Occurrence of a characteristic Wealden fern (*Weichselia reticulata*) in the Wasia Formation, central Saudi Arabia

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More than fifty fragments of vegetative pinnae and pinnules of *Weichselia reticulata* are reported from a clay quarry in the Wasia Formation (Cenomamian and Turonian? age).

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Introduction

Stratigraphic details of the Wasia Formation in the central area of Saudi Arabia were first published by Steineke et al. (1985). Wasia beds typically weather to an upward-steepening slope that terminates in an almost sheerface beneath the scarp-forming limestone of the Aruma Formation. Power et al. (1966) mentioned that a lenticular bed of red sandy dolomite occurs in the vicinity of Wasia. A local lens of soft nodular limestone contains an ammonite, *Neolobites vibrayeanus* d'Orbigny, which is known from many localities around the Mediterranean and which is a fair index for the upper Cenomanian. Fossil wood present as ferruginous molds in the top 19.2 m of the type section are the only plant remains ever recorded from the Wasia Formation (Powers et al., 1966, p. D142).

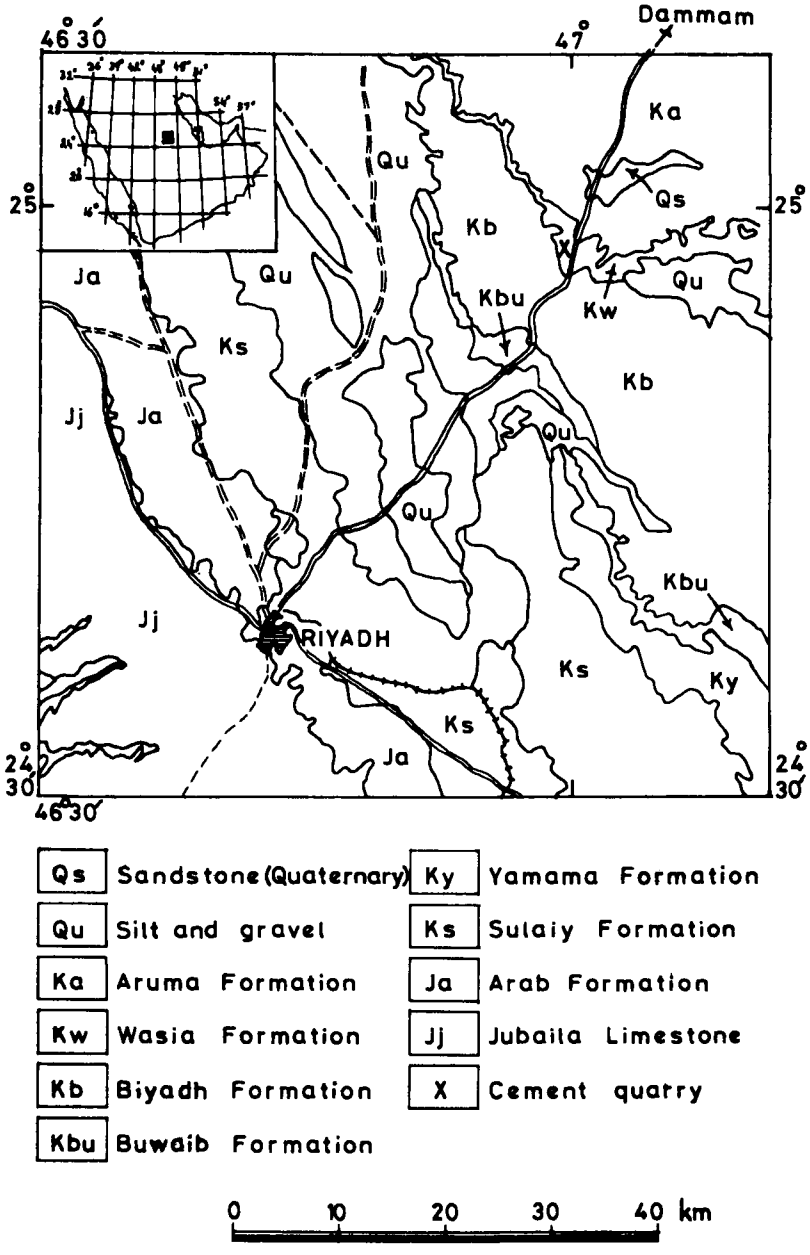

Fig. 1. Geologic map of Riyadh and surrounding areas showing the location of the clay quarry of the Yammama Cement Co. (modified from Bramkamp & Ramirez, 1958).

The Wasia Formation is 42 m thick and is composed of sandstones and pale-grey to yellow claystones with occasional siltstone intercalations. Thin brown to black ironstone partings are common. The claystones exhibit sometimes red and purple colours. The pale-yellow claystones contain numerous fragments of *Weichselia reticulata*, which show a clear and characteristic reticulate venation. These fragments comprise either isolate

pinnules or pinnules attached to a slender (secondary pinna) rachis. Pinnules show a range of variation. Naked rachides and some striated plant remains, which may represent large rachides of *Weichselia*, also exist. The plant imprints are stained with haematite and no cuticle is preserved. Other plant remains are present at a higher level but will be dealt with in a later paper. The claystones also contain unidentified bivalves and one small gastropod.

