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Biostratigraphy and Biochronology

Chaired by José F. Longoria and Martha A. Gamper

So far, regardless of the new criteria use to do chronology, biostratigraphy and biochronology remain the only truly independent, undoubted criteria to correlate and to establish temporal relationships of sedimentary successions. This session aims at bringing together a variety of studies on local, regional and global biochronological schemes, covering a wide spectrum of the geological column which will allow us to analyze problems and strategies in common in the process of biochronological determinations and biocorrelations, from a wide geographic range. Problems related to biozone definition and delination of FADs (First Appearance Datum) and LADs (Last Appearance Datum), and to biozonations based on both planktic and benthic foraminfera will be considered. The potential of biochronology in resolving geologic problems will be stressed. Contributions include, but are not limited to:

(1) Integration of Shallow-water to Deep water environments.

(2) Integration of benthic and planktic communities.

(3) Integration of foraminiferal distribution to ammonites.

(4) Integration based on multiple criteria (more than two fossil groups).

(5) Integration of foraminiferal biozonations to nannoplakton zones.

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Calibrating the Neogene of the Nordic Atlantic region

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Norway has one of the longest coastal margins in the world. Bathymetrically, the Norwegian offshore follows a number of sub-basins from the shallower epeiric North Sea through the Central and Viking grabens into the deeper Norwegian Sea, its adjoining continental shelf, and farther northwards to the Barents Sea. While the pre-Neogene stratigraphies of the Norwegian continental margin are relatively well understood due to petroleum exploration, Nordic Neogene biostratigraphies are still poorly constrained.

In the boreal Nordic region the Neogene biostratigraphy is based primarily upon foraminifers and dinoflagellate cysts. Despite more than 60 years of study the relationship between the Neogene North Sea and Norwegian Sea biostratigraphies to that of the Mediterranean and the global stage definitions is still poorly understood. At these subpolar latitudes many of the standard ‘global' marker species (planktic foraminifera), present in the Mediterranean and low to mid latitudes, are absent. Neogene foraminiferal zonations for the Nordic high-latitudes therefore have a large benthic component, notably the deterministic zonation of King (1989). However, these benthic zones often show facies-dependency and diachroneity between sub-basins. This problem is confounded by the fact that North Sea foraminiferal zonations have been primarily based upon contamination-prone cuttings samples. Part of the solution to improving this stratigraphy was hence a quantitative statistical approach using ranking and scaling methods, notably the zonation of Gradstein & Bäckström (1996). Both these deterministic and probabilistic approaches have had their main age calibrations based upon the paleomagnetic age interpretations of Ocean Drilling Program (ODP) Leg 104 and Deep Sea Drilling Project (DSDP) Leg 94.

A comparison of existing foraminiferal and dinoflagellate zonations reveals a more stable dinoflagellate stratigraphy in the Nordic high-latitudes. These high-fidelity dinoflagellate events have been calibrated to the magnetostratigraphies of ODP Leg 151 Sites in the Norwegian-Greenland Sea (Smelror et al., in press). The foraminiferal zonations show a degree of diachroneity, with only a few bioevents isochronous across sub-basins (e.g. LO *N. atlantica* (sinistral), LO *G. praescitula-zealandica*). Of the total 16 identified planktic foraminiferal events, only half have been calibrated to paleomagnetics. The resolution of the present foraminiferal zonations is 1-2 million years for the Pliocene, and 2-4 million years for the Miocene. If the planktic foraminiferal zonation is supplemented by *Bolboforma* (incertae sedis) events, of which 9 of 12 have been calibrated, temporal resolution is improved to around 1 million years for the Late Miocene to Early Pliocene.

In an effort to refine and improve these age calibrations this study has involved an updating of ODP and DSDP interpretations in the light of the astronomically-tuned magnetostraphic Neogene time scale of Lourens *et al.* (2004). In addition, detailed biostratigraphies were constructed for three offshore exploration wells and one onshore borehole along a north-south transect from the vicinity of ODP Leg 104, to the marginal North Sea (onshore Denmark). One of the results of this study has been an improved biofacies characterization of Neogene sand units in the North and Norwegian Seas. Ongoing work and data points will result in a better understanding of the fidelity of each bioevent, allowing for a choice of the most robust markers and a better integration with dinoflagellate zonations. Results will be compared to “degree of crossover” results from the quantitative methods of RASC and CONOP. Key events will then be chosen for radiometric strontium ($^{87}Sr/^{86}Sr$) isotope dating.

Due to the rapid and simple preparation methods for Neogene foraminiferal micropaleontology, an improved calibration will prove a valuable tool in the Neogene stratigraphy of the Nordic region.

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Late Cretaceous–Tertiary larger foraminifera in carbonate paleoenvironments of Costa Rica

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Larger Foraminifera from the principal carbonate rocks of Costa Rica were studied in several hundred oriented thin sections and oriented sections of isolated specimens that were studied by cathodoluminescence, transmitted light microscopy and SEM for isolated and washed material. X-ray microtomography (see abstract of C. Baumgartner *et al.* This volume) was also used to produce 3D-imaging of some forms. ^{87}Sr / ^{86}Sr ratios were measured for age calibration in Campanian-Maastrichtian, Paleocene, Eocene and Oligocene samples.

Southern Central America is formed by a collage of oceanic and arc-derived terranes that were accreted to what is now the trailing edge of the Caribbean Plate. In this context, carbonate paleoenvironments were short-lived and formed either on (now accreted) volcanic edifices (seamounts and island arcs) or on blocks uplifted into the photic zone by collisional tectonics.

The oldest larger Foraminifera are found in a late Campanian–Maastrichtian carbonate system (El Viejo – Peña Bruja – Cerro Cebollín) resting unconformably on the Nicoya Complex of N-Costa Rica. It includes rudistid biostromes flanked by carbonate banks and slope deposits with the presence of *Pseudorbitoides rutteni*, *Pseudorbitoides israelski*, *Sulcoperculina* sp. and *Sulcoperculina globosa*, small rotaliids and few porcellanaceous forms.

No carbonates are known so far from the early Palaeocene. Larger Foraminifera were found in marginal facies of the originally > 900 km^2 Barra Honda carbonate platform (Tempisque Basin), now dated as late Paleocene (Thanetian) by planktonic foraminifera and ^{87}Sr / ^{86}Sr ratios. Thanetian insular carbonate shoals (atolls?) are documented by resediments in Quepos (Playa Macha , Playa Espadilla and Quebrada Camaronera) and Burica Peninsula (Playa Mangle and Quebrada Piedra Azul, Rio Palo Blanco, Panama), interpreted as accreted seamonts/plateaus. In all areas we note the presence of *Ranikothalia* with its three forms *catenula*, *soldadensis*, *tobleri* and *R. antillea* associated with *Discocyclina barkeri* and *Amphistegina* sp.

