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A Persian Sigillaria

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VI. *A Persian* Sigillaria.

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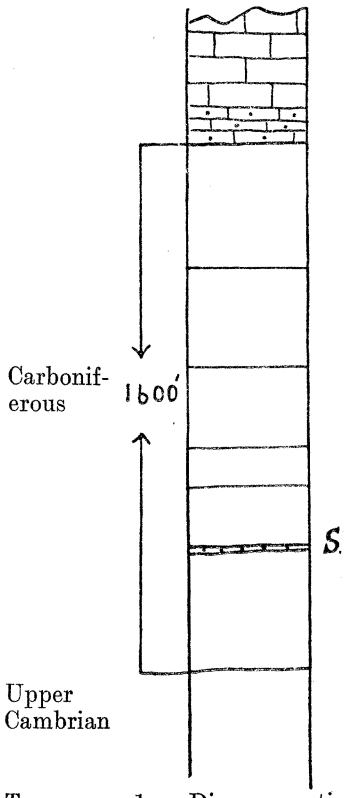
(Plates 34 and 35.)

This communication may conveniently be divided into two parts: the first is mainly descriptive; in the second part some general observations are made on the genus *Sigillaria*.

Part I.

The fossils described in the following pages were discovered by Mr. J. V. Harrison, of the Anglo-Persian Oil Company, in the course of a geological reconnaissance in south-western Persia, and were sent to me for examination in October 1931 by Dr. G. M. Lees, the chief geologist of the Company. I am grateful to Dr. Lees for affording me an opportunity of describing specimens which are interesting both botanically and geologically; to Mr. J. V. Harrison, who kindly furnished a description of the locality and the stratigraphy; also to the Anglo-Persian Oil Company for a grant towards the cost of providing illustrations.

The fossils were found in the valley of Chal-i-Sheh* (lat. 32°, 55′ N.; long. 49°, 30′ E.; text-fig. 3, P), in the central part of the Bakhtiari country on the southern front of the Qal'eh Kuh mountain-complex, a district in south-western Persia inhabited by the Bakhtiari tribes. The Chal-i-Sheh valley, Mr. Harrison adds, lies to the north-east of the normally folded zone, near the front of the zone of shearing; it is about 8500 ft. above sea-level. The accompanying diagrammatic section is based on a more detailed section prepared by Mr. Harrison and on information given to me by Dr. Lees. Fossil plants were obtained at one locality only, Darreh Sheh,† in quartzitic sandstone (text-fig. 1, S): marine fossils from limestones similar to those shown at the upper end of the section are being described by Dr. Douglas, of Oxford, who tells me that he regards them as Permo-Carboniferous species. A



Text-fig. 1.—Diagrammatic section showing the position of the fossiliferous bed, S.

* Chal-i-Sheh means the "black or dark nest or depression among the hills."

† Darreh Sheh means "black or dark valley."

brachiopod and trilobite fauna from shales and micaceous sandstones below the Carboniferous strata is in the hands of Professor W. B. R. KING.

So far as I am aware, neither Carboniferous nor Permian plants have previously been recorded from Persia. The specimens recently discovered are impressions and casts in sandstone, and the great majority, possibly all of them, probably belong to one species of *Sigillaria* in different states of preservation. One may visualise a river or current undermining a bank occupied by a pure stand of *Sigillaria* and sweeping the broken pieces of stem and branches into a delta or estuary. After some hesitation the distinctive name *Sigillaria persica* has been given to the specimens. The plant so named is included as a form of unusual interest in the group-species *Sigillaria Brardi*, BRONGN. A further reference to nomenclature is made on p. 383.

Description of specimens.

Sigillaria persica may be defined as follows: stems occasionally branched dichotomously, fig. 16, Plate 35; the surface of young or fertile branches covered with leaf-scars which may be contiguous and without cushions: slightly above the middle line of the leaf-scars is a small leaf-trace, often horse-shoe shaped, flanked by elongate-oval parichnos scars. The hexagonal scars vary in breadth from 2 to 4 mm., figs. 5 and 10, Plate 34; their arrangement is usually vertical rather than spiral. On one and the same stem or branch there is a gradual transition from contiguous leaf-scars to scars occupying the upper end of a kite-shaped cushion, figs. 1 and 5, Plate 34; a zonal arrangement of large and small cushions is also a noteworthy character. There is a small ligular scar in the middle of the upper border of the leaf-scar, fig. 7, A, Plate 34. The cushions, some of which reach a length of 1·7 cm., are usually arranged in regular vertical series, figs. 1, 3, 7, 8, Plate 34.

Irregular verticils of circular scars with a central umbo occur on branches on which the leaf-bases are relatively crowded: older or partially decorticated stems are fissured and superficially resemble ribbed Sigillarias, figs. 18–20, 25, Plate 35: the *Syringodendron* state is also represented, fig. 15, Plate 35.

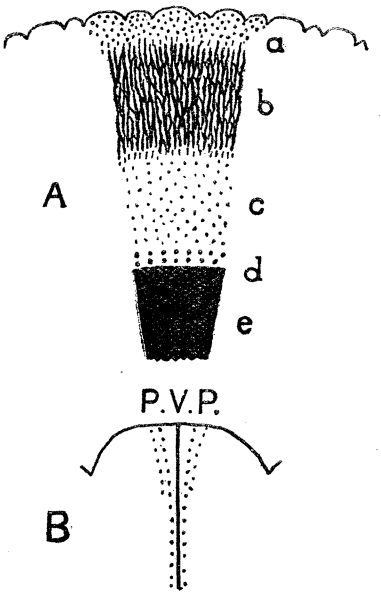
Leaves characterised by a broad median keel, or groove; they vary in breadth from 2 to 4 mm.

(No strobili were found.)

Figs. 1, 1, A, 1, B, 2, Plate 34. The upper part of fig. 1, in which the surface-features appear as shallow depressions, resembles some forms of *Lepidodendron*, *e.g.*, *L. volkmannianum*, STERNB., in which the cushions are disposed in vertical series, but the parichnos scars are confined to the leaf-scar and are not visible, as they are in a *Lepidodendron*, on the cushions. At the lower end of the specimen the cushions are much reduced in size and the surface-features are more definitely Sigillarian. A piece of fig. 1 is shown in relief in fig. 2. Figs. 1, A, and 1, B, illustrate the difference in the form and size of the cushions in the upper and lower parts, respectively: the longest cushion is 1·7 cm. in length and has a maximum breadth of 7 mm. The upper half

of the cushion is bounded by curved ridges which bend sharply inwards at the level of their greatest spread and curve downwards as the edges of the narrow basal portion. The leaf-scar lies close to the upper end of the cushion, where a small ligular pit is occasionally visible as a projecting cast: on the scar and slightly above the middle line is a horse-shoe shaped cast of the leaf-trace and an elongated parichnos scar on each side.

Figs. 3, 3, A, 4.—In fig. 3, a photograph of the actual specimen, the cushions are relatively broad and less pointed apically (fig. 3, A) than those of fig. 1: the leaf-scars are imperfectly preserved and only a single, small prominence can be seen. It is probable that the true surface of the stem is not preserved: the parichnos strand, as shown in the diagram, text-fig. 2, B, accompanies the leaf-trace from the inner cortex and bifurcates a short distance below the base of the leaf. Another indication of partial decortication is afforded by the clearly marked longitudinal striation (fig. 2, A), which is caused by the outer part of the strengthening tissue characteristic of Sigillarian stems. Text-fig. 2, A, shows part of a diagrammatic transverse section of a Sigillarian stem as an aid to the better interpretation of the features exposed in stems preserved in different states of decortication.



