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Alternative global Cretaceous paleogeography

William W. Hay
GEOMAR, Wischhofstr. 1-3, D-24148, Kiel, Germany; Cooperative Institute for Research in Environmental Sciences, Campus Box 216, University of Colorado, Boulder, Colorado 80309; Department of Geological Sciences, Campus Box 250, University of Colorado, Boulder, Colorado 80309
Robert M. DeConto* and Christopher N. Wold*
Cooperative Institute for Research in Environmental Sciences, Campus Box 216, University of Colorado, Boulder, Colorado 80309; National Center for Atmospheric Research, P.O. Box 3000, Boulder, Colorado 80307
Kevin M. Wilson
812 Fourth Avenue S., Escanaba, Michigan 49829-3642
Silke Voigt
Institut für Geologie, Bergakademie Freiberg, B.-v.-Cotta-Str. 2, 09596 Freiberg/Saxony, Germany
Michael Schulz
Geologisch-Paläontologisches Institut, Christian-Albrechts-Universität, Olshausenstr. 40, D-24148 Kiel, Germany
Adrienne Rossby Wold*
4500 19th Street #62, Boulder, Colorado 80304
Wolf-Christian Dullo
GEOMAR, Wischhofstr. 1-3, D-24148, Kiel, Germany
Alexander B. Ronov and Alexander N. Balukhovsky
V. N. Vernadski Institute of Geochemistry, Russian Academy of Sciences, Ulica Kosygina D19, Moscow B-334, Russia
Emanuel Söding
GEOMAR, Wischhofstr. 1-3, D-24148, Kiel, Germany

ABSTRACT

Plate tectonic reconstructions for the Cretaceous have assumed that the major continental blocks—Eurasia, Greenland, North America, South America, Africa, India, Australia, and Antarctica—had separated from one another by the end of the Early Cretaceous, and that deep ocean passages connected the Pacific, Tethyan, Atlantic, and Indian Ocean basins. North America, Eurasia, and Africa were crossed by shallow meridional seaways. This classic view of Cretaceous paleogeography may be incorrect.

The revised view of the Early Cretaceous is one of three large continental blocks—North America–Eurasia, South America–Antarctica-India-Madagascar-Australia; and Africa—with large contiguous land areas surrounded by shallow epicontinental seas. There was a large open Pacific basin, a wide eastern Tethys, and a circum-African Seaway extending from the western Tethys ("Mediterranean") region through the North and South Atlantic into the juvenile Indian Ocean between Madagascar-India and Africa. During the Early Cretaceous the deep passage from the Central Atlantic to the Pacific was blocked by blocks of northern Central America and by the Caribbean plate. There were no deep-water passages to the Arctic. Until

*Present addresses: DeConto: Department of Geosciences, University of Massachusetts, Amherst, Massachusetts 01003. C. N. Wold: Platte River Associates, 2790 Valmont Rd., Boulder, CO 80304. A. Rossby Wold: 2045 Windcliff Dr., Estes Park, CO 80517-0783.

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the Late Cretaceous the Atlantic-Indian Ocean complex was a long, narrow, sinuous ocean basin extending off the Tethys and around Africa.

Deep passages connecting the western Tethys with the Central Atlantic, the Central Atlantic with the Pacific, and the South Atlantic with the developing Indian Ocean appeared in the Late Cretaceous. There were many island land areas surrounded by shallow epicontinental seas at high sea-level stands.

BACKGROUND

Until recently, plate tectonic reconstructions for the Cretaceous have assumed that the major continental blocks—Eurasia, Greenland, North America, South America, Africa, India, Australia, and Antarctica—had separated from one another by the end of the Early Cretaceous, and that deep ocean passages between them connected the Pacific, Tethyan, Atlantic, and Indian Ocean basins (Dietz and Holden, 1970; Smith et al., 1973, 1981a, b; Briden et al., 1974, 1981; Smith and Briden, 1977; Zonenshain and Gorodnitskiy, 1977; Smith, 1981; Barron et al., 1981; Ziegler et al., 1982; Zonenshain et al., 1984, 1985; Barron, 1987; Scotese et al., 1988; Scotese, 1991). North America, Eurasia, Africa, and Australia were crossed by shallow meridional seaways (Kauffman, 1979, 1984; Vinogradov, 1968; Reyment, 1980; Wilford, 1983). Figure 1 shows the reconstruction most often used for paleoclimate and paleocean circulation modeling, that for 100 Ma by Barron (1987). To make this reconstruction directly comparable with the others presented here, we used the ATLAS™ Program Version 3.2 (Cambridge Paleomap Services Limited, P. O. Box 246, Cambridge CB2 3DW, England, United Kingdom) to apply Barron's rotations to the digitized 200-m isobaths for the continents supplied with the program, and have sketched on the shorelines shown in Barron (1987). Major features of this plate tectonic reconstruction are six continental blocks—North America-Greenland, South America, Africa, Antarctica-Australia, India-Madagascar, and Eurasia—separated by deep ocean passages. The paleogeographic features include an open Norwegian Sea passage from the North Atlantic to the Arctic, a northern boundary of the deep Tethys at 35°N in Europe, a deep-water passage from the Atlantic to the Pacific between Central and South America, an open passage from the South Pacific into the South Atlantic between South America and Antarctica, and an isolated India-Madagascar island between Africa and Australia. Reexamination of the data shows that this view of mid-Cretaceous paleogeography as isolated, largely flooded continental islands in a world ocean is incorrect.

Impetus for a detailed reexamination of Cretaceous paleogeographic reconstructions came from an attempt to answer the objections by vertebrate paleontologists to the scenario of "island continents" separated by deep ocean basins (Hallam, 1967, 1972, 1974; Charig, 1973; Colbert, 1975, 1976, 1979, 1980; Chatterjee and Hotton, 1986). Many of them have noted that reconstructions with island continents are in conflict with the distribution of Cretaceous dinosaurs that did not swim. In particular, the Late Cretaceous dinosaur assemblage of the Lameta Beds of India, originally thought to be Turonian (Colbert, 1979) but more recently determined to be Maastrichtian (Buffetaut, 1987), is similar to those of Patagonia: *Titanosaurus*, *Antarctosaurus*, and *Laplatasaurus* occur in both areas. Chatterjee and Hotton (1986) argued that because endemic faunas and floras did not develop in India during the Cretaceous and early Cenozoic, it was never an isolated island. Most paleogeographic reconstructions would require the dinosaurs to swim either the Drake Passage and South Indian Ocean or the South Atlantic and then the Indian Ocean to reach India. Although the reconstructions by Barron et al. (1981) showed a strait between South America and Antarctica to be open in the Mesozoic, closed in the early Cenozoic, and then reopened as the Drake passage, Barker and Burrell (1977) believe that there was no deep passage between South America and Antarctica until about 12 Ma. A shallow-water connection between the South Atlantic and South Pacific, perhaps intermittently open, may have existed across southern South America or the Antarctic Peninsula in the Late Cretaceous (Thomson, 1981, 1982a, b; Crame, 1982, 1992; Kelley, 1992).

There is other evidence from land animals and plants for connections between the southern continents during the Late Cretaceous. Ankylosaurid dinosaur remains in Campanian sediments on James Ross Island, Antarctica, suggest unimpeded terrestrial communication between South America and Antarctica, because it is unlikely that ankylosaurs crossed water barriers (Olivero et al., 1991). A contiguous land connection between South America, Antarctica, and Australia has also been implied as an explanation for the dispersal of marsupials between these continents during the Late Cretaceous and early Tertiary (Woodburne and Zinsmeister, 1984). Vegetational elements such as *Nothofagus* (southern hemisphere beech) may have originated in Antarctica during the Late Cretaceous (Dettman, 1989), dispersing by terrestrial connections to South America, and Australia. Askin (1989) noted that extant species of *Nothofagus* are incapable of crossing all but the narrowest water gaps.

Taken together, the observations from land and shallow-marine faunas suggest that South America, Antarctica, and India were often connected by land until near the end of the Cretaceous. Because the locations of South America, Africa, India, and Antarctica relative to each other are known from magnetic lineations on the sea floor (Nürnberg and Müller, 1991; Patriat and Segoufin, 1988, 1989; Royer et al., 1988, 1989; Besse and Courtillot, 1988), there must be other features that connected the continents.

Until recently, global plate tectonic models have been concerned only with the major continental blocks and large fragments of continental crust; the resulting maps are most appropriately

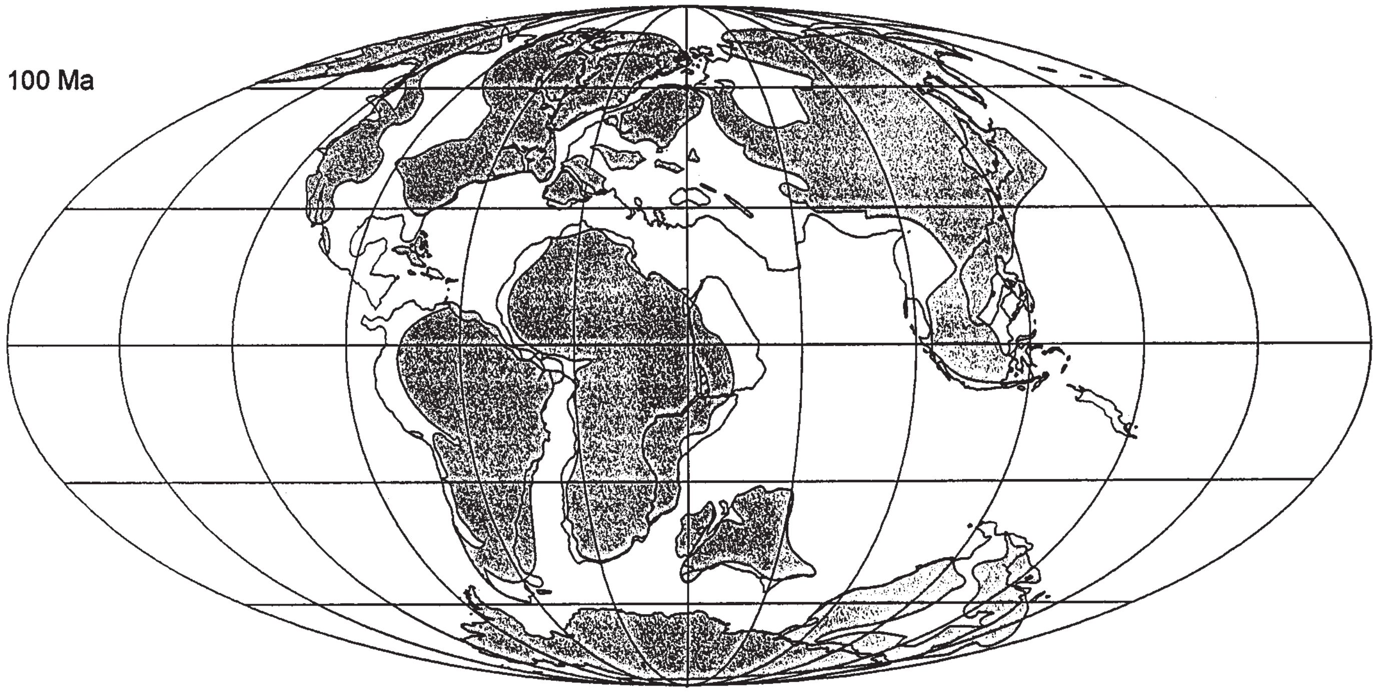

Figure 1. Paleogeographic map for 100 Ma, after Barron (1987). The original map is presented in cylindrical equidistant projection. We used Barron's rotations and continental outlines supplied with the Atlas™ Program to plot positions of the continental blocks, and sketched the shorelines onto the blocks.

termed paleocontinental reconstructions (Dietz and Holden, 1970; Smith et al., 1973, 1981a, b; Briden et al., 1974, 1981; Smith and Briden, 1977; Zonenshain and Gorodnitskiy, 1977; Smith, 1981; Zonenshain et al., 1984, 1985; Scotese et al., 1988). Some reconstructions have also included shorelines on the major blocks (Barron et al., 1981; Ziegler et al., 1982; Barron, 1987; Ronov et al., 1989; Smith et al., 1994). Most global plate tectonic models have neglected the smaller fragments, termed blocks or terranes, but recent regional analyses, such as those for the Tethys by Dercourt et al. (1986, 1992), demonstrate that these smaller tectonic units play a major role in oceanic circulation. Only the reconstructions of Scotese et al. (1987) and Golonka et al. (1994) have begun to deal with this complexity on a global scale. Internal deformation of the continental blocks, stretching of their margins during rifting, and the drift of terranes have been described in regional models (Howell et al., 1985), but generally neglected in global models.

In order to produce a new paleogeography to serve as the base for paleoclimate and paleocean circulation models, we have made new reconstructions based on new digitization of the continental blocks and terranes. On the plate tectonic reconstructions, we have superposed shorelines and attempted to reconstruct the paleotopography.

CONTINENTAL BLOCKS, TERRANES, AND PLATEAUS

The starting point for any modern paleogeographic reconstruction is a plate tectonic model reflecting the state of knowledge of the location of continental blocks, terranes, and oceanic plateaus in the past.

Correcting for stretching of passive margins

Initial fits of the continental blocks must be made using their shapes before stretching of the passive margins occurred. Most prior reconstructions have adopted the practice introduced by Bullard et al. (1965) of fitting the 2,000-m isobaths. This has seemed quite reasonable, because in many areas the 2,000-m isobath is halfway down the continental slope from the shelf break to the base of the continental rise. If the gradient of the continental slope and rise represents the collapse of an initially vertical plane of separation between the continental blocks, fitting them together along the 2,000-m isobath would restore their original configuration. However, it has become apparent that passive margins are usually stretched during separation, and sedimentation has often caused the shelf break and continental slope and rise to migrate seaward since separation. In some areas, as along the eastern margin of the United States, the history has been complex. The initially stretched margin had a series of grabens and horsts; in the Early Cretaceous these were supplanted by a reef that expanded the shelf, moving the shelf break seaward; by the Late Cretaceous the reef had died, and since then the shelf break has been migrating shoreward (Folger et al., 1979; Sheridan, 1989). Austin and Uchupi (1982) noted that in many areas the 2,000-m isobath coincides with the ocean-continent crustal boundary (OCB). They have proposed that in the absence of more detailed information, this isobath can be considered to mark the OCB. If the OCB lies beneath the 2,000-m isobath, the original continental margin must have been landward of it.

Le Pichon and Sibuet (1981) noted that the lithosphere of passive margins is stretched during the rifting process prior to separation. They described stretching along margins in terms of the "β factor" introduced by McKenzie (1978). The value of β is the original thickness of the lithosphere divided by the thickness of the stretched lithosphere, and varies from 1 in unstretched lithosphere to ∞ at the continent-ocean crust transition (see Einsele, 1992, p. 332–341, for discussion). For lithosphere stretched to half its original thickness, the value of β is 2. Assuming that the upper part of the continental lithosphere, the continental crust, is not stretched preferentially relative to the underlying lithospheric upper mantle, the relative thicknesses of the crust, which can be determined from seismic studies, can be used to estimate the value of β. Savostin et al. (1986) suggested that in the absence of more detailed information, the average value of β can be considered to be 2, and the average width of stretched crust between two plates to be 200 km. This implies an average width of stretched crust underlying passive continental margin shelves of 100 km.

Where possible, we used the stretching of the margins indicated by seismic profiling to determine the original position of the edge of the continent (e.g., see papers in Burke and Drake, 1974; Watkins and Drake, 1982). This frequently turned out to be the present position of the 2,000-m isobath (Wold et al., 1994), so this isobath was generally used as marking the original edge of the continental block where the stretching factor is otherwise unknown. After examining the shapes of the continental margins having different stretching factors we realized that the stretching can be estimated from the width of the continental slope, and made corrections where appropriate. For example, along the eastern margin of the United States, the average value of β is about 2, estimated from the seismic profiles interpreted by Folger et al. (1979). The distance from the shelf break (at a depth of about 150 m) to the base of the slope (3-km isobath) is about 100 km; so the slope is about 1/30. On the northern margin of the Bay of Biscay the value of β is about 1.1 (Chenet et al., 1983), and the distance from the shelf break to the base of the slope (3 km) is about 30 km, so that the slope is about 1/10. The amount of stretching varies with the direction of motion of the separating plates. Because orthogonal motion typically produces a stretching factor with an average value of 2 and transcurrent motion produces a stretching factor approaching 1, it follows that the stretching factor $\beta = \sin\theta + 1$, where θ is the angle between the margin and the spreading direction.

Correcting for bending of passive margins

Along their length, the shape of passive continental margins has been changed by bending as a result of the stretching associated with failed third arms of rifts (aulacogens). Burke and Dewey (1973) noted that when plume-generated triple junctions appear beneath a continent, two of the arms may remain active forming a new ocean basin while the third arm becomes an aulacogen, forming a basin on the continental margin. Burke (1976) showed that there are a number of marginal basins along the length of the Atlantic that are probably aulacogens, and Hay (1981) showed how these later guide major rivers to the sea. McKenzie (1978) proposed that basin formation involves extension, with stretching of the lithosphere. Warm asthenospheric material may well up beneath the stretched lithosphere and cause initial uplift. Subsequent cooling causes the lithosphere to subside creating accommodation space for the accumulation of sediments. The marginal basin formed by an aulacogen involves lithospheric stretching extending into the continent from the triple junction.

The fit of South America to Africa requires bending of one or both continental margins. Bullard et al. (1965) used an intermediate fit with the 2,000-m isobath, noting both offlaps and overlaps. The problem is that when the northeastern Brazilian margin is fit to the Gulf of Guinea margin of Africa, the Brazilian margin south of Cabo Branco fits against the margin of Africa to Cabo Frio, but farther to the south there is a widening gap between the southern parts of the continents. Burke and Dewey (1974) improved the fit by assuming that Africa behaves as two plates, with the boundary being the Benoue Trough. This solution is not entirely satisfactory because it results in overlap of the Brazilian margin between Cabo Branco and the Torres Depression with Africa and requires an ad hoc motion between the two parts of Africa in order to close the gap farther to the south.

The fit of South America and Africa is greatly improved if the bending of the South American margin resulting from stretching along three aulacogens—the Salado, Colorado, and San Jorge Basins—is removed (Wold et al., 1994). These marginal basins are well depicted on the *Tectonic Map of South America* (de Almeida et al., 1978). To correct for the bending of the continental margin, Wold et al. (1994) determined the thickness of the continental crust using the method described by Hay et al. (1989). The thickness of the continental crust can be estimated from the present-day topography or bathymetry, the gravity anomaly, the sediment thickness, and knowledge of the age of stretching. To determine the thickness of continental crust in the South American Basins, Wold et al. (1994) assumed an isobaric surface at 100 km depth, then

$$T_w + T_s + T_c + T_m = 100 + h, \quad (1)$$

where T_w is the depth of seawater, T_s is the thickness of the sediment, T_c is the thickness of the crust, T_m is the thickness of the upper mantle between the base of the crust and the 100-km isobar, and h is the elevation of the land surface if no seawater is present. Also,

$$T_w \times \rho_w + T_s \times \rho_s + T_c \times \rho_c + T_m \times \rho_m = \kappa, \quad (2)$$

where ρ_w, ρ_s, ρ_c, and ρ_m are the densities of the seawater, sediment, crust, and mantle respectively. These densities are taken to be $\rho_w = 1{,}027$, $\rho_c = 2{,}750$, and $\rho_m = 3{,}300$ kg m^{-3}, and

$$\rho_s = S \times \rho_g + P \times \rho_w \quad (3)$$

where S is the solidity, ρ_g is the grain density of the solid phase of the sediment, and P is the porosity, which is related to solidity by

$$S = 1 - P. \quad (4)$$

Using the general relation for solidity to depth of Baldwin and Butler (1985),

$$S = 1 - [0.49/e^{(D/3.7)}], \quad (5)$$

the density for the sediment can be determined. The term κ was determined to be 31.218×10^6 kg, by assuming a reference section with the following characteristics; the depth of unloaded 200-Ma ocean crust = 6,268 m (using the Parsons and Sclater, 1977, subsidence equation), the thickness of the ocean crust = 6,500 m, its density to be 2,750 kg m^{-3}, the thickness of mantle above the 100-km isobaric surface = 87,232 m, and the density of the 200-Ma mantle to be 3,300 kg m^{-3}.

The thicknesses of the stretched continental crust beneath the basin and the thickness of the adjacent unstretched crust define the β factor, which works out to be averages of 1.18, 1.21, and 1.24, for the Salado, Colorado, and San Jorge basins, respectively. For each of these South American aulacogens, the stretching is greatest at the continental margin and diminishes inland. The greatest sediment thicknesses are at the margin, as are the widest part of the basins. The Euler pole of rotation, about which the stretching occurred, and the angle through which the sides of the basin rotated were found from the taper of the basins toward the interior of the continent. When the shape of South America is corrected by closing these basins and the Torres Trough east of the Parana, the bending of Africa at Benoue Trough is no longer required, and southern South America wraps so tightly around southern Africa that the two continents could not separate without these movements taking place first.

A problem analogous to the fit of South America and Africa exists between Eurasia and Greenland. It is impossible to fit the margin of western Europe and Scandinavia tightly to the eastern margin of Greenland. The Scandinavian margin will fit tightly against the eastern margin of Greenland north of Scoresby Sund, but then there is a gap between the southern margin of Greenland and western Europe/Rockall-Hatton Bank when Rockall Trough is closed. This problem can be solved by assuming a rotation of southeast Europe relative to the rest of Eurasia along an arc extending from the North Sea through Viking Graben and along the north German basins to Hannover, parallel to the trend of the Tornquist Line (see plates with Jurassic and Cretaceous maps in Ziegler, 1988). The rotation required to make a tight fit of both the Scandinavian and western European-Rockall-Hatton margin to East Greenland is the same as the rotation that opens Rockall Trough. The motion along this arc was almost, but not quite, transcurrent. There was extension in the North Sea, transpression and transtension in northeastern Germany, and compression in the Harz (Hay and Wold, 1990). In this region, the direction of motion is defined by the basins and the stretching was estimated from data on sediment thicknesses, gravity, and bathymetry of the North Sea.

There is also no tight fit of the western Greenland margin against eastern Canada. To improve the fit, we assumed stretching of Greenland along a line connecting the east and west coast Thulean volcanic provinces, the Blosseville Coast south of Scoresby Sund, and the region of Disco Island. These areas appear to be a continuation of the Greenland-Iceland-Shetland Ridge. Although the volcanism in Greenland is Eocene (Ziegler, 1988), we assume that the stretching preceded it in the Cretaceous as the Labrador Sea opened. For this region there are no data on geology or sediment thicknesses beneath the ice, so the stretching was deduced from the fit.

In some places there is morphologic evidence for incipient rifting in the form of a trough, for example, between the Baffin Block and adjacent North America, and between the Elisabeth Islands and the rest of the Canadian Archipelago, as can be seen on General Bathymetric Chart of the Ocean (GEBCO, 1978–1982) Sheets 5-04 and 5-17; these features have been previously noticed by Burke (1976) and Ziegler (1988). The incipient rifting stretched the continent internally but did not result in separation. When we made a correction for the Baffin Block, the fit of Greenland to Canada improved. Like aulacogens, incipient rifting changes the shape of the margin along its length, and the correction needs to be made before blocks are fitted together. We corrected for such incipient rifting where it could be easily recognized.

Terranes

A very large number of terranes (now probably in excess of 2,000) have been described, ranging in size from subcontinents to slivers having an area of a few tens of kilometers. Many of the terranes described in the literature are fragments or composites of other terranes, and there is no systematic standard nomenclature for them, so that there has been a proliferation of names. The selection of blocks and terranes we use is that of Wilson (1989; most are also in Wilson et al., 1989a), with the addition of some oceanic plateaus. The 324 continental blocks, terranes, and plateaus for North America, South America, Africa, Australia, southeast Asia, Antarctica, Asia, and the Indian and Pacific Oceans are shown in Figures 2–8. Each block or terrane is indicated by a three-letter abbreviation (or four-letter abbreviation in the case of terranes with parts that are required to move separately). The key to abbreviations and list of names of fragments used in the reconstructions are given in Tables 1–11. Fourteen blocks or terranes known to have formed during the Cenozoic were not used in the Cretaceous reconstructions; these are indicated in Tables 1–11 by "X."

We used the maps in the *Geological World Atlas* (Choubert and Faure-Muret, 1976) as basis for digitization of the continental blocks and terranes. Conversion of the digitized outlines to latitude-longitude coordinates requires a reverse transformation for each projection. The maps in the *Geological World Atlas* are on several different projections. The maps of North and South

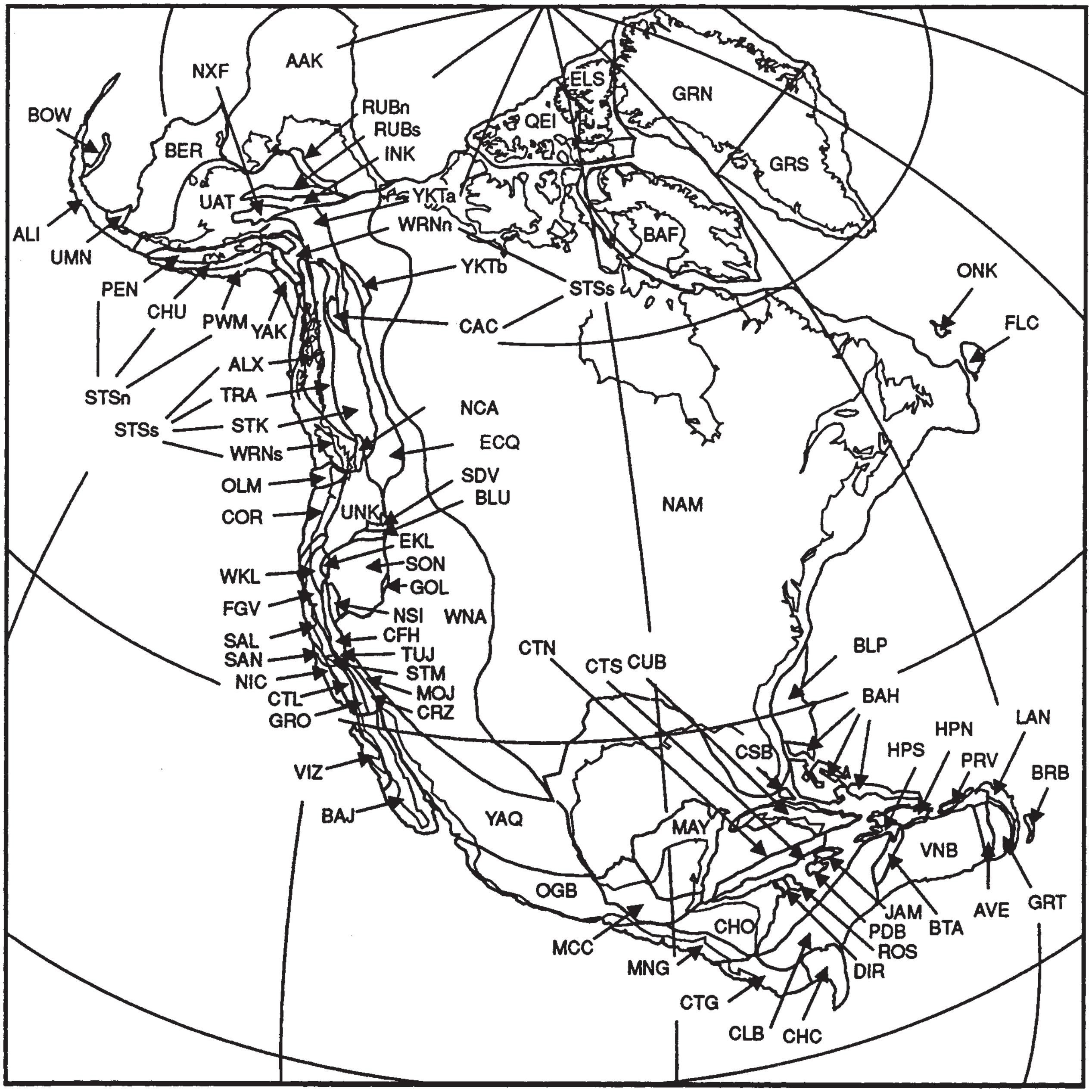

Figure 2. Continental blocks, terranes, and oceanic plateaus in the North American Central American and Caribbean regions used in the plate tectonic model. Key to the abbreviations for the fragments is given in Tables 1–3.

America are on Miller's Bipolar Oblique Conic Conformal Projection. The forward and reverse transformations for this projection have been published by Sprinsky and Snyder (1986). The maps of the polar regions are on Polar Stereographic Projections; these are standard projections for which the reverse transformations can be found in a variety of sources, including Snyder (1982) and Pearson (1990). The maps of Africa, Europe, Asia, and Australia and the adjacent South Pacific are on Miller's Oblated Oblique Stereographic Projection. This projection has the advantage that the maps of this entire region can be shown as a single unit without great distortion anywhere, but its complexity is indicated by the sinuosity of the lines of latitude and longitude. The forward transformation for this projection has been published by Sprinsky and Snyder (1986). Unfortunately, because of its complexity, there can be no exact reverse transformation for Miller's Oblated Oblique Stereographic Projection. However, the functional equivalent of the reverse transformation was developed by one of us (Wold, in preparation), and used to convert the digitized data. The functional equivalent substitutes for the reverse transformation by using a series of iterations to calculate increasingly exact approximations of latitude-longitude coordinates that correspond to points digitized on the map sheets.

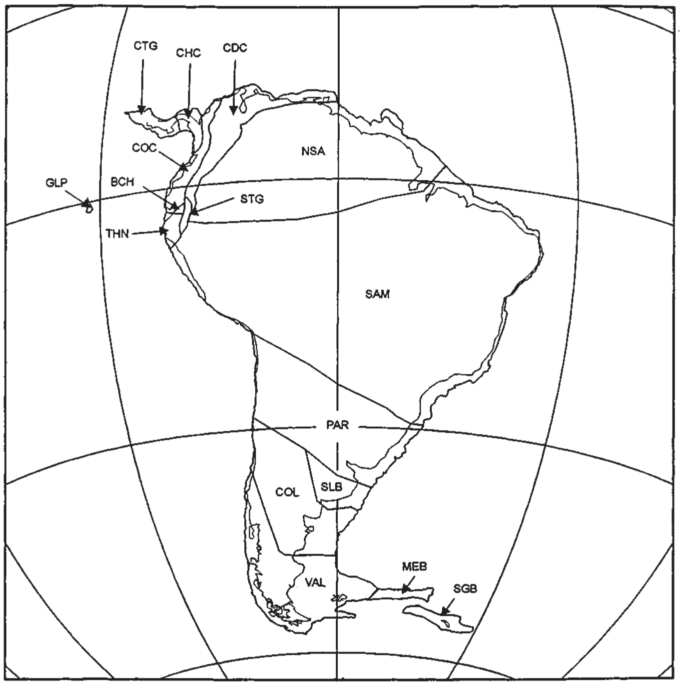

Figure 3. Continental blocks and terranes in the South American region used in the plate tectonic model. Key to the abbreviations for the fragments is given in Table 4.

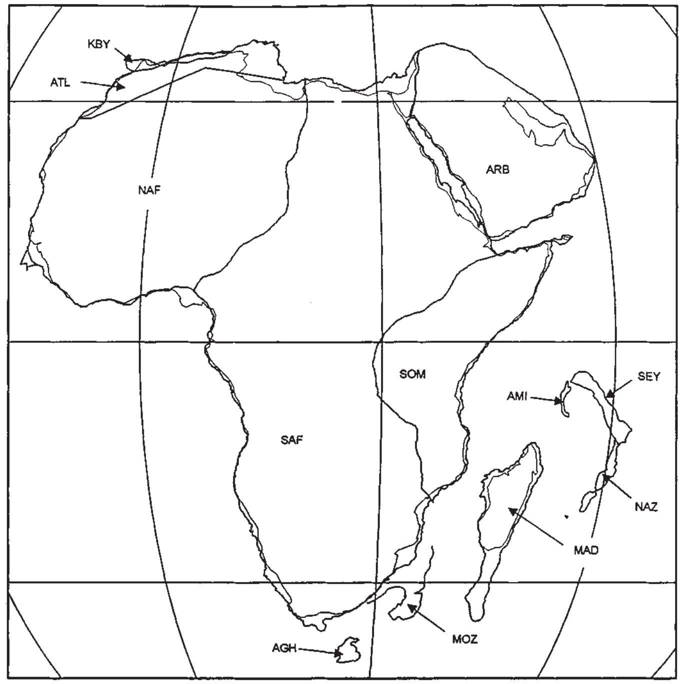

Figure 4. Continental blocks, terranes, and oceanic plateaus in the African and western Indian Ocean region used in the plate tectonic model. Key to the abbreviations for the fragments is given in Tables 5 and 6.

