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A Cretaceous Time Scale[1]

J. E. VAN HINTE[2]
Houston, Texas 77001

Abstract An emendation of published Cretaceous time scales is proposed on the basis of presently available age data. The standard geochronologic subdivision is combined with a linear numeric scale, biostratigraphic framework, and geomagnetic-reversal time scale. The biostratigraphic framework includes standard Tethyan and boreal pelagic macrofossil zonations and planktonic as well as benthic microfossil zones and biohorizons. Basement ages at some Deep Sea Drilling Project sites are evaluated and related to the geomagnetic-reversal scale.

INTRODUCTION

Integration of marine and terrestrial geophysical, paleontologic, paleomagnetic, and other historical geologic data and application of new quantitative techniques important in stratigraphic exploration necessitates an increasingly refined numeric geologic time scale. This paper is an attempt to combine a Cretaceous numeric time scale with biostratigraphic schemes and the geomagnetic-reversal scale.

In 1964 the Geological Society of London published the Phanerozoic time scale (PTS), which it emended in 1971 (Harland and Francis, 1971). Other scales have been published since 1964 (see Fig. 1), but the original PTS scale still is the most widely used for the Cretaceous. Casey (1964, p. 199), who covered the Cretaceous for the PTS, clearly stated that the scale was "set up purely as a basis for discussion in the absence of a more positive scale of calibration." In other words, the scale was considered to be "no more than a simple working hypothesis" (Internat. Union Geol. Sci., 1967, p. 378). The PTS 1964 scale assumed that all Cretaceous stages represented equal time intervals (6 Ma each; 1 Ma = 1 megayear = 1 million years).

Using the PTS during the past few years as a working model, the writer somewhat changed it (and will do so further) either when new relevant data became available or for pragmatic reasons when inconsistencies in the results of its application suggested such change. An early version of this scale was published in 1972 with a geomagnetic-reversal scale and a planktonic foraminiferal scheme (van Hinte, 1972). A later unpublished version was used successfully by Vail et al (1974), by Berggren et al (1975), and in unpublished reports. A wider distribution of its present emended form (Fig. 2) seems useful in anticipation of establishment of a more authoritative scale. For further general considerations, see van Hinte (1976).

RADIOMETRIC DATA

Published Cretaceous radiometric age determinations have been compiled by the Geological Society of London (1964; Harland and Francis, 1971) in a numbered-item list and generally are referred to as "PTS items." To obtain an overview of the published information, the writer plotted the radiometric age of selected PTS items, and of data published after 1971, against a relative geologic time scale (Figs. 3, 4). In these figures, the numeric dates are presented without their analytic error (about 2 to 5 percent), but their possible relative-age span is given by a vertical line.

The relative-age span was determined from the published information in accordance with the biostratigraphic scheme of Figure 2. This scheme enables one to plot directly most of the later European dates, and very few adjustments had to be made in the stratigraphic ages of the PTS items. For the North American data, the writer followed Obradovich and Cobban (1975) by drawing the boundary of the Campanian/Maastrichtian[3] at the base of the *Baculites reesidei* Zone, the Santonian/Campanian boundary between the *Desmoscaphites bassleri* Zone and the *Scaphites*

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[2]Exxon Production Research Co.

I thank W. A. Berggren (Woods Hole) for continuously stimulating me to improve and expand on earlier published and unpublished versions of "a Cretaceous time scale," and am grateful to Exxon Production Research Company's management for giving the opportunity to complete this work. R. M. Jeffords and D. O. Smith (both of Houston, Texas) critically read the manuscript, and their corrections and suggestions are highly appreciated. This compilation would have been impossible without the support of EPRCo.'s library staff.

[3]The author's spelling of Maastrichtian is contrary to the spelling used by the *Bulletin* (Maestrichtian) but has been retained at the author's request. His request to use "planktic" in lieu of "planktonic" as the adjectival derivative of "plankton" was not honored.

hippocrepis Zone, the Coniacian/Santonian boundary below the *Inoceramus undulataplicatus* Zone, the Cenomanian/Turonian boundary below the *Inoceramus labiatus* Zone, and the Albian/Cenomanian boundary above the *Neogastroplites* Zones (see also Owen, 1973). The Turonian/Coniacian boundary, however, is drawn above the *Inoceramus deformis* Zone (cf. Seitz, 1956; Ernst, 1970).

Owens and Sohl's (1973) glauconite dates from the New Jersey Monmouth Group were plotted as Maastrichtian and those from the Matawan Group as Campanian (Olsson, 1964, found *Globotruncana gansseri* and *G. calcarata* in these units, respectively), and the radiometric ages were averaged per formation.

The PTS item 365 Bearpaw Formation data were grouped as in Figure 3 of Folinsbee et al (1965), whose ages also were followed (365 a-h); the Kneehills Tuff sanidine dates were averaged per locality (365 i, j, l), the biotite date being kept separate (365 k). Caldwell (1968) and North and Caldwell (1970) reviewed the relative-age assignment of the Bearpaw Formation.

Lambert (1971a) suggested rounding of pre-Tertiary major boundary ages to 5 Ma. The present scale follows his -65 and -135? Ma for the ages of the end and the beginning of the Cretaceous. With respect to the Cretaceous-Jurassic boundary, Lambert stated somewhat pessimistically: "At the very best the boundary may fall in the range 125 to 145 m.y. and there is no sound reason for taking the mean figure as the most likely." The radiometric age of the end of the Cretaceous is known more accurately and in all likelihood could not be as far from -65 Ma as the round figures -60 or -70 Ma; the correct age, though, very well could be -64 rather than the -65 Ma generally used (Berggren, 1972) and here retained.

More controversial is the third starting point of our scale: -100 Ma for the Lower/Upper Cretaceous (= Albian/Cenomanian) boundary. Age assignments for this boundary in literature range from -93 to -110 Ma (Fig. 1). Bentonite (Obradovich and Cobban, 1975) and glauconite (Juignet et al, 1975) dates obtained recently suggest that the Albian indeed may have ended 5 or 6 Ma later, that is, at -95 or -94 Ma. Other dates (PTS items 202, 226, 319, 336; van Hinte et al, 1975), however, indicate that the early Cenomanian may be considerably older than -95 Ma, and we decided not to change Casey's 1964 estimate of -100 Ma (cf. Rubinshteyn, 1967, p. 113-121).

With the three main points of the scale fixed at conservative figures, somewhat more flexibility seems justified in diverging from the PTS "equal stage" principle with respect to other stage boundaries. Radiometric dates (Figs. 3, 4) strongly indicate that the Campanian/Maastrichtian boundary should be drawn at -69 or -70 Ma. The Santonian/Campanian and Coniacian/Santonian boundaries rather clearly are at -78 and -82 Ma. The Turonian/Coniacian boundary can be drawn at -86 Ma between the oldest Coniacian glauconite date and the youngest Turonian bentonite date. Acceptance of these boundaries gives the Coniacian and Santonian equal duration, both being shorter than other Late Cretaceous ages, and has the advantage that equal duration can be assigned to Coniacian, Santonian, and Campanian ammonite zones. Most authors place the Cenomanian/Turonian boundary at -90 Ma or slightly younger, but some have it at -94 or -95 Ma and few at -99 or -100 Ma (Fig. 1). In the absence of accurate data, a boundary age of -92 Ma seems reasonable—especially because this gives the same duration to ammonite zones in both the Turonian and the Senonian.

Radiometric dates for the Lower Cretaceous are scarce, and nearly all are based on glauconites which become less reliable with increasing age of the section. Two Albian dates (PTS items 203, 217) led some authors (Bandy, 1967; Suppe, 1969; Dickinson and Rich, 1972; Baldwin et al, 1974) to accept an "old Albian" (see Fig. 1), whereas Casey (1964) and others placed more weight on a younger (-99 Ma) date on item 217 and took into account that the Albian age for item 203 is a youngest stratigraphic age. The Albian and Aptian beginnings are drawn in this work near the oldest glauconite ages at -108 and -115 Ma, respectively.

