North American Species of *Tempskya* and Their Stratigraphic Significance

GEOLOGICAL SURVEY PROFESSIONAL PAPER 874

North American Species of *Tempskya* and Their Stratigraphic Significance

By SIDNEY R. ASH *and* CHARLES B. READ

With a section on STRATIGRAPHY AND AGE OF THE *TEMPSKYA*-BEARING ROCKS OF SOUTHERN HIDALGO COUNTY, NEW MEXICO

By ROBERT A. ZELLER, JR.

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A description of two new species of the Early Cretaceous tree fern Tempskya *and a discussion of the characters and distribution of the other North American species*

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CONTENTS

ILLUSTRATIONS

[Plates follow index]

NORTH AMERICAN SPECIES OF *TEMPSKYA* AND THEIR STRATIGRAPHIC SIGNIFICANCE

By Sidney R. Ash and Charles B. Read

ABSTRACT

Two new species of the fossil tree fern *Tempskya*—*T. reesidei* and *T. zelleri*—are described in this report. Both are from the Lower Cretaceous Mojado Formation of Hidalgo County, N. Mex., and are associated with marine invertebrates that date them quite adequately. *T. reesidei* is somewhat smaller than, but reminiscent of, *T. grandis*, whereas *T. zelleri* appears to be related to the group that is characterized by *T. knowltoni*.

The report also contains a history of the investigations of *Tempskya* and a resumé of the 43 reported occurrences of *Tempskya* in the United States. In-place occurrence of the genus *Tempskya* in the United States now total 34; all but one are from west of the Mississippi River, and most of them are in strata in the Rocky Mountain area. In addition, rocks of Late Cretaceous or Cenozoic age, particularly, contain much reworked *Tempskya* material, once again in the Western United States.

In-place occurrences of the genus *Tempskya* seem to be mainly in rocks of latest Early Cretaceous (Albian) age, as indicated by the associated invertebrate fossils. The age of a few of these localities, however, is still questioned by some observers.

INTRODUCTION

In 1955, Robert A. Zeller, Jr., of the State Bureau of Mines and Mineral Resources Division of the New Mexico Institute of Mining and Technology, showed the junior author of the present report a peculiar specimen of obviously organic origin in an effort to obtain an approximate generic identification. The specimen was a poorly preserved cast in fine-grained sandstone. Read expressed the opinion that the specimen might be a fragment of the enigmatic fern genus *Tempskya* rather than a sponge which it superficially resembled. Later in 1955, the junior author accompanied Carle H. Dane, of the U.S. Geological Survey, and Zeller to the locality in the southern part of the Big Hatchet Mountain area, Hidalgo County, N. Mex., where the fossil had been obtained. On that trip, many well-preserved specimens of *Tempskya* were collected. At first (Zeller and Read, 1956), these specimens were thought to be examples of *Tempskya minor* Read and Brown. Additional study, however, now indicates that the species actually differs from all others, and it is described as *Tempskya zelleri* n. sp. in this report.

During the 1955 field trip, Zeller pointed out that the specimens of *Tempskya* were associated with many marine invertebrates. A few collections of the invertebrates were made and sent to the late John B. Reeside, Jr., for study. Later in 1955, and from then until his death in July 1958, there was active correspondence between the authors of this report and Reeside concerning the nature of the occurrence and the age of the containing strata. In the spring of 1956, Reeside visited the localities in Hidalgo County and made additional collections of the invertebrates. As indicated elsewhere in this report, he concluded, on the basis of the marine fossils, that the containing rocks are Early Cretaceous (Albian) in age.

Continued correspondence between Reeside and Read led to speculation that all the American occurrences of the genus *Tempskya* may be in Albian strata. Unfortunately, before Dr. Reeside's death, it was impossible for the junior author of this report to go into the details of the many occurrences. However, early in 1959, a detailed study of the new species from the Big Hatchet Mountains began, together with the assembling of data on American occurrences in general.

Later in 1959, Robert A. Zeller obtained additional specimens of *Tempskya* in similar Cretaceous marine strata on the eastern flanks of the Animas Mountains, Hidalgo County, N. Mex. These specimens were determined to belong to a second new species, here to be named and described as *Tempskya reesidei*. In 1960, the authors of this report visited the locality with Zeller and collected a considerable quantity of material, including additional pieces of the false trunk of the holotype and of the paratype as shown in figure 8.

It was then decided to reevaluate the various species of *Tempskya* that are known in the United

States, both as regards their morphologic characteristics and also the stratigraphic occurrences. The principal product of the study is this report, although a preliminary paper assessing the stratigraphic value of *Tempskya* in the western United States has been published (Read and Ash, 1961b).

Early during this investigation it was recognized that the association of marine invertebrates with *Tempskya* in southwestern New Mexico was especially significant. As a result, during the mid-1960's, Zeller prepared a section for this report in which he discussed the Lower Cretaceous stratigraphy of the area and described the occurrence of invertebrates with the fern in some detail. Since then, it has become necessary to make a few changes in the section in order to bring it up to date. Unfortunately, Zeller's unexpected death early in 1970 prevented him from seeing these changes. They, however, are so small that they do not modify the section in any essentials, and it is still very close to the version originally submitted by Zeller.

ACKNOWLEDGMENTS

The writers are indebted to Professor Chester A. Arnold, University of Michigan, for the loan of type slides and the gift of type material of *Tempskya wesselii*, *T. wyomingensis*, and *T. superba*, which have been used in this report. We are also indebted to Sergius H. Mamay and Arthur D. Watt, U.S. Geological Survey, for the loan of thin sections and type material of *T. grandis*, *T. knowltoni*, and *T. minor*, and also for locality data regarding occurrences of *Tempskya*. E. Guerry Newton, U.S. Geological Survey, has checked the bibliography used in this report.

John D. Strobell, U.S. Geological Survey, made a special trip to the Carrizo Mountains, Ariz. and N. Mex., to help the junior author collect from a locality earlier discovered by Strobell. Thanks are here expressed for the interest and encouragement given by the late Carle H. Dane, U.S. Geological Survey, in connection with the study.

The late Esther R. Applin, U.S. Geological Survey, supplied helpful information on the vertical range of *Cribratina texana*, one of the critically diagnostic Foraminifera used in stratigraphic correlation of the Lower Cretaceous rocks in southwestern New Mexico. Mr. Takio Suski, University of California, Los Angeles, identified some of the earlier invertebrate collections that were made by Zeller. The staff of paleontologists of the U.S. Geological Survey and the U.S. National Museum (Natural History) have made identifications of most of the collections of invertebrate fossils, and their contributions are acknowledged with thanks. They include Norman F. Sohl, who studied the gastropods; Ruth Todd, who examined the Foraminifera; the late John B. Reeside, Jr., who reviewed the entire fauna; and W. A. Cobban, who worked on the marine fauna from the Animas Mountains.

