Triassic Pollen Date Moroccan High Atlas and the Incipient Rifting of Pangea as Middle Carnian

Abstract. *Palynomorphs from the High Atlas Mountains south of Marrakech define the* Minutosaccus-Patinasporites *Concurrent Range Zone, which is time-stratigraphically equivalent to the Swiss and English middle Keuper, type Carnian of Austria, and North American Triassic beds in Virginia, North Carolina, Pennsylvania, New Jersey, Texas, New Mexico, and Arizona, thus dating an early episode of continental rifting between Africa and North America.*

The Triassic System of Morocco consists of red beds, basalt flows, and marine evaporites that were deposited in rift valleys at the time North America and northwest Africa began to separate (*1*). Although a considerable body of radiometric and paleomagnetic data is available on the subject, virtually no definitive paleontologic data exist, and consequently the geologic age of the rifting and the initial opening of the North Atlantic Basin is an unsettled question (*2*). The purpose of this report is to present new paleontologic data on the age of the Triassic System in the High Atlas Mountains of Morocco, which make it possible to correlate this section with its time-stratigraphic equivalents of North America and Europe, and to offer more precise paleontologic information on the initiation of continental rifting of Pangea, which preceded sea-floor spreading between eastern North America and northwest Africa.

The geologic age of the Triassic System of the High Atlas has heretofore been determined solely by dating fossils from the Argana Valley of southwestern Morocco (*3*). These fossils include the phyllopods *Estheria minuta* Alberti and *Estheria destombesi* Defretin (*4*), and long-ranging vertebrate fossils including stegocephalian amphibians, phytosaurs (aff. *Mystriosuchus plieninger* Meyer), dinosaurs, pseudosuchians, dicynodont reptiles (aff. *Kannemeyeria* sp.), and a dipnoid fish tooth attributed to *Ceratodus* sp. (*5*). Further refinement and substantiation of a Late Triassic age has not been possible, because no other age-restricted Triassic fossils have been reported from the High Atlas. Radiometric dates from basalt lava flows near the upper part of the section are not precise, ranging from 218 ± 21 million to 196 ± 20 million years (*6*). According to the 1964 Geological Society Phanerozoic time scale, the limits of these dates range from the Late Permian to the Middle Jurassic (*7*).

Advances in pollen biostratigraphy of Triassic sediments in the North Sea basin (*8*), Switzerland (*9, 10*), Austria (*11*), England (*12, 13*), and North America (*14–16, 21*) have focused considerable attention on applying these results to palynological studies of the Triassic red beds in the High Atlas. Samples show that the red beds carry a diversified Late Triassic palynoflorule. The productive horizon occurs in the upper part of the Oukaimeden Sandstone, 3 km northeast of Oukaimeden, along the Oukaimeden-Ourika road in the Central High Atlas, and about 125 km east of the fossil locality in the Argana Valley. The lens sampled occurs stratigraphically about 200 m below the base of basalt flows that have a radiometric date of 196 ± 20 million years (*17*).

Figure 1 is a histogram based on 355 palynomorphs identified in the Moroccan material. The palynoflorule is composed predominately of *Triadispora* species and is dominated by pollen of presumed gymnospermous affinities (66 percent bisaccate, 16 percent nonsaccate, and 9 percent monosaccate). Only 8 percent of the forms are assignable to spore-producing plants. No striate saccate pollen was identified. Of the 21 palynomorph species identified, 17 have been described from the Swiss Keuper (*9, 10*).

Figure 2 shows cited stratigraphic and geographic occurrences of the palynomorphs identified in the Moroccan sample. The citations in Fig. 2 are keyed to the reference list. Palynomorphs shown on the chart fall into the following five range groups:

1) Pre-Carnian to middle Carnian.
2) Pre-Carnian to uppermost Carnian.
3) Pre-Carnian to post-Carnian.
4) Basal Carnian to post-Carnian.
5) Middle Carnian to post-Carnian.

