Inorganic Nitrogen Compounds in Ocean Stagnation and Nutrient Resupply

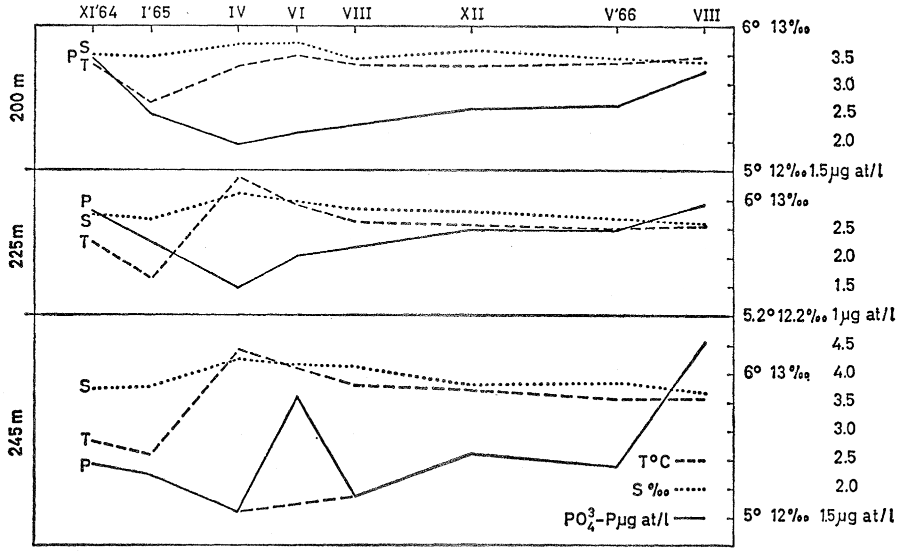
Abstract. *The interrelations and time-dependence of nitrate, nitrite, and ammonia in a deep basin of the Baltic Sea yield a measurement of stagnation history and may provide a means of prediction of resupply of nutrients to the upper productive layers.*

In semienclosed basins having positive water balance, stagnation occurs when utilization of oxygen by decaying organic matter exceeds the supply, which depends primarily on the inflow of water of higher density over the sill depth. During periods of negative O_2 budget, occasioned by diminished inflow or by increased oxidation of organic detritus, nitrate is reduced to ammonia and part of the sulfate is reduced to hydrogen sulfide, in that order; the final result is development of complete stagnation. In basins in which the inflow of new water over the sill depth is insignificant relative to the total volume of the deeper water, stagnation becomes a permanent phenomenon as in the Black Sea and the Cariaco Trench (Gulf of Venezuela).

In basins of smaller dimensions, periods of stagnation alternate with flushing of the bottom water. One such area is Gotland Basin in the central Baltic; it lies east of the island of Gotland, has a sill depth of about 60 m, and is as deep as 249 m (57°20′N, 20°03′E). Several occurrences of stagnation in this basin have been reported (*1*), all with total disappearance of oxygen and consequent appearance of hydrogen sulfide. I now describe the state of inorganic nitrogen compounds and the associated changes between shortly after the end of one period of stagnation and development of the next. My observations suggest that the inorganic nitrogen compounds may be used as an indicator for study of the development and history of stagnation in any such area.

Concentrations of nitrate, nitrite, and ammonia were measured eight times between November 1964 and August 1966 in Gotland Deep. Concurrent observations of temperature, salinity, dissolved oxygen, and phosphate came from the records of the Fishery Board of Sweden.

There was a short period of stagnation in this basin during 1963, which was interrupted by the inflow of new water about April 1964; when my observations began in November the renewal was still proceeding. Figure 1 shows the states of temperature, salinity, and phosphate at three sampling depths just above the bottom. The temperatures and salinities increase after November 1964, reaching maximum values in April 1965 before they decrease. It has been reported (*2*) that water flowed into the basin about April 1965; that maximum inflow occurred at the 245-m level was shown by the temperature values which increased from 5.72°C at 200 m to 6.16°C at 245 m. The inflow is also reflected by the oxygen values (Fig. 2) which reached a maximum in the deepest layer during April 1965. The inflowing water was always relatively poor in phosphate (Fig. 1); the high value during June 1965 may be attributable to the sample bottle going very close to the bottom before being reversed; it has been postulated (*3*) that phosphate is dissolved from the sediments or sedimenting mineralogenic matter, with lowering of the *p*H. In the absence of inflow, the bottom water slowly becomes diluted by turbulent diffusion with the overlying water; the results are slow decrease in temperature and salinity, whereas the concentration of phosphate is increased by the increased amount liberated by oxidation of organic matter. Because the greatest amount of inflow occurred there, the 245-m level was selected for detailed study.



