by George D. Klein and Benoit Beauchamp¹

Project PANGEA workshop

The Project PANGEA workshop, held in Lawrence, Kansas, USA, in May 1992, was attended by 80 people from 15 countries and was run under the auspices of the Global Sedimentary Geology Program, a commission of the International Union of Geological Sciences. International research recommendations that were made at the workshop focus on paleoclimate modeling, sedimentary criteria and constraints on paleoclimates, late Paleozoic and early Mesozoic plate-tectonic reconstructions as a baseline for paleoclimate studies, stratigraphic constraints on late Paleozoic and early Mesozoic time scales, improved time scales and time-stratigraphic correlation, occurrences of phosphorites, oil, coal, and metals in late Paleozoic and Mesozoic sedimentary rocks, and causes of biological extinctions during the existence of the supercontinent of Pangea. Research initially will emphasize time-slice reconstructions for the Moscovian (315–305 Mega-annum), Kazanian (269–264 Mega-annum), and Carnian (228–220 Mega-annum) as a focus of detailed global study. Detailed paleogeographic maps also are planned for the Stephanian-Autunian, Kazanian, Scythian, Carnian, and Pliensbachian intervals.

An international workshop was held from May 23 through 28, 1992, in Lawrence, Kansas, USA, in order to organize the research effort for Project PANGEA, which is the second project sponsored by the Global Sedimentary Geology Program (GSGP), a commission of the International Union of Geological Sciences (IUGS). Convened by George D. Klein (USA) and Benoit Beauchamp (Canada), the workshop was funded by grants and gifts from the U.S. National Science Foundation (Award EAR-91-17687), U.S. Geological Survey, Division of Sedimentary Geology of the Geological Society of America, Society for Sedimentary Geology (SEPM), International Association of Sedimentologists, Chevron Oil Field Research Corporation, and Allen Press, Inc. A total of 80 individuals attended the workshop, including 15 graduate students. A field trip to Pennsylvanian and Permian cyclic sediments in eastern Kansas concluded the workshop (figs. 1–5). Participants came from Argentina, Australia, Canada, People's Republic of China, Czechoslovakia, Ethiopia, Germany, The Netherlands, Poland, Russia, South Africa, Switzerland, Taiwan, UK, and USA.

The goal of the workshop was to recommend international and multidisciplinary research objectives within the framework of Project PANGEA. The principal objectives for Project PANGEA are (1) to understand global processes, their magnitude, and their temporal variations during the time of the accretion, zenith, and breakup of the supercontinent Pangea; (2) to examine the global sedimentary record and its variability from the start of the Pennsylvanian (middle Carboniferous) through the Middle Jurassic; (3) to determine the cause and nature of climate variability during Pangea's existence; and (4) to determine the causes of the Permian-Triassic and Triassic-Jurassic extinctions. However, during the workshop, it became clear that the major objective, which is expected to lead to new, significant, and different results for Project PANGEA, is the paleoclimate modeling and the subsequent geological verification of such models.

The Project PANGEA workshop itself was organized into an opening plenary session of invited papers, a special plenary session on paleoclimate modeling, and individual sessions by the working groups. These groups formulated recommendations for research, as well as hosted sessions of short contributed papers.