Having no dates available to help determine the Hauterivian/Barremian boundary, with the Hauterivian likely being younger than 127 Ma (item 75), the Valanginian being older than 124 Ma (Suppe, 1973, 105-124 Ma old ages for metamorphic Hellhole-Williams rocks with Tithonian-Valanginian *Buchia*), and the Berriasian possibly older than 131 Ma (items 177, 215, 328), the writer drew the boundaries at -121, -126, and -131 Ma. Thus, the present model assumes equal duration for the Valanginian and Hauterivian, both being shorter than the Barremian and longer than the Berriasian. However, this assumption is based largely on intuition and on reasons of practical utility.

The feasibility of the proposed model may be judged from Figure 5, which summarizes the available chronometric information and illustrates its position with respect to the preferred scale and an "equal stage" scale.

HISTORY OF CRETACEOUS NUMERICAL TIME-SCALE

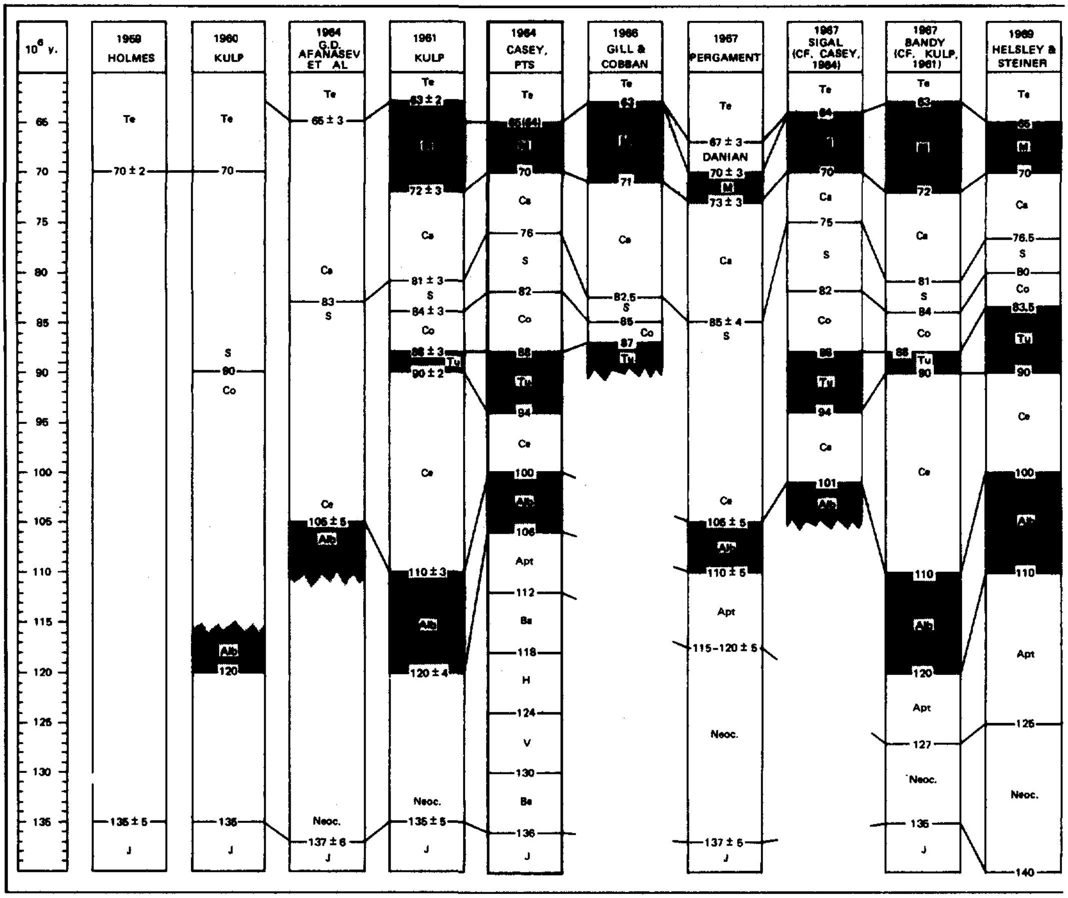
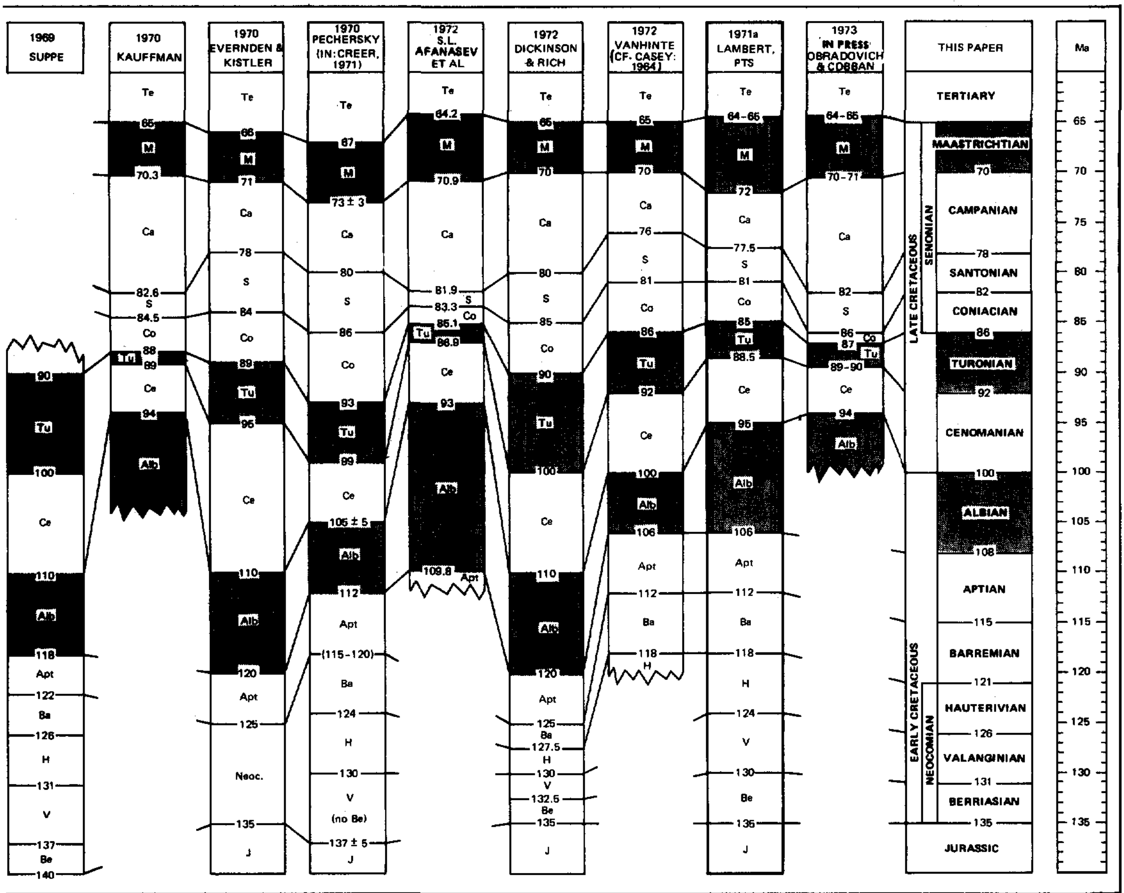


FIG. 1—Different numeric time scales proposed since 1959 for the Cretaceous. No attempt has been made to convert numbers of early and Russian scales to 1964 PTS standards. Maastrichtian, Turonian, and Albian ages are shaded for easy comparison. Gill and Cobban (1966), Pergament (1967), Kauffman (1970), and Obradovich and Cobban (in press) presented their scale with a molluscan biostratigraphic scheme; Bandy (1967), Sigal (1967), and van Hinte (1972) scales were accompanied by planktonic foraminiferal zonation.

