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MOLLUSCAN FAUNA OF THE PUNGO RIVER FORMATION, LEE CREEK MINE, NORTH CAROLINA

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INTRODUCTION

Kimrey (1964, p. 195) named the Pungo River Formation for "interbedded phosphatic sands, silts and clays, diatomaceous clays, and phosphatic and non-phosphatic limestone" in the subsurface in the vicinity of Beaufort County, eastern North Carolina. The Pungo River Formation has no natural exposure on land, but mining operations of the Texasgulf Co. at Lee Creek near Aurora, Beaufort County, have permitted collection of its fossils. There the Pungo River Formation is bounded below by the sandy limestone of the Eocene Castle Hayne Formation, and above by the shelly sands, silts and clays of the Pliocene Yorktown Formation (see introduction to this guidebook for map location and stratigraphic section).

The Pungo River Formation consists of two members at the Lee Creek mine: the lower, Belhaven Phosphatic Sand Member and the upper, Bonnerton Member. The Belhaven Member is primarily a dark greenish brown phosphatic sand intercalated with greenish gray, indurated diatomaceous clay and phosphatic, sandy limestone. The Bonnerton Member grades upward from a gray, phosphatic limestone to gray, phosphatic, sandy limestone with molluscan molds and casts, plus gray sand with shell fragments, greenish white phosphatic limestone, calcareous clay, clayey sand, and, near the top of the section, light green to yellow-green diatomaceous to calcareous clay and sand with abundant fragmental bryozoans, barnacles, pectinids, and hydrozoans (Gibson, 1983a; 1987).

Riggs and others (1982) defined four depositional sequences in the Pungo River Formation at Lee Creek (A-D), each characterized by sediment patterns grading from siliciclastic and phosphate-rich at the base to less phosphate and more carbonate-rich at the top. The same trend is observed from from Unit A upward to Unit D, with the higher units being generally richer in limestone. Units A, B and the basal part of C correspond with the Belhaven Member, whereas Unit D and the upper part of C correspond with the Bonnerton Member.

The present study focuses on the biostratigraphic and paleoenvironmental significance of mollusks found in three Pungo River lithologies which are easily differentiated in spoil piles at the Lee Creek mine:

Lithology 1: Dark greenish brown predominantly medium phosphatic sand with abundant arthropod burrows. This includes Units 1 and 3 of Gibson (1987) and Units A and B of Riggs and others (1982), all from the Belhaven Member.

Lithology 2: Gray phosphatic sandy limestone with abundant molluscan molds and casts. This is Unit 5 of Gibson (1987), and the top of Unit C of Riggs and others (1987), that is, the base of the Bonnerton Member.

Lithology 3: Yellow green sand and silty, clayey sand with hydrozoan and/or bryozoan fragments. This includes Units 6 and 7 of Gibson (1987), and Unit D of Riggs and others (1982), that is, the upper part of the Bonnerton Member.

PREVIOUS PALEONTOLOGIC WORK

Gibson (1967, 1987) described *Pecten humphreysii* Conrad, "'*Pecten*' *madisonius* (Say)" [= *Chesapecten nefrens*?], *Turritella* sp., *Ecphora tricostata* Martin, and a *Glycymeris* similar to *Glycymeris parilis* (Conrad) from the Bonnerton Member at Lee Creek. Gibson (1982, p. 2[illegible]) also mentioned a pectinid from the lower Pungo River Formation, which resembles a species characteristic of the Haywood Landing Member of the Belgrade Formation of North Carolina.

Gibson (1987) described a possible descendant of *Pecten humphreysii*, *Pecten mclelleni*, from the Bonnerton Member, plus *Chesapecten coccymelus*, *Chesapecten nefrens* (in the uppermost bed), and possibly a new species of *Amusium*.

Wilson (1987a) described the oyster *Pycnodonte* (*Gigantostrea*) *leeana* from spoil piles of the Pungo River Formation at Lee Creek. He also noted and *Ecphora aurora* Wilson, *Ecphora tricostata* Martin, and *Ecphora pamlico* Wilson (= subspecies *tricostata pamlico* according to Ward, 1992) in the Pungo River Formation at Lee Creek.

