NEW LIGHT ON THE EARLY PHYLOGENY OF THE VASCULAR PLANTS AND ON THE INFLUENCE OF CYCLES OF PAST GLACIATION AND MOUNTAIN-BUILDING ON PLANT EVOLUTION*

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IN two recent papers[1,2] by the present authors and Mr. R. N. Shrivastava, several types of cutinised spores and tracheids of vascular plants from known Cambrian sediments in India were reported. These are of some importance as very few authentic remains of vascular plants are known from sediments earlier than the Middle Silurian. It was not suspected till recently that the vascular plants could have evolved as early as the Cambrian. As only to be expected, the spores recovered by us, most of them with well-developed tri-radiate marks, belong to the lower groups of vascular plants, namely, the primitive Pteridophyta and the Pteridospermæ. The tracheids obtained are too fragmentary for reference to any particular group. But they all possess simple pits.

It is now fairly certain that vascular plants were evolved even as early as the Cambrian. A careful study of the spores indicates that for them to have reached this stage of development, the plants to which they belonged might have had a long period of evolution, most probably extending back even to the late Pre-Cambrian (? Proterozoic).

Spores and tracheids of vascular land plants were obtained from known horizons in the Middle and Upper Cambrian sediments of Kashmir, Spiti and the Salt Range.[1] Comparative study of these somewhat poorly preserved spores with those of the known younger Palæozoic groups of plants cannot be considered satisfactory. Between the Middle and Upper Cambrian, and the Devonian or Carboniferous a long span of time had elapsed during which the earliest vascular plants should have undergone rapid evolution. But it would appear that the spores which are the reproductive elements, retained their essential distinctive features of the groups thus enabling us to suggest to a certain extent their possible affinities. From the study of these Middle and Upper Cambrian spores[1] we suspect that the representatives of the primitive Pteridophytes and the Pteridosperms had already been differentiated as distinct stocks at least by the Middle Cambrian time. The spores had already reached a fairly high stage of organisation including the development of rudimentary wings or bladders in some. This surprising result induced us to look for the remnants of comparatively more primitive plant remains in earlier sediments.

Investigations were therefore extended to still earlier sediments than the Middle Cambrian, and from the upper part of the Lower Vindhyan, a horizon believed to be older than the Cambrians considered above, several well-preserved spores, possibly referable to the primitive Pteridophytes, and (?) the Pteridosperms were recovered.[2] The age of the Vindhyans is doubtful, but there is accumulating evidence that the Lower Vindhyans may be Lower Cambrian in age, if not older.

Amongst the Vindhyan spores believed to be Pteridophytic, we suspect the presence of those of the Psilopsida, Lycopsida and (?)[2] the Sphenopsida. The Pteridosperms (of the Pteropsida) are also possibly represented. If our surmises are correct, we are inclined to put forward the tentative suggestion that the Psilopsida, Lycopsida and (?) the Sphenopsida among the primitive Pteridophytes, and possibly even the Pteridosperms of the group Pteropsida had already developed as distinct lines of evolution even in the early Cambrian possibly getting back to the late Pre-Cambrian. It is not quite impossible that the Pteropsidan Cœnopteridales and Cordaitales might be traced in strata older than the Devonian.

The differentiation of these major primitive plant groups, *i.e.*, the Psilopsida, the Lycopsida and (?) the Sphenopsida, even in such early geological times seems to suggest that they had evolved probably *along parallel lines from distinct ancestral stocks of higher Thallophytes or some form of "vascularised thallus"* about which we can make very little surmises at present. The Pteridospermæ of the group Pteropsida probably originated from the Psilopsidan stock very early in the Lower Cambrian, if not in the late Pre-Cambrian.

It is not quite certain whether or not the two lines of the main radiations in the Cormophyta, namely, the Stachyosporous (the Psilopsida, the Lycopsida and the Sphenopsida) and the Phyllosporous (the Pteridospermæ in part) groups were differentiated as early as the Lower Cambrian; for, at present, we are ignorant of the Pteridospermous spores obtained by us from the Lower Cambrian belong to Stachyosporous or Phyllosporous plants. The advanced groups

