U.S. GEOLOGICAL SURVEY

Remarks on calcareous and siliceous nannoplankton biostratigraphy for some Cretaceous and Tertiary core samples from southern New Jersey

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Open File Report 90-278

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1990

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ABSTRACT

Coccoliths and silicoflagellates in 50 samples from five coreholes in southern New Jersey are assigned to transoceanic zones for Campanian, Maestrichtian, Eocene and Miocene. Noteworthy zonal guide species in the core samples include *Broinsonia parca* and *Marthasterites furcatus* (Zone CC18) in the lower Campanian of the Clayton Well, *Nephrolithus frequens* (Zone CC26) in the upper Maestrichtian of the Atco Well, *Isthmolithus recurvus* (Subzone CP 15b) in the upper Eocene of the Ragovin Well, *Helicosphaera ampliaperta* (Zone CN3) in the lower Miocene of the Clayton Well and *Distephanus stauracanthus* (*D. stauracanthus* Subzone) in the middle Miocene of the Acow 2 Well. Many of the samples studied are near series or subseries boundaries and were intended to aid boundary resolution where multiple microfossil zonations are available.

INTRODUCTION

Several stratigraphic reference coreholes in Mesozoic and Cenozoic of New Jersey have been studied and described recently (Owens and others, 1988, and Poore and Bybell, 1988). The application of nannoplankton zonation has been helpful in establishing long-range subsurface correlations. In this report some Late Cretaceous and Tertiary intervals which were selected by J. Owens and N. Sohl for detailed coccolith and silicoflagellate zonation have been studied. The zonations are related to global standards of nannoplankton succession as described by Barron and others (1985), Bukry (1973, 1981), Bukry and Bramlette (1970), Okada and Bukry (1980), Perch-Nielsen (1985), Roth (1978), and Sissingh (1978). See Owens and others (1988) for recent descriptions of the New Jersey Coastal Plain formations. This report will deal with the nannoplankton assemblages and their correlation.

A total of 50 samples containing nannoplankton were studied from five coreholes designated ACOW 1, ACOW 2, ATCO, CLAYTON, and RAGOVIN in southern New Jersey (Figure 1). A majority (37) of the nannoplankton samples studied are from the Clayton Well. Light-microscope techniques were used for calcareous nannoplankton smear slides and siliceous nannoplankton acid-residue strewn slides. All but four slides were prepared at Menlo Park by M. McCormick using the preparation techniques described for Deep Sea Drilling Project cores (Bukry, 1986). Previously prepared slides from J. Owens were used for samples ATCO 370', 390', 490' and RAGOVIN N5635X 1298. Remarks on the nannoplankton biostratigraphic results follow.

COREHOLE NANNOPLANKTON BIOSTRATIGRAPHY

Atco Well (lat. 39°45'20"N, long. 74°54'01"W).

The Atco Well in Winslow Township, Camden County used ground level as the zero depth reference. Three prepared microscope slides from 370 feet, 390 feet, and 490 feet were received for age evaluation of nannoplankton assemblages. The samples are from sidewall cores (J. Owens, written communication, 1989). Calcareous nannoplankton of Late Cretaceous and early Tertiary age occur.

Sample N6919, 490': Latest Campanian or early Maestrichtian Zone CC22 or CC23.

The deepest sample contains common coccoliths and calcareous debris. The overlapping ranges of several species such as *Arkhangelskiella cymbiformis*, *Broinsonia parca*, *Calculites obscurus*, *Ceratolithoides aculeus*, *Reinhardtites levis*, and *Tranolithus phacelosus* indicate the zonal assignment. Older Campanian species that occur in New Jersey, such as *Eiffellithus eximius* and *Marthasterites furcatus*, are missing. Also, younger Maestrichtian taxa that occur in New Jersey, such as *Lithraphidites quadratus* and *Nephrolithus frequens*, are missing. Low-latitude zonal markers, *Quadrum sissinghii* and *Q. trifidum* are absent in this and other correlative samples from New Jersey.

Sample N6918. 390': Early Maestrichtian Zone CC24.