Ecphora tricostata occurs in the Bonnerton Member and in the Calvert Formation of Maryland. *Ecphora aurora* occurs in the Belhaven Member, judging from its phosphatic matrix. According to Wilson (1987b), *Ecphora aurora* also occurs in the Burdigalian (N5-N8) and possibly also in the Helvetian (N15-N17) of France. According to Petuch (1988a, p. 40), "*Siphoecphora aurora* (Wilson, 1987)" is "apparently confined to Unit 4 (of Gibson, 1987), and possibly Unit 2, of the Belhaven Member..." Note, however, that Unit 4 comprises the base of the Bonnerton Member at the Lee Creek mine, not the upper part of the Belhaven Member (Gibson, 1987, p. 59).

Wilson (1987b, p. 21) speculated that *Ecphora pamlico* occurs in strata above *E. aurora* but below *tricostata*, that is, probably in the lower Bonnerton Member. Wilson (1987b) also noted that a species closely related to *E. pamlico* occurs in the Calvert Formation of Maryland and in the Tortonian of France. Petuch (1988a) reported "*Ecphorosycon pamlico* (Wilson, 1987)" in the upper Bonnerton Member and in the Calvert Formation of Maryland.

Petuch (1988a) described the new species *Ecphora* (*Trisecphora*) *chamnessi*, *Ecphora* (*Trisecphora*) *prunicola* and *Ecphora* (*Trisecphora*) *xenos* from the Bonnerton Member of the Pungo River Formation at the Lee Creek mine. *Ecphora prunicola* (including the subspecies *carolinensis* Petuch, 1988a) also occurs in the Calvert Formation of Maryland. According to Ward (1992), *E. prunicola* and *E. chamnessi* are junior synonyms of *Ecphora tricostata tricostata*.

Furnish and Glenister (1987) noted internal casts of the nautiloid *Aturia* sp. in the Bonnerton Member.

Zullo (1984) noted that *Balanus imitator* Zullo, 1984, occurs throughout the Pungo River Formation at Lee Creek, but is most abundant near the top of the unit. *Fistulobalanus klemmi* Zullo, 1984, is known only from specimens on a single pectinid shell from the Pungo River Formation.

PREVIOUS BIOSTRATIGRAPHIC WORK

Foraminifera from the upper Pungo River Formation at Lee Creek correlate with planktic foraminiferal biochronozones N8 to early N9 (Brown, 1958; Gibson, 1967, 1971, 1983b, p. 359-360). Gibson (1967, 1971) found that the lower Pungo River Formation lacks a well-preserved foraminiferal fauna, but its molluscan molds suggest closer affinity with Oligocene than Miocene faunas. East and northeast of the Lee Creek mine, the lower Pungo River Formation contains benthic foraminifera and an unidentified pectinid, which suggest correlation with the early Miocene Haywood Landing Member of the Belgrade Formation of North Carolina (N4?) and the early Miocene Torreya Formation of Florida (Gibson, 1982, p. 20). The Torreya Formation correlates with planktic biochronozone N5 (Gibson, 1982, p. 20) or perhaps with zones N5 through lower N7 (Hunter and Huddlestun, 1982; Tedford and Hunter, 1984).

Gibson (1982) indicated that the Pungo River Formation in east central and southeastern North Carolina represents three transgressions separated by unconformities. The upper sequence correlates with planktic foraminiferal biochronozones N8-N9 and N11, and the lower sequence correlates with the Dunkirk beds of the Calvert Formation of Maryland. The Dunkirk beds are a sand and diatomaceous clay sequence which contains early Burdigalian (N5 or N6) silicoflagellates (Andrews, 1978; Gibson, 1982, p. 8).