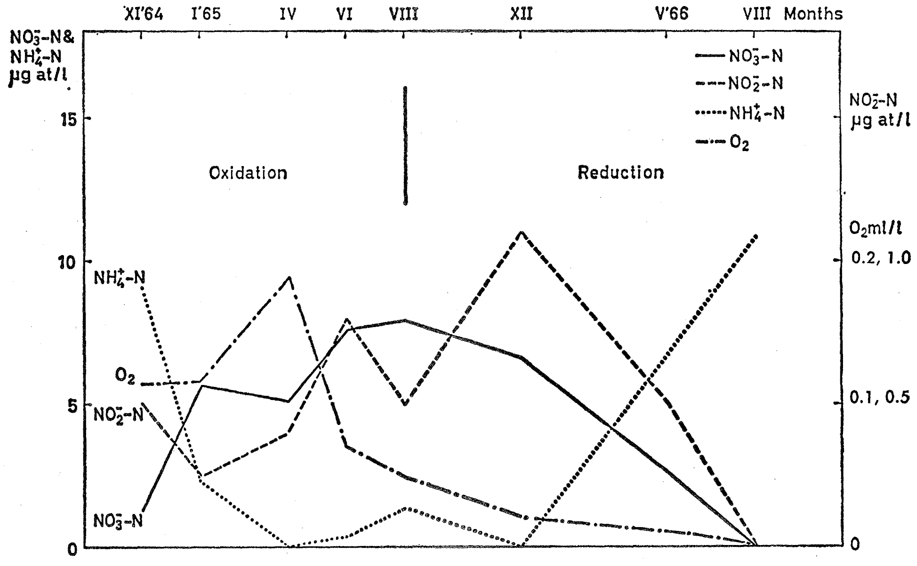


Fig. 1 (top). Conditions of the bottom layers in Gotland Deep. Fig. 2 (bottom). Nitrification and denitrification at 245 m in Gotland Deep.

Figure 2 shows the different stages of oxidation and reduction at the 245-m layer; until August 1965, nitrate values increased, with corresponding decrease in ammonia and oxygen; the increase in nitrite reflects its appearance as an intermediate product of the nitrification process. The situation is reversed after August 1965. Considering the almost complete disappearance of dissolved oxygen (to less than 0.5 ml/liter) one may say that the process of denitrification started thereafter and that the decaying organisms started to utilize oxygen from the nitrate for their oxidation, wtih resultant formation of a reducing layer.

During December 1965 a significant increase in nitrite was associated with decrease in nitrate and an almost zero value for ammonia. Because ammonia, the end product of denitrification, did not increase, it is apparent that the process was not completed during the observation; it was in the intermediate or nitrite stage. After this observation the whole process proceeded systematically; the nitrate and nitrite decreased gradually and disappeared completely, along with oxygen, during August 1966, with the consequent formation of ammonia and appearance of stagnation.

During stagnation the ammonia content increases until new water flows in. In the absence of nitrite and nitrate one may assume that the inorganic nitrogen has been completely utilized and that the increase in ammonia is due to denitrification of organic nitrogen compounds, since some amino acids are known to produce ammonia by denitrifying bacteria under anoxic conditions. No observation was made between May and August 1966, and one may suppose that this process also may have contributed to the high concentration of ammonia, if the stagnation developed during this period.

