MICROFORAMINIFERAL LININGS AS A PROXY FOR PALEODELTA AND PALEOSALINITY ANALYSIS: DANUBE DELTA EXAMPLE

Mudie, P.J., [1] and Yanko-Hombach, V. [2]

[1]Natural Resources Canada, Geological Survey Atlantic, 1 Challenger Drive, Dartmouth, NS B2Y 4A, Canada; mudiep@ns.sympatico.ca
[2] Department of Physical and Marine Geology, 2 Shampansky Per., Odessa I.I. Mechnikov National University, Odessa 65058, Ukraine
valyan@onu.edu.ua
[3] Avalon Institute of Applied Science, 976 Elgin Ave, Winnipeg MB R3E 1B4, Canada
valyan@avalon-institute.org

Introduction

Microforaminiferal linings are the acid-resistant, chitin-like linings of small (<150 μm) foraminiferal tests that are recovered in organic residues after palynological processing of sediments or acid treatment of rock samples. These palynomorphs are considered reliable indicators of brackish and marine paleoenvironments, and they are a proxy for foraminiferal production when carbonate preservation is reduced (Mathison and Chmura, 1995). Presence or absence of microforaminiferal (abbrev. microforam) linings is an important criterion used in palynofacies models to distinguish the transition from coastal lakes across delta front, prodelta, and shelf sub-environments (Fig. 1).

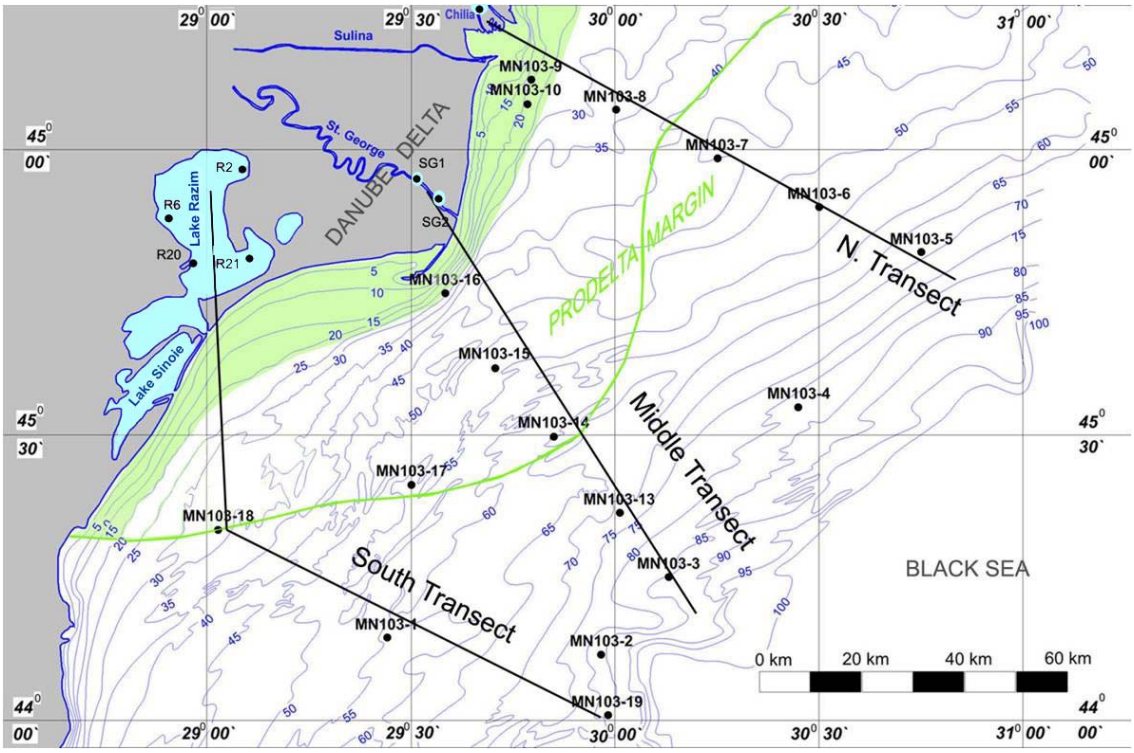


Figure 1. Map of the NW Black Sea study area showing bathymetry, locations of sample sites along coast-offshore transects, and approximate boundaries of the delta front (green shade), prodelta (green line), and shelf environments.

Microforam linings also mark Miocene marine incursions into the Pannonian Basin and into the Caspian-Black Sea - Mediterranean Corridor; they are important for validating paleosalinity models of Paratethyan Sea basin inter-connections.