TEXT-FIG. 2.—A. Diagrammatic transverse section of part of a *Sigillaria* stem illustrating the relation of anatomical characters to the surface-features of impressions or casts of different regions. *a*, the outermost cortical zone of comparatively delicate tissue including the leaf-cushions; *b*, a broad zone of thicker-walled, strengthening tissue; *c*, lacunar inner cortex; *d*, the tissue immediately external to the wood corresponding to phloem; *e*, part of the woody cylinder. B. Diagram showing the relation of the parichnos, P, to the leaf-trace V, as seen in a transverse section through the outer cortical region.

Fig. 4, Plate 34, shows part of fig. 3 in relief.

Figs. 7, 7, A, 8, 9, 14.—Figs. 7 and 8 are two views of portions of the same specimen: fig. 7, A, shows a cushion slightly enlarged and a leaf-scar with leaf-trace, parichnos scars and, above, the cast of a ligular pit. A cushion and leaf-scar of a similar specimen, with leaf-trace and parichnos, is seen in fig. 14. The leaf-cushions of a third specimen shown in fig. 9 illustrate the resemblance to *Lepidodendron volkmannianum*. These specimens are intermediate in the form of the cushions between figs. 1 and 3.

Figs. 5 and 10.—On the lower part of the impression shown in fig. 5 the leaf-cushions are identical in form with those of fig. 3; above the two strobilar scars, *f*, the cushions are smaller and towards the upper end of the specimen there are contiguous leaf-scars (*cf.* fig. 24, Plate 35).

The condition in the upper part of fig. 5 is repeated over the whole of the specimen shown in fig. 10, on which the scars are still smaller.

Figs. 22, 24, Plate 35.—Fig. 22 is a piece of an almost cylindrical cast, 30 cm. long, of a partially decorticated branch on which the position of the leaves is clearly indicated by rounded projections (*Knorria* state) varying in size from one part to another. In fig. 24 the relatively small cushions occur as deep depressions on which the fibrous tissue of the cortex, text-fig. 2, A, *b*, has left longitudinal striations. Two bases of fertile shoots are seen at *f*.

Fig. 16.—This specimen, similar in its decorticated surface to figs. 22 and 24, is evidently part of a branching stem; it bends slightly outwards to the right. At *f* is an oblique row of oval scars of fertile shoots, each scar having a central umbo with a pit marking the place of exit of a vascular strand.

Fig. 18.—In this small specimen the outlines of the cushions are practically obliterated, but at *c*, *c*, a short oblique ridge marks the position of the curved boundary of one side of two of the cushions. The irregular vertical ridges are no doubt cracks filled by the enclosing sand.

Figs. 19, 20, 21, 23, 25.—The convex areas in fig. 21, bounded by sinuous grooves, and longitudinally striated, define the limits of long cushions on which the parichnos scars of leaves are indistinctly preserved. A further stage of decortication is seen in fig. 19; here the boundaries of the cushions are discontinuous and the parichnos scars are more conspicuous. Figs. 20 and 25 bear a superficial resemblance to ribbed species of *Sigillaria*, but the ribbing is irregular and due to longitudinal fissures in the bark. In fig. 23 the ribbing is still less regular and less prominent; the leaf-scars are farther apart. There is no proof of the specific identity of this specimen with those previously described, though such identity is probable. A specimen similar to those shown in figs. 18, 20 and 23 is included by Zeiller (1906, fig. 1, Plate 44) in a series referred to *S. Brardi* from the Lower Permian coal-field of Blanzy.

Fig. 15.—This is an example of the typical *Syringodendron* state of an older stem: the parichnos scars are a prominent feature, also the fine longitudinal ribbing. The short transverse grooves seen here and there may be due to horizontal plates of resistant tissue associated with the fibrous cortex.

Fig. 17.—This specimen, characterised by longitudinal ribbing in the upper part, which is replaced over most of the surface by elongate, oval areas, cannot be specifically determined; it is not improbably a more deeply decorticated stem of *Sigillaria persica*.

Figs. 11–13, Plate 34.—Imperfectly preserved leaves are fairly common in association with the stems: they vary in breadth from 2 mm., fig. 11, to about 4 mm., fig. 13, and have a prominent median ridge, or groove. The form of the leaf fragments is consistent with the structural features of the foliage of *Sigillaria Brardi* as described by Renault, 1896, Plate 37; there is a prominent median keel on the lower surface of the lamina between two stomatal grooves.

Comparison of the Persian Sigillaria *with other examples of the* S. Brardi *Group.*

One of the most instructive sets of specimens described under the name *Sigillaria Brardi* is that admirably illustrated by ZEILLER (*loc. cit.*), Plates 42–44, in his *Bassin houiller et Permien de Blanzy et du Creusot.* The leaf-cushions on part of his fig. 1, Plate 42, are practically identical with those of the Persian stem shown in figs. 1 and 2, Plate 34; the cushions on the upper part of the Blanzy specimen correspond with those on the lower part of my fig. 1. The specimens reproduced in ZEILLER's Plate 43 present an equally close resemblance to the Persian forms shown in figs. 5, 10, 16, 22 and 24 both in the form and arrangement of the leaf-scars and in the occurrence of irregular verticils of strobilar scars. Reference has already been made to a similarity of ZEILLER's fig. 1, Plate 44, to the fissured specimens reproduced in my figs. 18, 20, 23 and 25. Similarly, ZEILLER's *Syringodendron*, which he regards as a state of *Sigillaria Brardi*, fig. 4, Plate 44, differs in no essential features from my fig. 15, Plate 35.

Other figures with which comparison may be made are in the Atlas of the well-known monograph by WEISS and STERZEL (1893). WEISS substituted the specific name *mutans* for *Brardi* on grounds which need not be discussed: he employed additional terms to denote forms and varieties of *S. mutans*. Specimens from Wettin described as *S. mutans* forma *subrhomboidea*, WEISS and STERZEL, Plate 13, show the same surface-features as those on my figs. 1, 2, 5 and 7: the deeper cortical layer exposed on fig. 54 of the German monograph agrees exactly with surfaces of decorticated examples of *S. persica* which are not illustrated in this paper. A variety of *S. mutans* forma *wettinensis*, called by STERZEL *convexa*, is hardly distinguishable from my figs. 3 and 4. The leaf-cushions of *S. mutans* forma *urceolata* WEISS and STERZEL, Plate 14, also from Wettin, bear a striking resemblance to my figs. 1, 2 and 7. Other forms included by WEISS and STERZEL under *S. mutans* forma *Brardi*, Plates 15, 17, afford good examples of the zonal (periodical) reduction in the size of the cushions and of a transition from the surface-features seen in the lower part of my fig. 1 to the crowded leaf-scars in the upper part of fig. 5. The specimens figured by WEISS and STERZEL as *S. mutans* forma *Menardi*, BRONGN. sp., Plates 18, 19, and forma *favulina*, WEISS, Plate 18, are exactly like that reproduced in fig. 10 of this paper.

Reference might be made to many other illustrations of Sigillarian stems described as *S. Brardi* or under other specific names, which appear to be indistinguishable from the Persian form. GRAND'EURY's (1890) figures of *S. Grasiana*, BRONGN. (fig. 10, Plate 10, and *S. Brardi*, BRONGN., figs. 1 and 2, Plate 11), agree very closely with my fig. 10. KIDSTON's (1885) *S. MacMurtrei* from Radstock resembles some examples of *S. persica* in which the leaf-cushions are large and prominent. An older species described by KIDSTON (1916) as *S. incerta* from beds in the upper part of the Millstone Grit is similar to, though probably not identical with, my fig. 10. KIDSTON spoke of *S. incerta** as intermediate between the Favularian and Clathrarian forms of stem and

* I am indebted to Dr. R. CROOKALL for enabling me to examine this and other Sigillarias in the Kidston Collection at the Museum of Practical Geology.

believed it to be easily distinguishable from *S. Brardi* by "the lateral angle of the leaf-scar joining the margin of its cushion some distance above the lateral angle of its cushion, except in those conditions where the leaf-scar occupies almost the entire cushion."