The material has been collected from the upper Wasia beds, 10.5 m below the vuggy limestone of the basal Aruma Formation (Coniacian-Maestichtian), in a clay quarry of the Yammama Cement Factory, 65 km from Riyadh on the road to Dammam (Fig. 1). It is now partly stored in the palaeontological collections of the King Saud University, at Riyadh, duplicate material being housed in the Rijksmuseum van Geologie en Mineralogie (National Museum of Geology and Mineralogy) at Leiden, the Netherlands, under the registration numbers RGM 382 427-382 432.

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Stratigraphy

The Cenomanian and Turonian sediments are represented in central Saudi Arabia by a thin persistent unit, the Wasia Formation, which consists mainly of sandstone. Claystone is commonly interbedded and thin dolomite and limestone layers are also present locally. Most of the sandstone is brown, and cross bedded: interbedded claystone and siltstone are variegated: red, purple, yellow, grey, and green. The thickness of these beds is 42 m at the type locality.

Powers et al. (1966) reported the age of the sandstone-claystone sequence as Cenomanian; this was based on rare ammonite finds of *Neolobites vibrayeanus* d'Orbigny, found in outcrop in central Najd where thin limestone lenses occur. The Wasia Formation rests on Barremian and Aptian sandstones named the Biyadh Formation, which is 425 m thick.

The Wasia Formation is everywhere in disconformable contact with the overlying Coniacian Aruma Formation, which consists mainly of limestone (Asa'ad, 1977). The break is clearly marked by a change from sandstone below to reddish brown, coarsely crystalline dolomite and dolomitic limestone above.

The section at the Yammama Cement Factory quarry, 65 km east of Riyadh on the Riyadh-Dammam road is composed of claystones, minor siltstones, and thin sandstone layers at the top (Fig. 2). The complete section (13.29 m) is as follows:

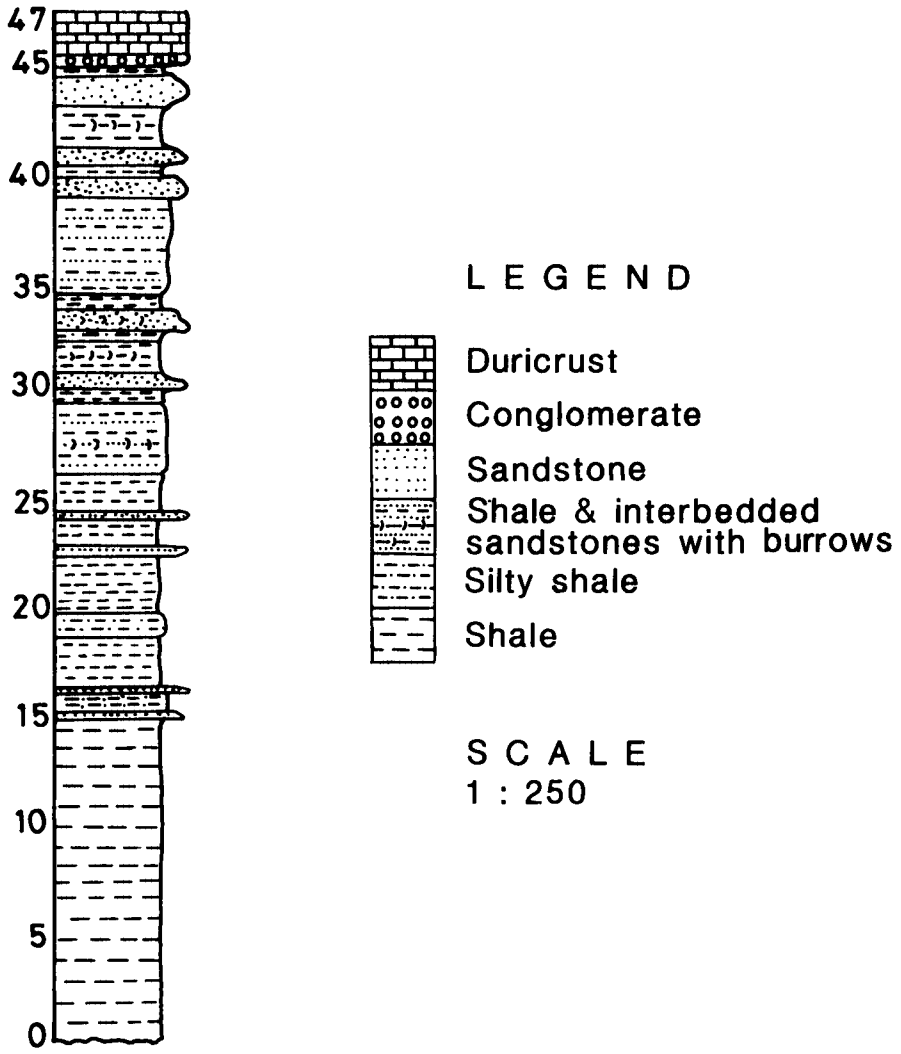


Fig. 2. Stratigraphic section of the clay quarry of the Yammama Cement Co. 65 km on the Riyadh-Dammam road.