Oceanic plateaus and some continental margin areas were digitized from GEBCO (1978–1982) sheets, which are on either Mercator or Polar Stereographic projections for which the reverse transformations are well known (Snyder, 1982; Pearson, 1990).

Figures 2 and 6, which are all on the same scale, show that the terranes active in the late Mesozoic and Cenozoic form a fringe of roughly constant width along the western margin of North America and eastern margin of Asia. All of the terranes in this region are elongate parallel to the margin, although they are thought to have been emplaced by two different processes. The terranes on the margin of western North America are thought to have moved northward along the continental margin from sites of origin to the south (Wilson et al., 1991). In contrast, the terranes of eastern Asia are usually thought to have originated in the Pacific and been brought to their present sites by motions more or less orthogonal to the present margin (Howell et al., 1985; Wilson et al., 1989a).

The term “block” is more commonly used for the terranes forming the fringe of southern Asia, the Mediterranean region, the Caribbean, and Central America. These blocks are more equidimensional than the terranes of the northern Pacific margins. Many blocks in the Eurasian region have an obvious continental origin along the northern margin of Gondwanaland. The reason why the margin of the Gondwanan continent shed long slivers that drifted across the Tethys is related to the relative strength of continental and oceanic lithosphere. Oceanic lithosphere, in spite of its young age, is stronger that continental lithosphere, which tends to be softened by radiogenic heat generation in the continental crust (Steckler and ten Brink, 1986). As a result, a rift is more likely to propagate through continental crust parallel to and near its contact with ocean crust. Steckler and ten Brink (1986) cited the failure of the Gulf of Suez rift to break through into the Mediterranean, and the development of the Gulf of Aqaba–Dead Sea Rift as an example of this process. During the earlier Mesozoic this process occurred over and over again along the Gondwanan margin. By Cretaceous time most of the slivers had collided with or were approaching the Asian margin.

Magnetic lineations

Sea floor magnetic lineations are the best clues used in the reconstruction of the positions of continents and shapes of the ocean basins in the Cenozoic. They are also very useful in reconstructing the Mesozoic Atlantic. However, they tend to be of lesser importance in the other oceans for the Mesozoic because of the subduction of large tracts of ocean floor. The lineations used in our reconstructions are those from the map of Cande et al. (1989), digitized by Greg Cole of the Los Alamos National Laboratory and included as a data set on the CD-ROM “Global Relief Data” (available from the National Oceanic and Atmospheric Administration, NOAA, National Geophysical Data Center, Boulder, Colorado).

Shorelines and paleotopography

For most of the shorelines and paleotopographic features we used the maps of Ronov et al. (1989; see Hay, 1992, for detailed

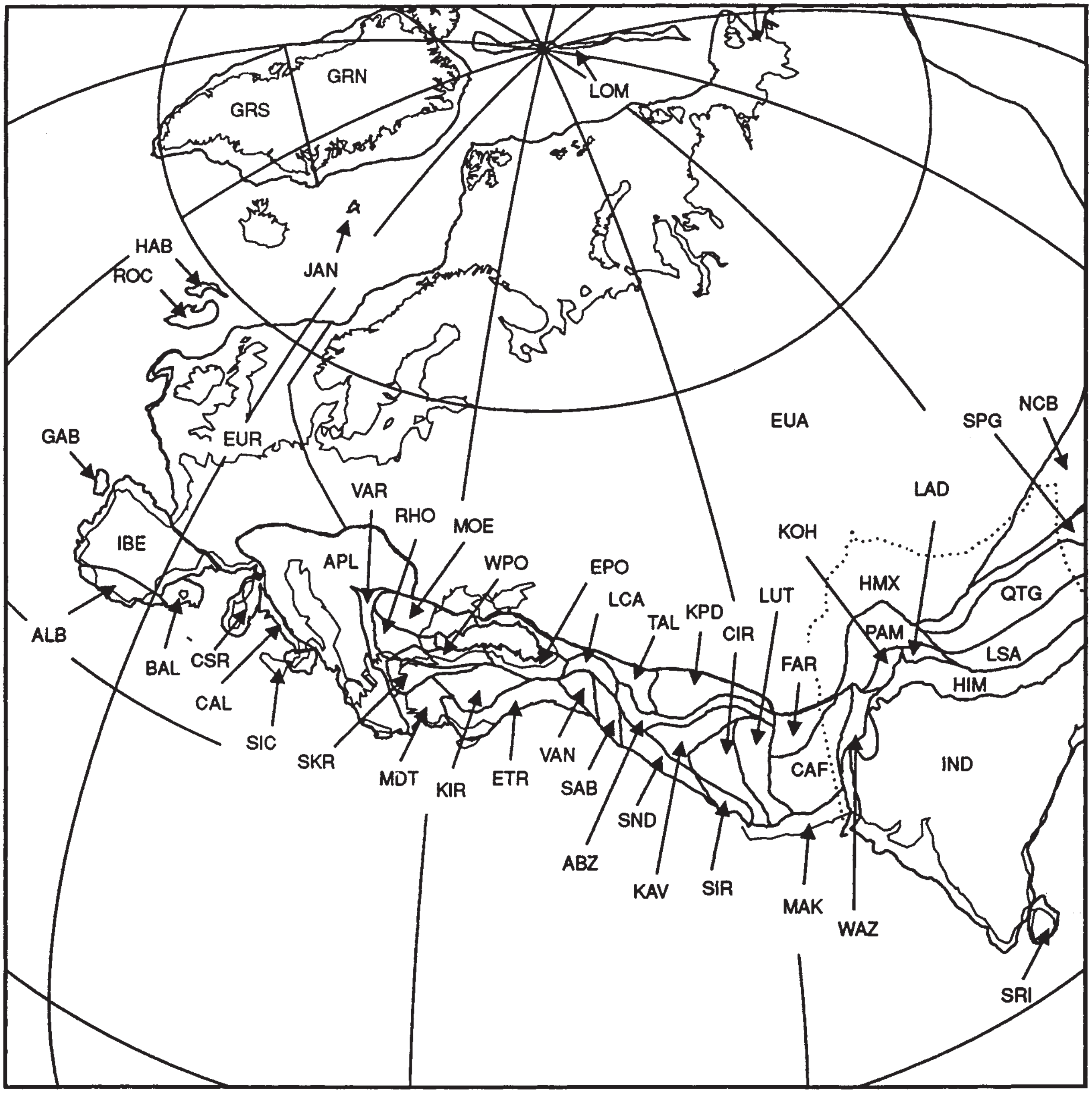

Figure 5. Continental blocks, terranes, and oceanic plateaus in the western Eurasian region used in the plate tectonic model. Key to the abbreviations for the fragments is given in Tables 7 and 8.

description of the atlas). These maps were compiled from 691 references covering the paleogeographic literature for the Mesozoic and Cenozoic from 1970 to 1985. The first series of 11 maps in the atlas is at a scale of 1:48,000,000, and shows lithologies and paleogeography of the continents and ocean basins in their present positions on a polyconic projection. These maps are 43- by 71-cm foldouts. There are also corresponding maps of the polar regions at a scale of 1:36,000,000, shown on a polar projection. There is a third set of maps at a scale of 1:167,000,000 that show the lithologic and paleogeographic information on global palinspastic reconstructions based on the plate tectonic maps of Gahagan et al. (1986). Two of the maps in each set are for the Cretaceous, one for the Early Cretaceous, in which most of the information is Aptian-Albian, and one for the Late Cretaceous, in which most of the information is Campanian. Both high and low sea-level shorelines are indicated on the maps. The maps were constructed by plotting data on sediment type from many literature sources on a fine latitude-longitude grid with present continental outlines and rivers. For some areas there are maps that show shorelines, but it is rarely indicated whether a high or low stand of sea level is represented. For many regions, the position of the shoreline must be determined from the nature of the

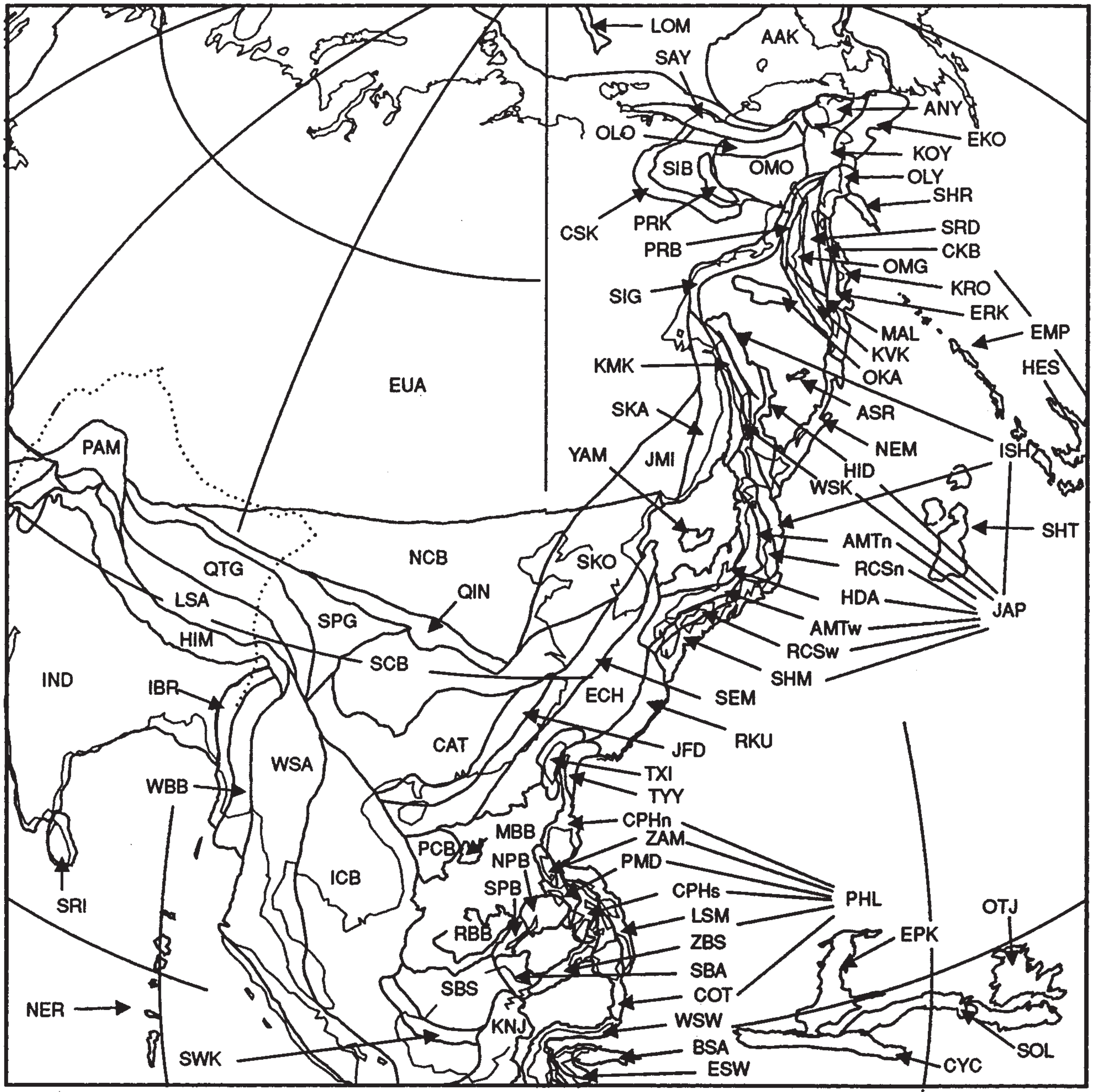

Figure 6. Continental blocks, terranes, and oceanic plateaus in the eastern Asian region used in the plate tectonic model. Key to the abbreviations for the fragments is given in Tables 8 and 11.

sediment and descriptions of the fossils, which Ronov and his co-workers have painstakingly done.

The Ronov et al. (1989) 1:48,000,000 maps are on a variety of polyconic projections developed by the Central Scientific Institute of Geodesy, Air Survey, and Cartography in Moscow (TsNIIGAiK), and widely used in Soviet publications. To permit shorelines and other features on the maps to be digitized and converted to latitude-longitude coordinates, programs for both the forward and reverse transformations were devised by Michael Schulz and others of our group in cooperation with Alexander B. Ronov (Schulz et al., 1995). The digitized shorelines were superposed on the 0-age continental block-terrane map to determine which segments of shoreline lie on a specific block or terrane, and the digitized shoreline was then broken into pieces. The shoreline segments were then assigned to fragments so that they could be rotated independently of one another, and stored in separate files. It might be questioned whether it would not be easier to digitize the original data sources rather than transform the complex projection used for the Ronov et al. (1989) atlas. The most common problem in transferring geologic information from the literature to other maps is that authors only rarely identify the map projection used; two of the critical parameters required for

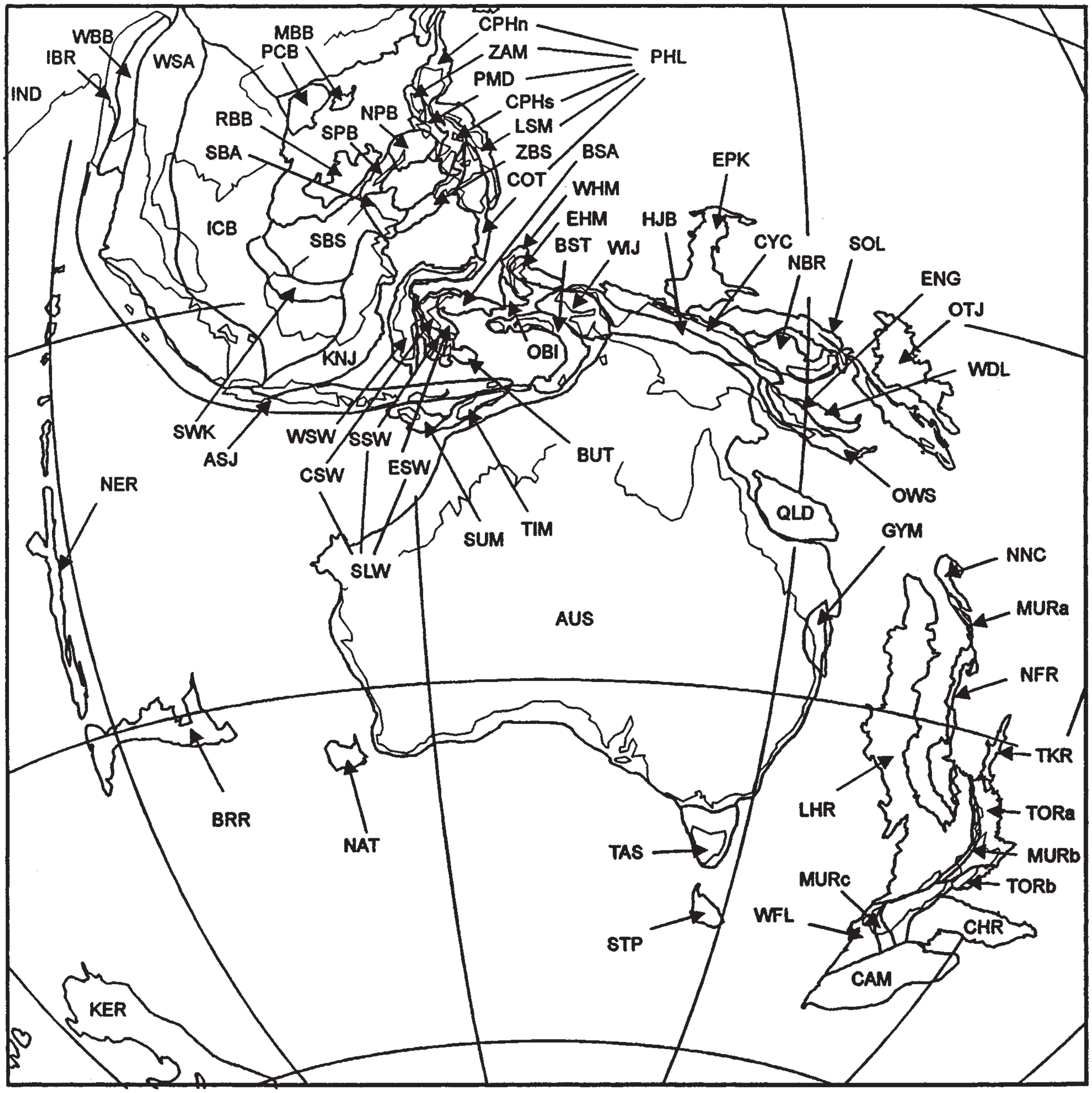

Figure 7. Continental blocks, terranes, and oceanic plateaus in the Australasian and western Pacific regions used in the plate tectonic model. Key to the abbreviations for the fragments is given in Tables 6, 8, 9, and 11.

digitization, center of the projection and earth radius, are almost never given. The other problem in preparing paleogeographic maps lies in stratigraphic correlation. The better the stratigraphic resolution, the less the amount of data available. To produce a shoreline for a particular time interval requires careful evaluation of the data used to establish chronostratigraphy. These time consuming tasks have already been performed in compiling the atlas.

Another potential source of global shoreline data is the set of stage by stage maps of Cretaceous shorelines, published by Funnell (1990) and Tyson and Funnell (1987, 1988) as well as the related atlas of Smith et al. (1994). In these cases, the shorelines were transferred from literature sources onto plate tectonic base maps (Smith, personal communication, 1995). However, they cannot be digitized without undoing all of the rotations of the blocks used in the reconstructions, a major task.

New seaways

Some modifications were made to the shorelines of Ronov et al. (1989). We added an arm of the Western Interior Seaway extending to the head of the Labrador Sea, following a suggestion by Cobban and Merewether (1983), and as indicted by Kauffman

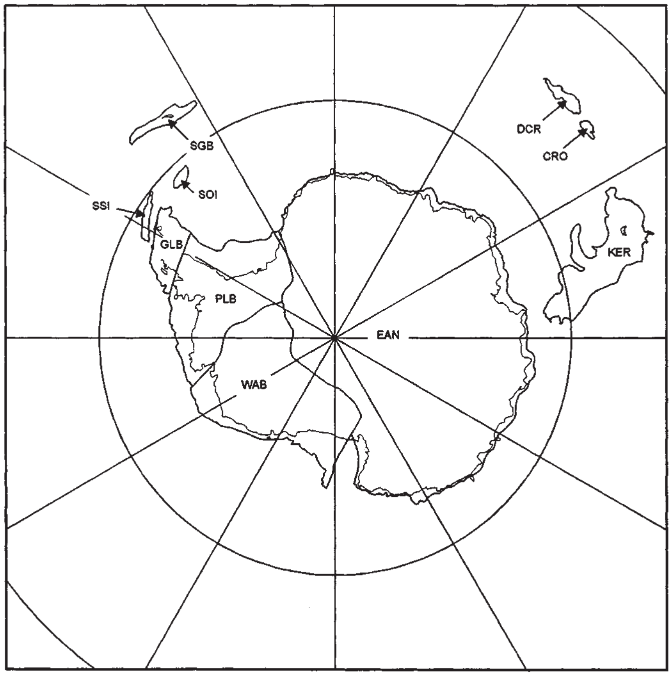

Figure 8. Continental blocks, terranes, and oceanic plateaus in the Antarctic region used in the plate tectonic model. Key to the abbreviations for the fragments is given in Tables 6 and 7.

(1985). We also added a continuation, as a seaway in the stretched region across Greenland, from Disco Island to Scoresby Sund and on to Europe. Stretching in this region is supported by the track of the Iceland Hotspot from northern Ellesmere through the Nares Strait to the vicinity of Disco Island and then across to Scoresby Sund. The center of the hotspot and the associated volcanism did not reach this region until the end of the Cretaceous and persisted until the late Eocene (Lawver and Müller, 1994).

New lands

Some added shorelines delineate previously unrecognized land areas, such as the Kerguelen Plateau–Broken Ridge–Ninetyeast Ridge complex.

The Atlantis concept. Coffin (1992a, b) recognized that much of Kerguelen Plateau must have had a long subaerial history. He backtracked five Ocean Drilling Program (ODP) sites on the plateau and concluded that their elevations at the time of emplacement ranged between 490 and 1,850 m above present sea level. His backtrack curves indicate that the sites were emergent for 10 to 40 m.y. after emplacement. He concluded that "many large igneous provinces in the marine realm have experienced a significant portion of their development subaerially and in shallow water. . . . The progressive development . . . in response primarily to thermal subsidence is what I coin 'Atlantis'-type evolution." (Coffin, 1992a, p. 949). To backtrack the elevation-depth history of the sites he followed the suggestion of Detrick et al. (1977), that it is valid to apply age-depth relationships for oceanic lithosphere to aseismic ridges and oceanic plateaus in the absence of evidence for later tectonism or thermal rejuvenation of the lithosphere. Parsons and Sclater (1977) had developed a simple thermal subsidence curve for sea floor produced at a mid-ocean ridge assuming cooling of the lithosphere as a single unit:

$$H = -2{,}500 - 350\ t^{1/2}, \qquad (6)$$

where 2,500 is assumed to be the mean depth of the mid-ocean ridge in meters, and 350 is an estimated global empirical subsidence constant also expressed in meters.

To estimate subsidence of Kerguelen Plateau, Coffin (1992a) used a modification of Equation 1:

$$D_0 = D_c - t^{1/2}, \qquad (7)$$

where D_0 is the elevation at the time of emplacement, D_c is the present elevation of the igneous basement corrected for isostatic response to the sediment load, C is an empirical subsidence constant determined from known age-depth curves, and t is the age of emplacement. D_0, D_c, and C are in meters and t is in millions of years.

Parsons and Sclater's (1977) original global estimate of the subsidence constant C = 350 m has been revised by Hayes (1988) to a global value of C = 300 m, and a regional value of C = 290 m for the southeast Indian Ocean. Coffin (1992a, b) used the latter value for his calculations of subsidence of Kerguelen Plateau, concluding, for example, that Site 749 had been emplaced 1,850 m above present sea level.

Parsons and McKenzie (1978) recognized that the single layer model of Parsons and Sclater (1977) overestimated the depth of older ocean crust. They proposed a two-layer model, in which both layers thicken with age, but the lower unit eventually starts to convect, bringing heat to the base of the upper layer and retarding its further thickening. This resulted in another thermal subsidence curve for the mid-ocean ridge:

$$h = -6{,}400 + 3{,}200e^{-t/62.8} = -6{,}400 + 3{,}200e^{0.0159t}. \qquad (8)$$

Stein and Stein (1992) proposed a better approximation of the observed data. For the first 20 m.y. of subsidence of ocean crust, they suggested

$$h = -2{,}600 - 365t^{1/2}, \qquad (9)$$

and for older crust

$$h = 5{,}651 + 2{,}473e^{-0.0278t}. \qquad (10)$$

Figure 9 shows a comparison of these subsidence curves and gives an impression of the uncertainty in subsidence analysis. The crossover between the depths of the Parsons and Sclater (1977) and Parsons and McKenzie (1978) curves is at 26.3 m.y., but if the Hayes (1988) equations are substituted, the crossover

TABLE 1. BLOCKS AND TERRANES IN THE NORTH AMERICAN SECTOR

Abbreviation	Name	Fixed to	Abbreviation	Name	Fixed to
AAK	Arctic Alaska Composite Terranes		NXF	Nixon Fork Terrane	UAT
ALX	Alexander Terrane	STSs	OLM	Olympic Mountains	X*
ALI	Aleutian Island Arc		ONK	Orphan Knoll	
BAF	Baffin Island Block		PEN	Peninsular Terrane	STSn
BAH	Bahamas Block		PWM	Prince William Terrane	STSs
BAJ	Baja California		QEI	Queen Elizabeth Islands	NAM
BER	Bering Shelf		ROS	Rosalind Bank	
BLP	Blake Plateau		RUBn	Northern Ruby Terrane	UAT
BLU	Blue Mountains		RUBs	Southern Ruby and Angayucham Terranes	AAK
BOW	Bowers Ridge		SAL	Salinian Block	
CAC	Cache Creek Terrane	STSs	SAN	San Simeon Terrane	SAL
CFH	Calaveras-Foothills Terrane	WNA	SDV	Seven Devils Terrane	
CHU	Chugach Terrane	STSn	SJN	San Juan Terrane	
COR	Coastal Oregon		SON	Sonomia Composite Terrane	WNA
CSB	Cay Sal Bank	NAM	STK	Stikinia Composite Terrane	STSs
CTL	Catalina Block	BAJ	STM	Stanley Mountain Terrane	SAL
CRZ	Cortez Block	BAJ	STSn	Superterranes I + II, Alaskan Peninsular segment	
DIR	Diriangen Bank				
ECQ	Eastern Composite Terrane and Quesnellia	WNA	STSs	Superterranes I + II, Southern Alaska-Western Canada	WNA
EKL	Eastern Klamaths	WNA			
ELS	Ellesmere Island Block		TRA	Tracy Arm-Bridge River Terrane	STSs
FGV	Franciscan-Great Valley Terrane	WNA	TUJ	Tujunga Terrane	SAL
FLC	Flemish Cap		UAT	Undifferentiated Alaskan Terranes	
GOL	Golconda Allochton	WNA	UMN	Umnak Plateau	
GRN	Northern Greenland		UNK	Unknown	
GRO	Guerrero Block	BAJ	VIZ	Vizcaino Terrane	
GRS	Southern Greenland		WKL	Western Klamaths	WNA
INK	Innoko Terrane	UAT	WNA	Western North America	
LAN	Lesser Antilles		WRNn	Wrangellia, northern segment	STSs
MOJ	Mojave Block	WNA	WRNs	Wrangellia, southern segment	STSs
NAM	Central North America		YAK	Yakutat Block	
NCA	Northern Cascades Range	X*	YKT_a	Yukon-Tanana Terrane, west	WNA
NIC	Nicolas Terrane		YKT_B	Yukon-Tanana Terrane, east	WNA
NSI	Northern Sierra Nevada	WNA			

Note: See Figure 2.
*X = not used in Cretaceous reconstructions.

TABLE 2. BLOCKS AND TERRANES IN THE CENTRAL AMERICAN SECTOR

Abbreviation	Name	Fixed to
CHC	Choco Block	
CHO	Chortis Block	
CTG	Chorotega Block	
MAY	Maya Block	NAM
MCC	Meseta Central de Chiapas	NAM
MNG	Maritime Nicaragua-Guatemala Terrane	
OGB	Oaxaca-Guerrero Block	WNA
YAQ	Yaqui Block	WNA

Note: See Figure 2.
NAM, Central North America; WNA, Western North America.

does not occur until about 140 to 150 m.y. Hence, the equations used by Coffin (1992a) are valid even though emplacement of Kerguelen Plateau took place between 101 and 114 Ma (Whitechurch et al., 1992). According to Coffin's calculations, areas of the plateau where basement lies less than 1,200 m below sea level would have been land at 70 Ma, but this does not take into account any subsequent history of thermal rejuvenation or the higher sea levels of the Cretaceous. Coffin estimated the elevations of emplacement to have been 500–1,850 m above present sea level, not taking subaerial erosion into account. The Stein and Stein (1992) formulae result in slightly lower estimates (50–60 m) of the original elevations.

The Detrick et al. (1977) suggestion that aseismic ridges and oceanic plateaus would subside in the same way as a mid-ocean ridge assumed that after emplacement there is no subsequent addition of heat. It applies to aseismic ridges like Walvis Ridge and Rio Grande Rise that formed at the Tristan da Cunha Hotspot that has

TABLE 3. BLOCKS AND TERRANES IN THE CARIBBEAN SECTOR

Abbreviation	Name	Fixed to
AVE	Aves Swell	LNT
BRB	Barbados Ridge	
BTA	Beata Ridge	LNT
CLB	Colombian Basin	LNT
CTN	Cayman Trough, north side	NAM
CTS	Cayman Trough, south side	
CUB	Cuba	
DIR	Diriangen Bank	
GRT	Grenada Trough	LNT
HPN	Hispaniola, northern part	
HPS	Hispaniola, southern part	
JAM	Jamaica	
LAN	Lesser Antilles Arc	
PDB	Pedro Bank	JAM
PRV	Puerto Rico-Virgin Islands Block	
ROS	Rosalind Bank	
VNB	Venezuelan Basin	LNT

Note: See Figure 2.
NAM, Central North America.

TABLE 4. BLOCKS AND TERRANES IN THE SOUTH AMERICAN SECTOR

Abbreviation	Name	Fixed to
BCH	Biron-Chaucha Block	SAM
CDC	Cordillera Oriental, Central y de la Costa	
CHC	Chaco Block	
COC	Cordillera Occidental	CDC
COL	Colorado Block	
CTG	Chorotega Block	
GLP	Galapagos	
MEB	Maurice Ewing Bank	VAL
NSA	Northern South America	
PAR	Parana Block	
SAM	Central South America	
SGB	South Georgia Block	
SLB	Salado Block	
STG	Santiago Block	SAM
THN	Tahuin Block	SAM
VAL	Valdez Block	

Note: See Figure 3.

TABLE 5. BLOCKS AND TERRANES IN THE AFRICAN SECTOR

Abbreviation	Name	Fixed to
ARB	Arabia	
ATL	Atlas Block	NAF
KBY	Kabylia	
NAF	Northwest Africa	
SAF	Southeastern Africa	NAF
SOM	Somalia Block	

Note: See Figure 4.

TABLE 6. BLOCKS AND TERRANES IN THE INDIAN OCEAN SECTOR

Abbreviation	Name	Fixed to
AGH	Agulhas Plateau	NAF
AMI	Amirante Bank	
BRR	Broken Ridge	
CHA	Chagos Bank	IND, X*
CRO	Crozet Island	EAN, X*
DCR	Del Cano Rise	EAN, X*
KER	Kerguelen Plateau	EAN
MAD	Madagascar Block	
MAU	Mauritius	
MOZ	Mozambique Plateau	NAF
NAZ	Nazareth Bank	SEY
NER	Ninetyeast Ridge	BRR
SEY	Seychelles Bank	

Note: See Figures 4, 7, and 8.
NAF, Northwest Africa; IND, India; EAN, East Antarctica
*X = not used in Cretaceous reconstructions.

TABLE 7. BLOCKS AND TERRANES IN THE EUROPEAN SECTOR

Abbreviation	Name	Fixed to
ALB	Alboran Block	
APL	Apulian Promontory	
BAL	Balearic Block	
CAL	Calabrian Block	
CSR	Corso-Sardinian Block	
EPO	Eastern Pontides	
ETR	Eastern Taurides	
EUR	Western Europe Block	
GAB	Galicia Bank	
GRN	Northern Greenland	
GRS	Southern Greenland	
HAB	Hatton Bank	
IBE	Iberia	
JAN	Jan Mayen	
KIR	Kirsehir Block	
KPD	Kopet Dagh	
LOM	Lomonosov Ridge	
MDT	Menderes-Taurus Block	
MOE	Moesian Platform	EUA
RHO	Rhodope Block	
ROC	Rockall Bank	
SKR	Sakarya Continental Block	
SIC	Sicily	NAF
VRZ	Vardar Zone	X*
WPO	Western Pontides	

Note: See Figure 5.
EUA, Eurasia; NAF, Northern Africa
*X = not used in Cretaceous reconstructions.