Geological Age of the Persian Fossils.

Sigillarian stems described by authors as *S. Brardi*, the species, or the collection of forms, with which the Persian specimens agree most closely, are recorded from the upper part of the Upper Carboniferous formation and from Lower Permian beds. In England *S. Brardi* occurs in the upper and middle Coal Measures. The genus *Sigillaria* seems to have reached its maximum development in the Middle Coal Measures, but the ribless forms are more characteristic of rather higher Carboniferous horizons and are usually found in Stephanian and Lower Permian beds. The specimens which show the closest resemblance to some of the Persian stems are from the Lower Permian strata of Blanzy—though, as ZEILLER pointed out, the boundary between the uppermost Carboniferous and the lowest Permian rocks is ill defined in that district—and from the Stephanian of Germany. The evidence furnished by the Persian fossils is therefore in favour of a high Carboniferous or a low Permian horizon, though the possibility of a Westphalian age is by no means excluded.

PART II.

The more one compares the published illustrations of Sigillarian stems described under different names, the more hopeless it seems to attempt to employ specific terms connoting well-defined differences which are not an expression of differences in age or of the state of the specimens at the time of fossilisation. The Persian fossils agree most closely with *S. Brardi*, a species remarkably protean in its surface-features. It may seem inconsistent to employ a new name for the specimens which are described in these pages: the name *S. persica* is adopted partly because it draws attention to the occurrence of the genus in a new region, and in part because the forms so named demonstrate in an unusual degree the wide range in variation illustrated by a single type. It is significant that all the fossils, about fifty in number, submitted to me were found at one locality: the only genus is *Sigillaria*, and of that genus there is good reason to believe only one species is represented.

It has been customary to allocate the numerous forms of *Sigillaria* to groups designated by names having reference to the surface-features of the stem. In the majority of Sigillarias the most obvious feature is the arrangement of the leaf-scars in vertical rather than in spiral series: in some forms the leaf-scars, though spirally disposed, are so placed that it is the vertical rows which are dominant. Stems in which a vertical seriation is the most striking character are included in the section *Eusigillaria*, and this is usually subdivided into two groups: (*a*) *Rhytidolepis*, stems with rounded vertical ribs separated by grooves and bearing leaf-scars at regular intervals;

(*b*) *Favularia*, stems on which the leaf-scars are contiguous and not separated by smooth portions of the stem-surface: as the leaf-scars are contiguous and hexagonal the vertical grooves characteristic of *Rhytidolepis* are replaced by zigzag grooves between the scars.

The minority of Sigillarian stems are referred to the section *Subsigillaria*, in which a spiral arrangement of leaf-scars is the dominant feature: in the group *Leiodermaria* the scars occur in regular spirals on a smooth or sculptured bark, and are not in contact with one another. In the group *Clathraria*—or *Cancellatae* as Weiss (1869, p. 158) preferred—the scars are in contact as in *Favularia*, but the zigzag boundaries are rather spiral than vertical. This classification is purely artificial and does not represent any fundamental differences. In the genus *Lepidodendron*, which cannot always be clearly distinguished from *Sigillaria*, the leaf-cushion is a characteristic feature: the leaf-scar lies on a projecting and well-defined area of the stem-surface. Some Sigillarias have clearly defined leaf-cushions, though in most forms there are none. For example, on some stems of the Leiodermarian group the leaf-scars, instead of being spirally disposed on a smooth bark, lie on well-defined, contiguous leaf-cushions.

It has been shown by many authors that the relative position of leaf-scars varies within wide limits on a single stem: the ribbed, *Rhytidolepis* form passes into a Favularian type. Similarly, both the Leiodermarian and Clathrarian forms occur on one and the same stem. It is indeed very doubtful whether the two sections *Eusigillaria* and *Subsigillaria* can be regarded as expressing two distinct sets of plants. The contrast between a typical ribbed stem and one that is smooth is clear enough; but when the leaf-scars on a smooth stem occur, as they sometimes do, on well-marked cushions, the distinction disappears. It is, moreover, by no means easy to decide whether some stems with crowded leaf-scars should be assigned to the Favularian group of the Eusigillariæ or to the Clathrarian group of the Subsigillariæ.*

The two sections of *Sigillaria* cannot be said to be characterised by any constant anatomical differences in the structure of the stem. Such knowledge of cones and leaves as we possess does not enable us to draw distinctions between the various forms of the genus.

It is clear that the classification of Sigillarian stems is not based on any satisfactory and natural differences. Dr. F. Němec (1930) goes so far as to say that every palæobotanist knows that the stems which he describes as species of *Sigillaria* are not species at all in the strict sense, and not even analogous to species of ferns and pteridosperms. We must admit that, while it is necessary for purposes of description and references, to make use of some distinctive names, such names do not imply well-defined species in the sense understood by students of living plants.

The type with which the Persian specimens show the closest agreement is that described by Brongniart (1822, fig. 5, Plate 72), as *Clathraria Brardi*, and subsequently

* The range in surface-features in Sigillarian stems is discussed by several authors; see, for example Zeiller (1889), Kidston (1896), Hirmer (1927), p. 265, figs. 314–318; Seward (1890).

transferred to the genus *Sigillaria* (Brongniart, 1828). The lists of "species" included by authors under *S. Brardi* (cf. Koehne, 1904), illustrate the range in surface-features on stems assigned to a single species. It is sometimes convenient to employ a form or varietal designation as an indication of minor differences or geographical distribution: this method is adopted by Weiss, and by Weiss and Sterzel (1893) in their well-known memoir on *Sigillaria*. If we recognise that the emphasis placed on fine distinctions by the application of distinguishing names is not intended to denote differences comparable with those shown by species and varieties of living plants, this method is unobjectionable.

The Persian specimens, as already stated, are believed to be pieces of stems of one species, the differences being due either to different degrees of decortication or to differences in the relative size and position of leaf-scars correlated with varying rates of growth. Specimens from other parts of the world which agree most closely with those now under consideration are usually described as *Sigillaria Brardi*, a designation covering a wide range in surface-features and including forms which may or may not be true species in the narrower sense. The Persian specimens are assigned to the *Brardi* group under the name *S. persica* because of the exceptionally good evidence of variation in (*a*) the form and distribution of the leaf-scars; (*b*) the presence or absence of leaf-cushions; (*c*) the range in size and form of the cushions; and in view of the provenance of the plant.

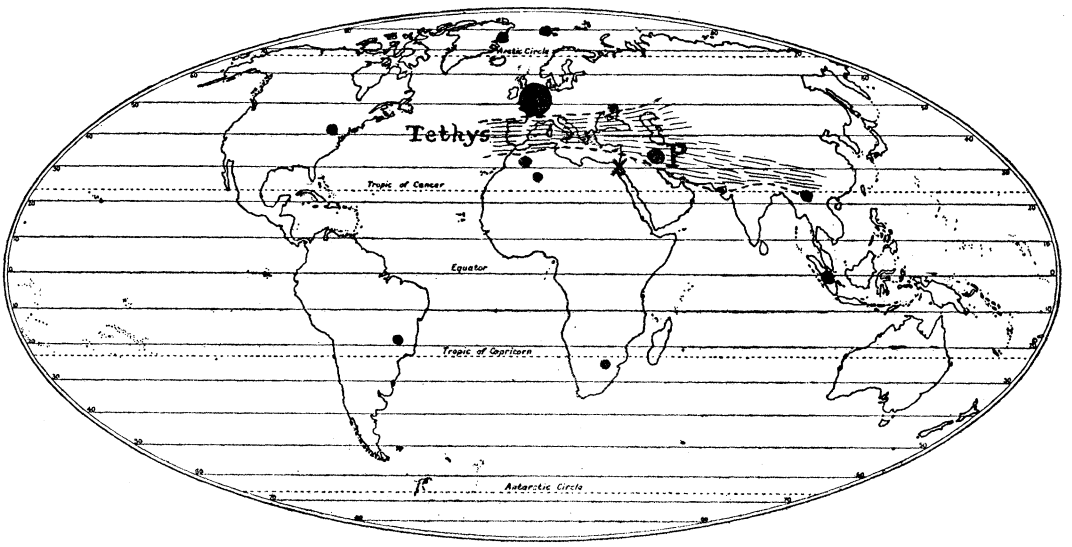
The Geological and Geographical Range of Sigillaria.

