Late Permian plants including Charophytes from the Khuff Formation of Saudi Arabia

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Synopsis

A fossil flora of probable Late Permian age is reported from the Khuff Formation of central Saudi Arabia. The coniferous element is of typical European, Zechstein composition, whilst other elements provide hitherto unrecognized similarities between Permian floras of the western and eastern hemispheres. Stems and reproductive structures of a charophyte – *Palaeonitella tarafiyensis* sp. nov. – represent an unusually complete occurrence of this group in the Permian.

Introduction

The discovery of Permian plants in the clastic facies of the Lower Khuff Formation (El-Khayal, Chaloner & Hill 1980, Lemoigne 1981*a, b*) has stimulated further search of Khuff beds exposures by A. A. El-Khayal. The Lower Khuff has continued to yield a diverse flora which will be further described elsewhere. The present note reports for the first time a markedly different plant assemblage, from the Middle Khuff beds, and one which indicates a later Permian age than the Lower Khuff flora.

The plant remains were collected from a clay quarry 15 km NNE of Buraydah, the capital city of Qasim province, at the base of the escarpment named Jāl al Watāh on the road from Buraydah to Al Tarafīyah (Fig. 1). Exposures in the quarry are approximately at the base of the Khartam escarpment, in the Midhnab Shales which outcrop near the top of the Middle Khuff beds as described by Powers *et al.* (1966: D31). The rock matrix is a deeply weathered grey-brown claystone. Plant megafossils occur sparsely; they are limonitized and lack cuticles, but show some cellular detail of internal structure. Our descriptions are brief, because both the diversity and quality of preservation of the assemblage are limited.

Systematic descriptions

Division **TRACHEOPHYTA**

The tracheophytes in the present assemblage range from more or less fragmentary foliar remains (Figs 2–4, 11), the majority indeterminable, to relatively well preserved coniferous shoots and cones (Figs 5–8). The indeterminable pinna shown in Fig. 2 is of generalized cycadalean aspect whilst the scale-like foliar organ of Fig. 3 may be pteridospermous. Two specimens of such scales are known, one apparently trilobed and with coarse venation diverging from the assumed base of the scale. At intervals the veins dichotomize and anastomose. At the centre in both specimens there is a more or less well developed scar, suggesting attachment of some other organ, possibly an ovule or reproductive branch. In view of its incomplete preservation we refrain from naming this organ formally, other than as

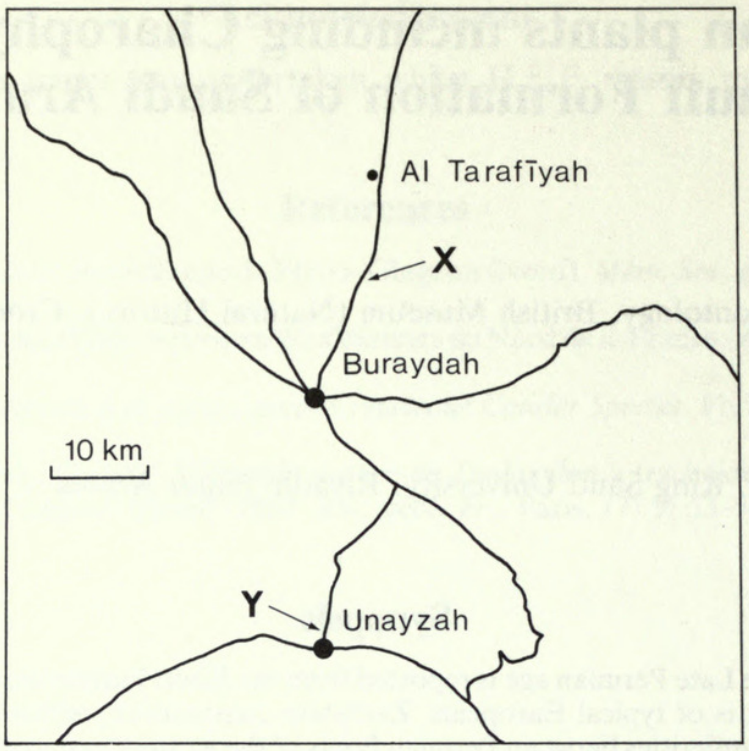


Fig. 1 Road map of Buraydah region showing location of present outcrop at X and of site reported by El-Khayal *et al.* (1980) at Y.

'Problematicum A', in the hope that determined search may yield better specimens. Clearly it is of considerable interest as it displays some hints of glossopterid affinity.