TABLE 8. BLOCKS AND TERRANES IN THE ASIAN SECTOR

Abbreviation	Name	Fixed to
AAK	Arctic Alaska Composite Terranes	
ABZ	Alborz Block	
AMTn	Akiyoshi-Mino-Tamba Composite Terrane (north)	
AMTw	Akiyoshi-Mino-Tamba Composite Terrane (west)	
ANY	Anadyr Terrane	
ASJ	Andaman-Sumatra-Java Arc	X*
ASR	Academy of Sciences Rise	
BSA	Banggai-Sula Terrane	
BST	Buru-Seram-Tanimbar Terrane	
CAF	Central Afghanistan	
CAT	Cathaysia	EUA
CIR	Central Iran Block	
CKB	Central Kamchatka Basin	
COT	Cotobato Terrane	PHL
CPHn	Central Phillipines, northern segment	PHL
CPHs	Central Phillipines, southern segment	PHL
CSK	Cherskiy Terrane	EUA
CSW	Central Sulawesi	SLW
CYC	Cyclops Terrane	
ECH	East China Sea Shelf	EUA
EHM	East Halmahera	OBI
EKO	Ekonay Terrane	X*
ERK	Eastern Ranges of Kamchatka	
ESW	East Sulawesi	SLW
EUA	Central Eurasia	
FAR	Farah Block	EUA
HDA	Hida-Abean Terrane	
HID	Hidaka-Tokoro Terrane	
HIM	Himalaya	IND
HMX	Precollision Himalaya, expanded outline dotted	IND
IBR	Indo-Burman Ranges	
ICB	Indo-China Block	EUA
IND	India	
ISH	Ishikari Terrane	
JAP	Japanese Terrane	
JFD	Jiangfudong Block	EUA
JMI	Jiamusi-Bureya Block	EUA
KAV	Kavir Block	
KMK	Kamuikotan Terrane	
KNJ	Kalimantan-N. Java	EUA
KOH	Kohistan Arc	
KOY	Koryak Terrane	X*
KPD	Kopet Dagh	EUA
KRO	Kronotskiy Terrane	
KVK	Kvakhon Terrane	
LAD	Ladakh Arc	
LCA	Lesser Caucasus	
LOM	Lomonosov Ridge	
LSA	Lahsa Block	EUA
LSM	Luzon-Saar-Mindanao Block	PHL
LUT	Lut Block	
MAK	Makran Block	X*
MAL	Malkinsk Terrane	
MBB	Macclesfield Bank Block	
NCB	North China Block	EUA
NEM	Nemuro Belt-Kuril Arc	
NER	Ninety east Ridge	
NPB	North Palawan Block	
OBI	Obi-Bacan Terrane	
OKA	Okhotsk Arch	
OLO	Oloi Terrane	
OLY	Olyutorsk Terrane	
OMG	Omgon Terrane	KVK
OMO	Omolon Massif	EUA
PAM	Pamir Block (Fixed to Karakorum)	EUA
PCB	Paracel Islands Block	EUA
PHL	Philippine Terrane	
PMD	Panay-Mindoro Block	PHL
PRB	Pribrezhnaya Terrane	
PRK	Prikolymsk Block	EUA
QIN	Qinling Belt	EUA
QTG	Qiangtang Block	EUA
RBB	Reed Bank Block	
RCSn	Ryoke-Chichibu-Sakawa Terrane (north)	
RCSw	Ryoke-Chichibu-Sakawa Terrane (west)	
RKU	Ryukyu Arc	
SAB	South Armenian Block	
SAY	South Anyui Terrane	
SBA	East Sabah	
SBS	East Sarawak-Brunei-West Sabah Block	SBA
SCB	South China Block	EUA
SEM	Southeast Maritime China	EUA
SHM	Shimanto Terrane	
SHR	Sirshov Ridge	
SIB	Undifferentiated Siberia	EUA
SIG	Siglan-Visk.-Neyneg Terrane	EUA
SIR	Sirjan Block	
SKA	Sikhote Alin Terrane	EUA
SKO	Sino-Korea Block	EUA
SLW	Sulawesi Block	
SND	Sanandaj Belt	
SOL	Solomon Islands	
SPB	South Palawan Block	SBA
SPG	Songpan-Ganze Block	EUA
SRD	Sredinniy Range	
SRI	Sri Lanka	
SSW	Central and Southeast Sulawesi	SLW
SWK	West Sarawak	EUA
TAL	Talesh	EUA
TXI	Taixi Terrane	EUA
TYY	Tailuko-Yuli-Yaeyama Terrane	X*
VAN	Van Block	
WAZ	Waziristan Block	
WBB	Western Burma Block	EUA
WHM	West Halmahera	OBI
WSA	Western Southeast Asia	EUA
WSK	Western Sakhalin	
WSW	West Sulawesi	SLW
YAM	Yamato Rise	
ZAM	Zambales Terrane	PHL
ZBS	Zamboanga-Sui Block	

Note: See Figures 5, 6, and 7.
*X = not used in Cretaceous reconstructions.

TABLE 9. BLOCKS AND TERRANES IN THE AUSTRALIAN AND SOUTHEAST ASIAN SECTORS

Abbreviation	Name	Fixed to
AUS	Australia	
BUT	Buton-Tukang Terrane	
CAM	Campbell Plateau	
CHR	Chatham Rise-Torlesse-South Island New Zealand Block	CAM
CYC	Cyclops Terrane	
ENG	East New Guinea	CYC
GYM	Gympie Terrane	AUS
HJB	Hunstein-Jimi-Bismark Terrane	
LHR	Lord Howe Rise	
MURa	Murihiku Terrane, northern segment	
MURb	Murihiku Terrane, central segment	
MURc	Murihiku Terrane, southern segment	
NAT	Naturaliste Plateau	AUS
NBR	New Britain Arc	
NNC	North New Caledonia	LHR
NFR	Norfolk Ridge	CAM
OWS	Owen-Stanley Range	
PHL	Philippine Terranes	
QLD	Queensland Plateau	
SOL	Solomon Islands	
STP	South Tasman Plateau	
SUM	Sumba	TIM
TAS	Tasmania	
TIM	Timor	
TKR	Three Kings Ridge	LHR
TOR_a	Torlesse-North IslandNew Zealand Block, north	CAM
TOR_b	Torlesse-North IslandNew Zealand Block, south	
WDL	Woodlark Island Block	
WFL	Western Foreland Block	CAM
WIJ	West Irian Jaya Block	

Note: See Figure 7.

TABLE 10. BLOCKS AND TERRANES IN THE ANTARCTIC SECTOR

Abbreviation	Name	Fixed to
CRO	Crozet Bank	
DCR	Del Cano Rise	
EAN	East Antarctica	
GLB	Graham Land Block	PLB
KER	Kerguelen Plateau	
PLB	Palmer Land Block	
SGB	South Georgia Island Block	
SOI	South Orkney Island Block	
SSI	South Shetland Islands	
WAB	West Antarctic Block	EAN

Note: See Figure 8.

TABLE 11. PLATEAUS AND ISLAND CHAINS IN THE PACIFIC

Abbreviation	Name	Fixed to
EMP	Hawaiian-Emperor Seamounts	PAC
EPK	Eauripik Rise	PAC
HES	Hess Rise	PAC
OTJ	Ontong-Java Plateau	PAC
SHT	Shatsky Rise	PAC

Note: See Figures 6 and 7.
PAC, Pacific Plate.

remained on the crest of the Mid-Atlantic Ridge while they moved away from it. It applies roughly to the Hawaiian-Emperor Seamount Chain that formed at the Hawaii intraplate hot spot as the Pacific plate moved over it, provided the age of the surrounding ocean crust at the time of emplacement is taken into account. It does not apply if the plateau remains over or near a hot spot that continues to be active for a long period of time (e.g., Iceland). Crough (1979) noted that there are large areas of ocean floor where the depths do not conform to simple subsidence, and observed that hotspots are a major source of bathymetric anomalies. Hotspots may create a thermal welt 1,000 km or more in diameter that can reverse the expected subsidence of ocean crust. The subsidence history of many of the atolls and guyots drilled on ODP Leg 143 did not follow the expected mid-ocean ridge analog (Sager et al., 1993). Similarly, the sedimentary record of the Iceland-Scotland Ridge supports a complex history of initial formation in the mid-Cretaceous with thermal rejuvenation in the Paleocene (Wold et al., 1993). Subsidence depending on thermal heat loss cannot proceed faster than the curves in Figure 9 indicate, but it may be slower or reversed if there is additional or subsequent heat supply.

Subsidence can also be the result of stretching. If stretching occurs rapidly, the subsidence resulting from it might outpace that resulting from contraction due to heat loss. However, stretching implies that deeper mantle material must upwell into the space created to maintain isostatic equilibrium. Depending on the thermal contrast between the cooler stretched lithosphere and the warmer upwelling asthenospheric material, the subsidence due to stretching can be much reduced or reversed.

Since its emplacement 114–101 Ma (Whitechurch et al., 1992), Kerguelen Plateau has experienced both thermal rejuvenation and stretching. Thermal rejuvenation of the northern part of the plateau has occurred during the time of formation of Broken Ridge about 88 Ma (Duncan, 1991), during the separation of Broken Ridge from Kerguelen Plateau about 43 Ma (Munschy et al., 1992), and since 39 Ma (Giret and Lameyre, 1983). Stretching has occurred in the Ragatt Basin of the southern part of the plateau at 88 Ma in the east and at 66 Ma in the west (Fritsch et al., 1992). Stretching of large areas of the plateau may have occurred during separation of Kerguelen Plateau–Labuan Basin from the Broken Ridge–Diamantina Zone by sea-floor spreading at 45–42 Ma (Fritsch et al., 1992). Clearly, with all of these complications to its history, Kerguelen Plateau cannot have subsided as rapidly as Coffin suggested, and must have been a large land area even longer than he proposed in

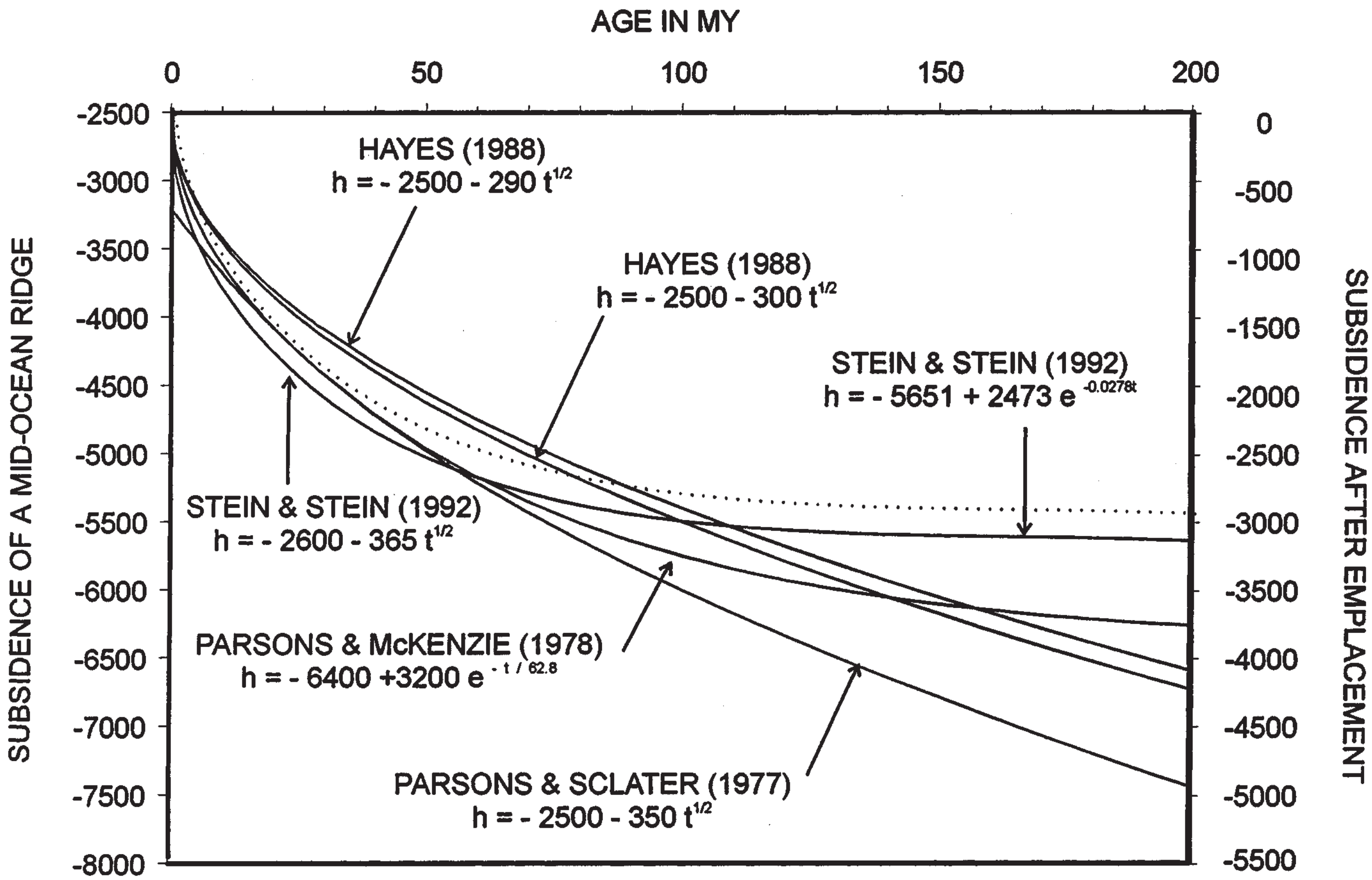

Figure 9. Subsidence of ocean crust and oceanic plateaus with no reheating after formation. The curves are from the literature sources indicated. t = age of emplacement in millions of years ago. The Parsons and Sclater (1977), Parsons and McKenzie (1978), and Hayes (1988) curves for subsidence of ocean crust assume the original depth of emplacement at the mid-ocean ridge crest to have been 2,500 m. Stein and Stein (1992) assumed the original depth of emplacement at the mid-ocean ridge crest to have been 2,600 m. The two equations of Stein and Stein are equal at t = 20. The scale at the right side of the diagram can be used to estimate the depth or elevation of emplacement of oceanic plateaus, following Detrick et al.'s (1977) assumption that it is parallel to normal ocean crust subsidence. The dotted curve is the Stein and Stein (1992) curve plus 100 m (assuming the original depth of emplacement at the mid-ocean ridge crest to have been 2,500 m rather than 2,600 m) to make it directly comparable with the others.

spite of the higher sea levels of the Late Cretaceous. The stratigraphic evidence from ODP drilling does not help determine how long large areas of the plateau were above sea level. At ODP Site 750, on the margin of the plateau in a present water depth of 2,030 m, there is an hiatus between nonmarine Albian coal-bearing beds and upper Turonian chalk and marl. It is difficult to estimate the depth of deposition of Late Cretaceous chalks at high latitudes; their occurrence implies only that the sea floor was below the photic zone. At ODP Site 747, where the present water depth is 1,695 m, there is a hiatus between 106-Ma basaltic basement and lower Santonian chalk and chert. At ODP Site 749, on the southern part of the plateau in water 1,069 m deep, there is a hiatus between 110-Ma basaltic basement and early Eocene chalk and chert.

Even if Kerguelen were emergent for much of the Late Cretaceous, the question remains how it would have been possible for large land tetrapods to reach Kerguelen Plateau from Antarctica across the deeper ocean floor that separated Kerguelen Plateau from Prydz Bay, and how they would have reached India from Kerguelen Plateau. With present water depths of 3,600 m and sediment thickness of 1.5 km (Heezen and Tharp, 1980), the depth of emplacement would have been about 1,500 m.

As mentioned above, large land animals find water a major barrier. The biogeographic boundary in Indonesia, "Wallace's Line," between Bali and Lombok and extending northward as the Macassar Strait between Borneo and Celebes, has been recognized as a major boundary between the faunas of southeast Asia and Australia. Other parts of the Indonesian archipelago were connected to the southeast Asian mainland by land during the low sea level stands of the late Quaternary, but there was water between Bali and Lombok. Similarly, the end of separation of the North and South American mammals during most of the Cenozoic has been linked to the closure of the Isthmus of Panama (Marshall, 1985).

The history of the Indian Ocean prior to 84 Ma (Anomaly 34) is poorly constrained. Most of the earlier development took place during the Cetaceous magnetic quiet zone (84–118 Ma). According to Cande et al. (1989), the only magnetic anomalies of the M series (118–165 Ma) that can guide plate tectonic reconstruction in the Antarctic sector are along the Astrid Fracture Zone north of Queen Maud Land (M0–M9, 118–129 Ma). These lie in the zone of separation between Antarctica and Africa. Near Africa, M anomalies have been recognized off southeastern South Africa (M0–M12, 118–135 Ma), in the Mozambique Channel (M2–M22, 123–152 Ma), and in the Somali Basin (M0–M22, 118–152 Ma). Parts of the M series have also been recognized off northwestern Australia (M0–M25, 118–155 Ma). An anomaly has been noted along much of the Antarctic margin (shown in Lawver et al., 1992), but is probably related to the ocean-continent crustal boundary. There are no anomalies in the Enderby Basin, between Kerguelen Plateau and Enderby Land.

One possibility for connection to Antarctica is that Kerguelen Plateau was originally adjacent to Antarctica and the separation occurred during the Cretaceous Magnetic Quiet Interval (120.4–83.5 Ma), possibly along a transform as the Enderby Basin opened. Another possibility is that Kerguelen Plateau originally formed in the space between Antarctica and India as the latter separated, and originally had an east-west orientation. It could then have rotated to its present northwest-southeast orientation as the Enderby Basin opened during the Cretaceous Magnetic Quiet Interval.

The connection from Kerguelen Plateau to India via Sri Lanka existed as late as 80 Ma. There may have also been a land route along Ninetyeast Ridge, although Coffin's (1992b) estimates of its elevation at the time of emplacement are in the order of 300 m. Subsiding at the rate of a mid-ocean ridge, the islands would have been above sea level for only about a million years.

There exists a possibility that India remained connected to Madagascar for some time after separation via the Mascarene Plateau (Storey et al., 1992). The age of the oceanic part of Mascarene Plateau is usually cited as 64–33 Ma (Duncan and Hargraves, 1990; Meyerhoff and Kamen-Kaye, 1981), but these dates reflect volcanism at the time of separation from India and later. These younger strata would have covered volcanic deposits formed at the time of separation from Madagascar. Coffin (1992b) estimated the elevation of emplacement of Mascarene Plateau to be in the order of 600 m above present sea level. It is thought to be a product of the Reunion hotspot (Morgan, 1981) and may have an anomalous subsidence history. It could have formed a land bridge between Indian-Seychelles and Madagascar as late as 75 Ma.

Could there have been a land connection from Madagascar to Africa? Today, Madagascar is separated from Africa by the Mozambique Channel. The Davie Fracture Zone runs obliquely through the Mozambique Channel from southwestern Madagascar to northern Mozambique. Davie Ridge, less than 200 m deep, is one of several elevated segments of the fracture zone. Intervening segments are deep (>2,900 m) and buried beneath thick sedimentary fill. The Mozambique Strait is not a site of sea-floor spreading, but a region that has been characterized by transform movements; its subsidence history is obscure. Neither is it clear why some segments should be so shallow while others are deep. Could it at some time have been emergent, acting as a gangplank from Africa to Madagascar?

Fracture zones are known to have unusual subsidence histories. The Romanche Fracture Zone in the Central Atlantic is capped by several carbonate platforms that are currently at depths of about 1 km. Dredged rocks suggest that these carbonate caps formed when the fracture zone was emergent or close to the surface sometime during the Neogene (Bonatti et al., 1977, 1994). The vertical tectonics are thought to be a function of transpression and transtension. Deformation of the sea floor as a result of intraplate stress is thought to be large enough to affect sea-level both regionally and globally (Cloetingh, 1986). It has also become apparent that intraplate stresses affect the interior of the continents and are reflected in rifted basins (Janssen et al, 1995).

In contrast to the Atlantic, the Indian Ocean has experienced several major episodes of plate reorganization, with new spreading ridges cutting across older ocean floor (Sclater et al., 1977). This has resulted in intraplate stress that is recognized in the series of undulations of the ocean floor west of Ninetyeast Ridge (Cloetingh and Wortel, 1985). Transient intraplate stress might have caused the Davie Fracture Zone to become emergent at some time in the past, and might be responsible for the great differences in bathymetry along its length.

There are a number of plateaus in the Pacific Basin that were probably at least partly emergent at the time of their emplacement: Shatsky Rise, Hess Rise, Magellan Rise, Manihiki Plateau, Ontong Java Plateau, and Euaripik Rise. In addition to these, there are a number of terranes in eastern Asia, the Bering Sea, and on the Alaskan margin that were probably either plateaus or island arcs in the Pacific during the Cretaceous: the Philippine Arc, Ishikari Terrane, Hidaka-Tokoro Terrane, the Siglan-Viskichun-Neyneg Terrane, Okhotsk Arch, Academy of Sciences Rise, the Nemuro Belt, Kvakhon Terrane, Prikolymsk Block, Omgon Terrane, the Sredinniy Range, the Eastern Ranges of Kamchatka, Malkinsk Terrane, Olyutorsk Terrane, Kronotskiy Terrane, Koryak Terrane, Ekonay Terrane, Shirshov Ridge, Bowers Ridge, Umnak Plateau, Prince William Terrane, and the Yakutat Block. However, unlike the features in the Indian Ocean, they were isolated from each other and from other emergent areas and probably had only a minor effect on surface ocean circulation.

SUBMARINE RIDGES AND PLATEAUS

In addition to the oceanic plateaus that were emergent after their emplacement, there are a larger number of areas of extensive flood basalt volcanism that formed shallower areas of ocean floor when they were emplaced (Larson, 1991a, b; Coffin and Eldhom, 1993a, b). These include the East Mariana Basin flood basalts, the Nauru Basin flood basalts, the Pigafetta Basin flood basalts, and the Caribbean flood basalts. If, since emplacement, they have undergone normal subsidence, their present depths indicate that they were about 2,000 m deep at the time of their origin. These extensive areas, shallower than most of the mid-ocean ridge crest, would have had a major influence on deep ocean circulation. These features are not shown on the maps presented here.

Continental topography

The continental topography for the Campanian (80 Ma) was reconstructed from the Late Cretaceous map of Ronov et al. (1989) by assigning elevations to boundaries defining their "orogenic areas" (1,000–3,000 m), their "intermontane basins" (500–1,000 m), their "areas of continental erosion" (200–500 m), and their "areas of continental deposition" (0–200 m). The boundaries were digitized and converted to the corresponding contour elevations. The digitized contours were then superposed on the global tectonic model and broken into segments, using the same procedure as for shorelines. After being rotated to their Cretaceous positions, the contours were reconnected to produce the paleotopographic map shown in Figure 10. The Cretaceous contours were then gridded onto a 1° by 1° grid using the continuous splines in tension algorithm of Smith and Wessel (1990). The 1° by 1° grid was then averaged to 2° by 2° to be used as a boundary condition for a GENESIS climate simulation (DeConto et al., this volume, Chapter 21).

DISCUSSION

Global reconstructions at 20-m.y. intervals from 140–80 Ma are shown in Figures 11–14. The rotations are discussed in the Appendix. The relative positions of the major continental blocks are determined by sea-floor magnetic lineations. Most previous reconstructions for the Early and early Late Cretaceous show six continental blocks—North America–Greenland, South America, Africa, Antarctica-Australia, India-Madagascar, and Eurasia—separated by deep ocean passages. Our model has only three continental blocks—North America–Greenland-Eurasia, South America–Antarctica-Australia-(Kerguelen)-India-Seychelles-Madagascar, and Africa— throughout most of the Cretaceous. As discussed above, the Kerguelen Plateau is mostly an oceanic plateau but connected India-Madagascar to Antarctica until late in the Late Cretaceous. The effect of this configuration is that the North, Central, and South Atlantic, and the developing Indian Ocean form an isolated deep marginal sea off the Tethys, connected to the Pacific across the relatively shallow Caribbean plate until the Late Cretaceous. The areas in which our reconstructions differ most significantly from others are the Arctic, the North Atlantic, the Caribbean, the South Atlantic, the Indian Ocean, and the Antarctic.

Arctic

Because of its potential as a site of deep water formation, the size of the Arctic Ocean basin and the depth of connections between it and other ocean basins are critical to understanding paleoceanography.

The Canadian Basin of the Arctic Ocean opened during the Early Cretaceous with a "windshield wiper" motion of the Arctic Alaska–Chukotka Block (Rowley and Lottes, 1988, 1989; Lawver and Scotese, 1990; Lawver et al., 1990). However, this block alone does not fill the space between North America and northern Asia, leaving room for an older ocean basin in the western Arctic. We included the terranes of central Alaska ("Undifferentiated Alaskan Terranes") and the Bering Sea Shelf in this rotation; adding these blocks fills most of the space between North America and northern Asia, but leaves the possibility of a smaller Arctic Basin connected with the Pacific in the Jurassic and early Early Cretaceous. The collision of the Arctic blocks with the Superterranes off western North America is shown as causing the oroclinal bending that produced the Alaskan Peninsula. The times for these motions are not well constrained, and are guesses based on meager evidence and geometrical constraints. We assume that the rotation opening the Canadian Basin started at 134 Ma, the collision with the Superterranes began at 123 Ma, and that the rotation ceased at 90 Ma. The Bering Sea Block continued on, reaching its present position at 50 Ma.

The formation of the Aleutian Arc, trapping a piece of the Kula plate with Shrishov Ridge, Bowers Ridge, and Umnak Plateau, is assumed to be synchronous with the initiation of opening of the Norwegian-Greenland Sea at about 58 Ma. The reorganization of plate motions that caused spreading to jump from the Labrador Sea to the Norwegian-Greenland Sea was a response to compression of the Pacific Arctic as a result of convergence between North America and Asia. The Labrador Sea had been opening like a fan, and the Norwegian-Greenland Sea opened as a transform motion, with the sides remaining parallel. This reorganization resulted in splitting the Lomonosov Ridge off from the eastern Eurasian margin, in development of the Eurasian (Amundsen-Nansen) Basin, and significant enlargement of the Arctic Basin.

Removing the effects of stretching between the Baffin Block and North America makes a tighter fit of northern Greenland to North America, but when this fit is tight a space remains between southern Greenland and North America. We divided Greenland into a northern and southern part to achieve a tighter fit of southern Greenland against North America and to ensure that magnetic lineations younger than the Cretaceous Quiet Interval match properly. We assume that the stretching occurred between 116.5 and 83.5 Ma along a line connecting the sites of the younger large Thulean volcanic provinces (70–40 Ma; Ziegler, 1988). The Thulean volcanics are exposed on both the west and east coasts of Greenland and formed as the Iceland hot spot moved beneath the continent (Lawver and Müller, 1994). Because Eurasia is attached to northern Greenland, the stretching we incorporated into the model has effects throughout the Arctic. It enlarges the Arctic Basin slightly, allowing the rotation of Arctic Alaska–Chukotka, Central Alaska, and the Bering Shelf to proceed without overlap of these blocks on Eurasia. Motions for southern Greenland are defined by magnetic lineations in the Labrador Sea; the rotations we used are after several literature sources, following Wold (1995).

Figure 10. Paleotopographic map for the Campanian (80 Ma). Contour intervals are 0.2, 0.5, 1.0, 2.0, and 3.0 km.

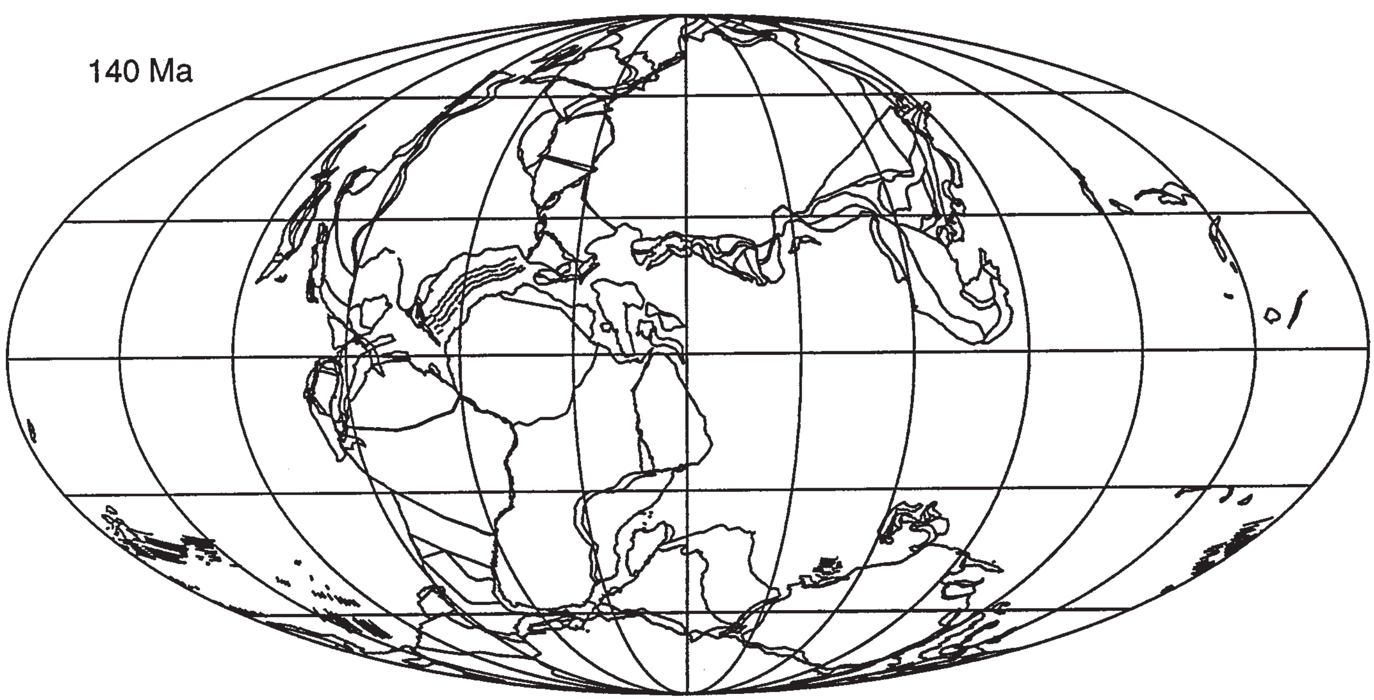

Figure 11. Global plate tectonic reconstruction for 140 Ma.

120 Ma

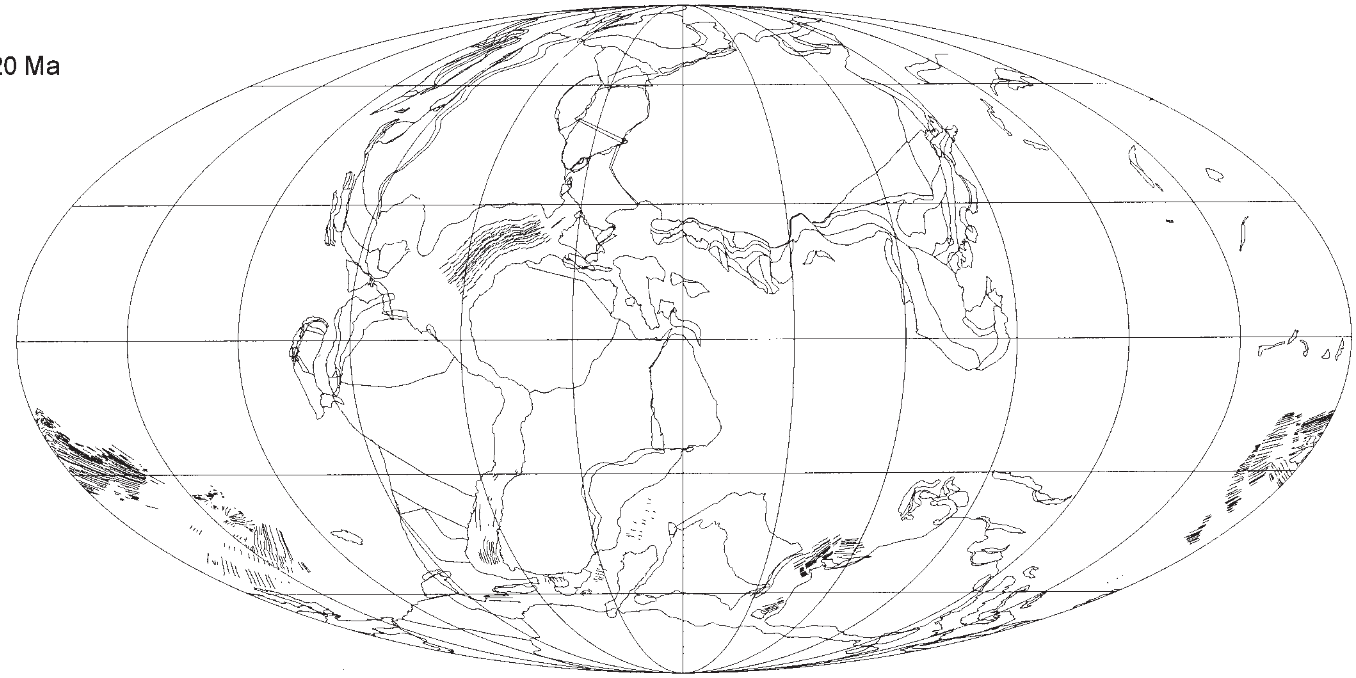

Figure 12. Global plate tectonic reconstruction for 120 Ma.

