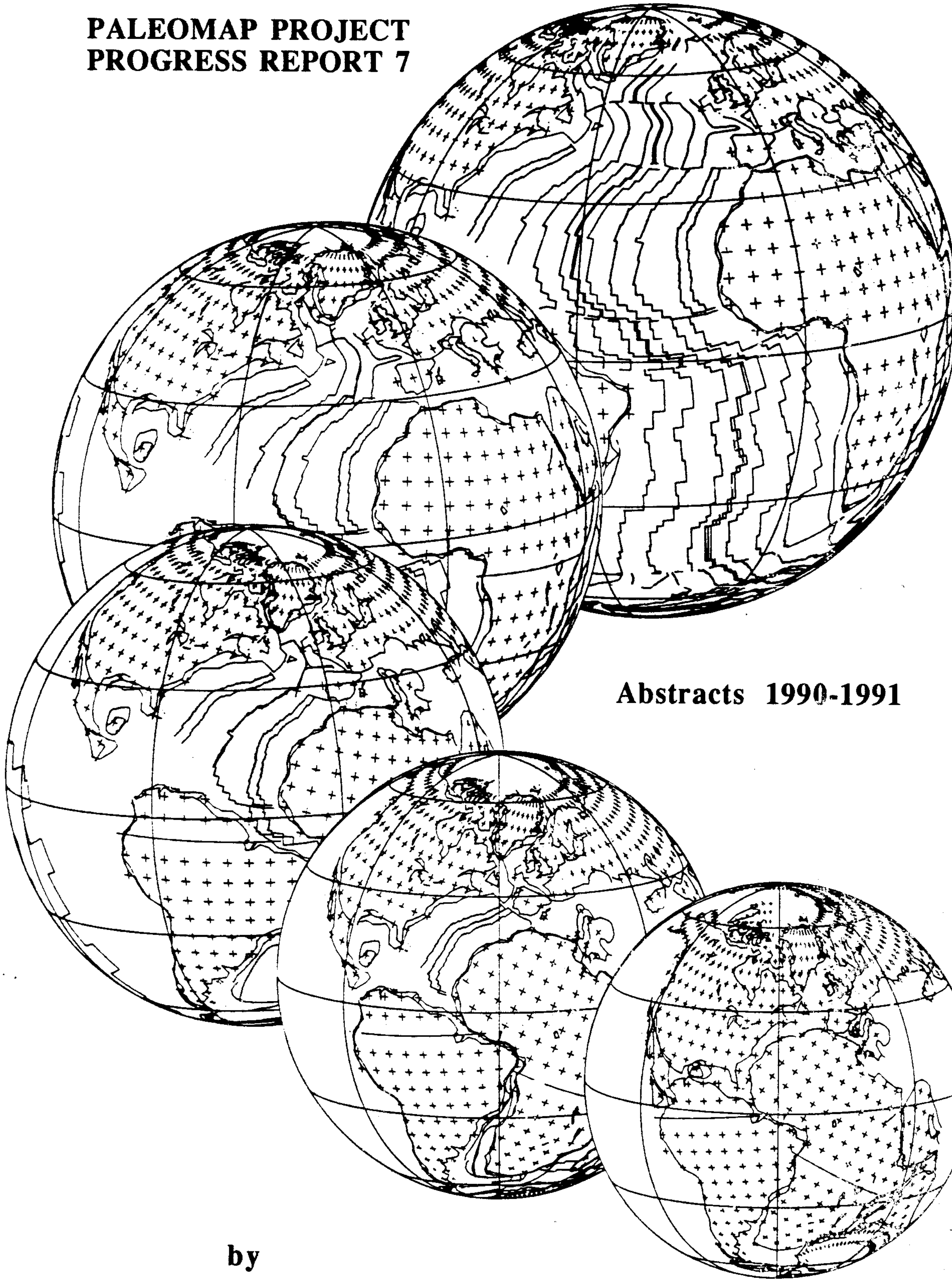
PALEOMAP PROJECT
PROGRESS REPORT 7



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by

Christopher R. Scotese and others

The **PALEOMAP** Project: Plate Tectonic Evolution of the Earth during the last 600 Million Years