In this paper, we investigate the relationship between the morphology of the microforams and foraminiferal assemblages in seabed samples collected concurrently along transects off the Danube Delta, in the northwestern Black Sea. Paired comparisons are made of the morphology, abundance, and preservation state in test linings and the foraminiferal populations from the same samples along a surface salinity gradient from coast to outer shelf. This is the first study linking the organic linings with known Black Sea foraminiferal taxa and showing the quantitative relationship between the two paleosalinity proxies.

Material and methods

The study area (Fig. 1) is on the NW Black Sea shelf, between latitudes 44.0^{o} and 45.1^{o} N, and from longitude 29.0^{o} to 30.75^{o} W, in water depths mainly from 17.5 to 80.5 mbsl. Samples for palynological and microbenthos comparisons were collected with a van Veen grab or a multicorer on WAPCOAST cruise MN103 of R/V "Mare Nigrum" in Spring, 2012. Concurrent CTD, dissolved oxygen (DO), and nutrient data (see Yanko-Hombach et al., 2017) revealed a freshwater plume (5 to 17 psu) on top of shelf water of salinity 17.8 to 18.5 psu, and a strong stratification creating hypoxic conditions below c. 15 m.

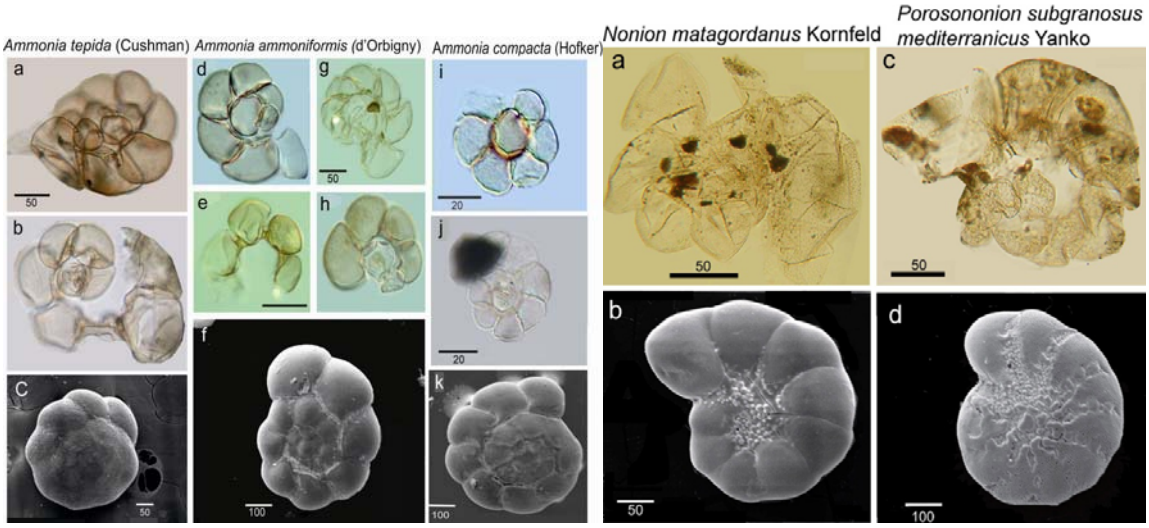
Surface sediment samples (0 to 2 cm depth) at 17 sites were taken for palynology (2 to 5 cm^3 volume) and for microfossil studies (c. 150 cm^3 volume), then stored at room temperature. Six additional palynological samples were obtained from grab samplers at shallower (2 to 6 m depth) coastal sites, including the Chilia and St. George distributaries of the Danube Delta and Lake Razim, which is a microtidal lagoon (Fig. 1) with water salinity less than 2 psu. Laboratory processing of palynology samples follows the standard methods for marine palynology reported by Mudie et al. (2011), and uses *Lycopodium* tables to estimate abundances/g sediment of microforaminiferal linings. Microscope studies for palynology used a Zeiss Research Microscope with Normarski Interference Contrast objectives. Foraminifera were prepared for study by staining with Rose Bengal and washing on a 63 μm sieve; then they were studied by binocular and SEM microscopy as reported in Yanko-Hombach et al. (2017).

Results

Microforaminiferal lining morphology and benthic foraminiferal sources

Three categories of microforaminiferal linings were found in surface samples off the Danube Delta: trochospiral, planispiral, and linear morphotypes. The trochospiral morphotypes were further grouped into large (>50 μm) and small (<50 μm) forms. The small trochospiral forms correspond to the linings of *Ammonia compacta* (Fig. 2i-k) that have a dimpled surface texture without conspicuous pores.

