

CALLIANASSID, BURROWING BIVALVE, AND GRYPHEID OYSTER BIOFACIES IN THE UPPER CRETACEOUS NAVESINK FORMATION, CENTRAL NEW JERSEY: PALEOECOLOGICAL AND SEDIMENTOLOGICAL IMPLICATIONS

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ABSTRACT

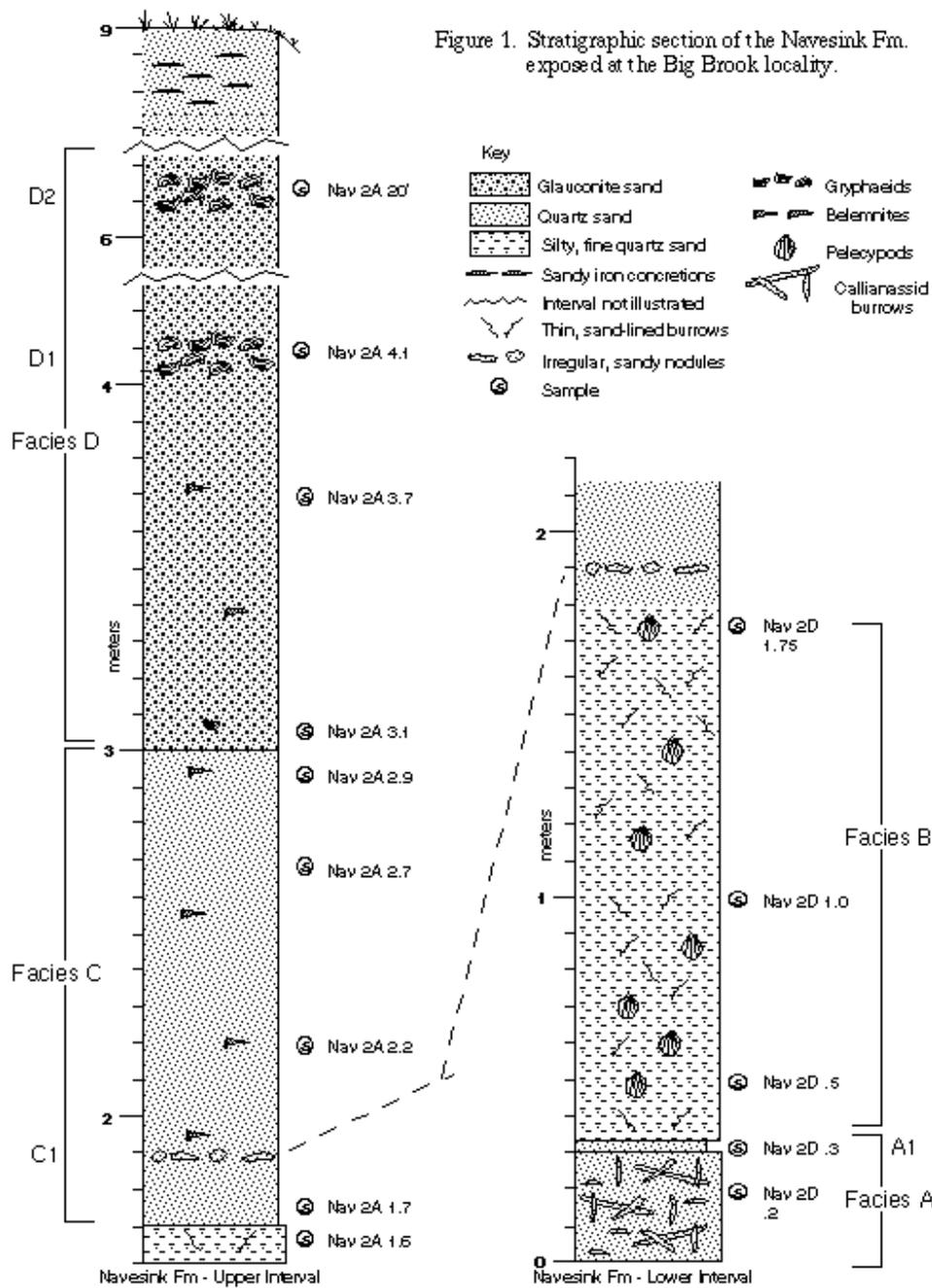
In Monmouth County, New Jersey, the Upper Cretaceous Navesink Formation is well-exposed along the banks of Big Brook at the Boundary Road Bridge (see Bennington *et al.*, 1996 for locality information). To better understand the development of benthic environments through the Navesink transgression, we sampled Navesink sediments and fossils at 14 stratigraphic levels. Our analysis of the stratigraphic section at Big Brook reveals four distinct facies, each with a characteristic fossil fauna and sedimentological profile. This sequence of facies has not been previously described in the Navesink Formation. The overall change in depositional environments upsection is from inner shoreface to outer shelf. Facies of the inner shoreface are characterized by abundant quartz sand, callianassid burrows, and a diverse bivalve fauna. Outer shelf facies are characterized by glauconite sands and contain low diversity faunas dominated by gryphaeid oysters. The abrupt transitions noted between facies suggest discontinuous rates of sedimentation and / or sea-level rise during the Navesink transgression. The restriction of gryphaeid oyster faunas to the outer shelf implies that this was a particularly favorable habitat for these sessile, 'mud floating' pelecypods, perhaps because it was a relatively undisturbed environment devoid of predators.