Dr. Eugene Callaghan, former director of New Mexico Bureau of Mines and Mineral Resources, supported and personally encouraged the earlier efforts of Zeller in connection with the stratigraphic study of the Cretaceous rocks that led to the discovery of *Tempskya* in southwestern New Mexico. Mr. Allen M. Alper of the Corning Glass Company worked with Zeller in the mapping of the Mojado Formation in the Animas Mountains, a project that led to the discovery of one of the new species here described.

The assistance of Mr. W. R. West, Carolina Biological Supply Company, who supplied us with information on the new occurrence of *Tempskya* in North Carolina, is appreciated.

Finally, the writers wish to acknowledge particularly the aid and encouragement of W. W. Rubey and the late John B. Reeside, Jr. Rubey, who for many years has conducted stratigraphic and structural studies in western Wyoming and adjacent parts of Idaho, is responsible for many of the discoveries of *Tempskya* localities and has provided much thoughtful and helpful information regarding the stratigraphic occurrences. Reeside encouraged Brown and Read during their earlier investigations of *Tempskya* and was both extremely interested in and actively concerned with the occurrences of *Tempskya* in southwestern New Mexico.

HISTORY OF INVESTIGATIONS OF *TEMPSKYA*

In 1937, the junior author and one of his associates published a historical statement regarding the genus *Tempskya*. The report (Read and Brown, 1937) has been out of print for some time. In consequence, a summary is needed of the historical account earlier published.

The first written record of *Tempskya* is an account of *Endogenites erosa* (Stokes and Webb, 1824) in a report on the plant material collected by Mantell in Tilgate forest. The plant material was believed to have affinities with palms, hence the name.

Cotta (1832) described similar material under the name *Porosus marginatus* and suggested that it might be part of a large fern stem. Mantell (1833) agreed with this opinion after reexamining material he himself had collected some 10 years before.

Fitten (1836) described similar material collected near Hastings. He returned apparently to the opinion of Stokes and Webb (1824) and referred the specimens to *Endogenites erosa.*

Unger (1845) reexamined the material under question, as well as new collections, and expressed his opinion that *Endogenites erosa* was simply a mode of preservation of *Protopteris. Protopteris* was the generic name used in the early days of paleobotany for certain fern stems that were either petrified or preserved as casts or molds.

In 1845, Corda published his observations on a large series of petrifications of various types and established the genus *Tempskya* in honor of a contemporary naturalist, Tempsky. The type material was four specimens from localities in Bohemia and adjacent regions. The generic description (Corda, 1845, p. 81) is as follows:

Truncus * * * Rachis rotundata, plicata vel alata; cortice crassiuscula, fasciculis vasorum ternatis, majori clauso vel lunulato et supra incurvo, minoribus oppositis lunulatis. Radices minutae numerosissimae; fasciculo vasorum centrali unico.

Corda's interpretation was that *Tempskya* was a member of the *Phthoropterides.* The material was believed to be silicified masses of branched petioles, sheathed by a thick mat of roots. The species *T. pulchra, T. macrocaula, T. microrrhiza,* and *T. schimperi* were described. The preservation of the material that Corda studied appears to be rather poor. In consequence, although the account is historically quite important, few data of morphological value resulted from the investigation.

In 1871, Schenk suggested that *Tempskya* is a complete stem of marattiaceous affinities, the vascular bundles being sheathed in a ground mass of parenchyma and sclerenchyma.

Feistmantel in 1872 suggested that *Tempskya* is not a valid genus but rather a type of preservation of certain kinds of fern stems. This opinion impressed a number of investigators, and several papers were published in support of the opinion. Velenovsky (1888) supported the theory and produced additional corroborative evidence.

Seward, in his catalog of the Wealden flora published in 1894, included a very interesting and valuable account of the literature on *Tempskya.* Feistmantel's ideas were seriously questioned, although not completely discredited. Seward's conclusions (1894, p. 158) are as follows:

In *Tempskya schimperi* we have masses of branched diarch fern roots associated with petiole axes, which occasionally afford evidence of branching; probably some forms of *Tempskya* and *Protopteris* are very closely related, if not identical plants; but, so far as English specimens are concerned, there is an absence of any direct proof of such organic connection between the two fossils, as Feistmantel and Velenovsky have previously suggested.

The true nature of *Tempskya* was first tentatively hinted in 1897 by Stenzel, who offered three possible morphological explanations:

1. Lateral organs of a tree fern growing downward and encased in downward-growing roots. (This hypothesis is similar to that suggested by Corda, although not identical with it.)
2. Independent stems climbing upward between roots.
3. Upward-growing and branching fern stems encased in their own downward-growing roots.

Stenzel appears to have preferred the third explanation, although there is no final commitment. This explanation is the one accepted by all later investigators.

Detailed morphological studies of well-preserved *Tempskya* material were carried out for the first time in 1911 by Kidston and Gwynne-Vaughan. These investigators described *T. rossica* from the Karanganda River basin in Russia. Although the material is very well preserved, its geologic age is uncertain; the material came from a Tertiary conglomerate but, in the opinion of all investigators, has been reworked from older strata. These investigators concluded that the siliceous masses that had caused so much speculation in the past were false trunks, or dichotomously branching systems of stems sheathed in a mass of adventitious roots. Kidston and Gwynne-Vaughan speculated on the growth habit of *T. rossica* and suggested that it may have stood erect and produced a crown of leaves or fronds. Although they were unable to establish close affinities, they suggested that *Tempskya* belongs in some family of the Leptosporangiatae.

The first American material referred to *Tempskya* was described by Berry (1911b) from the Patapsco Formation of the Atlantic Coastal Plain. The material is poorly preserved, and although the validity of the generic identification is unquestioned, Berry's account of *T. whitei* does not contribute greatly to morphological knowledge.

In 1915, Dr. Marie Stopes presented a summary of investigations of *Tempskya* in the catalog of Lower Greensand plants of Great Britain. In addition, she redescribed *T. erosa* which, as stated above, was the first species to be noted. Stopes included a reconstruction of *T. rossica* which was provided by Kidston and Gwynne-Vaughn. The drawing shows an erect false trunk with a terminal cluster of small fronds similar to those borne by modern tree ferns and cycads. (See fig. 1.)