Sigillaria reached its maximum development, as measured by the abundance of different forms, in the Upper Carboniferous period: in Britain its greatest development was in the Middle Coal Measures. The genus persisted into the earlier part of the Permian period, and then, so far as we know, became extinct: the ribbed forms are older than those with smooth stems. *Sigillaria Brardi* is characteristic of the upper part of the Coal Measures and of the lower part of the Permian system. There are a few records of *Sigillaria* from beds of Lower Carboniferous age, and recently Professor Zalessky has described some imperfectly preserved stems from Upper Devonian rocks in southern Russia which closely resemble the decorticated form of older Sigillarian stems known as *Syringodendron*. For these Russian fossils a new generic name, *Helenia* (Zalessky, 1931), is instituted. It can hardly be said that we have proof of the existence of true Sigillarias in Devonian floras; though it is very probable that the genus or at least some near relation of the genus had already been evolved. A few Lower Carboniferous forms were described by Dr. Kidston (1894, p. 261; 1905, p. 787) from southern Scotland and an obscure specimen has recently been described by Professor Walton (1931) as *Sigillaria* sp. from the Lower Carboniferous Teilia beds of North Wales. Other Lower Carboniferous Sigillarias are recorded from Morocco, South Russia, Upper Silesia, Spitsbergen, and Greenland (Halle, 1931). A Lower Carboniferous species described by Professor Zalessky (1903), from the Donetz basin

of Russia as *Sigillaria Tchirkovaeana*, which he includes in a new sub-genus *Heleniella*, resembles KIDSTON'S *S. Youngiana*, another Lower Carboniferous form, and is characterised by sinuous ribs. The Russian author suggests that the earlier forms of the *Rhytidolepis* type of stem may have been characterised by sinuous ribs in contrast to ribs of uniform breadth, which are a distinguishing feature of the Upper Carboniferous forms.

Sigillarian stems described as *Sigillaria Brardi*, or under other form or varietal names and included in the group-species *S. Brardi*, are from Upper Carboniferous (Stephanian and Yorkian) or Lower Permian rocks. Though none of the few species recorded from Lower Carboniferous rocks agree as closely as *S. Brardi* with *Sigillaria persica*, it may be said that in some of their features the older forms are comparable with members of the *Brardi* group. It is, for example, worth noting that the vertical disposition of the leaf-cushions in *Lepidodendron volkmannianum*, STERNB., a species characteristic of Lower Carboniferous floras, and the form of the alternately expanded and contracted ribs of the Russian *S. Tchirkovaeana*—suggesting an approach to leaf-cushions—are features shared by the Persian stems. But, on the whole, the evidence afforded by the specimens described in the first part of this paper undoubtedly points to an horizon not lower than Westphalian (Yorkian), and more probably Stephanian. Considering the plant remains without reference to marine fossils, a Lower Permian age is by no means excluded.

The accompanying map, text-fig. 3, affords an indication of the wide geographical



TEXT-FIG. 3.—Map illustrating the wide geographical range of forms of *Sigillaria* included in the group-species *S. Brardi*. *P*, the Persian locality; *X*, the locality in the Sinai Peninsula where a species of *Lepidodendron* was found. The shading marks the position of part of the Tethys Sea.

range of the genus: by no means all localities are shown. Most of the records are from Upper Carboniferous or Lower Permian beds, though a few, as stated below, are

from Lower Carboniferous horizons. The Persian locality (P) falls within the Tethys Sea as usually represented in geographical reconstructions. The North African localities are close to its southern shore, and the Carboniferous *Lepidodendron mosaicum*, SALTER, recently described* from the Sinai peninsula, text-fig. 3, X, must have grown close to the water's edge. There must have been a land connexion in the latter part of the Carboniferous period, if not earlier, across the old Mediterranean Sea.

N. Africa.—The Abbé CARPENTIER (1930) described a ribbed form of *Sigillaria* and another species "of the type *S. Brardi*" from Westphalian beds in Morocco. It had been previously pointed out by DOUVILLÉ and ZEILLER (1908) that the Upper Carboniferous flora on the southern border of the Tethys Sea very closely resembles that on the European side.

S. Africa.—The partially decorticated stems described by myself (1897) from the Ecca (Lower Permian) beds of Vereeniging as *Sigillaria Brardi* should, as Dr. Gothan and some other authors have said, be referred rather to the *Brardi* group. The opinion expressed by KOEHNE (1904, p. 67) that the Vereeniging plant is probably a *Lepidodendron* is not supported by any adequate reasons: a re-examination of the specimens confirms my view that the plant is a *Sigillaria*.

N. America.—*Sigillaria Brardi* is said to be abundant in the Coal Measures of Pennsylvania (WHITE, 1900) and a similar, though probably not identical, species, *S. approximata* Font. and Wh., is described as a rare Lower Permian plant in Virginia.

S. America.—Poor specimens, which cannot be determined with confidence, are recorded from Permo-Carboniferous beds in Brazil as examples of *S. Brardi* (WHITE, 1908; LUNDQVIST, 1919). A specimen, which may be a *Sigillaria*, was described by myself (1922) from Carboniferous (probably Lower Carboniferous) beds in Peru as "*Sigillaria* or *Lepidodendron* sp."

Sumatra.—Posthumus (1927, ii) includes *S. Brardi* in the list of members of a Sumatran flora which is said to be Lower Permian in age.

China.—Professor HALLE (1927) described a *Sigillaria* from beds in Yunnan, which he assigns to the lower part of the Permian system, as *S. acutangula*, HALLE, and compares it with *S. Defrancei*, BRONGN., a form which may be included in the *S. Brardi* group. He records a very similar form as *S. Brardi*. HALLE also describes specimens from Shansi as *Lepidodendron oculus-felis*, ABB., from beds "not older than Lower Permian." This specific name was given by ABBADO (1900) to Chinese fossils which, with others, he included in *Sigillaria*; ZEILLER (1901) subsequently substituted *Lepidodendron* as the generic designation, and HALLE agrees with this: it is, however, possible that ABBADO's original determination is correct. One cannot express any very definite opinion on the

* In a paper by the author, which will be published this year (1932) in the Quarterly Journal of the Geological Society of London.

precise affinity of the specimens, but they afford one of many examples of the difficulty of drawing a definite line between the two allied Palæozoic genera.

Spitsbergen and Greenland.—The late Professor NATHORST (1914) described a Sigillarian stem as *Sigillaria* sp. from the Lower Carboniferous plant-beds of Spitsbergen, and recently Professor HALLE (1931) has described a piece of stem, in the *Syringodendron* state, from eastern Greenland, which is possibly of Namurian age, that is, a member of the oldest Upper Carboniferous flora. It is possible that some of the Spitsbergen specimens included by NATHORST (1914, fig. 22, Plate 10) in *Lepidodendron* may be *Sigillaria*. His *Lepidodendron* cf. *Volkmannianum* may be compared with some of the Persian forms.