The coccolith flora of N6918, 390' is abundant and well preserved. Disarticulated segments of *Braarudosphaera bigelowii* are fairly common , but the entire pentaliths are sparse. There is a very sparse (<1%) admixture of Paleocene and Eocene taxa. The Late Cretaceous coccoliths are assigned to Zone CC24 by the presence of common *Arkhangelskiella cymbiformis* with sparse *Reinhardtites levis* and *Calculites obscurus*, in the absence of *Tranolithus phacelosus*. Although *Lithraphidites carniolensis* is common, a search for zonal guide *L. quadratus* was negative. The Paleogene admixture is indicated by such species as *Chiasmolithus solitus*, *Coccolithus pelagicus*, *Reticulofenestra samodurovii*, *Transversopontis pulcheroides*, and *Zygrhablithus bijugatus*.

Sample N6917. 370': Latest Maestrichtian Zone CC26.

The shallowest sample available from the Atco Well contains *Nephrolithus* frequens, the zonal guide species for the youngest zone of the Maestrichtian. Like the two lower samples, Cretaceous taxa predominate the admixed Paleogene (<1%), and Braarudosphaera bigelowii segments are evident. But, poorer preservation is indicated for the 370' sample by the lower species diversity and greater fragmentation of specimens. Paleogene admixture includes Coccolithus formosus, Reticulofenestra samodurovii and Toweius sp.The Cretaceous flora lacks older taxa from deeper samples, such as Calculites obscurus and Reinhardtites levis.

Remarks: A temperate, shallow-water coccolith assemblage from late Campanian at 490' to late Maestrichtian at 370' occurs in three sidewall samples from the Atco Well. Minor drilling admixture of Paleogene taxa in samples at 370' and 390' indicates that sediment as young as Eocene occurs higher in the drilled section. These coccolith results do not support the stratigraphy anticipated from regional relations, and J. Owens (written communication, 1989) considers these samples could be mislabeled or severely contaminated.

The 370' sample was expected to be the early Tertiary Vincetown Formation (Heliolithus kleinpellii Zone CP5) (J. Owens, written communication, 1989), but contains a late Maestrichtian assemblage with only a trace of Paleogene taxa (no Heliolithus kleinpellii). Coccoliths are abundant on the slide that was received.

Similarly, coccoliths are abundant in the sample 390' slide, where the trace Paleogene includes Paleocene Chiasmolithus bidens, Ellipsolithus macellus and Toweius craticulus along with Eocene Pemma sp., Transversopontis pulcheroides and Zygolithus dubius. The only way for this assemblage to reproduce the regionally predicted early Paleocene age (Ellipsolithus macellus

Zone CP3) would be by very massive local reworking of early Maestrictian beds during the Paleocene, with subsequent Eocene downhole drilling contamination.

Finally, the sample 490' slide is from a level predicted to be early Maestrichtian, based on _Belemnitella americana_ from nearby wells. The coccolith slide assemblage confirms this interval as Zone CC22 or Zone CC23 which are latest Campanian and early Maestrichtian.

The overwhelming predominance and abundance of Late Cretaceous coccoliths in the three slides from the Atco Well, with only trace amounts of Eocene and Paleocene taxa, make the extrapolated Paleocene assignments doubtful.

Ragovin Well (lat. 39°25'07"N, long. 74°52'25"W).

The Ragovin Well is located east of Millville, Cumberland County. One prepared slide and two side-wall core splits were received for coccolith age determinations. No core description was available, so the relative depths are uncertain. Coccoliths range in age from early Campanian to late Eocene.

Ragovin core 1524: Late Eocene Subzone CP15b.

The meager etched coccolith assemblage includes _Cribrocentrum reticulatum_ and _Isthmolithus recurvus_, indicating the correlation, and _Dictyococcites bisectus_, _Discoaster tanii_, and _Reticulofenestra umbilica_. Sparse Cretaceous _Micula decussata_ suggests minor reworking.

Ragovin core 1544: Mixed ages from early Campanian to late Eocene.