Christopher R. Scotese, Department of Geology, University of Texas, Arlington, Texas 76019

As a result of the exploration of the oceans and continental margins, our understanding of the plate tectonic evolution of the ocean basins and continents has dramatically increased during the last 20 years. Plate tectonic models have been published for nearly every ocean basin and preliminary plate tectonic models for the evolution of the Earth during the Paleozoic have been proposed. Despite these successes, no comprehensive set of maps is available that illustrates the changing positions of the continents during the the last 600 million years. Such a folio of plate tectonic reconstructions would provide the necessary geographic context for further investigations in paleoclimatology, paleoceanography, paleobiogeography, and global geology. For these reasons the **PALEOMAP** project has been formed.

This lecture will review the recent accomplishments of the **PALEOMAP** Project and will outline the plate tectonic development of the ocean basins and continents during the last 600 million years. 50 global plate tectonic reconstructions, based on recent compilations of seafloor linear magnetic anomalies, paleomagnetic poles, satellite altimetry, and paleoclimatic and biogeographic data, will be presented. The changing configuration of the continents and ocean basins has played a key role in global changes in sea level, climate, ocean circulation, and evolutionary events.

GLOBAL APPARENT POLAR WANDER AND THE MOTION OF THE PLATES IN THE HOT SPOT REFERENCE FRAME

Chris R. Scotese
Shell Development Company
Rob Van der Voo
University of Michigan
Dietmar Müller
University of Texas

Paleomagnetism provides accurate information concerning the latitudinal orientation of the plates through time, but does not constrain their longitudinal position. The hot spot reference frame, on the other hand, provides both latitudinal and longitudinal control, but there are few hot spots older than 80 million years, and it has been argued that the hot spots themselves are in motion, and as a consequence can not be used as a fixed frame of reference. Our analysis of paleomagnetic data and plate motions inferred from the trajectory of hot spot tracks indicates that a select group of hot spots (Walvis, Reunion, 90 E. Ridge) provide an adequate frame of reference for the last 100 million years.

In our analysis of a Global Apparent Polar Wander Path (Global APW Path) was constructed by compiling reliable paleomagnetic poles for the major continents (North America, South America, Africa, Europe, India, Australia and Antarctica), and then rotating these paleomagnetic poles into "reconstructed" coordinates using a global plate tectonic model. Global mean poles were calculated at 20 million year intervals and were connected to form a sinuous Global APW path. This Global APW path is in good agreement with previously published apparent polar wander paths for the individual continents.

The Global APW path can be used to determine a continents changing latitude through time. Hot spot tracks can also provide an independent measurement of a continent's latitudinal motion. In our analysis, the African, Indian, Antarctic, and Australian plates were reconstructed relative to the Walvis Ridge, Reunion, and 90 E. Ridge hot spots. These hot spots were chosen because they have generated long, continuous tracks, the hot spots are long-lived, and the ages along the hot spot track are well-dated. Table 1 compares the changing latitude of a point in central Africa based on Global APW with the changing latitude based on the hot spot model. The results indicate that the paleolatitudes predicted by the Hot Spot Model are in excellent agreement with the paleolatitudes determined by paleomagnetism back to 100 million years. It is difficult to extend this analysis beyond 100 million years due to the lack of hot spot tracks older than 100 million years.

Phanerozoic Plate Tectonic Reconstructions: Insights into the Driving Mechanism of Plate Tectonics

Christopher R. Scotese, Bellaire Research Center, Shell Development Company, P.O. Box 481, Houston, Texas 77001

Plate tectonic models describing the development of the Atlantic Ocean (Srivastava, Rowley, and Cande), Indian Ocean (Patriat, Royer) and Pacific Ocean have been combined with preliminary plate tectonic models for Asia (Rowley), Tethys (Sengor, Dercourt et al.), the Soviet Union (Zonenshain et al.), and the Paleozoic (Scotese, McKerrow) to produce a global model of Phanerozoic plate motions. 50 plate tectonic reconstructions will be presented illustrating the movement of the continents and the development of the world's ocean basins since the late Precambrian.
The maps are the preliminary draft of the PALEOMAP Phanerozoic Atlas Project, a jointly sponsored IUGG/IUGS program.