The opening plenary session on Sunday, May 24, 1992, consisted of the following invited talks: George D. Klein (USA, Project PANGEA), "Goals and Developments; Tectonic-Climatic Discrimination of Cyclic Deposition"; John J. Veevers (Australia), "Pangea: Evolution of a Supercontinent and Its Consequences for Earth's Paleoclimate and Sedimentary Environments"; Thomas J. Crowley (USA), "Pangean Paleoclimates"; George T. Moore, D.N. Hayashida, C.A. Ross, and S.R. Jacobson (USA), "The Paleoclimate of Pangea During Its Formation (Late Permian) and Disintegration (Late Jurassic)"; Jane Francis (UK), "Paleoclimates of Pangea (Geological Evidence)"; Martin A. Perlmutter and M.D. Matthews (USA), "Global Cyclostratigraphy: Depositional Response to Climate Change and Basin Evolution"; Ethan L. Grossman (USA), "The Stable Isotope Record During the Evolution of Pangea: Progress and Prospects"; John J. Veevers and S.E. Shaw (Australia), "Turning Point in Pangean Environmental History at or About the Permian-Triassic Boundary"; Sarah Fowell (USA), "Late Triassic Palynofloral Evolutions and Climate Cyclicality, Eastern North America"; Benoit Beauchamp (Canada), "Carboniferous to Triassic Tectonoclimatic Evolution of Northern Pangea"; Erik Flugel (Germany), "Pangean Shelf Carbonates: Controls of Permian and Triassic Reef and Platform Development"; and Aymon Baud (Switzerland), "Late Permian to Late Triassic of the Tethys: Existing Problems, New Facts, and Theories, a Review."

In order to assist in developing synergism between sedimentary geology and paleoclimate modeling, a separate, special plenary session was entitled "Paleoclimate Modeling and Model—Geological Observations and Comparisons." Organized by Dr. Bette Otto-Bleisner and Mark Chandler (USA), this session brought together the paleoclimate modeling community and the sedimentary geology community for the first time.

The following presentations were given by: Chris R. Scotese and Jan Golonka (USA), "Phanerozoic Paleogeographic Maps"; Malcolm I. Ross, C.R. Scotese, A.J. Boucot, Chen Xu, and Anne Raymond (USA), "Late Carboniferous Climatic Simulation Using a Simple Parametric Climate Model"; John E. Kutzbach and A.M. Ziegler (USA), "Numerical Simulation of the Climate of Pangea: Late Carboniferous Climatic Simulation Using a Simple Parametric

¹ With contributions by Aymon Baud, Boris I. Chuvashov, Oscar R. Lopez-Gamundi, Judith T. Parrish, Charles A. Ross, Peter A. Scholle, Christopher R. Scotese, and W. Lynn Watney

Climate Model"; Eric D. Gyllenhaal and A.M. Ziegler (USA), "Comparisons of Lithologic and Paleobotanical Data With Predictions of Atmospheric General Circulation Models: Examples From the Late Permian"; Starley L. Thompson, David Pollard, W.W. Hay, and Kevin Wilson (USA), "Simulations of Triassic Climate Using a Global Circulation Climate Model"; Peter J. Fawcett and Eric J. Barron (USA), "The Climatic Evolution of India and Australia From the Late Permian to Jurassic: A Comparison of Climate Model Results With the Geologic Record"; Bruce W. Sellwood, P. Valdes, and G. Price (UK), "Climate Modeling in the Jurassic: General Circulation Model Predictions in Comparison With the Geological Data Base"; Mark Chandler (USA), "Pangean Climate of the Early Jurassic: General Circulation Model Simulations, the Paleoclimate Record, Climate Feedbacks, and Increased Heat Transport"; Robert J. Oglesby (USA), "Modeling the Effects of Orbital Insolation Changes on Pre-Pleistocene Climates and Sedimentary Cycles"; and Thomas R. Worsley, T.L. Moore, C.R. Scotese, and Carmen M. Fraticelli (USA), "Phanerozoic Paleooceanography and Global Climate."

The final plenary session on May 27 consisted of presentations on the recommendations from each working group for future research activities within Project PANGAEA.

Workshop recommendations

Project PANGAEA was organized originally into five working groups, but it became clear during the workshop that the structure of

the working groups needed some revision and reorganization. The principal recommendations made by the new working groups are summarized below.