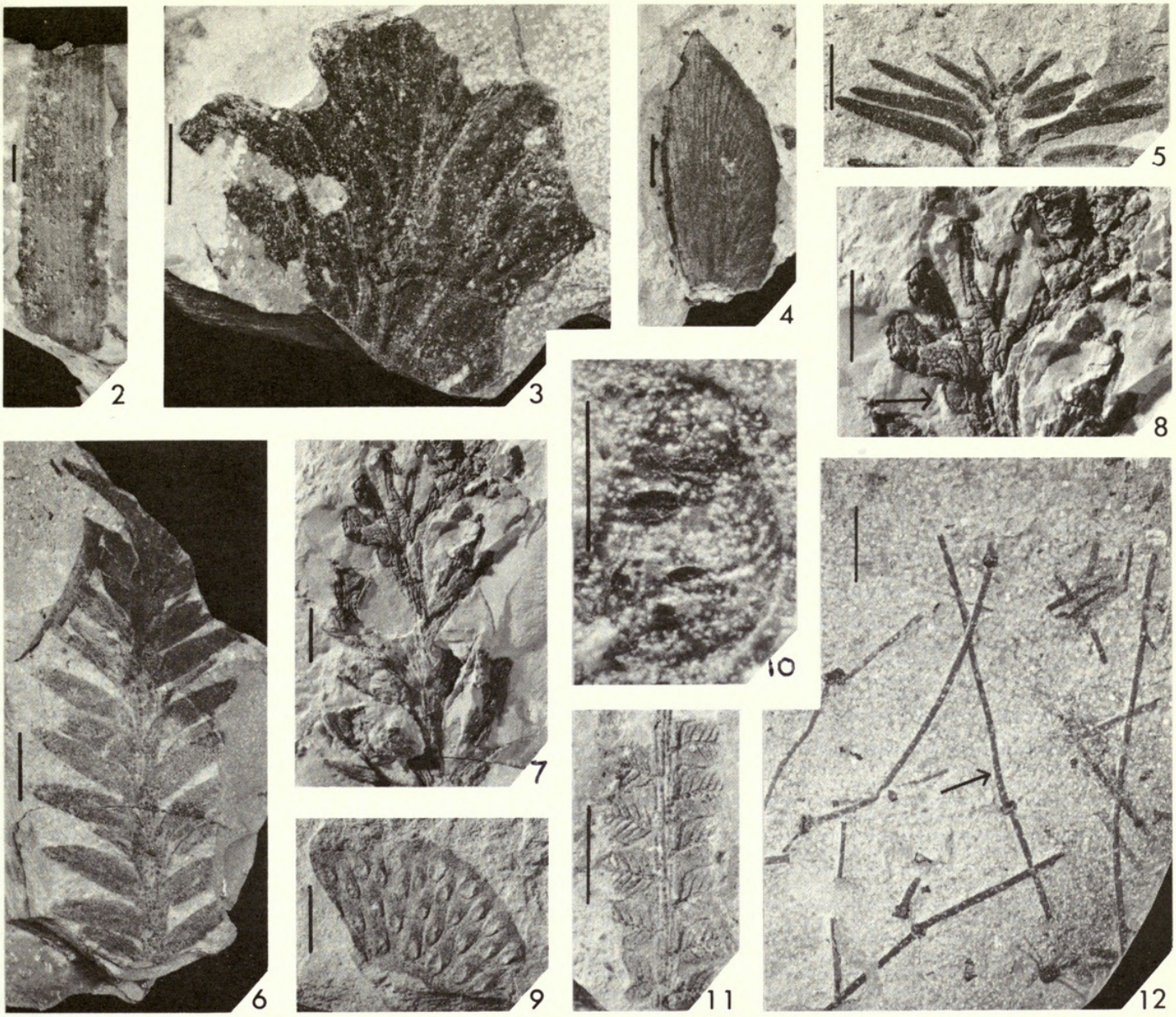
The leaf pinna of Fig. 4, although also of obscure botanical affinity, may be securely named as *Wattia texana* Mamay (1967), originally described from the Early Permian of North America. *Wattia* is possibly of noeggerathialean affinity. Similar fossils occur in the Russian Permian.