Plate 1

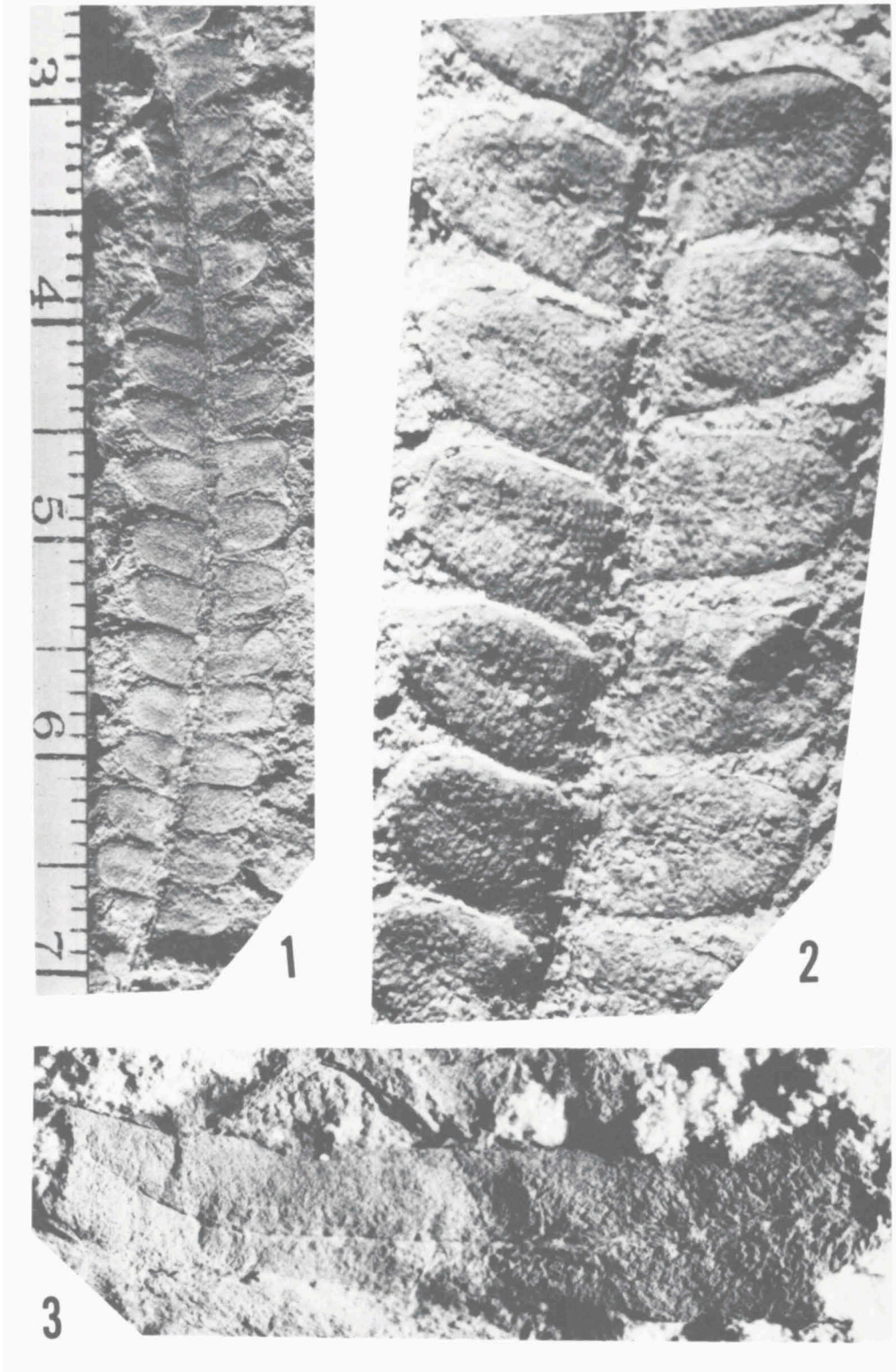
Weichselia reticulata (Stokes & Webb) Fontaine

Fig. 1. Part of a pinna with more than 16 pinnules on each side of pinna rachis; no. KSU (KW 37), × 1.

Fig. 2. Enlargement of a part of fig. 1, × 10.

Fig. 3. Part of a long pinnule showing the reticulate venation on the lower half, no. KSU (KW 39), × 1.