Working Group 1, "Paleoclimate" (Judith T. Parrish, USA, Chair)

The scientific rationale for pursuing modeling studies of paleoclimate is twofold. For climatologists, such studies provide opportunities for testing the sensitivity of climate models to changing, realistic boundary conditions. The supercontinent of Pangea represented an extreme paleogeography and possibly an associated extreme climate regime. The successful simulation of this extreme climate would demonstrate the robustness of the climate models. For geologists, modeling studies enhance the understanding of the effects of climate on the geologic record, especially on sedimentation, diagenesis, evolution, extinction, and biogeography. Climatic models also may provide a global framework within which the relatively scattered data on paleoclimate might be interpreted.

Working Group 1 (WG-1) participants observed that first-order agreement was achieved when comparing the results of all the climate models that were applied to Pangea. Thus, future work should focus on climate forcing and response. Three general and overlapping recommendations were offered as to the areas of future research: (1) specific studies of critical paleoclimatic processes, (2) model-model comparisons, and (3) data and model-data comparisons. Although geological participation is critical for the third recommendation, cooperation with the other working groups is needed in all these areas of research.

Critical paleoclimatic processes

WG-1 recommended that the climate modeling research community, whenever possible, should target critical climatic processes for treatment using sensitivity tests. Sensitivity tests are successive model runs in which one or two variables are changed. The tests permit analysis of model behavior, and they help identify the processes that are particularly important for climate when given certain starting conditions (such as paleogeography). The critical climatic processes that already have been identified as appropriate for such treatment are (1) ocean heat transport/sea surface temperature, (2) orbital variability, (3) CO₂, (4) paleogeography, especially topography and sea level, and (5) ice. Currently, ocean heat transport/sea surface temperature are either computed or specified, but, in both cases, they are constrained artificially. WG-1 recommended minimizing the constraints, as well as conducting sensitivity tests.

So far, the model results suggest that climate may be very sensitive to topography. Therefore, WG-1 recommended that WG-2 emphasize determining not only the distribution of highlands but also their altitudes and topographic profiles.

The most complete climate models are those that couple the oceans and atmosphere. Creating coupled ocean-atmosphere models is a major effort underway in climatology, but such models still are relatively undeveloped. Nevertheless, WG-1 foresees the possibility that such models will become available during the lifetime of Project PANGAEA and, thus, recommended, as a long-term goal, the creation of paleogeographic models of paleobathymetry. These models will permit the effective study of deep-ocean circulation.

Model-model comparisons

WG-1 recommended that climate modelers, when presenting results in published papers, should address specifically the differences among various models because these differences are important for

Figure 1.—Daniel Merriam (USA) and John Veevers (Australia) discuss a compelling point about Pangean tectonic history and stratigraphy. (Photograph by Erika Veevers.)

interpreting the geologic record. Geologists are not equipped by training to interpret the differences in model results and, thus, depend on the expertise of climate modelers to make those interpretations. In order to facilitate comparisons, WG-1 recommended that the modeling community should use, when possible, some boundary conditions in common. Specifically, WG-1 recommended using common values of (1) percent change in solar constant, (2) rotation rates, (3) the present CO₂ values from the Berner curve, (4) seasonal, rather than perpetual, models, and (5) values for orbital parameters, that is, eccentricity=0 and perihelion=0. Additionally, WG-1 recommended that climate modelers should address both interannual variability and long-term planetary averages. A long-term goal of WG-1 is to produce a document that will compare model results and will discuss the implications of model results from the interpretation of paleoclimates.

Data and data-model comparisons

WG-1 strongly supported efforts within WG-3 to gain the participation of experts on various paleoclimate indicators in order to facilitate the compilation of data in a manner that will exploit the full potential of the geologic record. WG-1 also supported the ongoing efforts to calibrate the sedimentological and paleontological indicators by using the modern climate. Additionally, WG-1 recommended the collection of data in a manner that will capture the full range of variability for each modeled interval. This will tie the geologic record more effectively into the model runs that examine climatic maximums and minimums with respect, for instance, to orbital parameters and sea level.

