not tied to the central purposes of an agency be considered for inclusion in a department of science, with the National Science Foundation as a core. Science has now assumed such importance to the nation that its position would be stronger if it had a voice at the Cabinet table.

However, in making that proposal I want to make it clear that I would *not* consider concentrating *all* of our science activities into a central agency. A strength of the American establishment is the realization that *science is part of everything.* Those research activities which are integral to a department's mission or which form the basis for its future should be left where they are. More than that, agencies should be encouraged to strengthen their research and development base. But there are other scientific activities of agencies which may be somewhat peripheral to the main job of an agency but are nonetheless important, and these would flourish if transferred to a department of science.

In determining the organizational elements of a department of science, thought will have to be given to the department's relationship to advanced education on the one hand and technological advance on the other. The more the department is oriented toward new technology, the less it is equipped to deal with academic science and advanced education, including the humanities. The more it is oriented toward basic research and academic science, the more it is fitted for a broader role in higher education. On this score, one could invent several cuts that would represent an improvement over the present situation, but I am far from sure what the best cut would be. My present feeling, though, is that the critical questions concern basic research and higher education, and that technological development is more appropriately conducted by agencies with specific tasks and missions.

In the power equation of Washington, such a department of science, if it is to be influential, should have a budget of $2 billion or more. Its principal officer would have line responsibility and public accountability and, most importantly, the interest and confidence of the President, the attention of the Bureau of the Budget, and the ear of the Congress.

With a strong cabinet officer for science in the Executive Branch, there would automatically be a strong congressional counterpart committee having a broad interest in the problems of science and technology, not a minor or incidental interest. We already have committees like the Joint Committee on Atomic Energy and the House Science and Astronautics Committee that are broadly educated in particular spheres of scientific and technological activities, and I am confident we could have committees of this caliber to supervise this department too.

Conclusion

Both the problems and opportunities facing government science policies loom larger than ever before us. I have been privileged to have had a part in setting U.S. science policy and am proud of what has been accomplished so far.

Despite the last 25 years' evolution of the U.S. science structure in the U.S. government, we are still in the early stages of learning how to realize the potential of science and technology for the national good. But we have built a strong foundation, on which further additions and structural changes can be made wtih confidence.

References

1. V. Bush, *Science: The Endless Frontier* (Government Printing Office, Washington, D.C., 1945).
2. G. Soule, *Economic Forces in American History* (Sloane, New York, 1952).
3. J. D. Watson, *The Double Helix* (Atheneum, New York, 1968).

Brazil-Gabon Geologic Link Supports Continental Drift

Newly discovered tectonic province in Brazil matches province in Gabon.

Gilles O. Allard and Vernon J. Hurst

The idea that continents now separated by thousands of miles of oceans once could have been united is more than a century old. A reconstruction of the earth's crust before the drift occurred, very similar to that of Carey *(1)* and Bullard (*2*), was published 100 years ago (*3*). Wegener's papers and book (*4*) did much to popularize the concept in Europe. North American geologists remained rather cold to the idea until the geophysicist brought out strong arguments based on paleomagnetic studies (*5*).

At a symposium on continental drift in London in 1964, Bullard (*2*) predicted that some of the most important data bearing on continental drift would probably come from detailed comparative geological studies of geometrically matching areas which have structures truncated at the continental margin. Humphrey and Allard (*6*), working in Brazil from 1959 to 1964, discovered a Precambrian tectonic province trending roughly S70°E and apparently truncated by the Brazilian coast (Fig. 1). This pointed to a specific locale where a field test of the theory of continental drift might be made.

Geology of the Brazilian Area

Detailed mapping around the Itabaiana Dome in Sergipe, Brazil, by Humphrey, Allard, and others and reconnaissance mapping by Humphrey and Allard in the states of Sergipe and adjacent parts of Bahia and Alagoas, established the presence of the important Precambrian Propria geosyncline, trending N70°W, nearly normal to the trend of the Precambrian basement as formerly represented on the geologic

Dr. Allard is associate professor in the department of geology, University of Georgia at Athens, and Dr. Hurst is head of the department of geology, University of Georgia.

maps of Brazil (*7*). The stratigraphic relations presented in Fig. 2 summarize the geology of the Sergipe area.