Plate 1



Dolomitic limestone, reddish brown, sandy, vuggy (partly filled with crystalline calcite) (basal Aruma Formation)	1.25 m.
Sandstone, brown to light-brown, fine- to medium-grained ferruginous (top of Wasia Formation)	0.65 m.
Silty claystone, red to purple, abundant ferruginous concretions	1.15 m.
Silty claystone, light-grey, with small iron-oxide concretions	1.20 m.
Grey claystone, partly red to purple	0.30 m.
Claystone, white to light-grey	0.35 m.
Gypsiferous grey clay	0.50 m.
Claystone, red, with ferruginous concretions, many contain calcite crystals	0.10 m.
Silty claystone, white to grey, with small fragments of poorly preserved plant remains	2.00 m.
Claystone, grey, thinly bedded, contains poorly preserved plant remains; thin (0.10 m) layer of iron-oxide concretions is present	0.30 m.
Silty claystone, tan to yellow	0.50 m.
Claystone, red	0.13 m.
Claystone, light-grey 0.30 m.	
Claystone, light-grey to light-yellow,with plant impressions, some red to yellow iron-oxides colouration in place of angiosperm leaves	0.45 m.
Claystone, white to brown, purple, with iron-oxide concretions	0.23 m.
Claystone, brown, laminated with siltstone, with plant remains	0.15 m.
Claystone, grey	0.41 m.
Claystone, brown to red, with iron-oxide concretions	0.07 m.
Claystone, grey	0.45 m.
Claystone, with siltstone forming bands of purple, red, grey and white colours	0.90 m.
Claystone, yellow to dark-yellow	0.25 m.
Claystone, red, with bivalves 0.45 m.	
Claystone, yellow to red, contains bivalves and fragments of *Weichselia reticulata*	0.47 m.
Claystone, grey to red	0.13 m.
Claystone, red and purple	0.10 m.
Claystone, banded with yellow to red colouration, with iron-oxide concretions	0.35 m.
Claystone, yellow	0.15 m.

Systematics

Order Filicales
Family Weichselliaceae Zimmermann
Genus *Weichselia* Stiehler

Weichselia reticulata (Stokes & Webb) Fontaine
Pls 1-4.

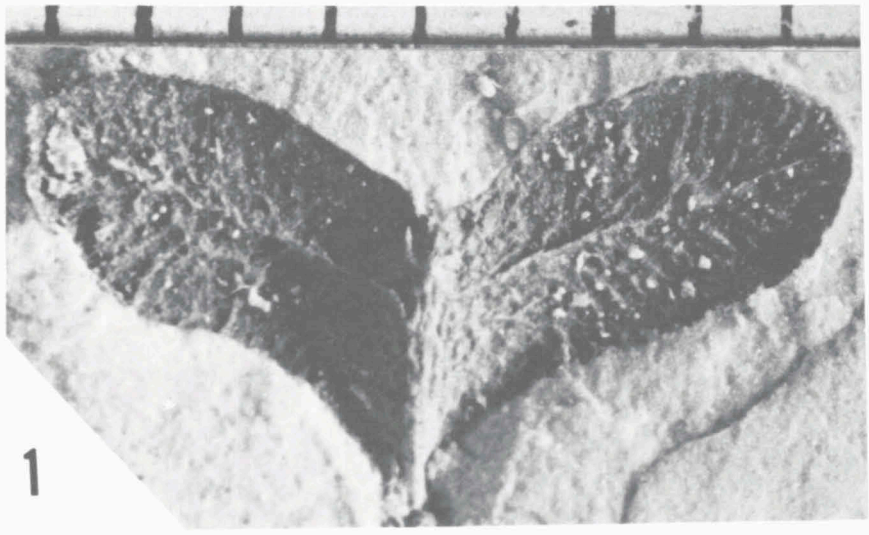
Synonymy — See Seward, 1894; Alvin, 1971.

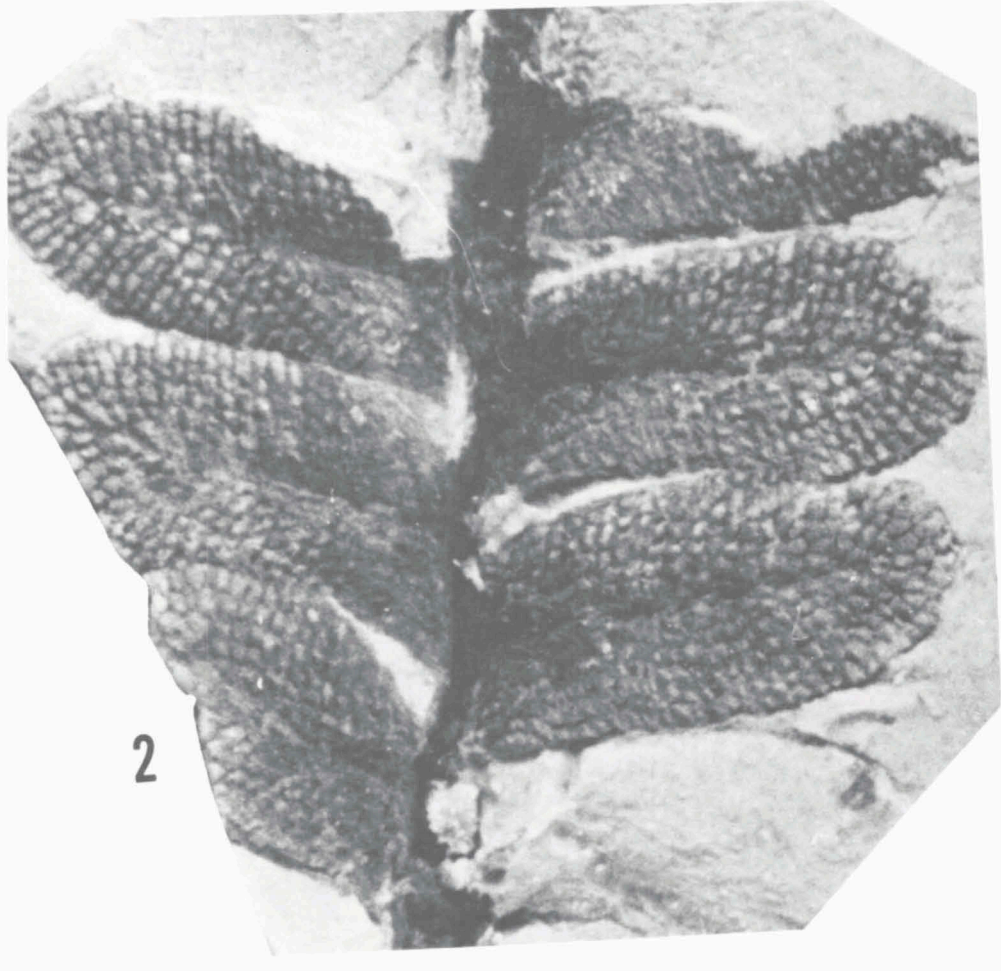
Description — Convex, elliptical, small and rather slender pinnules ranging from 4-13 mm in length and 2-3 mm in width but average is 4-5 mm in length and 2-2.5 mm in width, sometimes slightly falcate, alternately and broadly attached by the full width of the base