Although Cretaceous specimens are the most numerous, a diverse array of ages is represented in the well-preserved abundant coccolith assemblage. Late Cretaceous _Marthasterites furcatus_ indicates a source no younger than early

Campanian Zone CC18 (Bukry, 1969 and Perch-Nielsen, 1985; also see Clayton Well). *Arkhangelskiella cymbiformis* indicates the late Campanian or Maestrichtian. Various levels in the Paleocene are indicated by short-ranged *Ellipsolithus distichus*, *E. macellus*, *Fasciculithus involutus*, *Heliolithus kleinpellii*, and *Neochiastozygus distentus*. The lower Eocene is represented by *Discoaster lodoensis* and *Tribrachiatus orthostylus*, and the upper Eocene by *Chiasmolithus oamaruensis*, *Cribrocentrum reticulatum*, and *Isthmolithus recurvus*.

Ragovin N5635X1298 washed core: Late Campanian or early Maestrichtian?

This poorly prepared slide is mainly calcareous debris with sparse, fragmented and overgrown Cretaceous coccoliths. A few specimens of *Arkhangelskiella cymbiformis*, *Broinsonia parca*, *Reinhardtites levis*, and *Tranolithus phacelosus* suggest a late Campanian or early Maestrichtian age.

Remarks: The three Ragovin Well samples contain Campanian to Eocene coccoliths. Mixing and lack of information preclude analysis.

ACOW 1 (lat. 39°19'52"N, long. 74°25'89"W).

Atlantic City Offshore Well #1 is located about 1.7 miles south of Atlantic City. All five core samples from 424' to 658' were prepared and studied for silicoflagellate biostratigraphy. The sparse assemblages belong to the middle Miocene *Distephanus stauracanthus* Subzone of the *Corbisema triacantha* Zone, based on the occurrence of the nominal species in the upper and lower samples. This subzone represents the time interval from approximately 12.5 Ma to 14 Ma (Barron and others, 1985). According to Andrews (1988) this time interval should include the upper East Coast Diatom

Zone (ECDZ) 5 and all of ECDZ 6 and 7. As attested by Abbott (1978), the overlap of *Distephanus stauracanthus* and the diatom *Coscinodiscus lewisianus*, which occurs only in ACOW 1 at 658', marks a short interval in the early middle Miocene diatom Zones V and VI. Therefore, it is most likely that the whole studied interval belongs in the early middle Miocene.

Sample 658': Middle Miocene *Distephanus stauracanthus* Subzone.

The diverse 100-specimen assemblage is predominated by *Distephanus crux crux* (52%), but has diverse *Bachmannocena* spp. (9%) in addition to stratigraphic guide taxa *B. circulus apiculata* (1%), *Corbisema* sp. cf. *C. triacantha* (2%), *Distephanus stauracanthus* (3%), and *Dictyocha pulchella* var. *inflata* (2%). The presence of the diatom *Cosinodiscus lewisianus* was also recorded and suggests that this sample correlates with the base of ECDZ 6 or older intervals (Andrews, 1988). Terrigenous biosilica contribution is indicated by panicoid opal phytoliths from grassland areas.

Sample 656': Middle Miocene *Distephanus stauracanthus* Subzone.

The sparse 50-specimen assemblage contains *Distephanus stauracanthus* (6%) and is predominated by quadrate taxa *D. crux crux* (44%), *D. crux parvus* (16%) and *D. crux scutulatus* (18%).

Sample 577': Middle Miocene *Corbisema triacantha* Zone.

The 100-specimen assemblage is preponderated by *Distephanus crux crux* (67%) and *D. crux scutulatus* (13%). Minor components include *Bachmannocena apiculata curvata* (2%) and *Corbisema triacantha* (1%). Subzonal guide taxa *B. circulus apiculata* and *D. stauracanthus* were not found.

Sample 510': Middle Miocene.

A 50-specimen assemblage includes Caryocha depressa (4%) and Dictyocha pulchella var. inflata (2%) and is preponderated by Distephanus crux crux (67%). D. pulchella var. inflata has also been reported from North Atlantic DSDP Site 555 in the D. stauracanthus Subzone (Bukry, [1984] 1985).

Sample 424': Middle Miocene Distephanus stauracanthus Subzone.

The 50-specimen assemblage is predominated by Distephanus crux crux (80%) and includes D. stauracanthus (2%) and Corbisema triacantha (2%).