The core of the Itabaiana Dome, a topographic low, is underlain by Early Precambrian gneisses. The rim of the dome exposes the metasediments of the Miaba Group, a miogeosynclinal facies (quartzite, metalimestone, metadolomite, and minor metagraywacke). The eugeogynclinal facies is made up of a thick series of metasediments and metavolcanics referred to as the Vasa Barris Group (Fig. 3). This eugeosynclinal prism has been thrust southward over the Macambira thrust on top of either the basement gneisses or the rocks of the Miaba Group (Fig. 4). The rocks show intense folding, axial plane cleavage, and abundant minor thrusts. The general strike is N60° to 70°W; the dip is steep to the north except along the flanks of the Itabaiana Dome. The major rock types, in decreasing abundance, are phyllites, metasiltstones, pebbly metagraywacke, metasandstone, metalimestone, metadolomite, and metavolcanics. The Vasa Barris rocks grade northward into garnet-biotite schists which Humphrey and Allard (*6*) called hornfelses to indicate their genetic relations to the contact metamorphism caused by the plutons of the Gloria batholith. This batholith was intruded along the axis of the eugeosyncline and might have caused the southward thrusting of the sedimentary prism along the Macambira thrust. The batholith is made up of individual plutons of biotite granodiorite with septa and roof pendants of hornfelses. The granodiorite plutons give way northward to quartz monzonite and granite plutons.

The eastern coasts of Sergipe and Alagoas are underlain by Cretaceous sediments of the Sergipe and Alagoas basins (grabens). All the basement samples obtained by Petrobrás in drill holes show that the metasediments of the Vasa Barris Group and intrusions of the Gloria batholith extend underneath these Cretaceous sediments all the way to the Atlantic coast.

West of the Itabaiana Dome, the metasediments and batholithic rocks abruptly terminate at a border fault along the east side of the Tucano basin to reappear west of the basin in the Canudos area. They continue westward to the major bend in the Sao Francisco River and may extend farther, but no detailed mapping has been done west of that natural barrier.

The Estancia series unconformably overlies the rocks of the Vasa Barris Group and the basement gneisses. It consists of limestone and dolomite at the base and overlying massive well-indurated red and green sandstone. The limestone and dolomite are cream-colored, dense, aphanitic, with few oomicrite beds and some sulfur-rich dark gray beds. Good development of *Collenia* algae was observed in a quarry in Crisopolis, Bahia. The sandstones are fine- to medium-grained, immature, made up of rock fragments, feldspar, and quartz, with a matrix containing chlorite, calcite, clinozoisite, and quartz. The Estancia series has irregular gentle dips and shows no systematic pattern of deformation, although it is affected by the Cretaceous block faulting which produced the surrounding basins. From a study of Cretaceous conglomerates and fanglomerates, outcrops, deep-well cores, and seismic surveys, Allard and Tibana (*8*) showed that the Estancia extended before and during Lower Cretaceous as far south as Salvador and all along the coast. Similar rocks have been observed much farther south by Petrobrás' geologists. It is possible that the Estancia formed a thin veneer over most of east-central Brazil before Cretaceous time.

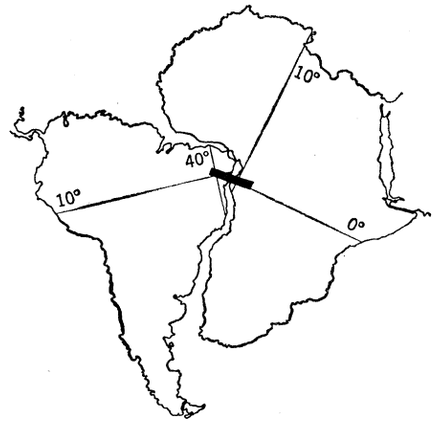


Fig. 1. The west end of the black rectangle gives the position and trend of the Propria geosyncline in northeastern Brazil. The east end of the rectangle marks the position of a similar tectonic province in Gabon, Africa. The fit of the continents is from Bullard *et al.* (*2*).

The Precambrain geosynclinal prism in eastern Brazil is more than 350 kilometers long, and it is 80 kilometers wide. Its size and extent on the mainland of Brazil would suggest a reasonable extension eastward from the coast of Brazil. If continental drift has separated Brazil from Africa, the same rocks in a similar tectonic setting should be found in Africa within Gabon. This background information prompted our search in west-central Africa for a possible continuation of the Brazilian Propria geosyncline and Gloria batholith.