Concurrence by overlapping ranges in European localities of the lower occur-

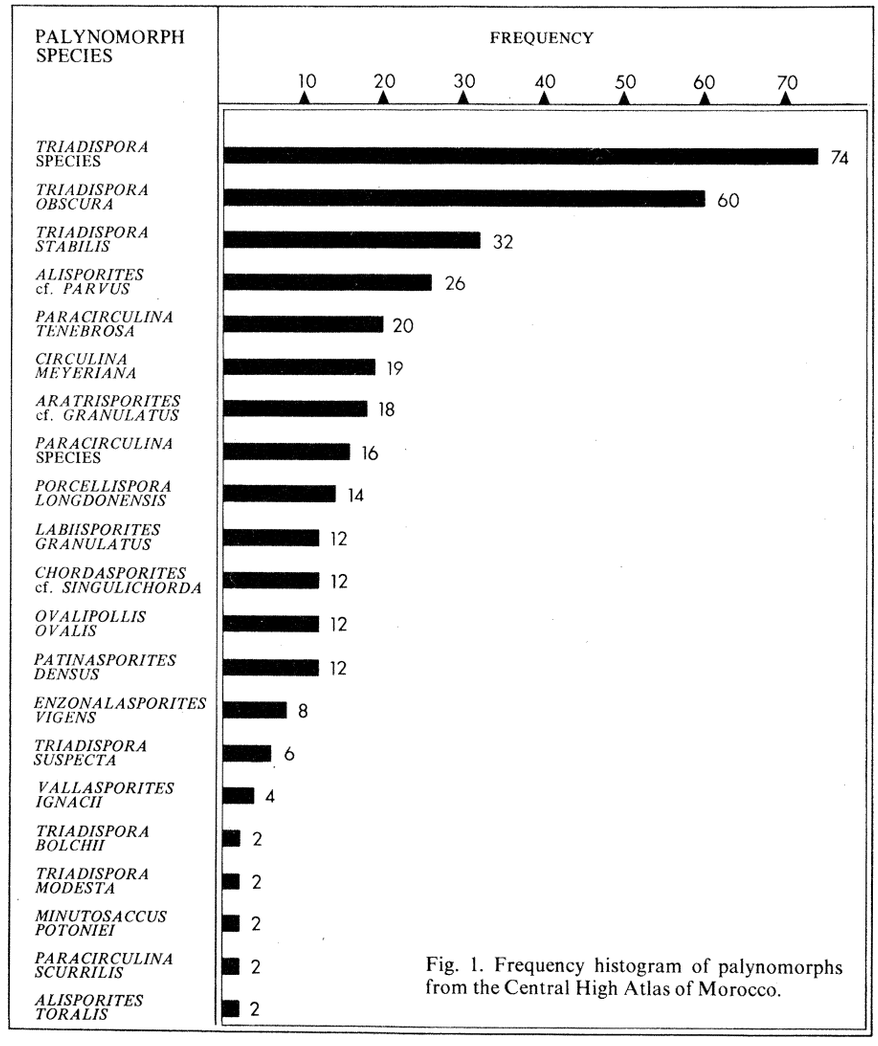

Fig. 1. Frequency histogram of palynomorphs from the Central High Atlas of Morocco.