WG-1 identified three major problems that are worthy of particular attention and that require geologic data. These problems and some of the required data are as follows: (1) The study of strong winter cooling and the extreme seasonality of temperature in the Southern Hemisphere requires paleobotanical and other biotic data, sedimentary evidence of freezing, soil isotopes, and moisture estimates. (2) The study of CO₂ requires proxy data for CO₂ such as isotopes in paleosols and marine organic carbon. (3) The study of tropical and polar sea surface temperatures requires isotopes such as a strontium-calcium paleothermometer. Because, for example, coals are not precise rainfall indicators but indicate water levels instead, WG-1 advised both modelers and geologists to be critical in making interpretations of the moisture balance in their models and to compare model output with appropriate data.

WG-1 also discussed targeting specific slices of time. The group concluded that their model studies should focus on the time slices proposed by WG-2 and WG-3 because those groups chose time slices by using the same criteria that WG-1 would use, namely data availability. Modeling studies are still experimental, so these studies require the best data available for distinguishing among the results of various sensitivity tests. WG-1 observed that the number of modeling studies on Pangea indicates that these intervals present problems that are inherently of interest to modelers. Geological expertise is essential to these studies for identifying important aspects of the problem of Pangean climates.

Figure 2.—George D. Klein (USA), workshop leader, looks relieved at the end of the field trip because the workshop is completed. (Photograph by Erika Veevers.)

Figure 3.—Workshop participants examine a Permian paleosol near Manhattan, Kansas, USA. (Photograph by G.D. Klein.)

Working Group 2, "Plate Tectonics and Paleogeography" (Christopher R. Scotese, USA, Chair)

The principal goal of WG-2 is to produce large-scale paleogeographic maps illustrating the distribution of mountains, land, shallow oceans, and deep-ocean basins for five time intervals during the history of Pangea, namely the latest Carboniferous to earliest Permian (Stephanian-Autunian), Late Permian (Kazanian), earliest Triassic (Scythian), Late Triassic (Carnian), and Early Jurassic (Pliensbachian). Preliminary versions of these maps will be distributed to other working groups and would serve as base maps on which biogeographic, oceanographic, economic, sedimentological, and paleoclimatic data could be compiled. Besides the five detailed paleogeographic maps, WG-2 will produce approximately 15 plate-tectonic base maps (one for each stage from the late Carboniferous through the Middle Jurassic).

Final versions of these maps will show the distribution of mountains, land, and sea, active plate boundaries and major structural features, major lithofacies, significant accessory lithofacies (reefs, coal, evaporites), important paleogeographic features (lakes, major rivers, impact sites), and political boundaries and modern geographic features for reference, as well as index maps providing the sources of the information that is displayed on the maps. All this information will be compiled on a set of present-day base maps (Mercator projection, scale 1:10,000,000) and then will be digitized and replotted on reconstructed base maps at the preferred publication scale of 1:20,000,000.

WG-2 formed nine regional panels (table 1) that are to assemble the information for these maps. Panel coordinators will compile the paleogeographic information for each time slice. The PALEOMAP Project at the University of Texas at Arlington, Texas, USA, will provide the base maps, will coordinate the digital compilation of the paleogeography, and will produce the final reconstructions.

A sample map, a preliminary map legend, a manual outlining procedures for paleogeographic data collection and interpretation, and base maps were sent to the regional panel coordinators by September 1, 1992, in order to facilitate the compilation of paleogeographic data. Copies of the map legend and data collection manual are available to other working groups on request.

Working Group 3, "Global Synchronicity of the Sedimentary Record" (Benoit Beauchamp, Canada, and Peter A. Scholle, USA, Coauthors)

WG-3 made two major recommendations.