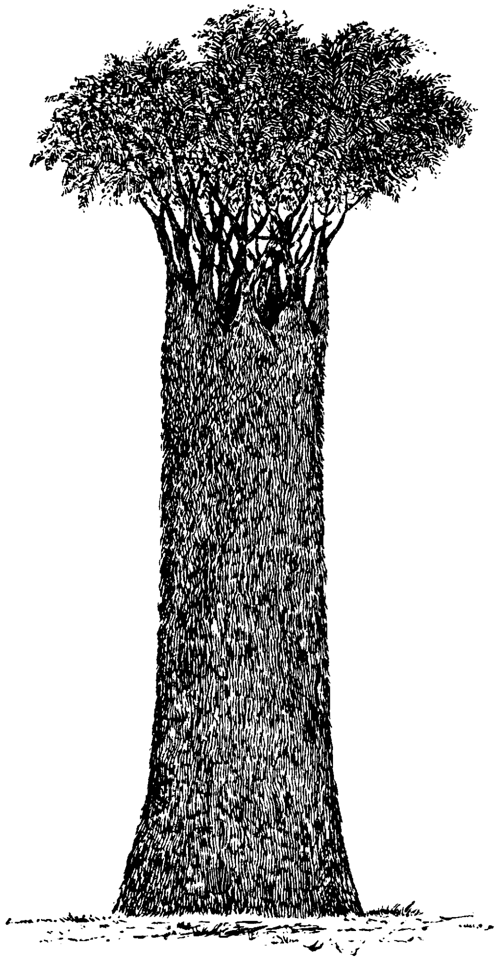


FIGURE 1.—Restoration of *Tempskya rossica* by Kidston and Gwynne-Vaughn. The figure is based mainly on the specimen of *T. rossica* they described in 1911 from the Karaganda River basin of Russia. It was first published by Stopes (1915, text-fig. 5, p. 15) and is reproduced here with the permission of the Trustees of the British Museum (Natural History).

Professor A. C. Seward of Cambridge University described the first well-preserved specimen of *Tempskya* from the United States in 1924. The specimen was obtained by A. C. Silberling in 1908 from the Cretaceous rocks in the valley of the Musselshell River in central Montana. Because of the nature of the preservation, the specimen was at first interpreted as a caudal spine of the dinosaur *Stegosaurus*. (See Seward 1924, p. 485.) F. H. Knowlton recognized the true nature of the material, but, being busy on other investigations, suggested that it would be appropriate for Seward to study the specimen. *Tempskya knowltoni* is a very well preserved specimen, and the study in general corroborates that of Kidston and Gwynne-Vaughn on *T. rossica*. There is one significant difference between the two species, however. In *T. knowltoni*, the entire false stem is dorsiventral by reason of the orientation of the individual true stems; this arrangement caused Seward (1924, p. 505) to describe *T. knowltoni* as "a root-encircled bundle of stems, obconical and tapering, lying obliquely in the soil, a few of the stem branches bearing crowded fronds near the ground level." Seward suggested that *Tempskya* may be a member of the Schizaeaceae. This conclusion was arrived at partly on the basis of stelar similarities and in part on the characteristics of spores and sporangia that were found not only in *T. knowltoni*, but also in some of the English material.

During the period 1930–35, W. W. Rubey and several of his associates were quite active in carrying out a mapping program in eastern Idaho and adjacent parts of Wyoming. Many specimens of *Tempskya* were collected from the Wayan Formation of Idaho and the Aspen Shale of Wyoming. These units, which are in part correlative, are classified as Cretaceous in age. The abundant well-preserved material collected by this group was of sufficient interest to Read and Brown that they decided to collaborate in an account. The report was published in 1937 and was an attempt to discuss all the *Tempskya* material known at that time in the United States. Two new species, *T. grandis* and *T. minor*, were described, and additional observations were published on *T. knowltoni* and *T. whitei*.

Two groups or subgenera of *Tempskya* were recognized on the basis of radial symmetry of the false trunks in one group as opposed to the dorsiventral nature of the false trunks in the other group. After the characteristics of the various species of *Tempskya* had been reviewed and compared with those of modern ferns, it was concluded that a new family, the Tempskyaceae, should be provisionally established inasmuch as within the Leptosporangiatae reasonable comparisons may be made between the species of *Tempskya* and the Schizaeaceae, the Loxsomaceae, and the Gleicheniaceae.

Read and Brown (1937) speculated on the probable growth habit of the species of *Tempskya* and suggested that in the case of the group represented by *T. grandis*, all the facts, including the radial symmetry of the false trunks, supported the idea that these ferns had a habit similar to that of low tree ferns. However, they noted that the plants represented by the dorsiventral false trunk types typified by *T. knowltoni* might have had a liana- or vinelike growth habit. An attempt was made to discuss the stratigraphic significance of the American tempskyas. Read and Brown concluded that in the Western United States, the genus *Tempskya* ranges in age from Turonian to Senonian. However, in the Eastern United States, *T. whitei* occurs in Albian rocks and hence is older than the western occurrences. These conclusions were, of course, based to a large extent on the opinions then held by invertebrate paleontologists regarding the age of the containing rocks. Material was reported from Wyoming, Idaho, Montana, Oregon, Nevada, Utah, and Maryland.

In 1939, Read published a summary of his views on the growth habit of *Tempskya* and on the possible course of development of the habit. He restated the opinion that on the basis of the morphology of the false trunks there are two groups of *Tempskya*, one of which is radially symmetrical and the other dorsiventral. The dorsiventral false trunk types were believed to have been lianalike and also to have been the more primitive group. He speculated that the radial forms were developed from these climbing types as a result of the assumption of a free upright habit. This change may have been quite accidental, or possibly the result of an increase in rigidity of the composite organ because of increase in size of the true stems.

Another American who has studied *Tempskya* is Chester A. Arnold. In 1945, he described two new species, *T. wesselii* from Montana and Oregon and *T. wyomingensis* from Wyoming. The concept of two groups or subgenera of *Tempskya* proposed by Read and Brown (1937) was accepted by Arnold, with certain reservations, and he placed his new species in the radially symmetrical group.

Later, Arnold (1958) described a new species of *Tempskya* from Nebraska and named it *T. superba*. This species is similar to *T. grandis* internally, but the stems of *T. superba* are larger than those of *T. grandis*. This new species also was assigned to the radially symmetrical group.