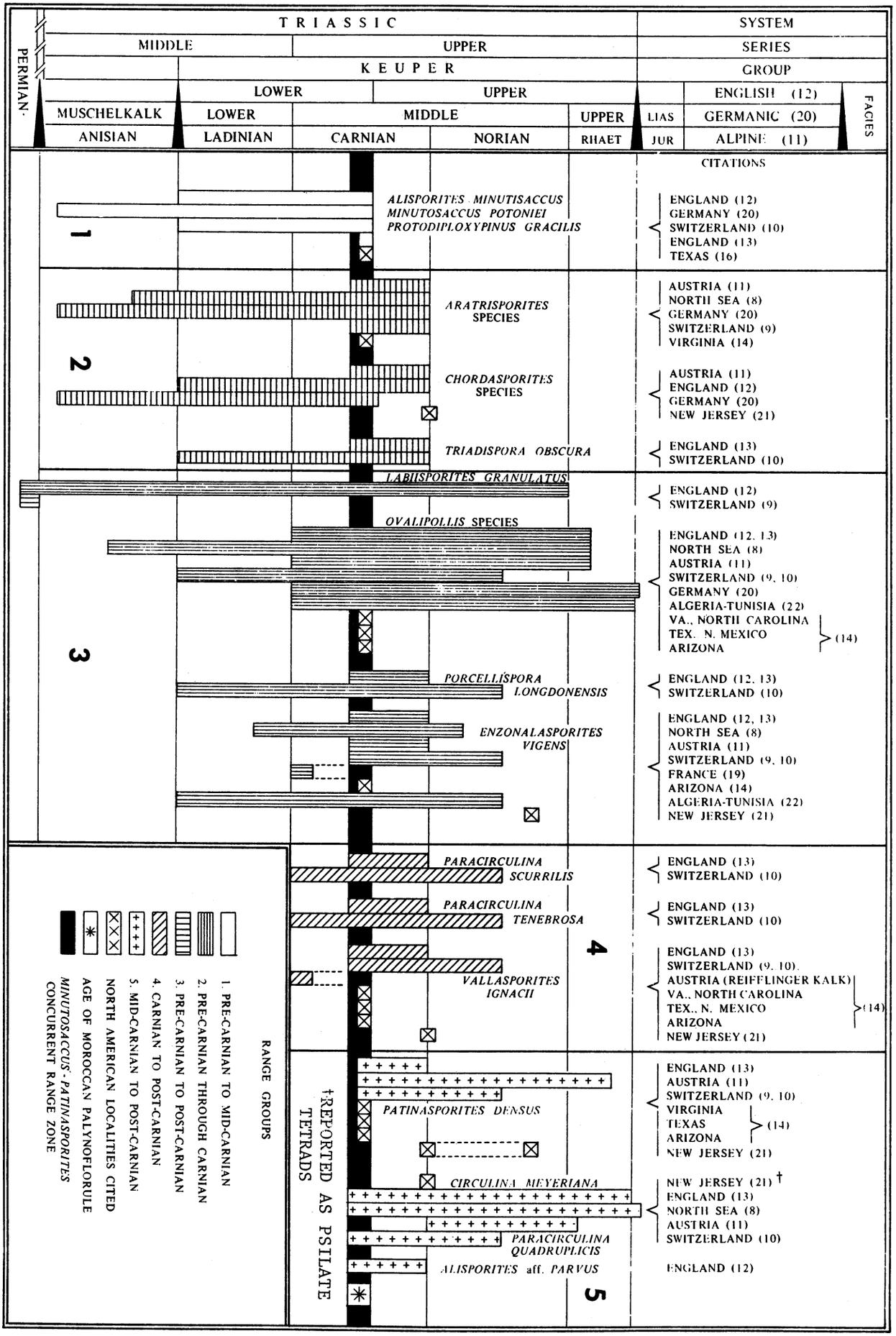

Fig. 2. Cited stratigraphic and geographic occurrences of age-diagnostic palynomorphs from the Central High Atlas of Morocco.

rence of *Circulina meyeriana* Klaus, *Patinasporites densus* Leschik, and *Paracirculina quadruplicis* Scheuring with the uppermost range of the bisaccate species *Alisporities minutisaccus* Clarke, *Minutosaccus potoniei* Mädler, and *Protodiploxypinus gracilis* Scheuring (*23*) restricts the geologic age of the Moroccan material to from middle to early late Carnian and defines the *Minutosaccus-Patinasporites* Concurrent Range Zone (*18*). This age and its suggested radiometric equivalent of 205 million years for the Carnian (*7*) are congruent with a radiometric date of 196 ± 20 million years for the basalts overlying the Oukaimeden Sandstone.

