Minilecture from www.foraminifera.eu written by Michael Hesemann as a digest of scientific papers

Foraminiferal assemblages record anthropogenic pollution

A major problem in coastal marine areas is man-made pollution. The main pollutants are chemical like heavy metals, organic sewage, nutrients, hydrocarbons and physical like thermal, paper pulp, plastic and oil. Subrecent fossil assemblages of foraminifera provide a record of past environments and are used as a record of anthropogenic pollution.

Response of foraminiferal faunas to environmental changes

About 4500 recent genera of foraminifera are known, each being adopted to a specific range of environmental parameters such as water-temperature, depth, salinity, nutrition flux and pollution. Each location in the ocean is characterized by a specific mixture of foraminiferal species (=faunas) indicating a specific range of environmental parameters. The environment though is not stable and continuously changes during the day and the seasons. Each foraminiferal generation has to cope with these changes during its lifetime of up to two years. Long-term and permanent changes of environmental factors will cause changes in the faunas as well as adaptation and changes in single genera. The adaptation or extermination process though may last for a long period until parameters pass critical levels, which are not tolerated by genera anymore. Changes of environmental parameters and its reflection in the foraminiferal faunas are complex and not fully understood. Numerous species though occur in near shore environments and their ecological requirements are well documented in decades of study worldwide. Many studies link faunal changes and test abnormalities with pollution.

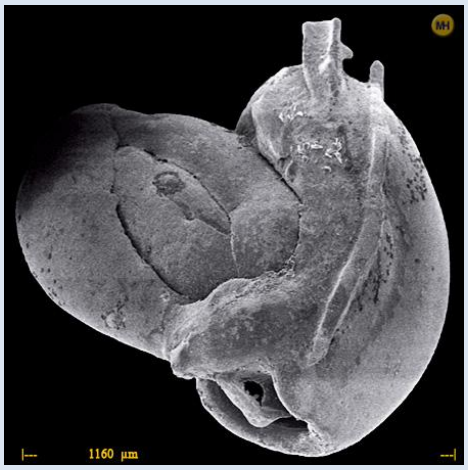
Specimens from Weddell Sea, Antarctica representing a typical deep sea fauna with planktonis from above Plummer cell with fields of 5x5mm

The usage of sediment cores as a record of environmental changes and anthropogenic pollution

1g of sediment may contain 1000 or more tests of dead foraminifera, reflecting as a specific fauna the environmental conditions during their life. As the reproduction cycle of foraminifera is short (between 3 months and 2 years) short-term environmental changes are recorded in the sediment by the foraminiferal tests sunken to the ground after death. In an area of a high sedimentation rate such as 2mm/year a sediment core of 20 cm will reflect 100 years of sedimentation and each foraminiferal test-layer its environmental conditions. Speeding and slowing of harbor activity of ancient ports has been shown by analyses of sediment-cores as well as the influence of sewage and metal pollution. A proper analysis of sediment-cores needs a good knowledge of species and their life-style as well as faunal composition of similar habitats.

All types of foraminifera may be buried together. Planktonic foraminifera drift with the currents and are used for large-scale or global environmental analysis. Recently thinning of their tests has been linked to ocean acidification. Benthic foraminifera will properly reflect pollution of a specific area. Deep infaunal living specimens may be affected by pollution not at all or differently than epifaunals.

A dead assemblage of foraminiferal tests will not be identical to the assemblage of the living specimens it is derived from. Sedimentation-processes and currents, dissolution, different sinking rates of tests and other factors may cause an overall and structural deviation between living and dead assemblages. Smaller, fragile tests are subject to a longer transport than bigger and solid tests, they will easily break or be lost totally.



Twin Quinqueloculina, North Sea

Indicators of pollution

Test abnormalities are commonly used as indicators of pollution, though they may be caused by natural environmental factors. Deformation may occur during the ontogeny or during the life of the adult specimen, indicating different causes. Aberrant chamber shape and size, twisted or distorted chamber arrangement, protuberances, multiple apertures, enlarged apertures, reduced chamber size, twinned forms and other deformations have been described. Pollution by elevated heavy metal concentration has been shown as an anthropogenic cause for abnormal tests. The percentage of abnormal tests typical of the normal environments should be compared to percentages in polluted environments.