100 Ma

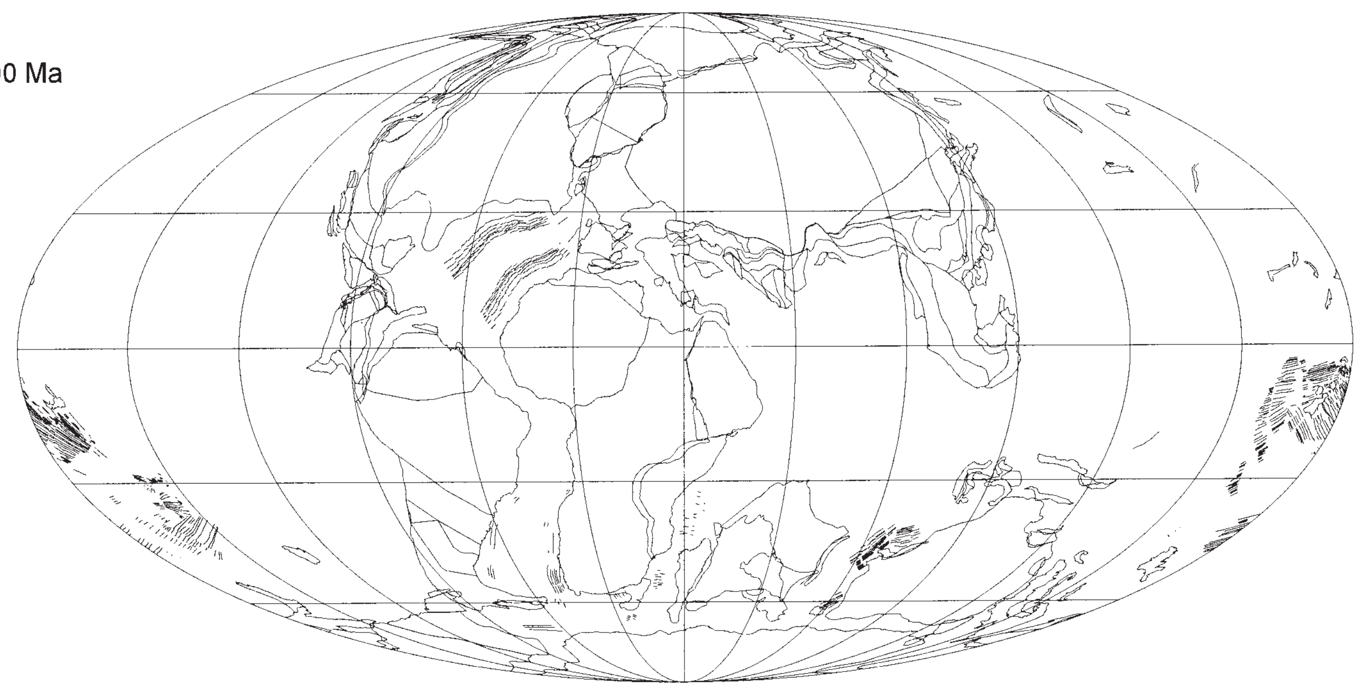

Figure 13. Global plate tectonic reconstruction for 100 Ma.

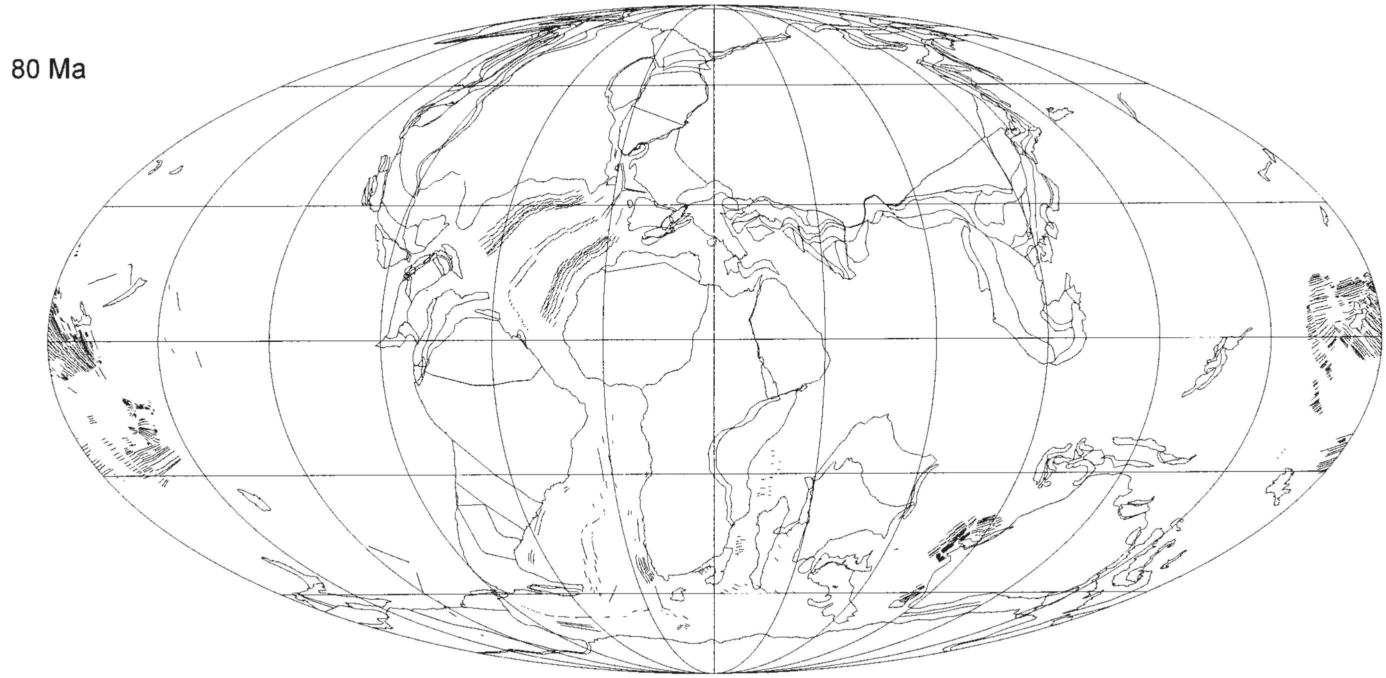

Figure 14. Global plate tectonic reconstruction for 80 Ma.

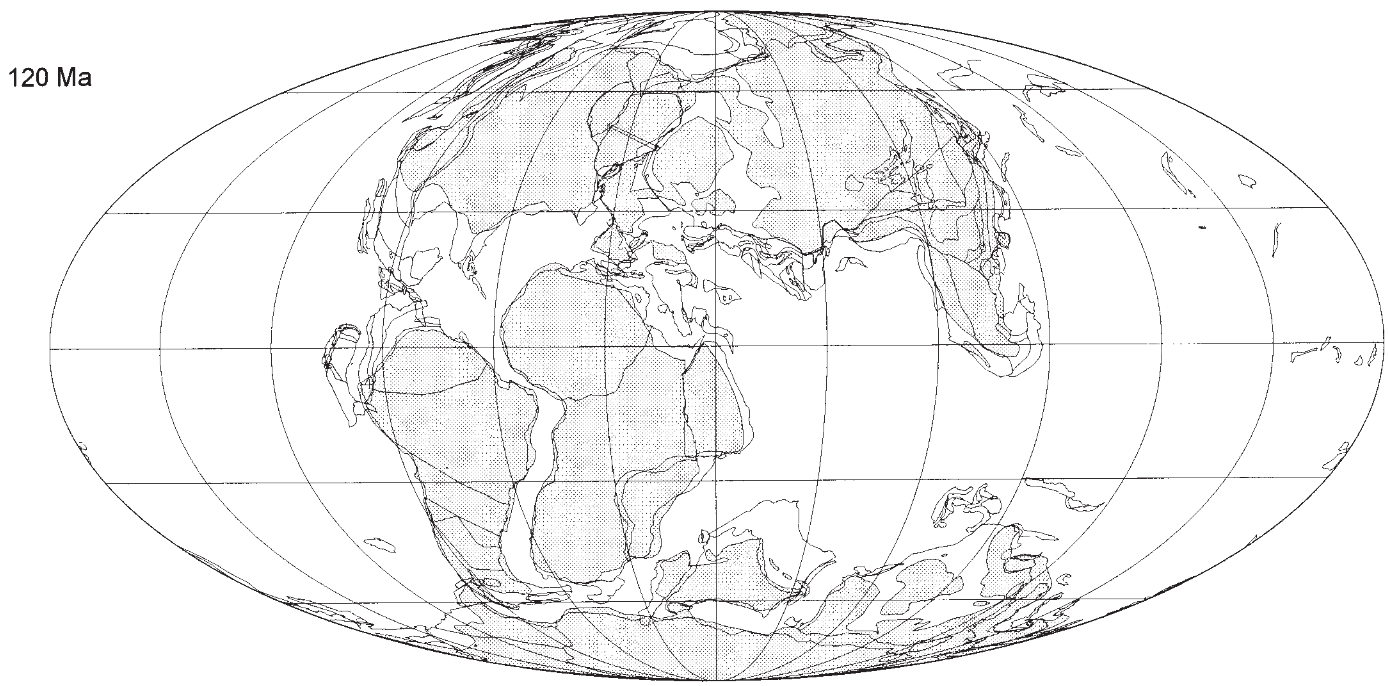

Figure 15. High sea-level stand shorelines, mostly from the data of Ronov et al. (1989), for the Early Cretaceous superposed on the plate tectonic reconstruction for 120 Ma. Shaded areas are land. Lakes are in black.

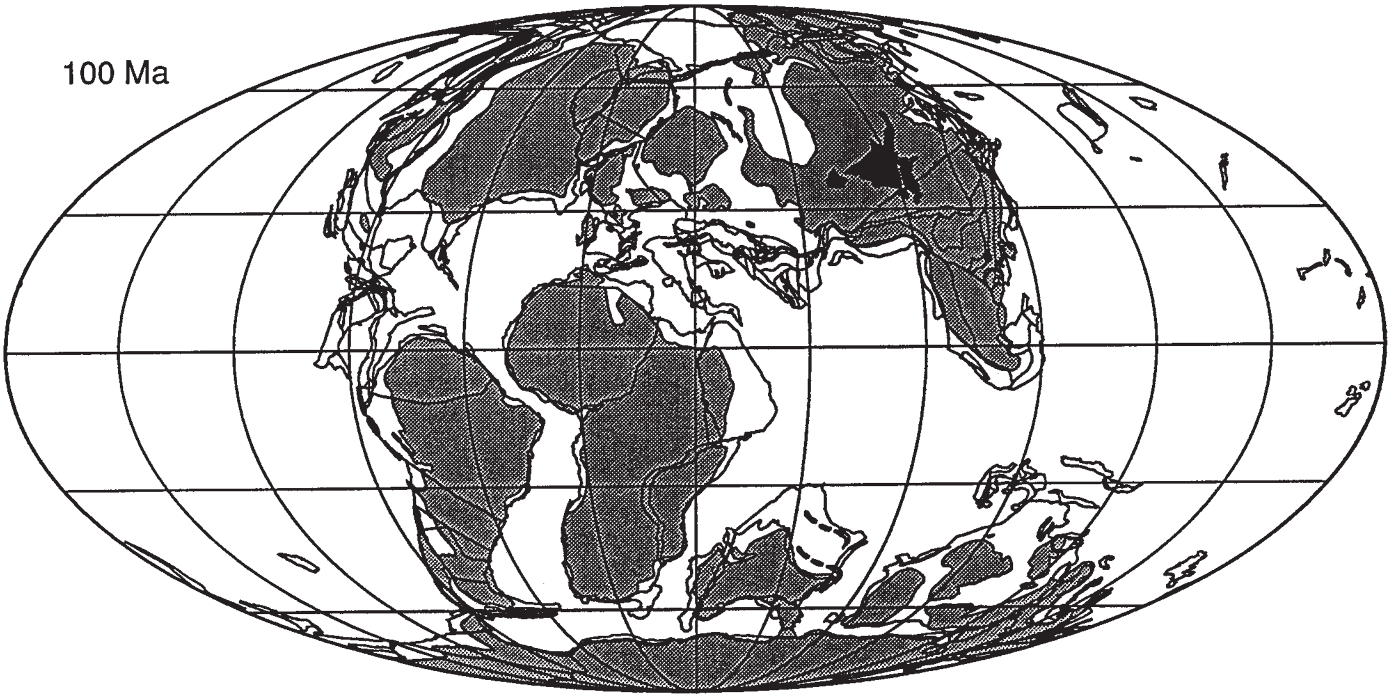

Figure 16. High sea-level stand shorelines, mostly from the data of Ronov et al. (1989) for the Early Cretaceous superposed on the plate tectonic reconstruction for 100 Ma. Shaded areas are land. Lakes are in black.

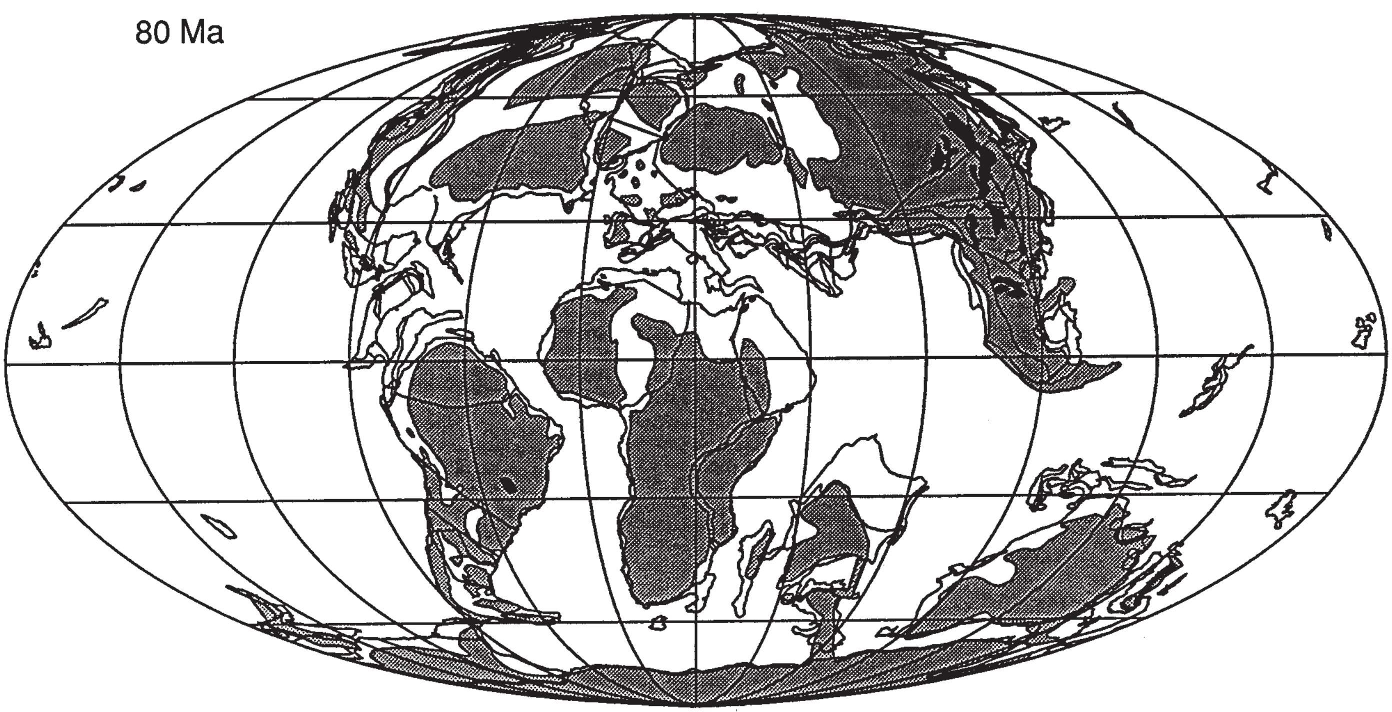

Figure 17. High sea-level stand shorelines, mostly from the data of Ronov et al. (1989), superposed on the plate tectonic reconstruction for 80 Ma. Shaded areas are land. Lakes are in black.

The Norwegian-Greenland Sea has been shown as partly open since the late Paleozoic on several maps (e.g., Barron et al., 1981; Ziegler, 1988). This was because the nature and age of Vøring Plateau was not known, and overlap of such a large feature with Greenland was unacceptable. Vøring Plateau is now known to be Eocene (Thiede, 1980), and it is recognized that there are large areas of early Cenozoic volcanics on the East Greenland and western European margins (Coffin and Eldholm, 1993a, b). Srivastava and Tapscott (1986) showed a closed Norwegian-Greenland Sea at Anomaly 25 time (55.90 Ma), and this has been followed by subsequent reconstructions (Rowley and Lottes, 1988, 1989; Lawver and Scotese, 1990; Lawver et al., 1990). We used the rotations of Wold (1995) for the opening of the Norwegian- Greenland Sea from 57.55 Ma (Anomaly 26), and assume that stretching of the margin occurred between then and about 80 Ma.

Our reconstruction results in a deep Canadian Basin being formed during the Cretaceous, but there are no deep passages leading from it to the North Atlantic. Geometric considerations indicate that if narrow deep passages existed between the Canadian Basin and the Pacific they were open only briefly.

North Atlantic

The North Atlantic, the region between the Greenland-Iceland-Scotland Ridge in the north and the Oceanographer Fracture Zone, has had a particularly complex history. Iberia cannot be closed tightly to the Grand Banks with Flemish Cap and Galicia Bank in their present positions. Anomaly M0 (120.40 Ma) is the only guide to an Early Cretaceous location of Iberia relative to the Grand Banks. No older anomalies have been identified that would help constrain the fit of Iberia to the Grand Banks. On the European margin, Porcupine Bight is a notch the size and shape of Flemish Cap (GEBCO sheet 5-04). Porcupine Bight is usually considered to be an aulacogenlike feature formed by spreading (Roberts et al., 1981b), but its dimensions and depth are not like other aulacogens. We included some arbitrary rotations that move Flemish Cap and Orphan Knoll into Porcupine Bight and fill in the small space between Rockall Trough and the Grand Banks with Galicia Bank (Fig. 11). These allow the Iberian and Grand Banks margins to be fitted tightly together at 130 Ma. Except for Anomaly 34 (83.5 Ma, shown in Fig. 14), magnetic lineations only allow the motions of Iberia to be determined relative to North America, not to Europe. As Srivastava and Tapscott (1986) discussed, reconstructions of magnetic lineation patterns require an additional plate, which they named the “Porcupine plate” between Iberia and the European margin.

The next motion in the North Atlantic region was the formation of Rockall Trough, discussed above and shown in Figures 12 and 13. We assume that this motion occurred during the Early Cretaceous, synchronous with stretching in the North Sea and formation of basins in northern Germany.

The next opening was the Labrador Sea, which started during the Cretaceous Magnetic Quiet Interval and ended by Anomaly 13 (33.06 Ma); only its younger history is well constrained by magnetic lineations. We followed the rotations of Roest and Srivastava (1989) to Anomaly 31, but devised new rotations for the older history. We assume that the Labrador Sea was closed tightly at 116.5 Ma and that it opened as a rift propagated from south to north. The opening of the Labrador Sea may have stopped because the propagating rift encountered the stronger lithosphere of the Canadian Basin, analogous to the Red Sea rift stopping before reaching the Mediterranean (Steckler and ten Brink, 1986). The fan-shaped opening of the Labrador Sea had another significant effect in forcing compression on the far side of the Arctic.

Early in the Cenozoic, the opening of the Labrador Sea slowed and sea-floor spreading changed to produce a transform motion between North America–Greenland and Eurasia, opening both the Norwegian-Greenland Sea and the Eurasian Basin of the Arctic. In our model, stretching of the Norwegian and Greenland margins occurred from about 80 to 58 Ma. The separation of Greenland from Scandinavia did not occur until the late Paleocene. Because of the Greenland-Iceland-Scotland Ridge (Bott, 1985; Wold et al., 1993), there has never been a deep-water connection between the North Atlantic and the Arctic.

Caribbean

There have been many models of the evolution of the Caribbean. Pindell and Barrett (1990) reviewed 12 that had been suggested by earlier investigators and proposed a new one, which was subsequently slightly modified by Pindell (1993). The older reconstructions reflected belief that the Caribbean plate had been generated in situ, whereas most later reconstructions assumed it had been formed as an oceanic platform in the Pacific. All of the Pacific entry models implied plastic deformation of the Caribbean plate proper (Venezuelan Basin, Beata Ridge, Colombian Basin) as well as the smaller peripheral entities (Greater and Lesser Antilles, Chortis, Panama–Costa Rica, etc.), as shown in the figures of Pindell and Barrett (1990) and Pindell (1993). Some of the reconstructions suggesting entry of the Caribbean plate from the Pacific showed the Greater Antilles on what is now the eastern edge of the plate, but did not explain how they came to be along the northern side today. Other reconstructions have shown the Caribbean plate entering sideways, with the present northern margin being the leading edge, with the Lesser Antilles alongside the Greater Antilles, but did not explain the translation of the Lesser Antilles to their present position on the eastern edge of the plate. The Pindell and Barrett (1990) reconstruction required Chortis to “back out” from its position in Central America into the Pacific to allow the Caribbean plate to enter, and then to return to its present position, like a swinging door.

Montgomery et al. (1994) cited the presence of Early Jurassic (195 Ma) radiolaria on Hispaniola as proof of a Pacific origin of the Caribbean plate. These fossils were deposited in deep waters before the separation of North America and Africa, and before there was any Proto-Caribbean Seaway between North and South America.

Hay and Wold (1996) found that the earliest time of passage through the gap between North and Central America and South America is tightly constrained to be about 100 Ma, and shown in Figure 13. They also noted that if the Caribbean plate is oriented to fit through the gap when it first becomes wide enough for passage, its eastern margin lies offshore South America and has the same shape as the northern South American margin. They found very tight fits between the present southern margin of the Caribbean plate and the Mesozoic rocks of the Cordillera Occidental that formed the western margin of northern South America in the Early Cretaceous, as shown in Figure 11. This suggested that at least the south side of the Venezuelan and Colombian Basins might be thinned continental material, as had been suspected from a seismic section in Aruba Gap showing dipping reflectors interpreted as sediments beneath horizontal basalts (Hopkins, 1973), and from subsequent seismic investigations revealing an extensive area with layered rocks beneath the basalts (Stoffa et al., 1981).

The “Caribbean Plate” consisting of the Grenada Trough, Aves Swell, Venezuelan Basin, Beata Ridge, and Colombian Basin, is one of the largest anomalously shallow submarine regions. Hay and Wold (1996) suggest that its advance into the Atlantic was stopped by collision with South Florida and the Bahama Platforms at the end of the Cretaceous. This caused a major reorganization of Atlantic plate motions, evident in the change of strike of North Atlantic fracture zones from southeast-northwest to nearly east-west, as shown on the map of Cande et al. (1989).

South Atlantic Ocean

Most reconstructions have shown the South Atlantic to have opened like a fan, widest in the south and narrowing to the north (Barron et al., 1981; Barron, 1987; Scotese et al., 1988, 1989; Scotese, 1991), although it must be noted that the effect is enhanced on Mercator and Cylindrical Equidistant projections. The fanlike opening results, in part, from not accounting for the bending of the South American margin by the stretching that formed the aulacogens of the southern Atlantic margin. It also results from making a smooth rotation from the separation of the Brazilian margin south of Cabo Branco to Anomaly 34. With our continental outlines this results in an overlap of South America and Africa during part of the Cretaceous Magnetic Quiet Interval. We assume that the initial motion of opening the equatorial and southern tropical parts of the South Atlantic was accomplished by a transform motion along the northeast Brazilian margin of South America and the conjugate Guinea margin of Africa. This results in a parallel-sided South Atlantic during most of the Cretaceous Magnetic Quiet Interval, as shown in Figure 12. In our model, the early South Atlantic was similar to the modern Red Sea, but three times as long.

At present, most of the South Atlantic lies in regions of excess evaporation over precipitation. The loss of fresh water to evaporation is partially offset by runoff from land. The South Atlantic receives the flow of two of the world’s largest rivers, the Amazon and Zaire (Congo). However, before the Miocene the flow of these rivers was to the Pacific and Indian Oceans, respectively (Emery and Uchupi, 1984). This suggests that during much of its history the South Atlantic may have had higher than average salinities. This is especially likely to have been true during the Cretaceous when the South Atlantic was much narrower than it is today.

Indian Ocean

The Indian Ocean region has had a complex history. Its late Cenozoic development can be understood from magnetic lineations but many models have been proposed for its earlier evolution (McKenzie and Sclater, 1971; Sclater et al,, 1977; Norton and Sclater, 1979; Besse and Courtillot, 1988; Powell et al., 1988, 1989; Royer et al., 1992). The few magnetic lineations in the Indian Ocean older than Anomaly 34 do little to constrain movements during the Cretaceous.

In most reconstructions, Madagascar is assumed to have moved almost due south from its home on the Somali margin to its present position, carrying India, Antarctica, and Australia with it (Barron, 1987; Lawver et al., 1992). The north-south motion is based on an interpretation of magnetic lineations and fracture zones in the Somali Basin by Cochran (1988). There are five north-south ship tracks on which the magnetics of the Somali Basin were recorded. Cochran’s interpretation assumed that the magnetic lineations run east-west and are offset by fracture zones between each of the ship tracks parallel to the Davie Fracture Zone where it is well observed in the Mozambique Channel. The alternative explanation is that the lineations are oriented northeast-southwest. We believe that the separation of Madagascar from Africa is linked to the opening of basins along the margin of South America. We noticed that the poles for stretching in these aulacogens are close to published poles for the motion of Madagascar. In the rotation file, we attached Madagascar, India, Antarctica, and Australia to the San Jorge Block of South America from 160 to 132.07 Ma. As the San Jorge, Colorado, Salada, and Parana Basins of South America open, that continent “unwraps” from Africa; the Falkland Plateau carries Madagascar clockwise in an arc from Somalia to its present position, as shown in Figures 11 and 12. We move Madagascar with the San Jorge Block of South America from its fit to its present position. This motion is an arc, not the southward motion shown by Rabinowitz et al. (1983) and Coffin and Rabinowitz (1987). The motion would correspond to magnetic lineations having a northeast-southwest orientation in the northern part of the Somali Basin, acquiring a more east-west orientation north of modern Madagascar. However, the existing lineations are not violated by our proposed motion of Madagascar.

The motion of India relative to East Antarctica is known only back to Anomaly 34; earlier positions must be inferred from the age of Kerguelen Plateau. After moving with the San Jorge Block until about 132 Ma, India began to rotate away from Antarctica and to move relative to Madagascar (Fig. 12). The separation of India from Madagascar is usually assumed to be pull apart, either a fan-shaped opening widest in the north (Barron, 1987), or orthogonal (Scotese et al., 1988, 1989; Lawver et al., 1992). The straight margins of eastern Madagascar and western India suggest that transform motion occurred. In our model, the movement of India away from Antarctica caused left-lateral transform motion relative to Madagascar, producing the straight margins of eastern Madagascar and western India (Figs. 11 and 12). The separation of Madagascar from India probably occurred in conjunction with an extensive short-lived episode of volcanism from the Marion Hotspot at 88 Ma (Storey et al., 1995). Figure 13 shows the position of the two blocks 8 m.y. after separation.

We assume the Seychelles to be a fragment of Africa, initially attached to Madagascar (Fig. 11). It was then transferred to India by the transform motion between India and Madagascar (Fig. 12), and subsequently transported with India to its present position (Figs. 13 and 14). The age of the basement rocks recovered on Mascarene Plateau is circa 64 Ma, about the time of separation of Seychelles from India. We believe that the substructure of the Mascarene Plateau may be older, because it fits well along the Indian margin and fills the space between India and Madagascar on our 100 Ma reconstruction. Nazareth Bank basement ages are not known, but we show that if it existed in the Late Cretaceous, it could have served as a land bridge between India and Madagascar. Figure 13 shows Nazareth Bank to demonstrate that its initial formation might have been from the Marion Hotspot as India moved away from Madagascar.

Separation of Broken Ridge from Kerguelen Plateau occurred during the Cenozoic (Munschy et al., 1992).

We assumed that the Indo-Burman Ranges had their original home between India and Australia, and that they moved on a transform along the Indian Margin during most of the Cenozoic.

Antarctic Peninsula

Early reconstructions fit the Antarctic Peninsula into the space between South America and Africa (Smith and Hallam, 1970). Harrison et al. (1979), Powell et al. (1980), and Barron et al. (1981) showed that the Antarctic Peninsula fits well along the Andean margin of South America.

As shown in Figures 11 through 14, our model does not require any of the major deformation of West Antarctica relative to East Antarctica, as suggested by Lawver et al. (1992). This is because the shape of southern South America was changed by closing the aulacogens. We have used the separate rotations for the two parts of Antarctica relative to southern Africa proposed by Royer et al. (1989; East Antarctica to southern Africa) and Besse and Courtillot (1988; West Antarctica to southern Africa). Only a slight translation of the Palmer Land Block is required to keep the Antarctic Peninsula in contact with the southern Andes throughout the Cretaceous. The required translation of the Palmer Land Block is even less if one assumes that East and West Antarctica were fixed to each other during the Cretaceous.

PALEOGEOGRAPHY

Major paleogeographic features of most earlier reconstructions are an open Norwegian Sea passage from the North Atlantic to Arctic, a northern boundary of the deep Tethys at 35° N in Europe, a deep-water passage from Atlantic to Pacific between Central and South America, an open passage from the South Pacific into the South Atlantic between South America and Antarctica, and an isolated India-Madagascar island between Africa and Australia.

Figures 15 through 17 show paleocoastline maps for 120, 100, and 80 Ma. Figure 15 shows a generalized Early Cretaceous low sea-level coastline superimposed on the 120-Ma plate tectonic reconstruction. Figure 16 shows a generalized Early Cretaceous high sea-level stand coastline superimposed on the 100-Ma plate tectonic reconstruction. Figure 17 shows a Late Cretaceous high sea-level stand coastline superimposed on the 80-Ma plate tectonic reconstruction. The land areas are shaded. Because of the different reference frame, the northern border of the deep Tethys is about 5–10° farther south than in the Barron (1987) reconstruction (compare Figs. 1 and 16).

In the Early Cretaceous (Fig. 15) there are three large continental blocks with shallow seas: North America–Eurasia; South America-Antarctica–India-Madagascar-Australia; and Africa. There is a large open Pacific Basin, a wide eastern Tethys, and a circum-African Seaway extending from the western Tethys ("Mediterranean") region through the North and South Atlantic into the juvenile Indian Ocean between Madagascar-India and Africa. The connection from the eastern Tethys through the western Tethys into the Atlantic was partially blocked by terranes that formed shallow water banks. During much of the Early Cretaceous, the deep-water passage from the Central Atlantic west into the Pacific was blocked first by the blocks of northern Central America, and then by entry of the relatively shallow Caribbean plate. There were no deep water passages from the Atlantic to the Canadian Basin in the Arctic.

An Early Cretaceous Earth with a long, narrow, sinuous ocean basin extending off the Tethys (Figs. 15 and 16) is more compatible with the geologic data, but contrasts strongly with the traditional view of separated island continents. The new reconstructions provide a markedly different and more realistic set of boundary conditions for global climate model simulations.

The new paleogeography suggests that the early Cretaceous Atlantic became a site of deposition of organic carbon because it was isolated from the Pacific by the entry of the Caribbean plate through Central America, from the eastern Tethys by Apulia and other shallow blocks, and separated from the South Atlantic by the Guinea-Brazil Straits.

