Role of Methane Hydrates in Climate Change:
Compelling evidence and debate

James P. Kennett (kennett @geol.ucsb.edu, 805-893-3103)
Department of Geological Sciences and Marine Science Institute
University of California Santa Barbara
Santa Barbara, CA 93106

The methane hydrate reservoir has largely been ignored as a component of climate change in the Quaternary. However there is growing acceptance that changes in the methane hydrate reservoir played an important role in climate change prior to the Quaternary. The origin of several brief episodes of global warming has been linked with massive dissociation of hydrates and CH_4 transfer into the ocean/atmosphere as recorded by large, negative carbon isotope excursions.

The remarkable similarity of atmospheric methane (CH_4) and temperature variations recorded in ice cores suggests that CH_4 played an important role in late Quaternary climate change. We have proposed that the late Quaternary (last 800 kyr) was also a time of significant instability of the methane hydrate reservoir and associated episodic greenhouse climatic forcing due to transfer of CH_4 to the atmosphere (Kennett, Cannariato, Hendy and Behl, submitted).

Unlike the prevailing interpretation that continental wetlands were the principal source for the rapid atmospheric CH_4 increases during the late Quaternary, we suggest a marine sedimentary methane hydrate source. Negligible wetland ecosystems existed during the last glacial episode as a result of global aridity, low sea level, incised, well-flushed river systems and low water tables. Wetland ecosystems were insufficiently developed during the last glacial episode to account for the rapid atmospheric CH_4 increases during glacial and stadial terminations recorded in polar ice cores. The large, modern wetland ecosystems (peatlands, tropical floodplains, and coastal wetlands) developed almost exclusively during the Holocene, well after the rapid atmospheric CH_4 increases during the last glacial termination.

According to the *Clathrate Gun Hypothesis* (Kennett et al., submitted) episodic atmospheric CH_4 emissions resulting from instability of the marine sedimentary methane hydrate (clathrate) reservoir contributed significantly to the distinctive behavior of late Quaternary climate on orbital (Milankovitch) and millennial time scales. Resulting CH_4 releases to the atmosphere/ocean system provided crucial amplification to "jump-start" rapid warmings at stadial and glacial terminations that were significantly reinforced by other greenhouse gases, especially water vapor. Collectively, these changes shifted the climate system into an interglacial/interstadial state.

Late Quaternary methane hydrate instability occurred largely because of frequent, rapid upper intermediate water temperature oscillations over wide areas of the upper continental margins in the depth zone of potential hydrate instability. These temperature oscillations led to successive intervals of methane hydrate instability during the transitions and early portions of warm intervals and stability during cool intervals. Switching to sources of warm intermediate waters at stadial and glacial terminations created instability in the methane hydrate reservoir and massive release of CH_4 into the ocean/atmosphere system due to sediment disruption that unroofed hydrates on the upper continental slopes. This led to the well-known abrupt warmings of the late Quaternary on different time scales and magnitudes and also produced the sawtooth pattern of late Quaternary climate and atmospheric CH_4 variability exhibited in the 100-kyr cycle, Bond cycles, and individual interstadials. The hypothesis predicts extensive instability of upper continental slope sediments during rapid atmospheric CH_4 increases. This instability would have been reflected by widespread development of slumps, debris flows, and pockmarks on continental slopes, and associated mass sediment transport into the ocean basins.

Many fruitful areas exist to test the hypothesis that the methane hydrate reservoir was inherently unstable during the late Quaternary and was a crucial component in climate change. These include, but are not limited to the following:

- Geochemical tests of primary CH_4 source during abrupt atmospheric increases.
- Refine models and chronology of CH_4/temperature phasing in ice cores.
- Better determine wetland evolution and variability.
- Strengthen proxies of past oceanic CH_4 emissions.
- Determine variability of major CH_4 emissions from hydrates.
- Investigate shifts in intermediate water masses and associated temperature change.
- Determine history of oceanic mass sediment wasting.
- Refine climate models to include CH_4 changes from hydrates.
- Expand global studies of abrupt millennial scale climate change.
- Compare earlier millennial/decadal scale climate behavior with the Quaternary.