Alb, Albian; *Apt*, Aptian; *Ba*, Barremian; *Be*, Berriasian; *Ca*, Campanian; *Ce*, Cenomanian; *Co*, Coniacian; *H*, Hauterivian; *J*, Jurassic; *M*, Maastrichtian; *Neoc*, Neocomian; *S*, Santonian; *Te*, Tertiary; *Tu*, Turonian; *V*, Valanginian.


1969 SUPPE
1970 KAUFFMAN
1970 EVERNDEN & KISTLER
1970 PECHERSKY (IN: CREER, 1971)
1972 S.L. AFANASEV ET AL
1972 DICKINSON & RICH
1972 VANHINTE (CF. CASEY: 1964)
1971a LAMBERT, PTS
1973 IN PRESS OBRADOVICH & COBBAN
THIS PAPER
Ma
TERTIARY
MAASTRICHTIAN
CAMPANIAN
SANTONIAN
CONIACIAN
TURONIAN
CENOMANIAN
ALBIAN
APTIAN
BARREMIAN
HAUTERIVIAN
VALANGINIAN
BERRIASIAN
JURASSIC
LATE CRETACEOUS
SENONIAN
EARLY CRETACEOUS
NEOCOMIAN

Biostratigraphic Schemes

The French colloquia on the Upper and Lower Cretaceous set the stage for relating macrofossil biostratigraphy to the type sections of stages. The conclusions of the colloquia (Dalbiez, 1959; Anon., 1963) form the basis for the Cretaceous ammonite zonation of Figure 2. Subsequent work has refined this "standard" and established its correlation with the boreal faunal succession (Fig. 2, authors listed at base of column).

The planktonic foraminiferal scheme is after van Hinte (1972) and is, with the alterations (Figs. 6-8) briefly discussed later, firmly related now to the stratotypes of stages through first-order and second-order (macrofossils, benthic foraminifers) correlation. The zones have been given letter-number designations for easy reference.

Recent work on stratotypes and on correlations between benthic and planktonic foraminiferal zones, between foraminiferal and macrofossil zones, and between boreal and Tethyan biostratigraphic subdivisions provided a better basis for relating the planktonic foraminiferal scheme to the Santonian and Coniacian stratotypes and stage boundaries (i.e., Ernst, 1970; Scheibnerova, 1972; Séronie-Vivien, 1972; micropaleontologic literature listed under Figure 6; see also discussion in Barr, 1972, p. 6).

The top of the *Rotalipora cushmani* Zone now is drawn to coincide with the Cenomanian/Turonian boundary for reasons illustrated in Figure 7, a conclusion that had been reached earlier by other authors for the same or for different reasons (cf. Bolli, 1966; Pessagno, 1969, p. 22).

Wider geographic recognition of Moullade's (1966) Albian-Aptian foraminiferal ranges and biostratigraphy and repeated confirmation of the phylogenetic interpretation suggest that a generalization of his scheme is justified. The derivation of the present zonation for this part of the section is illustrated in Figure 8.

Van Hinte (1972) selected planktonic foraminiferal biohorizons that are recognized widely and most likely have time significance; in Figure 2 some Senonian biohorizons were added after Herm (1965), Premoli Silva and Bolli (1973), and Smith and Pessagno (1973).

The present biostratigraphic scheme includes a neritic and littoral benthic foraminiferal phylozonation for accurate dating of Senonian shallower water sediments in which pelagic markers are lacking (Fig. 6). In Figure 2, other widely distributed benthic markers of proved time significance were added for the same purpose.

Allemann et al (1971) and Thierstein (1973) related their respective calpionellid and Early Cretaceous nannofossil zonations to macrofossil zones and/or to foraminiferal zones and to type sections of stages. The stratigraphic ages of their boundaries and biohorizons, therefore, are reliable. Those of the Late Cretaceous nannofossil scheme and of the radiolarian zonation are less well established and, therefore, had to be drawn as broken lines in Figure 2.

Geomagnetic-Reversal Scale

Since 1968, various geomagnetic-reversal time scales have been published for the Cretaceous (Fig. 9), some based on measurements made on land, others on marine-anomaly data. The scale presented here combines several of the earlier proposals. The subdivision of the Beringov interval is after the Heirztler et al (1968) scale as revised by Sclater et al (1974). The Serra Geral interval is recalibrated after Larson and Pitman (1972) using -145 and -125 Ma as calibration points instead of -155 and -120 Ma (see van Hinte, 1976). Green and Brecher (1974), Green et al (1974), and Jarrard (1974) recorded three brief reversed zones in upper Albian sediments (Proto Decima, 1974) at DSDP Site 263 which are included in the conclusion column as "Site 263 Mixed" Zone. Keating et al (1975) mentioned that the Akoh Formation recently has been dated radiometrically as 92-104 Ma old, which suggests that the Akoh reversals are within the Site 263 Mixed Zone. But because no further reference to

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FIG. 2—Numeric Cretaceous time scale proposed in this paper. Younger part of geomagnetic-reversal scale is after Sclater et al (1974), older part is after Larson and Pitman (1972, recalibrated see text), and middle zones are after McElhinny and Burek (1971), Green and Brecher (1974), and Jarrard (1974). Geomagnetic interval and zonal names are after McElhinny and Burek (1971) and Pechersky and Khramov (1973). Foraminiferal scheme is newly compiled (see text); other biostratigraphic data are after literature listed at bottom of each column in figure. Foraminiferal literature listed refers to benthic biohorizons. Note that first and last occurrences of *Globotruncana* and *Bolivinoides* species do not refer to typological species (see text). Most planktonic foraminiferal zones are phylozones, and they as well as selected biohorizons can be expected to have good geochronologic reliability.