In 1947, Andrews and Kern published a very excellent discussion of large collections of *Tempskya* material made by Thomas, Manion, and Andrews. Their report contributes very little to the morphological details described by Kidston and Gwynne-Vaughn, Seward, and Read and Brown, but the paper has a very stimulating discussion of false trunk morphology. These investigators suggested that in all probability all the false trunks referred to *Tempskya* were originally radially symmetrical and that accidents of preservation are responsible for the alleged dorsiventral types. Their reconstruction of a radially symmetrical *Tempskya* shows a treelike fern in which the upper two-thirds of the false trunk is characterized by irregular clusters of small fronds (see fig. 2). Andrews and Kern made comparisons between *Tempskya* and *Hemitelia smithii*, *H. crenulata*, *Todea barbara*, and *Dicksonia fibrosa*. In addition, they discussed the late Paleozoic zygop-

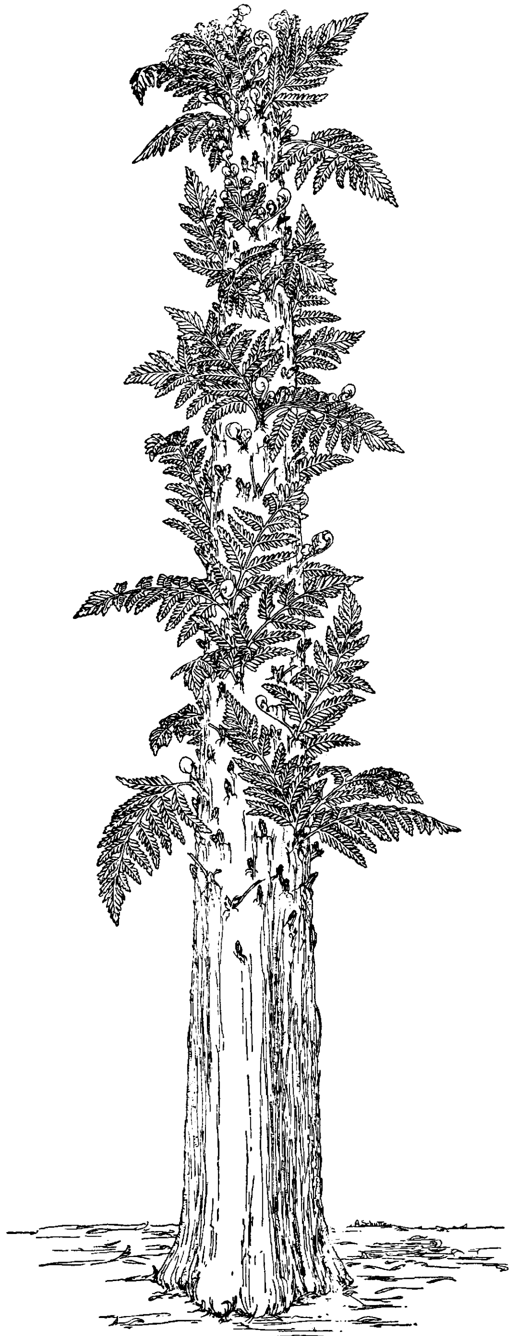


FIGURE 2.—Reconstruction of *Tempskya* by Andrews and Kern (1947). The figure is based mainly on specimens of *T. wesselii* Arnold (1945) from the Wayan Formation of southeastern Idaho. Reprinted with the kind permission of H. N. Andrews.

terid tree fern *Clepsydropsis australis* and pointed out analogies with *Tempskya.*

In 1961, the authors of the present report reappraised (Read and Ash, 1961a, b) the stratigraphic distribution of *Tempskya* in the western part of the United States in the light of modern data. We showed that specimens of the genus often occur in or adjacent to marine units containing invertebrates of latest Early Cretaceous (Albian) age. We concluded, therefore, that the age of *Tempskya* is more restricted than formerly thought (Read and Brown, 1937) and that the genus is probably of latest Early Cretaceous (Albian) age in the Western United States.

In 1968, a new *Tempskya* was described from southern England by Chandler. The single small specimen on which her study is based resembles *T. grandis,* but because of the limited amount of material available, it was not referred to a species. The age of the specimen is questionable, as it was found on the surface of the beach at the famous upper Eocene London Clay plant locality near Sheppey in Kent. The new *Tempskya* is silicified, whereas plant remains in the London Clay are usually pyritized or preserved in some other manner. Thus, it seems unlikely that the new *Tempskya* was originally deposited in the London Clay. Chandler suggested (1968, p. 179) that the most likely source of the specimen is the lower Eocene Woolwich Beds, which are exposed at nearby Herne Bay and which contain silicified dicotyledonous wood. Another likely source for the specimen is the Lower Cretaceous Lower Greensand, which is exposed in nearby areas and which yielded *T. erosa,* the first species of the genus to be recognized.

Several nicely preserved specimens of *Tempskya* have been reported from gravel deposits in Harnett County, N.C., by West (1968, 1970) of the Carolina Biological Supply Company. The fossils have not yet been described, but pictures supplied by Mr. West show that they do not represent any of the species considered in this report.

OCCURRENCES OF *TEMPSKYA* IN THE UNITED STATES

Specimens of *Tempskya* have been reported from about 43 localities in the United States (fig. 3). Most of the localities are in the Rocky Mountain geosyncline region of the western interior of the United States. Two are in the Mexican geosyncline area in the southwestern United States, and two are in the Eastern United States. Thirty-four of these localities contain specimens that are in place. These in-place specimens in the Rocky Mountain geosyncline area are considered first, by formations from north to south. Those in the Mexican geosyncline region and the one in the Atlantic Coastal Plain in the Eastern United States are then briefly discussed. Specimens that clearly have been reworked into Tertiary or Quaternary formations from older rocks are dealt with last. Locality numbers used in the text are keyed to the index map (fig. 3), and in-place specimens are keyed to the correlation chart (fig. 4).

IN-PLACE SPECIMENS

ROCKY MOUNTAIN GEOSYNCLINE

BLACKLEAF FORMATION

The holotype of *Tempskya wesselii* was collected from the "bad lands" northwest of Great Falls, Mont., at locality 1 (fig. 4) by Louis Wessel (Arnold, 1945, p. 26). The collector thought that the specimen came from the Kootenai Formation of Early Cretaceous age. It may have come, however, from the overlying Blackleaf Formation, which is also exposed in the area and which is known to contain *Tempskya* a few miles south of the "bad lands" at locality 2. Specimens of *T. knowltoni* have been collected from the Vaughn Member of the Blackleaf Formation (of the Colorado Group) west of Great Falls at locality 2, as reported by Cobban (1951, p. 2180). These specimens, which were identified by R. W. Brown, occur in the so-called red speck zone. An additional specimen of *Tempskya* sp. was collected by Fergus Mitchell in 1947 near locality 3. It probably was also derived from the "red speck zone" or adjacent strata.

The Bootlegger Member of the Blackleaf, which overlies the Vaughn Member, contains the ammonite *Neogastroplites,* which is considered to be of late Albian Age (Reeside and Cobban, 1960, p. 17, 60; Cobban and others, 1959, p. 2792). Thus, the specimens of *Tempskya* in the Blackleaf are of late Early Cretaceous (Albian) age or slightly older.