These botanically rather obscure remains are associated with well-preserved coniferous leafy shoots that make up about half of the specimens collected. Shoots with relatively long, narrow leaves (Fig. 5) are determined as *Pseudovoltzia* Florin, and those with broad leaves (Fig. 6) as *Culmitzschia* Ullrich, both characteristic of the Late Permian Zechstein floras of Europe (Florin 1963, Schweitzer 1968). A well-preserved female cone (Fig. 7) is also referred to *Pseudovoltzia*. Fig. 8 illustrates the deeply divided cone scale with five fingerlike lobes and a seed (arrowed), as in comparably preserved European material of *Pseudovoltzia liebeana* (Geinitz) Florin (Schweitzer 1963, 1968). We refer the Saudi material to the same species. In view of its limited preservation, however, we cannot entirely rule out similarities with female cones of allied conifers such as *Voltzia* Brongniart and *Glyptolepis* Schimper, which range into the Mesozoic.

Three specimens (Fig. 9) resemble Halle's (1927) 'Problematicum', reported from the Permian of China, though the Saudi material has a more pronounced distal taper to the scars considered to represent points of attachment of sporangia. Halle's material is now known to represent small fragments of detached scales from the possibly noeggerathialean cone *Discinites orientalis* Li *et al.*, *in* 'Gu & Zhi'[1] (1974), which Li & Yao (1980) assign to an Early Permian age. Despite differences from Halle's specimens the Arabian ones fall well within the range of form of *D. orientalis* as figured by 'Gu & Zhi' and are identified with it. *Discinites* is reported also from the Early Permian of North America (Mamay 1954) and species occur widely but sparsely in the Euramerian Carboniferous (Boureau 1964).

Two fragmentary specimens of *Pecopteris* (Fig. 11) were collected, showing evidence of basal fusion of the pinnules and with a simple venation of a kind common in Stephanian and Permian

[1] 'Gu & Zhi' represents the contracted and latinized name of an editorial committee called 'Zhongguo *Gu*shengdai *Zhi*wu' (literally, 'Chinese Palaeozoic Plants'), and has been used as an author citation by the Chinese ('Gu & Zhi' 1974: 1). The actual authors, who appear to be the members of the committee ('Gu & Zhi' 1974: 2) are Li Xingxue, Deng Longhua, Zhou Zhiyan, Xu Ren & Zhu Jiagou. If so the full citation given here is redundant and might well be reduced to Li *et al.* alone, bearing in mind however that the authors' names do not appear on the title page of the work.



Figs 2–12 Plant fossils from the Middle Khuff beds, 15 km NNE of Buraydah, Permian of central Saudi Arabia. Scale bars each represent 5·0 mm except for Fig. 10 where the bar represents 0·5 mm. Fig. 2, indeterminable pinna. Fig. 3, Problematicum A. Fig. 4, *Wattia texana* Mamay. Fig. 5, *Pseudovoltzia liebeana* (Gienitz) Florin, foliage. Fig. 6, *Culmitzschia* sp. Figs 7, 8, *Pseudovoltzia liebeana* (Geinitz) Florin: Fig. 7, female cone; Fig. 8, female cone scale at higher magnification, with ovule arrowed. Fig. 9, *Discinites orientalis* Li *et al. in* 'Gu & Zhi'. Figs 10, 12, *Palaeonitella tarafiyensis* sp. nov.: Fig. 10, oosporangium (scale bar 0·5 mm), see also Fig. 13; Fig. 12, stems with **holotype** stem arrowed, BM(NH) Palaeontology Dept. no. V.60935. Fig. 11, *Pecopteris* sp. indet. All specimens except those of Figs 10, 12, are in the Geology Department, King Saud University, Riyadh.

pecopterids. In the absence of pinna terminals and of larger fragments indicating the range of variation within the frond, we do not attempt specific identification.

All the tracheophyte specimens are housed in the Geology Department, King Saud University, Riyadh.