Remarks: According to the biostratigraphy available on the gamma-ray log provided by J. Owens (written communication, 1989) for ACOW 1, Sample 424' is in ECDZ 6 (12.8 to 13.8 Ma) and all the other samples are in ECDZ 2 (15.7 to 17.4 Ma). In paleomagnetically dated samples from the Pacific (Barron and others, 1985), the D. stauracanthus Subzone ranges from 12.5 to 14 Ma. Therefore, ACOW 1 reveals a discrepancy in diatom/silicoflagellate correlation. The silicoflagellate assemblages are similar throughout with no missing biostratigraphic interval. If D. stauracanthus first occurs in coccolith Subzone CN5a at about 14 Ma (Barron and others, 1985), then it is unlikely to be associated with diatoms older than 15.7 Ma, because this would be equivalent to lower Zone CN4 or upper Zone CN3 (Bukry, 1981).

The younger age for the ACOW 1 interval in and above Sample 658', as indicated by D. stauracanthus has been subsequently confirmed by John Barron (USGS, Menlo Park Office) who examined the silicoflagellate preparation and identified the additional key diatoms Crucidenticula nicobarica and Denticulopsis hustedtii. The overlap of C. lewisianus and D. hustedtii indicates the Coscinodiscus lewisianus Zone of Barron (1985) and an age interval of 12.8 to 13.65 Ma in the middle Miocene (J.A. Barron, verbal communication, 1989).

ACOW 2 (lat. 39°17'26"N, long. 74°22'21"W).

Atlantic City Offshore Well 2 is located about 5.3 miles south of Atlantic City. Of six samples available from ACOW 2 only two have sufficient silicoflagellates to warrant preparation and study. Quadrate Distephanus species predominate as at ACOW 1. Many of the same lower to middle Miocene species are present, but zonal guide taxa Corbisema triacantha and Distephanus stauracanthus are missing. A slightly older interval than ACOW 1 is suggested by an ellipticoid variant of Distephanus crux in ACOW 2, 794'. A similar variant was illustrated from DSDP Hole 391A, Core 13 in the late early Miocene Zone CN3 at lat. 28°13.67'N, long. 75°36.88'W (Bukry, 1978). The similarity in the two ACOW 2 assemblages and the absence of guide taxa Naviculopsis and Distephanus stauracanthus, combined with the ellipticoid D. crux occurrence suggests the early part of the 14 to 17.5 Ma interval, probably the Zone CN3 equivalent. The absence of Corbisema and the sparseness of Bachmannoccena is probably ecologically controlled.

Sample 794': Early? Miocene.

The 100-specimen assemblage is predominated by Distephanus crux (60%), D. crux scutulatus (7%) and D. crux (ellipticoid) (12%) which appears to be a form of D. crux in transition to Bachmannocena elliptica by elimination of the apical struts and separation of the apical ring elements (See Bukry, 1978, pl. 3). No specimens of Bachmannocena or Naviculopsis were found. Distephanus (97%) overwhelms Dictyocha (3%) in the assemblage.

Sample 658': Early? Miocene.

The 100-specimen assemblage is dominated by Distephanus (98%). D. crux

crux (84%) overwhelms *Dictyocha brevispina* (1%) and *Bachmannocena apiculata curvata* (1%).

Remarks: The biostratigraphy on the annotated gamma-ray log for ACOW 2 shows Sample 658' assigned to middle Miocene ECDZ 6 and Sample 794' to early Miocene ECDZ 2, with no intervening ECDZ 3 to 5. Silicoflagellates tend to support the early Miocene assignment for Sample 794', but owing to the low diversity and similarity in species between Samples 658' and 794' the assignment of 658' to middle Miocene is not supported. Even the poorest assemblage of ACOW 1, in Sample 424' which was assigned to middle Miocene ECDZ 6, has both subzonal guide taxa present (*Corbisema triacantha* and *Distephanus stauracanthus*). There are more older silicoflagellate species in both ACOW 2 samples than in the upper two samples at ACOW 1 (424' and 510' which represent ECDZ 6). For example, *Distephanus speculum hemisphaericus* and *D. stradneri* are more typical of early Miocene assemblages. There is no silicoflagellate evidence to indicate that ACOW 2, 658' is significantly younger than ACOW 2, 794'. But there is silicoflagellate evidence from nearby ACOW 1 to suggest the ACOW 2 samples are not assignable to the silicoflagellate *D. stauracanthus* Subzone or the time interval of ECDZ 6. The ACOW 2 samples both appear to be older than all of the ACOW 1 samples studied.