It is clear that Sigillarian plants agreeing generally with *S. persica* were widely distributed in the latter part of the Carboniferous period. The data available hardly suffice to enable us to follow the wanderings of these plants from an ancestral home. They flourished in some regions of Gondwanaland, but so far no Sigillarias have been found in Australia and India. We know that Lower Carboniferous *Lepidodendra*, very similar to, if not specifically identical with, European and arctic forms, existed in Australia, but negative evidence hardly justifies the assumption that *Sigillaria* was not a member of the same flora. Such evidence as there is favours the view that *Sigillaria* began its career in the Old World and in the northern hemisphere, whence species spread across some connecting strip of land from one shore of the Tethys Sea to the other.

Was Sigillaria *a Succulent Plant?*

Many specimens referred by authors to *Sigillaria Brardi* are characterised by leaf-scars spirally disposed at varying distances apart on a smooth or finely wrinkled surface: it is noteworthy that this form of stem does not occur in the Persian collection.

The zonal arrangement of the leaf-scars has often been noted as a common character in *S. Brardi* (POTONIÉ, 1894), and it is well marked in several specimens of *S. persica*. Comparison has been made with stems of recent plants in which there is a periodic change in the distances separating the leaves: the stem of *Kleinia neriifolia*, HARV. (= *Senecio Kleinia* Less.) reproduced on a small scale in fig. 6, Plate 34, illustrates a regular alternation of zones of relatively crowded and more sparsely scattered leaf-scars. It is by no means unlikely that a comparison of a succulent stem of a flowering plant with stems of *Sigillaria* may be based on more than a mere analogy. Dr. MÄGDEFRAU (1931) has recently suggested that the Triassic genus *Pleuromeia* was a halophyte; it is possible that *Sigillaria*, or at least some species, were also succulents. This is no new idea: some of the earlier writers on *Sigillaria* were struck by its superficial resemblance to stems of succulent Euphorbias; but the similarity may be deeper. If the stem of a succulent, such as *Kleinia*, is gradually dried the smooth surface becomes wrinkly and below each leaf-trace a prominent elongated ridge stands out as a conspicuous feature. It may be that some of the forms of Sigillarian stems are related to degrees

of shrinkage before preservation. Moreover, the broad inner cortex of loose and thin-walled tissue may have served as a reservoir of water, and the enlarged parichnos scars (Coward, 1907) of older stems, which have often been compared with lenticels, may be correlated with existence in a salt marsh or some other habitat where the soil was deficient in oxygen.

Conclusion.

In the course of a geological reconnaissance in 1931 in south-western Persia by members of the Anglo-Persian Oil Company, several plant remains were discovered at one locality in a bed of sandstone believed to be Carboniferous in age. It is believed that all the specimens, about fifty in number, are impressions or casts of a single species of *Sigillaria*, which agrees very closely with the variable Upper Carboniferous and Lower Permian species *S. Brardi*, Brongn.: for reasons stated in the paper, the Persian plant is named *Sigillaria persica* and included in the species-group *S. Brardi*.

The fossils afford a striking illustration of the wide range in form, size, and arrangement of the leaf-cushions and leaf-scars, also in the surface-features of the impressions and casts dependent on different degrees of decortication and age; they also afford evidence of the comparative worthlessness of specific determinations based on a few specimens.

Carboniferous plants have not hitherto been recorded from Persia, and it is noteworthy that they were discovered in a region which is generally believed to be on the site of the Tethys Sea.

Emphasis is laid on the artificial nature of the classification which is commonly adopted for Sigillarian stems.

Attention is called to the very wide geographical distribution of forms of *Sigillaria* agreeing generally with *S. persica*.

The zonal arrangement of the leaf-bases is compared with that on stems of some recent succulent plants, and it is suggested that there may be more than a superficial resemblance between certain types of Sigillarian stems and those of succulent flowering plants.

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EXPLANATION OF PLATES.

Photographs by Mr. E. T. Scott; drawings by Mr. T. A. Brock.

Unless otherwise stated, the specimens are reproduced natural size.

The figured specimens have been deposited, with the consent of the Anglo-Persian Oil Company, in the British Museum.

Plate 34.

Figs. 1–5; 6–14.—*Sigillaria persica.* Fig. 6.—*Kleinia neriifolia.*

Fig. 1.—Impression of the surface of a stem showing transition from a Lepidodendroid to a Sigillarian (Clathrarian) form.

Figs. 1A and 1B.—Details from the upper and lower part of the stem (× 1½). Specimen No. 1.

Fig. 2.—Part of the same specimen in relief.

Fig. 3.—Portion of an impression showing broader and shorter cushions.

Fig. 3A.—A single cushion and leaf-scar, with leaf-trace (× 2). No. 44.

Fig. 4.—Part of fig. 3 in relief. No. 44.

Fig. 5.—A partially decorticated stem in which the leaf-cushions become gradually reduced in size from below upwards. Scars of fertile shoots at *f*. No. 5.

Fig. 6.—A piece of *Kleinia neriifolia* Harv. showing a zonal variation in the distances between the leaf-scars (1/3 natural size).

Fig. 7.—Piece of a stem with leaf-cushions intermediate between those of figs. 1 and 3. No. 44.

Fig. 7A.—Cushion and leaf-scar with ligule-scar, scars of leaf-trace and parichnos. (× 2.)

Fig. 8.—Part of the specimen shown in fig. 7 in relief. No. 44.

Fig. 9.—A row of three cushions showing the leaf-trace, ligular scar and the parichnos scars (× 1½). No. 16.

Fig. 10.—Part of a stem with contiguous and smaller leaf-scars, *cf.* the upper part of fig. 5. No. 8.

Figs. 11–13.—Pieces of leaves (× 1½). No. 39.

Fig. 14.—A single cushion and leaf-scar (× 1½). No. 44.

Plate 35.

All the specimens are believed to be forms of *Sigillaria persica.*

Fig. 15.—Part of an older stem in the *Syringodendron* state with pairs of large parichnos scars. Specimen No. 34.

Fig. 16.—A piece of a branching, decorticated stem showing a row of strobilar scars (*f*). No. 13.

Fig. 17.—Portion of a more deeply decorticated stem assumed to be *S. persica.* No. 17.

Fig. 18.—A piece of a partially decorticated and fissured stem with indistinct remains of the boundaries of cushions at C (× 1½). No. 32.

Fig. 19.—A partially decorticated stem with grooves, indicating the form of the cushions (× 1½). No. 38.

Fig. 20.—An irregularly ribbed, partially decorticated stem. No. 42.

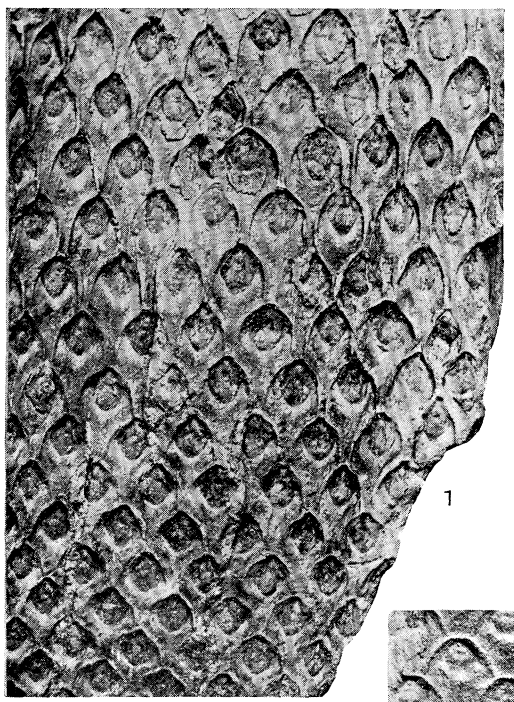
Fig. 21.—Piece of a decorticated stem with long leaf-cushions. No. 30.

Fig. 22.—Part of a cast showing crowded bosses representing the leaf-scars of a partially decorticated stem. No. 17.

Fig. 23.—*Sigillaria persica.* Piece of stem with leaf-scars far apart and an irregularly fissured hypodermal cortex. No. 25.