Plate 2

Weichselia reticulata (Stokes & Webb) Fontaine
Fig. 1. Fragment of a pinna showing two pinnules in a butterfly position, no. KSU (KW6), × 1.
Fig. 2. Fragment of a pinna, no. KSU (KW 7), × 12.

Plate 2





to a rather prominent, slender rachis, 0.5 mm wide. The midvein of the pinnules stops short of the broadly rounded apex. The reticulate venation, which characterises this species, is preserved on all the pinnules. It has 5-6 vein meshes between midvein and margin. Midrib and veins are more prominent on adaxial convex side. The butterfly position of the pinnules described by many authors is observed in the Saudi material.

Discussion — The Saudi material shows only fragments of pinnae and isolate pinnules, but these fragments show clearly the anastomosing lateral veins.

Weichselia ferns have been studied by Lipps (1923, 1932), Reymanówna (1965), Daber (1968), and Alvin (1968, 1971). Reymanówna (1965) pointed out that (in a Mesozoic context) the indentification of the genus *Weichselia* from fragments poses no problems, as they possess a very characteristic reticulate venation. Therefore, the fragments found in the claystones of the Wasia Formation in Central Saudi Arabia can safely be assigned to the genus *Weichselia*. The rather blunt pinnules are very similar to the type C, as designated by Lipps (1923, p. 344, fig. 2; 1932, p. 249-250, pl. 26, figs. 1a, b) who emphasized the falcate appearance. Reymanówna (1965) and Schuster (1930, p. 63) have indentified this type C as *Weichselia reticulata* (Stokes & Webb, 1824). It is similar to the material illustrated by Alvin (1971, pl. 4). Daber (1968) reconstructed *Weichselia reticulata*, and this reconstruction was emended later by Alvin (1971) based on material from the Wealden of Belgium.