Eocene (chiefly middle to late) shallow carbonate deposits are most widespread and occur:

1) rarely as small "in situ" carbonate banks of < 50 m thickness with a limited extension (Mal Pais, S-Nicoya Peninsula; Damas, Quepos; Las Animas, Turrialba)
2) as larger carbonate ramps of up to 300 m thickness and regional extension (Fila de Cal- El Cajon; Fila Dragon).
3) redeposited in turbidtes or channel –fills in slope series (Cabo Blanco - Ario, S-Nicoya; Punta Serrucho, Quepos).
4) redeposited as clasts and deformed debris flows in the Osa-Caño Accretionary Complex.

Eocene larger foraminifera facies are characterized by many species of *Amphistegina, Asterocyclina, Discocyclina, Euconoloides, Eofabiania, Fabiania, Gypsina, Helicolepidina, Heterostegina, Homotrema, Lepidocyclina, Linderina, Neodiscocyclina, Nummulites, Operculinoides, Orthophragmina, Polylepidina, Proporocyclina* and *Sphareogypsina*.

Upper Oligocene carbonate banks occur at Punta Peladas and Punta Nosara (Nicoya Peninsula) and in Rio Zapote (Agua Buena, Fila de Cal). At Punta Peladas high angle cross-bedding indicates a high energy shore-face to off-shore environment, dated as Chattian by ^{87}Sr / ^{86}Sr ratios. Larger foraminifera include: *Heterostegina antillea, H. israelkyi, Miogypsina tani, M. gunteri, M.* cf. (*Miolepidocyclina*) *panamensis, Miogypsina* sp., *Lepidocyclina (Nephrolepidina*) *vaughani, L. yurnagurensis* , *L. undosa*, and *Nummulites* spp.

Lower-middle Miocene carbonates occur, among others, as discontinous lenses and displaced blocks in the area of Herradura (Rio Tarcolitos, Ganado, Rio Caña Blancal) with *Miogypsina*, *Miolepidocyclina* and *Amphistegina*.

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Orthophragminids and associated fossils in paleogeographic interpretation of transitional beds (Croatia)

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One of the most prominent structures in Perimediterranean geologic evolution is the Adriatic Dinaridic carbonate platform (AdCP). The end of the development of this long lasting entity (early Jurassic to Eocene) is defined by sedimentation of the so-called Transitional beds. This unit represents the transition from a shallow-marine environment to a basin setting where turbiditic events produced an impressive sedimentological succession in terms of thickness and textures.

The evolution of the Transitional beds shows the complexity of “drowning” of a platform regime from a sedimentological and paleontological point of view. Two phases are recorded: the first phase is known as sedimentation of the “Marls with crabs” and the second phase produced “*Globigerina* marls”. The unit named “Marls with crabs” is characterized by co-occurrences of larger benthic (orthophragminids and “operculinids”) and planktonic foraminifera with decapod crustaceans (*Harpactocarcinus* sp., Schweitzer *et al.*, 2005. *Journal of Paleontology*, 79: 663-669). This phase, in fact, starts when in shallow marine sediments orthophragminid tests outnumber numulitids *s.str.* within foraminiferal limestones unit (Cosovic *et al.*, 2004. *Facies*, 50: 61-75), and is characterized by diachronic beginning. We compared the orthophragminid and planktonic fauna from crustacean-bearing sediments from two groups of sections: one located in the northwestern part of the AdCP (Istrian sections: Floricici, Pican-Zajci, Roc and Buzet, of Lutetian age, Biozone P11 to P12, *sensu* Berggren *et al.*, 1995. *Society of Economic Paleontologists and Mineralogists, Special Publication* 54: 129-212), and the other from the central part (Podstina section, Bartonian age, Biozone P 14), in order to see the species composition, test morphologies and paleoenvironmental needs. The similar morphology (thin, flattened tests), and "Odd couples" (Hottinger, 1999. *Eclogae geologicae Helvetiae*, 92 (3):385-393) indicate conditions that allowed orthophragminids to live at their limit. The identified species groups are *Discocyclina sella*, *D. augustae*, *D. trabayensis*, *D. discus*, *D. radians* and *Orbitoclypeus varians* from the Istrian sections and *D. radians*, *D. sella*, *O. varians* and *Asterocyclina stellata* from the Podstina section. The middle to late Lutetian planktonic assemblages are dominated by shallow dwelling, oligotrophic species such as *Acarinina bullbrooki*, *A. spinuloinflata*, *Morozovella lehneri*, *Turborotalia pomeroli*, *T. frontosa*, *Truncorotaloides. rohri*, *Globigerinatheka barri*, while *T. pomeroli*, *G. index*, *G. barri*, *Globigerina praebulloides*, occurred in Bartonian sediments. The thermocline dwelling subbotinids (*S. linaperta*, *S. yeguanensis vs. S. eocaena*) are less common in sediments from both regions. Such stable, oligotrophic, subtropical conditions suggest a position for the AdCP within a "greenhouse desert belt".

The age differences and distance between studied sections, suggest that the "drowning "of the platform was a continuous process over a huge area. When the process had started, it progressed to the southeast following the same pattern: fine-grained sediments with "operculinids" and orthophragminids and shallow-dwelling planktonic foraminifera and crustaceans were deposited first, followed by "*Globigerina* Marls".

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Foraminiferal resolution of conflicting interpretations for late Tertiary deposits along the coast of central Chile

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A consensus on the biostratigraphic age and depositional environment of the Navidad, Ranquil, and Lacui Formations exposed along the tectonic margin of central Chile has been elusive due to conflicting evidence. This study was undertaken to resolve this dilemma and to gain further insight regarding the history of the Chilean coast. Problematic interpretations primarily stem from the remarkable similarity between the molluscan fauna of these units with that well-documented for the late Oligocene-early Miocene of Peru.