The Rotalid foraminifera *Ammonia tepida* (trochospiral) and *Porosononion subgranosus* (planispiral) that dominate the assemblages on the delta front (Sta. 9, 10, 16) have microforam linings distinguishable by their shape, porosity, and chamber structure (Figs. 2 and 3). *A. tepida* has a large trochospiral lining that is strongly microperforate (Fig. 2a-c), and the *Porosononion* lining is subspherical and irregularly, coarsely granulo-porate (Fig.3c). The trochospiral linings in the prodelta sites (Sta. 7, 8, 18) show greater morphological diversity, including test linings of *A. compacta* and *A. tepida* (Fig. 2) and planispiral linings of *Nonion matagordanus*, which can have a subspheroidal shape and regularly fine-granular surface (Fig. 3a).



Figures 2 (L) and 3 (R). Light microscope images (from PJM) of the most common foraminiferal linings in the NW shelf samples compared to SEM images (from VY-H). Left panel: *Ammonia* species, demonstrating the range from well-preserved specimens (top row) to less well-developed on poorly preserved linings (Fig. 2 b,e,h). Note the large amount of fine pyrite in specimen h, from the deepest water site MN103-19; specimen g has a *Lycopodium* spore on the inner chamber. Right panel: Planispiral species, apparently with ingested acid-resistant organic particles.

These features match the prodelta foraminiferal assemblage with diverse *Ammonia* spp., common *Nonion matagordanus*, less *Porosononium*, and occasional uni-, bi-seriate, and single-chambered taxa. The shelf sites have microforam linings dominated by large trochospiral forms corresponding to *Ammonia ammoniformis* (Fig. 2d-h), with rare uniserial linings. This palynomorph assemblage corresponds to the shelf assemblage of Yanko-Hombach et al. (2017), which is dominated by *Ammonia ammoniformis*, with common *N. matagordanus* and maximum species diversity, including some single cell and uniserial taxa.

Abundances and distribution of organic linings compared to microfauna

Abundances of foraminifera/g and microforaminiferal linings/g for the three transects (Fig. 4) show that the lining number was essentially the same as the foraminiferal abundance (for sites 9, 7, 5, 4, 13), or they exceeded the foraminifera by a factor of 2 to a maximum of 9 at delta front site 16.

Most freshwater (<2 psu) sites had neither linings nor foraminifera, but two sites in the microtidal Lake Razim contained a uniserial microforam lining of unknown affinity. The northern transect off the Sulina distributary, where sediment is finer-grained, had the largest number of near-matches in lining vs. test abundances, while the southern transect furthest from the delta discharge showed consistently high lining numbers but a steady decrease in lining abundances offshore. The highest lining abundances are not correlated with sediment texture, and they possibly indicate development of anomalously small (<63 μm) foraminifera in the polluted NW Black Sea waters where Yanko-Hombach et al. (2017) showed that deformities in foraminiferal tests are common.

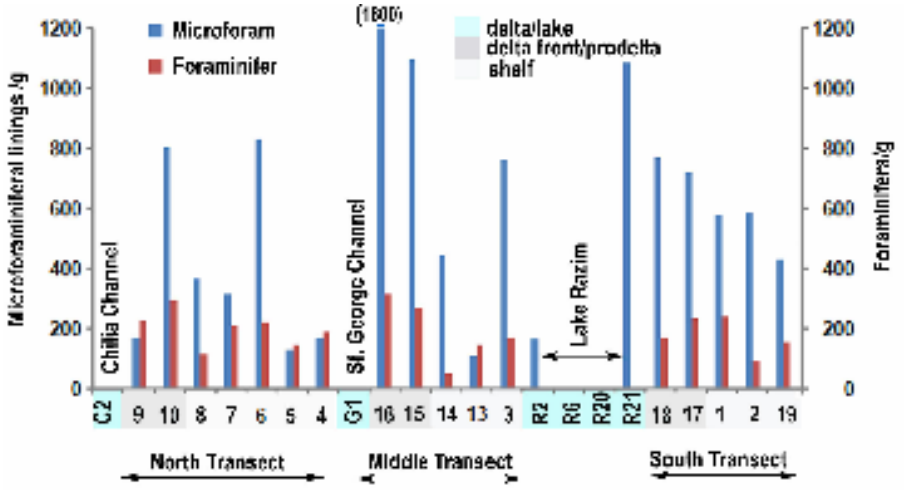


Figure 4. Abundances of microforaminiferal linings and foraminifera in surface sediments along three transects from the coast to outer shelf.