Geology of the African Area

The search was made from December 1966 to March 1967 in Cameroon, Spanish Guinea, and Gabon. West-central Africa, straddling the Equator, is characterized by tropical rain forest and deep laterite. The geologic information obtainable in 3 months of field-

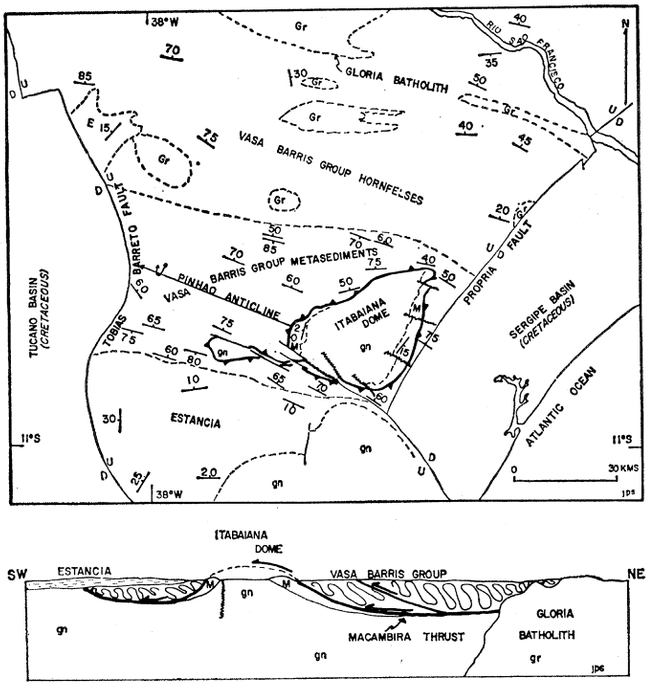
	BRAZIL	AFRICA
CENOZOIC	Continental deposits	Continental deposits
	unconformity	*unconformity*
CRETACEOUS	Sedimentary rocks	Sedimentary rocks
	upper part-marine (limestone & shale)	upper part-marine (limestone & sandstone)
	salt beds	salt beds
	lower part-continental	lower part-continental
	unconformity	*unconformity*
LATE(?) PRECAMBRIAN	Estancia series	Série Schisto-Calcaire
	limestone & dolomite	
	sandstone	Série Schisto-Gréseuse
	unconformity	*unconformity*
PRECAMBRIAN	Plutonic rocks – Gloria batholith	Plutonic rocks – Massif du Chaillu
	intrusive contact	*intrusive contact*
	Vasa Barris Group metasediments	Ndjolé series
	Macambira thrust	*thrust fault*
	Miaba Group metasediments	
	unconformity	
	Basement gneisses & granulites	Basement gneisses & granulites

Fig. 2. Generalized stratigraphic section comparing geologic units of the Sergipe area, Brazil, with central Gabon, Africa.

work is much less than can be obtained in an area like northeast Brazil which has a semiarid climate, little soil cover, and abundant outcrops.

The geological record of Cameroon and Gabon was completed on a reconnaissance basis by French geologists *(9)*. Spanish Guinea has not been studied in the same detail. Our fieldwork was greatly assisted by a new highway along the Ogooué River, from Lalara westward for about 10 kilometers (Figs. 5–7). The new highway, crossing an area well dissected by the Ogooué River and its tributaries, provided road cuts up to 30 meters high, and nearly continous outcrops across the strike of the belt in which rocks similar to those of the Propria geosyncline might be expected.