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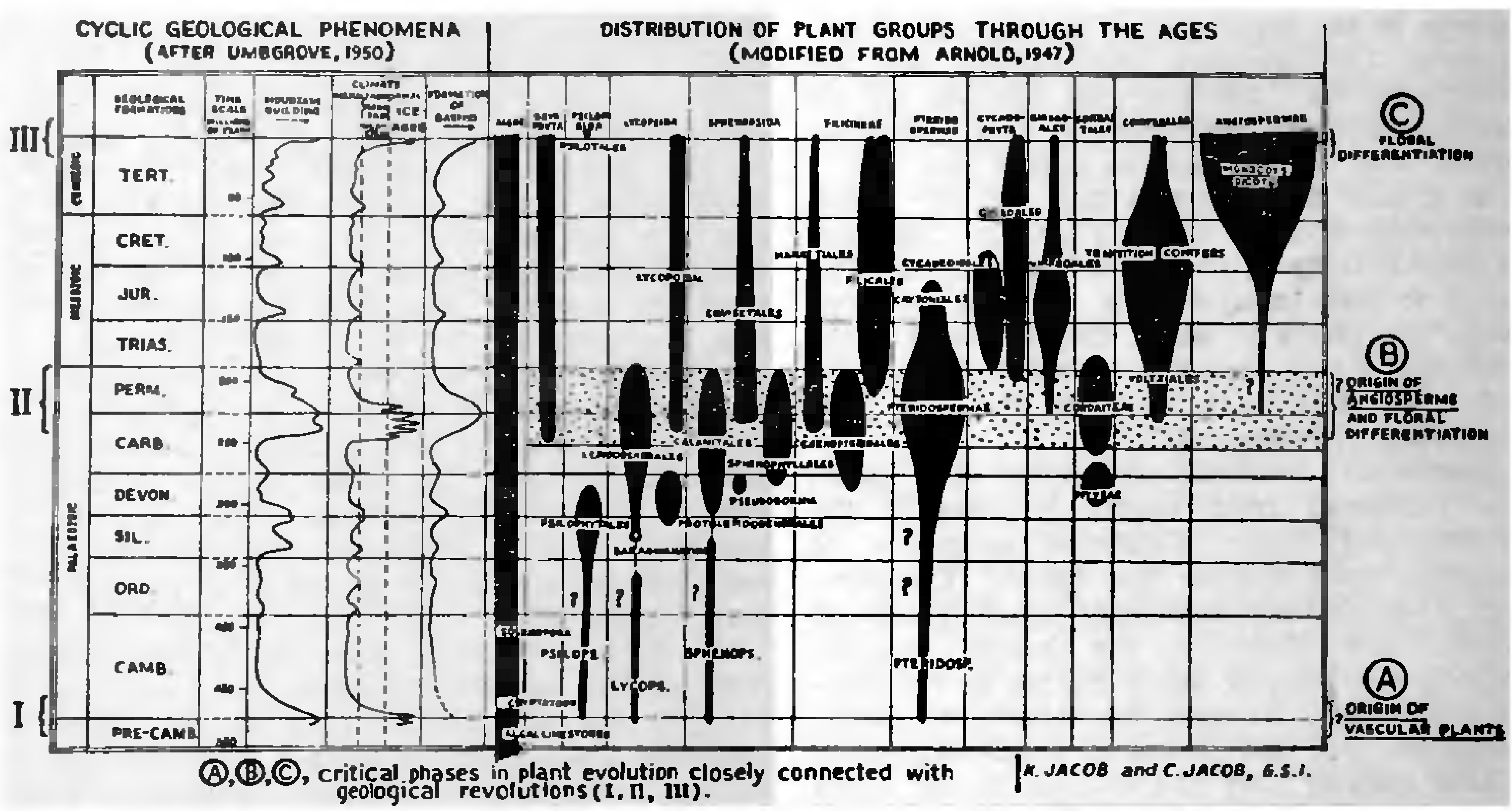
of vascular plants of the Pteropsida (the Filicinæ, the higher Gymnospermæ and the Angiospermæ) were probably derived in later geological periods from the major primitive groups mentioned above.

Elsewhere,[3] while discussing the origin of the Angiosperms, we put forward the tentative suggestion that the rigours of the *late Carboniferous glaciation* of the Southern Hemisphere and the other marked changes in environmental conditions brought about by the accompanying geological convulsions might have induced certain of the advanced Gymnosperms or Pteridosperms to protect their seeds more efficiently, thus giving rise to the first Angiosperms probably along more than one line of development. It may not be very unlikely that the first vascular plants too came into existence as a direct consequence of the extreme climatic conditions

In the left half of the accompanying Chart, the rhythmic geological phenomena are graphically represented (after Umbgrove[4]) and in the right half is shown the distribution of the plant groups in geological time (modified from Arnold[5]). From the Chart, the origin of the early land plants is apparently closely related to the geological revolutions of the late Pre-Cambrian (I, A, in Chart). Later in the late Palæozoic, by which time several major groups of plants had been well differentiated, a very critical period in the history of the plant kingdom is remarkably exemplified in the Permo-Carboniferous (approximately between 212 and 250 million years), when the next cycle of major geological convulsions took place (II, B, in Chart). During this critical phase (stipled portion in Chart) certain large and established groups of plants were wiped out while others