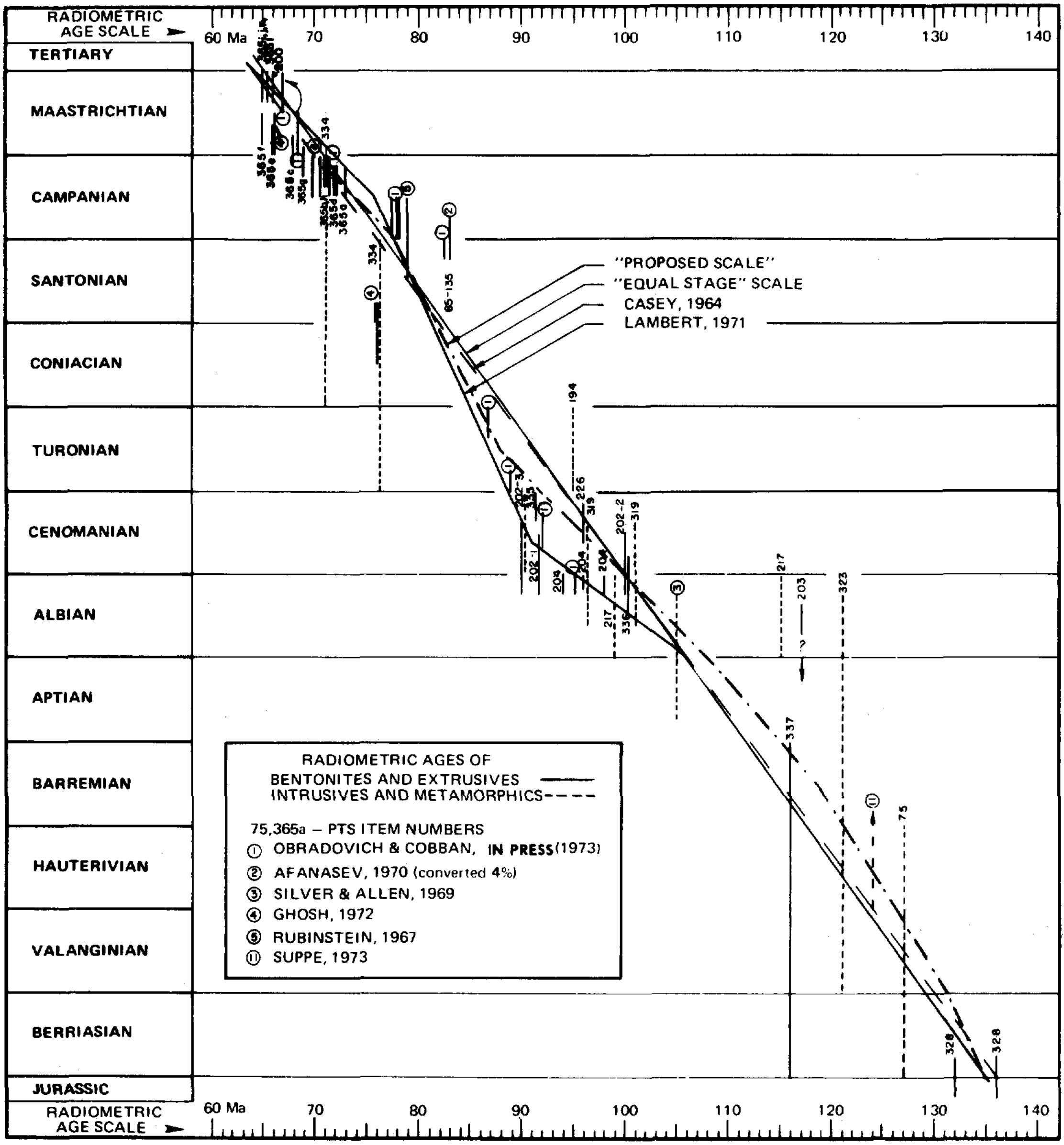


FIG. 3—Plot of radiometric age against relative age for Cretaceous dates on minerals other than glauconite. Data after literature listed on figure. PTS items are those selected by Casey (1964) plus items 334, 335, and 336 and minus items 198 and 199.

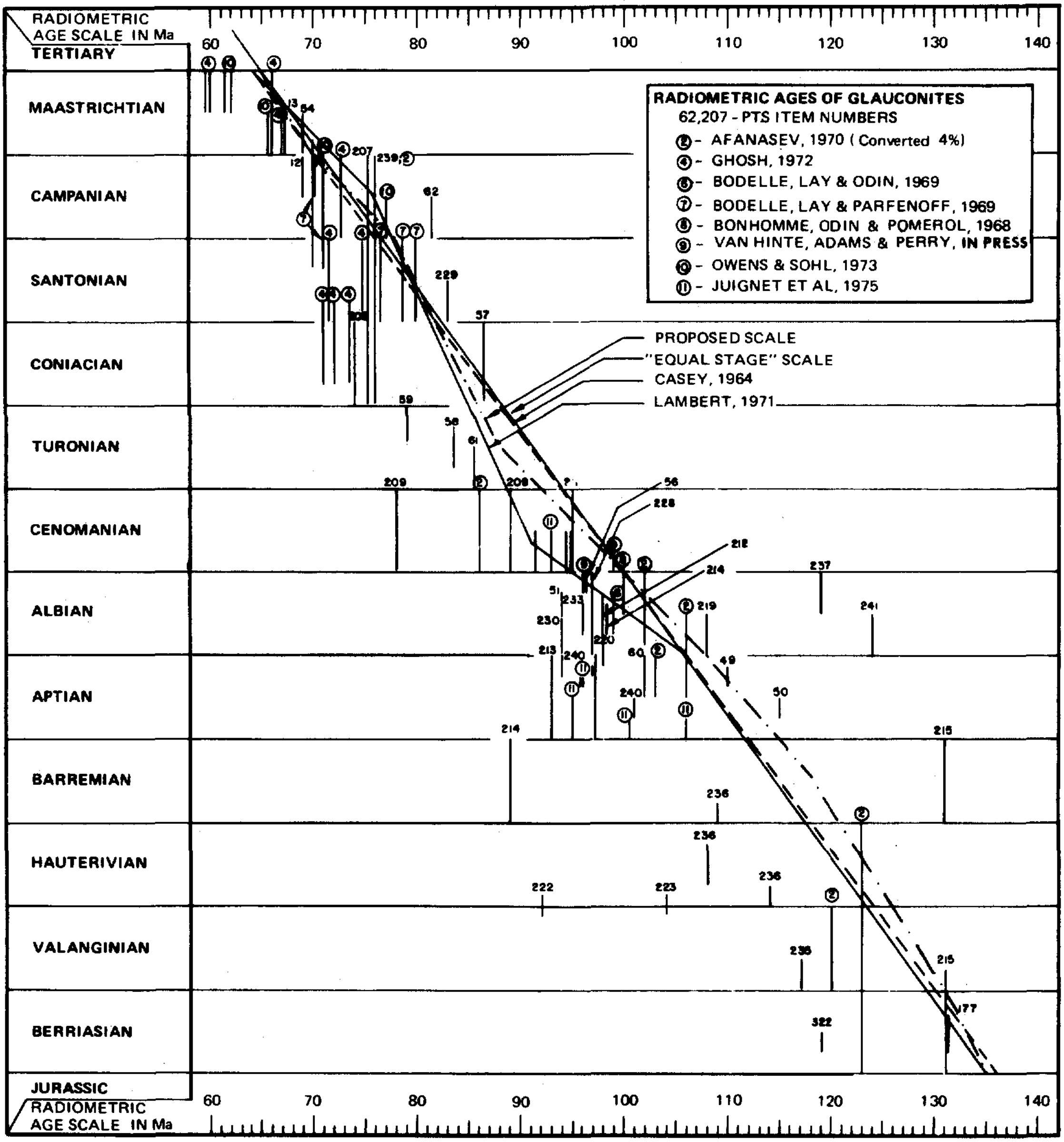


FIG. 4—Plot of radiometric age against relative age for Cretaceous glauconites. Data after literature listed on figure. PTS items are those selected by Casey (1964) plus items 51, 59, 207, 213, 228, 233, and 239.