During the Late Cretaceous (Fig. 17) the size of the land areas became smaller, and deep passages appeared between the western Tethys and Central Atlantic, between the Central Atlantic and the Pacific, and between the South Atlantic and the forming Indian Ocean. However, the eastern and western Indian Ocean were probably isolated. The Central Atlantic extended across

8,000 km at latitude 25° N. The South Atlantic was narrowest in the equatorial region, and about 3,000 km wide in the arid zone of the Southern Hemisphere. With the flow of equatorial rivers directed away from it (Emery and Uchupi, 1984), the only part of the Atlantic that may have received large amounts of fresh water was the southern South Atlantic, with a zonal extent of 5,500 km at 60° S. The widest, deepest connection to the Pacific was between the Caribbean plate and South America, located almost directly on the equator. At this time the Atlantic was probably the global source of ocean deep water. We suspect that it supplied warm saline water that could be upwelled in the polar regions of the Pacific as well as in the South Atlantic, and that this resulted in the warm equable climate of the Late Cretaceous.

SUMMARY AND CONCLUSIONS

Most plate tectonic reconstructions for the Cretaceous have assumed that five major continental blocks—Eurasia, North America–Greenland, South America, Africa, India-Madagascar, and Australia-Antarctica—had either completely or partially separated from one another and were surrounded by deep ocean passages. There were deep connections between the Pacific, Tethyan, Atlantic, and Indian Ocean basins. North America, Eurasia, and Africa were crossed by shallow meridional seaways. This classic view of Cretaceous paleogeography applies only to the latest Late Cretaceous.

In the north, the Canadian Basin formed by rotation of the Arctic Alaska–Chukotka Block, the terranes of central Alaska, and the Bering Sea Shelf Block during the Early Cretaceous. Stretching of northern from southern Greenland enlarged the Arctic, facilitating the rotation. The Labrador Sea formed as a propagating rift, but did not break through into the Arctic Basin. The formation of the Greenland-Iceland-Norwegian Sea proper did not occur until the Cenozoic. Although there may have been ephemeral deep-water connections between the Pacific and the Canadian Basin as it formed, there have never been deep-water connections from the Arctic to the northern Atlantic.

During the Late Cretaceous, an arm of the Western Interior Seaway extended across the site of Hudson Bay to the northern end of the Labrador Sea and across Greenland to Europe. There may have been shallow water passages to the Arctic across Europe, over the site of the future Norwegian-Greenland Sea. There was a shallow seaway from Tethys to the Arctic west of the Urals.

The Iberian and Grand Banks margins separated about 130 Ma. This motion was followed by the opening of Rockall Trough, which was synchronous with stretching in the North Sea and formation of basins in northern Germany.

The Labrador Sea started to open during the Cretaceous Magnetic Quiet Interval and had finished by 33 Ma. The opening of the Labrador Sea slowed during the early Cenozoic and seafloor spreading shifted to the transform motion between North America–Greenland and Eurasia that has been opening both the Norwegian-Greenland Sea and the Eurasian Basin of the Arctic since 57 Ma.

The original Early Cretaceous "home" of the Caribbean plate is suggested to be along the western margin of northern South America. The earliest time it can pass between northern Central America and South America is about 100 Ma. Its advance into the Atlantic was stopped by collision with South Florida and the Bahama Platforms at the end of the Cretaceous resulting in a major reorganization of Atlantic plate motions. During much of the Cretaceous the deep water passage from the Central Atlantic to the Pacific was blocked by the Caribbean plate.

The opening of the South Atlantic began with "unwrapping" of the San Jorge, Colorado, Salada, and Parana basins of South America from Africa. As these motions occurred, the Falkland Plateau carried Madagascar-India-Antarctica-Australia with it in an arc. Subsequently, South America and Africa separated along a transform fault between the northeastern margin of Brazil and the Guinea Coast of Africa. Antarctica then moved south, but the Antarctic Peninsula remained in contact with the southern Andes, forming a continuous mountain chain that was not interrupted until the Oligocene.

In the Indian Ocean region, India first moved south with Antarctica and Madagascar. Beginning in the Early Cretaceous, India began to rotate away from Antarctica, moving along a transform and sliding past Madagascar. However, it remained connected to Antarctica by a land bridge formed by Kerguelen Plateau, Sri Lanka, and possibly also by Ninetyeast Ridge until final separation occurred in the Late Cretaceous. In the Late Cretaceous, India separated from Madagascar.

In summary, the view of the Early Cretaceous is one of three large continental blocks: North America–Eurasia, South America–Antarctica-India-Madagascar-Australia, and Africa; a large open Pacific Basin; a wide eastern Tethys; and a circum-African Seaway extending from the western Tethys ("Mediterranean") region through the North and South Atlantic into the juvenile Indian Ocean between Madagascar-India and Africa. There were no deep-water passages to the Arctic. An Early Cretaceous Earth with a long, narrow, sinuous ocean basin extending off the Tethys, contrasts strongly with the traditional view of separated island continents and provides a markedly different set of boundary conditions for a climate model.

Deep-water passages between the Tethys, the Atlantic, the Pacific, and the developing Indian Ocean formed during the Late Cretaceous. There were many isolated land areas in the Late Cretaceous, but they were mostly separated by epicontinental seas.

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APPENDIX

Rotations

Several terms are used to describe the poles and rotations used in plate tectonics: finite-difference poles and rotations, stage poles and rotations, total poles and rotations, reconstruction poles and rotations, and instantaneous poles and rotations. All poles and rotations are "finite-difference" in that they represent the pole and rotation between one time and another. However, sometimes the terms finite-difference pole and rotation are used as synonymous with stage pole and rotation. Stage poles and rotations describe the rotation from one age with a well-located position to the next age with a well-located position (well-located usually means that the rotation will make magnetic lineations of equal age from two adjacent plates coincide). The intermediate positions for stage poles and rotations are interpolations between known positions. Total and reconstruction poles and rotations are synonyms, meaning the pole and rotation required to bring a point from its present location to the position it had in the past. Positions of the point at intermediate ages are meaningless. Instantaneous poles and rotations are the pole position and rotation vector at a moment in the past.

The plate tectonic elements (blocks, terranes, and plateaus) were rotated into their Cretaceous positions using the ATLAS™ Program of Cambridge Paleoservices, Inc. The ATLAS Program is a commercially available descendant of the Supermap program written by R. L. Parker in 1969, which had been used at Cambridge University for many years. The rotation program is based on an "Assembly and Orientation" (*.A&O) file that contains all of the rotations for each fragment relative to some other fragment. The rotations can be entered either as stage pole rotations or as total rotations or intermixed in the A&O file. The stage pole rotations define the motion of a fragment from one time to the next. The total rotation is the sum of all of the stage pole rotations and rotates the block to the position it had at a given time. The A&O file is then converted into a binary "Master" rotation file (*.MAS) that includes all of the information necessary to calculate the position of any fragment at any time. Because of the way in which the A&O file is converted into a MAS file, there is a limit to the number of ages that can be used in an A&O file. For this reason, there are a number of ages of separation of blocks and intermediate positions that may not be well known but are arbitrarily assigned to the age of a magnetic anomaly used elsewhere in the file. This gives an impression of precision of knowledge of the ages that could be misleading.

The A&O file used for our reconstruction is presented in abbreviated form in Table 12. We have eliminated two columns from the A&O file to simplify the table; one that includes the numbers assigned to each fragment, and another column that lists the beginning age of each total rotation. Our total rotations are from the present (0 Ma). When rotations are based on matching of magnetic lineations, the number of the lineation is given. If the age of a lineation is used, but no lineation number cited, it means that the age is used as a "best guess." To make it easier to change docking times, we used stage pole rotations when blocks were moved on one of the Pacific plates. We have also omitted all lines for which the rotations of one element relative to another are from 0 back to the beginning of the Cretaceous. Some 125 blocks terranes and plateaus that are fixed relative to another element throughout the Cenozoic and Cretaceous are indicated in the column "Fixed to" in Tables 1–10. "Fixed to" does not necessarily mean that the fragments are adjacent to each other, but implies that they are on the same plate. Removing the 130 fragments that are fixed to other fragments and the 14 fragments that did not exist in the Cretaceous reduces the number of rotations in the A&O file to those of the remaining 194 fragments. The actual A&O file used for the reconstructions shown here is 534 lines long (T25.A&O).

The first column of the table lists the fragment being moved, followed by the fragment to which its motion is referred (e.g., WNA-NAM = Western North America with respect to Central North America). The second column lists the age for the finite (or total) rotation, assuming the present position at age 0 (e.g., 40.0 means that the rotation given in the next three columns will place the block in the position it occupied at 40.0 Ma relative to the reference block). The MAS file will determine the position of the fragment at any age by interpolating between the total rotations that bracket it. Thus, if a block has four consecutive total rotations, for times 1, 2, 3, and 4, its position at time 3.5 will be midway between its position at times 3 and 4. The next three columns, "Lat," "Long," and "Rot," define the rotation. The pole is defined by its latitude and longitude relative to the reference block, and the rotation about the pole is counterclockwise if positive, clockwise if negative, following the "right-hand" rule. The last column, "Magnetic Anomaly, Source, and Comment," lists the magnetic anomaly on which the rotation is based, the author(s) and date of the publication, and comments.

Whenever possible the rotation of one block relative to another is based on superposing sea-floor magnetic anomalies. Except where noted, we assumed that the literature sources used the youngest side of the magnetic anomaly for matching. The ages assigned to magnetic anomalies have changed as more information becomes available, so that the ages given for rotations in the literature depend very much on when the paper was written. We have corrected all of the ages for the anomalies of the Cenozoic and Late Cretaceous to the time scale of Berggren et al. (1995).

Magnetic anomalies provide no guidance for motions during the Cretaceous Quiet Interval, from 83.5 to 120.4 Ma. Magnetic anomalies are also often indistinct along rifted margins and may not define a fit. In any case, fits of major blocks using the new digitized outlines will always be different from those previously published. Except in the western and northern Pacific, sea-floor magnetic anomalies are of little use in defining terrane motions because the critical lineations have been subducted. Paleomagnetic data from a terrane may provide useful information about its latitude at a given time, but not about its longitude. Plate tectonics assumes that blocks, terranes, and oceanic plateaus are attached to rigid plates. However, the motions of terranes described in the regional literature are often ad hoc solutions based on paleomagnetic data. From these rotations alone one could come to the conclusion that each terrane moves on its own plate. We have attempted to determine groups of terrane motions that can be accommodated by a single rotation; these are listed as terranes "Fixed to" other terranes or blocks in Tables 1–11.

The rotation of each fragment is given with reference to some other fragment previously listed in the table. For example, the position of South America relative to North America is not known directly because there are no intervening magnetic anomalies. However, the position of Africa relative to North America is known from the North Atlantic anomalies, and the position of central South America (our Parana Block) with respect to Africa is known from the South Atlantic anomalies. The rotations for fragments are chained together, ultimately coming back to the reference frame rotations at the beginning of the file. Some of the chains of rotations are quite long and complex. The abbreviated version A&O file is shown in Table 12. It is divided into segments for ease of discussion.

Reference frame

The first set of rotations (REFERENCE FRAME) moves North America relative to the reference frame. There are many possible reference frames, some based on paleomagnetics (McElhinney, 1973; Irving, 1979; Harrison and Lindh, 1982; Cox and Hart, 1986), others based on hotspots (Morgan, 1971, 1972, 1981, 1983; but see also Molnar and Atwater, 1973; Molnar and Stock, 1987; Lawver and Müller, 1994), others based on "true polar wander" (Livermore et al., 1984; Andrews, 1985; Courtillot and Besse, 1987), and others based on "absolute plate

TABLE 12. TOTAL RECONSTRUCTION POLES USED IN CRETACEOUS AND CENOZOIC RECONSTRUCTIONS

Fragments	Recon Age	Lat	Long	Rot	Magnetic Anomaly, Source, Comments
REFERENCE FRAME					
NAM-MAG	20.00	0.00	61.10	4.10	Harrison & Lindh (1982), North America to Paleomagnetic Reference Frame (MAG)
NAM-MAG	30.00	0.00	67.70	5.30	Harrison & Lindh (1982), North America to Paleomagnetic Reference Frame (MAG)
NAM-MAG	40.00	0.00	75.40	6.60	Harrison & Lindh (1982), North America to Paleomagnetic Reference Frame (MAG)
NAM-MAG	50.00	0.00	88.20	6.90	Harrison & Lindh (1982), North America to Paleomagnetic Reference Frame (MAG)
NAM-MAG	60.00	0.00	93.80	10.00	Harrison & Lindh (1982), North America to Paleomagnetic Reference Frame (MAG)
NAM-MAG	70.00	0.00	98.40	13.40	Harrison & Lindh (1982), North America to Paleomagnetic Reference Frame (MAG)
NAM-MAG	80.00	0.00	105.10	19.40	Harrison & Lindh (1982), North America to Paleomagnetic Reference Frame (MAG)
NAM-MAG	90.00	0.00	102.00	21.10	Harrison & Lindh (1982), North America to Paleomagnetic Reference Frame (MAG)
NAM-MAG	100.00	0.00	96.10	20.90	Harrison & Lindh (1982), North America to Paleomagnetic Reference Frame (MAG)
NAM-MAG	110.00	0.00	92.20	20.50	Harrison & Lindh (1982), North America to Paleomagnetic Reference Frame (MAG)
NAM-MAG	120.00	0.00	89.10	22.00	Harrison & Lindh (1982), North America to Paleomagnetic Reference Frame (MAG)
NAM-MAG	130.00	0.00	74.30	23.80	Harrison & Lindh (1982), North America to Paleomagnetic Reference Frame (MAG)
NAM-MAG	140.00	0.00	66.50	24.00	Harrison & Lindh (1982), North America to Paleomagnetic Reference Frame (MAG)
NAM-MAG	150.00	0.00	67.80	23.40	Harrison & Lindh (1982), North America to Paleomagnetic Reference Frame (MAG)
NORTH AMERICAN ROTATIONS					
WNA-NAM	50.00	0.00	0.00	0.00	Western North America - Post Laramide
WNA-NAM	67.50	15.00	-92.00	2.00	Laramide Deformation
STS-WNA	90.00	0.00	0.00	0.00	after Wilson et al. (1991) Collision of Superterrane I+II (Sevier Orogeny)
STS-WNA	120.00	0.00	-13.50	5.00	after Wilson et al. (1991)Superterrane I+II starts to converge with North America
STS-WNA	130.00	-38.56	323.48	12.80	after Wilson et al. (1991)
STS-WNA	180.00	7.08	343.41	45.45	after Wilson et al. (1991)
ALP-STS	90.00	0.00	0.00	0.00	Alaska-Aleutian Peninsula in present position
ALP-STS	123.00	-61.60	32.52	70.00	New, Alaska-Aleutian Peninsula rotated
BAJ-WNA	20.00	37.40	274.69	7.86	Baja California moving along North American margin
VIZ-BAJ	100.00	0.00	0.00	0.00	after Wilson et al. (1991) Vizcainao fixed to Baja California
VIZ-BAJ	110.00	90.00	0.00	-3.00	after Wilson et al. (1991) Vizcaino forms back-arc basin
VIZ-BAJ	130.00	0.00	0.00	0.00	after Wilson et al. (1991) Vizcaino rifts from Baja California
SAL-BAJ	110.00	30.79	332.25	17.48	after Wilson et al. (1991) Salinian Terrane moving north
SAL-BAJ	130.00	34.80	333.00	18.29	after Wilson et al. (1991) Salinian Terrane moving north
NIC-BAJ	110.00	39.15	334.79	13.84	after Wilson et al. (1991)
NIC-BAJ	130.00	39.93	335.54	14.75	after Wilson et al. (1991)
AAK-NAM	90.00	0.00	0.00	0.00	Rowley & Lottes (1988)
AAK-NAM	133.99	67.59	226.93	-59.58	?Anomaly M12? Rowley & Lottes (1988) "Windshield-wiper" opening of the Arctic Basin
UAT-AAK	150.00	0.00	0.00	0.00	Central Alaskan Terranes move with Arctic Alaska-Chukotka
ALI-UAT	50.00	0.00	0.00	0.00	New, Aleutian Island Chain fixed to Central Alaskan Terranes
BOW-ALI	60.00	0.00	0.00	0.00	New, Bowers Ridge fixed to the Aleutian Island Chain

TABLE 12. TOTAL RECONSTRUCTION POLES USED IN CRETACEOUS AND CENOZOIC RECONSTRUCTIONS (continued, p. 2)

BOW-KUL	*79.65*	0.00	0.00	0.00	New, Bowers Ridge moving on the Kula Plate
BOW-FAR	*155.00*	0.00	0.00	0.00	New, Bowers Ridge moving on the Farallon Plate
UMN-BOW	155.00	0.00	0.00	0.00	New, Umnak Plateau fixed relative to Bowers Ridge
YAK-ALP	4.18	0.00	0.00	0.00	New, Yakutat Plateau fixed to the Alaskan Peninsula (after Von Huene et al., 1985)
YAK-KUL	*70.00*	0.00	0.00	0.00	New, Yakutat Plateau moving on the Kula Plate
PRW-ALP	42.54	0.00	0.00	0.00	New, Prince William Terrane fixed relative to the Alaskan Peninsula
PRW-KUL	*79.56*	0.00	0.00	0.00	New, Prince William Terrane moving on the Kula Plate
GRS-NAM	33.06	0.00	0.00	0.00	Anomaly 13 Srivastava & Tapscott (1986)
GRS-NAM	42.54	-62.10	119.37	3.19	Anomaly 20 Wold (1992)
GRS-NAM	46.26	-61.71	110.51	4.42	Anomaly 21 Wold (1992)
GRS-NAM	52.36	-5.36	18.33	2.03	Anomaly 24 Wold (1992)
GRS-NAM	55.90	-24.48	42.75	3.12	Anomaly 25 Roest & Srivastava (1989)
GRS-NAM	57.55	20.61	-148.20	-3.27	Anomaly 26 Roest & Srivastava (1989)
GRS-NAM	60.92	27.63	-149.41	-3.72	Anomaly 27 Roest & Srivastava (1989)
GRS-NAM	67.64	43.94	-145.31	-4.92	Anomaly 31 Roest & Srivastava (1989)
GRS-NAM	74.47	-28.03	50.65	5.53	New, Anomaly 33
GRS-NAM	83.50	14.86	15.46	6.91	New, Anomaly 34
GRS-NAM	92.00	66.60	-119.48	-12.20	Roest & Srivastava (1989)
GRS-NAM	116.50	-63.68	49.14	10.96	New Fit
GRN-GRS	83.50	0.00	0.00	0.00	Greenland in its present form
GRN-GRS	116.50	-75.96	48.00	3.00	New, hypothetcal rifting between Disco island and Scoresby Sound removed
BAF-NAM	74.47	0.00	0.00	0.00	Present position
BAF-NAM	100.00	-75.29	106.75	7.38	New Fit
ELS-NAM	27.03	0.00	0.00	0.00	Present position
ELS-NAM	33.06	70.88	-89.65	-1.52	Rowley & Lottes (1988)
ELS-NAM	46.26	70.88	-89.65	-5.78	Rowley & Lottes (1988)
ELS-NAM	52.36	70.88	-89.65	-7.53	Rowley & Lottes (1988)
ELS-NAM	55.90	70.88	-89.65	-10.41	Rowley & Lottes (1988)
ELS-NAM	74.47	70.88	-89.65	-10.41	Rowley & Lottes (1988)
ELS-NAM	130.87	70.88	-89.65	-15.56	?M10 Rowley & Lottes (1988)
AFRICA TO NORTH AMERICA					
NAF-NAM	9.74	80.12	50.80	-2.52	Anomaly 5 Mueller et al. (1991)
NAF-NAM	19.05	79.57	37.84	-5.29	Anomaly 6 Klitgord & Schouten (1986)
NAF-NAM	33.06	75.37	1.12	-10.04	Anomaly 13 Mueller et al. (1991)
NAF-NAM	46.26	75.30	-3.88	-15.25	Anomaly 21 Mueller et al. (1991)
NAF-NAM	55.90	79.68	-0.46	-18.16	Anomaly 25 Mueller et al. (1991)
NAF-NAM	65.58	82.90	4.94	-20.76	Anomaly 30 Mueller et al. (1991)
NAF-NAM	70.97	81.35	-9.15	-22.87	Anomaly 32 Klitgord & Schouten (1986)
NAF-NAM	74.47	80.76	-11.76	-23.91	Anomaly 33y Klitgord & Schouten (1986)
NAF-NAM	79.65	78.30	-18.35	-27.06	Anomaly 33o Klitgord & Schouten (1986)
NAF-NAM	83.50	76.55	-20.73	-29.60	Anomaly 34 Klitgord & Schouten (1986)

TABLE 12. TOTAL RECONSTRUCTION POLES USED IN CRETACEOUS AND CENOZOIC RECONSTRUCTIONS (continued, p. 3)

NAF-NAM	90.00	74.33	-22.65	-33.86	Roest (1987)
NAF-NAM	94.00	72.00	-24.39	-36.49	Roest (1987)
NAF-NAM	100.00	69.42	-23.52	-40.46	Roest (1987)
NAF-NAM	106.00	68.08	-22.66	-45.36	Roest (1987)
NAF-NAM	116.50	66.21	-21.00	-53.19	Roest (1987)
NAF-NAM	120.40	66.09	-20.17	-54.45	Anomaly M0 Roest et al. (1992)
NAF-NAM	126.72	65.97	-19.43	-56.63	Anomaly M4 Roest et al. (1992)
NAF-NAM	132.07	66.14	-18.72	-58.03	Anomaly M11 Roest et al. (1992)
NAF-NAM	137.88	66.24	-18.33	-59.71	Anomaly M16 Roest et al. (1992)
NAF-NAM	146.75	66.24	-18.33	-62.14	Anomaly M21 Roest et al. (1992)
AFRICAN ROTATIONS					
SOM-NAF	40.00	-27.26	42.20	4.54	New, East African Rift opening, separating Somalia from NAF
ARB-NAF	4.18	15.20	32.80	1.08	Opening of axial trough, Red Sea (Richardson & Harrison, 1976)
ARB-NAF	33.06	15.20	32.80	1.08	No motion in Red Sea (Girdler & Styles, 1974)
ARB-NAF	42.54	-32.58	206.37	7.30	New fit: Arabia to North Africa
SOUTH AMERICA TO AFRICA					
PAR-NAF	4.18	60.00	-39.00	1.21	Anomaly 3 Nuernberg & Mueller (1991)
PAR-NAF	9.74	60.00	-39.00	3.15	Anomaly 5 Nuernberg & Mueller (1991)
PAR-NAF	11.93	59.50	-38.00	4.05	Anomaly 5A Nuernberg & Mueller (1991)
PAR-NAF	16.01	59.50	-38.00	5.75	Anomaly 5C Nuernberg & Mueller (1991)
PAR-NAF	19.05	59.50	-38.00	7.05	Anomaly 6 Nuernberg & Mueller (1991)
PAR-NAF	20.52	59.50	-37.75	7.60	Anomaly 6A Nuernberg & Mueller (1991)
PAR-NAF	23.35	59.50	-37.00	8.80	Anomaly 6C Nuernberg & Mueller (1991)
PAR-NAF	24.73	59.00	-36.00	9.50	Anomaly 7 Nuernberg & Mueller (1991)
PAR-NAF	27.03	58.00	-35.00	10.55	Anomaly 9 Nuernberg & Mueller (1991)
PAR-NAF	29.40	57.00	-34.50	11.60	Anomaly 11 Nuernberg & Mueller (1991)
PAR-NAF	33.06	57.50	-34.00	13.38	Anomaly 13 Nuernberg & Mueller (1991)
PAR-NAF	35.34	57.00	-33.25	14.40	Anomaly 16 Nuernberg & Mueller (1991)
PAR-NAF	38.43	57.50	-32.50	15.80	Anomaly 18 Nuernberg & Mueller (1991)
PAR-NAF	42.40	57.50	-31.75	17.60	Anomaly 20 Nuernberg & Mueller (1991)
PAR-NAF	46.26	58.50	-31.50	19.07	Anomaly 21 Nuernberg & Mueller (1991)
PAR-NAF	49.04	59.00	-31.50	20.10	Anomaly 22 Nuernberg & Mueller (1991)
PAR-NAF	52.36	60.00	-32.00	21.20	Anomaly 24 Nuernberg & Mueller (1991)
PAR-NAF	55.90	61.50	-32.50	22.30	Anomaly 25 Nuernberg & Mueller (1991)
PAR-NAF	60.92	62.50	-33.00	23.55	Anomaly 27 Nuernberg & Mueller (1991)
PAR-NAF	63.98	63.00	-33.30	24.30	Anomaly 29 Nuernberg & Mueller (1991)
PAR-NAF	65.58	63.00	-33.30	24.70	Anomaly 30 Nuernberg & Mueller (1991)
PAR-NAF	70.97	63.00	-33.50	26.60	Anomaly 32 Nuernberg & Mueller (1991)
PAR-NAF	74.47	63.00	-33.50	27.90	Anomaly 33 Nuernberg & Mueller (1991)
PAR-NAF	79.65	63.00	-34.00	31.00	Anomaly 33R Nuernberg & Mueller (1991)

TABLE 12. TOTAL RECONSTRUCTION POLES USED IN CRETACEOUS AND CENOZOIC RECONSTRUCTIONS (continued, p. 4)

PAR-NAF	120.40	45.45	329.55	57.17	New rotation to describe motion along transform
PAR-NAF	126.72	44.38	329.55	57.17	Wold et al. (1994), fit of PAR to NAF
SOUTH AMERICAN ROTATIONS					
CDC-SAM	24.73	0.00	0.00	0.00	Cordilleras Central, Oriental y de la Costa in present position
CDC-SAM	65.00	-3.46	-78.92	15.00	Cordillera Central, Oriental y de la Costa before compression (T. Villamil, pers. comm., 1995)
SIO-SAM	24.73	0.00	0.00	0.00	Serrania del Inerior Oriental in present form
SIO-SAM	35.34	0.00	30.00	-0.30	Compression of Serrania del Inerior Oriental (T. Villamil, pers. comm., 1995)
SAM-PAR	123.00	0.00	0.00	0.00	Central South America in present position relative to Parana Block
SAM-PAR	126.72	68.20	15.05	0.30	New, stretching along Amazon basin
SLB-PAR	132.07	0.00	0.00	0.00	Wold et al. (1994) (Salado fixed to Parana)
SLB-PAR	133.99	-22.00	-63.50	1.00	Wold et al. (1994) (Salado rotating to Parana)
COL-SLB	133.99	0.00	0.00	0.00	Wold et al. (1994) (Colorado fixed to Salado)
COL-SLB	137.88	-35.00	-61.70	4.00	Wold et al. (1994) (Colorado rotating to Salado)
VAL-COL	146.75	0.00	0.00	0.00	Wold et al. (1994) (Valdez fixed to Colorado)
VAL-COL	155.00	-38.00	-66.00	5.00	Wold et al. (1994) (Valdez rotating to Colorado)
SNJ-VAL	155.00	0.00	0.00	0.00	Wold et al. (1994) (San Jorge fixed to Valdez)
SNJ-VAL	160.00	-40.00	-72.00	3.00	Wold et al. (1994) (San Jorge rotating to Valdez)
SGB-SNJ	40.00	-67.96	310.10	30.62	New, South Georgia stretches from Falkland Plateau
CENTRAL AMERICAN AND CARIBBEAN ROTATIONS					
CTS-MAY	24.73	-77.15	1.65	3.33	Anomaly 7 Rosenkrantz et al. (1988) Cayman Trough, slow opening
CTS-MAY	50.00	-77.15	1.65	11.36	Before A6 Rosenkrantz et al. (1988) Cayman Trough, fast opening
CHO-CTS	24.73	0.00	0.00	0.00	Chortis moving with south side of Cayman Trough around Chiapas
CHO-OGB	50.00	-36.48	87.22	25.72	Hay & Wold (1996)
DIR-CHO	10.00	0.00	0.00	0.00	Diriangen Bank in present position
DIR-CHO	20.00	-74.36	10.49	0.10	Stretching Nicaragua Rise, after Droxler et al. (1992)
ROS-DIR	10.00	-74.36	10.49	0.00	Rosalind Bank in present position
ROS-DIR	20.00	-74.36	10.49	0.10	Stretching Nicaragua Rise, after Droxler et al. (1992)
CUB-NAM	67.50	0.00	0.00	0.00	Hay & Wold (1996)
CUB-MCC	83.50	-16.32	88.82	23.20	Hay & Wold (1996)
CUB-MCC	100.00	-27.68	73.53	26.83.50	Hay & Wold (1996)
LNT-CTS	50.00	0.00	0.00	0.00	Hay & Wold (1996)
LNT-CUB	67.50	5.54	284.91	75.86	Hay & Wold (1996)
LNT-CUB	100.00	4.89	285.01	70.92	Hay & Wold (1996)
LNT-COC	120.00	-4.04	292.99	61.72	Hay & Wold (1996)
LNT-COC	130.00	-1.11	294.74	61.57	Hay & Wold (1996)
BRB-SIO	24.73	-51.13	117.06	5.99	Hay & Wold (1996)
HPN-VNB	50.00	45.45	291.99	7.91	Hay & Wold (1996)
HPS-VNB	30.00	0.00	0.00	0.00	Hay & Wold (1996)
HPS-VNB	50.00	36.70	288.24	5.17	Hay & Wold (1996)
PRV-HPN	10.00	-18.23	114.13	20.00	Hay & Wold (1996)

TABLE 12. TOTAL RECONSTRUCTION POLES USED IN CRETACEOUS AND CENOZOIC RECONSTRUCTIONS (continued, p. 5)

PRV-HPN	50.00	-21.97	112.19	20.52	Hay & Wold (1996)
PRV-HPN	67.50	-21.97	112.19	20.52	Hay & Wold (1996)
PRV-VNB	80.00	-11.61	112.43	6.09	Hay & Wold (1996)
JAM-HPN	50.00	56.30	191.00	3.61	Hay & Wold (1996)
EURASIA TO NORTHERN GREENLAND					
EUA-GRN	9.74	68.00	137.00	-2.50	Anomaly 5 Srivastava & Tapscott (1986)
EUA-GRN	19.05	68.94	135.30	-5.09	Anomaly 6 Wold (1992)
EUA-GRN	24.73	67.05	128.95	-5.85	Anomaly 7 Bott (1985)
EUA-GRN	33.06	68.00	129.90	-7.78	Anomaly 13 Srivastava & Tapscott (1986)
EUA-GRN	42.54	48.92	134.88	-8.10	Anomaly 20 Wold (1992)
EUA-GRN	46.26	69.44	137.86	-11.15	Anomaly 21 Wold (1992)
EUA-GRN	52.36	46.78	126.85	-10.50	Anomaly 24 Wold (1992)
EUA-GRN	57.55	41.70	124.50	-10.15	Fit, Wold (1992)
EUA-GRN	79.65	-66.77	286.79	18.68	New fit of Greenland to Eurasia
SOUTHWESTERN EUROPE TO EURASIA AND SOUTHERN GREENLAND					
EUR-EUA	100.00	0.00	0.00	0.00	Southwestern Europe in present position relative to Eurasia
EUR-GRS	120.00	-74.41	273.51	23.38	New fit of southwestern Europe to southern Greenland
SOUTHWESTERN EUROPEAN ROTATIONS					
JAN-EUA	24.73	0.00	0.00	0.00	Anomaly 7 Nunns (1983)
JAN-EUA	33.06	65.90	-12.30	-8.00	Anomaly 13 Nunns (1983)
JAN-GRN	42.54	77.61	-3.30	-32.82	Anomaly 20 Wold (1992)
JAN-GRN	46.26	90.00	0.00	-9.50	New fit of Jan Mayen to northern Greenland
ROB-EUR	55.90	0.00	0.00	0.00	Rockall Bank in present positon
ROB-GRS	79.65	-78.61	242.15	23.96	New, opening South Iceland Basin
HAB-EUR	55.90	0.00	0.00	0.00	Hatton Bank in present position
HAB-GRS	79.65	-63.36	293.52	14.29	New, opening South Iceland Basin
IBE-EUR	33.06	0.00	0.00	0.00	New, Anomaly 13, Iberia fixed to Europe
IBE-ENA	46.26	-82.16	256.77	12.80	New, Anomaly 21
IBE-ENA	52.36	-62.38	310.84	10.82	New, Anomaly 24
IBE-ENA	55.90	-71.77	318.49	12.90	New, Anomaly 25
IBE-ENA	67.64	-76.21	311.79	18.66	New, Anomaly 31
IBE-ENA	74.47	-72.06	325.82	19.27	New, Anomaly 33r
IBE-ENA	83.50	-74.11	316.79	20.76	New, Anomaly 34, Opening Bay of Biscay
IBE-ENA	100	-75.85	160.61	35.16	New
IBE-ENA	120.40	-67.03	160.38	53.64	New, M0, fit of Iberia to Armorican Massif
IBE-EUR	130.00	-46.57	184.83	27.22	New, Iberia closed to the Grand Banks
ALB-IBE	30.00	90.00	0.00	4.20	New, Alboran Block moving west relative to Iberia (after Gealey, 1989)
KBY-ATL	19.05	0.00	0.00	0.00	Kabylia in present position
KBY-ALB	24.73	35.06	354.37	20.06	New, Kabylia separating from Alboran Block (after Dercourt et al., 1986)