GRAPHIC REPRESENTATION OF CYCLIC GEOLOGICAL PHENOMENA & THEIR INFLUENCE ON PLANT EVOLUTION THROUGH THE AGES

of the late *Pre-Cambrian glaciation* when, as in the late Carboniferous, the apparently cyclic processes of mountain-building, basin formation, regression of sea-level, magnetic extrusion (bringing about changes in CO_2 available in the atmosphere), etc., were pronounced geological phenomena which too probably helped to accelerate evolutionary tendencies in organisms existing during that time (see in Chart I, A; II, B). Some of these phenomena were probably closely connected with the amount of solar energy reaching the earth,

came into existence. The origin of the Angiosperms or the flowering plants was also probably connected very closely with the major revolution of this period[3] (II, B, in Chart). Thus the two most vital steps in the evolutionary history of the plant kingdom, namely, first the advent of the vascular land plants (A, in Chart), and later of the flowering plants or Angiosperms (B, in Chart), may perhaps be considered to be the direct responses of the two major geological revolutions of the late Pre-Cambrian (I, in Chart) and the Permo-Carboniferous (II, in

Chart) respectively, on the adaptive processes of the plant organisms. The Voltziales and other transition Conifers, the Ginkgoales, the Cycadales, the Bennettitales and the true ferns may be said to have evolved during the critical phase in the Permo-Carboniferous while the Lepidodendrales, the Calamariales, the Sphenophyllales and the Cœnopteridales faded out completely (II, B, in Chart).

The third major revolution (III, in Chart) which was initiated in the Pleistocene was mainly responsible in breaking up the more generalised floras into the complex pattern of plant association which exists to-day (III, C, in Chart). It was then that the second peak of floral differentiation (botanical provinces) took place, the first having occurred in the Permo-Carboniferous.[7] But it should be noted that the Pleistocene revolution which may be considered to be still in progress, "began far too recently for us to observe more than the beginnings of its effects on plant evolution".[6] Thus, except during these three phases of major geological revolutions (late Pre-Cambrian, Permo-Carboniferous and Pleistocene), evolution in the plant kingdom may be said to have progressed slowly during the intervening periods creating no spectacular changes probably because the hereditary characters of the germ cells remained comparatively stable in the absence of any markedly violent environmental changes like extensive glaciation, large-scale mountain-building, regression of sea-level, etc. Such physical factors might have generally determined the basic patterns along which the plant kingdom developed through the ages.

It is indeed a fascinating suggestion put forward by Umbgrove[4,7] that the more or less equal intervals of about 250 million years between each of the three major revolutions and the accompanying spurt in plant evolution, probably represent the time required for a full rotation of our galactic system! It is becoming increasingly apparent that in order to make as complete an appreciation as possible of the factors that influenced organic evolution we shall have to look beyond the confines of the earth

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"JET STREAM" UNDER STUDY

STUDIES recently completed by Dr. Vincent J. Schaefer, of the General Electric Company, U.S.A., show that winds in the "jet stream" blow at speeds ranging from 80 to more than 200 miles an hour at altitudes of 20,000' to 50,000'. These winds often double the speed of high-flying aircraft. It is found that the "jet stream" shifts about over the northern hemisphere as the seasons change. It moves often from south-west to north-east, but occasionally veers to the west, north-west or north. Sometimes two or more streams may be identified. In summer, the speed of the winds in the stream decreases to about half of the tremendous winter-time speeds.

Other indications of the proximity of the major axis of the stream include gusty winds at the ground level; persistent cool, crisp air; generally blue skies with visibility unlimited, and rapid changes in the amount of sky covered by clouds. When the "jet stream" is nearby, the coverage of the sky by clouds often changes from one-tenth of the sky to nine-tenths and back again in less than an hour.

Scientists believe that this air corridor may be responsible for many unusual weather conditions for which there has previously not been any adequate explanation. Thus, for example, the stream can quickly carry extremely cold air from the north to warm southern areas and can convey tropical air masses to the north in the space of a few hours Many floods, droughts and persistent hot and cold spells are also attributed to its influence.

In the past there has been no way to locate the "jet stream" quickly in order to warn aircraft or to study its probable effects on the weather. Dr. Schaefer's studies have now shown that its location and the direction of its winds could be determined by carefully co-ordinated observation of cloud formations by weather stations located in different parts of a country.

Four "specific and rather spectacular" cloud types are visual indicators of the location of the high-speed wind stream. There are cirrus streamers, high cirro-cumulus clouds, alto-clouds and billowing alto-cumulus clouds that often extend from horizon to horizon, with parallel waves running at right angles to the direction of the air flow.