of Science and Technology, London, U.K.; S. Spezzaferri, University of Milano, Milan, Italy; and S. Sturrock, British Petroleum Ltd., Sunbury, U.K. We thank J.V. Browning, Rutgers University, for his assistance in the preparation of figures.

ABBREVIATIONS.—Index of abbreviations used in the atlas for foraminifer collections and collection examiners is as follows.

Foraminifer Collections:

BP	British Petroleum, London, England
CC	Cushman Collection Catalog (USNM)
CPC	Commonwealth Paleontological Collection, Canberra, Australia
GAN	Geological Institute, Academy of Sciences, Moscow, Russia
P	Protozoa Catalog (USNM)
UC	Collections of the University of Chicago Walker Museum in the Field Museum, Chicago, Illinois
USNM	Collections of the former United States National Museum now in the National Museum of Natural History, Smithsonian Institution, Washington, D.C.
UWA	University of Western Australia, Perth, Australia
VNIGNI	Vsesoyuznogo Neftyanogo Nauchno-Issledovatel'skogo Geologo Instituta (All Union Petroleum Scientific Research Geological Institute), St. Petersburg, Russia
VNIGRI	Vsesoyuznogo Neftyanogo Nauchno-Issledovatel'skogo Geologo-Razvedochnogo Instituta (All Union Petroleum Scientific Research Geological Prospecting Institute), St. Petersburg, Russia

Examiners:

BTH	Brian T. Huber
CL	Chengjie Liu
FR	Fred Rögl
GJ	Graham Jenkins
RDN	Richard D. Norris
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SD	Steven D'Hondt
WAB	William A. Berggren

BIOSTRATIGRAPHY

(by W.A. Berggren and R.D. Norris)

The use of planktonic foraminifera in biostratigraphy may be said to be an essentially post-World War II phenomenon (although there were several pre-war contributions of less than lasting value) that resulted from the recognition of their usefulness in local and regional biostratigraphic zonation and correlation. These studies were often, but not exclusively, connected with the exploration for petroleum, particularly in the North Caucasus, Crimea, Tadzhik Depression, and other southwestern portions of the former Soviet Union (Subbotina, 1947, 1953; Morozova, 1959, 1961; Leonov and Alimarina, 1960; Alimarina, 1962, 1963), in the Caribbean region (Brönnimann, 1952; Bolli, 1957a, 1957b), and in the Gulf of Mexico and Atlantic Coastal Plain regions (Loeblich and Tappan, 1957a). Various biostratigraphic zonal schemes were developed by the authors cited above and by others, and these have been rapidly ensconced in the classic biostratigraphic hagiography of the past half century. Since the advent of the DSDP (1968) and its successor program the ODP (1985–present) the various zonal schemes have found widespread application in regional and global biostratigraphic studies. In the following section we present a brief review of the major Paleocene biostratigraphic zonal schemes developed over the past 50 years. It should be remembered that some of these schemes were developed as part of a larger zonal scheme—the Paleogene or the Cenozoic—so that reference to the larger framework is unavoidable in certain instances.

A detailed zonal biostratigraphy of the Danian and Montian stages (as recognized) in the Crimea, North Caucasus, and "Boreal" areas (Russian Platform and Precaspian Basin) was developed by Morozova (1959, 1960). In these and subsequent studies (Morozova, 1961), she recognized several taxa that have become important in lower Paleocene (lower Danian Stage) biostratigraphy, such as *Eoglobigerina eobulloides* and *Globigerina taurica*.