TABLE 12. TOTAL RECONSTRUCTION POLES USED IN CRETACEOUS AND CENOZOIC RECONSTRUCTIONS (continued, p. 6)

BAL-IBE	20.00	0.00	0.00	0.00	Balearic Bock fixed to Iberia in present position
BAL-IBE	35.34	39.50	2.47	25.00	New, Balearic Block rotating from Iberia (after Dercourt et al., 1986)
ONK-NAM	80.00	0.00	0.00	0.00	Orphan Knoll in present position
ONK-EUR	94.00	86.50	306.33	36.34	New, Orphan Knoll fit to southwestern Europe
FLC-NAM	80.00	0.00	0.00	0.00	Flemish Cap in present position
FLC-EUR	94.00	66.09	325.88	66.25	New, Flemish Cap fit to southwestern Europe
GAB-IBE	80.00	0.00	0.00	0.00	Galicia Bank in present position
GAB-IBE	116.50	-42.39	172.03	35.05	New, Galicia Bank stretching from Iberia
GAB-IBE	120.00	-42.39	172.03	35.05	New, Galicia Bank stretching from Iberia
GAB-IBE	130.00	-40.34	170.62	19.34	New, Galicia Bank stretching from Iberia
GAB-EUR	100.00	-45.52	174.78	61.58	Galicia Bank attached to southwestern Europe
WESTERN TETHYAN ROTATIONS					
APL-EUA	20.00	0.00	0.00	0.00	Apulia in present position
APL-EUA	80.00	33.68	108.20	3.61	Nwe, Apulia closing on and moving with Europe (after Dercourt et al., 1986)
APL-NAF	130.00	65.57	47.17	6.15	New, Apulia fit to Africa (after Dercourt et al., 1986)
CSR-EUR	19.05	0.00	0.00	0.00	Corso-Sardinian Block in present position
CSR-EUR	24.73	-43.50	189.52	42.69	New, Corso-Sardinian Block fit to Provence-Catalunia (Dercourt, 1986; Burrus, 1984)
CAL-CSR	10.00	41.80	11.20	-70.00	New, Calabrian Block fit to Corso-Sardinian Block (after Dercourt et al., 1986)
RHO-EUA	100.00	0.00	0.00	0.00	Rhodope Block in present position
RHO-EUA	130.00	40.33	39.80	5.10	New, Nish-Trojan-Flysch-trough opened (after Dercourt et al., 1986)
RHO-EUA	150.00	0.00	0.00	0.00	New, Nish-Trojan-Flysch-trough closed (after Dercourt et al., 1986)
WPO-EUA	50.00	-40.35	205.15	14.67	New, Black Sea Basin forming from trapped Tethys (after Dercourt et al., 1986)
WPO-EUA	70.00	40.33	39.80	5.10	New, Black Sea Basin forming from trapped Tethys (after Dercourt et al., 1986)
WPO-EUA	110.00	40.33	39.80	5.10	New, Black Sea Basin forming from trapped Tethys (after Dercourt et al., 1986)
WPO-RHO	130.00	0.00	0.00	0.00	New, Western Pontides moving with Rhodope Block (after Dercourt et al., 1986)
WPO-EUA	150.00	39.22	35.72	19.74	New, Western Pontides moving toward the Rhodope Block (after Dercourt et al., 1986)
WPO-EUA	190.00	43.49	29.01	20.68	New, Western Pontides moving toward the Rhodope Block (after Dercourt et al., 1986)
EPO-EUA	50.00	-40.34	206.57	15.52	New, Eastern Pontides moving toward Europe (after Dercourt et al., 1986)
EPO-EUA	110.00	-40.34	206.57	15.52	New, Eastern Pontides moving toward Europe (after Dercourt et al., 1986)
EPO-EUA	170.00	-41.93	216.20	15.34	New, Collision in Mid-Jurassic (after Dercourt et al., 1986)
EPO-EUA	190.00	38.71	43.67	14.72	New, Rifting north of Eastern Pontides (after Dercourt et al., 1986)
SKR-EUA	50.00	-40.35	205.15	14.67	New, Black Sea Basin forming (after Dercourt et al., 1986)
SKR-EUA	80.00	43.73	42.28	4.36	New, Sakarya fit to Pontides (after Dercourt et al., 1986)
SKR-EUA	90.00	-34.92	202.77	19.63	New, Sakarya moving relative to Europe (after Dercourt et al., 1986)
SKR-EUA	110.00	-23.60	192.61	19.26	New, Sakarya in the Aptian (after Dercourt et al., 1986)
SKR-ARB	130.00	27.02	292.07	6.94	New, Sakarya moving with Arabia (after Dercourt et al., 1986)
SKR-ARB	150.00	27.02	292.07	6.94	New, Sakarya moving with Arabia (after Dercourt et al., 1986)
SKR-ARB	190.00	31.25	289.31	6.10	New, Sakarya moving with Arabia (after Dercourt et al., 1986)
KIR-EUA	50.00	-40.35	205.15	14.67	New, Black Sea Basin forming (after Dercourt et al., 1986)
KIR-EUA	70.00	-42.14	201.58	10.76	New, Kirsehir fit to Pontides (after Dercourt et al., 1986)
KIR-EUA	90.00	-34.92	202.77	19.63	New, Kirsehir moving reltive to Europe (after Dercourt et al., 1986)

TABLE 12. TOTAL RECONSTRUCTION POLES USED IN CRETACEOUS AND CENOZOIC RECONSTRUCTIONS (continued, p. 7)

KIR-EUA	110.00	-23.60	192.61	19.26	New, Kirsehir in the Aptian (after Dercourt et al., 1986)
KIR-ARB	130.00	27.02	292.07	6.94	New, Kirsehir moving with Arabia (after Dercourt et al., 1986)
KIR-ARB	150.00	27.02	292.07	6.94	New, Kirsehir moving with Arabia (after Dercourt et al., 1986)
KIR-ARB	190.00	31.25	289.31	6.10	New, Kirsehir moving with Arabia (after Dercourt et al., 1986)
MDT-SKR	35.34	0.00	0.00	0.00	New, Menderes Taurus fit to Sakarya (after Dercourt et al., 1986)
MDT-ARB	50.00	-39.80	309.45	3.90	New, Menderes Taurus moving with Arabia (after Dercourt et al., 1986)
MDT-ARB	65.00	-26.56	309.95	3.35	New, Menderes Taurus at the K/T boundary (after Dercourt et al., 1986)
MDT-ARB	74.47	37.73	33.48	5.02	New, Late Cretaceous overthrusting (after Dercourt et al., 1986)
MDT-ARB	80.00	1.67	12.08	4.39	New, Menderes Taurus at the Santonian/Campanian boundary (after Dercourt et al., 1986)
MDT-ARB	110.00	-29.91	229.05	14.12	New, Trough exists between Taurus and Arabia (after Dercourt et al., 1986)
MDT-ARB	150.00	-29.91	229.05	14.12	New, Trough forms between Taurus and Arabia (after Dercourt et al., 1986)
MDT-ARB	170.00	-31.58	216.34	23.07	New, Menderes Taurus fit to Arabia (after Dercourt et al., 1986)
ETR-KIR	30.00	0.00	0.00	0.00	New, Eastern Taurides fit to Kirsehir (after Dercourt et al., 1986)
ETR-ARB	50.00	-39.80	309.45	3.90	New, Eastern Taurides moving with Arabia (after Dercourt et al., 1986)
ETR-ARB	65.00	-26.56	309.95	3.35	New, Eastern Taurides at the K/T boundary (after Dercourt et al., 1986)
ETR-ARB	74.47	37.73	33.48	5.02	New, Late Cretaceous overthrusting (after Dercourt et al., 1986)
ETR-ARB	80.00	1.67	12.08	4.39	New, EasternTaurides at the Santonian/Campanian boundary (after Dercourt et al., 1986)
ETR-ARB	110.00	-31.76	228.71	18.48	New, Trough exists between Taurus and Arabia (after Dercourt et al., 1986)
ETR-ARB	150.00	-31.76	228.71	18.48	New, Trough forms between Taurus and Arabia (after Dercourt et al., 1986)
ETR-ARB	170.00	-33.76	220.21	28.25	New, Eastern Taurides fit to Arabia (after Dercourt et al., 1986)
EASTERN TETHYAN ROTATIONS					
ABZ-EUA	35.34	0.00	0.00	0.00	Alborz Block in present position
ABZ-EUA	90.00	35.15	61.15	15.07	New, Alborz Block moving relative to Europe (after Dercourt et al., 1986)
ABZ-EUA	110.00	0.00	0.00	0.00	New, Alborz Block fit to Asia (after Dercourt et al., 1986)
ABZ-EUA	200.00	0.00	0.00	0.00	New, Alborz Block fit to Asia (after Dercourt et al., 1986)
LCA-EUA	110.00	0.00	133.58	3.50	New, Lesser Caucasus moving relative to Europe (after Dercourt et al., 1986)
LCA-EUA	130.00	0.00	133.58	2.00	New, Stretching the Caucasus basin (after Dercourt et al., 1986)
LCA-EUA	140.00	0.00	0.00	0.00	New, Lesser Caucasus fit to Asia (after Dercourt et al., 1986)
VAN-ARB	20.00	0.00	320.00	1.00	New, Closure of Neo-Tethys (after Dercourt et al., 1986)
VAN-EUA	40.00	0.00	133.58	3.50	New, Van Block moving relative to Asia (after Dercourt et al., 1986)
VAN-EUA	110.00	0.00	133.58	3.50	New, Van Block fixed offshore Asia (after Dercourt et al., 1986)
VAN-EUA	130.00	0.00	133.58	2.00	New, Stretching the Van Block (after Dercourt et al., 1986)
VAN-EUA	140.00	0.00	0.00	0.00	Van Block fit to Asia (after Dercourt et al., 1986)
VAN-EUA	190.00	34.92	46.36	33.57	New, Van Block moving relative to Asia (after Dercourt et al., 1986)
SAB-ARB	20.00	0.00	320.00	1.00	New, Closure of Neo-Tethys (after Dercourt et al., 1986)
SAB-EUA	40.00	0.00	133.58	3.50	New, South Armenian Block moving relative to Asia (after Dercourt et al., 1986)
SAB-EUA	110.00	0.00	133.58	3.50	New, South Armenian Block fixed offshore Asia (after Dercourt et al., 1986)
SAB-EUA	130.00	0.00	133.58	2.00	Stretching the Caucasus Basin (after Dercourt et al., 1986)
SAB-EUA	140.00	0.00	0.00	0.00	South Armenian Block fit to Asia (after Dercourt et al., 1986)
SAB-EUA	190.00	36.87	47.72	40.01	New, South Armenian Block moving relative to Asia (after Dercourt et al., 1986)
SND-ARB	20.00	0.00	320.00	1.00	New, Closure of Neo-Tethys (after Dercourt et al., 1986)

TABLE 12. TOTAL RECONSTRUCTION POLES USED IN CRETACEOUS AND CENOZOIC RECONSTRUCTIONS (continued, p. 8)

SND-EUA	40.00	-9.46	148.40	3.04	New, Sanandaj moving relative to Asia (after Dercourt et al., 1986)
SND-EUA	110.00	-9.46	148.40	3.04	New, rifting south of Alborz (after Dercourt et al., 1986)
SND-EUA	130.00	0.00	0.00	0.00	Sanandaj fit to Asia (after Dercourt et al., 1986)
SND-EUA	190.00	13.78	39.40	25.55	Sanandaj Belt moving relative to Asia (after Dercourt et al., 1986)
KAV-EUA	20.00	0.00	0.00	0.00	Kavir in present position
KAV-EUA	80.00	-9.46	148.40	3.04	New, Kavir moving relative to Asia (after Dercourt et al., 1986)
KAV-EUA	110.00	-9.46	148.40	3.04	New, rifting south of Alborz (after Dercourt et al., 1986)
KAV-EUA	130.00	0.00	0.00	0.00	Kavir fit to Asia (after Dercourt et al., 1986)
KAV-EUA	170.00	0.00	0.00	0.00	Kavir fit to Asia (after Dercourt et al., 1986)
KAV-EUA	190.00	-35.91	228.17	10.82	New, Kavir moving relative to Asia (after Dercourt et al., 1986)
SIR-ARB	20.00	0.00	320.00	1.00	New, Closure of Neo-Tethys (after Dercourt et al., 1986)
SIR-EUA	40.00	-9.46	148.40	3.04	New, Sirjan Block moving relative to Aisa (after Dercourt et al., 1986)
SIR-EUA	110.00	-9.46	148.40	3.04	New, rifting south of Alborz (after Dercourt et al., 1986)
SIR-EUA	130.00	0.00	0.00	0.00	Sirjan Block fixed to Asia (after Dercourt et al., 1986)
SIR-EUA	190.00	13.78	39.40	25.55	New, Sirjan Block moving relative to Aisa (after Dercourt et al., 1986)
CIR-EUA	20.00	0.00	0.00	0.00	Central Iran in present position
CIR-EUA	80.00	-9.46	148.40	3.04	New, Central Iran moving relative to Asia (after Dercourt et al., 1986)
CIR-EUA	110.00	-9.46	148.40	3.04	New, rifting south of Alborz (after Dercourt et al., 1986)
CIR-EUA	130.00	0.00	0.00	0.00	Central Iran fixed to Asia (after Dercourt et al., 1986)
CIR-EUA	170.00	0.00	0.00	0.00	Central Iran fixed to Asia (after Dercourt et al., 1986)
CIR-EUA	190.00	-35.91	228.17	10.82	New, Central Iran moving relative to Asia (after Dercourt et al., 1986)
LUT-EUA	20.00	0.00	0.00	0.00	Lut Block in present position (after Dercourt et al., 1986)
LUT-EUA	80.00	-9.46	148.40	3.04	New, Lut Block moving relative to Asia (after Dercourt et al., 1986)
LUT-EUA	110.00	-9.46	148.40	3.04	New, rifting south of Alborz (after Dercourt et al., 1986)
LUT-EUA	130.00	0.00	0.00	0.00	Lut fixed to Asia (after Dercourt et al., 1986)
LUT-EUA	170.00	0.00	0.00	0.00	Lut fixed to Asia (after Dercourt et al., 1986)
LUT-EUA	190.00	-35.91	228.17	10.82	New, Lut Block moving relative to Asia (after Dercourt et al., 1986)
FAR-EUA	190.00	0.00	0.00	0.00	Farah block fixed to Asia (after Dercourt et al., 1986)
CAF-EUA	130.00	0.00	0.00	0.00	Central Afghanistan fixed to Asia (after Dercourt et al., 1986)
CAF-EUA	190.00	29.66	80.36	16.21	New, rifting between Central Afghanistan and Farah Block (after Dercourt et al., 1986)
LAD-EUA	90.00	0.00	0.00	0.00	Ladakh Arc in present position (after Dercourt et al., 1986)
LAD-EUA	110.00	0.00	166.85	6.00	New, opening of Shiyokia (after Dercourt et al., 1986)
LAD-EUA	130.00	0.00	166.85	4.00	New, island arc forms (after Dercourt et al., 1986)
KOH-EUA	90.00	0.00	0.00	0.00	Kohistan Arc in present position (after Dercourt et al., 1986)
KOH-EUA	110.00	0.00	162.45	6.00	New, opening of Shiyokia (after Dercourt et al., 1986)
KOH-EUA	130.00	0.00	162.45	4.00	New island arc forms (after Dercourt et al., 1986)
EASTERN ASIAN ROTATIONS					
AMT-EUA	20.00	0.00	223.45	-5.00	New, movement of Akiyoshi-Mino-Tamba opening of Sea of Japan
YAM-EUA	20.00	0.00	223.45	-2.00	New, movement of Yamato Rise opening of Sea of Japan
ISH-AMT	20.00	0.00	231.52	-5.00	New, motion of Ishikari opening of Sea of Japan
HID-ISH	100.00	0.00	0.00	0.00	New, Hidaka-Tokoro fixed to Ishikari (after Taira et al., 1989)

TABLE 12. TOTAL RECONSTRUCTION POLES USED IN CRETACEOUS AND CENOZOIC RECONSTRUCTIONS (continued, p. 9)

HID-FAR	*126.72*	0.00	0.00	0.00	New, Hidaka-Tokoro moving on the Farralon Plate
HID-IZ1	*155.00*	0.00	0.00	0.00	New, Hidaka-Tokoro moving on the Izanagi 1 Plate
NEM-ISH	20.00	43.78	144.13	-22.00	New, Nemuro Belt-Kuriles opening the Kuril Basin
NEM-ISH	70.00	43.78	144.13	-22.00	New, Nemuro Belt-Kuriles closed against Okhotsk
NEM-PAC	*100.00*	0.00	0.00	0.00	New, Nemuro Belt-Kuriles moving on the Pacific Plate
SIG-EUA	110.00	0.00	0.00	0.00	New, Siglan-Viskichun-Neyneg fixed to Eurasia
SIG-FAR	*155.00*	0.00	0.00	0.00	New, Siglan-Viskichun-Neyneg moving on the Farallon Plate
PRB-SIG	100.00	0.00	0.00	0.00	New, Pribrezhnaya fixed to Siglan-Viskichun-Neyneg
PRB-FAR	*155.00*	0.00	0.00	0.00	New, Pribrezhnaya moving on the Farallon Plate
KVK-SIG	80.00	0.00	0.00	0.00	New, Kvakhon fixed to Siglan-Viskichun-Neyneg
KVK-PAC	*155.00*	0.00	0.00	0.00	New, Kvakhon moving on the Pacific Plate
SRD-KVK	70.00	0.00	0.00	0.00	New, Sredinniy Range fixed to Kvakhon
SRD-KUL	*155.00*	0.00	0.00	0.00	New, Sredinniy Range moving on the Kula Plate
OKA-SIG	90.00	0.00	0.00	0.00	New, Okhotsk Arch fixed to Siglan-Viskichun-Neyneg
OKA-PAC	*132.07*	0.00	0.00	0.00	New, Okhotsk Arch moving on the Pacific Plate
CKB-KVK	57.56	0.00	0.00	0.00	New, Central Kamchatka Basin obducted onto Kvakhon
CKB-PAC	*155.00*	0.00	0.00	0.00	New, Central Kamchatka Basin moving on the Pacific Plate
ERK-CKB	55.90	0.00	0.00	0.00	New, Eastern Ranges of Kamchatka collide with Central Kamchatka Basin
ERK-KUL	*79.65*	0.00	0.00	0.00	New, Eastern Ranges of Kamchatka moving on the Kula Plate
ERK-FAR	*155.00*	0.00	0.00	0.00	New, Eastern Ranges of Kamchatka moving on the Farallon Plate
KRO-ERK	*2.00*	0.00	0.00	0.00	New, Kronotskiy Terrane fixed to the Eastern Ranges of Kamchatka
KRO-PAC	*155.00*	0.00	0.00	0.00	New, Kronotskiy Terrane moving on the Pacific Plate
MAL-KVK	100.00	0.00	0.00	0.00	New, Malkinsk Terrane fixed to Kvakhon
MAL-KVK	130.00	26.55	246.07	4.47	New, Malkinsk Terrane moving on a transform toward Kvakhon
ASR-NEM	20.00	-39.74	340.43	-22.71	New, Academy of Sciences Rise as a part of the Nemuro Belt
KOY-EUA	100.00	0.00	0.00	0.00	New, Koryak fixed to Eurasia
KOY-FAR	*155.00*	0.00	0.00	0.00	New, Koryak moving on the Farallon Plate
EKO-KOY	80.00	0.00	0.00	0.00	New, Ekonay fixed to Koryak
EKO-FAR	*155.00*	0.00	0.00	0.00	New, Ekonay moving on the Farallon Plate
OLY-KOY	70.00	0.00	0.00	0.00	New, Olyutorsk fixed to Koryak
OLY-FAR	*155.00*	0.00	0.00	0.00	New, Olyutorsk moving on the Farallon Plate
SHR-OLY	60.00	0.00	0.00	0.00	New, Shirshov Ridge fixed to Olyutorsk
SHR-KUL	*79.65*	0.00	0.00	0.00	New, Shirshov Ridge moving on the Kula Plate
SHR-FAR	*155.00*	0.00	0.00	0.00	New, Shirshov Ridge moving on the Farallon Plate
NORTHERN ASIAN ROTATIONS					
OLO-EUA	140.00	0.00	0.00	0.00	Oloi Terrane in present position
SAY-EUA	133.99	0.00	0.00	0.00	South Anyui Terrane in present position
SAY-EUA	150.00	-49.52	21.58	11.27	New, assembling northeast Siberia
ANY-EUA	135.00	0.00	0.00	0.00	Anadyr Terrane in present position
ANY-EUA	150.00	-49.52	21.58	6.00	New, assembling northeast Siberia
LOM-EUA	9.74	64.64	136.93	2.29	Rowley & Lottes (1988)

TABLE 12. TOTAL RECONSTRUCTION POLES USED IN CRETACEOUS AND CENOZOIC RECONSTRUCTIONS (continued, p. 10)

LOM-EUA	19.05	67.99	130.22	4.57	Rowley & Lottes (1988)
LOM-EUA	33.06	68.76	136.02	7.69	Rowley & Lottes (1988)
LOM-EUA	46.26	65.65	139.16	10.52	Rowley & Lottes (1988)
LOM-EUA	52.36	62.42	141.02	12.52	Rowley & Lottes (1988)
LOM-EUA	55.90	64.17	142.37	14.08	Rowley & Lottes (1988)
LOM-EUA	67.64	64.16	146.56	16.44	Rowley & Lottes (1988)
LOM-EUA	70.97	65.29	147.22	17.21	Rowley & Lottes (1988)
LOM-EUA	80.00	67.27	148.50	18.78	Rowley & Lottes (1988)
ANTARCTICA TO AFRICA AND SOUTH AMERICA					
EAN-NAF	42.54	11.40	-43.70	7.81	Anomaly 20 Royer et al. (1988),
EAN-NAF	46.26	10.30	-42.90	8.77	Anomaly 21 Royer et al. (1988)
EAN-NAF	52.36	6.70	-40.60	9.97	Anomaly 24 Royer et al. (1988)
EAN-NAF	57.55	3.80	-39.70	10.63	Anomaly 26 Royer et al. (1988)
EAN-NAF	62.50	0.60	-39.20	11.32	Anomaly 28 Royer et al. (1988)
EAN-NAF	63.98	-0.40	-39.40	11.59	Anomaly 29 Royer et al. (1988)
EAN-NAF	67.64	1.10	-41.60	11.84	Anomaly 31 Royer et al. (1988)
EAN-NAF	70.97	-1.80	-41.40	13.47	Anomaly 32 Royer et al. (1988)
EAN-NAF	74.47	-4.70	-39.70	16.04	Anomaly 33 Royer et al. (1988)
EAN-NAF	83.50	-2.00	-39.20	17.85	Anomaly 34 Royer et al. (1988)
EAN-NAF	90.00	-5.91	326.97	29.34	New, Intermediate position
EAN-SNJ	130.00	-62.38	226.54	45.67	East Antarctica fit to San Jorge Block
ANTARCTIC ROTATIONS					
PLB-WAB	83.50	0.00	0.00	0.00	Antarctic Peninsula in present position relative to West Antarctica
PLB-WAB	130.00	86.84	151.76	10.84	New, motion of Palmer Land Block along a transform on its southern margin
SOB-GLB	46.26	-83.08	42.64	6.65	South Orkney Island Block stretching from Antarctic Peninsula
SSI-GLB	10.00	60.31	106.04	7.07	South Sandwich Islands rifting from Antarctic Peninsula, opening Bransfield Strait
AUSTRALIA TO EAST ANTARCTICA					
AUS-EAN	9.74	9.70	36.50	-6.80	?Anomaly 5 Barron (1987)
AUS-EAN	19.05	19.20	32.70	-5.40	?Anomaly 6 Barron (1987)
AUS-EAN	24.73	16.10	19.40	-4.00	?Anomaly 7 Barron (1987)
AUS-EAN	30.50	2.10	38.80	-3.00	?Anomaly 12 Barron (1987)
AUS-EAN	33.06	5.00	33.20	-1.60	?Anomaly 13 Barron (1987)
AUS-EAN	36.62	-0.30	34.80	-3.20	?Anomaly 17 Barron (1987)
AUS-EAN	42.54	13.00	31.50	-24.10	Anomaly 20y Konig (1980, 1987)
AUS-EAN	46.26	-12.80	28.50	-28.80	Anomaly 21 Besse & Courtillot (1988)
AUS-EAN	52.36	-11.50	32.00	-31.20	Anomaly 24 Besse & Courtillot (1988)
AUS-EAN	62.50	9.66	33.13	-25.57	Anomaly 28y Powell, Roots & Veevers (1988)
AUS-EAN	83.50	4.48	35.60	-26.90	Anomaly 34y Powell, Roots & Veevers (1988)
AUS-EAN	94.00	1.50	37.00	-27.85	Veevers (1987)

TABLE 12. TOTAL RECONSTRUCTION POLES USED IN CRETACEOUS AND CENOZOIC RECONSTRUCTIONS (continued, p. 11)

AUS-EAN	120.40	4.78	36.21	-29.14	M0 Powell, Roots & Veevers (1989)
AUS-EAN	132.07	6.89	35.70	-30.09	M11 Powell, Roots & Veevers (1989)
AUS-EAN	150.00	9.07	223.54	32.55	New fit, unstreched margins
AUSTRALIAN AND SOUTHWEST PACIFIC ROTATIONS					
TAS-AUS	55.90	0.00	0.00	0.00	Tasmania in present position
TAS-AUS	65.58	42.34	328.94	15.66	Tasmania stretching from Australia
STP-TAS	55.90	0.00	0.00	0.00	South Tasman Plateau in present position
STP-TAS	65.58	44.08	329.83	38.63	South Tasman Plateau stretching from Tasmania
WLB-AUS	50.00	0.00	0.00	0.00	Woodlark Basin open
WLB-AUS	65.00	-14.02	241.47	6.18	Woodlark Island Block opening Woodlark Basin
QLD-AUS	24.73	-45.00	239.82	0.42	Queensland Plateau stretching from Australia
CAM-EAN	9.74	68.70	280.30	9.40	Anomaly 5 Barron & Harrison (1979)
CAM-EAN	25.82	71.99	287.50	15.74	Anomaly 8 Barron & Harrison (1979)
CAM-EAN	33.06	74.53	302.81	27.90	Anomaly 13 Barron & Harrison (1979)
CAM-EAN	38.43	71.94	272.70	27.45	Anomaly 18 Barron & Harrison (1979)
CAM-EAN	55.90	62.05	261.47	31.50	Anomaly 25 Barron & Harrison (1979)
CAM-EAN	65.58	65.91	286.34	43.79	Anomaly 30 Barron & Harrison (1979)
CAM-EAN	74.47	67.92	309.95	66.02	Anomaly 33 Barron & Harrison (1979)
LHR-AUS	52.35	0.00	0.00	0.00	Anomaly 24 Weissel & Hayes (1972)
LHR-AUS	55.90	1.50	318.50	2.60	Anomaly 25 Weissel & Hayes (1972)
LHR-AUS	63.98	5.50	320.67	6.69	Anomaly 29 Weissel & Hayes (1972)
LHR-AUS	65.58	11.33	321.59	12.81	Anomaly 30 Weissel & Hayes (1972)
LHR-AUS	74.47	13.97	322.06	19.07	Anomaly 33 Weissel & Hayes (1972)
HJB-AUS	20.00	0.00	0.00	0.00	New, Hunstein-Jimi-Bismark fixed relative to Australia (after Wilson, 1989)
HJB-AUS	60.00	44.31	39.50	4.00	New, Hunstein-Jimi-Bismark moving relative to Australia (after Wilson, 1989)
HJB-AUS	130.00	48.10	286.94	16.47	New, Hunstein-Jimi-Bismark at original site on the Australian margin (after Wilson, 1989)
WIJ-AUS	20.00	0.00	0.00	0.00	New, West Irian-Jaya fixed relative to Australia
WIJ-AUS	40.00	44.31	39.50	4.00	New, West Irian-Jaya moving with Hunstein-Jimi-Bismark
BSA-AUS	20.00	0.00	0.00	0.00	New, Banggai-Sula fixed relative to Australia
BSA-AUS	40.00	44.31	39.50	3.50	New, Banggai-Sula converging on Australia
OBI-AUS	20.00	0.00	0.00	0.00	New, Obi-Bacan fixed relative to Australia
OBI-AUS	40.00	44.31	39.50	3.00	Nwe, Obi-Bacan converging on Australia
BST-AUS	20.00	0.00	0.00	0.00	New, Buru-Seram-Tanimbar fixed relative to Australia
BST-AUS	40.00	44.31	39.50	2.50	New, Buru-Seram-Tanimbar converging on Australia
BUT-AUS	20.00	0.00	0.00	0.00	New, Buton-Tukang fixed relative to Australia (after Wilson, 1989)
BUT-AUS	40.00	44.31	39.50	2.00	New, Buton-Tukang converging on Australia (after Wilson, 1989)
CYC-AUS	130.00	44.31	39.50	10.00	New, Cyclops converging on Australia, (after Wilson (1989)
OWS-CYC	130.00	0.00	0.00	0.00	New, Owen Stanley Range fixed relative to Cyclops Terrane (after Wilson, 1989)
TIM-AUS	70.00	-33.52	153.87	15.35	New, Timor moving relative to Australia (after Wilson (1989)
TIM-AUS	200.00	0.00	0.00	0.00	New, Timor moving with Australia (after Wilson (1989)
RBB-EUA	10.00	0.00	0.00	0.00	Reed Bank Block fixed relative to Asia

TABLE 12. TOTAL RECONSTRUCTION POLES USED IN CRETACEOUS AND CENOZOIC RECONSTRUCTIONS (continued, p. 12)