COLORADO GROUP (UNDIFFERENTIATED)

The first well-preserved example of the genus *Tempskya* to be described from the United States was obtained by A. C. Silberling in 1908 in Montana at locality 4. The fossil was eventually sent to Professor A. C. Seward who published (1924) an account of the specimen, naming it *T. knowltoni.* At that time it was thought that the specimen probably came from the Kootenai Formation of Early Cretaceous age. Later, when Read and Brown (1937) redescribed *T. knowltoni,* they showed that the specimen undoubtedly came from what is now called the shale and sandstone member of the Colorado Shale.

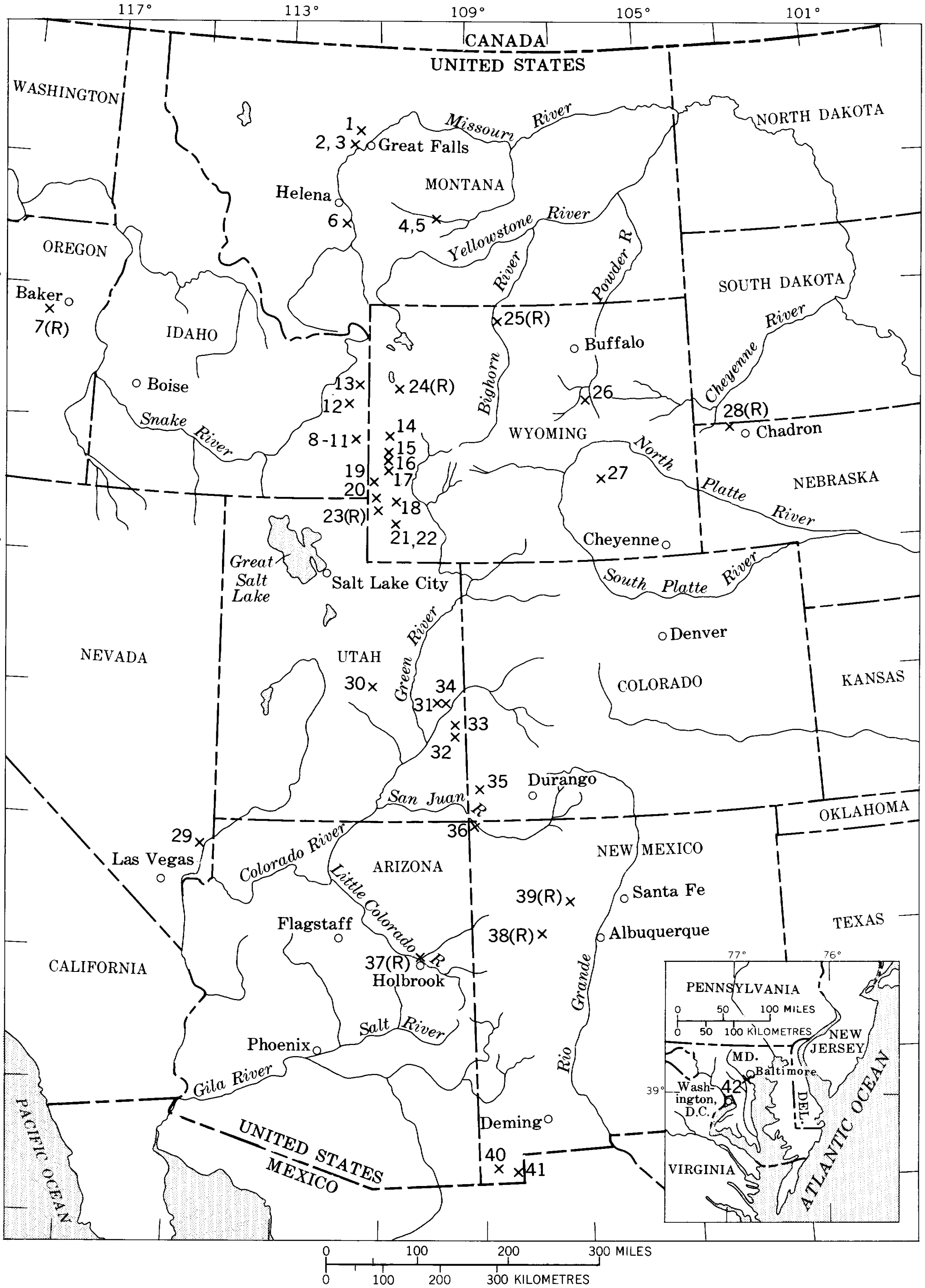


FIGURE 3.—General location of occurrences (×) of *Tempskya* spp. in the United States. Numbers refer to localities mentioned in text and figure 4; (R) indicates that remains of this plant have been reworked from Cretaceous rocks into younger units.