Clayton Well (lat. 39°32'15"N, long. 75°06'10"W).

Remarks: Early Campanian, middle Eocene and early Miocene coccoliths occur in 37 of the 49 core samples studied from the Clayton Well, Gloucester County. According to annotated gamma-ray log summary section, the middle Eocene strata (188' to 190') belong to the Shark River Formation and the early

Miocene strata (157.1' to 171.8') belong to the Kirkwood Formation. The Campanian strata (610.5 to 701') were not assigned to a formation. Coccoliths are common to abundant in the Campanian, common in the Eocene, and sparse to common in the Miocene strata.

The Campanian coccolith assemblages are zoned using the Sissingh (1978) terminology and the range-chart synthesis of Perch-Nielsen (1985). Older Zone CC18 and younger Zone CC19 are clearly distinguished between 645.5' and 649.5' by the last occurrence of zonal marker Marthasterites furcatus. This level (646') was also designated as the Santonian to Campanian boundary by ostracode biostratigraphy (J. Owens, written communication, 1989). But the presence of Broinsonia parca parca and B. sp. cf. B. parca constricta (four-pored) with M. furcatus in Zone CC18b (649.5' to 668') indicates the early Campanian (see Bukry, 1969, Bukry and Bramlette, 1970, Manivit, 1971, Sissingh, 1978, Hattner, Wind and Wise, 1980 and Perch-Nielsen, 1985).

In the Cenozoic part of the core, regional geology from other wells indicates that samples from 150' to 181' are equivalent to ECDZ 1 and equivalent to beds assigned to foraminiferal Zone N5 in ACOW 1 by R.Z. Poore (J. Owens, written communication, 1989). Coccolith samples from 157' to 171.8' in the Clayton core, itself, provide direct evidence and are assigned to early Miocene Zone CN3 based on the occurrence of secondary markers Discoaster variabilis and Helicosphaera scissura, with primary marker H. ampliaperta occurring in Sample 168.8'. Therefore, coccoliths indicate an interval only slightly younger, 16 to 17.5 Ma (Barron and others, 1985), than the ACOW 1 foraminiferal Zone N5 at 18.1 to 20 Ma (Barron and others, 1985). Although there are no diatoms in the Clayton Well samples, the regional ECDZ 1, estimated at 18.9 to 19.1 Ma (Andrews, 1988), would be older. Within the present state of interregional chronologies the microfossil evidence does concur with the late early Miocene age for the 157.1' to 171.8' interval of the Clayton Well.

Mesozoic Coccoliths:

The Cretaceous coccolith assemblages of the Clayton Well are divided between Zone CC18 ending at 649.5' and Zone CC19 beginning at 645.5' by the last occurrence of *Marthasterites furcatus*. Additionally, the first occurrence of *Broinsonia* sp. cf. *B. parca constricta* (four-pored) at 668' suggests the presence of subzonal boundary CC18a/CC18b in this section. The identification of the basal unit (CC18a) is most questionable because there is considerable drilling admixture of Eocene taxa there. Representative samples of each biostratigraphic unit are described below.

Mixed Early Campanian CC18a? and Eocene (673' to 701'):

The coccolith assemblage of sample 676' contains Cretaceous taxa *Broinsonia parca parca*, *Calculites obscurus*, *Cribrosphaera ehrenbergii*, *Eiffellithus turriseiffeli*, *Gartnerago costatum*, *Micula decussata*, and *Watznaueria barnesae*, but no *B.* sp. cf. *B. parca constricta* (four-pore morphology). Cooccurring long-ranged Eocene coccoliths include *Chiasmolithus solitus*, *Coccolithus pelagicus*, *Pontosphaera distincta*, *Transversopontis pulcher*, and *Zygrhablithus bijugatus*.