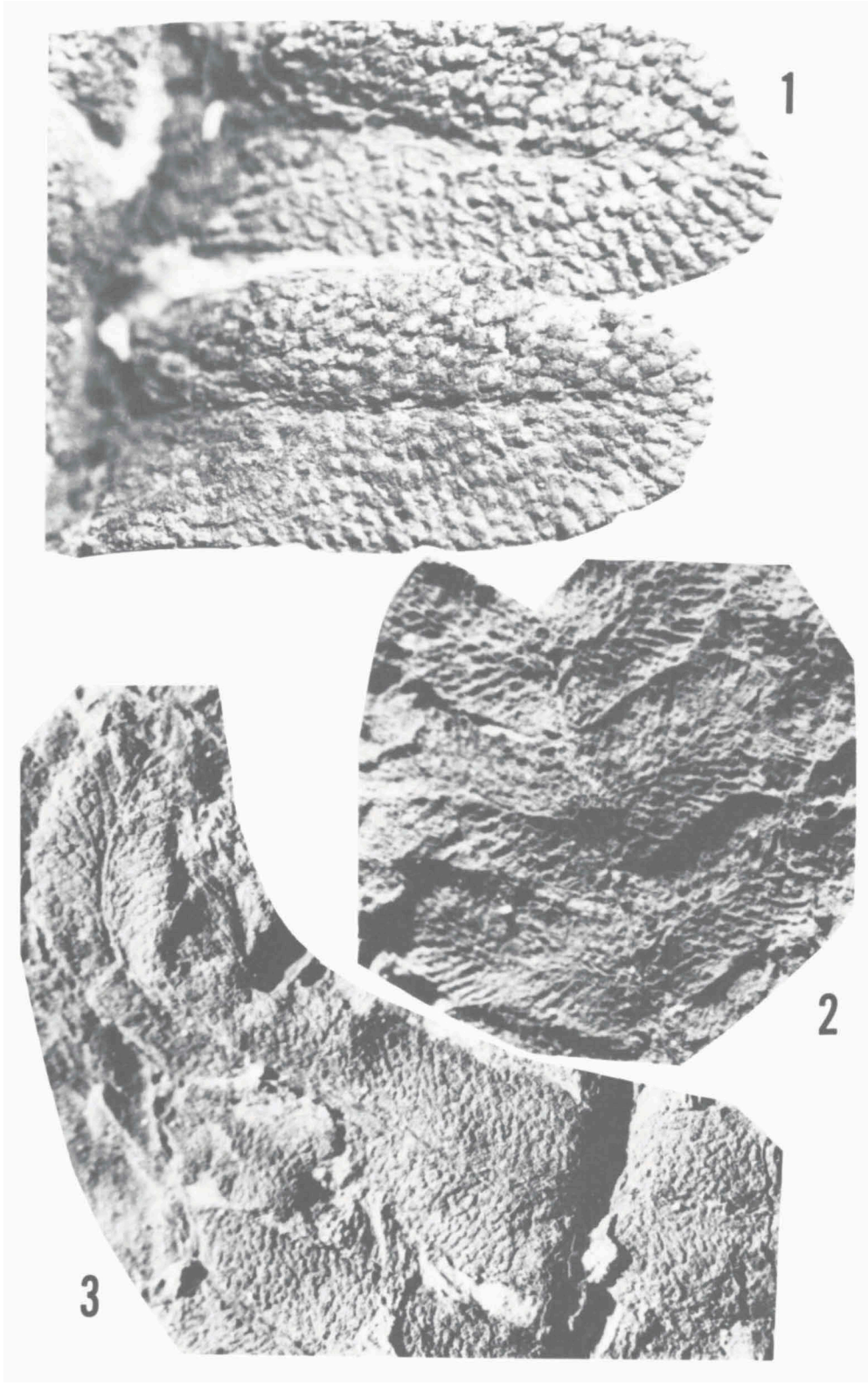
Distribution — *Weichselia reticulata* is a widely distributed fern (Fig. 3) and the discovery of this species in central Saudi Arabia fills a gap in its distribution. It has been recorded from elsewhere in the Middle East from Europe, North Africa, India, Siberia, North, and South America; stratigraphically the range is from Bathonian to Cenomanian (cf. Koeniguer, 1975; Aubry et al., 1982).

In Europe, *Weichselia* was described for the first time from the Wealden of England by Stokes & Webb (1824) and later by Seward (1894). From Quadlinburg in Germany, poorly preserved large fragments of *Weichselia* in a sandy matrix have been reported by Richter (1906, 1909), Gothan (1910, 1923), Mägdefrau (1932), and Daber (1953, 1968). Other places in Europe include Poland (Reymanówna, 1965), showing material similar to that collected from the Wealden of Belgium (Alvin, 1969, 1971), and N. Spain (Barale, 1979). Vakhrameev (1964, p. 209, fig. 33) has summarised the distribution of *Weichselia reticulata* in the Lower Cretaceous of Eurasia. It extends from England and Portugal through western, central and eastern Europe to central Siberia and the Far East (Primorsk kray), Kazakhstan, and Uzbekistan (Vakhrameev, 1964), north central India (Sahni, 1936; Bose & Sukh Dev, 1959). From the Middle East Edwards (1929, 1933) has recorded the presence of a couple of specimens found in light brownish clay from Madayrij (near Hammana about 24 km east of Beirut, Lebanon) and from the Nubian Sandstone (at Wadi Jabbok, Wadi Kenetri and Nahr es Zerka) in Jordan. These plant fossils seem to have been collected from the uppermost part of the lower Cretaceous (according to Bender, 1974, p. 72).

Plate 3

Weichselia reticulata (Stokes & Webb) Fontaine
Fig. 1. Enlargment of two pinnules of a fragment shown on Pl. 2, fig. 2, no. KSU (KW 7), × 17.
Fig. 2. Adaxial side of a secondary pinna, no. KSU (KW 7), × 10.
Fig. 3. Part of a secondary pinna with longer pinnules, no. KSU (KW 30), × 10.