However, planktic foraminifers indicate the Chilean sections accumulated in the late Miocene-early Pliocene interval following a regional hiatus that extends into the Eocene. The prevalence of mixed-depth bathyal assemblages of benthic foraminifers, most of which include lower bathyal (> 2000 m) indicators, reveals that downslope displacement was a primary mode of deposition in the basins. Although the molluscan and ostracodal assemblages are dominated by shallow marine taxa, most include species that range into or are restricted to deeper waters. Sedimentary features connote rapid subsidence and deep-water deposition of gravity flows. Although older Tertiary and Cretaceous planktic foraminifers in several assemblages indicate reworking of older units, lack of data on pre-Tortonian faunas of this region precludes recognition of other age-discordant components that could constitute a significant portion of the recovered fauna. The findings of this study revise the prevailing conception of the region's geologic history that considered these units to be early Miocene shelfal deposits, and indicate that infilling and uplift have characterized the nearshore basins since the late Pliocene.

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Cenozoic biochronostratigraphy in southeastern Mexico: Planktonic foraminifera from the Sonda the Campeche

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Based on detailed subsurface biostratigraphic studies, Cenozoic planktonic foraminifera bioevents were identified at the Sonda de Campeche, Southeastern Mexico, giving evidence of Paleogene and Neogene chronostratigraphic boundaries. Planktonic foraminifera biochronostratigraphic analysis permitted to zone the Tertiary column, where 6 chronostratigraphic bioevents are identified: LAD´S of *Globorotalia (Menardella) miocenica*, +/- 2.3 Ma; *Globoturborotalita nepenthes*, +/- 4.18 Ma; *Paragloborotalia mayeri*, +/- 11.4 Ma; *Catapsydrax dissimilis*, +/- 17.3 Ma, and *Morozovella velascoensis*, +/- 54.7 Ma, as well as the *Globoturborotalita nepenthes* FAD, +/- 11.8 Ma. Based on the cyclostratigraphic, paleobathymetric, and biostatistic studies, stratigraphic surfaces and subsurface facies evolution tracts were recognized (unconformities, paraconformities, condensed sections, etc.), important in target oil exploration. Two regionally correlated transgressive events are identified in the area: one at the upper Paleocene (*Luterbacheria pseudomenardii* Zone, P4 ±54.7 Ma), and the other at middle Pliocene (*Globorotalia (Menardella) miocenica* Zone, N21 ±2.3 Ma).

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Foraminiferal biostratigraphy of the Turonian-early Campanian depositional subcycle from selected oil wells in Iraq

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The stratigraphy of the Turonian-early Campanian depositional subcycle in Iraq has been investigated. The data and samples were taken from the records of ten oil wells located in the northern, middle and southern parts of Iraq, they are: Kirkuk 117, Jambour 13, Sammarra 2 , Balad 2 , East Baghdad 2, Dhifriyah 2 , Nasriyah 4, West Kifl 1, Zubair 3 and Tuba 1.

The studied depositional subcycle is represented by the Kometan and the Gulneri formations in the northern part of Iraq, and by the Khasib, Tanuma and Sa'adi formations in the middle and southern parts. However, these formations are not detected in the western part of Iraq indicating that it was a positive area during the deposition of the subcycle.

A total of 445 samples were obtained from the studied subsurface sections. They were investigated together with 832 thin sections with regard to their foraminiferal contents.

The deposits of the studied subcycle are characterized by varying predominance of the planktonic and benthonic foraminifera. Depending upon assemblages of the planktonic foraminifera, the successions of the studied formations were divided into six biozones extending from the late Turonian to the early Campanian. They are: *Marginotruncana sigali* Partial range Zone, *Dicarinella primitive* Partial range Zone, *Dicarinella concavata* Partial range Zone, *Contusotruncana fornicata* Assemblage Zone, *Globotruncanita elevata* Partial range Zone, and *Globotruncana stuartiformis* Partial range Zone.

Three benthonic foraminiferal assemblage Zones were distinguished within the Sa'adi, Tanuma and Khasib formations in the well West Kifl 1, representing a late Turonian – early Campanian age interval: *Gavelinella belorussica*, *Gavelinella thalmani* and *Gavelinella clementiana* Assemblage Zones. The recognized foraminiferal zones suggest the following stages for the studied formations:

- Gulneri Formation: upper Turonian;
- Kometan Formation: upper Turonian – lower Campanian;
- Sa'adi Formation: upper Coniacian – lower Campanian;
- Tanuma Formation: upper Turonian – lower Coniacian;
- Khasib Formation: upper Turonian – lower Coniacian.

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Biostratigraphy and diversity of mid-Cretaceous benthic foraminifers of Adriatic Platform, South Croatia

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The Late Mesozoic Barremian to Cenomanian southern interior part of the Adriatic platform, Croatia, is characterized by exclusively shallow water carbonate facies that were deposited in shallow water, peritidal environments. The succession is characterized by a relatively rich association of shallow marine benthic organisms, primarily foraminifers and dasyclad algae. The analysis of the entire microfossil association has provided a detailed biostratigraphic zonation based on the stratigraphic distribution of either benthic foraminifera or calcareous algae. Both the fossil and the sedimentary record point to several episodes of change in relative sea level, paleoenvironments, and distribution of paleocommunities dominated by benthic foraminifers and dasyclad algae. The Barremian to Cenomanian benthic foraminiferal assemblages, including a total of 106 species and 57 genera, were analyzed to establish the principal diversity patterns at (sub)stage level of resolution. The diversity patterns of benthic foraminifers in the study area appear related to regional changes in relative sea level, coupled with related changes in habitats.

The observed diversity pattern of benthic foraminifers shows that after a relatively high diversification in the Barremian, the early Aptian marked the foraminiferal diversity maximum. Foraminifers diversified into a suite of euphotic habitats backed by a relative sea-level rise that coincided with oceanic anoxic event (OAE-1A). The regional regression in the late Aptian resulted in loss of “deeper” subtidal habitats and, consequently, foraminiferal diversity dropped. Transgression in the early Albian and probable associated decrease in platform waters fertility, resulted in the gradual increase of diversity throughout the Albian. Regional onset of regression in the latest Albian, again could have increased nutrient supplies to surface waters, and consequently, the subsequent early Cenomanian foraminiferal association reached its mid-Cretaceous diversity minimum. The middle Cenomanian relative sea-level rise led to a gradual recolonization of the platform interior and the renewal of the benthic foraminiferal association.