Description of Navesink Facies at Big Brook (illustrated in Figure 1.)

Facies A) Overlying a basal transgressive lag deposit (not exposed at this locality) is a thin basal interval of fine quartz sand with abundant carbonaceous matter and some glauconite. This interval is extensively burrowed, with the distinctive trace fossil *Spongiomorpha* (similar in form to the better known *Ophiomorpha* but with unlined burrow walls marked by longitudinal ridges [Bromley, 1996]). The claws of the callianassid crustacean *Callianassa sp.* are commonly preserved within the burrows at the Big Brook locality. At the upper contact of the callianassid burrow facies is a thin layer of coarse sand (A1).

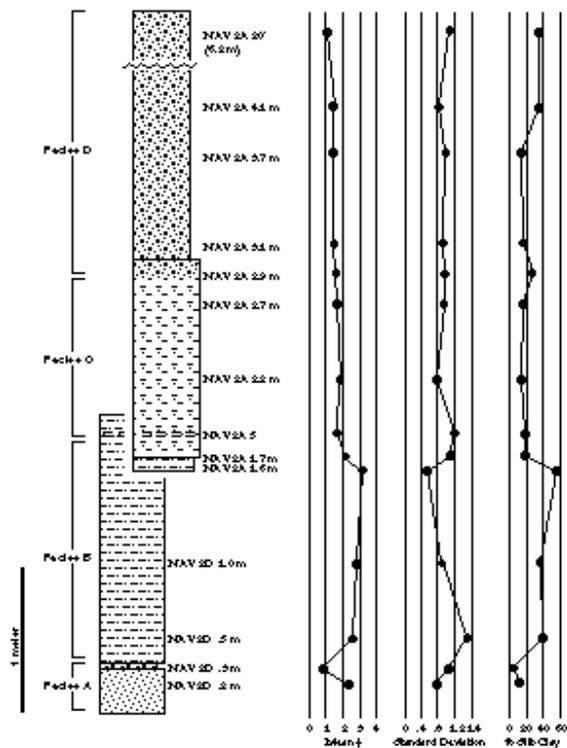
Facies B) Above the thin sand layer is a fining-upward interval of muddy, fine to very fine quartz sand with abundant carbonaceous matter and some glauconite. This facies is characterized by a diverse bivalve fauna, including both epifaunal and burrowing forms, preserved as composite molds in the unlithified sediment. Genera identified include *Inoceramus*, *Trigonia*, *Crassatellites*, *Lima*, *Periplomya* (?), and *Linearea*. Callianassid burrows are not present in this facies.

Facies C) Near a horizon marked by irregular pockets and nodules of coarse quartz sand (C1) is a coarsening-upward transition to medium quartz sands. These sands include increasing numbers of glauconite grains and an apparent decrease in carbonaceous matter. Also present are phosphatic grains. Macrofossils in this interval include rare gryphaeid oysters and common belemnites.