The pattern of plate motion during the last 600 million years can be characterized as "episodic". Long intervals of steady state plate motion (lasting 20 -50 million years) have been interrupted at irregular intervals by tectonic events that have triggered global changes in the rates and directions of plate movement. At least 12 times of global plate reorganization can be recognized during the Phanerozoic. These events took place during the: latest Precambrian, middle Ordovician, early Devonian, early-late Carboniferous, early Permian, late Triassic, middle Jurassic, early Cretaceous (Valanginian), early Eocene, and early Miocene.

It appears that these global plate reorganizations arise from interactions between the plates and are not the result of deep-seated events in the asthenosphere. The loss of a major subduction zone due to continent-continent collision, or the loss of a spreading center due to subduction of a ridge, are the two principal events that trigger global plate reorganizations. From the patern of plate motion during the last 600 million years, it is clear that the forces that drive the plates are concentrated in the lithosphere (slab pull and risge push) and that the pattern of convection in the Earth's interior does not play an active role in determining the ovemnt of the plates.

CRETACEOUS PLATE TECTONIC REORGANIZATIONS: MECHANISM FOR GLOBAL CHANGE

SCOTESE, C.R.
Dept. of Geology, University of Texas, Arlington, TX 76019 USA

Nine plate tectonic reconstructions are presented illustrating the changing configuration of the continents and ocean basins during the Cretaceous. The data used to produce these maps were compiled as part of the PALEOMAP Project, International Lithosphere Program. These Cretaceous reconstructions are a synthesis of the regional plate tectonic models produced by individual working group members (Atlantic: Srivastava, Müller, Klitgord, Cande; Indian: Royer, Patriat; Pacific: Atwater, Stock; Asia: Rowley; Tethys: Sengor, Dewey; Circum-Antarctic: Lawver).

The orientation and paleolatitudes of the continents was determined by using paleomagnetic data and by back-tracking the motion of the plates along hot spot tracks. A Global Apparent Polar Wander (APW) path has been constructed by compiling reliable paleomagnetic data for the major continents (Van der Voo) and then rotating them into "reconstructed" coordinates using the global plate model. A comparison of plate motions derived from hot spot tracks (Müller) with the predictions from paleomagnetism suggests that the African and Indian hot spots have remained nearly fixed with respect to the spin axis, since the mid-Cretaceous.

An analysis of plate motions during the Cretaceous indicates that long intervals of nearly steady-state plate motion were interrupted at irregular intervals by global tectonic "events" during which there was a major change in plate motion. Continent-continent collisions, or the subduction of major spreading centers may have been the principal causes of these global plate tectonic reorganizations. During the Cretaceous, the major global tectonic events occurred at 140–130 Ma (Berriasian - Valanginian), at 95–85 Ma (Cenomanian - Santonian), and at 75–65 Ma (Campanian-Maestrichtian). Several secondary events can also be resolved.

We believe that these major global tectonic events may have been an underlying cause for global changes in climate, sea-level, ocean circulation, and primary productivity during the Cretaceous.

PALEOGEOGRAPHIC & PLATE TECTONIC RECONSTRUCTIONS OF PANGEA

SCOTESE, Christopher R., Dept. Geology, U. Texas at Arlington, Box 19049, Arlington, Texas 76019