RBB-EUA	30.00	14.75	94.27	14.58	New, Reed Bank Block separates from China (after Hutchison (1989)
RBB-EUA	55.90	14.75	94.27	21.58	New, Reed Bank Block separates from China (after Hutchison (1989)
MBB-EUA	30.00	0.00	0.00	0.00	Macclesfield Bank Block in present position
MBB-EUA	55.90	16.22	112.33	45.17	New, Macclesfield Bank Block separates from China (after Hutchison (1989)
NPB-RBB	55.90	0.00	0.00	0.00	New, North Palawan Block moves with Reed Bank Block (after Hutchison, 1989)
PHL-EUA	5.89	0.00	0.00	0.00	New, Phillipine Arc in present position (after McCabe and Cole, 1989)
PHL-EUA	7.50	90.00	0.00	1.50	New, Philipine Arc converging on the North Palawan Block (after McCabe and Cole, 1989)
PHL-EUA	11.93	-2.09	308.38	40.05	New, Phillipine Arc rotating clockwise (after McCabe and Cole, 1989)
PHL-PAC	*140.00*	0.00	0.00	0.00	Philippine Arc moving on the Pacific Plate
PLN-PHL	40.00	0.00	0.00	0.00	New, Northern Phillipine Sea fixed to Phillipine Arc (after McCabe and Cole, 1989)
PLN-PHL	55.90	-20.00	220.00	17.00	New, Northern Phillipine Sea spreading from Phillipine Arc (after McCabe and Cole, 1989)
PNS-PHL	40.00	0.00	0.00	0.00	New, Southern Phillipine Sea fixed to Phillipine Arc (after McCabe and Cole, 1989)
PLN-PHL	55.90	-20.00	220.00	-17.00	New, Southern Phillipine Sea spreading from Phillipine Arc (after McCabe and Cole, 1989)
SBS-EUA	100.00	0.00	0.00	0.00	East Sarawak-Brunei-West Sabah Block in present position
CSW-SBS	40.00	90.00	0.00	-2.00	New, Central Sulawesi closes on East Sarawak-Brunei-West Sabah Block (after Wilson (1989)
INDIAN ROTATIONS					
IND-EAN	43.79	16.40	28.80	-25.41	Anomaly 20old Powell, Roots & Veevers (1988)
IND-EAN	47.91	12.80	28.50	-28.67	Anomaly 21old Powell, Roots & Veevers (1988)
IND-EAN	62.50	11.10	15.40	-44.24	Anomaly 28y Powell, Roots & Veevers (1988)
IND-EAN	83.50	7.30	9.30	-64.78	Anomaly 34 Powell, Roots & Veevers (1988)
IND-EAN	90.00	-2.60	10.30	-78.64	Powell, Roots & Veevers (1988)
IND-EAN	110.00	-2.60	10.30	-78.64	Royer & Coffin (1992)
IND-EAN	120.40	-0.80	9.70	-81.97	"M0" Royer & Coffin (1992)
IND-EAN	132.07	3.05	196.91	90.24	New
IND-EAN	150.00	-3.60	15.10	-92.01	Lawver & Scotese (1987)
SRI-IND	83.50	0.00	0.00	0.00	Sri Lanka in present position relative to India
SRI-IND	100.00	-10.27	260.35	26.20	New, Sri Lanka closed to India (118 Ma is a guess)
IBR-IND	10.00	0.00	0.00	0.00	Indo-Burman Ranges attached to India
IBR-IND	50.00	8.51	4.15	10.11	New, Indo-Burman Ranges sliding along Indian margin
INDIAN OCEAN ROTATIONS					
MAD-SOM	120.00	0.00	0.00	0.00	Present Position
MAD-SNJ	132.07	-43.10	168.04	51.21	Madagascar rotating with San Jorge Block
SEY-SOM	65.00	0.00	0.00	0.00	Seychelles in present position
SEY-IND	67.64	17.62	320.23	29.42	Seychelles attached to India
SEY-IND	126.00	17.62	320.23	29.42	Seychelles attached to India
SEY-MAD	128.00	4.67	224.60	55.15	Seychelles attached to Madagascar
BRR-KRG	38.43	10.30	34.70	-23.60	Anomaly 18 Weissel et al. (1977)
BRR-KRG	46.26	-42.75	200.34	23.12	New fit (timing after Munschy et al., 1992)
PACIFIC OCEAN ROTATIONS					

TABLE 12. TOTAL RECONSTRUCTION POLES USED IN CRETACEOUS AND CENOZOIC RECONSTRUCTIONS (continued, p. 13)

PAC-EAN	1.00	36.00	284.00	0.90	Engebretson et al. (1984)
PAC-EAN	*16.01*	68.90	278.60	13.50	Engebretson et al. (1984)
PAC-EAN	*20.00*	74.10	234.90	3.60	Engebretson et al. (1984)
PAC-EAN	*42.54*	62.60	313.60	16.10	Engebretson et al. (1984)
PAC-EAN	*70.00*	9.30	283.20	18.00	Engebretson et al. (1984)
PAC-EAN	*140.00*	41.20	294.10	54.75	Engebretson et al. (1984)
FAR-PAC	5.89	-19.00	207.00	3.10	Engebretson et al. (1984)
FAR-PAC	9.74	-69.00	186.00	6.30	Engebretson et al. (1984)
FAR-PAC	16.01	-79.00	188.00	12.60	Engebretson et al. (1984)
FAR-PAC	25.82	-81.00	205.00	20.00	Engebretson et al. (1984)
FAR-PAC	33.06	-88.00	155.00	32.60	Engebretson et al. (1984)
FAR-PAC	38.43	-87.00	85.00	43.50	Engebretson et al. (1984)
FAR-PAC	46.26	-86.00	70.00	51.40	Engebretson et al. (1984)
FAR-PAC	55.90	-85.00	49.00	61.70	Engebretson et al. (1984)
FAR-PAC	62.50	-86.00	32.00	65.00	Engebretson et al. (1984)
FAR-PAC	65.58	-86.00	13.00	68.10	Engebretson et al. (1984)
FAR-PAC	70.97	-86.00	352.00	71.30	Engebretson et al. (1984)
FAR-PAC	79.65	-85.00	315.00	80.30	Engebretson et al. (1984)
FAR-PAC	120.40	-78.00	285.00	107.40	Engebretson et al. (1984)
FAR-PAC	126.72	-75.00	275.00	108.80	Engebretson et al. (1984)
FAR-PAC	132.07	-71.00	269.00	110.50	Engebretson et al. (1984)
FAR-PAC	137.88	-68.00	269.00	114.20	Engebretson et al. (1984)
FAR-PAC	155.00	-63.00	270.00	121.70	Engebretson et al. (1984)
KUL-PAC	42.54	90.00	0.00	0.00	Revised time of demise of Pacific-Kula Ridge (after Cox et al., 1989)
KUL-PAC	46.26	-18.00	291.00	6.50	Engebretson et al. (1984)
KUL-PAC	55.90	-18.00	291.00	16.90	Engebretson et al. (1984)
KUL-PAC	60.92	-18.00	291.00	18.60	Engebretson et al. (1984)
KUL-PAC	65.58	-18.00	291.00	21.60	Engebretson et al. (1984)
KUL-PAC	70.68	-18.00	291.00	26.40	Engebretson et al. (1984)
KUL-PAC	79.65	-18.00	291.00	40.00	Engebretson et al. (1984)
IZ1-PAC	79.65	90.00	0.00	0.00	Engebretson et al. (1984)
IZ1-PAC	120.40	48.00	3.00	50.40	Engebretson et al. (1984)
IZ1-PAC	126.72	48.00	3.00	62.70	Engebretson et al. (1984)
IZ1-PAC	132.07	48.00	3.00	81.80	Engebretson et al. (1984)
IZ1-PAC	137.88	44.00	10.00	84.20	Engebretson et al. (1984)
IZ2-PAC	128.97	90.00	0.00	0.00	Engebretson et al. (1984)
IZ2-PAC	137.88	-16.00	308.00	23.10	Engebretson et al. (1984)

motions" (Kaula, 1975). Hay et al. (1990) showed that differences in latitude of as much as to 25° can be produced by different reference frames.

We used the paleomagnetic reference frame for North America of Harrison and Lindh (1982). This paleomagnetic reference frame was originally considered best because at the time it was published the largest number of reliable paleomagnetic pole positions were from North America. Barron (1987) determined his reference frame by interpolation between the mean paleomagnetic poles for the Jurassic, Cretaceous, and Paleogene from McElhinney (1973). We continue to use the Harrison and Lindh (1982) reference frame because it places Triassic climate-sensitive sediments at appropriate paleolatitudes (Wilson et al., 1994).

Fragment rotations

In constructing the rotation file we applied Ockham's "Principle of Parsimony" ("Occam's Razor") whenever possible, using the simplest possible set of rotations required to describe the motions of fragments relative to each other. If the smaller fragments, blocks, and terranes are being moved on plates, many of the fragments should have the same motion at any given time. We always try to use the same rotation for as many fragments as possible. A recurring theme described along active margins is rifting of a block from the margin, formation of a back-arc basin, and closure of the back-arc basin and collision of the block with the margin from which it rifted (e.g., examples in the Tethys, described by Dercourt et al., 1992). In constructing the rotation file we followed the descriptions of these motions as closely as possible.

The NORTH AMERICAN ROTATIONS start with removal of the general effects of the Laramide orogeny from 49.5 to 67.5 Ma, opening a space along the sinuous line separating western North America from central and eastern North America. It is assumed that many of the terranes of northwestern North America had been assembled into a single Superterrane I + II before the Cretaceous, and this large block collided with North America causing the Sevier orogeny from 135 to 120 Ma (Wilson et al., 1991). In this A&O file, the bending of the terranes of the Alaskan Peninsula is considered to have occurred between 123 and 90 Ma as a result of the "windshield wiper" motion of the Arctic Alaska–Chukotka Block opening the Canadian Basin is after Rowley and Lottes (1988, 1989), but the times are poorly constrained; we assumed the motion occurred between 134 and 90 Ma. Motions of the Ellesmere Block to remove effects of the Innuitian orogeny are after Rowley and Lottes (1988, 1989). More detailed rotations for individual faults have been published by Lawver et al. (1990) but were not used here.

Motions of AFRICA TO NORTH AMERICA are after several literature sources. Africa is considered a single block, although in previous reconstructions we had used a separation along the Benoue Trough and other rifts, shown as a line in Figures 9–14. Removing the Early Cretaceous bending of the margin of South America, as described above, provides a tight fit to Africa without appreciable stretching along Benoue Trough.

Fits and rotations of Somalia and Arabia to nuclear Africa (AFRICA ROTATIONS) are new. A separate Socotra Block is not needed.

Motions of SOUTH AMERICA TO AFRICA are after Nürnberg and Müller (1991) except for the fit and a new rotation at 120.40 Ma required to avoid an overlap of our continental outlines in the region of the Guinea Plateau. The new rotation was chosen to produce a transform motion along the Guinea Coast–Northeast South American margins. It results in a parallel-sided South Atlantic during the late Early Cretaceous.

SOUTH AMERICAN ROTATIONS describe the internal deformation of the continent as a result of stretching associated with the formation of aulacogens (Wold et al., 1994), as described above. These motions allow South America to "unwrap" from Africa during the Early Cretaceous.

CENTRAL AMERICAN AND CARIBBEAN ROTATIONS are those used by Hay and Wold (1996) and reflect a new interpretation of the origin and history of the Caribbean plate and the paleoclimatologically important connection between Atlantic and Pacific.

EURASIA TO NORTHERN GREENLAND rotations are the sequence of previously published and new rotations used by Wold (1992) in his study of the opening of the northern North Atlantic and Norwegian-Greenland Sea.

SOUTHWESTERN EUROPE TO EURASIA AND SOUTHERN GREENLAND rotations open Rockall Trough, take the translation and stretching out of the North Sea, and make a tight fit of southwestern Europe against Greenland. The timing is taken to be Early Cretaceous ("Late Kimmerian"), following Megson (1987) and Ziegler (1990), rather than Late Cretaceous, as had been suggested by the interpretation of weak magnetic lineations by Bott (1978) and Roberts et al. (1981a).

SOUTHWESTERN EUROPEAN ROTATIONS move the smaller continental fragments in the North Atlantic to their home positions and restore the effects of stretching.

WESTERN TETHYAN ROTATIONS move the blocks in the western Tethys to the positions shown on the maps of Dercourt et al. (1986). These are essentially the same positions given in the more recent Atlas of maps of the Tethys published by Dercourt et al. (1992).

EASTERN TETHYAN ROTATIONS move the blocks in the eastern Tethys to the positions shown on the maps of Dercourt et al. (1986). These are essentially the same positions given in the more recent Atlas published by Dercourt et al. (1992). There are a number of cases in which fragments rift from Asia and then collide with it again: the Alborz, Sanandaj, Sirjan, Central Iran, and Lut Blocks during the Early Cretaceous.

EASTERN ASIAN ROTATIONS follow the general evolutionary pattern for Asia proposed by Maruyama et al. (1989). The evolution of the South China Sea is after Hutchison (1989). The rotations for the Philippines and Philippine Sea reproduce the paleomagnetic latitude positions for the Philippines and nearby Deep Sea Drilling Project (DSDP) sites given by McCabe and Cole (1989). However, we close the Japan Sea by sliding the terranes of Japan northward. This is a simpler solution than the bending of the Japanese arc proposed by Taira et al. (1989). The formation of the Sea of Okhotsk and Kamchatka is after Watson and Fujita (1985).

NORTHERN ASIAN ROTATIONS attempt to follow suggestions by Zonenshain and Natapov (1989) and Zonenshain et al. (1990) for the motions of the blocks of northeastern Siberia. The motions of Lomonosov Ridge are after Rowley and Lottes (1988, 1989).

ANTARCTICA TO AFRICA AND SOUTH AMERICA gives the position of East Antarctica relative to Africa for magnetic anomalies back to 34, and uses an intermediate position in the Cretaceous Quiet Interval from Royer and Coffin (1992). It then attaches East Antarctica to the San Jorge Block of South America at anomaly M11 time. The position of West Antarctica is relative to Africa for anomalies back to 34, and independent of East Antarctica. At 110 Ma, during the Cretaceous Magnetic Quiet Interval, its position relative to East Antarctica is assumed to be the same as at the present time. The fit of East Antarctica to Africa is essentially the same as that of Lawver et al. (1992). The problem of the overlap of the Antarctic Peninsula with South America is resolved by removing the subsequent bending of southern South America caused by the aulacogens, as discussed above.

ANTARCTIC ROTATIONS are very limited in this model, following Wilson et al. (1989b). They allow the Antarctic Peninsula to remain in contact with the southern Andes, forming a continuous mountain chain that was not interrupted until the Oligocene. There is a slow transform motion of the Palmer Land Block so that it remains in contact with the San Jorge Block during the Cretaceous. The motions of South Orkney Island Block and South Sandwich Islands take into account the separation of these blocks from the Antarctic Peninsula.

AUSTRALIA TO EAST ANTARCTICA rotations are a composite of those in the literature with a new fit.

AUSTRALIAN AND SOUTHWEST PACIFIC ROTATIONS account for the motions of the blocks to the south, east, and north of Australia, generally following Spörli and Ballance (1989) and using rotations from the literature. They include stretching of Tasmania and the South Tasman Plateau from the Australian nuclear block, and the motions of the terranes in the New Guinea region, the Philippines, and effects of opening of the South China Sea (McCabe and Cole, 1989; Hutchison, 1989).

INDIAN OCEAN ROTATIONS describe the motions of blocks and plateaus in the Indian Ocean.

PACIFIC OCEAN ROTATIONS describe the motion of the Pacific, Nazca, Coccos, Kula, Farallon, and Izanagi plates and the terranes that traveled with them, following Engebretson et al. (1984, 1985, 1987), Debiche et al. (1987), Cox et al. (1989), and Nur and Ben-Avraham (1989).

REFERENCES CITED

Andrews, J. A., 1985, True polar wander: An analysis of Cenozoic and Mesozoic paleomagnetic poles: Journal of Geophysical Research, v. 90, p. 7737–7750.

Askin, R. A., 1989, Endemism and heterochroneity in the Late Cretaceous (Campanian) to Paleocene palynofloras of Seymour Island, Antarctica: implications for origins, dispersal and paleoclimates of southern floras, *in* Alistair, C. J., ed., Origins and evolution of Antarctic biota: Geological Society of London Special Publication 147, p. 107–119.

Austin, J. A., Jr., and Uchupi, E., 1982, Continental-oceanic transition of southwest Africa: American Association of Petroleum Geologists Bulletin, v. 66, p. 1328–1347.

Baldwin, B., and Butler, C. O., 1985, Compaction curves: American Association of Petroleum Geologists Bulletin, v. 69, p. 622–626.

Barker, P. F., and Burrell, J., 1977, The opening of Drake Passage: Marine Geology, v. 25, p. 15–34.

Barron, E. J., 1987, Cretaceous plate tectonic reconstructions: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 59, p. 3–29.

Barron, E. J., and Harrison, C. G., 1979, Reconstructions of the Campbell Plateau and the Lord Howe Rise: Earth and Planetary Science Letters, v. 45, p. 87–92.

Barron, E. J., Harrison, C. G., Sloan, J. L., and Hay, W. W., 1981, Paleogeography, 180 million years ago to the present: Eclogae Geologicae Helvetiae, v. 74, p. 443–470.

Berggren, W. A., Kent, D. V., Aubry, M. P., and Hardenbol, J., 1995, eds., Geochronology, time scales and global stratigraphic correlation: A unified temporal framework for an historical geology: Society of Paleontologists and Mineralogists Special Publication 54, p. 392.

Besse, J., and Courtillot, V., 1988, Paleogeographic maps of the continents bordering the Indian Ocean since the Early Jurassic: Journal of Geophysical Research, v. 93, p. 11791–11808.

Bonatti, E., Sarnthein, M., Boersma, A., Gorini, M., and Honnorez, J., 1977, Neogene crustal emersion and subsidence at the Romanche Fracture Zone, equatorial Atlantic: Earth and Planetary Science Letters, v. 35, p. 369–383.

Bonatti, E., Ligi, M., Gasperini, L., Peyve, A., Raznitsin, Y., and Chen, Y. J., 1994, Transform migration and vertical tectonics at the Romanche Fracture Zone, equatorial Atlantic: Journal of Geophysical Research, v. 99, p. 21779–21802.

Bott, M. H., 1978, The origin and development of the continental margins between the British Isles and south-eastern Greenland, *in* Bowes, D. R., and Leake, B. E., eds., Crustal evolution in NW Britain and adjacent regions: Geological Journal, Special Issue 10, p. 377–392.

Bott, M. H., 1985, Plate tectonic evolution of the Icelandic transverse ridge and adjacent regions: Journal of Geophysical Research, v. 90, p. 9953–9960.

Briden, J. C., Drewry, G. C., and Smith, A. G., 1974, Phanerozoic equal-area world maps: Journal of Geology, v. 82, p. 555–574.

Briden, J. C., Hurley, A. M., and Smith, A. G., 1981, Paleomagnetism and Mesozoic-Cenozoic paleocontinental maps: Journal of Geophysical Research, v. 86, p. 11361–11656.

Buffetaut, E., 1987, On the age of the dinosaur fauna from the Lameta Formation (Upper Cretaceous) of central India: Newsletters in Stratigraphy, v. 18, p. 1–6.

Bullard, E. C., Everett, J. E., and Smith, A. G., 1965, The fit of the continents around the Atlantic, *in* Symposium on Continental Drift: Philosophical Transactions of the Royal Society of London, Series A, v. 258, p. 41–51. Organized by P. M. S. Blackett, Sir Edward Bullard, and S. K. Runcorn.

Burke, C. A., and Drake, C. L., eds., 1974, The geology of continental margins: Berlin, Springer Verlag, 1009 p.

Burke, K., 1976, Development of graben associated with the initial ruptures of the Atlantic Ocean: Tectonophysics, v. 36, p. 93–112.

Burke, K., and Dewey, J. F., 1973, Plume generated triple junctions: Key indicators in applying plate tectonics to old rocks: Journal of Geology, v. 81, p. 406–433.

Burke, K., and Dewey, J. F., 1974, Two plates in Africa during the Cretaceous?: Nature, v. 249, p. 313–316.

Burrus, J., 1984, Contribution to a geodynamic synthesis of the Provencal Basin (northwestern Mediterranean): Marine Geology, v. 55, p. 247–269.

Cande, S., LaBrecque, J. C., Larson, R. L., Pitman, W. C., III, Golovchenko, X., and Haxby, W. F., 1989, Magnetic lineations of the world's ocean basins: Tulsa, Oklahoma, American Association of Petroleum Geologists, scale 1:27,400,000, 1 sheet, 13 p. text.

Charig, A. J., 1973, Jurassic and Cretaceous dinosaurs, *in* Hallam, A., ed., Atlas of paleobiology: Amsterdam, Elsevier, p. 339–352.

Chatterjee, S., and Hotton, N., III, 1986, The paleoposition of India: Journal of Southeast Asian Earth Sciences, v. 1, p. 145–189.

Chenet, P., Montadert, L., Gairaud, H., and Roberts, D., 1983, Extension ratio measurements on the Galicia, Portugal, and northern Biscaye continental margins: Implications for evolutionary models of passive continental margins, *in* Watkins, J. S., and Drake, C. L., eds., Studies in continental margin geology: American Association of Petroleum Geologists Memoir 34, p. 703–715.

Choubert, G., and Faure-Muret, A., 1976, Geological world atlas: Paris, UNESCO, scale 1:10,000,000, 22 sheets with explanations.

Cloetingh, S., 1986, Intraplate stresses: A new tectonic mechanism for fluctuations of relative sea level: Geology, v. 14, p. 617–620.

Cloetingh, S., and Wortel, R., 1985, Regional stress field of the Indian plate: Geophysical Research Letters, v. 12, p. 77–80.

Cobban, W. A., and Merewether, E. A., 1983, Stratigraphy and paleontology of the Mid-Cretaceous rocks in Minnesota and contiguous areas: U.S. Geological Survey Professional Paper 1253, p. 52.

Cochran, J. R., 1988, Somai Basin, Chain Ridge, and origin of the Northern Somali Basin gravity and geoid low: Journal of Geophysical Research, v. 93, p. 11985–12008.

Coffin, M. F., 1992a, Subsidence of the Kerguelen Plateau: The Atlantis concept, *in* Wise, S. W., Jr., Schlich, R., and Palmer Julson, A. A., eds., Proceedings, Ocean Drilling Program, Scientific Results, v. 120 (Part 2): College Station, Texas, Ocean Drilling Program, p. 945–949.

Coffin, M. F., 1992b, Emplacement and subsidence of Indian Ocean Plateaus and submarine ridges, *in* Duncan, R. A., Rea, D. K., Kidd, R. B., von Rad, U., and Weissel, J. K., eds., Synthesis of results from scientific drilling in the Indian Ocean: Washington, D.C., American Geophysical Union, Geophysical Monograph 70, p. 115–125.

Coffin, M. F., and Eldholm, O., 1993a, Scratching the surface: Estimating dimensions of large igneous provinces: Geology, v. 21, p. 515–518.

Coffin, M. F., and Eldholm, O., 1993b, Large igneous provinces: Scientific American, v. 269, p. 42–49.

Coffin, M. F., and Rabinowitz, P. D., 1987, Reconstruction of Madagascar and Africa: evidence from the Davie Fracture Zone and western Somali Basin: Journal of Geophysical Research, v. 92, p. 9385–9406.

Colbert, E. H., 1975, Mesozoic tetrapods and the northward migration of India: Journal of the Paleontological Society of India, v. 20, p. 138–145.

Colbert, E. H., 1976, Fossils and the drifting continents: Fossils Magazine, v. 1, p. 5–22.

Colbert, E. H., 1981, The distribution of tetrapods and the break-up of Gondwana, *in* Cresswell, M. M., and Vella, P., eds., Gondwana Five: Selected Papers and Abstracts of Papers Presented at the Fifth International Gondwana

Symposium, Wellington, New Zealand, 11-16 February 1980, p. 277-282.
Courtillot, V., and Besse, J., 1987, Magnetic field reversals, polar wander and core-mantle coupling: Science, v. 237, p. 1140–1147.
Cox, A., and Hart, R. B., 1986, Plate tectonics: How it works: Oxford, Blackwell Scientific Publications, 392 p.
Cox, A., DeBiche, M. G., and Engebretson, D. C., 1989, Terrane trajectories and plate interactions along continental margins in the North Pacific Basin, *in* Ben-Avraham, Z., ed., The evolution of the Pacific Ocean margins: New York, Oxford University Press, p. 20–35.
Crame, J. A., 1982, Late Mesozoic bivalve biostratigraphy of the Antarctic Peninsula region: Journal of the Geological Society of London, v. 139, p. 771–778.
Crame, J. A., 1992, Early Cretaceous bivalves from the South Shetland Islands, Antarctica: 4th International Cretaceous Symposium, Hamburg, Abstracts.
Crough, S. T., 1979, Hotspot epeirogeny: Tectonophysics, v. 61, p. 321–333.
de Almeida, F. M., Martin, C. F., Ferreira, E. O., and Furque, G., 1978, Tectonic map of South America: Tulsa, Oklahoma, American Association of Petroleum Geologists, scale 1:5,000,000, 2 sheets.
Debiche, M. G., Cox, A., and Engebretson, D. C., 1987, The motion of allochthonous terranes across the North Pacific Basin: Geological Society of America Special Paper 207, 49 p.
Dercourt, J., Zonenshain, L. P., and Ricou, L., 1986, Geological evolution of the Tethys belt from the Atlantic to the Pamirs since the Lias: Tectonophysics, v. 123, p. 241–315.
Dercourt, J., Ricou, L. E., and Vrielynck, B., editors, 1992, Atlas Tethys paleoenvironmental maps: Paris, Gauthier-Villars, 307 p.
Detrick, R. S., Sclater, J. G., and Thiede, J., 1977, The subsidence of aseismic ridges: Earth and Planetary Science Letters, v. 34, p. 185–196.
Dettman, M. E., 1989, Antarctica: Cretaceous cradle of austral temperate rainforests?, *in* Crame, J. A., ed., Origins and evolution of the Antarctic biota: Geological Society of London Special Publication 47, p. 89–105.
Dietz, R. S., and Holden, J. C., 1970, The breakup of Pangaea: Scientific American, v. 223, no. 4, p. 30–41.
Droxler, A. W., Cunningham, A., Hine, A. C., Hallock, P. Duncan, D., Rosencrantz, E., Buffler, R., and Robinson, E., 1992, Late middle (?) Miocene segmentation of an Eocene-early Miocene carbonate megabank on the northern Nicaragua Rise tied to tectonic activity at the North American/Caribbean plate boundary zone: Eos, (Transactions, American Geophysical Union) v. 73, Supplement no. 43, p. 299.
Duncan, R. A., 1991, Age distribution of volcanism along aseismic ridges in the eastern Indian Ocean, *in* Weissel, J., Pierce, J., Taylor, E., and Alt, J., eds., Proceedings of the Ocean Drilling Program, Scientific Results, Volume 121: College Station, Texas, Ocean Drilling Program, p. 507–517.
Duncan, R. A., and Hargraves, R. B., 1990, $^{40}Ar/^{39}Ar$ geochronology of basement rocks from the Mascarene Plateau, the Chagos Bank, and the Maldives Ridge, *in* Duncan, R. A., Backman, J., and Peterson, L. C., eds., Proceedings of the Ocean Drilling Program, Initial Reports, Volume 104: College Station, Texas, Ocean Drilling Program, p. 43–51.
Einsele, G., 1992, Sedimentary basins: Evolution, facies, and sediment budget: Berlin, Springer-Verlag, p. 628.
Emery, K. O., and Uchupi, E., 1984, The Geology of the Atlantic Ocean: New York, Springer-Verlag, p. 1050.
Engebretson, D. C., Cox, A., and Debiche, M., 1987, Reconstructions, plate interactions and trajectories of oceanic and continental plates in the Pacific Basin, *in* Monger, J. W., and Francheteau, J., eds., Circum-Pacific orogenic belts and evolution of the Pacific Ocean Basin: American Geophysical Union Geodynamics Series, v.18, p. 19–27.
Engebretson, D. C., Cox, A., and Gordon, R. G., 1984, Relative motions between oceanic plates of the Pacific Basin: Journal of Geophysical Research, v. 89, p. 10291–10310.
Engebretson, D. C., Cox, A., and Gordon, R. G., 1985, Relative motions between oceanic and continental plates in the Pacific Basin: Geological Society of America Special Paper 206, 59 p.
Folger, D. W., Dillon, W. P., Grow, J. A., Klitgord, K. D., and Schlee, J. S., 1979, Evolution of the Atlantic continental margin of the United States, *in* Talwani, M., Hay, W., and Ryan, W. B., eds., Deep drilling results in the Atlantic Ocean: Continental margins and paleoenvironment: Washington, D.C., American Geophysical Union, Maurice Ewing Series 3, p. 87–108.
Fritsch, B., Schlich, R., Munschy, M., Fezga, F., and Coffin, M. F., 1992, Evolution of the southern Kerguelen Plateau deduced from seismic stratigraphic studies and drilling at Sites 748 and 750, *in* Wise, S. W., Jr., Schlich, R., and Palmer Judson, A. A., eds., Proceedings of the Ocean Drilling Program, Scientific results, Volume 120 (Part 2): College Station, Texas, Ocean Drilling Program, p. 895–906.
Funnell, B. M., 1990, Global and European Cretaceous shorelines, stage by stage, *in* Ginsburg, R. N., and Beaudoin, B., eds., Cretaceous resources, events and rhythms: The Netherlands, Kluwer Academic Publishers, p. 221–235.
Gahagan, L., Scotese, C. R., and Larson, R. L., 1986, Plate tectonic reconstructions of the Larson et al. (1985) Bedrock geology of the world map, *in* 1986 Geodynamics Symposium: Mesozoic and Cenozoic Plate Reconstructions, College Station, Texas, Texas A and M University, April 23–25, 1986, Abstracts.
Gealey, W., 1989, Plate tectonic evolution of the Mediterranean–Middle East region, *in* Scotese, C. R., and Sager, W. W., eds., Mesozoic and Cenozoic plate reconstructions: Amsterdam, Elsevier, p. 285–306.
GEBCO, 1978–1982, General Bathymetric Chart of the Ocean: Ottawa, Canadian Hydrographic Service.
Girdler, R. W., and Styles, P., 1974, Two stage Red Sea floor spreading: Nature, v. 247, p. 7–11.
Giret, A., and Lameyre, J., 1983, A study of Kerguelen plutonism: petrology, geochronology, and geological implications, *in* Oliver, R. L., James, P. R., and Jago, J. B., eds., Antarctic earth science: Canberra, Australian Academy of Science, p. 646–651.
Golonka, J., Ross, M. I., and Scotese, C. R., 1994, Phanerozoic paleogeographic and paleoclimatic modeling maps, *in* Embry, A. F., Beauchamp, B., and Glass, D. J., eds., Pangaea: Global environments and resources: Canadian Society of Petroleum Geologists Memoir 17, p. 1–47.
Hallam, A., 1967, The bearing of certain paleozoogeographical data on continental drift: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 3, p. 201–241.
Hallam, A., 1972, Continental drift and the fossil record: Scientific American, v. 227, p. 55–66.
Hallam, A., 1974, Changing patterns of provinciality and diversity of fossil animals in relation to plate tectonics: Journal of Biogeography, v. 1, p. 213–225.
Harrison, C. G., and Lindh, T., 1982, A polar wandering curve for North America during the Mesozoic and Cenozoic: Journal of Geophysical Research, v. 87, p. 1903–1920.
Harrison, C. G., Barron, E. J., and Hay, W. W., 1979, Mesozoic evolution of the Antarctic Peninsula and the southern Andes: Geology, v. 7, p. 374–378.
Hay, W. W., 1981, Sedimentological and geochemical trends resulting from the breakup of Pangaea: Oceanologica Acta, v. 4/Supplement, p. 135–147.
Hay, W. W., 1992, Atlas of lithological-paleogeographical maps of the world: Mesozoic and Cenozoic of continents and ocean basins, by Ronov, A. B., Khain, V. E., and Balukhovsky, A N., authors, Barsukov, V. L., and Laviorov, N. P., eds., Editorial Publishing Group, Moscow, 1989, 79 p, (Order from Editorial Publishing Group NVNIIZarubezhgeologia, Novocheryomushkinskaya St. 96 B, Moscow, 117418 Russia, $350): Geology Today, v. 2, p. 97.
Hay, W. W., and Wold, C. N., 1990, Kinematischer Zusammenhang: Öffnung Rockall Trog, Nordsee, Norddeutsche Senken und Zusammenschub Harz: Nachrichten, Deutsche Geologische Gesellschaft, v. 43, p. 36–37.
Hay, W. W., and Wold, C. N., 1996, A simpler plate-tectonic history for the Caribbean: Zentralblatt für Geologie und Paläontologie, v. 199, p. 917–934.
Hay, W. W., Wold, C. N., and Shaw, C. A., 1989, Mass-balanced paleogeographic reconstructions: Geologische Rundschau, v. 78, p. 207–242.
Hay, W. W., Wold, C. N., Shaw, C. A., and Wilson, K. M., 1990, Paleogeographic maps: A status report, *in* Ginsburg, R. N., and Beaudoin, B., eds., Creta-

ceous resources, events and rhythms: The Netherlands, Kluwer Academic Publishers, p. 203–219.

Hayes, D. E., 1988, Age-depth relationships and depth anomalies in the Southwest Indian Ocean and South Atlantic Ocean: Journal of Geophysical Research, v. 93, p. 2937–2954.

Heezen, B. C., and Tharp, M., 1980, Antarctic Ocean, *in* Choubert, G., and Faure-Muret, A., eds., Geological world atlas: Paris, UNESCO, scale 1:100,000,000, Sheet 18.