The rocks of the Ndjolé series com-



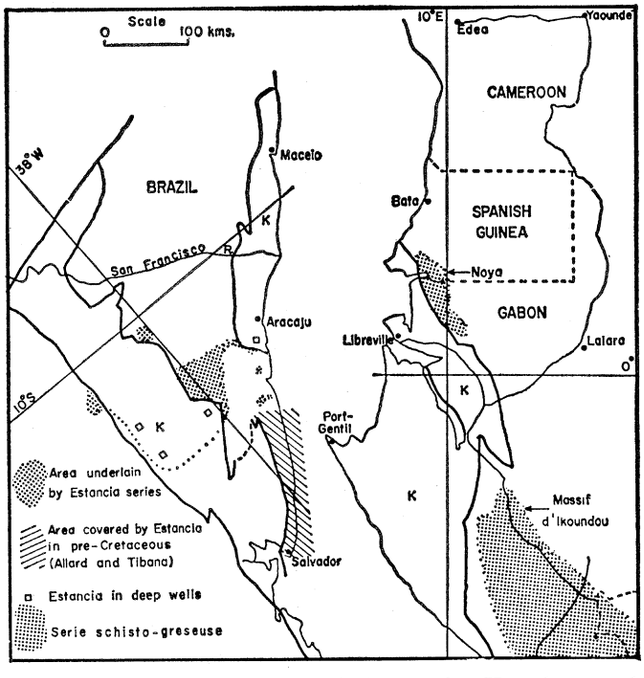
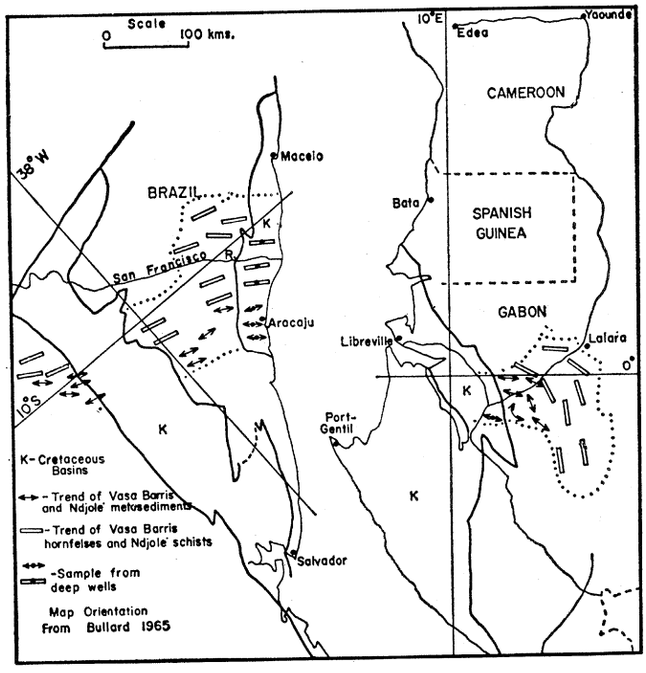


Fig. 3 (top left). Geology of the east end of the Propria geosyncline. [Adapted from an unpublished map by Humphrey and Allard (*6*)] Fig. 4 (bottom left). North-south cross section across the area of Fig. 3, through the western edge of the Itabaiana Dome. Fig. 5 (right). Extent of the Estancia series in Brazil and its African equivalent, the Série schisto-calcaire and Série schisto-gréseuse of Gabon, Congo, and Angola. The pre-Cretaceous extent of the Estancia, north of Salvador, is taken from Allard and Tibana (*8*).



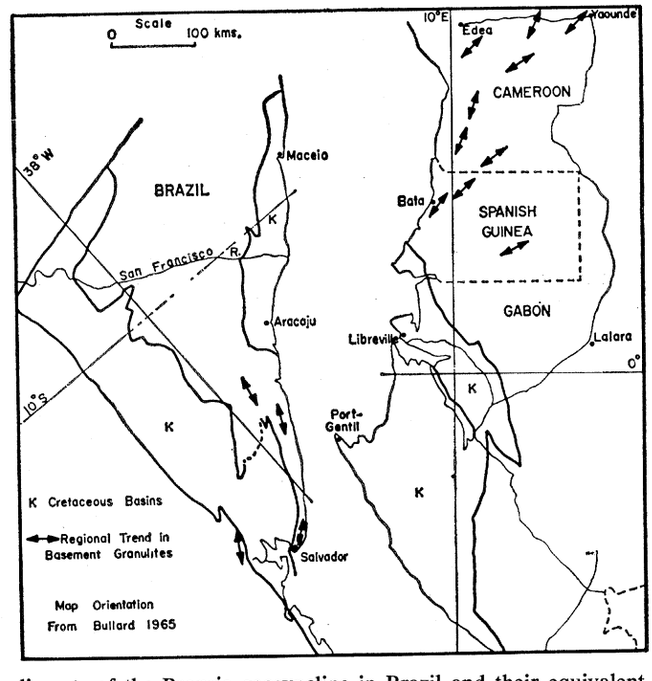


Fig. 6 (left). Extent and regional trend of the Vasa Barris metasediments of the Propria geosyncline in Brazil and their equivalent Ndjolé metasediments in Gabon, grading northeastward and northward into garnet-biotite Vasa Barris hornfelses and Ndjolé schists. Fig. 7 (right). Regional trend of pyroxene garnet granulites mapped in the Salvador area of Brazil and in Cameroon (*15*).