Anomalous lining morphologies include opening of normally coiled specimens (Fig. 2b) and incomplete chamber development (Fig. 2e). Some high lining counts may reflect inflated values resulting from duplication of torn lining fragments in species with weakly acid-resistant linings. Oxygen deficiency in the bottom water is also indicated by fine pyrite inclusions in 20 to 50% of the linings in water shallower than 60 m and >50% in water deeper than 100 m.

The composition of benthic foraminifera in the MN103 microfossil samples (Yanko-Hombach et al., 2017) indicates biologically stressful bottom water conditions resulting in low species diversity and richness along a coast-to-shelf gradient of species. The distribution of the total microforam linings/g shows no correlation with water depth or distance offshore, suggesting a widespread cross-shelf mixing of linings from inner and outer shelf populations. There is a weak (R^2 = 0.35) polynomial relation between lining abundance and surface salinity that also suggests mixing of linings from inner and outer shelf foraminiferal populations. Based on raw counts of all *Ammonia* species linings, however, there is a relatively strong relationship (R^2 = 0.67) between total numbers of trochospiral linings and water depth. The trend shows gradual rise in trochospiral microforams across the delta front and prodelta, with a peak around 45 mbsl that declines to values of 0 at 78 m and in deeper water.

Discussion

Previous studies of microforaminiferal linings in the Caspian-Black Sea-Mediterranean corridor (Mudie et al., 2011) showed that variable amounts (5 to >500 linings/g dry sediment) occur in surface sediments from the Eastern Mediterranean to the Caspian Sea. A simple classification of nine microforam lining types was presented, and it was noted that linings were absent in freshwater lakes, salt-flats, and deep anoxic basins.

Our new data confirms the absence of linings in the delta channels and at half of the Lake Razim coastal lagoon sites. The occurrences of a few *Ammonia compacta* linings and some unidentified lining morphotypes at two Lake Razim sites may reflect dredging disturbance or storm overwash. The high lining abundances (average 489/g; range 168 to 1737/g) may reflect the eutrophic waters of the region but higher abundances (2,000–8,000/g) are recorded for Louisiana marshlands (Mathison and Chmura, 1995). In general, the nearshore to offshore

progression of foraminifera from *A. tepida* to *A. compacta*, then to *A. ammoniformis*, and the seaward increase of polyhaline Lagenida in the assemblages (Yanko-Hombach et al., 2017) is reflected in the occurrences of trochospiral microforam linings that are most strongly correlated with water depth. There is also a weak link between total lining abundances and surface water salinity. Overall, the assemblages of microforam linings reflect the dominance of benthic foraminifera tolerant of fluctuating salinity on the delta front (*A. tepida* and *P. subgranosus mediterranicus*), and common occurrence of *Nonion matagordanus* in the shelf beyond the prodelta, but uniserial, biserial, and single-chambered species are rare or absent. The sparseness of the non-coiled linings in the palynological assemblages distinguishes the deltaic-shelfal setting from saltmarsh environments.

Acknowledgments

This paper is a contribution to EU BLACK SEA ERA.NET-WAPCOAST 076 project "Water pollution prevention options for coastal zones and tourist areas: Application to Danube Delta front area." It also contributes to the IGCP 610 “From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary” project sponsored by UNESCO and IGU.

References

Mathison, S.W., and Chmura, G.L., 1995. Utility of microforaminifera test linings in palynological preparations. *Palynology* 19(1): 77–84.

Mudie, P.J., Leroy, S.A.G., Marret, F., Gerasimenko, S.P., Kholief, S.E.A., Sapelko, T., and Filipova-Marinova, M., 2011. Nonpollen palynomorphs: Indicators of salinity and environmental change in the Caspian–Black Sea–Mediterranean corridor. In: I.V. Buynevich, V. Yanko-Hombach, A.S. Gilbert, R.E. and Martin (Eds.), *Geology and Geoarchaeology of the Black Sea Region: Beyond the Flood Hypothesis*. Geological Society of America Special Paper 473, pp. 89-115. Boulder, Colorado, Geological Society of America,.

Yanko-Hombach, V., Kondariuk, T., and Motnenko, I., 2017. Benthic foraminifera indicate environmental stress from river discharge to marine ecosystems: Example from the Black Sea. *Journal of Foraminiferal Research* 47(1): 70–92.