The presence of the *Minutosaccus-Patinasporites* Concurrent Range Zone in European localities is indicated in the English Arden Sandstone (by concurrence of *Circulina meyeriana* Klaus, *Patinasporites densus* Leschik, and *Protodiploxypinus gracilis* Scheuring) (*13*), in the Swiss upper Gipskeuper and lower Schilfsandstein beds (by concurrence of *Paracirculina quadruplicis* Scheuring, *Patinasporites densus* Leschik, and *Protodiploxypinus gracilis* Scheuring) (*10*), and in several North Sea localities (by the range overlap of *Circulina meyeriana* Klaus and *Minutosaccus potoniei* Mädler) (*8*). Its presence in the North American Dockum Group of Texas is also indicated, by the concurrence of *Minutosaccus potoniei* Mädler (*16*) and *Patinasporites densus* Leschik (*14*).

Thus, the pollen data indicate that the upper part of the Triassic section in Morocco is a time-stratigraphic equivalent of the European upper Gipskeuper and Schilfsandstein Formations of the Alpine Forelands (*9, 10*), the type Carnian section of Austria (*11*), and the Arden Sandstone and Keuper Marls of England (*12, 13*). Because of the common occurrence of age-diagnostic palynomorphs, it is also a time-stratigraphic equivalent of lower portions of the Newark Group in the Taylorsville and Richmond basins of Virginia and the Deep River basin in North Carolina, as well as the Dockum Group of Texas and New Mexico, and the Chinle Formation of Arizona and New Mexico (*14*). Preliminary data suggest that it is also of comparable age to the lower and middle New Oxford Formation, Gettysburg basin, Pennsylvania (*15*), and is older than most Newark Group sediments in New Jersey and New England, which are of Rhaetic to Liassic age (*15, 21*).

Because the Triassic beds are syntectonic and were laid down in zones of active rifting (*1*), these data demonstrate that rifting began no later than middle Carnian time. It is significant that the oldest dated Triassic rocks in the widely separated basins along the margins of the North Atlantic between Africa and North America were deposited at a time of active rifting during the Carnian stage. Clearly, an important large-scale tectonic event occurred during Carnian time that is related to the subsequent breakup of Pangea and the opening of the Protoatlantic basin.

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18. The localities cited in Fig. 2 include the following stratigraphic units: English and German standard sections and many subsurface sections in the North Sea area (*8*); upper Gipskeuper and Schilfsandstein formations (subsurface samples) (*9*); entire Swiss Keuper excluding Rhaetic, exposed in tunnel (*10*); Austrian type Carnian (*Halobia, Cardita* Lunzer beds), Norian, and Rhaetic (*11*); entire English Triassic correlated with Alpine subdivisions (*13*); North American Newark Group, Dockum Group, and Chinle Formation (*14*); North American Newark Group in Connecticut and New Jersey (*15*); Moroccan Ourika Valley Triassic section, Oukaimeden Sandstone (*17*); Dockum Group, Texas (*16*); Lettenkohle, France (*19*); entire type Germanic Triassic (*20*); lower portion of the Brunswick Formation exposed near Newark and Milford, N.J. (*21*); Triassic strata drilled in the Algerian and Tunisian Sahara region (*22*).
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Field Evaluation of Benzopyrene Hydroxylase Induction as a Monitor for Marine Petroleum Pollution

Abstract. *Fish from petroleum-contaminated sites in the marine environment have elevated levels of benzopyrene hydroxylase activity in liver and gill tissue. This sublethal response appears to be a practical biological monitor for marine petroleum pollution.*

We recently demonstrated that benzopyrene hydroxylase (E.C. 1.14.14.2) is induced in fish by exposure to petroleum (*1*). Besides establishing a directly measurable sublethal response, we speculated on the potential of enzyme induction as a biological monitor for petroleum hydrocarbons in the sea. A field trial has now been carried out.

The cunner (*Tautogolabrus adspersus* Walbaum, 1792) was selected as a suitable species for the trial (*2*). This nonmigrant fish stays near its home territory throughout the year (*3*) and is plentiful and easy to trap. Its range extends from Newfoundland to Chesapeake Bay (*4*). Cunners were collected at four sites (Fig. 1). Livers and gills were immediately removed from the fish and frozen in Dry Ice for transport to the laboratory. Extracts were prepared and benzopyrene hydroxylase activity was measured as previously described (*1*). Site