Early Campanian Subzone C18b (649.5 to 668'): The coccolith assemblage of representative Sample 651.0' contains only Cretaceous taxa including: *Broinsonia parca parca*, *B.* sp. cf. *B. parca constricta* (four-pored), *Calculites obscurus*, *C. ovalis*, *Chiastozygus* spp., *Cretarhabdus crenulatus*, *Eiffellithus eximius*, *E. turriseiffeli*, *Gartnerago costatum*, *Kamptnerius magnificus*, Lucianorhabdus cayeuxii, Marthasterites furcatus, Micula decussata, Watznaueria barnesae, Zygodiscus spiralis, and Z. spp.

Early Campanian Subzone CC19a (610.5' to 645.5'): The coccolith assemblage of sample 619.8' contains only Cretaceous taxa which include: Biscutum spp., Broinsonia parca parca, B. sp. cf. B. parca constricta, Calculites obscurus, Eiffellithus eximius, E. turriseiffeli, Gartnerago costatum, Kamptnerius magnificus, Microrhabdulus decoratus, Micula decussata, Prediscosphaera cretacea, Reinhardtites anthophorus, Watznaueria barnesae, and W. biporta.

The highest Campanian coccolith assemblage available in Sample 610.5' is composed of Cretaceous taxa similar to 619.8'. Taxa present include Broinsonia parca parca, Calculites obscurus, Chiastozygus amphipons, Coronocyclus sp., Eiffellithus eximius, E. turriseiffeli, Gartnerago costatum, Kamptnerius magnificus, Lithastrinus grillii, Lucianorhabdus cayeuxii, Micula decussata, Prediscosphaera cretacea, Reinhardtites anthophorus, Vagalapilla octoradiata, Watznaueria barnesae, Zygodiscus bicrescenticus, and Z. theta.

Cenozoic Coccoliths: The middle Eocene coccolith Subzone CP13c occurs in three samples from 188.0' to 190.25'. Biostratigraphically the level of these samples is very near the Subzone CP14a boundary because Discoaster sp. cf. D. bifax occurs sparsely in each sample. Other guides to CP14a, such as Cyclicargolithus floridanus, Dictyococcites bisectus or Reticulofenestra umbilica are missing. This suggests an age from 43 to 44 Ma using the Berggren and others (1985) correlation for the Paleogene. Also, this assemblage is very similar to one from a shallow marine inlier at the San Diego Natural History Museum Aviara section in north San Diego County that is associated with Uintan vertebrate fossils (T. Demere and D. Bukry, unpublished data. 1989). Coccoliths present in representative Clayton Sample 189.0-189.25' include *Braarudosphaera bigelowii*, *Cepekiella lumina*, *Chiasmolithus expansus*, *C. grandis*, *C. solitus*, *Discoaster barbadiensis*, *D.* sp. cf. *D. bifax*, *D. deflandrei*, *Helicosphaera bramlettei*, *Lithostromation* sp., *Micrantholithus crenulatus*, *Nannotetrina* sp., *Reticulofenestra samodurovii*, *Transversopontis pulcheroides*, *Zygolithus dubius*, and *Zygrhablithus bijugatus*.

A sandy interval occurs above the Subzone CP13c samples. The first significant coccolith assemblage above the sandy interval, from Sample 175.8-175.9' to Sample 186.0-186.25', is an early Miocene assemblage in Sample 170.8-171.05'. Only a trace of Miocene coccoliths occurs in Samples 181.0-181.25' and 171.8-172.05'. Although coccoliths are common, they are most fragmented in the Sample 170.8-171.05' which also contains carbonate rhombs and pyritized diatom fragments. A Miocene age is indicated by the presence of *Helicosphaera carteri* with *Coccolithus miopelagicus*. The late early Miocene is indicated by the presence of *Discoaster variabilis*. The remainder of this assemblage includes *Braarudosphaera bigelowii*, *Coccolithus pelagicus*, *Cyclicargolithus floridanus*, *Discoaster deflandrei*, *Pontosphaera* sp. and *Reticulofenestra* sp.