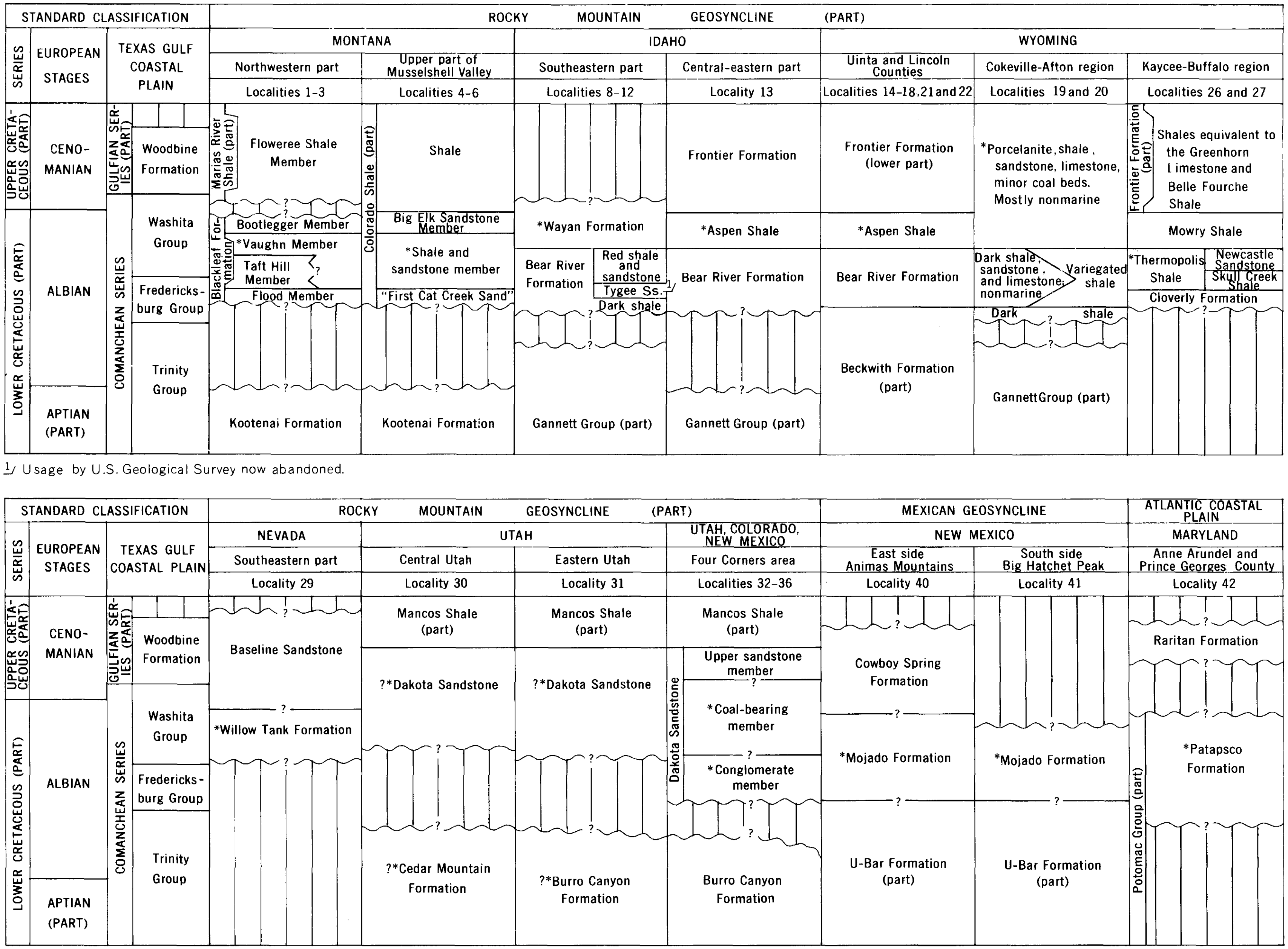


FIGURE 4.—Correlation chart of parts of the Cretaceous System at selected localities in the United States showing rock sequences where *Tempskya* spp. have been reported. Formations containing *Tempskya* are marked by an asterisk (*). Locality numbers keyed to figure 3 and text. Correlations from Cobban and Reeside (1952), Reeside and Cobban (1960), and L. C. Craig (written commun., 1963).

Arnold (1945, p. 30) reported the occurrence of *T. grandis* in Wheatland County, Mont. Probably this specimen also came from the *Tempskya*-bearing zone in the lower part of the Colorado Shale in the Musselshell valley, Mont., near locality 5. An additional specimen of *Tempskya* was obtained from the lower part of the Colorado Shale at locality 6 in Broadwater County, Mont., by Klepper (1950). The strata at the locality are equivalent to the *Tempskya*-bearing Mowry Shale to the south and the shale and sandstone member of the Colorado Shale which contains *Tempskya* several miles to the east.

Several species of the late Albian fossil *Neogastroplites* have been identified (Reeside and Cobban, 1960, p. 17, 21, 27) in the same zone that contains *Tempskya* at localities 4–6 in Montana. Thus, the specimens of *Tempskya* occurring at these localities evidently are of late Early Cretaceous (Albian) age.

WAYAN FORMATION

Read and Brown (1937, p. 127) reported that G. R. Mansfield, W. W. Rubey, and J. S. Williams found several specimens of *T. minor* loose on the surface of the Wayan Formation southeast of Grays Lake, Idaho, at locality 8. Additional specimens also were seen but not collected at locality 9, northwest of Grays Lake. It was thought that all the specimens were derived from the uppermost part of the Wayan Formation.

Additional collections were made in nearby areas at localities 10 and 11 by C. Henry Thomas and Henry N. Andrews during the late 1930's and in the 1940's. Another locality (12) was found about 40 miles to the northwest. Collections were made here during the 1940's by Mr. E. Manion and Mr. H. N. Andrews. Andrews (1961, p. 117) believes that at this new locality *Tempskya* occurs in the Wayan Formation. The collections of Thomas and Andrews and Manion and Andrews have been discussed in several publications (Andrews 1943, 1948, 1961; Andrews and Kern, 1947).

Apparently in all of these localities *Tempskya* spp. are present only in the upper half of the Wayan in Rubey's units D and E (Moritz, 1953, p. 68–69). Rubey correlated his unit D with the upper part of the Bear River Formation of Wyoming and his unit E with the Aspen Shale and the basal part of the Frontier Formation of Wyoming. Cobban and Reeside (1952a, chart 10b, cols. 62 and 63) showed the Wayan as being equivalent to the Aspen Shale and the base of the Frontier Formation.

As shown elsewhere in this report, it has been established on the basis of marine faunas that the Bear River Formation and the Aspen Shale are of late Early Cretaceous (Albian) age. If the stratigraphic correlations between these formations and the *Tempskya*-bearing upper part of the Wayan Formation are correct, then the age of that part of the Wayan and of the *Tempskya* spp. in it is also late Early Cretaceous (Albian).

The present writers agree with the statement by Read and Brown (1937, p. 127) that

> The finding of *Tempskya minor* in the Wayan formation only 40 miles distant from the Aspen localities in Wyoming, in a region of relatively similar lithology, indicates a fairly close correlation in age, and that the Wayan formation, or a portion of it, may reasonably be regarded as of Colorado age and the time equivalent of the Aspen shale of Wyoming.

ASPEN SHALE

Idaho.—A specimen of *Tempskya* sp. was collected by W. W. Rubey in 1934 from the Aspen Shale about 400 feet above the Bear River Formation in eastern Idaho at locality 13 (USGS fossil plant loc. 8425 TBI). Here, as in western Wyoming, the Aspen consists of olive-green and gray-green siliceous shale, tan sandstone, porcelanite and greenish siltstone or fine-grained sandstone, according to Moritz (1953, p. 69). The Aspen Shale of Idaho is generally considered to be correlative with the Aspen Shale of southwestern Wyoming (Cobban and Reeside, 1952a). The occurrence of *Tempskya* sp. in the Aspen Shale in both Idaho and Wyoming is additional evidence for this correlation.

In Wyoming, the Aspen Shale is now thought to be of late Early Cretaceous (Albian) age by most geologists as discussed below. If the correlation of the Aspen Shale in Idaho and Wyoming is justified and the current age assignment of the Aspen in Wyoming is correct, then it can be concluded that the Aspen Shale in Idaho and the specimens of *Tempskya* sp. which occur in it are probably of late Early Cretaceous (Albian) age.