The present study, calibrated against the standard regional biostratigraphic zonation for the Eastern Adriatic mid-Cretaceous (Barremian to Cenomanian), documents that several species of benthic foraminifers have exceptional age-diagnostic value for the Barremian to Cenomanian biostratigraphy, the most important being orbitolinids (*Campanellula capuensis*, *Palorbitolina lenticularis*, *Praeorbitolina cormyi*, *Orbitolina* (*M.*) *lotzei*, *O.* (*M.*) *parva*, *O.* (*M.*) *texana*, "*Valdanchella*" *dercourti*, *Neoiraqia insolita*, *N. convexa*), and alveolinids (*Archaealveolina reicheli*, *Ovalveolina crassa*, *O. maccagnoae*, *Sellialveolina viallii*, *Cisalveolina fraasi*), as well as ataxophragmiids (*Voloshinoides murgensis*) and chrysalinids (*Protochrysalidina elongata*, *Chrysalidina gradata*). These are generally abundant, have a widespread distribution and a restricted stratigraphic range. They evolved rapidly and became extinct suddenly.

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Biostratigraphical and micropaleontological studies on the cutting samples of Karbassi well # 1, Fars Province, southwestern Iran

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The Karbassi well # 1 is located in the southwestern Iran. This well was drilled by EGOCO in 1975. A total of 1557 thin-sections were prepared and studied from the cutting samples of the drilled sequence of this well in order to determine the age relationships of the drilled rock units. The rock units of this well are in ascending order the Asmari, Jahrum, Pabdeh, Gurpi, Ilam, Sarvak, Kazhdumi, Dariyan, Gadvan and Fahliyan formations. The age of these rock units are arranged from the Lower Cretaceous to the Oligocene.

Biozonation of the drilled sequence of the Karbassi well # 1 is based on Wynd (1965), which it is standard biozonation for the Zagros Basin in southwestern Iran. Therefore, based on micropaleontological studies, 20 biozones were established throughout the drilled rock units of the Karbassi well # 1.

Five hiatuses are present throughout the drilled sequence of the Karbassi well # 1. The first hiatus is between the Asmari and Jahrum formations and it encompasses the upper Eocene-lower Oligocene strata. The second hiatus occurs in the Gurpi Formation and it encompasses the uppermost Maestrichtian strata *Abathomphalus mayaroensis* Zone # 40. The third hiatus is between Gurpi and Ilam formations and it includes the Santonian-Campanian strata biozone #32 *(Globotruncana ventricosa-Dicarinella concavata- carinata* assemblage zone and subzone 31).The fourth hiatus is between Ilam and Sarvak formations and it includes the Turonian-Coniacian strata. The fifth hiatus occurs between the Kazhdumi and Dariyan formations and it encompasses the assemblage zone # 17 of the lowermost Albian.

The presence of benthic and pelagic foraminifera in the above-mentioned rock units indicates the different environmental conditions during that geological time in this part of Zagros basin. So that, for example, the Gurpi and Pabdeh formations are sattled in the deep marine environment, whereas, other formations of drilled sequence in the Karbassi well # 1 mainly are formed in the shallower water marine.

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Oligocene biostratigraphy of the Palmyra region, Syria

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A detailed micropaleontological investigation was performed on planktonic foraminiferal assemblages, spanning the interval from Zone P18 to Zone P22 (Zone from O1 to O6) in three deep exploration wells (Jihar-1, Jihar-4 and Jihar-5) in Palmyra region in Syria. As all analyses have been done from drill-cuttings, biostratigraphical zonal boundaries are based on the last occurrence of the index taxa. Late Eocene deposits are composed of argillaceous limestones of wackestone type sporadically silicified. Oligocene rocks consist of marls and argillaceous limestones, wackestone and wackestone/packstone types with occasional occurrences of calcareous marls. The changes of planktonic foraminiferal assemblages indicate a general cooling trend and eutrophication of the euphotic zone between Eocene and Oligocene time. Highly diversified, subtropical to warm fauna, where K-mode life strategy predominated, were gradually replaced by low diversified assemblages with dominance of cooler r-strategists taxa. The observed extinctions began with the onset of global cooling in the middle Eocene, and culminated near the Eocene-Oligocene boundary. The Eocene/Oligocene boundary is marked by ocean temperature droop, which is the result of the formation of sea ice sheets around the Antarctic, and of the development of heavy cold water circulation locally on the bottom of the ocean. Faunal overturn is indicated by the extinction of specialized Eocene forms (K-strategists), such as turborotalids, globigerinathekids, hantkeninids, and their replacement by generalized globigerinid form species. In addition, the decrease in the size of specimens is remarkable as well as increased abundances of the opportunistic taxa and cool water indices, increased numbers of the non spinose, deeper dwelling forms and decrease of the diversity. The early Oligocene Zone P18 (O1) foraminiferal association of Palmyra region includes *Tenuitella gemma*, *T. munda*, *"Globigerina" venezuelana*, *"G." rohri*, *Paragloborotalia nana*, *Pseudohastigerina naguewichiensis*, *Chiloguembelina cubensis* and *Turborotalia ampliapertura*. The end of Zone 18 (O1) is marked by the extinction of *Pseudohastigerina naguewichiensis*.

Planktonic foramiferal association of Zone P19 (O2) is consists of *"Globigerina" tapuriensis, "G." rohri, T. ampliapertura, Cassigerinella chipolensis, C. cubensis, Catapsydrax martini* and tenuitelids. Beginning of Zone P20 (O3) is marked by last appearance of *T. ampliapertura*. In this Zone *C. cubensis, C. chipolensis, Globigerina praebulloides* and tenuitelids have been observed. Planktonic foraminiferal association in Zone P21a (O4) is consist of *Globoturborotalita anguliofficinalis*, *G. ciperoensis*, *G. angulisuturalis*, *Paragloborotalia opima*, *C. cubensis*, globigerinids and tenuitelids. The disappearance of *C. cubensis* is signified for the early/late Oligocene boundary. In the investigated Syrian wells, the planktonic foraminiferal assemblage in the lower part of the late Oligocene (Zone P21b – O5) is characterised by the following species: *P. opima "Globigerina" rohri*, *"G." tripartita*, *C. chipolensis*, *Globigerina officinalis*, *G. praebulloides* and some others forms. Zone P22 (O6) is characterized by extinction of *P. opima*. The planktonic foraminiferal association of the Zone P22 (O6) consists of globigerinids, globoturborotalitids, tenuitelids and some large "globigerinids". Planktonic foraminiferal assemblages dominated by turborotalids, pseudohastigerinids, small acarinids and rare tenuitelids prevail in late Eocene. Very low number of benthic foraminifera implies sedimentation in deep, open sea environment. Gradual increase of the benthic foraminifera proportions going upwards through the Oligocene interval indicates shallowing of the sedimentary environment. At the Eocene/Oligocene boundary specialized, subtropical planktonic foraminifera were replaced by opportunistic, cooler forms, such as globigerinids, cassigerinelids and globoturborotalitids that coincide with a global maximum cooling event.