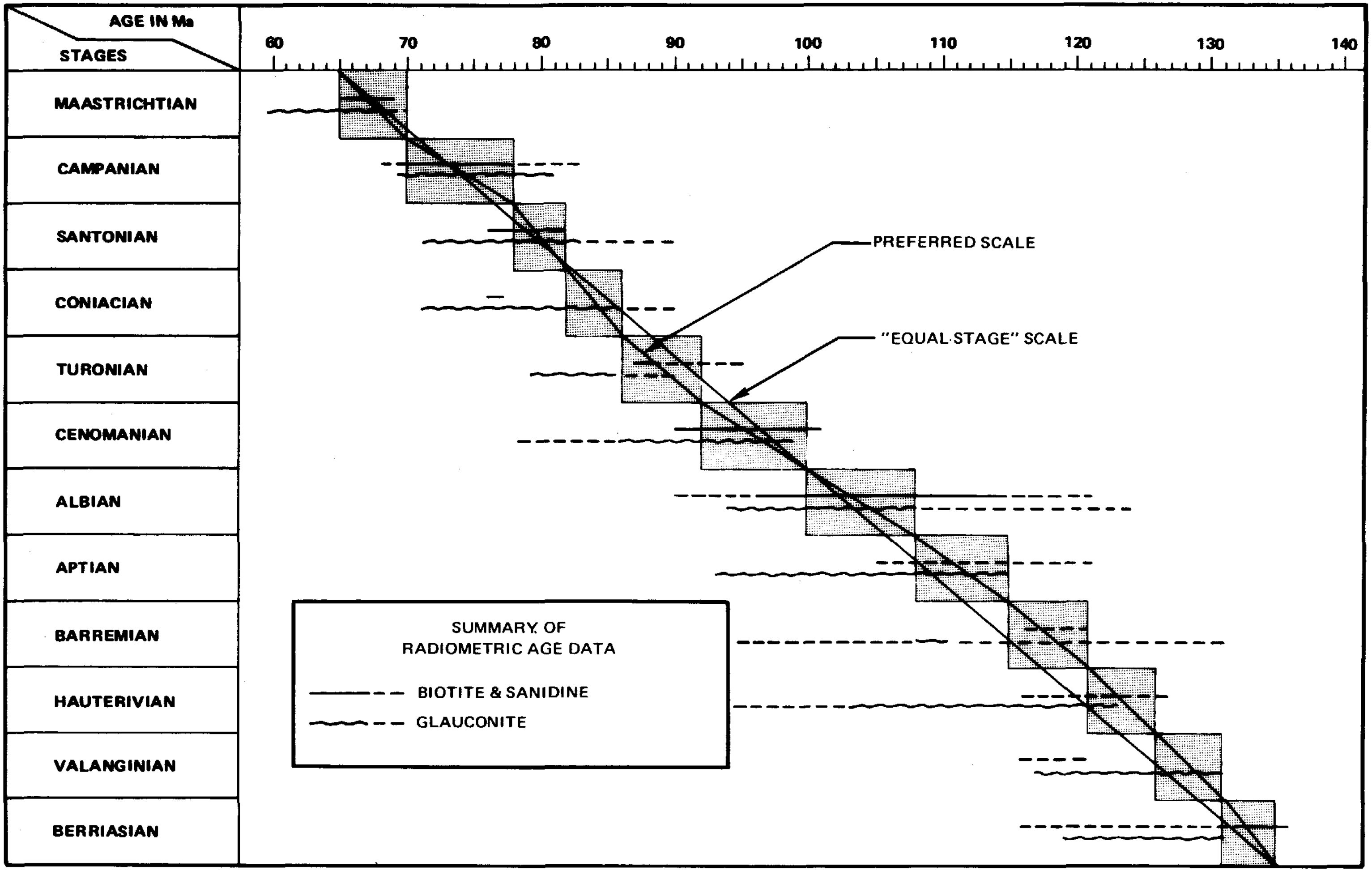


FIG. 5—Summary of Figures 3 and 4. Figure illustrates relation of published radiometric data with preferred scale (shaded) and compares line representing equal duration of stages with line representing preferred scale.

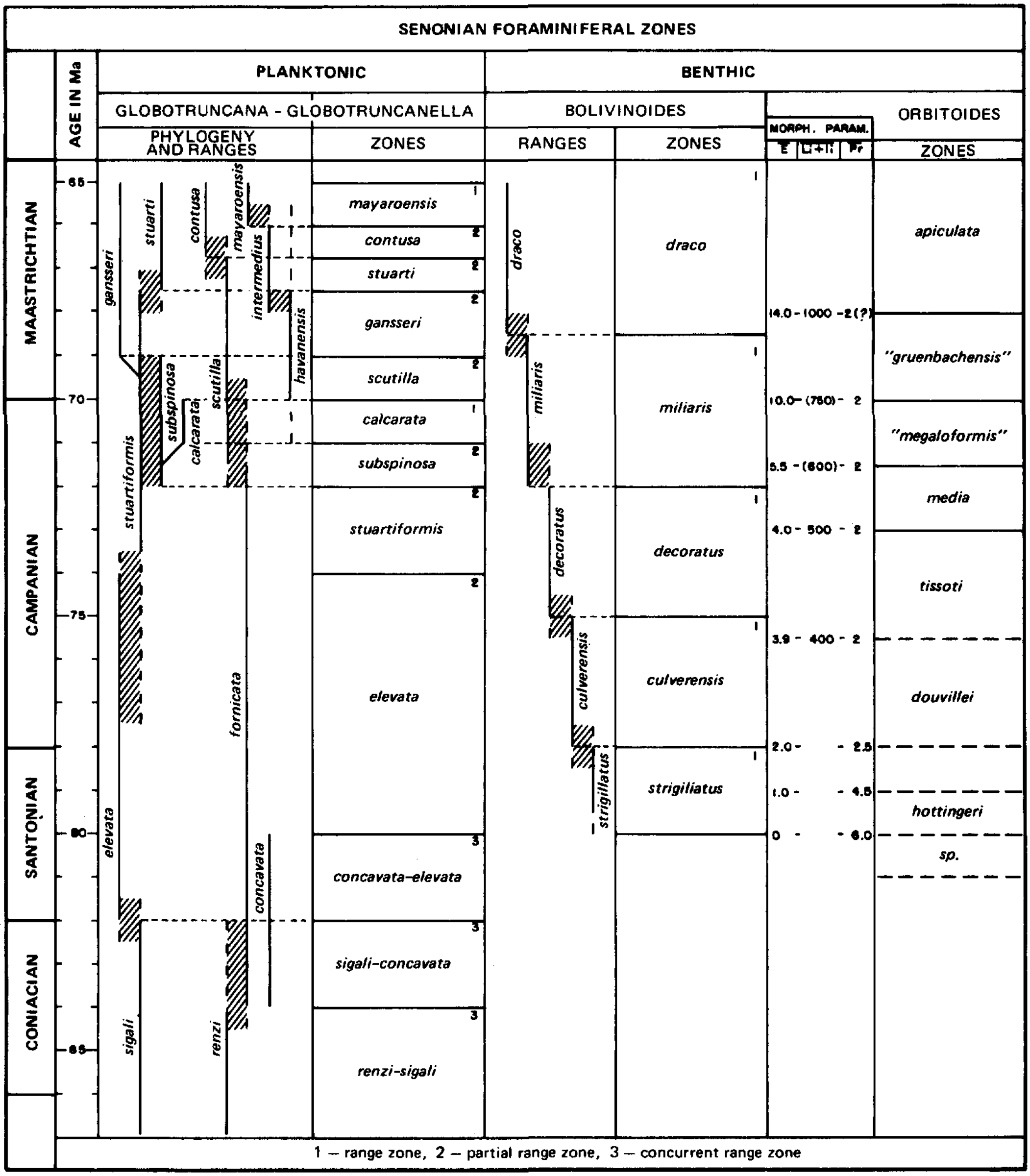


FIG. 6—Senonian foraminiferal zonal scheme. Multiple and single phylozones mainly after Papp (1956), Hiltermann (1963), van Hinte (1963-1969), and Barr (1962-1972). Correlation with stratotypes and macrofossil zones after just mentioned authors, after older literature referred to in van Hinte (1972), and after Reiss (1962), Donze et al (1970), Kuhri (1970), Salaj and Bajanik (1972), Séronie-Vivien (1972), van Gorsel (1973a, b), and Colin (1974). Vertical lines represent ranges of typologic "species," interval of presence of two successive and of intermediate morphotypes is shaded. Nomenclature of parts of *Orbitoides* lineage is uncertain because quantitative descriptions are not available for all taxa. "Morph. param." stands for morphologic parameters; *E* is number of epiauxiliary chambers, *Li + li* is measure for size of embryo, *Pr* is budding number of progressive chamber; for definitions see van Hinte (1966a, b).

