Abrupt increase of nitrous oxide production in the Indo-Pacific at the onset of the Bölling warm period

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Nitrous oxide (N_2O) is a potent greenhouse gas, generated in terrestrial soils and in oxygen-poor regions of the ocean, particularly the thermocline of the north Indo-Pacific. The atmospheric concentration of N_2O during the last glacial maximum was ~200 ppbv and rose abruptly to near the pre-industrial value of ~270 ppbv at the onset of the Bölling warm period 14.6 kybp [1]. The abrupt rise has been variously ascribed to the terrestrial and marine biospheres [2, 3], but there is uncertainty over their relative importances [4].

Recently, geochemical measurements of sediments from the northern Pacific and Indian Oceans have converged to evoke a glacial state in which the deep ocean had lower oxygen concentrations while the thermocline was better oxygenated [5]. Geochemical proxies measured in sediments spanning the Northern Indo-Pacific thermocline all show, ca. 14.6 kybp, a rapid departure from the glacial condition to a state of intense oxygen-depletion. At the same time, the deep ocean beneath became better oxygenated, a feature which has been linked to changes in global deep ocean circulation [5].

We suggest that the fundamental change in large-scale ocean circulation at the onset of the Bölling, which included increased North Atlantic Deep Water (NADW) formation, caused a rapid intensification of thermocline oxygen depletion throughout a vast volume of the northern Indo-Pacific ocean. Simulations with a coupled biogeochemistry - ocean general circulation model support this, showing that increased NADW formation can produce depletions of Indo-Pacific oxygen distribution comparable to that required to explain the Bölling N_2O rise. This suggests that the expansion of low-oxygen waters in the north Indo-Pacific thermocline drove the abrupt deglacial N_2O rise.

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Why the Moon is depleted in iron and enriched in refractory elements?

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Unlike the currently accepted model of formation of planets by way of collision of solid planetesimals we adopt here the previously suggested model [1, 2] of formation of a planet embryo as a result of gravitational collapse of a cloud of particles in the protoplanetary nebula.

Due to adiabatical release of heat during the collapse particles are subjected to partial evaporation. The process of evaporation has several important consequences. Firstly, a repulsive force emerges, which modifies the force balance of the gravitational compaction. As a result the rotational moment of a cloud becomes sufficient for its fragmentation. Secondly, evaporation into the internal space of a cloud is featured by negligible thermodynamic isotope effect instead of significant kinetic isotope effect occurring in case of evaporation into an open space. Thirdly, experimental data showed the volatility of iron in vacuum, some loss of Mg and Si during evaporation of a silicate melt and growth of concentration of Al, Ca and Ti in the residue. After evaporation of 40% of the initial amount of material of carbonaceous chondrite composition (CI) the residue approaches the composition of the bulk Moon.

Component	1	2	3	4
MgO	23,8	23,8	32,0	31,9
SiO_2	34,9	33,9	43,5	42,9
FeO	36,6	37,5*	13,0*	15,8
Al_2O_3+ +CaO+ +TiO_2	4,54	4,73	10,8	9,4

Table 1: 1 – CI; 2 – Earth; 3 – Moon (after [3]); 4 – Residue after evaporation of 40% of CI-material.* – Fe + FeO.

Computer modelling shows that, if the emerged fragments are different in mass, the larger one (future Earth) accumulates almost the all remaining material of the cloud, approaching the initial chondritic composition, while the smaller one (future Moon) grows insignificantly retaining its high-temperature composition.

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