Wyoming.—Several specimens of *T. grandis* and *T. minor* were collected by W. W. Rubey and J. S. Williams during the early 1930's from the Aspen Shale at localities 14 and 15 in western Wyoming. There is a good exposure of the Aspen Shale and adjacent formations in sec. 17, T. 35 N., R. 115 W., near locality 14; a generalized section which illustrates the lithology of these rocks was published previously (Read and Brown, 1937, p. 126). It shows that the Aspen Shale is about 1,200 feet thick in this area and consists mainly of gray shale and thin beds of gray tuffaceous sandstone. The specimens of *Tempskya* occur in the lower part of the Aspen approximately 400 feet above the Bear River Formation.

Other examples of *Tempskya* have been obtained from the Aspen Shale in western and southwestern Wyoming at localities 16–18 by Rubey during the 1950's. He and Reeside also collected specimens from a porcelanite bed at localities 19 and 20 that they consider to be a nearshore equivalent of the Aspen Shale.

Several specimens of *Tempskya* have been collected in southwestern Wyoming near locality 21 by Rubey and Reeside in 1949 and at locality 22 by H. R. Christner in 1950. Here they were found in strata which have been referred to the basal part of of the Frontier by Cobban and Reeside (1952b). Rubey, however, preferred to place these strata in the Aspen Shale (written commun., 1961). Judging by the other occurrences of *Tempskya* in the Aspen Shale of nearby areas, the writers agree with Rubey and would prefer to consider the strata in question as the upper part of the Aspen Shale rather than basal Frontier.

The Aspen Shale was considered to be of early Late Cretaceous (Cenomanian) age until 1951. In that year, Cobban and Reeside (1951) demonstrated that the impressions and crushed internal molds of ammonites that occur in the Aspen and other formations in the western United States had been misidentified. Actually the fossils belong to genera that are apparently of late Early Cretaceous (Albian) age. Thus, the Aspen and certain other formations in the western interior of the United States were classified as probably of late Early Cretaceous age. Yen (1952, p. 757, 764) disagreed with the age revision because he identified fresh-water mollusks that he considered to be of early Late Cretaceous (Cenomanian) age in the underlying Bear River Formation. Nevertheless, Cobban and Reeside have continued to argue for a late Early Cretaceous age for the Aspen, although they recognize that it might possibly be of early Late Cretaceous (Cenomanian) age (Cobban and Reeside, 1952a; Reeside and Cobban, 1960; Moritz, 1953, p. 69). At any rate, the Aspen Shale now is generally regarded as being of late Early Cretaceous (Albian) age. Thus, the specimens of *Tempskya* sp. occurring in the Aspen are also of latest Early Cretaceous (Albian) age.

THERMOPOLIS SHALE

A specimen of *Tempskya minor* was collected from the Thermopolis Shale in the Powder River valley area of Wyoming at locality 26 by C. H. Wegemann in 1910 (Read and Brown, 1937, p. 127). It was associated with a coal bed 25 feet below the base of the overlying Mowry Shale and in a unit just above the Muddy Sandstone Member of the Thermopolis, which is sometimes included in the Mowry (Reeside and Cobban, 1960, p. 4). Another specimen of *Tempskya* was collected about 35 miles northeast of Medicine Bow, Wyo., at locality 27 by B. W. Siegmund in 1939. He indicated that the specimen came from a gray shale bed. The Thermopolis Shale is exposed in this area and does contain *Tempskya* about 100 miles to the north at locality 26 in the Powder River area, so it is assumed that the *Tempskya* at locality 27 probably came from the Thermopolis.

Until recently the Thermopolis Shale was thought to be of early Late Cretaceous age. However, the recognition of the probable late Early Cretaceous ammonite *Neogastroplites* in it at several localities has recently caused geologists to regard it as Albian (Cobban and Reeside, 1951, p, 1893; Reeside and Cobban, 1960, p. 48–49). This age assignment is supported by the discovery of arenaceous Foraminifera in the Thermopolis as reported by Eicher (1958, p. 80–81). He found that the previously described species that occur in the shale below the Muddy Sandstone Member of the Thermopolis had been reported from rocks of late Early Cretaceous age in Kansas, Texas, Alaska, and western Canada. Some of the species in the shale overlying the Muddy Sandstone Member are known only from rocks of late Early Cretaceous age in Alaska and western Canada. Skolnick (1958a, b) has described an assemblage of Early Cretaceous Foraminifera in the Newcastle Sandstone and the Skull Creek Shale, which are equivalent to the Thermopolis, and in the lower part of the Mowry Shale, which overlies the Thermopolis Shale. Thus, it can be concluded that the Thermopolis Shale in the Powder River valley and the specimens of *Tempskya* occurring in it at locality 26 and possibly at locality 27 are of late Early Cretaceous (Albian) age.

WILLOW TANK FORMATION

In 1934, fragments of silicified plant material collected from the Overton Fanglomerate of southeastern Nevada at locality 29 by Eugene Callaghan and W. W. Rubey were identified by R. W. Brown as *Tempskya* sp. In 1937, these fragments were referred to the new species *T. minor* by Read and Brown. They were obtained from a bed of gray clay about 100 feet thick that overlies a thin conglomerate in the lower part of the Overton, 6 miles southwest of Kaolin, Nev. (Rubey and Callaghan, 1936, p. 121). The remains of another fern *Microtaenia paucifolia* were found several hundred feet above the zone containing *Tempskya.* Such fern fronds are known elsewhere only in the Aspen and Frontier Formations. Originally the entire thickness of the Overton had been considered of probable Tertiary age by Longwell (1928, p. 89). However, on the basis of the specimens of *T. minor* and *Microtaenia paucifolia,* both of which were known only from what was thought at that time to be the lower to middle part of the Upper Cretaceous, the lower part of the Overton was classified as of early or middle Late Cretaceous age (Rubey and Callaghan, 1936, p. 121–122; Read and Brown, 1937, p. 127).

Subsequently, Longwell (1949) divided the lower half of the Overton into two formations, applying the name Willow Tank to the lower formation, which includes the *Tempskya*-bearing zone, and the name Baseline Sandstone to the overlying formation, which contains *Microtaenia paucifolia* near the base. The name Overton Fanglomerate was retained for only the upper half of the original Overton. An additional collection of fossils was obtained from the Willow Tank Formation by Longwell, who submitted it to John B. Reeside, Jr., for study. The following forms were identified by him:

Unio aff. *U. hamili* McLearn and *U. vetustus* Meek
Unio sp., fragments of a large oval form
Diplodon? n. sp.
Musculiopsis? sp.
Viviparus cf. *V. montanensis* Stanton
Lioplax? cf. *L.*? *endlichi* (White) and *Coniobasis ortmanni* Stanton
Melampus? cf. *M. caurinus* McLearn
Physa cf. *P. usitata* White
Lymnaea (*Pleurolimnaea*) n. sp.
Planorbis (*Gyraulus*) cf. *P. praecursoris* White
Helix? sp.
Cyprid ostracodes, several species
Fish teeth and bones
Fruits of *Chara* or a related plant

Reeside (written commun., 1956) stated:

> The most significant specimens are two beak fragments of a corrugated *Unio* that belongs to a type we have not had above the Bear River, i.e., early Upper Cretaceous. * * * My best judgment of the age of the beds, based on the fauna alone, is that they are not younger than early Upper Cretaceous and might be as old as the Lower Cretaceous beds at Eureka, Nevada. However, the *Tempskya* argues strongly for early Upper Cretaceous. The assemblage, incidentally, is that of a quiet pond.