Hopkins, H. R., 1973, Geology of the Aruba Gap Abyssal Plain near Deep Sea Drilling Project Site 153, *in* Edgar, N. T., and Saunders, J. B., eds., Initial Reports of the Deep Sea Drilling Project, Volume XV: Washington, D.C., U.S. Government Printing Office, p. 1039–1050.

Howell, D. G., Jones, D. L., and Schermer, E. R., 1985, Tectonostratigraphic terranes of the circum-Pacific region, *in* Howell, D. G., ed., Tectonostratigraphic terranes of the Circum-Pacific region: Tulsa, Oklahoma, Circum-Pacific Council for Energy Minerals and Resources, p. 3–30.

Hutchison, C. S., 1989, Displaced terranes of the southwest Pacific, *in* Ben-Avraham, Z., ed., The evolution of the Pacific Ocean margins: New York, Oxford University Press, p. 161–175.

Irving, E., 1979, Pole positions and continental drift since the Devonian, *in* McElhinney, M. M., ed., The Earth: Its origin, structure and evolution: London, Academic Press, p. 567–593.

Janssen, M. E., Stephenson, R. A., and Cloetingh, S., 1995, Temporal and spatial correlations between changes in plate motions and the evolution of rifted basins in Africa: Geological Society of America Bulletin, v. 107, p. 1317–1332.

Kauffman, E. G., 1979, Cretaceous, Part A: Fossilization (Taphonomy), biogeography, and biostratigraphy, *in* Robison, R. A., and Teichert, C., eds., Treatise on invertebrate paleontology: Boulder, Colorado and Lawrence, Kansas, Geological Society of America and University of Kansas Press, p. A418–A487.

Kauffman, E. G., 1984, Paleobiogeography and evolutionary response dynamic in the Cretaceous Western Interior Seaway of North America, *in* Westermann, G. E., ed., Jurassic-Cretaceous biochronology and paleogeography of North America: Geological Association of Canada Special Paper 27, p. 273–306.

Kauffman, E. G., 1985, Cretaceous evolution of the Western interior basin of the United States, *in* Pratt, L. M., Kauffman, E. G., and Zelt, F. B., eds., Fine-grained deposits and biofacies of the Cretaceous Western Interior Seaway: Evidence of cyclic sedimentary processes: Society of Economic Paleontologists and Mineralogists, 1985 Midyear Meeting, Golden, Colorado, Field Trip Guidebook No. 4: Tulsa, Oklahoma, Society of Economic Paleontologists and Mineralogists, p. iv–xiii.

Kaula, W. M., 1975, Absolute plate motions by boundary velocity minimizations: Journal of Geophysical Research, v. 80, p. 244–248.

Kelly, S. R., 1992, The Austral paleobiogeography of an Early Cretaceous (Albian) trigoniid bivalve assemblage from the upper part of the Fossil Bluff Group, Alexander Island, Antarctica: International Cretaceous Symposium, 4th, Hamburg, 1992, Abstracts.

Klitgord, K. D., and Schouten, H., 1986, Plate kinematics of the Central Atlantic, *in* Vogt, P. R., and Tucholke, B. E., eds. The Western Atlantic region: Boulder, Colorado, Geological Society of America, The Geology of North America, v. M, p. 351–378.

Konig, M., 1980, Geophysical investigations of the Southern Continental Margin of Australia and the Conjugate Sector of East Antarctica [Ph. D. thesis]: New York, Columbia University, p. 311.

Konig, M., 1987, Geophysical data from the continental margin of Wilkes Land, Antarctica — Implications for breakup and dispersal of Australia-Antarctica, *in* Eittreim, S. L., and Hampton, M. A., eds., Geology and geophysics of offshore Wilkes Land: Circum-Pacific Council on Energy and Mineral Resources, Earth Science Series, v. 5A, p. 117–145.

Larson, R. L., 1991a, Latest pulse of the Earth: Evidence for a mid-Cretaceous superplume: Geology, v. 19, p. 547–550.

Larson, R. L., 1991b, Geological consequences of superplumes: Geology, v. 19, p. 963–966.

Lawver, L. A., and Müller, R. D., 1994, Iceland hotspot track: Geology, v. 22, p. 311–314.

Lawver, L. A., and Scotese, C. R., 1987, A revised reconstruction of Gondwanaland, *in* McKenzie, D., ed., Gondwana Six: Structure, tectonics and geophysics: American Geophysical Union, Geophysical Monograph Series, v. 40, p. 17–24.

Lawver, L. A., and Scotese, C. R., 1990, A review of tectonic models of the evolution of the Canada Basin, *in* Grantz, A., Johnson, L., and Sweeney, J. F., eds., The Arctic Ocean region: Boulder, Colorado, Geological Society of America, The Geology of North America, v. L, p. 593–618.

Lawver, L. A., Müller, R. D., Srivastava, S. P., and Roest, W., 1990, The opening of the Arctic Ocean, *in* Bleil, U., and Thiede, J., eds., Geological history of the Polar oceans: Arctic versus Antarctic: NATO Advanced Studies Institute series, Series C: Mathematical and Physical Sciences, v. 308, p. 29–62.

Lawver, L. A., Gahagan, L. M., and Coffin, M. F., 1992, The development of paleoseaways around Antarctica, *in* Kennett, J. P., and Warnke, D. A., eds., The Antarctic paleoenvironment: A perspective on global change, Part One: American Geophysical Union, Antarctic Research Series, v. 56, p. 7–30.

Le Pichon, X., and Sibuet, J., 1981, Passive margins; A model of formation: Journal of Geophysical Research, v. 86, p. 3708–3720.

Livermore, R., Vine, F. J., and Smith, A. G., 1984, Plate motions and the geomagnetic field — II Jurassic to Tertiary: Geophysical Journal of the Royal Astronomical Society, v. 79, p. 939–961.

Marshall, L. G., 1985, Geochronology and land-mammal biochronology of the transamerican faunal interchange, *in* Stehli, F. G., and Webb, S. D., eds., The great American biotic interchange: New York, New York, Plenum Press, p. 49–85.

Maruyama, S., Liou, J. G., and Seno, T., 1989, Mesozoic and Cenozoic evolution of Asia, *in* Ben-Avraham, Z., ed., The evolution of the Pacific Ocean margins: New York, New York, Oxford University Press, p. 75–99.

McCabe, R., and Cole, J., 1989, Speculations on the late Mesozoic and Cenozoic evolution of the southeast Asian margin, *in* Ben-Avraham, Z., ed., The evolution of the Pacific Ocean margins: New York, New York, Oxford University Press, p. 143–160.

McElhinney, M. W., 1973, Palaeomagnetism and plate tectonics: Cambridge, United Kingdom, Cambridge University Press, 357 p.

McKenzie, D., 1978, Some remarks on the development of sedimentary basins: Earth and Planetary Science Letters, v. 40, p. 25–32.

McKenzie, D. P., and Sclater, J. G., 1971, The evolution of the Indian Ocean since the Late Cretaceous: Journal of the Royal Astronomical Society, v. 25, p. 437–528.

Megson, J. B., 1987, The evolution of Rockall Trough, *in* Brooks, J., and Glennie, K., eds., Petroleum geology of northwest Europe: London, United Kingdom, Graham and Trotman, p. 653–665.

Meyerhoff, A. A., and Kamen-Kaye, M., 1981, Petroleum prospects of Saya de Malha and Nazareth Banks, Indian Ocean: American Association of Petroleum Geologists Bulletin, v. 65, p. 1344–1347.

Molnar, P., and Atwater, T., 1973, Relative motion of hot spots in the mantle: Nature, v. 246, p. 248–291.

Molnar, P., and Stock, J., 1987, Relative motion of hotspots in the Pacific, Atlantic, and Indian Oceans since Late Cretaceous time: Nature, v. 27, p. 587–591.

Montgomery, H., Pesagno, E. A., and Pindell, J. L., 1994, A 195 Ma terrane in a 165 Ma sea: Pacific origin of the Caribbean plate: Geological Society of America, Today, v. 4, no. 1, p. 1–6.

Morgan, J., 1971, Convection plumes in the lower mantle: Nature, v. 230, p. 42–43.

Morgan, J., 1972, Deep mantle convection plumes and plate motions: American Association of Petroleum Geologists Bulletin, v. 56, p. 203–213.

Morgan, J., 1981, Hot spot tracks and the opening of the Atlantic and Indian Oceans, *in* Emiliani, C., ed., The oceanic lithosphere. The sea, Volume 7: New York, Wiley-Interscience, p. 443–487.

Morgan, J., 1983, Hotspot tracks and the early rifting of the Atlantic: Tectonophysics, v. 94, p. 123–139.

Müller, R. D., Sandwell, D. T., Tucholke, B. E., Sclater, J. C., and Shaw, P. R., 1991, Depth to basement and geoid expression of the Kane Fracture Zone: Marine Geophysical Research, v. 13, p. 105–129.

Munschy, M., Dyment, J., Boulanger, M. O., Boulanger, D., Tissot, J. D., Schlich, R., Rotstein, Y., and Coffin, M. F., 1992, Breakup and sea-floor spreading between the Kerguelen Plateau–Labuan Basin and the Broken Ridge–Diamantina Zone, *in* Wise, S. W., Jr., Schlich, R., and Palmer Julson, A. A., eds., Proceedings of the Ocean Drilling Program, Scientific Results, Volume 120 (Part 2): College Station, Texas, Ocean Drilling Program, p. 931–944.

Norton, I. O., and Sclater, J. G., 1979, A model for the evolution of the Indian Ocean and breakup of Gondwanaland: Journal of Geophysical Research, v. 84, p. 6803–6830.

Nunns, A. G., 1983, Plate tectonic evolution of the Greenland Scotland Ridge and surrounding regions, *in* Bott, M. H., Saxov, S., Talwani, M., and Thiede, J., eds., Structure and Development of the Greenland Scotland Ridge: New methods and concepts: New York, Plenum Press, NATO Conference Series, Series IV: Marine Sciences, v. 8, New York, p. 661–678.

Nur, A., and Ben-Avraham, Z., 1989, Oceanic plateaus and the Pacific Ocean margins, *in* Ben-Avraham, Z., ed., The evolution of the Pacific Ocean margins: New York, New York, Oxford University Press, p. 7–19.

Nürnberg, D., and Müller, R. D., 1991, The tectonic evolution of the South Atlantic from Late Jurassic to present: Tectonophysics, v. 191, p. 27–53.

Olivero, E. B., Gasparini, Z., Rinaldi, C. A., and Scasso, R., 1991, First record of dinosaurs in Antarctica (Upper Cretaceous, James Ross Island), palaeogeographical implications, *in* Thomson, M. R. A., Crame, J. A., and Thomson, J. W., eds., Geological evolution of Antarctica: Cambridge University Press, International Symposium on Antarctic Earth Science, v. 5, p. 617–622.

Parsons, B., and McKenzie, D. P., 1978, Mantle convection and the thermal structure of the plates: Journal of Geophysical Research, v. 83, p. 4485–4496.

Parsons, B., and Sclater, J. G., 1977, An analysis of the variations of ocean floor bathymetry and heat flow with age: Journal of Geophysical Research, v. 82, p. 803–827.

Patriat, P., and Segoufin, J., 1988, Reconstruction of the central Indian Ocean: Tectonophysics, v. 155, p. 211–234.

Patriat, P., and Segoufin, J., 1989, Reconstruction of the central Indian Ocean, *in* Scotese, C. R., and Sager, W. W., eds., Mesozoic and Cenozoic plate reconstructions: Amsterdam, Elsevier, p. 211–234.

Pearson, F., II, 1990, Map projections: Theory and applications: Boca Raton, Florida, CRC Press, 372 p.

Pindell, J. L., 1993, Regional synopsis of Gulf of Mexico and Caribbean evolution, *in* Proceedings; Gulf Coast Section, Society for Sedimentary Geology Foundation, 13th Annual Research Conference, July 1, 1993, p. 251–274.

Pindell, J. L., and Barrett, S. F., 1990, Geologic evolution of the Caribbean region: A plate-tectonic perspective, *in* Dengo, G., and Case, J. E., eds., Caribbean: Boulder, Colorado, Geological Society of America, The Geology of North America, v. H, p. 405–432.

Powell, G. M., Roots, S. R., and Veevers, J. J., 1988, Pre-breakup continental extension in east Gondwanaland and the early opening of the eastern Indian Ocean: Tectonophysics, v. 155, p. 261–283.

Powell, G. M., Roots, S. R., and Veevers, J. J., 1989, Pre-breakup continental extension in east Gondwanaland and the early opening of the eastern Indian Ocean, *in* Scotese, C. R., and Sager, W. W., eds., Mesozoic and Cenozoic plate reconstructions: Amsterdam, Netherlands, Elsevier, p. 261–283.

Powell, C. M., Johnson, B. D., and Veevers, J. J., 1980, A revised fit of east and west Gondwanaland: Tectonophysics, v. 63, p. 13–29.

Rabinowitz, P. D., Coffin, M. F., and Falvey, D. A., 1983, The separation of Madagascar and Africa: Science, v. 20, p. 67–69.

Reyment, R. A., 1980, Biogeography of the Saharan Cretaceous and Paleocene epicontinental transgressions: Cretaceous Research, v. 1, p. 299–327.

Richardson, E. S., and Harrison, C., 1976, Opening the Red Sea with two poles of rotation: Earth and Planetary Science Letters, v. 30, p. 135–142.

Roberts, D. A., Masson, D. G., and Miles, P. R., 1981a, Age and structure of the southern Rockall Trough: New evidence: Earth and Planetary Science Letters, v. 52, p. 115–128.

Roberts, D. G., Masson, D. G., and Montadert, C., 1981b, Continental margin from Porcupine Seabight to the American Marginal Basin, *in* Illing, L. V., and Hobson, G. D., eds., Petroleum geology of the continental shelf of north-west Europe, Volume 1, Geology: London, Institute of Petroleum, p. 455–473.

Roest, W. R., 1987, Sea floor spreading pattern of the North Atlantic between 10° and 40° N: Geologica Ultraictina, v. 48, no. 1, p. 101–121.

Roest, W. R., and Srivastava, S. P., 1989, Seafloor spreading in the Labrador Sea; A new reconstruction: Geology, v. 17, p. 1000–1003.

Roest, W. R., Danobeita, J. J., Verhoef, J., and Colette, B. J., 1992, Magnetic anomalies in the Canary Basin and the Mesozoic evolution of the central North Atlantic: Marine Geophysical Research, v. 14, p. 1–24.

Ronov, A. B., Khain, V. E., and Balukhovsky, A. N., 1989, Atlas of lithological-paleogeographical maps of the world: Mesozoic and Cenozoic of continents and oceans, Barsukov, V. L., and Laviorov, N. P., eds.: Moscow, Editorial Publishing Group VNIIZarubezh-geologia, p. 79.

Rosenkrantz, E., Ross, M. I., and Sclater, J. G., 1988, Age and spreading history of the Cayman Trough as determined from depth, heat flow, and magnetic anomalies: Journal of Geophysical Research, v. 93, p. 2141–2157.

Rowley, D. B., and Lottes, A. L., 1988, Plate-kinematic reconstructions of the North Atlantic and Arctic: Late Jurassic to present: Tectonophysics, v. 155, p. 73–120.

Rowley, D. B., and Lottes, A. L., 1989, Plate-kinematic reconstructions of the North Atlantic and Arctic: Late Jurassic to present, *in* Scotese, C. R., and Sager, W. W., eds., Mesozoic and Cenozoic plate reconstructions: Amsterdam, Elsevier, p. 73–120.

Royer, J., and Coffin, M. F., 1992, Jurassic to Eocene plate tectonic reconstructions in the Kerguelen Plateau region, *in* Wise, S. W., Jr., Schlich, R., and Palmer Julson, A. A., eds., Proceedings of the Ocean Drilling Program, Scientific Results, Volume 120 (Part 2): College Station, Texas, Ocean Drilling Program, p. 917–928.

Royer, J., Sclater, J. G., Sandwell, D. T., Cande, S., Schlich, R., Munschy, M., Dyment, J., Coffin, M. F., Patriat, P., and Bergh, H. W., 1992, Indian Ocean plate reconstructions since the Late Jurassic, *in* Duncan, R. A., Rea, D. K., Kidd, R. B., von Rad, U., and Weissel, J. K., eds., Synthesis of results from scientific drilling in the Indian Ocean: Washington, D.C., American Geophysical Union, Geophysical Monograph Series, V. 70, p. 471–475.

Royer, J.-Y., Patriat, P., Bergh, H. W., and Scotese, C. R., 1988, Evolution of the southwest Indian Ridge from the Late Cretaceous (anomaly 34) to the middle Eocene (anomaly 20): Tectonophysics, v. 155, p. 235–260.

Royer, J. -Y., Patriat, P., Bergh, H. W., and Scotese, C. R., 1989, Evolution of the southwest Indian Ridge from the Late Cretaceous (anomaly 34) to the middle Eocene (anomaly 20), *in* Scotese, C. R., and Sager, W. W., eds., Mesozoic and Cenozoic plate reconstructions: Amsterdam, Elsevier, p. 235–260.

Sager, W. W., Winterer, E. L., and 25 others, 1993, Initial reports, Northwest Pacific atolls and guyots: Proceedings of the Ocean Drilling Program, Volume 143: College Station, Texas, Ocean Drilling Program, p. 724.

Savostin, L. A., Sibuet, J., Zonenshain, L. P., Le Pichon, X., and Roulet, M. J., 1986, Kinematic evolution of the Tethys belt from the Atlantic Ocean to the Pamirs since the Triassic: Tectonophysics, v. 123, p. 1–35.

Schulz, M., Wold, C. N., Ronov, A. B., and Hay, W., 1995, A forward and reverse transformation program for the "Atlas of Lithological-Paleogeographical Maps of the World": Computers and Geosciences, v. 21, p. 907–911.

Sclater, J. G., Abbott, D., and Thiede, J., 1977, Paleobathymetry and sediments of the Indian Ocean, *in* Heirtzler, J. R., Bolli, H. M., Davies, T. A., Saunders, J. B., and Sclater, J. G., eds., Indian Ocean geology and biostratigraphy: Washington, D.C., American Geophysical Union, p. 25–59.

Scotese, C. R., 1991, Jurassic and Cretaceous plate tectonic reconstructions: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 87, p. 493–501.

Scotese, C. R., Gahagan, L. M., Ross, M. I., Royer, J.-Y., Müeller, R. D., Nürnnberg, D., Mayes, C. L., Lawver, L. A., Tomlins, R. L., Newman, J. S., Heubeck, C. E., Winn, J. K., Beckley, L., and Sclater, J. G., 1987, Atlas of Mesozoic and Cenozoic plate tectonic reconstructions: Austin, Texas, Technical Report by University of Texas at Austin, Institute of Geophysics, Palaeoceanographic Mapping Project, unpaginated.

Scotese, C. R., Gahagan, L. M., and Larson, R. M., 1988, Plate tectonic reconstructions of the Cretaceous and Cenozoic ocean basins: Tectonophysics, v. 155, p. 27–48.

Scotese, C. R., Gahagan, L. M., and Larson, R. M., 1989, Plate tectonic reconstructions of the Cretaceous and Cenozoic ocean basins, *in* Scotese, C. R., and Sager, W. W., eds., Mesozoic and Cenozoic plate reconstructions: Amsterdam, Elsevier, p. 27–48.

Sheridan, R. E., 1989, The Atlantic passive margin, *in* Bally, A. W., and Palmer, A. R., eds., The Geology of North America: An overview: Boulder, Colorado, Geological Society of America, The Geology of North America, v. A, p. 81–96.

Sloss, P. W., editor, 1993, Global relief CD-ROM: Boulder, Colorado, Department of Commerce, National Oceanic and Atmospheric Administration, National Geophysical Data Center.

Smith, A. G., 1981, Phanerozoic equal-area maps: Geologische Rundschau, v. 70, p. 91–127.

Smith, A. G., and Briden, J. C., 1977, Mesozoic and Cenozoic paleocontinental maps: Cambridge, United Kingdom, Cambridge University Press, p. 63.

Smith, A. G., Briden, J. C., and Drewry, G. E., 1973, Phanerozoic world maps, *in* Hughes, N. F., ed., Special papers in paleontology, v. 12: Oxford, Paleontological Association, p. 1–42.

Smith, A. G., Hurley, A. M., and Briden, J. C., 1981a, Palaeokontinentale Weltkarten des Phanerozoikums (Paleocontinental World Maps of the Phanerozoic): Stuttgart, Federal Republic of Germany, Ferdinand Enke, p. 102.

Smith, A. G., Hurley, A. M., and Briden, J. C., 1981b, Phanerozoic paleocontinental world maps: Cambridge, United Kingdom, Cambridge University Press, p. 102.

Smith, A. G., Smith, D. G., and Funnell, B. M., 1994, Atlas of Mesozoic and Cenozoic coastlines: Cambridge, Cambridge University Press, p. 99.

Smith, W. H., and Wessel, P., 1990, Gridding with continuous curvature splines in tension: Geophysics, v. 55, p. 293–305.

Snyder, J. P., 1982, Map projections used by the U.S. Geological Survey: Washington, D.C., U.S. Government Printing Office, U.S. Geological Survey Bulletin 1532, p. 1–313.

Spörli, K. B., and Ballance, P. F., 1989, Mesozoic ocean floor/continent interaction and terrane configuration, southwest Pacific area around New Zealand, *in* Ben-Avraham, Z., ed., The evolution of the Pacific Ocean margins: New York, New York, Oxford University Press, p. 176–190.

Sprinsky, W. H., and Snyder, J. P., 1986, The Miller Oblated Stereographic Projection for Africa, Europe, Asia, and Australia: The American Cartographer, v. 13, p. 253–261.

Srivastava, S. P., and Tapscott, C. R., 1986, Plate kinematics of the North Atlantic, *in* Vogt, P. R., and Tucholke, B. E., eds., The Western North Atlantic Region: Boulder, Colorado, Geological Society of America, Geology of North America, v. M, p. 379–404.

Steckler, M. S., and ten Brink, U. S., 1986, Lithospheric strength variations as a control on new plate boundaries: Examples from the northern Red Sea region: Earth and Planetary Science Letters, v. 79, p. 120–132.

Stein, C. A., and Stein, S., 1992, A model for the global variation in oceanic depth and heat flow with lithospheric age: Nature, v. 359, p. 123–129.

Stoffa, P. L., Mauffret, A., Truchan, M., and Buhl, P., 1981, Sub-B″ layering in the southern Caribbean: The Aruba Gap and Venezuelan Basin: Earth and Planetary Science Letters, v. 53, no. 131–146.

Storey, M., Kent, R. W., Saunders, A. D., Salters, V. J., Hergt, J., Whitechurch, H., Sevigny, J. H., Thirlwall, M. F., Leat, P., Ghose, N. C., and Gifford, M., 1992, Lower Cretaceous volcanic rocks on continental margins and their relationship to the Kerguelen Plateau, *in* Wise, S. W., Jr., Schlich, R., and Palmer Julson, A. A., eds., Proceedings of the Ocean Drilling Program, Scientific results, Volume 120 (Part 1): College Station, Texas, Ocean Drilling Program, p. 33–53.

Storey, M., Mahoney, J. J., Saunders, A. D., Duncan, R. A., Kelley, S. P., and Coffin, M. F., 1995, Timing of hot spot-related volcanism and the breakup of Madagascar and India: Science, v. 267, p. 852–855.

Taira, A., Tokuyama, H., and Soh, W., 1989, Accretion tectonics and evolution of Japan, *in* Ben-Avraham, Z., ed., The evolution of the Pacific Ocean margins: New York, New York, Oxford University Press, p. 100–123.

Thiede, J., 1980, Palaeo-oceanography, margin stratigraphy, and palaeophysiography of the Tertiary North Atlantic and Norwegian-Greenland Seas: London, Philosophical Transactions of the Royal Society, Series A, v. 294, p. 177–185.

Thomson, M. R., 1981, Mesozoic ammonite faunas of Antarctica and the break-up of Gondwana, *in* Cresswell, M. M., and Vella, P., eds., Gondwana Five: Selected Papers and Abstracts of Papers Presented at the Fifth International Gondwana Symposium, Wellington, New Zealand, 11–16 February, 1980, p. 269–275.

Thomson, M. R., 1982a, A comparison of the ammonite faunas of the Antarctic Peninsula region and Magellanes Basin: Journal of the Geological Society of London, v. 139, p. 763–770.

Thomson, M. R., 1982b, Mesozoic paleogeography of West Antarctica, *in* Craddock, C., ed., Antarctic Geoscience: Oslo, Norway, International Union of Geological Sciences, Series B, v. 4, p. 331–337.

Tyson, R. V., and Funnell, B. M., 1987, European Cretaceous shorelines, stage by stage: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 59, p. 69–91.

Tyson, R. V., and Funnell, B. M., 1988, European Cretaceous shorelines, stage by stage, *in* Ginsburg, R. N., and Beaudoin, B., eds., Cretaceous resources, events and rhythms: The Netherlands, Kluwer Academic Publishers, p.237–272.

Veevers, J. J., 1987, The conjugate continental margins of Antarctica (Wilkes Land) and Australia, *in* Eittreim, S. L., and Hampson, M. A., eds., Geology and geophysics of Offshore Wilkes Land: Houston, Texas, Circum-Pacific Council on Energy and Mineral Resources, Earth Science Series, v. 5A, p. 45–73.

Vinogradov, A. P., 1968, Atlas of the lithological-paleogeographical maps of the USSR: Volume 3: Triassic, Jurassic, and Cretaceous: Moscow, Ministry of Geology of the United Soviet Social Republic, 71 sheets.

von Huene, R., Box, S. E., Detterman, R. L., Fisher, M. A., Moore, C., and Pulpan, H., 1985, A-2; Kodiak to Kuskokwim, Alaska, *in* Centennial continent/ocean transect, Volume G: Boulder, Colorado, Geological Society of America.

Watkins, J. S., and Drake, C. L., editors., 1982, Studies in continental margin geology: Tulsa, Oklahoma, American Association of Petroleum Geologists Memoir 34, 801 p.

Watson, B. F., and Fujita, K., 1985, Tectonic evolution of Kamchatka and the Sea of Okhotsk and implications for the Pacific Basin, *in* Howell, D. G., ed., Tectonostratigraphic terranes of the Circum-Pacific region: Houston, Texas, Circum Pacific Council for Energy and Mineral Earth Science Series Number 1, p. 333–348.

Weissel, J. K., and Hayes, D. E., 1972, Magnetic anomalies in the southeast Indian Ocean, *in* Hayes, D. E., ed., Antarctic oceanology, Volume 2, The Australian–New Zealand sector: Washington, D.C., American Geophysical Union, Antarctic Research Series, v. 19, p. 165–196.

Weissel, J. K., Hayes, D. E., and Herron, E. M., 1977, Plate tectonics synthesis: The displacements between Australia, New Zealand and Antarctica since the Late Cretaceous: Marine Geology, v. 25, p. 231–287.

Whitechurch, H., Montigny, R., Sevigny, J., Storey, M., and Salters, V. J., 1992, K-Ar and $^{40}Ar/^{39}Ar$ ages of Central Kerguelen Plateau basalts, *in* Wise, S. W., Jr., Schlich, R., and Palmer Julson, A. A., eds., Proceedings of the Ocean Drilling Program, Scientific results, Volume 120 (Part 1): College Station, Texas, Ocean Drilling Program, p. 33–47.

Wilford, G. E., 1983, Phanerozoic paleogeography, *in* BMR Earth Science Atlas of Australia: Canberra, Australia, Bureau of Mineral Resources, p 4.

Wilson, K. M., 1989, Mesozoic suspect terranes and global tectonics [Ph.D.

thesis]: Boulder, Colorado, University of Colorado, p. 372.

Wilson, K. M., Rosol, M. J., and Hay, W. W., 1989a, Global Mesozoic reconstructions using revised continental data and terrane histories: a progress report, *in* Hillhouse, J. W., ed., Deep structure and past kinematics of accreted terranes: Washington, D.C., American Geophysical Union/IUGG Monograph 50/5, p. 140.

Wilson, K. M., Rosol, M. J., Hay, W. W., and Harrison, C. G., 1989b, New model for the tectonic history of West Antarctica: A reappraisal of the fit of Antarctica in Gondwana: Eclogae Geologicae Helvetiae, v. 82, p. 1–35.

Wilson, K. M., Hay, W. W., and Wold, C. N., 1991, Mesozoic evolution of exotic terranes and marginal seas, western North America: Marine Geology, v. 102, p. 311–361.

Wilson, K. M., Pollard, D., Hay, W. W., Thompson, S. L., and Wold, C. N., 1994, General circulation model simulations of Triassic climates: Preliminary results, *in* Klein, G. D., ed., Pangaea: Paleoclimate, tectonics, and sedimentation during accretion, zenith, and breakup of a supercontinent: Boulder, Colorado, Geological Society of America, Special Paper 288, p. 91–116.

Wold, C. N., 1992, Paleobathymetry and sediment accumulation in the northern North Atlantic and southern Greenland-Iceland-Norwegian Sea [Ph.D. thesis]: Kiel, Germany, Christian-Albrechts-Universität, p. 255.

Wold, C. N., 1995, Palaeobathymetric reconstruction on a gridded database: the northern North Atlantic and southern Greenland-Iceland-Norwegian Sea, *in* Scrutton, R. A., Stocker, M. S., Shimmield, G. B., and Tudhope, A. W., eds., Sedimentation and palaeoceanography of the North Atlantic region: Oxford, Blackwell Scientific Publishers, Geological Society, London, Special Publication No. 90, p. 271–302.

Wold, C. H., Hay, W. W., Dullo, W., Wolf, T. C., and Bruns, P., 1993, Oligozäne Paläo-Ozeanographie des Grönland-Schottland Rückens: (Oligocene paleo-oceanography of the Greenland-Scotland Ridge) Die Geowissenschaften, v. 11, no. 10/11, p. 353–359.

Wold, C. H., Hay, W. W., and Wilson, K. M., 1994, Eine verbesserte Anpassung von Südamerika an Afrika: (A better fit between South America and Africa) Die Geowissenschaften, v. 12, no. 2, p. 48–54.

Woodburne, M. O., and Zinsmeister, W. J., 1984, The first land mammal from Antarctica and its biogeographic implications: Journal of Paleontology, v. 58, p. 913–948.

Ziegler, A. M., Scotese, C. R., and Barrett, S. F., 1982, Mesozoic and Cenozoic paleogeographic maps, *in* Brosche, P., and Sundermann, J., eds., Tidal friction and the Earth's rotation II: Berlin, Springer-Verlag, p. 240–252.

Ziegler, P. A., 1988, Evolution of the Arctic–North Atlantic and the western Tethys: Tulsa, Oklahoma, American Association of Petroleum Geologists Memoir 43, p. 198.

Ziegler, P. A., 1990, Tectonic and paleogeographic development of the North Sea rift system, *in* Blundell, D. J., and Gibbs, A. D., eds., Tectonic evolution of the North Sea rifts: Oxford, United Kingdom, Oxford University Press, p. 1–36.

Zonenshain, L. P., and Gorodnitskiy, A. M., 1977, Paleozoic and Mesozoic reconstructions of the continents and oceans 2: Late Paleozoic and Mesozoic reconstructions: Geotectonics, v. 11, p. 159–172.

Zonenshain, L. P., Kuzmin, M. I., and Natapov, L. M., 1990, Geology of the USSR: A plate tectonic synthesis: Washington, D.C., American Geophysical Union Geodynamics Series, v. 21, p. 242.

Zonenshain, L. P., and Natapov, L. M., 1989, Tectonic history of the Arctic region from the Ordovician through the Cretaceous, *in* Herman, Y., ed., The Arctic seas: Climatology, oceanography, geology and biology: New York, Van Nostrand Reinhold Co., p. 829–862.

Zonenshain, L. P., Savostin, L. A., and Sedova, P., 1984, Globalinye paleogeodinamicheskie rekonstruktsii dlya posledvich 160 mln let: (Global paleogeodynamic reconstructions of the last 160 million years) Geotektonika, v. 3, p. 3–16.

Zonenshayn, L. P., Savostin, L. A., and Sedov, P., 1985, Paleogeodynamic world base maps and paleobathymetry for the last 70 Ma: An explanatory note: Tectonophysics, v. 116, p. 189–207.

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