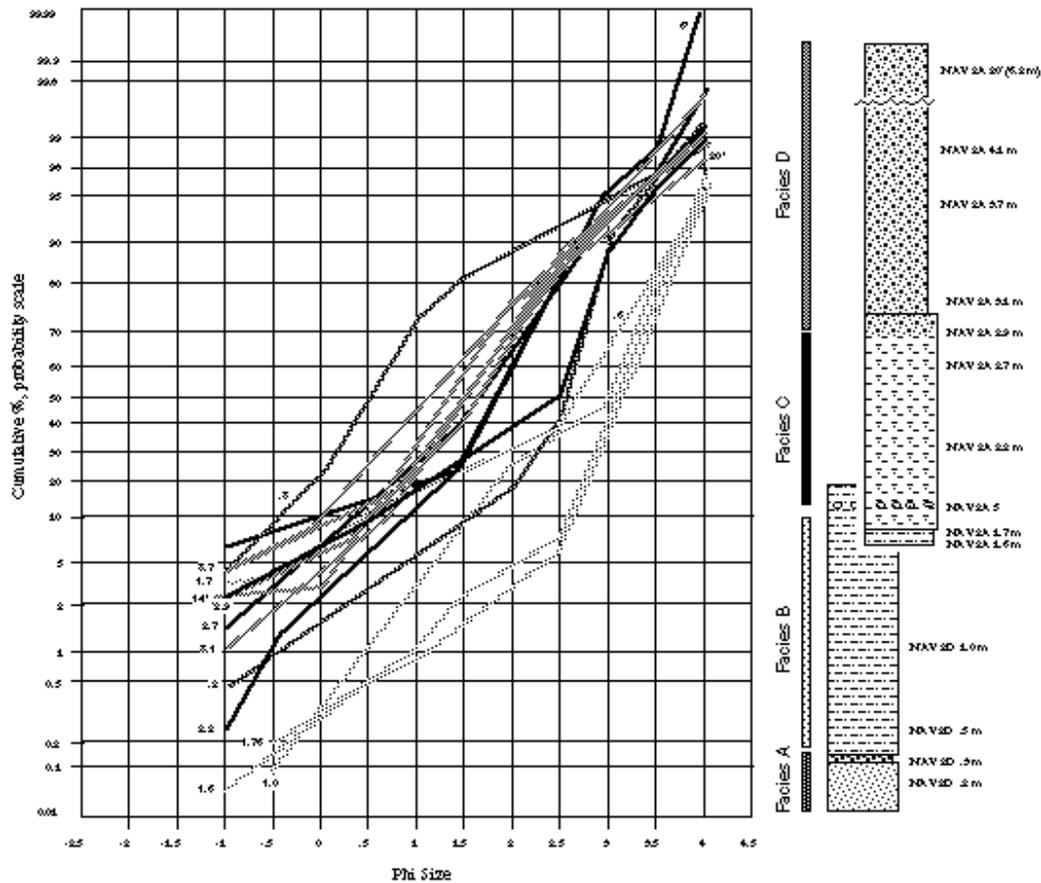
Facies D) Between 2.7 and 2.9 meters in the section is a transition from quartz sands mixed with glauconite to almost pure glauconite sands. The upper, glauconitic interval of the Navesink Formation includes two thin, shell-rich intervals with abundant gryphaeid oysters (**D1** and **D2**). The lower fossiliferous interval is dominated by the oyster *Exogyra quadracostata* and contains few other species. The upper fossiliferous interval is dominated by the oyster *Pycnodonte mutabilis* and is more diverse, with an accessory fauna of brachiopods, echinoids, and other oyster species.

Sedimentological Trends in the Navesink Formation



Graph 1 - Upsection trends in mean sediment size, sorting (standard deviation) and silt-clay content in the Navesink Formation at Big Brook.

Graph 1. The lower interval of the Navesink Formation at Big Brook is overall a fining-upward sequence. Medium and coarse sand at the base (facies A) changes to fine and very fine sand upsection (facies B), with a simultaneous increase in the proportion of silt- and clay-sized particles. The degree of sorting increases through facies B as larger sand sizes become less abundant. At the transition to facies C there is an abrupt increase in the abundance of medium and coarse sand and an abrupt decrease in clay and silt, both of which persist upsection. The transition from quartz sand to glauconite sand between 2.7 m and 2.9 m is not marked by any significant change in mean grain size, sorting, or abundance of silt and clay.



Graph 2. Overlay plot of cumulative size-frequency distributions for Navesink sediment samples.

Graph 2. An overlay plot of the cumulative size-frequency distributions for each Navesink sediment sample confirms the observations made above. Samples from facies A have unique distributions dominated by medium and coarse sand. The samples from facies B show similar distributions dominated by fine and very fine sands. Samples from facies C and D cannot be distinguished from one-another on the basis of their size-frequency distributions.