Recommendation 1

The first major recommendation is to scrutinize in great detail the sedimentary record of three time slices during the history of Pangea. These time slices are the Moscovian (315–305 Ma), Kazanian (269–264 Ma), and Carnian (228–220 Ma). The goal in analyzing these time slices is to compile an inventory of the total spectrum of marine and nonmarine climate-sensitive facies. This will allow the reconstruction of the global paleoclimatic-environmental setting for each time scale, and it will provide a standardized set of data to other specialists, especially climate modelers and paleogeographers.

Data to be compiled by WG-3 will include both published data and newly acquired data. Data collection will be completed in digital format, where possible, through the use of expert systems and questionnaires. A basic set of background information will accompany

Table 1.—Paleogeographic regional panels and coordinators, WG-2

Geographic Region	Coordinators
1. Gondwana	J.J. Veevers (Australia)
2. Southeast Asia	Ian Metcalfe (Australia), Dietrich Helmcke (Germany)
3. China	Wang Hongshen, Xu Xiaosong, Wang Chengshan (PRC)
4. Former USSR	L.P. Zonenshain, A. Egorov (Russia)
5. Northern Europe	P.A. Ziegler (Switzerland)
6. Tethys	J. Dercourte (France), A. Baud (Switzerland)
7. North Atlantic margins	W. Manspeizer (USA)
8. Western North America	D.B. Rowley (USA)
9. North American Arctic	Benoit Beauchamp (Canada)

each entry of data. This basic information will provide stratigraphic data, geographic data (today's longitude and latitude, sediment volume), detailed lithofacies and thickness, tectonic setting, vertical and lateral variability (eustatic, tectonic, or climatic changes), and fossil content.

Specific climatic indicators to be cataloged include the following:

- Exposure-related features: calcrete (pedogenic and nonpedogenic), paleosols, karst, bauxites and related deposits, red beds
- Glacial deposits: terrestrial (all types), marine, glendonites
- Eolian deposits: sand seas (dune deposits), eolian dust
- Lacustrine deposits: general lake sediments, tufa-sand travertines
- Coals and organic matter: coal types, organic geochemistry of marine sediments
- Fluvial and deltaic deposits: stream types, flow regimes and gradients
- Evaporites: terrestrial (saline and lacustrine), marine, minor versus extensive deposits
- Reefs: distinction of types having possible paleolatitudinal sensitivity
- Bioclastic limestone and skeletal associations: latitudinal changes in faunal and skeletal assemblages
- Other carbonates: original mineralogy of micrites, original mineralogy and distribution of ooids, original mineralogy and distribution of marine cements; diagenetic patterns in carbonate rocks as paleoclimatic indicators (hardgrounds, intensity of meteoric alteration, cyclicity of alteration)
- Silica deposits: bedded chert, nonbedded deposits, association with other deposit types
- Phosphorite deposits: major deposits, inventory of deposits of lower concentrations, identification of upwelling zones
- Iron-bearing mineral deposits: glauconite, chamosite, oolitic ironstone
- Shales: clay mineralogy, distinction of primary versus diagenetic assemblages
- Isotope geochemistry: oxygen and carbon on brachiopods, other oxygen and carbon studies (whole rock, phosphates, waters), sulfur on carbonates and evaporites, strontium, stratigraphic (secular) versus regional and climatic variations
- Paleobiogeography, paleoecology, paleocommunities: nonmarine (plants, tetrapods and other vertebrates, trace fossils), marine (biogeographic patterns of marine organisms, trace fossils (burrows and borings), determination of paleo-oxygenation levels (laminae and bioturbation patterns))

Figure 4.—Pennsylvanian age cyclothems capped by multiple paleosol horizons capture the attention of participants near Kansas City, Kansas, USA. (Photograph by G.D. Klein.)

Recommendation 2

The second major recommendation of WG-3 is to examine the global sedimentary record of a long-ranging interval of Pangea's history in order to establish links among seemingly unrelated, but often synchronous, aspects of the geologic record, such as climatic evolution, sequence boundaries, biogeography, tectonic shifts, and extraterrestrial impacts. This part of Project PANGAEA will examine Pangea as a highly interactive and dynamic system that was characterized by long periods of stability in the atmosphere, biosphere, hydrosphere, and lithosphere. However, this stability was, from time to time, disturbed by geologically rapid shifts of global magnitude. For the purpose of achieving this goal, one major time interval that ranged from the Kazanian through and including the Norian was selected for global analysis.