Coarsely muricate acarininids have figured prominently in middle to late Paleocene zonal biostratigraphies, particularly that of the "official" Paleogene zonation of the former Soviet Union (Permanent Interdepartmental Stratigraphic Commission for the Paleogene of the USSR, 1963). This is because of the general paucity of keeled morozovellids (*M. acuta, M. velascoensis*) and of globanomalinids (*G. pseudomenardii*) in the formation(s) above the strata bearing *Morozovella angulata–M. conicotruncata* in the northern foothills of the Caucasus Mountains (Subbotina, 1953; Alimarina, 1963) and in southwestern Crimea (Morozova, 1959, 1960). This latter scheme would appear to have drawn heavily upon the detailed studies by the authors cited above as well as those of Shutskaya (1956, Precaucasus; 1962, Crimea, Precaucasus, and Transcaspian Region; 1965, Turkmenistan). (The taxonomic treatment of taxa is not up-to-date, and the identification of some taxa shouldn't be attempted when preservation is so poor.) Shutskaya subsequently presented a detailed synthesis of her decade-long studies in the southwestern Soviet Union, including a detailed zonal scheme for the Paleocene to lower Eocene in her doctoral thesis (1965) and then concluded with an exhaustive historical overview of the Paleogene (bio)stratigraphic succession and zonal characteristics of the Crimea, northern Precaucasus, and western part of Central Asia (1970a). In the latter work she included 40 plates containing detailed illustrations of the faunal content (planktonic and benthic taxa) of each Paleocene and lower Eocene zone from each region, making it possible to better understand the basis for biostratigraphic subdivision of the Paleogene of the southwestern Soviet Union. It also allows for correlation of her zonal scheme with that subsequently proposed in the West over the past 35 years. Krasheninnikov (1965, 1969) also made significant contributions to Paleocene biostratigraphy of the southwestern area of the former Soviet Union as well as other (sub)tropical areas of the world.

Paleocene planktonic foraminiferal biostratigraphy in the West was essentially baptized in the form of a detailed zonation developed for the Paleocene and lower Eocene of Trinidad by Bolli (1957a; modified in 1966), which was followed soon after by a zonal scheme developed for (sub)tropical regions by Berggren (1969a, 1971a; modified and (re)defined by Berggren and Miller, 1988) and Blow (1979). Premoli Silva and Bolli (1973) made minor changes to the earlier zonation of Bolli (1957a) with the insertion of the *Globorotalia edgari* Zone between the *Globorotalia velascoensis* Zone (below) and the *Globorotalia rex* (= *G. subbotinae*) Zone (above; see Toumarkine and Luterbacher, 1985). Jenkins (1971) formulated a relatively broad zonal biostratigraphic scheme for the Paleocene (as part of a larger Cenozoic study) of New Zealand. With the recognition that Paleocene low latitude, (sub)tropical zonation(s) are not fully applicable at high latitudes, Stott and Kennett (1990) developed a zonal biostratigraphy for high (austral) latitudes of the Antarctic.

We have adopted the following seven-fold (sub)tropical biostratigraphic zonation of the Paleocene (Figure 1), which is based on the studies of Berggren and Norris (1993) who redefined the zonal boundary definitions of Zones P3a/b, P4/5, and proposed a threefold subdivision of Zone P4. This zonal biostratigraphy has been more fully defined and elaborated upon in Berggren et al. (1995). The definition of the seven Paleocene zones (and their subdivisions), magnetochronologic calibration, and estimated age is presented below. Additional information on the characterization of these zones may be found in Berggren et al. (1995). Modifications to this scheme have been proposed by Lu and Keller (1995) based on their study of DSDP Site 577. Additional information on the history of Paleogene/Paleocene planktonic foraminiferal biostratigraphy may be found in Berggren and Miller (1988).

P0. *Guembelitria cretacea* Partial Range Zone (P0, Keller, 1988; emendation of Smit, 1982).

Definition: Biostratigraphic interval characterized by the partial range of the nominate taxon between the Last Appearance Datum (LAD) of Cretaceous taxa (*Globotruncana, Rugoglobigerina, Globigerinelloides,* among others) at the K/P boundary as delineated by the essentially global iridium spike and the First Appearance Datum (FAD) of *Parvularugoglobigerina eugubina.*

Magnetochronologic calibration: Chron C29r (late).