prise tightly folded metasedimentary rocks characteristic of eugeosynclinal conditions of accumulation—phyllites, metasiltstones, massive metagraywackes, metagraywackes showing graded bedding, metavolcanics, and metasandstones. The rocks are isoclinally folded and are cut by thrust and transcurrent faults. The strike varies from west to northwesterly around Ndjolé, and becomes more northerly east of Alembé. Dips are steep (Fig. 6). The contact between the basement migmatites and gneisses and the Ndjolé series is a thrust fault (*10*) similar to the Macambira thrust in Brazil.

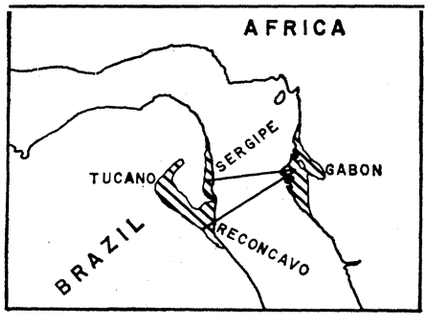
The rocks of the Ndjolé series extend under the Cretaceous basins as evidenced by deep-well samples supplied by the Société des Pétroles d'Afrique Equatoriale. Few wells have reached basement, and we do not know the western limit of this group of rocks in Africa.

The metasediments of the Ndjolé series are metamorphosed to the chlorite subfacies of the greenschist facies. In the vicinity of Alembé, the metamorphism increases rapidly eastward to the biotite subfacies and the almandine subfacies. The similarity between the rocks of the Vasa Barris Group and the Ndjolé series is striking.

Unconformably overlying the highly folded metamorphic rocks of the Ndjolé series is a group of sedimentary rocks belonging to the "Série schisto-calcaire" and "Série schisto-gréseuse" of Gabon. This group of rocks has also been called "Groupe du Congo occidental," "Système de la Noya," and other names. This group forms an extensive subhorizontal Precambrian platform covering parts of Gabon, Congo, and Angola. It is made up of dolomitic limestones at the base and impure red and green sandstones at the top. Dévigne (*11*) reports a slight increase in metamorphism to the south and a northerly provenance. *Collenia* have been reported in the limestones. The road between Tchibanga and N'Dendé, across the Massif d'Ikoundou, exhibits excellent outcrops of the sandstones of the Série schisto-gréseuse (Fig. 5); these rocks are very similar to the Estancia series of Brazil, exposed along the road between Lagarto and Estancia.

Comparison of Cretaceous Basins in Brazil and Gabon

Belmonte, Hirtz, and Wenger (*12*), and Fernandes and Viana (*13*) showed the remarkable similarity between the petroliferous basins of Gabon and the Sergipe-Alagoas Basin (Fig. 8). Both basins are controlled by normal faults, and the lithology of the lower section of the basins is identical (Fig. 8). The sediments are continental in character, and the fossil content is very similar. Krommelbein and Wenger (*14*) report 30 identical species of nonmarine ostra-



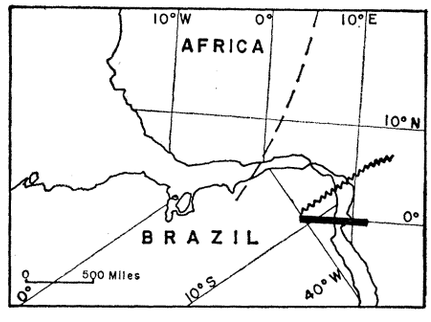


Fig. 8 (left). Index map showing the location of the Cretaceous sedimentary basins correlated in Fig. 10. Fig. 9 (right). Map of Bullard *et al.* (*2*) showing three geological trends continuing from Brazil into Africa. The heavy solid line represents the Propria geosyncline and its extension in Gabon; the wiggly line represents the large Recife and Patos mylonite zones connecting with the mylonite zones of north-central Cameroon; the dashed line represents the geochronogical border established by Hurley *et al.* (*16*).