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Reassessment of the age of the Asmari Formation, Iran

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Although the Asmari Formation is one of the most prolific oil producing sequences in the world, relatively little is known of its detailed stratigraphic palaeontology. The essential biostratigraphy of the Asmari Formation was outlined in the early 1950's. This was the only published record of the biostratigraphy before the Asmari Formation was formally described in the mid 1960's. The traditional Iranian biostratigraphy is based on unpublished reports. Unfortunately, the reports were written in a period when the Aquitanian stage was under debate. Thus, sediments ascribed to the Miocene "Aquitanian" may in fact be late Oligocene Chattian in age.

A literature study using a larger foraminifera zonation from the 1990's indicated a break between the middle and the upper Asmari Formation, and that the Aquitanian might be very reduced or even absent in the oilfields. The Oligocene (mainly Chattian) zones could readily be identified, whereas the Aquitanian zone seemed more elusive. This apparent reduction in the Aquitanian section differs significantly from the accepted Asmari stratigraphy. The younger Miocene zone within the Burdigalian was readily identified.

To address the questions about the interpretation of the Chattian-Aquitanian and the fossil ranges, strontium isotope dating was applied to cored sections from 10 Iranian oil fields and 9 outcrop sections, within the framework of a high resolution sequence stratigraphic study. For each section, fossil ranges were plotted against $^{87}Sr/^{86}Sr$ ratios and matching ages from the seawater strontium curve. The strontium ages called for a revision of the interpretation of the Chattian-Aquitanian boundary. The study verifies the condensed nature of the Aquitanian in the oilfields (but expanded in some of the outcrops) and shows that part of the Asmari Formation, previously referred to the Miocene, belongs to the Chattian of the Oligocene. The sequence stratigraphy also shows evidence for condensation/non-deposition in the Aquitanian interval.

In summary, there is evidence that the previous assignment of much of the Asmari Formation to the Aquitanian is incorrect. The study indicates the interval referred to as "lower Aquitanian" is in fact Chattian. Our data shows that, within the Oligocene, reticulate *Nummulites* are restricted to the Rupelian, in agreement with their known range elsewhere. Chattian markers are *Archaias* species: they generally become extinct at the Chattian/Aquitanian boundary, except in wells and outcrops from the north-eastern corner of the study area. *Miogypsinoides complanatus* is also a Chattian marker.

The Aquitanian is more difficult to pinpoint with marker species, and requires further integrated taxonomic and stratigraphic study of the major groups such as the miogypsinids. A generality is that when *Miogypsina* spp. and *Elphidium* sp. 14 occur together, it is probably Aquitanian. However, *Favereina asmaricus* appears to be a good marker for the Aquitanian, although it is only present in the northern part of our study area. The Burdigalian is easily picked by the occurrence of *Borelis melo curdica*. Besides dating stratigraphically important species, the study also showed which species are extremely facies dependant; e.g. *Peneroplis evolutus*, marker of the previously Aquitanian zone "*Austrotrilina howchini – Peneroplis evolutus* Assemblage Zone", ranges from Rupelian to Burdigalian in our dataset. Our data also suggest that *Eulepidina*, which last appears in the early Miocene elsewhere in Europe, the Mediterranean and the Far East, has a probable facies disappearance in the latest Oligocene in our study area.

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Foraminiferal biostratigraphy of Cretaceous-Tertiary succession of Cauvery Basin, India – An overview

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Cauvery Basin is one of the largest sedimentary basin in the east coast of south India. The Cretaceous-Tertiary (K/T) rocks occur in patchy outcrops in Tiruchirapalli, Vridhachalam and Pondicherry areas. Among these Tiruchirapalli outcrops are the largest and Archaean crystalline rocks forms the basement. The Upper Gondwana depositts (Shivaganga Formation) unconformably overlies the basement rocks of Archaean age and forms the first phase of continental sedimentation rich in plant fossils. Uttatur Group is the lower, oldest litho-unit consists of limestones and clays and contains planktic species such as *Hedbergella planispora*, *H. portsdownens*, *Praeglobotruncana stephani*, *Rotalipora appenainica* and *R. evoluta* of late Albian to Cenomanian age. The Trichinopoly Group is unconformably overlies Uttatur Group consist of sandstones and calcarenites. The planktic foraminiferal species *Marginotruncana renzi* and species of *Dicarinella* recorded from this group supports a Conician to Santonian age. It is also enriched with large sized ammonites, gastropods, brachiopods and fossil wood. The presence of fossil wood supports a littoral environment. The Ariyalur Group unconformably overlies the Trichinopoly Group, classified in ascending order into Sillakudi, Kallankurchchi, Ottakovil and Kallamedu Formation (Govindan *et al.*, 1998). The Sillakudi Limestone contains well preserved benthic foraminiferal species *Praestorrsella roestae*, and planktic species of *Globotruncana*, *Heterohelix*, *Hedbergella* and *Rugoglobigerina*, which suggests a Campanian-Maastrichtian age. Larger foraminiferal species like *Lepidorbitoides inornata*, *L. blanfordi*, *Orbitocyclina ariyalurensis*, *Siderolites calcitrapode*s and smaller foraminifera like *Goupilloudina*, along with *Gryphea* and *Inoceramus* are very distinct in Kallankurchchi Formation. *Nummofallotia* was reported for the first time in this formation (Gowda & Nagaraj 1977). Based on the recorded foraminiferal assemblage they assigned a Campanian age to this Formation. Ottakovil Formation conformably overlies the Kalllankurchchi Formation and is devoid of forams except for a few ostracodes. Mixing up of lithology in this formation may be a subsiding fan, which is a localized (not basinal) post depositional (regression) phenomena. Kallamedu Formation disconformably overlies the Ottakovil Formation, consisting of continental deposits**,** and contains sandy clays and sandstones. This sandstone horizon contain rare occurrences of dinosaurian remains. During the late Maastrichtian the Ariyalur area witnessed a regression due to an uplift along the north-south direction, causing a general regression towards east. The recorded foraminiferal assemblage of the Ariyalur Group suggests outer shelf to upper slope environments, with water depths of 150-300 m (Nagaraj, 1979).The post-Cretaceous transgression during early Tertiary resulted in the deposition of the Niniyur Formation which overlies the Ariyalur Group and underlains the Cuddalore Sandstone, often overlain by the recent Alluvium. The K/T boundary occurs over the continental sandstone beds of the Kallamedu Formation and below the marine limestones of the Niniyur Formation. This is marked by the complete disappearance of Upper Cretaceous planktic species such as *Globotruncana* and the emergence of smooth walled Palaeocene planktic species *Acarinina spiralis, Planorotalite chapmani* and species of *Morozovella*. Index species like *Gavelinella danica* and species of *Thalmannita* of Paleocene age are recorded from the Niniyur Formation (Malarkodi & Nagaraj, 1997, 1998). The Niniyur Formation was deposited in a shallow marine to brakish water environment with water depths not exceeding 75-100 m, of inner to middle shelf condition.