Abbott (1978) and Abbott and Ernissee (1983) analyzed two diatom beds in the Pungo River Formation a few miles northeast of the Lee Creek mine. The lower bed, which was believed to correspond with Gibson's Unit 2 (within the Belhaven Member), correlates with foraminiferal biochronozones N8 and N9. The upper diatom bed correlates with biochronozone N11. Based on these data, Abbott (1978, p. 29) concluded that these beds were equivalent to the lower middle Miocene top of the Calvert Formation and the middle Miocene Choptank Formation of Maryland. According to Gibson (1967, 1971), strata of N11 age are absent at the Lee Creek mine.

In southern Onslow Bay, south of Lee Creek, the Pungo River Formation consists of several unconformity-bounded sequences (Waters and Snyder, 1986) which correlate by planktic foraminifera with biochronozones N6 and early N7 (Waters and Snyder, 1986).

In summary, available microfossil and macrofossil evidence suggests that the Pungo River

Formation contains three major depositional phases correlating with foraminiferal biochronozones (1) N4? and N5-N7 (lower Miocene), (2) N8-N9 (upper lower Miocene and lower middle Miocene), and (3) N11 (middle Miocene). The earliest phase correlates with the lower Calvert Formation of Maryland and possibly also with the slightly older Haywood Landing Member of the Belgrade Formation of North Carolina. The middle phase correlates with the upper Calvert Formation of Maryland. The upper phase, apparently absent at Lee Creek, correlates with the lower Choptank Formation of Maryland.

PREVIOUS PALEOECOLOGIC WORK

According to Gibson (1967, 1968, 1982, p. 21), benthic foraminifera of the Pungo River Formation at Lee Creek indicate an open marine, cool-temperate environment of approximately 100 meters depth for the lower, more phosphatic beds, and less than 70 meters depth for the upper, carbonate-rich beds. Oxygen isotopes in lower Pungo River dolomites near Aurora and offshore in Onslow Bay confirm a cool thermal regime (Allen and Baker, 1984).

However, Leutze (1968) indicated that Gibson's (1967) depth estimates are too great. Snyder and others (1982b) and Katrosh and Snyder (1982) suggested shallower depths of 40-50 meters and 50-60 meters for the lower and upper Pungo River Formation, respectively, based on foraminiferal assemblages.

Snyder and others (1982b) inferred that the lower Pungo River Formation was deposited in an open marine setting where high nutrient supply and perhaps other unusual factors related to phosphogenesis limited faunal diversity. According to Miller (1982b), middle Miocene phosphorite deposition in the southeastern United States occurred where cool, southward flowing waters and sea floor topography induced upwelling of deep, nutrient-rich waters.

Abbott and Ernissee (1983) analyzed diatoms from two beds in the Pungo River Formation near Lee Creek. These beds may correlate with Unit 2 of the Belhaven Member. The lower bed contains abundant representatives of an extant subtropical species, whereas the upper bed contains species typical of coastal upwellings. They added that diatoms and silicoflagellates in the Pungo River Formation are all open marine and relatively near-shore species.

Gibson (1967) indicated that foraminifera and molluscs in the upper Pungo River Formation suggest that the southern boundary of the cool temperate regime was south of Lee Creek. However, the upper Pungo River Formation contains a higher percentage of warm-water foraminifera than the Calvert Formation of Maryland.

Miller (1982a, p. 11) indicated that benthic foraminifera from Pungo River strata in some parts of North Carolina indicate colder water or more adverse environmental conditions than at Lee Creek.

Rooney and Kerr (1967) suggested that the Pungo River Formation was deposited in a shallow marine basin characterized by reducing environments. Abbott and Ernissee (1983) observed thin rhythmites within the diatomaceous clay of Unit 2 of the Belhaven Member, which they said suggested periodically reducing conditions.

MOLLUSCAN FAUNA

Our preliminary review of the molluscan fauna of the Pungo River Formation integrates published information with new observations of hundreds of latex casts made from natural rock molds identified by lithology as coming from either the Belhaven or Bonnerton Members at Lee Creek.

Belhaven Member

The Belhaven Phosphatic Sand Member of the Pungo River Formation is generally barren of macrofossils except for large arthropod burrows. Where macrofossils occur, they appear as a low diversity assemblage dominated by the large venerid bivalve *Chione* n. sp., plus rare specimens of the bivalves *Tellidora* n. sp., *Rebeccapecten berryae* Ward, 1992, and the gastropods *Calyptraea* sp. cf. *C. aperta* (Solander, 1766) and *Ecphora aurora* Wilson, 1987. The fossils are generally preserved as internal and external molds, including some, but not all, of the originally calcitic shells.