Plate 3



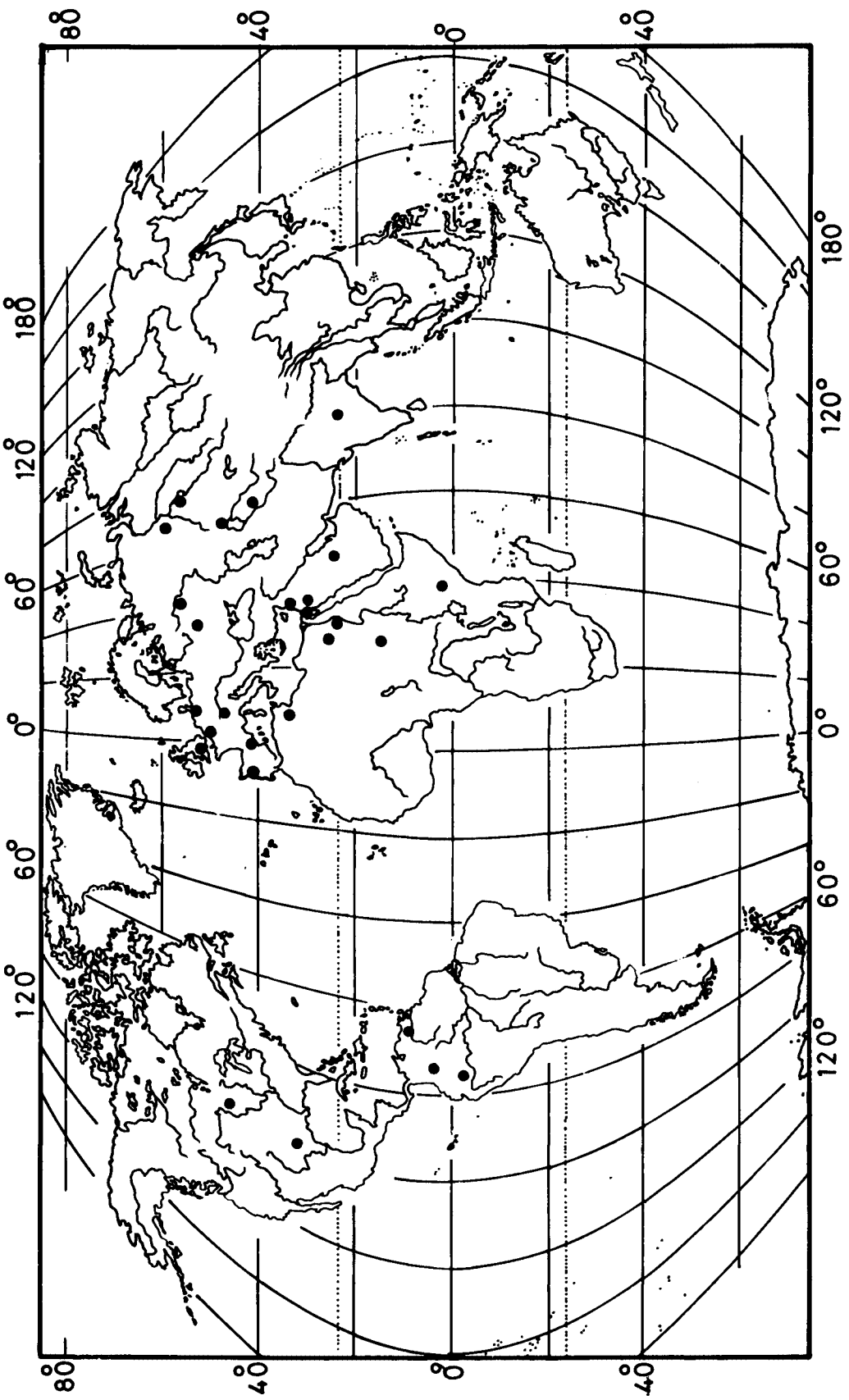


Fig. 3. Distribution of *Weichselia* in the world (modified in part from Vakhrameev, 1964, fig. 33).

In North Africa, Boureau & de Lapparent (1951) reported the presence of petrified axes of *Paradoxopteris stromeri* Hirmer from the Kimmeridgian and Portlandian sediments of southern Tunisia. Recently, Barthel and Boettcher (1978) have reported the presence of a pinna fragment of *Weichselia* from the top of the Abu Ballas Formation (Late Tithonian/Berriasian) in the southwestern desert of Egypt.

Southward from this location, Edwards (1932) reported it from the Nubian Sandstone in Jabal Dirra, Darfur, Western Sudan. Further south, Alvin (1971) recorded the presence of specimens consisting of primary and secondary pinnae with pinnules from Kailta in the Wergudud area of northern Kenya.

In South America, Neumann (1907) and Zeiller (1914) reported it from Peru, Schlagintweit (1919) from Venezuela (without illustration), and Berry (1937) from Colombia.

In North America, it has been reported from Dakota (Fontaine, 1893, in Ward, 1899) and Texas (Berry, 1928; Serlin, 1982). From the above mentioned localities it seems that the zone of distribution was probably a broad tropical to warm temperate belt as suggested by Alvin (1971).

The ecology of *Weichselia* has been discussed by Seward (1900), Gothan (1910), Edwards (1932), and Alvin (1971). It is believed that the plant grew in an arid dune region because most of the material of *Weichselia* occurred in sandstone and the morphology of the plant suggests a xerophyte. On the other hand, Daber (1968) suggested that the plant grew in a maritime setting on wet ground that underwent periods of drying. The *Weichselia* remains in the Wasia Formation are apparently concentrated in the siltstone bands. It is noted that considerable variation in pinnule size occurs here.