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Biostratigraphy and paleoenvironments of the Pliocene Kuwae Formation, Niigata, Japan

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Planktonic foraminiferal biostratigraphy is established for the late Pliocene Kuwae Formation exposed along the Tainai River, Kitakanbara district, Niigata Prefecture, central Japan. The *Orbulina universa* / *Globorotalia ikebei* Zone (PF 6) and the *Neogloboquadrina pachyderma* (dextral) / *Globorotalia orientalis* Zone (PF 7) of Maiya (1978) are recognized in the Kuwae Formation. In addition, the assemblage which is characterized by the abundant occurrence of *G. inflata* group (*G. orientalis* and *G. inflata praeinflata*) is identified in the Kuwae Formation. The base of the assemblages of rich *G. inflata* group lies between the FO (first occurrence) of *Neodenticula koizumii* (diatom, 3.5 Ma) and RI (rapid increase) of *N. koizumii* (3.0-3.1 Ma), and is dated at about 3.25Ma (Miwa *et al.*, 2004) by interpolation. *Globorotalia inflata* group occurs intermittently in the Kuwae Formation, suggesting intermittent inflow of relatively warm current into the Sea of Japan during late Pliocene. And we show the benthonic foraminiferal assemblages from the same series.

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Foraminiferal assemblages of the Gargasian of Cassis-La Bédoule (lower Aptian historical stratotype, SE France)

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The foraminiferal assemblages ranging in age from the Bedoulian-Gargasian transition to the middle Gargasian in the Cassis-La Bédoule area (SE France), the historical stratotype of the Lower Aptian substage, are thoroughly investigated. This region is particularly suitable for detailed studies of Aptian foraminifera owing to rapid and continuous sediment depositional rates and well-diversified microfaunas. The ranges of benthic forms appear to be fairly stable but some species (*Praedorothia praeoxycona, Lenticulina* cf. *nodosa, Astacolus crepidularis, Globorotalites bartensteini*) become extinct at the end of the Bedoulian and thus can be used to separate this substage from the Gargasian. The stratotypic area also offers an opportunity to follow the evolution of planktonic forms step by step at a crucial period of their history, when modalities of speciation and phylogenetic relationships appear to be particularly complex. The important morphologic variability of Aptian planktonic foraminifera does not help finding stable stratigraphic markers; nevertheless, we are able to propose a biozonation comprising five zones (*cabri, luterbacheri, ferreolensis, barri, algerianus;* Moullade *et al.*, 2005. *Notebooks on Geology*, 2: 1-20) for the interval under consideration, usually subdivided into three zones.

Taken as a whole the Aptian appears as the first significant period of radiation among planktonic foraminifera (Moullade *et al.*, 2002. *Cretaceous Research, London,* 23 (1): 111–148). Owing to the great detail obtainable because of the rapid rate of sedimentation in the stratotypic sections, it is possible to see that speciation during the Aptian, which actually had begun during the late Bedoulian, just before the anoxic event AOE1a (cf. Moullade *et al.*, 1998. *Géologie Méditerranéenne*, Marseille, XXV (3-4): 187–225) was not a sudden explosion of new forms but a rather gradual increase in the number of species.

The Bedoulian-Gargasian transitional beds correspond to a brief period of inactivity in planktonic speciation. This makes it difficult to subdivide them and to delimit the boundary between the two substages by means of planktonic foraminifera. It appears easier to approximate this boundary through the use of benthic foraminifera and ostracods.

The early/middle Gargasian was a time of moderate revival, in a progressive and regular rhythm, in the speciation of planktonic foraminifera. Their diversity continued to increase but only slowly because most species already in existence were still present at this level.

Therefore the intra-Aptian “radiation” is not a brutal or sudden phenomenon, but a progressive augmentation marked by two momentary episodes of acceleration in speciation (anagenetic phases):

1) the lower/middle portion of the late Bedoulian.
2) Gargasian (lowermost excluded), separated by a brief stasigenetic period straddling the Bedoulian-Gargasian boundary.

During the period of time considered, this radiation involves only microperforate (*Schackoina*) and finely perforate (*Praehedbergella, Globigerinelloides*) planktonic foraminifera; macroperforate species (e.g. *Hedbergella trocoidea*) do not appear until the late Gargasian

In our current state of knowledge it does not appear possible to relate these biologic processes to variations in geochemical and sedimentological parameters. Consequently, a direct causal relationship between speciation in planktonic foraminifera and external factors is at best hypothetical.

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An expanded Ypresian–Lutetian boundary section (Gorrondatxe, Basque Country, Western Pyrenees): Reappraisal of the position of planktonic foraminiferal significant FAD'S

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The Global Stratotype Section and Point of the Ypresian – Lutetian (Early – Middle Eocene) boundary is still awaiting formal definition by the International Commission on Stratigraphy. The Lutetian Stage was originally defined in Paris on the basis of nummulitids. Afterwards, however, the criterion most widely used for the definition of its lower boundary (i.e., the Early – Middle Eocene boundary) has been the First Appearance Datum (FAD) of hantkeninids (Bolli, 1957. *United States National Museum Bulletin*, 215: 155-172). Since hantkeninids are generally scarce, the FAD of *Guembelitrioides nuttalli* (= *G. higginsi*) has been proposed by Berggren & Pearson (2005. *Journal of Foraminiferal Research*, 35: 279-298) as an alternative marker.

We present here the results of a detailed study of the Ypresian – Lutetian transition carried out in Gorrondatxe beach, an easily accessible cliff section situated 15 km northwest of Bilbao (Basque Country). The succession is 700 m thick, and it is composed of hemiplagic marls and interbedded turbidites. The hemipelagic marls contain a diversified and well-preserved association of planktonic foraminifera and calcareous nannofossils, while most of the thick-bedded turbidites contain nummulitids. In addition, reliable magnetostratigraphic results have been obtained. The chronology of meaningful biostratigraphic and magnetostratigraphic events has thus been calibrated with great resolution.