The Kazanian-Norian interval was chosen for two reasons. First, this time interval encompasses two time slices that were selected for detailed analysis according to recommendation 1. Second, this time interval straddles the Permian-Triassic boundary, which was perhaps the culmination of the greatest global environmental perturbation in the Earth's history.

A first step toward achieving the goals of this project will be to examine the worldwide distribution of reefs, lacustrine carbonates, paleosols, biotic assemblages, carbonate mineralogy, phosphates, and carbon isotopes during the Kazanian through Norian interval. The data recovered through this "pilot project" will be integrated in a time scale that also will display the known sequence boundaries, climatic shifts, tectonic events, and episodes of volcanism. Ultimately, participants in Project PANGAEA will be able to rank the chronostratigraphic boundaries on the basis of the magnitude of the tectonic, climatic, and depositional shifts observed across them. In a later stage, the project will expand to include a much broader base of Kazanian through Norian data.

Working Group 4, "Stratigraphic Constraints on Global Synchronicity" (Charles A. Ross, USA, and Aymon Baud, Switzerland, Cochairs)

The major problem addressed by WG-4 concerned establishing a detailed time-stratigraphic correlation baseline for the time interval during which Pangea evolved (middle Carboniferous through Middle Jurassic). For this particular time interval, only three solid radiometric dates are available to define chronostratigraphic boundaries. WG-4 tentatively proposed a stratigraphic chart and time scale for the middle Phanerozoic for the purpose of determining where stratigraphic problems exist.

WG-4 recommended the following program of research in order to complete the major gaps in establishing reliable temporal constraints: (1) biostratigraphic studies to calibrate, globally, the zonal schemes for correlation; (2) event stratigraphy to piece together the provincial groupings in middle Permian rocks; (3) sequence stratigraphy to correlate with the standard global section and sequence boundaries to correlate with volcanic ash fall events for geochronological calibration; (4) a systematic program of radiometric dating to tie into recommendations 1 and 3; (5) a program of paleomagnetic stratigraphy to tie into recommendations 1, 3, and 4; and (6) interdisciplinary chronostratigraphy to combine all the correlation techniques so that the middle Phanerozoic time scale represented by the evolution of Pangea will be constrained adequately as a baseline for paleoclimatic and paleogeographic studies.

In addition, WG-4 recommended a detailed analysis that would integrate a variety of data emerging from WG-1, 2, and 3 and would address the nature of the timing and causes of extinction.

Working Group 5, "Resources" (W. Lynn Watney, USA, Boris I. Chuvashov, Russia, and Oscar R. Lopez-Gamundi, Argentina, Cochair)

WG-5 recognized that its activities are likely to overlap with those of the other working groups. Thus, WG-5 will focus on the same time slices proposed by WG-2 and WG-4. WG-5 chose to investigate the characteristics of the important resources associated with Pangea and to improve the precision and accuracy of information on the controlling processes, including climate, that are suited for simulation modeling and improving resource prediction.

WG-5's objectives include a short-term goal of understanding the known resources (that is, an inventory of and the location of deposits). The objectives also include a long-term goal of providing more refined process parameters for use in increasingly refined models, including climatic, stratigraphic, and sedimentological simulations.

Knowing more about the details of selected resources, including their locations in space and time, eventually may provide other diagnostic characteristics of climate that are unknown to us today. For instance, knowing the characteristics and distributional patterns of lacustrine source rocks in rift basins may establish more links to the larger scale climatic and paleogeographic factors that are being modeled now.