Soerfjord – the response of benthic foraminifera to pollution

Alve 1991 took two short sediment cores from heavy metal polluted Soerfjord at 15 and 53m water depth and analyzed each cm. Since the 1920s Soerfjord has received industrial waste from the area near Odda. A rise in test abnormalities has been observed, but all parts of the core contained abnormal test. Abnormalities were mainly attributed to the natural environmental stress of Soerfjord, but the dramatic nature of the abnormalities was seen as caused by anthropogenic pollution. Frequent occurrence of pyritized specimens was interpreted to be caused by weakened resistance against bacterial attacks and the affluence of reactive iron. The cores revealed a faunal shift from moderately polluted conditions with a Verneuilinoides assemblage towards an Eggerelloides scabrus assemblage indicating extreme pollution. Cassidulina laevigata and Bulimina marginata increased downcore towards unpolluted sediments. Eggerelloides scabrus as normally living in shallow depth tended to move downwards indicating its rising competiveness in deeper waters under polluted conditions.

Bulimina marginata Adriatic Sea normal specimen

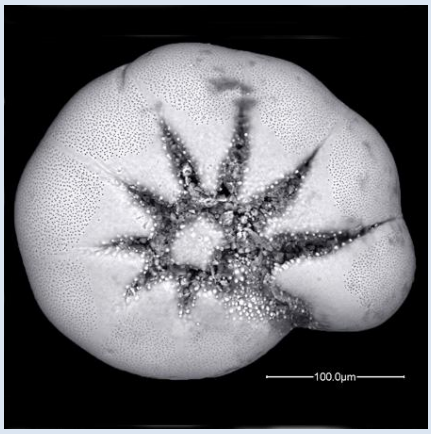
Why is the rate of abnormal tests in Kiel and Flensburg Fjord of the Baltic so high ?

Polovodova and Schönfeld, 2008 found in dead assemblages from Kiel and Flensburg Fjord (Baltic)

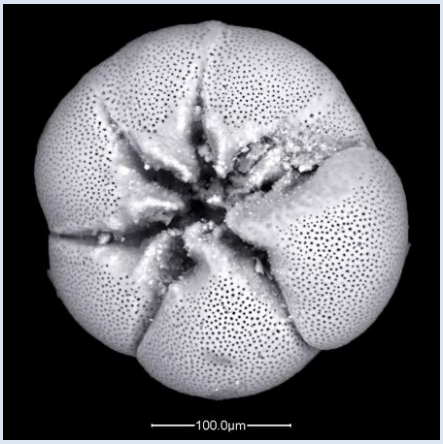
high rates of test abnormalities in *Ammonia beccarii* and in *Elphidium excavatum excavatum* (up to 25% of all tests). The Kiel fjord is highly urbanized and industrialized causing significantly elevated rates in heavy metal pollution and ashes in the sediment. This holds to a lesser degree for the Flensburg Fjord, which in contrast suffered in the 1980s more from eutrophication caused by agriculture. Polovodova and Schönfeld, 2008 found that small test deformities are correlated to short term environmental changes caused by natural factors such as intrusions of salt-rich waters from the Baltic. They also found a correlation between abnormalities and heavy metal pollution. They conclude that deformed tests must be used with care as an indicator of environmental pollution and natural factors should also be taken into consideration.

Monitoring of heavy metal pollution with benthic foraminifera in the central Adriatic Sea

Frontalini and Coccioni, 2007 analyzed 42 sediment samples from the central Adriatic Sea with the result: Heavy metal pollution causes faunal changes and an elevated rate of test abnormalities. *Ammonia parkinsoniana* as the dominant species of the benthic fauna prefers clean to low polluted environments and decreases in abundance with rising heavy metal pollution. Other species such as *Ammonia tepida* are more tolerant and increase in share with rising pollution. Both Ammonia species may be easily used as bio-indicators to monitor the heavy metal pollution in the central Adriatic Sea. *Ammonia tepida* differs markedly from *Ammonia parkinsoniana* by lacking a ventral boss. See images



Ammonia parkinsoniana, Adriatic Sea



Ammonia tepida Adriatic Sea

Literature:

ALVE, E., 1991, Benthic foraminifera in sediment cores reflecting heavy metal pollution in Soerfjord, Western Norway: Journal of Foraminiferal Research, v. 21, p. 1–19.
FRONTALINI, F., and COCCIONI, R., 2007, Benthic foraminifera for heavy metal pollution monitoring: a case study from the central Adriatic Sea coast of Italy: Estuarine Coastal and Shelf Science, v. 76, p. 404–427
POLOVODOVA, I. and SCHÖNFELD, J., 2008: Foraminiferal test abnormalities in the western Baltic Sea in Journal of Foraminiferal Research, v. 38 (4), p. 318-336.
MURRAY, J., 2006: Ecology and Applications of Benthic Foraminifera. Cambridge University Press

Images:

Ammonias and Bulimina provided by Dr. Fabrizio Frontalini and Prof. Rodolfo Coccioni, DiSUAN Laboratorio di Micropaleontologia Ambientale Facoltà di Scienze e Tecnologie Università degli Studi di Urbino"Carlo Bo", others own.

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