Coccoliths are abundant and moderately etched in Sample 168.8-169.05', which is the most biostratigraphically diagnostic. This sample is assigned to late early Miocene Zone CN3 based on the occurrences of *Discoaster variabilis*, *Helicosphaera ampliaperta* s.str., and *H. scissura*. Other samples in the interval are assigned to CN3 on the basis of *D. variabilis* and *H. scissura* in a virtually identical assemblage. The assemblage is also characterized by the common occurrence of _Coccolithus pelagicus_ and the absence of genus _Sphenolithus_.

A short upper interval (146 to 155') contains only trace assemblages, mainly composed of very sparse specimens of _Coccolithus pelagicus_ and _Cyclicargolithus floridanus_ which could be a residue of the underlying Zone CN3 material, or possibly a poorly preserved middle Miocene assemblage. The extinction of _C. floridanus_ in the lower middle Miocene provides an upper limit on the age of the highest coccolith-bearing Sample (146-146.25').

APPENDIX

List of Taxa Considered.

Mesozoic Coccoliths

Arkhangelskiella cymbiformis Vekshina

Braarudosphaera bigelowii (Gran and Braarud)

Broinsonia parca constricta Hattner et al.

B. parca parca (Stradner)

Calculites obscurus (Deflandre)

C. ovalis (Stradner)

Ceratolithoides aculeus (Stradner)

Chiastozygus amphipons (Bramlette and Martini)

Cretarhabdus crenulatus (Bramlette and Martini)

Cribrosphaera ehrenbergii Arkhangelsky

Eiffellithus eximius (Stover)

E. turriseiffeli (Deflandre)

Gartnerago costatum costatum (Gartner)

Kamptnerius magnificus Deflandre

Lithastrinus grillii Stradner

Lithraphidites carniolensis Deflandre

L. quadratus Bramlette and Martini

Lucianorhabdus cayeuxii Deflandre

Marthasterites furcatus Deflandre

Microrhabdulus decoratus Deflandre

Micula decussata Vekshina

Nephrolithus frequens Gorka

Prediscosphaera cretacea (Arkhangelsky)

Quadrum sissingh Perch-Nielsen

Q. trifidum (Stradner)

Reinhardtites anthophorus (Deflandre)

R. levis Prins and Sissingh

Tranolithus phacelosus Stover

Vagalapilla octoradiata (Gorka)

Watznaueria barnesae (Black)

W. biporta Bukry

Zygodiscus bicrescenticus

Z. spiralis Bramlette and Martini

Z. theta (Black)

Cenozoic Coccoliths

Braarudosphaera bigelowii (Gran and Braarud)

Chiasmolithus bidens (Bramlette and Sullivan)

C. expansus (Bramlette and Sullivan)

C. grandis (Bramlette and Reidel)

C. solitus (Bramlette and Sullivan)

Coccolithus formosus (Kamptner)

C. miopelagicus Bukry

C. pelagicus (Wallich)

Cribrocentrum reticulatum (Gartner and Smith)

Cyclicargolithus floridanus (Roth and Hay)

Dictyococcites bisectus (Hay, Mohler, and Wade)

Discoaster bifax Bukry

D. deflandrei Bramlette and Riedel

D. tanii Bramlette and Riedel

D. variabilis Martini and Bramlette

Ellipsolithus macellus (Bramlette and Sullivan)

Helicosphaera amliaperta Bramlette and Wilcoxon

H. carteri (Wallich)

H. scissura Miller

Heliolithus kleinpellii Sullivan

Isthmolithus recurvus Deflandre

Micrantholithus crenulatus Bramlette and Sullivan

Pontosphaera distincta (Bramlette and Sullivan)

Reticulofenestra samodurovii (Hay, Mohler, and Wade)

R. umbilica (Levin)

Toweius craticulus (Hay amd Mohler)

Transversopontis pulcher (Deflandre)

T. pulcheroides (Sullivan)

Zygolithus dubius Deflandre

Zygrhablithus bijugatus Deflandre

Cenozoic Diatoms

Coscinodiscus lewisianus Greville

Crucidenticula nicobarica (Grunow)

Denticulopsis hustedtii (Simonsen and Kanaya)

Cenozoic Silicoflagellates

Bachmannocena apiculata curvata (Bukry)

B. circulus var. *apiculata* (Lemmermann)

Caryocha depressa (Ehrenberg)

Corbisema triacantha (Ehrenberg)