Estimated age: 65.0–64.97 mya; earliest Paleocene (Danian).

Pα. *Parvularugoglobigerina eugubina* Total Range Zone (Liu, 1993; emendation of Pα of Blow, 1979; Luterbacher and Premoli Silva, 1964).

Definition: Biostratigraphic interval characterized by the total range of the nominate taxon, *Parvularugoglobigerina eugubina.*

Magnetochronologic calibration: Chron C29r (late).

Estimated age: 64.97–64.9 mya; earliest Paleocene (Danian).

P1. *Parvularugoglobigerina eugubina–Praemurica uncinata* Interval Zone (P1, defined in Berggren et al., 1995; emendation of Berggren and Miller, 1988).

Definition: Biostratigraphic interval between the LAD of *Parvularugoglobigerina eugubina* and the FAD of *Praemurica uncinata.*

Magnetochronologic calibration: Chron C29r (late)–Chron C27n(0).

Estimated age: 64.9–61.2 mya; early Paleocene (Danian).

P1a. *Parvularugoglobigerina eugubina–Subbotina triloculinoides* Interval Subzone (P1a, defined in Berggren et al., 1995; emendation of *Parasubbotina pseudobulloides* Subzone (P1a) in Berggren and Miller, 1988).

Definition: Biostratigraphic interval between the LAD of *Parvularugoglobigerina eugubina* and the FAD of *Subbotina triloculinoides.*

Magnetochronologic calibration: Chron C29r (late)–Chron C29n (middle).

Estimated age: 64.9–64.5 mya; early Paleocene (early Danian).

P1b. *Subbotina triloculinoides–Globanomalina compressa/Praemurica inconstans* Interval Subzone (P1b, defined in Berggren et al., 1995; emendation of, but equivalent to, Subzone P1b in Berggren and Miller, 1988).

Definition: Biostratigraphic interval between the FAD of *Subbotina triloculinoides* and the FADs of *Globanomalina compressa* and/or *Praemurica inconstans.*

Magnetochronologic calibration: Chron C29n (middle)–Chron C28n (middle).

Estimated age: 64.5–63.0 mya; early Paleocene (Danian).

P1c. *Globanomalina compressa/Praemurica inconstans–Praemurica uncinata* Interval Subzone (P1c, defined in Berggren et al., 1995; emendation of, but equivalent to, Subzone P1c in Berggren and Miller, 1988).

Definition: Biostratigraphic interval between the FAD of *Globanomalina compressa* and/or *Praemurica inconstans* and the FAD of *Praemurica uncinata.*

Magnetochronologic calibration: Chron C28n (middle)–Chron C27n(o).

Estimated age: 63.0–61.2 mya; early Paleocene (Danian).

P2. *Praemurica uncinata–Morozovella angulata* Interval Zone (P2, defined in Berggren et al., 1995; emendation of, but biostratigraphically equivalent to, Zone P2 in Berggren and Miller, 1988).

Definition: Biostratigraphic interval between the FAD of *Praemurica uncinata* and the FAD of *Morozovella angulata.*

Magnetochronologic calibration: Chron C27n(o)–Chron C27n(y).

Estimated age: 61.2–61.0 mya; late early Paleocene (late Danian).

P3. *Morozovella angulata–Globanomalina pseudomenardii* Interval Zone (P3, defined in Berggren et al., 1995; emendation of Zone P3 in Berggren and Miller, 1988).

Definition: Biostratigraphic interval between the FAD of *Praemurica angulata* and the FAD of *Globanomalina pseudomenardii.*

Magnetochronologic calibration: Chron C27n(y)–Chron C26r (middle).

Estimated age: 61.0–59.2 mya; late Paleocene (Selandian).

P3a. *Morozovella angulata–Igorina albeari* Interval Subzone (P3a, defined in Berggren et al., 1995).