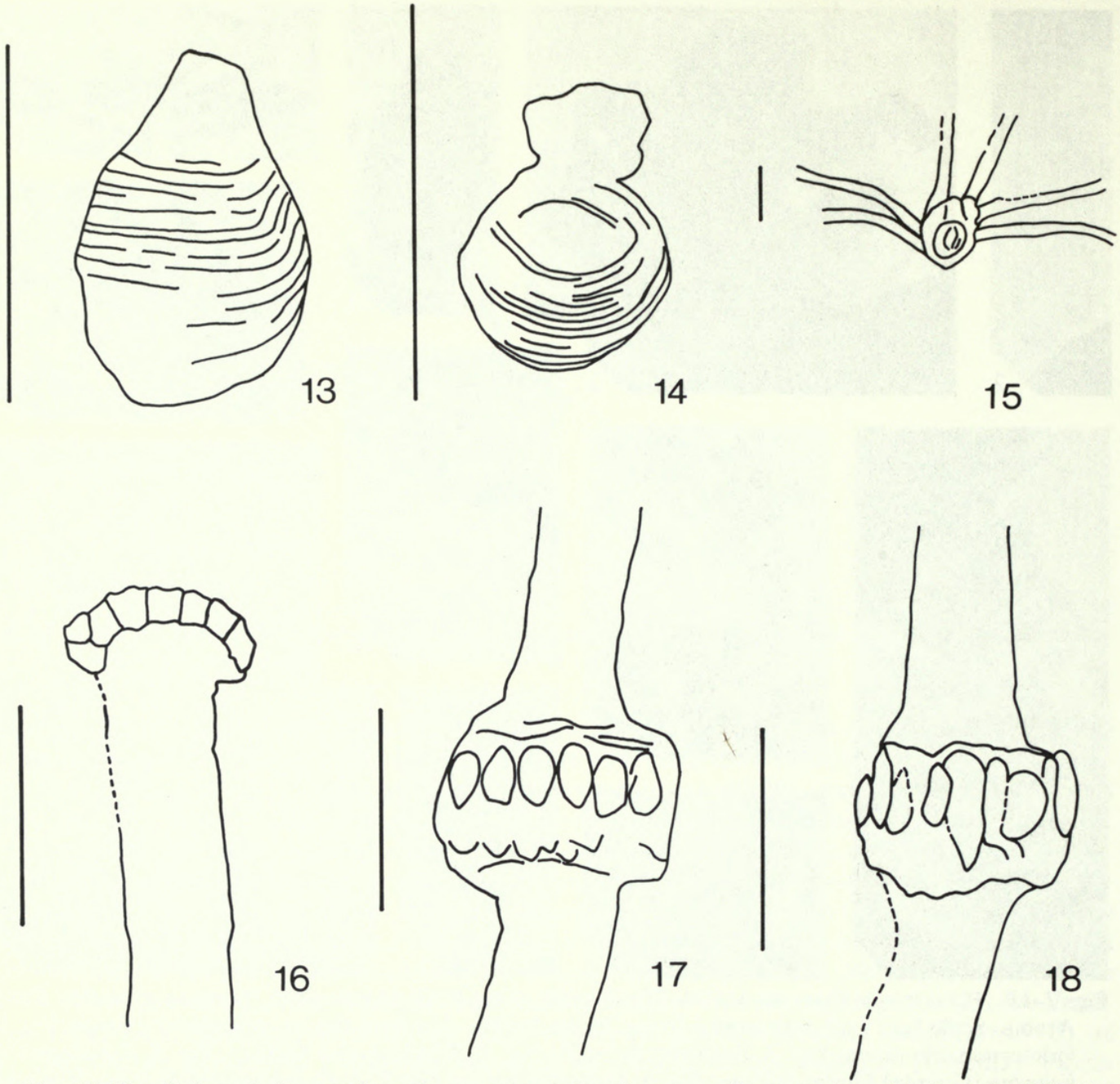
Plesion **CHAROPHYTA**

Genus ***PALAEONITELLA*** Pia *in* Hirmer, 1927

Palaeonitella tarafiyensis sp. nov.

Figs 10, 12–18

DESCRIPTION. Stems (broken during fossilization) exceeding 27 mm in length, internodes smooth and without preserved cortical cells, up to 0·7 mm wide; nodes occurring at intervals of



Figs 13–18 *Palaeonitella tarafiyensis* sp. nov., drawings on photographs. All from BM(NH) Palaeontology Dept. no. V.60935, scale bars each representing 1·0 mm. Figs 13, 14, oosporangia, Fig. 13 shown also in Fig. 10. Fig. 15, node compressed in plane of the whorl, showing six branches. Figs 16–18, portions of stem compressed laterally, showing nodes with basal scars of branches.

1–25 mm or more, swollen to about twice the width of the internodes. Nodes bearing a single ring of branches. (Branches seen when compressed in the plane of the whorl as in Fig. 15, whilst in denuded stems compressed sideways their points of attachment are represented by a ring of elliptical basal scars as in Figs 16–18). Obscure indications of additional cells or possibly stipulodes occur above or below the branch scars (Fig. 17). Branches 12–16 per node (count based mainly on numbers of basal scars). Reproductive structures (oosporangia) in intimate association but not seen definitely attached to stems, urn shaped, 1·0 mm long × 0·5 mm wide at broadest point, striated helically in sinistral direction, about 15–20 such stria per oosporangium; actual number of coiled cells unknown (Figs 10, 13, 14). (Superficially the coiling of striae looks dextral, since the surface visible is a mould of the oosporangium).