The upper part of planktonic foraminiferal zone P9 (=E7) and zone P10 (=E8) were recognized. The first specimens of *Subbotina boweri* (synonymous with *S. frontosa* for some authors) appear 100 m above the base of the succession. The FAD of *Globigerinatheka micra* occurs at 280 m, whereas that of *G. nuttalli*, which approximately coincides with that of *Truncorotaloides praetopilensis*, is located at 390 m. Finally, very rare specimens of hantkeninids first appear at 630 m. All of these planktonic foraminiferal events correlate with larger foraminiferal zones SBZ12 to 14, calcareous nannofossil zones NP14a to NP15b, and magnetic polarity chrons C22n to C20r.

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Biostratigraphy and paleobathymetry of the Cogollo Group (Lower Cretaceous), Maracaibo Basin, Venezuela

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A detailed micropaleontological study of core samples from the Lower Cretaceous Cogollo Group of eastern Zulia, western Venezuela, was carried out. The stratigraphic column in this Group comprises about 783 feet of the Apón, Lisure and Maraca formations. The Apón Formation is characterised by limestones and occasionally calcareous sandstones. Calcareous sandstones, interbeded with limestones and thin beds of calcareous shales, compose the Lisure Formation, whereas bioclastic limestones characterise the Maraca Formation.

On the basis of foraminiferal assemblages paleobathymetry and chronostratigraphy have been determined for the sequence. The assemblages in the Apón Formation are composed of diverse and abundant calcareous and agglutinated foraminifera, characteristic of an inner neritic environment, with occasional opportunistic planktonic foraminifera. Larger foraminifera are also observed, among which flattened *Orbitolina* species are the most significant. These are dominant in normal salinity, and normal to low oxygen conditions, with a high sediment and nutrient supply. The Apón Formation has been therefore interpreted as the Transgressive system tract of the sequence. Based on the occurrence of *Mesorbitolina subconcava* and *Choffatella decipiens* an Aptian / Albian age has been determined for this formation.

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Middle Campanian-early Maastrichtian foraminiferal bioevents in the Middle Vistula River section, Poland

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The Middle Vistula River section, comprising a set of natural and artificial exposures scattered along the Middle Vistula River, central Poland, offers an insight into the whole Upper Cretaceous succession of the area. It is a part of the Border Synclinorium, the geotectonic structure that originated at the Cretaceous/Paleogene passage through the tectonic uplift and inversion of the former Danish-Polish Trough (Kutek & G³azek, 1972. *Acta Geologica Polonica*, 22: 603-653).

Foraminiferal assemblages in the studied interval are moderately to highly diverse. More than 70 taxa were identified at the generic or specific level. In the studied interval P/B ratio values vary from 5 to 60%; H(S), the Shannon-Weaver heterogeneity index is rather low: < 2.0; number of benthic species in the assemblages exceeds 20 and the proportion of agglutinated tests is generally low (3- 10%). Benthic foraminiferal assemblages are dominated by epifaunal morphogroups in the lower part of the section, and by infaunal ones – in the upper part. P/B ratio values and H(S) diversity index indicate middle - outer shelf environment.

In the interval studied the following sequence of bioevents is recorded from bottom to top:

(a) FO of *Coryphostoma incrassata*;
(b) FO of *Osangularia navarroana*;
(c) LO of *Globorotalites michelinianus*,
(d) FO of *Coryphostoma decurrens*;
(e) LO of *Globorotalites hiltermanni*,
(f) FO of *Neoflabellina reticulata*;
(g) FO of *Bolivinoides draco miliaris*;
(h) FOs of *Rugoglobigerina pennyi*,
(i) FOs of *Rugoglobigerina milamensi*;
(j) FO of *Neoflabellina permutata*.

FOs of *Rugoglobigerina pennyi* and *Rugoglobigerina milamensis* are a good proxy for the Campanian – Maastrichtian boundary, as defined by inoceramids in the studied section (Walaszczyk, 2004. *Acta Geologica Polonica*, 54: 95-168).

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Oligocene-Pliocene planktonic foraminifera biostratigraphy from southwest Caribbean

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The Southwest corner of the Caribbean Sea contains valuable information of the history of the collision of the southern Central American volcanic arc with the South American plate and its effects on the closure of the Panama seaway and the Andes uplift. To reconstruct each chapter of the geological history of the area, local depositional events need to be dated. In this way, the studies of foraminiferal fossil record from outcrop sections of the Caribbean area of Colombia have produced several benthonic and planktonic biostratigraphic schemes. Nevertheless, using of outcrop biostratigraphic zonations in oil wells could restrict the stratigraphic correlations and basin interpretations. Excepting planktonic zonation of Stone (1968), most of outcrop biostratigraphic zonations strongly rely on First Appearance Datum (FAD) of index species. This criterion is not reliable in analysis of ditch cutting samples, often contaminated by previously drilled sediments and material sloughed from walls of the drill hole. Here, we present a foraminiferal zonation based on the analysis of 16 wells, located in northwest Colombia, in order to test the regional validity of the datum events of Stone (1968) and to refine temporal correlations between these wells, using Last Appearance Datum (LAD) of planktonic foraminifera.

Biostratigraphic data of ditch-cutting samples were analyzed using two biostratigraphic methods: Analysis of Observed Events (AOE) and Constrained Optimization. The AOE is the traditional way of assessing biostratigraphic data. It consists on a visual analysis of the sequence of fossil events within a section and across sections in order to establish a sequence of events of key fossils that do not overlap each other across wells. However, as the number of sections to be analyzed increases, the probability of these key fossil events crossing each other increases. Therefore, we used an alternative quantitative approach (Constrained Optimization) to estimate how reliable for correlation a given sequence of events is. Constrained Optimization is a quantitative technique used to improve the resolution of correlation of biostratigraphic events. The technique finds the best sequence of events. Best in this case means the sequence of fossil events that makes the less number of taxon range extensions across all the sections involved in the analysis. This technique allows use more taxa than AOE, and also quantifies how stable an event is in the best event sequence. Both sequence of events, from AOE and Constrained Optimization, were compared and the resulting sequence is the basis for the biostratigraphic zonation proposed here. Finally we tested the proposed zonation on sixty five wells that were not used to construct the zonation .