Fig. 24.—Partially decorticated stem showing two strobilar scars, *f*. No. 13.

Fig. 25.—An irregularly ribbed, partially decorticated stem. No. 30.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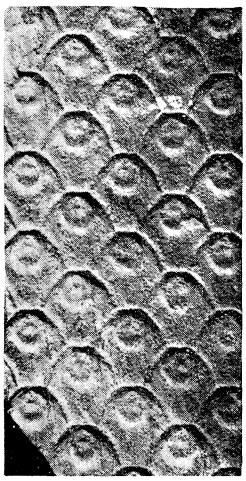
f

5


6


1 A


1 B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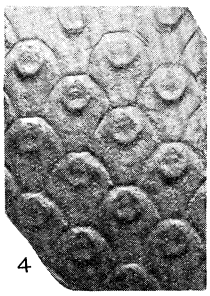
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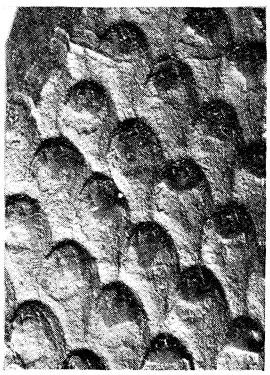
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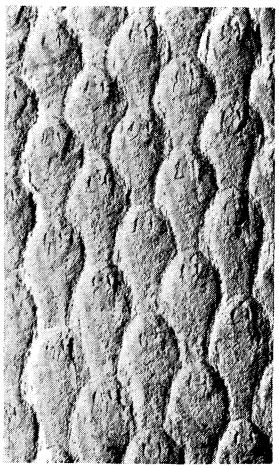
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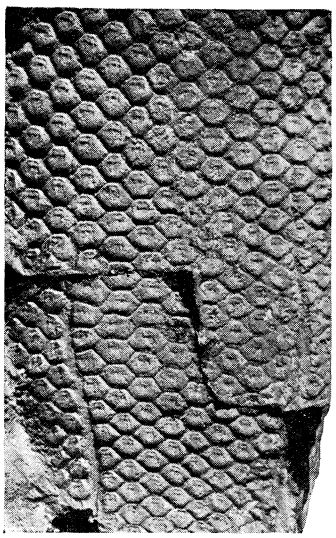
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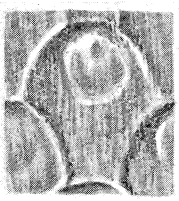
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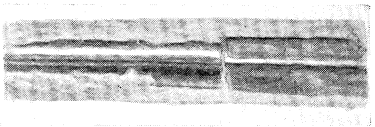
7 A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SIGILLARIA PERSICA

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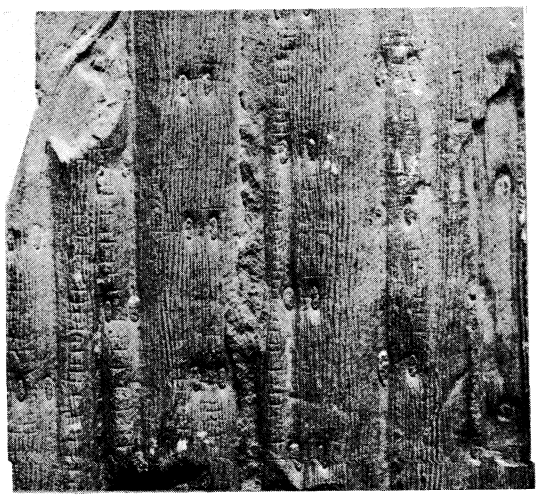

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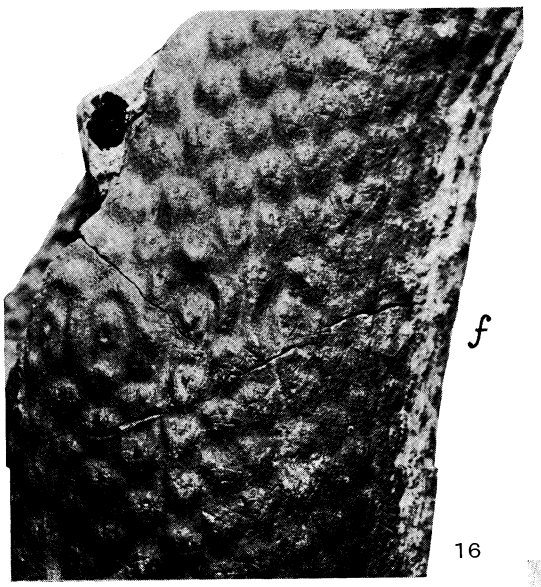

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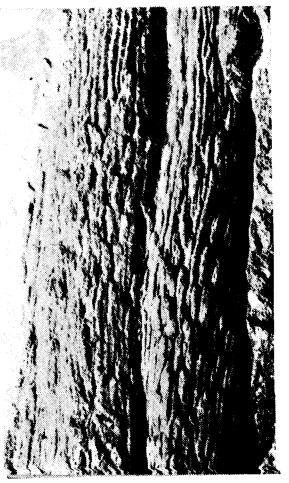

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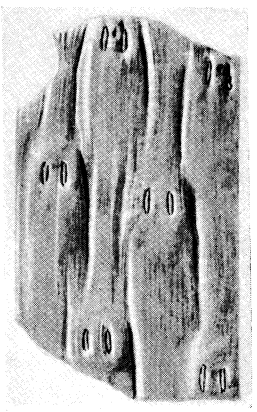

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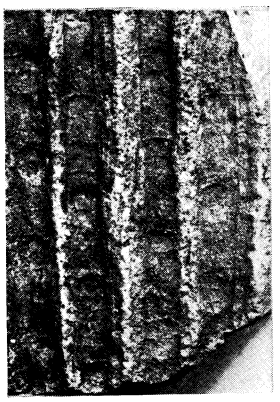

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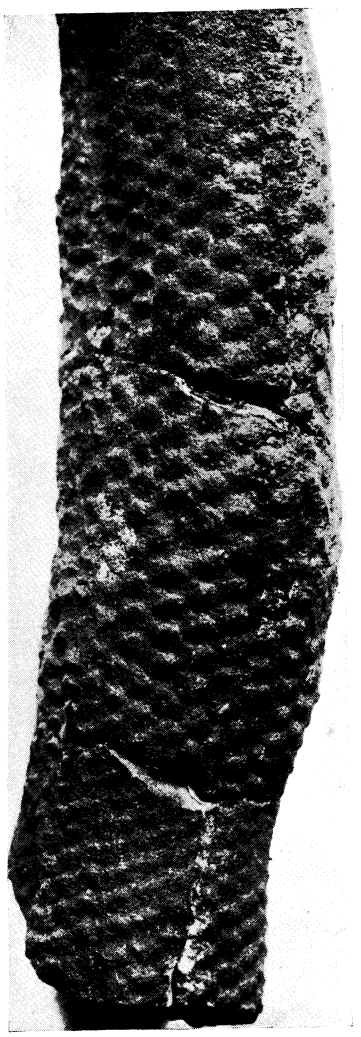