It seems that the Wasia plant grew in an arid dune region near the sea and that its remains were deposited by water in the back shore lagoons and swamps. It is noted that rainfall in the Cretaceous was more plentiful than it had been through the preceding three geological periods as is indicated by Schwarzbach (1963) from his world-wide study of various kinds of sediment found in Cretaceous strata. This is true in Saudi Arabia as shown by the thick Biyadh Sandstone (Barremian to Aptian), see Powers et al. (1966). These upper Lower Cretaceous rocks are 425 m thick, composed of cross-bedded sandstones of continental origin. The only fossils found in the Biyadh outcrops (25-30 km east of Riyadh) are large tree trunks of different seizes, reaching more than half a metre in diameter; some of these are in growth position.

The Biyadh Sandstone is unconformably overlain by 42 m of Wasia sandstones and claystones which contain varied plant remains.

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Plate 4

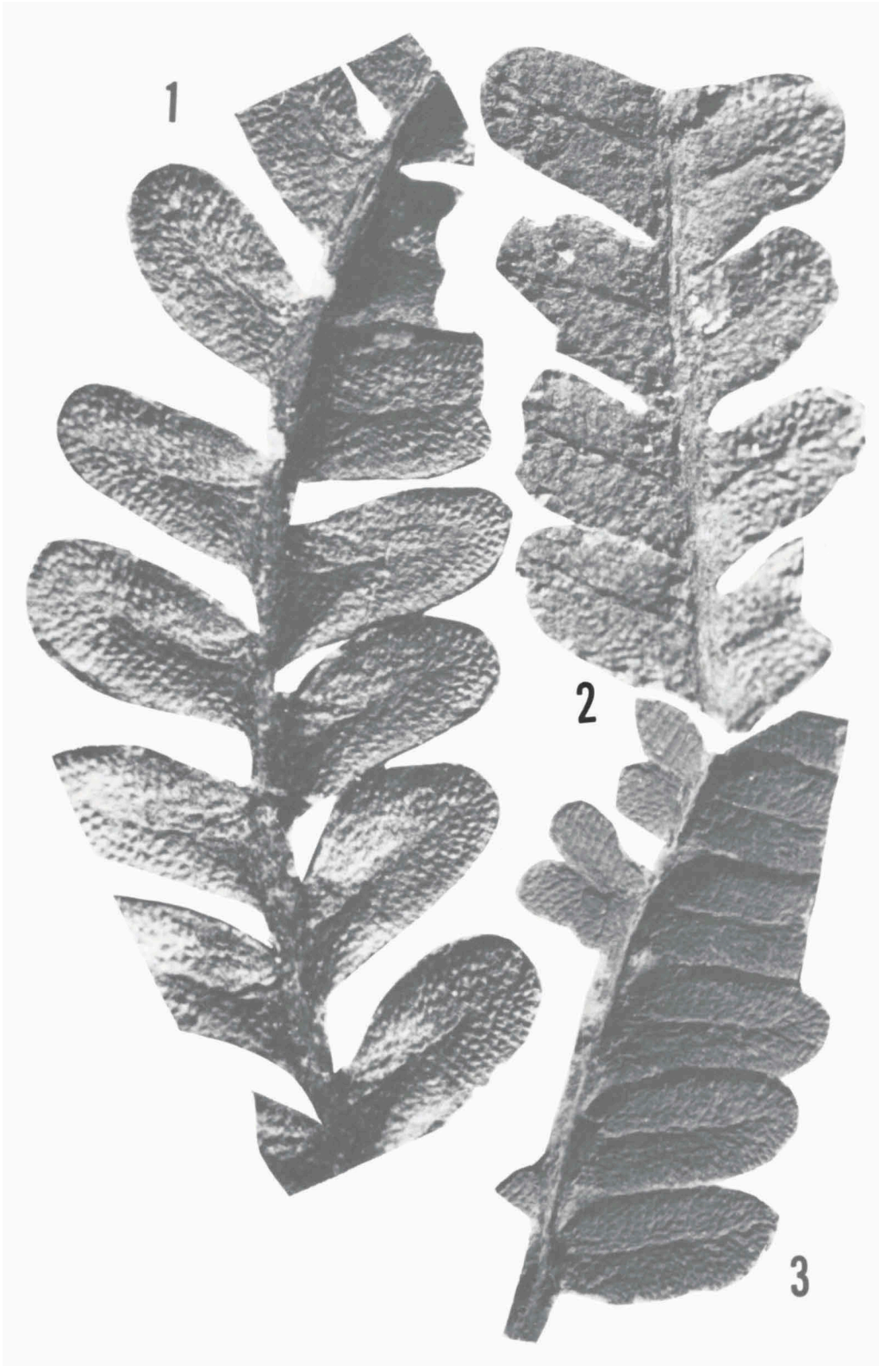
Weichselia reticulata (Stokes & Webb) Fontaine

Fig. 1. Fragment of a pinna, no. KSU (KW 32), × 10.

Fig. 2. fragment of a pinna, no. KSU (KW 9), × 10.

Fig. 3. Fragment of a pinna, no. KSU (KW 12), × 6.

Plate 4



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