HOLOTYPE. V.60935; specimen arrowed in Fig. 12 and portion shown also in Fig. 17.

MATERIAL. Several fragments, as shown in Fig. 12, all on one block only and apparently limited to one bedding plane.

LOCALITY AND HORIZON. As indicated in the Introduction, p. 105.

DIAGNOSIS. Differs from the only other species of the genus, *P. cranii* (Kidston & Lang) Pia *in* Hirmer, in its wider stems and in having branches that apparently lack septae.

PRESERVATION. The botanical as opposed to stratigraphic and palaeobiogeographic interest of the Middle Khuff flora is considerably enhanced by these charophytes. The material represents an early and exceptionally complete occurrence of plants of this group, which elsewhere is known as fossils almost solely from reproductive structures. There are notably few records from the Permian (Peck & Eyer 1963).

In the Saudi material vegetative remains occur closely association with reproductive organs. Their mode of preservation as impression fossils yields considerably less detailed information than is available from the usual preservation of charophytes as petrifactions. However, the preservation is sufficiently detailed to indicate that the Saudi stems were ecorticate, resembling those described by Kidston & Lang (1921) from the Devonian and by Ishchenko & Saidakovsky (1975) from the Silurian.

NOMENCLATURE. Since assignment of the Saudi specimens to a family is problematic we use a form genus. The name *Palaeonitella* was applied by Kidston & Lang (1921) to vegetative remains from the Rhynie Chert, some at least of which clearly resemble those of charophytes but with no oosporangia. The internodes are ecorticate. Unfortunately Kidston & Lang applied the name so informally that it cannot be attributed to them – they named their material *Algites (Palaeonitella) cranii* – and the name was only validated by Pia *in* Hirmer (1927). Horn af Rantzien (1956) discusses the nomenclatural details, with which we agree fully, though we believe the citation for the generic name should be in the form given here rather than as *Palaeonitella* (Kidston & Lang) Pia. This citation more properly belongs to the species name *Palaeonitella cranii*.

Although the attribution of Kidston & Lang's material to the Charophyta is open to some doubt in the absence of reproductive organs (Groves 1933), the name *Palaeonitella* is used here in order to limit gratuitous inflation of names (see Harris, 1962–3). We use it for any uncorticated stems resembling those of Charophyta and of which the oosporangia may be known – as in *P. tarafiyensis* – or may not be known – as in *P. cranii* – but of which the oosporangia even when known do not permit narrower determination than to the Charophyta as a whole. (*Charaxis* Harris is available for corticate stems). We note in passing that only the largest specimens of *P. cranii* fall within the range of stem width represented by the slenderest species of extant *Nitella*, whereas *P. tarafiyensis* is typical of the majority of extant species.

Such limited detail of the oosporangia as is preserved in *P. tarafiyensis* neither refutes nor supports assignment to the Porocharaceae, which would be the predicted familial determination based on the age of the material (Grambast 1974). Further specimens are needed.

PALAEOECOLOGY. These Permian stems are remarkably like stems of living species in size and known morphology, resembling ecorticate species of extant *Chara, Nitella* and *Tolypella*. Charophyta are of considerable palaeoecological interest since all living species are limited to fresh or brackish water environments, though some earlier Palaeozoic representatives are believed to have been shallow-marine (Racki 1982). Notably in this present fossil flora the charophyte remains are associated with fresh-water bivalves, suggesting a fresh-water – perhaps lacustrine – environment of deposition; presumably they were not transported far from their place of growth whereas other species in the flora are clearly drifted. There is no evidence to suggest *P. tarafiyensis* was lime-encrusted in life, in contrast to most described fossil charophytes and to many living species. The Middle Khuff matrix is in fact gypsiferous and lacks calcium carbonate.

Discussion

FLORISTIC AFFINITIES. The affinities of the assemblage as a whole are no less intriguing than those of the Lower Khuff flora (El-Khayal *et al.* 1980). In that flora, *Pecopteris, Fascipteris, Lobatannularia, Cordaites* and *Marattiopsis* are conspicuous elements whilst conifers are

lacking. The Middle Khuff flora is in stark contrast: out of the genera just mentioned only *Pecopteris* occurs, and that inconspicuously, whereas the strong coniferous element (*Pseudovoltzia, Culmitzschia*) is in marked contrast to the earlier assemblage. Such sharp differences in plant assemblages having rather slight age differences are unusual and surely signify a strong degree of environmental control, either ecologically or sedimentologically or both.