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Oligocene and Miocene planktonic foraminifera in southern Veracruz State, southeastern Mexico

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Biostratigraphic studies in Oligocene and Miocene terrigenous surficial sections outcropping in the Salina del Istmo Basin southern Veracruz state, SE Mexico, allowed recognition of foraminiferal associations representing the standard zonations of planktonic foraminifera. However, results indicate that some index species are depressed or absent, and therefore, it is proposed herein the use of some other taxa as local biostratigraphic tools, e.g.: *Subbotina gortanni* for the Oligocene, as well as *Globigerinoides diminutus* and *Dentoglobigerina altispira* at the lower Miocene. The Oligocene record at San Miguel (locality 1) is made up of conglomeratic beds with a few interbedded marl beds, in which two microfaunistic associations are recognized, based on the presence of *Turborotalia ampliapertura* or *Paragloborotalia opima opima*. Miocene rocks at Sayula (locality 2) are represented by marls, sands and sandstones with significant interbedded tuffs; for this interval *Globoquadrina dehiscens* FO's, *Globigerinoides altiapertura* FO's, *Dentoglobigerina altispira* FO's, *Catapsydrax dissimilis* LO's, *Praeorbulina sicana* FO's, *Orbulina suturalis, Fohsella peripheroacuta* FO's, and *Fohsella* s.s. FO's are considered as regional datums. Biozonation will be tested in the western part of the Salina del Istmo Basin, now being reexplored for hydrocarbons, in order to correlate them into a chronostratigraphic framework.

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Biochronostratigraphy and graphic correlation of three piston cores from the continental slope of Campos Basin, Rio de Janeiro – Brazil

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Foraminiferal studies have been carried out for 222 samples from three piston cores recovered in northern Campos basin, Rio de Janeiro – Brazil, range in age from the late Pleistocene to Holocene. The cores were located on the continental slope at 1270 m of water depth. The sediments of the piston core samples are marls and clays with variable calcium carbonate content; some thin sand interbedded layers occur at the base of Core C. Samples for foraminiferal investigations have been processed according to the standard methodology. The foraminiferal biozonation scheme used was based on Ericson & Wollin (1968), Kennett & Huddlestun (1972), Bé *et al.* (1976), Prell & Damuth (1978) and Vicalvi (1997 and 1999).

A biochronostratigraphic interpretation was established with the identification of 13 biozones, included into the four more recent biozones of Ericson & Wollin (1968) - W, X, Y and Z. They are: the subzones of Vicalvi (1999) - X3, X2, X1, Y5, Y4, Y3, Y2, Y1, Z2 and Z1, including the division of Y1 subzone in Y1B and Y1A (Bé *et al.*, 1976); and the W2 and W1 subzones of Kennett & Huddlestun (1972). The Y3 subzone was not identified in both wells A and B, suggesting a hiatus. In Core C, only three of eleven Vicalvi's X subzones had been recognized, characterizing an unconformity at the W/X boundary, also outlined by a sharp lithologic contact.

The X, Y and Z biozones of Ericson & Wollin (1968) were recognized and correlated between all the cores. The W zone occurs only in Core C. The Z zone (Holocene) is composed exclusively by marls. The main result of this correlation is the unconformity visualization related to the absence of Y3 subzone, which is stronger in the Core A, involving a larger time interval. It also occurs in Core B, but not in Core C, where the Y3 subzone was recognized.

For the Graphic Correlation study, the core sections have been individually analyzed and compared: Core A *vs.* Core B and Core C *vs.* Core B. Such method supplied approximate absolute values to the sediment accumulation rates and hiatuses ranges. The rates have ranged from 7 to 30 cm/kyr, and the hiatuses from 3 kyr (Core B) to 6 kyr (Core A).

The biochronostratigraphic and Graphic Correlation analyses of cores A, B and C based on planktonic foraminifera indicate changes in sediment accumulation rates, suggesting four different depositional realms in the slope, chronologically correlated between the cores. The first, exclusively in Core C, corresponds to W zone. The second involves the X3 and X2 subzones, finished in the X2/X1 boundary with an average sediment accumulation rate of 9 cm/kyr. The third, from X1 subzone until the top of Y4, present the highest rates, with average values of 16 cm/kyr. The fourth, above the top of Y4 subzone, with average sediment accumulation rate of 10 cm/kyr.

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Revised late Neogene mid-latitude planktic foraminiferalbiostratigraphy for the northwest Pacific (Shatsky Rise), ODP Leg 198

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We present a chronology for planktic foraminiferal evolution in the North Pacific based on magnetic reversal and calcareous nannofossil age datums in the upper Neogene section of Shatsky Rise (Ocean Drilling Program Sites 1207, 1208, and 1209). Astrochronologically-tuned magnetostratigraphies for each of the three expanded upper Neogene sections extend into the Miocene. Correlation among ODP Sites 1207, 1208 and 1209 allow a biostratigraphy that spans approximately 5° latitude from subtropical to temperate waters, transecting the ecotone created by the Kuroshio Current Extension. Foraminifer species associated with both temperate/transitional and subtropical environments occur consistently throughout the upper Neogene section at ODP Sites 1208 and 1209 (central high and southern high, respectively), allowing for the integration of low-and mid-latitude stratigraphies. Foraminiferal assemblages at ODP Site 1207 (northern high) are dominated by temperate species. The resulting revised datum ages for southern mid-latitude Pacific zonations (Jenkins, 1971. *Paleontological Buletin 42.* New Zealand Geological Survey; Kennett, 1973. *Initial Reports of the Deep Sea Drilling Project*, 21:575-639; Kennett & Srinivasan, 1983. *Neogene Planktonic Foraminifera, Stroudsberg, Pennsylvania, Hutchinson Ross Publishing Company*; Jenkins, 1993. *Antarctic Research Series*, 60: 125-144) and northern mid-latitude Pacific biostratigraphies (e.g., Maiya *et al.*, 1976. *Progress in Micropaleontology*: 395-422, American Museum of Natural History; Natori, 1976. *Progress in Micropaleontology:* 214-243, American Museum of Natural History; Ikebe *et al.*, 1977. *Proceedings of the First International Congress on Pacific Neogene Stratigraphy, Tokyo, 1976:* 92-114; Thompson, 1980. *Initial Reports of the Deep Sea Drillng Project*, 56-57 (2): 775-807; Keller 1982. *Marine Micropaleontology,* 7: 327-357) allow accurate correlation to the geologic time scale for mid-latitude marine sections in which carbonate is preserved. The new zonation is especially useful for age control in the North Pacific region.