WG-5 recommended some thematic projects that are related to resource inventories and prediction. They include the following:

Theme 1, Paleoclimatic controls on the spatial and temporal positions of suboxic and anoxic sediments

Project A is on phosphorites. Its goal is to inventory the phosphorites in sedimentary rocks of Carboniferous and Permian age. It will investigate the relationships among (1) the maximum phosphorite deposition and locations leading to a climax event, (2) the changes in ocean circulation and upwelling systems during the formation of Pangea, and (3) the glacioeustatic control of phosphate events. Case studies would include the Permian Phosphoria rock complex of the Rocky Mountains in North America and the late Carboniferous to Early Permian phosphorites in the Ciscaucasia-Ural region of Russia. The coordinators are Jorg Trappe (Germany) and Boris I. Chuvashov (Russia).

Project B is on black shales (the source rocks). Its goal is to inventory the deposits of the Carboniferous Westphalian and Stepha-

nian intervals because of the longer deposition of black shales in Europe and the Americas. The entire Permian section of organic-rich, high-latitude shales from Gondwana also is an excellent candidate for inventorying. The goal would be to investigate (1) the origin and nature (spatial and temporal distribution) of black shales and the relationship of their formation and character to glacial eustasy, (2) the stratigraphic correlation of black shales in Pangea (in progress), and (3) an independent, interdisciplinary way to evaluate the accumulation rates, sources of organic matter, modes of preservation of organic matter, and contribution and nature of organic productivity. Case studies would include both the organic-rich algal shales from high paleolatitudinal sites in Gondwana (Early Permian to early Late Permian) and the black shales from low paleolatitudes of Europe and the Americas, which contain terrestrial organic matter, have considerable ranges in total organic carbon, and include organic and inorganic compounds. Both these studies would be used as keys to correlate individual eustatic events over the widespread area of Pangea. The coordinators are Oscar R. Lopez-Gamundi (Argentina and USA) and W. Lynn Watney (USA).

Project C is on the source rocks and possibly the source bed-reservoir systems that were associated with Triassic-Jurassic rifting during the breakup of Pangea. This project would focus on the Triassic and Jurassic rocks of eastern North America, Greenland, and the North Sea in order to investigate their relationship to the tectonic and structural evolution and to the paleoclimate. In addition, the project would examine nonmarine grabens containing lacustrine source rocks that were deposited in parts of Gondwana during rifting, that were related to the margins of the paleo-Pacific Ocean, and that were part of a global transtensional event. The coordinators are Martin A. Perlmutter and Warren Manspeizer (USA).

Theme 2, Paleoclimatic controls on the spatial and temporal positions of potential hydrocarbon reservoirs

This theme would focus on the locations and types of carbonate rocks that may serve as hydrocarbon reservoirs in strategic time intervals and sites in Pangea. The time intervals suggested include the Carboniferous Westphalian and Moscovian ages.

The approach to be taken includes (1) making a short-term inventory of deposits; (2) establishing the multiscale facies architecture of carbonate buildups and surrounding strata, evaluating the influence of the paleotectonic setting, paleoclimate, and glacial eustasy, and characterizing the unusual key relationships critical to climate assessment (such as climatic influences upon reefs); and (3) possibly integrating the data through quantitative modeling for improved prediction of potential hydrocarbon reservoirs. Case studies would include the carbonate rocks deposited along the paleo-Tethyan shelves during the Permian and possibly the late Carboniferous. The coordinators are W. Lynn Watney and Martin A. Perlmutter (USA).

Theme 3, Paleoclimatic controls on the spatial and temporal positions of low-latitude and high-latitude coals

A few localities of temperate coals should be selected and compared with Tethyan coals and with peats that are forming in cold regions today. This new model stresses the temperate, postglacial climatic conditions under which the coals of Australia, South Africa, India, and South America were formed, in contrast to the better known European-American model in which coals are associated with humid, low-paleolatitude settings. These models need to be tested and refined through balanced sampling across Pangea. Coordination is recommended with the U.S. Geological Survey's Predictive Stratigraphic Analysis program, which has its focus on coal resources. The coordinator for this theme is Oscar R. Lopez-Gamundi (Argentina and USA).