During stagnation enormous amounts of phosphate and ammonia accumulate in the basin; when the water is displaced upward by new inflow, the ammonia, being gradually oxidized to nitrate, increases the nutrient contents of the overlying waters. When the nutrients reach the surface they increase productivity considerably. For example, during the big stagnation of 1956–61 about 1.1×10^5 tons of phosphate and 3×10^5 tons of mineralogenic nitrogen accumulated in Gotland Basin; when lifted to the surface they can be expected to have increased the normal concentrations of such nutrients in the productive layer of the whole Baltic Sea by about 50 percent. The result was increase in phytoplankton bloom and in fish.

By taking into consideration the volume of water below 60 m, the river discharge, and the inflow and outflow, the residence time of the deeper waters of the central Baltic has been calculated at about 5 years (*4*). The current spurt in fisheries in the Baltic may reflect the fact that the 1961 stagnant waters from Gotland Basin have reached the surface. Similar fertilizations of the Baltic may be expected about 1969 and 1972. The surface waters of the Baltic are very near the starvation point in nutrients, and it may be that only these periodic stagnations enable fishing to flourish there.

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References and Notes

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5. This report is portion of a thesis, Göteborgs Universitet, Göteborg, Sweden; it was presented before the 6th Int. Conf. Baltic Oceanographers, Gdynia, Poland, 1968. I thank B. Kullenberg for guidance and S. H. Fonselius for advice and discussions.

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Fetal Hemoglobin Variants in Mice

Abstract. *Two strains of mice, DBA and C3H, have a fetal globin polypeptide chain which differs in electrophoretic mobility from the corresponding fetal chain of the C57B1 strain. Mice of the DBA and C3H strains also differ from those of the C57B1 in adult hemoglobin type. Results of backcrossing the (DBA × C57B1) hybrid to the C57B1 suggest that the fetal chain locus and the adult β-chain locus are closely linked.*

In the embryonic and fetal stages of life many animals have hemoglobins that differ from those they possess as adults. The human hemoglobin F (Hb F) is the best-studied fetal hemoglobin, and its structure is very similar to that of the two adult human hemoglobins Hb A and Hb A_2. Hemoglobin A has the structure $\alpha_2\beta_2$, whereas Hb A_2 is $\alpha_2\delta_2$ and Hb F is $\alpha_2\gamma_2$. The β-, δ-, and γ-polypeptide chains show a great deal of homology with each other (*1*). The genes controlling the structures of the adult β- and δ-chains are closely linked and are thought to be tandem duplications of a primordial β-chain gene (*2*). The linkage of the β and δ genes was discovered by studying families in which a parent was doubly heterozygous for variant β- and δ-chains and the corresponding normal chains (*1*). Because of the structural homology of the β- and γ-chain polypeptides, it has been suggested that the β- and γ-chain genes are similarly related to each other by duplication (*2*) and may also be closely linked (*3*), but there is so far no direct evidence for this close linkage. Although newborn infants who possess structural variants of the γ-chain have been described (*4*), family studies with individuals doubly heterozygous for β- and γ-chain variants have not yet been possible.

In mice, two variants of adult hemoglobin, "diffuse" and "single," are known (*5*); the difference between them is due to differences at the β-chain locus (*6*). We now describe a variation in a fetal hemoglobin between two strains of mice which also differ in adult hemoglobin type. These differences make it possible for the first time to analyze unambiguously the linkage between the loci for a fetal polypeptide chain and the adult β-chain.

The difference in fetal hemoglobins between strains of mice has been demonstrated by two-dimensional starch-gel electrophoresis. The first dimension at gel *p*H 8.4 is used to separate the various native hemoglobins (*7–9*), and it gives results similar to those reported by Craig and Russell (*10*). The second electrophoretic dimension at right angles to the first is in an acidic gel 8*M* in urea and 0.07*M* in mercaptoethanol (*11–14*); this electrophoresis at gel *p*H 4.0 separates the globin subunits of the native hemoglobins already separated by the first electrophoresis.

Figure 1a shows the two-dimensional pattern of a hemolyzate from 12-day-old embryos of the C57B1/10SNJ mouse (*15*); C57B1/6J gives an identical pattern. Figure 1b shows the two-dimensional pattern for the 12-day-old embryo hybrid, C3H/HeAu ♂ × C57B1/6Au ♀, and Fig. 1c shows the pattern for the 12-day-old embryo C3H/HeAu (*16*). The three patterns are clearly different. The C57B1 em-