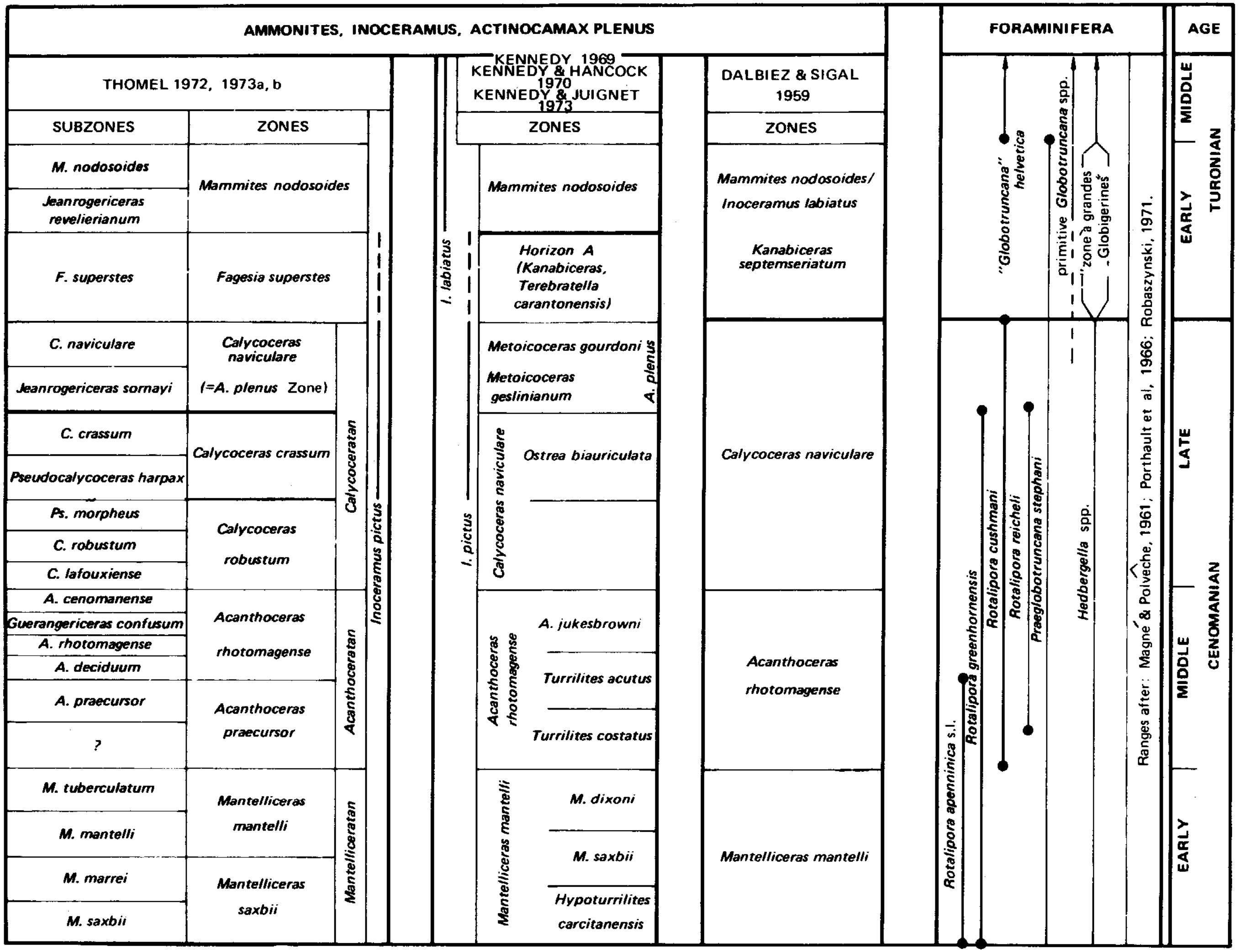


FIG. 7—Cenomanian-Turonian macrofossil zonations, some planktonic foraminiferal ranges, and different opinions on position of Cenomanian/Turonian boundary (heavy line). This paper follows resolutions of Colloque sur le Cretace Superieur Francais (Dalbiez, 1959) which are in accordance with Muller and Schenck (1943) in including *Actinocamax plenus* Zone in Cenomanian. No linear vertical scale.

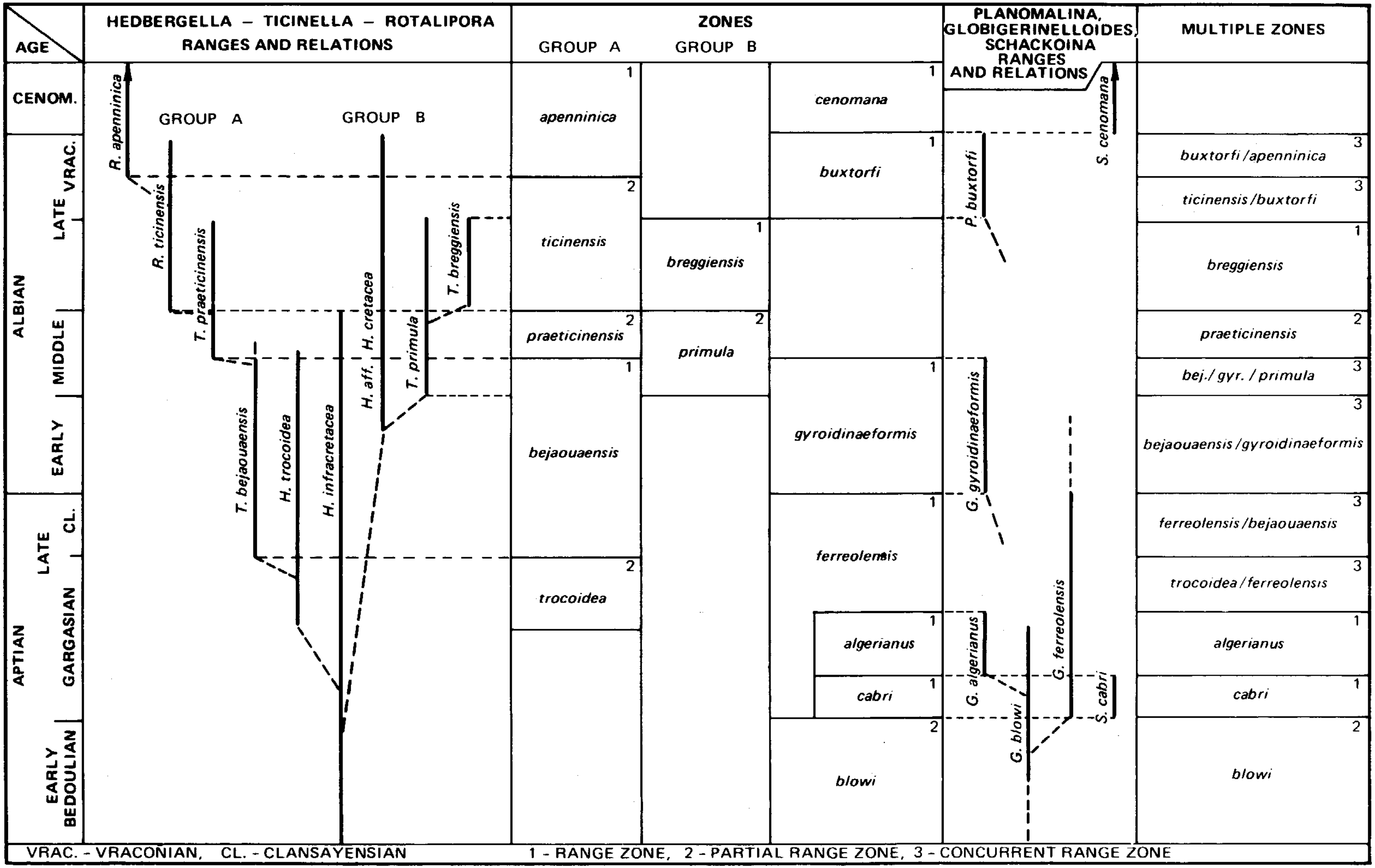


FIG. 8—Planktonic foraminiferal zonation of Aptian-Albian. Interpretation of phylogenetic relations largely after Risch (1971), ranges after Sigal and Moullade (*in* Anon., 1963), Sigal (1966), Moullade (1966), Hermes (1969), Cotillon (1971), Risch (1971), Kuhri (1971, 1972), and Salaj and Bajanik (1972). No linear vertical scale.

this new radiometric date is given, we provisionally leave the Akoh Reversed Zone at −79 to −77.5 Ma, following Helsley and Steiner (1969) and McElhinny and Burek (1971). The Gatan Reversed Zone is placed near −108 Ma, as it was assigned to the Albian-Aptian boundary by Pechersky and Khramov (1973). Jarrard (1974) suggested that he may have recorded this zone in sediments of DSDP Site 260.