Bonnerton Member

The carbonate-rich Bonnerton Member of the Pungo River Formation contains a richer molluscan assemblage with low dominance diversity. Calcitic shells remain well preserved, but the originally aragonitic shells are represented only by molds.

The Bonnerton molluscan fauna contains at least 51 species, including two new species or subspecies of *Chesacardium*, one new subspecies of *Semele carinata*, and one new subspecies of *Panopea goldfussii*. In the following list of Bonnerton mollusks, the species known to occur in the Calvert Formation (of Maryland) and/or in the Kirkwood Formation (of New Jersey) are indicated with an asterisk:

Cephalopod

Aturia sp.

Gastropods

Diodora sp. cf. *D. catilliformis alumensis* (Gardner, 1930)
Diodora sp. cf. *D. marylandica* (Conrad, 1838)
Calliostoma sp. cf. *C. bella* (Conrad)
Turritella sp. cf. *T. aequistriata* Conrad
Turritella sp. cf. *T. indenta* Conrad, 1841
Turritella sp. cf. *T. cumberlandia* (Conrad)
Serpulorbis granifera (Say, 1824)
Calyptraea sp. cf. *C. aperta* (Solander, 1766)
**Ecphora meganae meganae*? Ward and Gilinsky, 1988 [this subspecies includes *Ecphora calvertensis* Petuch, 1988, *fide* Ward, 1992]
**Ecphora tricostata tricostata* Martin, 1904 [this subspecies includes *Ecphora prunicola* Petuch, 1988, fide Ward, 1992]
Ecphora tricostata pamlico (Wilson, 1987)
Siphonalia sp. cf. *S. devexa* (Conrad)
Cancellaria sp. 1
Cancellaria sp. 2
Terebra sp.
Drillia sp. cf. *D. limatula* (Conrad, 1830)

Bivalves

Dallarca? *subrostrata* (Conrad, 1841)
Dallarca aff. *D. elevata* (Conrad, 1840)
**Glycymeris parilis* (Conrad, 1843)
Isognomon (*Hippochaeta*) sp.
Atrina sp.
Pecten humphreysii humphreysii Conrad, 1842
Pecten mclellani Gibson, 1987
Rebeccapecten berryae? Ward, 1992
**Chesapecten coccymelus* (Dall, 1898)
Chesapecten nefrens? Ward and Blackwelder, 1975
Ostrea mauricensis Gabb, 1860
Pycnodonte (*Gigantostrea*) *leeana* Wilson, 1987
**Pycnodonte* (*Gigantostrea*) *percrassa* (Conrad, 1840)
Mytilus conradinus d'Orbigny, 1852
Modiolus ducatellii Conrad, 1840
Lucinoma contracta (Say, 1824)
Timothynus subvexa (Conrad, 1838)
**Astarte cuneiformis* Conrad, 1840
Astarte thisphila? Glenn, 1904
Astarte cf. *A. thisphila* Glenn, 1904
Marvacrassatella turgidula? (Conrad, 1843)
**Marvacrassatella melina* (Conrad, 1832)
**Cyclocardia castrana* (Glenn, 1904)
Chesacardium n. sp. or subsp. 1
Chesacardium n. sp. or subsp. 2
Tellina? sp.
Semele carinata (Conrad, 1830) new subsp.
**Melosia staminea* (Conrad, 1839)
Dosinia acetabulum blackwelderi Ward, 1992
Lirophora latilirata (Conrad, 1841)
Bicorbula idonea (Conrad, 1833)
Corbula (*Caryocorbula*) *inaequalis* Say, 1824
**Varicorbula elevata* (Conrad, 1838)
Panopea goldfussii Wagner, 1839, n. subsp.