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SIGILLARIA PERSICA

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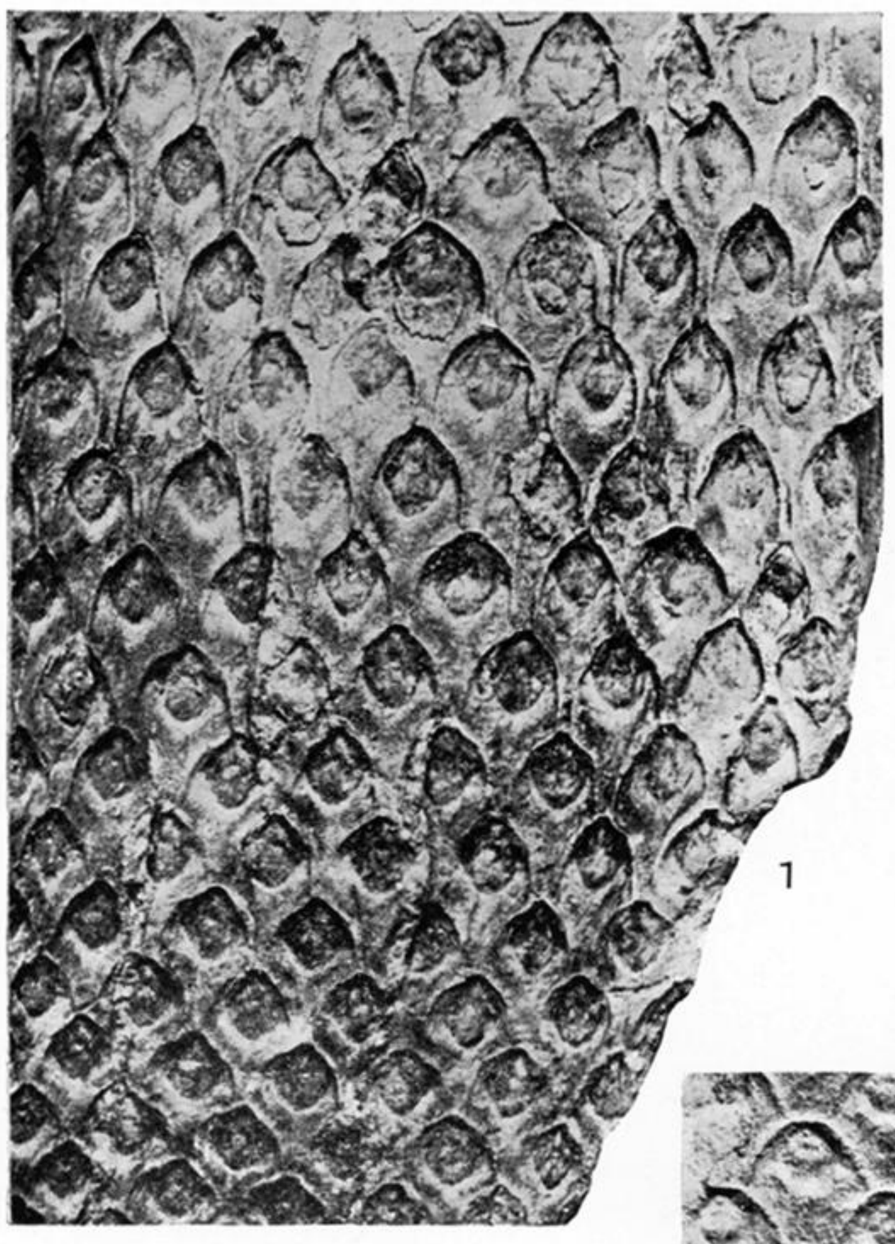

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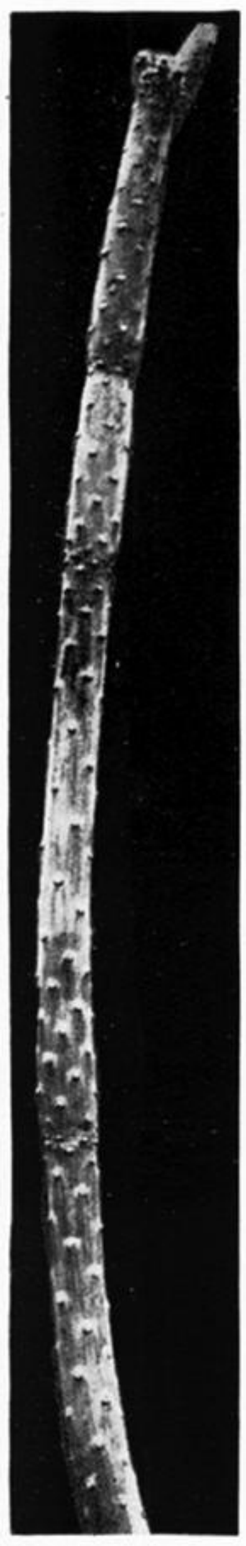

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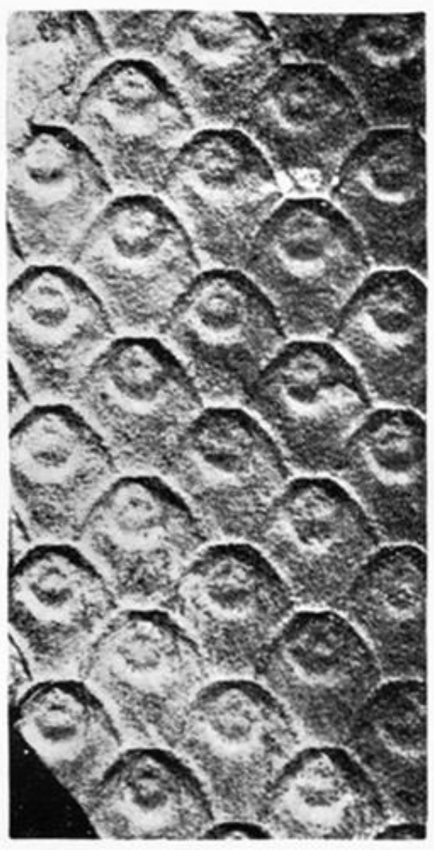

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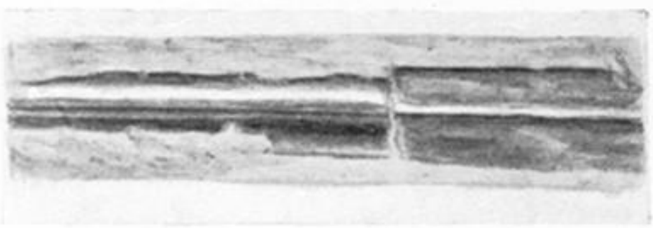

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SIGILLARIA PERSICA

Plate 34.

Figs. 1–5 ; 6–14.—*Sigillaria persica.* Fig. 6.—*Kleinia neriifolia.*

Fig. 1.—Impression of the surface of a stem showing transition from a Lepidodendroid to a Sigillarian (Clathrarian) form.

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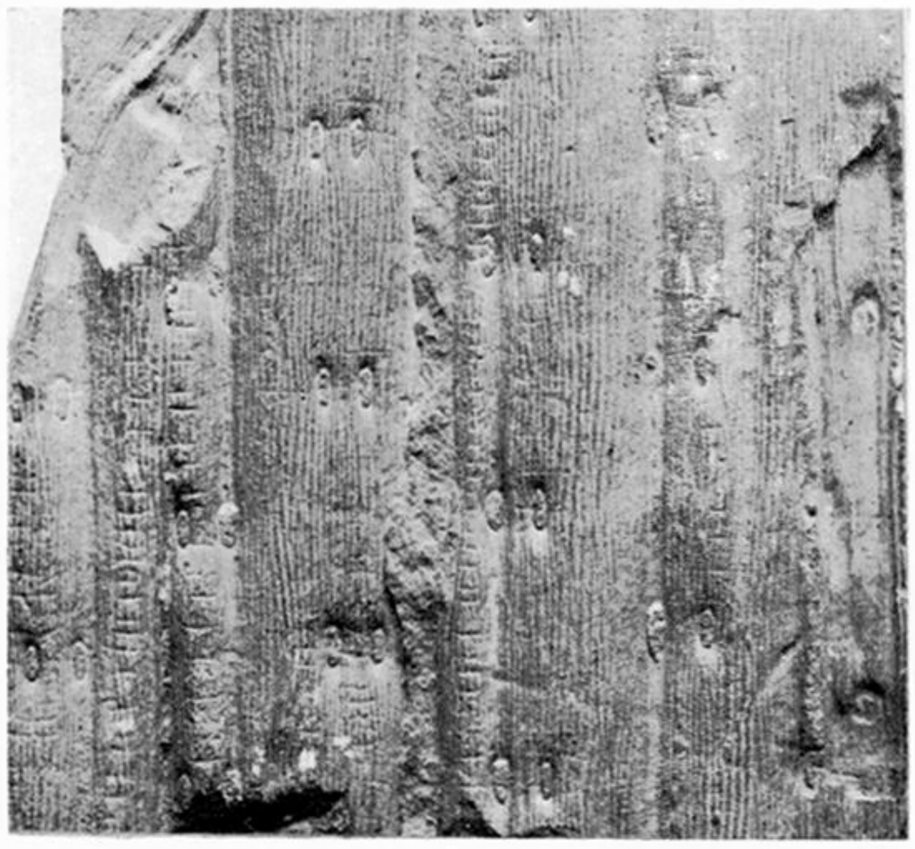

