Lett.*, *204*, 275–289.

Berger, A., and M.-F. Loutre (2003), Climate 400,000 years ago, a key to the future?, in *Earth's Climate and Orbital Eccentricity: The Marine Isotope Stage 11 Question*, *Geophys. Monogr. Ser.*, vol. 137, edited by A. W. Droxler, R. Z. Poore, and L. H. Burckle, pp. 17–26, AGU, Washington, D. C.

Chappellaz, J., T. Blunier, S. Kints, A. Dallenbach, J.-M. Barnola, J. Schwander, D. Raynaud, and B. Stauffer (1997), Changes in atmospheric CH_4 gradient between Greenland and Antarctica during the Holocene, *J. Geophys. Res.*, *102*, 15,987–15,997.

EPICA Community Members (2004), Eight glacial cycles from an Antarctic ice core, *Nature*, *429*, 623–628.

Petit, J. R. (1999), Climate and atmospheric history of the last 420,000 years from the Vostok ice core, Antarctica, *Nature*, *399*, 429–436.

Roberts, N. (1998), *The Holocene*, Blackwell, Malden, Mass.

Ruddiman, W. F. (2003), The anthropogenic greenhouse era began thousands of years ago, *Clim. Change*, *61*, 261–293.

Ruddiman, W. F. (2005), Cold climate during the closest stage 11 analog to recent millennia, *Quat. Sci. Rev.*, *24*, 1111–1121.

Ruddiman, W. F., and M. E. Raymo (2003), A methane-based time scale for Vostok ice, *Quat. Sci. Rev.*, *22*, 141–155.

Ruddiman, W. F., and J. S. Thomson (2001), The case for human causes of increased atmospheric CH_4 over the last 5000 years, *Quat. Sci. Rev.*, *20*, 1769–1777.

Schmidt, G. A., D. T. Shindell, and S. Harder (2004), A note on the relationship between ice core methane concentrations and insolation, *Geophys. Res. Lett.*, *31*, L23206, doi:10.1029/2004GL021083.

Shackleton, N. J. (2000), The 100,000-year ice-age cycle identified and found to lag temperature, carbon dioxide, and orbital eccentricity, *Science*, *289*, 1897–1902.

Smith, L. C., G. M. MacDonald, A. A. Velichko, D. W. Beilman, O. K. Borisova, K. E. Frey, K. V. Kremenetski, and Y. Sheng (2004), Siberian peatlands: A net carbon source and global methane sink since the early Holocene, *Science*, *303*, 353–356.

W. F. Ruddiman, Department of Environmental Sciences, University of Virginia, Charlottesville, VA 22904, USA. (wfr5c@virginia.edu)