Watkins and Cambray (1971) studied Campanian-Santonian dikes from Jamaica and found that "a normal geomagnetic field dominates (but not completely so)" and that their reversely magnetized dikes might be Maastrichtian or Santonian or "we may have detected the first Campanian reversed polarities." The second alternative would confirm the extrapolation of marine data by Heirtzler et al (1968). Irving and Couillard (1973) updated Helsley and Steiner's (1969) and McElhinny and Burek's (1971) compilation of Cretaceous radiometrically or paleontologically dated geomagnetic field data. They confirmed the long Cretaceous normal interval by consistently finding normal polarity for the PTS interval −109 to −82 Ma (middle Aptian-end of Coniacian), the PTS intervals −82 to −65 Ma and −160 to −109 Ma being of mixed polarity. Later paleomagnetic work by Hanna (1973) on the radiometrically dated Boulder batholith and by Keating et al (1975) on biostratigraphically dated sediments confirmed the mixed-polarity nature for post-Santonian time. A different result was obtained by Shive and Frerichs (1974), who found no reversed polarity in their study of paleomagnetism in 350 samples of the micropaleontologically dated Coniacian-early Maastrichtian Niobrara Formation in Wyoming. This is no surprise for the lower Coniacian/early Santonian part of the formation, *Globotruncana concavata* (= *G. c. primitiva*?), considered early Santonian by Shive and Frerichs (1974) and Frerichs and Adams (1973), but it poses a problem for the upper part unless the late Campanian/early Maastrichtian age assignment is not correct and the entire Niobrara Formation is Coniacian/Santonian as had been suggested by Cobban and Reeside (1962). The latter may be the case, for microfaunal evidence for a younger age is very weak. Furthermore, the Niobrara Formation is older than the Elkhorn Mountains volcanic rocks and the Boulder batholith (Klepper et al, 1957), both of which represent times of mixed polarity (Hanna, 1967, 1973, respectively); the younger Boulder batholith has been dated radiometrically as 78-68 Ma old (Hanna, 1973). This would make the base of the Maastrichtian older than 78 Ma, an unlikely high age.

Oceanic Basement Ages

Holes of the Deep Sea Drilling Project that reach basement of known magnetic-anomaly number offer an opportunity to age-calibrate the marine geomagnetic-reversal scale, and to provide a check on the consistency of the stratigraphic-radiometric time scale being used. In the following discussion, stratigraphic basement ages are estimated and expressed in numbers of the proposed time scale. These estimates are plotted in Figure 9 for ready comparison with the magnetic-reversal time scale. One age (Site 166) was used to calibrate the magnetic-reversal scale (Larson and Pitman, 1972; van Hinte, 1976); the others function as checks on the age assignment for the calibration point and its consequences for the geomagnetic-reversal scale. The figure demonstrates that none of the basement ages found by the drill contradict the age as it would have been predicted from the magnetic-anomaly position of the sites. This suggests that the present scale is a useful work model.

The following DSDP holes bottomed in Cretaceous oceanic basement of known linear magnetic-anomaly position: 10, 137, 138, 166, 239, 303, 304, 355, and 358 (nearly so). The estimates for the age of basement at Sites 166, 303, 304, and 307 (Late Jurassic) were discussed in van Hinte (1976).

DSDP Site 10 was drilled near anomaly 32. Campanian sediment (*Globotruncana stuartiformis* Zone) overlies basaltic basement at −456 m (Peterson et al, 1970; Cita and Gartner, 1971; Smali, 1973). The *Globotruncana calcarata* Zone is well defined in the section above. This zone is 20 m thick (−400 to −420 m); assuming that its duration is 1 Ma (−71 to −70 Ma), the average rate of sediment accumulation is 2 cm/1,000 years. Further, assuming that this rate is constant, it follows that the age at the base of sediment is 71 + 1.8 = 72.8 Ma old. If the *G. calcarata* Zone represents not 1 but 2 Ma, the average rate of sediment accumulation then would be 1 cm/1,000 years and the lowest sediment would be 75.6 Ma old. An upward extrapolation of the two rates would predict the top of the Cretaceous at −300 and −350 m, respectively. The Cretaceous top was not cored, but recovery of the *Globotruncanella mayaroensis* Zone in Core 10 (−291 to −299 m) indicates that the average rate of sediment accumulation was even slightly higher than 2 cm/1,000 years and supports the assumption of a 1-Ma duration for the *G. calcarata* Zone. Even incorporating the possibilities that the rate of sediment accumulation is not constant and that basement is somewhat older than the oldest sedi-

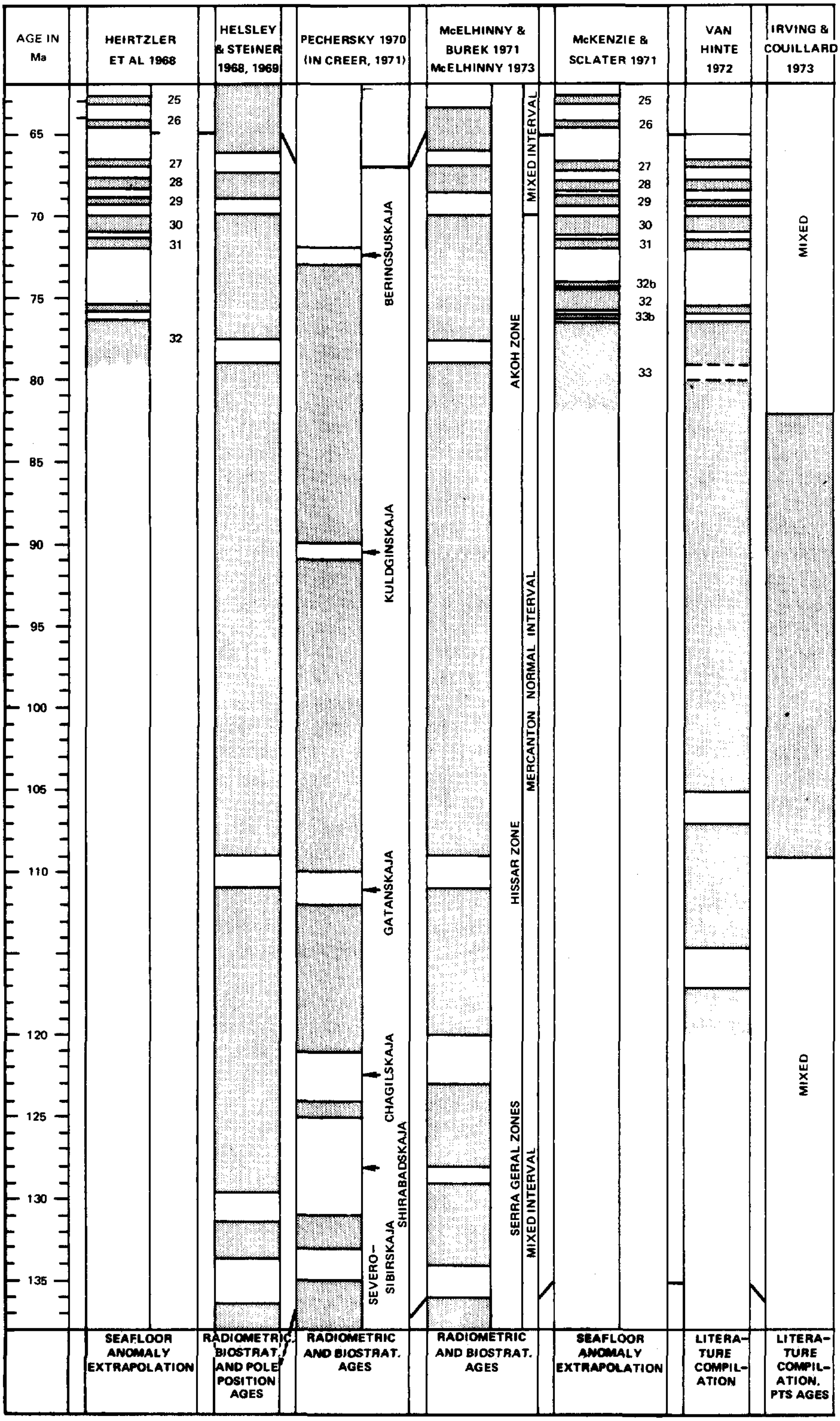
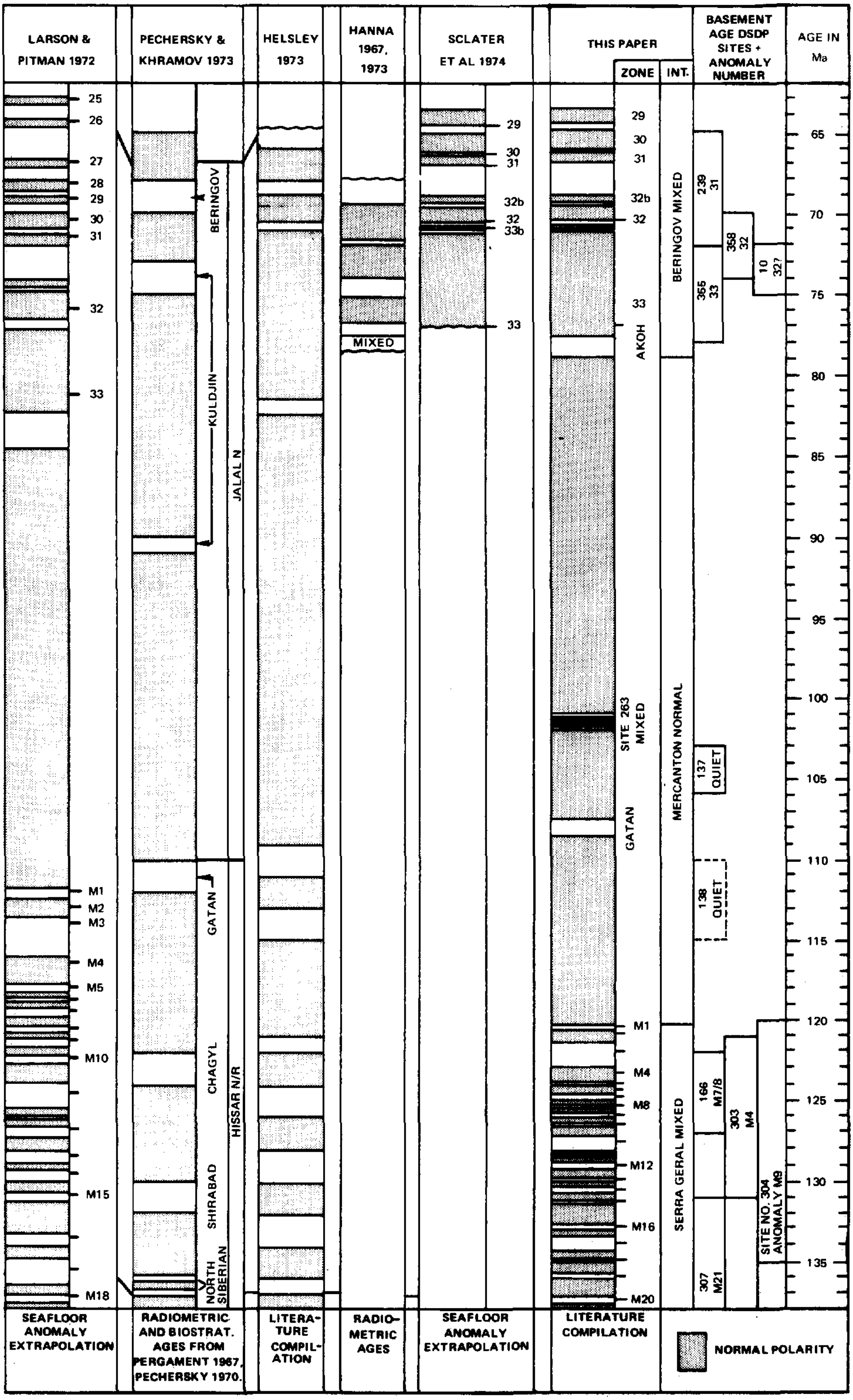