Dictyocha pulchella var. *inflata* Bukry

Distephanus crux crux (Ehrenberg)

D. crux parvus (Bachmann) Bukry emend.

D. crux scutulatus Bukry

D. stauracanthus (Ehrenberg)

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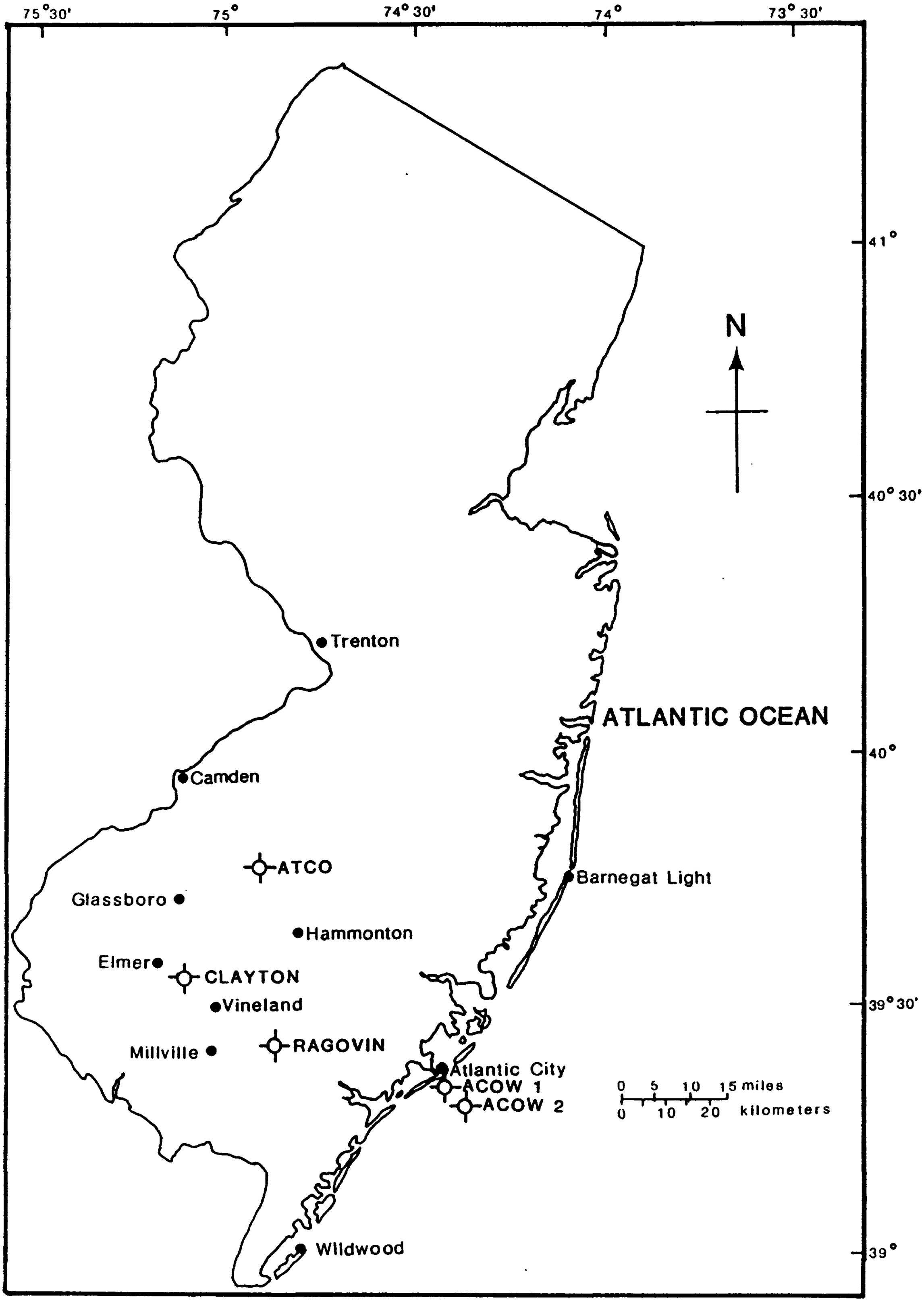

Figure 1. Location of New Jersey well sites.