Almost all the Middle Khuff species are unknown in floras of roughly comparable age from the Middle East but closely resemble those found in floras from far distant localities, mainly in the northern hemisphere Permian. The only hint of Gondwana affinities is provided by the scale-like foliar organ Problematicum A (p. 106), though that in itself – if its glossopterid affinities were substantiated – would be of great interest. *Wattia* is described from the Early Permian of Texas, U.S.A., *Discinites* ranges into the Early Permian of China, Korea and North America, but *Pseudovoltzia* and *Culmitzschia* are characteristic of the European Late Permian (Florin 1963). Clearly this flora fills a gap between the Permian floras of the Euramerian and Cathaysian areas of Chaloner & Meyen (1973) and thus represents a mixed flora. Lemoigne (1981*a*, *b*) argues similarly for the Lower Khuff flora reported briefly by El-Khayal *et al.* (1980). Lemoigne's perceptions of a strong Cathaysian element in that flora, extending vigorously along the shores of Tethys, rest however largely on the validity of his determinations and interpretations. We hope the further studies now in progress by Wagner & El-Khayal may resolve taxonomic problems raised by El-Khayal *et al.* (1980) and by Lemoigne's 1981*b*.

Stratigraphy. That the Middle Khuff assemblage reported here is younger than the Lower Khuff flora is certain from the field relations. If the strong coniferous element is emphasized at the expense of other taxa, the plant megafossils suggest a probable Late Permian age. Nevertheless, in such strictly palaeobotanic terms, exact age assignment may be regarded as problematic for a number of reasons. Firstly, the floras of the Arabian peninsula, as at Hazro in Turkey, are regionally unique. They fill gaps and thus obscure formerly clearly perceived boundaries between floral provinces, yet have a character of their own. Secondly, Permian floras worldwide are rather poorly known. Whilst they therefore represent a challenging and stimulating research topic, in which a great deal is still to be learnt, stratigraphic ranges of Permian megafossil plants are as yet poorly documented. The literature, too, is scattered. Thus, if the present floras in Saudi Arabia are in fact both Late Permian, they considerably extend the ranges of *Wattia* and *Discinites* whilst the ranges of *Marattiopsis, Pseudovoltzia* and other species remain as previously understood by Florin (1963), Burago (1977) and others. For these reasons the initial report by El-Khayal *et al.* (1980) on the Lower Khuff flora cautiously suggested a rather broad age range: from not older than Westphalian (Upper Carboniferous) to not younger than Early Permian, rather than a more precise age assignment. Others, notably Lemoigne (1981*a*, *b*) have felt able to provide a more detailed age range based on the palaeobotanical evidence, attributing a degree of precision to palaeobotanical dating which in our view may be premature for such limited floras in a Permian context. It also takes little account of a third limitation, the likely environmental as opposed to stratigraphic control over such marked changes as occur between the Lower and Middle Khuff floras. Nonetheless, by the same argument, we do not consider Lemoigne's specifically Late Permian age assignment for the Lower Khuff flora unreasonable. If pressed to give a narrower age range for the flora, however, we now tentatively favour an early Late Permian age for the Lower Khuff flora, based entirely on the plant data.

The evidently somewhat vexed question of the age of the Lower Khuff flora has been further discussed recently by Sharief (1982*a*, *b*) and Ibrahim (1982). In view of the limitations of palaeobotanic data when considered in isolation, referred to above, we believe Ibrahim overemphasizes the botanically-based age assignment of El-Khayal *et al.* (1980). Moreover, Popper (1959), Lakatos (1970) and others have stressed the importance of using independent lines of evidence to test and thus critically to evaluate scientific hypotheses. As Sharief (1982*b*) rightly points out, independent evidence is available from palynology – though regrettably unpublished ('Aramco' 1975). A Late Permian age is also indicated by the calcareous algae

(Rezak 1959). Such evidence, whilst not in itself necessarily superior to megafossil palaeobotanic evidence, uniformly suggests a Late Permian age for the Khuff Formation. Present evidence, therefore, all seems to favour a Late Permian age for both the Lower and Middle Khuff floras.

To clarify the stratigraphic nomenclature used in this discussion we should emphasize that usage of the term 'Khuff Formation' follows that of Powers *et al.* (1966), in including the Unayzah plant bed within the Lower Khuff. El-Khayal & Wagner (in preparation) argue that the Unayzah beds should be separated off from the Khuff as a separate Formation.

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