The term "Pangea" is a misnomer. There probably never was a single supercontinent comprising all the world's landmasses. Though by the late Paleozoic, Laurentia (North America), Baltica (N. Europe), Siberia, Kazakhstan, and the NW portions of Gondwana had collided to form the western half of Pangea, the eastern half of Pangea, composed of China, the Tibetan terranes, and Southeast Asia had yet to assemble. It was not until the early Mesozoic that the continents of southern Asia made their way across Paleotethys and collided with Siberia. However, though the eastern half of Pangea had assembled by the Early Jurassic, the western half was already beginning to break apart. In this regard, we propose that there were actually two, temporally distinct Pangeas. A late Carboniferous, or "Paleozoic Pangea" in which the Asian terranes were located adjacent to the northeastern margin of Gondwana, (Indo-Australia), and an early Jurassic, or "Mesozoic Pangea", in which the Asian continents had crossed Tethys and had become part of Laurasia. We are only beginning to understand the complex tectonic and palegeographic events that took place in the time interval separating these two Pangeas.

In this paper we present 6 plate tectonic and paleogeographic reconstructions illustrating the transition from the Paleozoic Pangea to the Mesozoic Pangea. Maps for the Late Carboniferous, Early Permian, Late Permian, Early Triassic, Late Triassic, and Early Jurassic, illustrate the changing plate geometries and the ancient distribution of land, sea, and mountains.

The PALEOMAP Project: Global Plate Tectonic Synthesis and New Software Tools.

Christopher R. Scotese, (chairman), Department of Geology, University of Texas, Arlington, Texas 76019.

Malcolm I. Ross, Department of Geology and Geophysics, Rice University, Houston, Texas, 77251.

The PALEOMAP Project is joint IUGG-IUGS program whose goal is to produce plate tectonic and paleogeographic synthesis describing the evolution of Earth during the last 600 million years. Plate tectonic models describing the development of the Atlantic Ocean (Srivastava, Müller, Cande), Indian Ocean (Royer, Patriat), Pacific (Atwater, Stock, Sager), Asia (Rowley), Tethys (Sengor, Dercourt), Soviet Union (Zonenshain) and Circum-Antarctic regions (Lawver) have been combined with Paleozoic plate reconstructions (Scotese, McKerrow) and a new Global Apparent Polar Wander Path for the major continents (Van der Voo) to produce a global model of Phanerozoic plate motions. An atlas of 50 global plate reconstructions will be published as a large format atlas by the AGU in 1991.

In addition to promoting and publishing this Phanerozoic synthesis, the PALEOMAP Project is also sponsoring the development of two new software packages: a Paleo- Geographic Information System (PGIS) and a UNIX-based plate reconstruction program (Paleogeographer™). The PGIS ™ is a Macintosh-based program that combines the relational database, 4th Dimension, with paleogeographic mapping software. Using PGIS™ it will be possible to directly connect information in pre-exisiting databases (e.g. coal or source rock database) to paleogeographic maps. Paleogeographer ™ is a plate reconstruction and modelling program that allows the user to produce maps and construct new plate models. Though similar to previous programs (i.e. Megadrifter™, Paleomap™), Paleogeographer will be supported on a variety of Unix-compatible platforms.

The Orizaba fault zone: link between the Mexican Volcanic Belt and strike-slip faults of northern Central America

Burke Burkart (Department of Geology, University of Texas at Arlington, Arlington, TX 76019)
C. R. Scotese (Department of Geology, University of Texas at Arlington, Arlington, TX 76019)

Splays of the Polochic and Motagua faults of northern Guatemala merge and continue westward along the southern margin of the Chiapas massif, where they join a complex, northwesterly-trending belt of right-lateral faults, the Orizaba fault zone (see map below). This fault zone, which intersects the Mexican Volcanic Belt (MVB) near Pico de Orizaba volcano, may link the MVB with strike-slip faults of northern Central America. The Orizaba fault zone has at least 100 km of right slip and separates the Sierra de Juarez from the Miocene Veracruz basin. Displacement across this fault zone appears to be the result of southeastward movement of Yucatan, with respect to North America, in concert with the eastward moving Caribbean plate. Right-lateral displacement along this fault zone may help to reconcile measured left-lateral offset across the Cayman trough (about 1100 km) with the amount of strike-slip offset observed in northern Central America (perhaps 200-300 km). Plate reconstructions illustrating motion along these faults since the Miocene will be presented.