MOLLUSCAN BIOSTRATIGRAPHY

Belhaven Member

Three of the five species in the Belhaven molluscan fauna are unique to this unit. Of the remaining two species, the *Calyptraea* probably represents a long-ranging taxon with little biostratigraphic significance, and *Rebeccapecten berryae* is otherwise known from the early Miocene Haywood Landing Member of the Belgrade Formation of North Carolina (see Fig. 59 in Carter and others, 1988, labeled *Pecten trentensis*).

Bonnerton Member

The molluscan fauna of the Bonnerton Member at Lee Creek confirms correlation with the lower and lower middle Miocene Calvert Formation of Maryland and with the Kirkwood Formation of New Jersey.

Of the 51 known Bonnerton species, 11 (marked with an asterisk in the preceding list) represent geographic range extensions from the Calvert and Kirkwood Formations of Maryland and New Jersey; and *Pecten humphreysii humphreysii* represents a new occurrence of a lower to middle Miocene species previously known from New Jersey, Maryland and Florida.

Of the remaining species, two which may (?) occur in the Bonnerton Member are known from the Calvert Formation and higher in the Miocene section of Maryland (*Chesapecten nefrens* and *Astarte thisphila*), and one occurs in the Kirkwood Formation of New Jersey and possibly also in the Choptank Formation of Maryland (*Ostrea mauricensis*).

Dallarca elevata is otherwise restricted to beds younger than the Calvert Formation, that is, to the upper middle Miocene Boston Cliffs Member of the Choptank Formation of Maryland and Virginia. Our Bonnerton *Dallarca* aff. *D. elevata* is only doubtfully referred to this species.

PALEOENVIRONMENTAL IMPLICATIONS

Belhaven Member

As noted above, previous sedimentologic and faunal analyses have suggested that the Belhaven Member was deposited in a subtropical to cool temperate, open-marine setting intermittently destabilized by upwelling of deep, nutrient-rich waters, with occasional dysaerobic or anoxic conditions.

The general absence of molluscan fossils, even as molds, and the few molluscan species in the rare mollusk-bearing zones within the Belhaven Member are compatible with the idea that this unit was deposited under generally adverse environmental conditions, punctuated by brief intervals of normal marine, probably cool temperate conditions.

The lower Pungo River molluscan fauna belongs in the "paratropical" Pungoian subprovince as opposed to the cooler but still "paratropical" Calvertian subprovince as defined by Petuch (1988b). Petuch's (1988b) "paratropical" refers to cool temperate or warm temperate but seasonally stable environments. Petuch listed the Belhaven gastropod *Ecphora aurora* as endemic to this subprovince. Both subprovinces belong in the early Miocene, cool temperate to paratropical Transmarian province of Petuch (1988b).

Petuch also included the early Miocene Haywood Landing fauna of the Belgrade Formation in his Pungoian subprovince. The Haywood Landing and Bonnerton faunas lie near the southern extent of this subprovince, which extends from Cape Fear to northern Virginia. This subprovince includes a few cool temperate mollusks, as well as characteristically warm temperate and tropical mollusks such as *Chama, Paphia, Conus, Strioterebrum* and *Cymatosyrinx*. The tropical families Strombidae, Cypraeidae, Cerithiidae and Turbinellidae are absent (Petuch, 1988b, p. 11).

Bonnerton Member

According to Snyder and others (1982b), benthic foraminifera in the upper Pungo River Formation suggest no unusual environmental conditions, and the phosphate in these beds is largely reworked from the lower Pungo River Formation. The present survey confirms the presence of a moderately diverse, open marine molluscan fauna in the Bonnerton Member.

This survey also confirms Gibson's (1967) suggestion that this molluscan fauna represents a predominantly cool temperate climate, although with the occasional introduction of subtropical species. Warmer elements of the fauna are largely restricted to the bivalve *Atrina* and the nautiloid cephalopod *Aturia*. Many of the associated species occur in early to middle Miocene strata as far north as Maryland and sometimes also New Jersey. This mixture of cool temperate and subtropical species in the Bonnerton Member probably reflects neashore cooler and offshore warmer conditions, the latter indicating influence from the Gulf Stream.

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