Interpretation of Navesink Facies

The contact of the Navesink with the subjacent Mt. Laurel Formation is agreed by most authors to be an erosional contact. Becker et al. (1996) demonstrate the presence of a reworked and temporally mixed fossil assemblage at the base of the Navesink (not exposed in our section), arguing for significant remobilization of sediments associated with shoreface retreat during the onset of Navesink transgression.

Overlying the basal transgressive lag (which we have not sampled) is facies A. The presence of abundant callianassid burrows supports a lower foreshore to shallow subtidal environment of deposition (Martino and Curran, 1990). The transition to facies B is abrupt and marked by a thin layer of coarse sand. This may represent a winnowed

horizon, perhaps formed during a prolonged hiatus in deposition. The upward fining trend in the stratigraphic interval occupied by facies B suggests deepening. The diverse pelecypod fauna of facies B is typical of inner to middle shelf environments.

The predominance of coarse and medium size grains in facies C is puzzling because it appears to indicate shallowing. However, we suggest that facies C was deposited in deeper water than facies B and that there was a significant reduction in the rate of clastic influx. Evidence for this comes from the failure of the bivalve fauna from the base of facies B to reappear and from the accumulation in facies C of abundant belemnite fossils, which are added to the benthos episodically. The relative scarcity in facies C of fine sand, silt, and mud could be the result of current winnowing of sediments exposed for prolonged periods on the seafloor, although no sedimentary structures are apparent to support this hypothesis. It is also possible that the increase in mean grain size is due to an increased abundance of authigenic glauconite grains, which tend to be large. To test this idea we are currently attempting to quantitatively assess the relative proportion of glauconite in each sample. The transition to the almost pure glauconite sands of facies D suggests continued deepening accompanied by a cessation of clastic input. The fact that there is very little difference in the sedimentary particle sizes accumulating on the seafloor between facies C and D corroborates the suggestion that glauconite grains are the major control on the sediment characteristics in facies C and D.

The initial transition to the overlying Sandy Hook Member of the Red Bank Formation is marked at the Poricy Creek locality by the reappearance of very fine quartz sand as a dominant component of the samples, mixed with the glauconite. The Sandy Hook Member has been interpreted to be a prodelta facies developed as fluvial systems built out from the shoreline following the end of the Navesink transgression (Owens and Gohn, 1985).

Gryphaeid Oysters and the Navesink Formation

Two shelly intervals are found within facies D at Big Brook, a lower interval dominated by an assemblage consisting of pectens and the oyster *Exogyra* and an upper interval dominated by the oysters *Pycnodonte*, *Agerostrea*, and the brachiopod *Choristothyris*. It is generally inferred that glauconite sands form in deep water on the outer shelf during periods of low detrital input (Owens and Sohl, 1969). Studies of modern glauconite formation off of the Atlantic coast of Africa show that depths of 200 m or more are optimal for the formation of 90% pure glauconite sands (Odin and Fullagar, 1988). Furthermore, the highly cracked appearance of the glauconite grains of facies D is characteristic of highly evolved glauconite pellets that spend long periods of time exposed on the seafloor. Thus, the environment favored by Gryphaeid oysters in the Navesink Formation appears to have been a deep water environment with a very low rate of sediment influx. It is also interesting to note that the upper shell interval (D2) can be traced at least 12 km to an exposure of the upper Navesink at Poricy Brook. The lateral persistence of the upper shell bed and the general rarity of oyster fossils in the glauconite sands between the shell beds (in spite of the presumed opportunity for colonizing the slowly accreting glauconite substrate) may indicate that these oyster-rich intervals

represent episodes of environmentally favorable conditions on the floor of the Cretaceous shelf, perhaps when oxygen or nutrient availability made colonization by benthic fauna favorable. Modern encrusting oysters occur in high abundance in shallow water, brackish environments where low salinity and other environmental stresses discourage gastropod predators. The association of gryphaeid oyster faunas with a deep water, low sedimentation-rate, outer shelf facies suggests that this environment may have provided a similar kind of refuge for gryphaeids, which were sessile, 'mud floating' pelecypods prone to attack by mobile predators and burial by high rates of clastic influx. Studies of the incidence of shell damage by boring and durophagous predators to Navesink gryphaeids are needed to assess this hypothesis.

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