Definition: Biostratigraphic interval between FAD of *Morozovella angulata* and FAD of *Igorina albeari.*

Magnetochronologic calibration: Chron C27n(y)–Chron C26r (early).

Estimated age: 61.0–60.0 mya; early late Paleocene (Selandian).

P3b. *Igorina albeari–Globanomalina pseudomenardii* Interval Subzone (P3b, defined in Berggren et al., 1995).

Definition: Biostratigraphic interval between FAD of *Igorina albeari* and the FAD of *Globanomalina pseudomenardii.*

Magnetochronologic calibration: Chron C26r (early)–Chron C26r (middle).

Estimated age: 60.0–59.2 mya; late Paleocene (Selandian).

P4. *Globanomalina pseudomenardii* Total Range Zone (P4, Bolli, 1957a).

Definition: Biostratigraphic interval characterized by the total range of the nominate taxon, *Globanomalina pseudomenardii.*

Magnetochronologic calibration: Chron C26r (middle)–Chron C25n(y).

Estimated age: 59.2–55.9 mya; middle part of late Paleocene (late Selandian–Thanetian).

P4a. *Globanomalina pseudomenardii/Acarinina subsphaerica* Concurrent Range Subzone (P4a, defined in Berggren et al., 1995).

Definition: Biostratigraphic interval characterized by the concurrent range of the nominate taxa between the FAD of *Globanomalina pseudomenardii* and the LAD of *Acarinina subsphaerica.*

Magnetochronologic calibration: Chron C26r (middle)–Chron C25r (early).

Estimated age: 59.2–57.1 mya; late Paleocene (latest Selandian–early Thanetian).

P4b. *Acarinina subsphaerica–Acarinina soldadoensis* Interval Subzone (P4b, herein defined).

Definition: Biostratigraphic interval between the LAD of *Acarinina subsphaerica* and the FAD of *Acarinina soldadoensis.*

Magnetochronologic calibration: Chron C25r (early)–Chron C25r (late).

Estimated age: 57.1–56.5 mya; late Paleocene (Thanetian).

P4c. *Acarinina soldadoensis/Globanomalina pseudomenardii* Concurrent Range Subzone (P4c, defined in Berggren et al., 1995).

Definition: Biostratigraphic interval characterized by the concurrent range of the nominate taxa between the FAD of *Acarinina soldadoensis* and the LAD of *Globanomalina pseudomenardii.*

Magnetochronologic calibration: Chron C25r (late)–Chron C25n(y).

Estimated age: 56.5–55.9 mya; late Paleocene (late Thanetian).

P5. *Morozovella velascoensis* Interval Zone (P5, Bolli, 1957a; P5 and P6a of Berggren and Miller, 1988).

Definition: Biostratigraphic interval between the LAD of *Globanomalina pseudomenardii* and the LAD of *Morozovella velascoensis.*

Magnetochronologic calibration: Chron C25n(y)–Chron C24r (middle).

Estimated age: 55.9–54.7 mya; latest Paleocene–earliest Eocene (latest Thanetian–earliest Ypresian).

Wall Texture, Classification, and Phylogeny

(by Ch. Hemleben, R.K. Olsson, W.A. Berggren, and R.D. Norris)

The recovery of early Paleocene planktonic foraminifera following the end of the Cretaceous mass extinctions led to fundamental changes in the wall structure of the test, changes linked to the way in which the earliest Paleocene species adapted to the water-mass environment. These changes in wall structure, consequently, reflect biological activity. Five species are known to have survived into the Paleocene. We believe that the planktonic foraminiferal species that came to occupy the Paleocene oceans were derived from three survivors, which rapidly gave rise to distinct lineages. The structural differences in the test wall allow basic groups to be recognized. Two groups are separated by pore size, one being microperforate (pore diameter < 1 µm) and the other normal perforate (pore diameter 2–7 µm). The microperforate species, which evolved from the survivor-species *Guembelitria cretacea,* have been