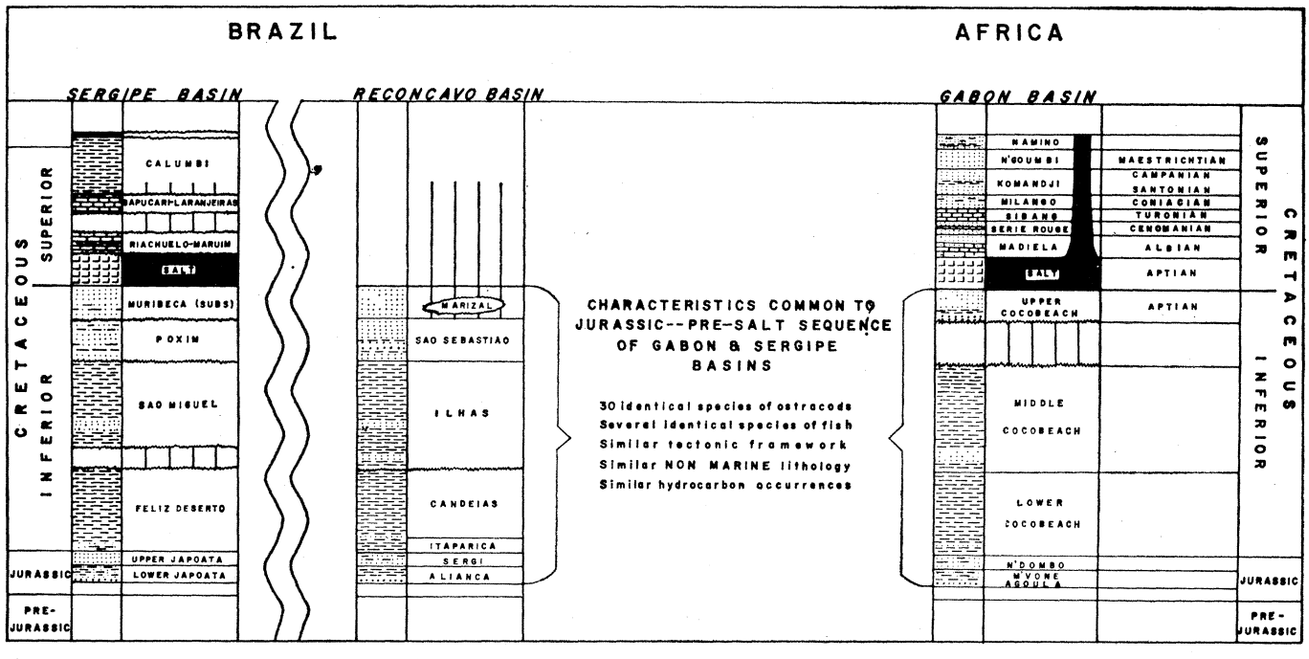


Fig. 10. Schematic stratigraphic and lithologic correlation between the Sergipe-Reconcavo Basin of eastern Brazil and the Gabon Basin in Africa (*12, 13*).

cods found in the Congo, Gabon, and Sergipe basins. The salt beds (Aptian) which overlie the continental section of the basins are present on both sides and point to the first ingression of seawater within a rift basin which had been previously freshwater lakes. This marks the first appearance of the Atlantic Ocean in the area of Sergipe-Gabon, and gives us an accurate timing on an important phase of continental drift.

Lithological and Structural Comparison between Brazil and Gabon

From the foregoing presentation of geological facts, the following correlations can be made.

1) The basement around Salvador and between Salvador and Aracaju in Brazil is underlain by metasediments metamorphosed to the pyroxene granulite facies (*15*). The trend of the granulites varies between N20°E and N60°E and strike toward similar rocks in Spanish Guinea and Cameroon (Fig. 7).

2) The Vasa Barris Group of Brazil correlates with the rocks of the Ndjolé series of Gabon in the lithology, general trend, deformation style, metamorphic facies, and gradation northeastward from greenschist facies to garnet-biotite schists.

3) The Estancia series of Brazil is similar to the Série schisto-calcaire and Série schisto-gréseuse of Gabon in the lithology, stratigraphy, tectonic setting, provenance direction, slight increase of metamorphism southward, and in the presence of *Collenia*.