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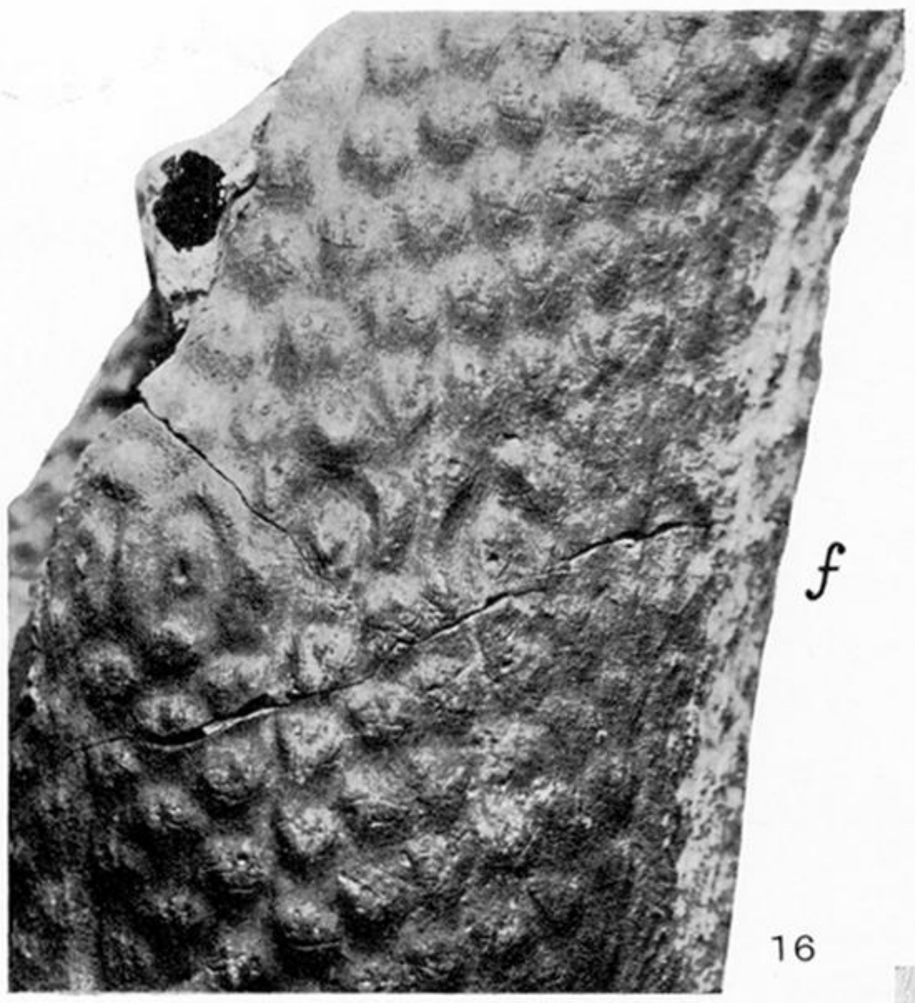

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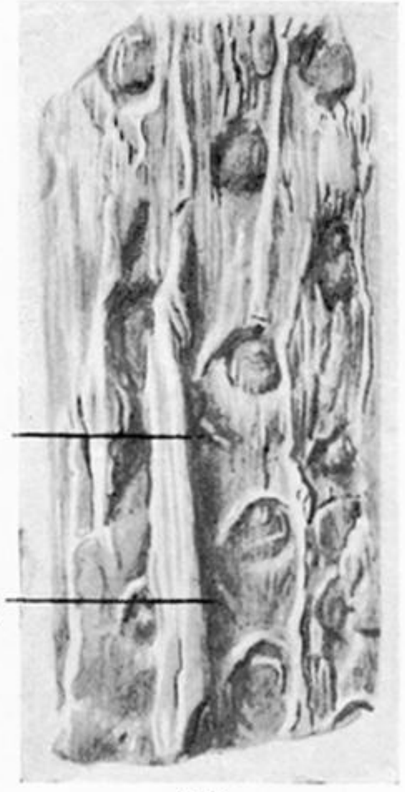

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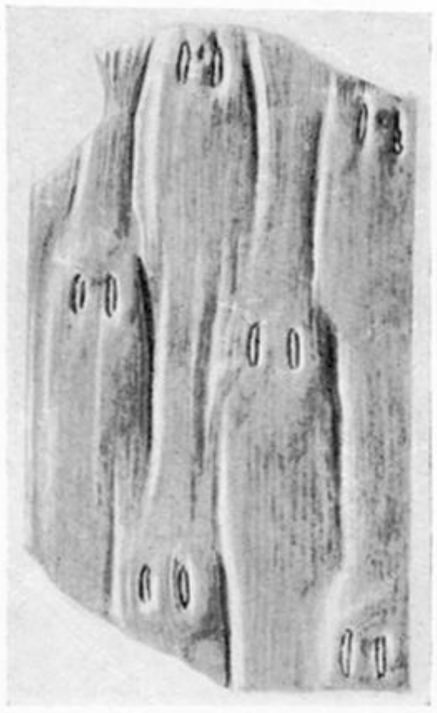

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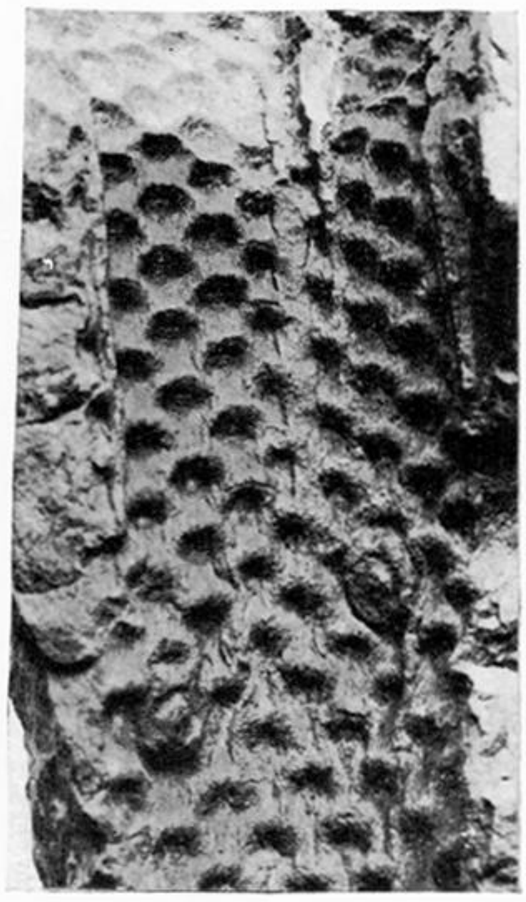

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SIGILLARIA PERSICA

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