FIG. 9—Cretaceous geomagnetic-reversal scales proposed by different authors. Linear vertical scale for each column follows original authors. No attempt was made to convert radiometric ages to PTS standards or to reinterpret biostratigraphic ages except for *This Paper* column. *Site 263 Mixed Zone* refers to mixed polarity found by Green and Brecher (1974) and Jarrard (1974) in cores from DSDP Site 263. See also caption of Figure 2. Cretaceous basement ages at DSDP sites are discussed in text.



LARSON & PITMAN 1972
PECHERSKY & KHRAMOV 1973
HELSLEY 1973
HANNA 1967, 1973
SCLATER ET AL 1974
THIS PAPER
ZONE
INT.
BASEMENT AGE DSDP SITES + ANOMALY NUMBER
AGE IN Ma
BERINGOV
KULDJIN
JALAL N
GATAN
CHAGYL
HISSAR N/R
SHIRABAD
NORTH SIBERIAN
MIXED
AKOH
SITE 263 MIXED
BERINGOV MIXED
MERCANTON NORMAL
SERRA GERAL MIXED
QUIET
SITE NO. 304 ANOMALY M9
SEAFLOOR ANOMALY EXTRAPOLATION
RADIOMETRIC AND BIOSTRAT. AGES FROM PERGAMENT 1967, PECHERSKY 1970.
LITERATURE COMPILATION
RADIOMETRIC AGES
SEAFLOOR ANOMALY EXTRAPOLATION
LITERATURE COMPILATION
NORMAL POLARITY

ment, it seems reasonable to estimate basement to be between 72 and 75 Ma old.

Basement age at Site 137 can be estimated from planktonic foraminiferal biohorizons given by Beckmann (1972): *Planomalina buxtorfi* (−100 Ma) in Core 14 at −341.7 m and *Ticinella (Biticinella) breggiensis* (−102 Ma) in Core 16 at −381.7 m. An extrapolation of the average rate of sediment accumulation derived from these data (2 cm/1,000 years) dates the base of sediment (−397 m) as 103 Ma old. A fair estimate for the age of basement seems to be −103 to −106 Ma.

Only a broad paleontologic age has been determined for the lowest sediment at Site 138. Radiolaria of Core 6 (−425 to −431 m) compare with those of Core 7 at Site 137, which is at the oldest late Cenomanian and probably closer to 90 than to 95 Ma old. Petrushevskaya and Kozlova (1972) dated the fauna as Cenomanian but mentioned that it could be Albian as well. One estimate for the age of the lowest sediment could be −92 to −105 Ma. But, is this close to basement age? The fact that at Site 138 sediment above the basalt was deposited below calcite-compensation depth might suggest that at time of deposition the location was too deep for the basalt to be "normal" basement and that the hole bottomed in a sill (Berger and von Rad, 1972, p. 878; above the carbonate-clay boundary, or CCB, Berger and Winterer, 1974). Sites 137 and 138 were drilled at comparable levels with regard to basement topography, and we may assume that basement at 138 was, as at 137, originally somewhere near 2,700 m depth (Berger and von Rad, 1972, Fig. 57, Site 137). A bold extrapolation of Berger and von Rad's Site 138 curve (1972, Fig. 57) to 2,700 m suggests that basement is in the order of 110-115 Ma old (Berger and von Rad use a different time scale but have, in Fig. 57, Core 6 at −92 Ma with which we would agree).

DSDP Site 239 was drilled on the older side of anomaly 31 (Schlich, 1974) and bottomed in basaltic basement overlain by less than a meter of Cretaceous sediment that in turn was covered by Paleocene. No Cretaceous planktonic Foraminifera were found, but the benthic fauna and the calcareous nannoflora suggest a Maastrichtian-latest Campanian age (not late Campanian exclusive of Maastrichtian as assumed by Schlich, 1974, and by Larson and Pitman, 1975). Although a late Maastrichtian basement age (−65 to −68 Ma) seems most likely, the writer plotted Site 239 as −65 to −72 Ma in Figure 9.

Sites 355 and 358 were drilled on anomalies 33 and 32, respectively, and sediment above basement was dated as early-middle Campanian and as late Campanian (Anon., 1975). Basement ages for these sites can be plotted as −78 to −72 Ma and −72 to −70 Ma, respectively.

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