4) The Cretaceous basins on both sides of the Atlantic have the following features in common in the pre-salt sequence (Fig. 8): 30 identical species of ostracods and several of fish (*12–24*), similar tectonic framework, similar nonmarine lithological sequence, and similar hydrocarbon occurrences.

Summary

A complex assemblage of rocks, like that traced in Brazil for 350 kilometers perpendicular to the coast, was located in Africa within the projected area by the use of Bullard's best fit of the continents as a base map. The excellent match between the geological features of Sergipe and Gabon strongly favors the theory of continental drift. One could travel the length of Brazil and across a great part of Africa without encountering a similar geological assemblage. This correlation of large bodies of rocks, arranged in the same order, at the right location, could be ascribed to coincidence only by the most ardent opponents of the theory of continental drift.

Hurley (*16*) located on a predrift map a north-south geochronological boundary (Fig. 9) going from Ghana in Africa to São Luis in Brazil. The Recife and Patos mylonite zones of Brazil connect with the mylonite zones of north-central Cameroon. Our lithologic and tectonic trend (Fig. 9), extending from Brazil to Gabon, provides a third link between the two continents. The accurate match of three independent trends on a predrift map (Fig. 9) strongly supports the hypothesis of continental drift.

References and Notes

1. S. W. Carey, *Continental Drift, A Symposium* (Geology Department, University of Tasmania, 1958).
2. E. Bullard, J. E. Everett, A. G. Smith, *Phil. Trans. Roy. Soc. London* **238**, 50 (1965).
3. A. Snider, *La Création et ses mystères dévoilés* (Franck, Paris, 1858).
4. A. Wegener, *The Origin of Continents and Oceans* (translation of the 4th edition of 1929) (Dover, New York, 1966).
5. A complete bibliography of paleomagnetic studies can be found in E. Irving, *Paleomagnetism* (Wiley, New York, 1964).
6. F. L. Humphrey and G. O. Allard, *Proc. Int. Geol. Congr. Prague 23rd* **4**, 123–139 (1968).
7. Departmento Nacional da Produção Mineral, *Mapa geológico do Brasil* (Rio de Janeiro, 1960).
8. G. O. Allard and P. Tibana, *Bol. Téc. Petrobrás* **9**, 1 (1966).
9. Gouvernement de l'Afrique Equatoriale Française, Direction des Mines et de la géologie, reports by Aubague (1959), Champetier de Ribes (1956, 1959), Cosson (unpublished), Dévigne (1957, 1958), and Hourcq (1950).
10. B. Choubert, *Les Terrains anciens du Gabon* (Desfossés, Paris, 1937); *Bull. No. 6, Gouvernement Général de l'Afrique Equatoriale Française* (1954).
11. J. P. Dévigne, *Bull. No. 11, Direction des Mines, Gouvernement Général de l'Afrique Equatoriale Française* (1959).
12. Y. Belmonte, P. Hirtz, R. Wenger, *Salt Basins around Africa* (Institute of Petroleum, London, 1965).
13. G. Fernandes and C. F. Viana, *Bol. Téc. Petrobrás* **9**, Nos. 3–4 (1966).
14. K. Krommelbein and R. Wenger, in *Symposium sur les Bassins Sédimentaires Cotiers post-Cambriens de l'Afrique de l'Ouest*, (New Delhi, 1964); C. Arambourg and D. Schneegans, *Compte Rendu Som. Seances Soc. Geol. Fr.* **5**, 170 (1935).
15. G. O. Allard, Internal report, Petrobrás, Departmento de Exploração, Salvador, Bahia, Brazil (1962); G. Champetier de Ribes and M. Aubague, *Territoire du Cameroun, Carte géologique de reconnaissance* (Yaoundé-est, 1956).
16. P. M. Hurley *et al.*, *Science* **157**, 495 (1967).
17. We thank Fred L. Humphrey for unpublished data and many individuals who assisted our field work in Africa, especially Dr. N. Guema N'Dong, Minister of Mines of Gabon, and his assistants, Drs. Moreau, Karlin, and Morel of the Department of Mines of Gabon; Dr. Chatué Kamga, Minister of Mines of Cameroon, and Dr. Louis Laplaine of the Department of Mines of Cameroon; Messrs. R. Wenger, M. Michelet, and I. de Glasz of Société des Pétroles d'Afrique Equatoriale in Port Gentil, Gabon. Supported by NSF grant GA-718 and by the Office of General Research of the University of Georgia.