Figure 5.—W. Lynn Watney (USA) points to salient features of a Pennsylvanian cyclothem at Clinton Reservoir at Lawrence, Kansas, USA. (Photograph by G.D. Klein.)

Theme 4, Metallic mineral resources

A recommendation from the plenary closing session reported that significant metallic mineral deposits are known from many of the sediment types associated with Pangea. A global perspective is needed on their occurrence. Manganese ore, particularly the significant deposits in the Urals, was considered. The coordinators are W. Lynn Watney (USA) and Boris I. Chuvashov (Russia).

Working Group 6, "Biogeography and Extinction" (David J. Bottjer, USA, and Jane Francis, UK, Cochairs)

This working group was proposed and developed during the closing plenary session, and thus it did not meet formally during the workshop. Initial plans include organizing research projects to investigate the two major Pangean mass extinctions at the Permian-Triassic and Triassic-Jurassic boundaries. Future discussions will establish priorities among some possible biogeographic research projects.

Working Group 7, "Synthesis" (George D. Klein, USA, Chair).

This working group will come more into the forefront as Project PANGAEA develops. Workshop activities will consist of coordinating communication among other working groups and of focusing on issues that are significant. Among items of significance that were reviewed are the following: (1) Data quality is important. All observations are to be recorded by present-day longitude and latitude so as to assure its transfer to paleogeographic base maps. (2) A need was expressed for the study of metalliferous sediments, and WG-5 is pursuing this. (3) The paleotopography needs to be simulated. Mass-balancing of sediment volumes to paleotopography needs to be factored in to assure relevant paleoclimatic modeling. (4) A strong geochronological effort needs to be established within the framework of WG-4. (5) The compilation of paleogeographic maps, the sedimentary data, and model simulations are expected to be the final products of the efforts by Project PANGAEA to calibrate paleoclimate simulations from a sedimentological perspective.

Papers presented during the workshop will be published in the Special Paper series of the Geological Society of America. A follow-up conference on Pangea is scheduled for August 15–19, 1993, in Calgary, Alberta, Canada. That conference is being organized by Benoit Beauchamp and Ashton F. Embry of the Geological Survey of Canada. It is being sponsored by the Canadian Society of Petroleum Geologists and the Global Sedimentary Geology Program. As of May 1, 1993, Peter A. Scholle of Southern Methodist University took George D. Klein's place as Codirector of Project PANGAEA. □

Dr. George D. Klein has been President of the New Jersey Marine Sciences Consortium since June 1, 1993. Born in the Netherlands and becoming a U.S. citizen in 1955, he was educated at Wesleyan University, the University of Kansas, and Yale University. Dr. Klein worked at Sinclair Research and taught at the Universities of Pittsburgh, Pennsylvania, and Illinois. He is best known for his research on tidal, Triassic, backarc basin, and cratonic sedimentology, basin analysis, origin of cratonic basins, and Pennsylvanian cyclothems. He is the recipient of numerous awards and has published over 250 refereed papers, books, and abstracts. (Photograph by Richard L. Klein.)

Dr. Benoit Beauchamp is a Research Scientist with the Geological Survey of Canada (GSC) in Calgary. He was born in Montréal in 1958 and completed his master's degree in 1983 at the University of Montréal. He received his doctorate from the University of Calgary in 1987, after which he joined the GSC. His research activities revolve around understanding the Carboniferous and Permian succession of Sverdrup Basin in the Canadian Arctic. Dr. Beauchamp has traveled frequently in many parts of the world, especially in Norway and Russia where his research has direct applications for oil and gas exploration in the Barents Sea. He is the General Cochairman of the Pangea Conference that will be held in Calgary, August 15–19, 1993.