R. E. Peck (written commun., 1956) identified the fossil fruits of *Chara* and related plants collected by Longwell and concluded that the *Chara*-bearing bed

> is pretty close to Bear River in age. My conclusion is based on the occurrence of *Aclistochara mundula* Peck—range, Upper and Lower Cretaceous, abundant throughout the Gannett group, upper part of the Kootenai, and Bear River, especially characteristic of the Bear River; *Chara* cf. *C. stantoni* Knowlton —*C. stantoni* is known only from the Bear River; numerous specimens of a species of *Metacypris* that are also found in the Gannett group and Bear River.

Peck (1957) has confirmed these stratigraphic occurrences of the fruits of *Chara* and related plants.

In summary, the fossils indicate that the Willow Tank Formation is probably equivalent to the Bear River and possibly to older formations, and that the lower part of the overlying Baseline Sandstone is equivalent to the younger Aspen Shale and Frontier Formation. Following the findings of the paleontologists, Longwell classified the Willow Tank Formation and the Baseline Sandstone as of Late Cretaceous age and the restricted Overton Fanglomerate as of early Cenozoic or Late Cretaceous age.

Since the work of Longwell, the Bear River Formation and the Aspen Shale have been reclassified as of late Early Cretaceous age (Albian) by Cobban and Reeside (1952a), and Reeside and Cobban (1960). Therefore, it can be concluded that the *Tempskya*-bearing Willow Tank Formation, which has been correlated with the Bear River, is of late Early Cretaceous age and that the specimens of *Tempskya minor* found in that formation are also of that age.

CEDAR MOUNTAIN FORMATION

Specimens of *Tempskya* have been collected from the Cedar Mountain Formation near the type locality of that formation in central Utah at locality 30 by W. L. Stokes (1944) and P. J. Katich, Jr. (1951). Those collected by Katich (1951, p. 2094) were identified only as *Tempskya* sp., whereas those collected by Stokes (1952, p. 1769) were identified tentatively as *T. minor*. More recently, Tidwell and Hebbert (1972) have discussed the occurrence of *Tempskya* in the Cedar Mountain near locality 30.

The Cedar Mountain Formation contains a few other fossils besides *Tempskya,* such as bone fragments of dinosaurs and other vertebrates, freshwater ostracodes, pelecypods, gastropods, and several plant fossils. Peck examined some of the fossils and came to the following conclusions regarding the ostracodes and the charophytes, as quoted by Stokes (1952, p. 1768):

> All of these are common fossils in the Gannett group, the Cloverly of northwestern Wyoming, and the limestones in the upper Kootenai of Montana. *Clavator harrisi* is common in the Trinity of the Gulf coast. None of these species occurs in the Morrison of the Front Range in Colorado, in eastern Wyoming,

or in the Black Hills. Their occurrence is an excellent indication of the Lower Cretaceous age of the formation.

Eupora onestae, a pelecypod of Aptian Age, which has been found in the Cedar Mountain is very common in the Kootenai Formation of Montana, according to Cobban (Katich, 1951, p. 2093).

Thus it is apparent that the Cedar Mountain is of Early Cretaceous age and correlates, at least in part, with the Kootenai Formation, Gannett Group, and Cloverly Formation of Wyoming and Montana. There is a question in regard to the part of the Early Cretaceous with which the Cedar Mountain correlates. The presence of *Tempskya* argues for a late Early Cretaceous (Albian) age, whereas the pelecypod, charophytes, and ostracodes suggest a middle Early Cretaceous (Aptian) age for the formation. At present, the authors regard the upper part of the Cedar Mountain as being of Albian Age and the lower part, of Aptian Age. They recognize, however, that the range of *Tempskya* may be longer than now thought and may include a part of Aptian time as suggested by the age of the other fossils in the Cedar Mountain Formation.

BURRO CANYON FORMATION

Specimens of an unidentified species of *Tempskya* have been collected from the upper part of the Burro Canyon Formation at locality 31 northwest of Moab, Utah (McKnight and Rigby, 1963). The fern is represented by many fragments, including several that resemble the holotype of *T. knowltoni* in external morphology. The Burro Canyon Formation is generally considered to be of Early Cretaceous age, but there is some question about its exact position within that part of the Cretaceous. A few additional fossils have been identified from the formation (Shawe and others, 1968, p. A73), of which the most significant for our purposes are the pelecypods *Protelliptio douglassi* Stanton and *Lampsilis farri* Stanton. They "are well known and widespread Early Cretaceous (Aptian) species," according to Shawe, Simmons, and Archbold (1968, p. A73). The presence of *Tempskya* sp. in the upper part of the formation suggests to the authors of this report that at least the upper part of the Burro Canyon Formation is probably Albian in age.

DAKOTA SANDSTONE

Utah.—Specimens of *Tempskya* sp. were collected in San Juan County, Utah, at locality 32 by C. B. Read during 1943. The specimens came from the middle coal-bearing member of the Dakota Sandstone.

Read and Brown (1937, p. 127) described the occurrence of *Tempskya* in the La Sal Mountains of Utah at locality 33 as follows:

> Frank L. Hess, of the United States Bureau of Mines, during an investigation of the carnotite deposits in the region of the La Sal Mountains, Utah, found a specimen of *Tempskya* lying in the soil on deposits overlying the Upper Jurassic Morrison formation (McElmo of some reports). The locality is on the divide southwest of Winburn's ranch, near the head and on the northwest side of Pack Creek, just west of Mount Peale in the La Sal Mountains. As the specimen came from deposits above the Morrison, its source must lie between the Cretaceous Dakota(?) sandstone and the Mancos shale. The Mancos shale is a dark marine shale deposit and is not likely to have contained the *Tempskya.* There remains the relatively thin deposit of light-colored Dakota(?) sandstone about 40 feet), which, however, Hess did not distinguish as a separate unit in the section at the time of his visit. The outcrop of the Dakota(?) thickens and thins considerably in this area because its top was greatly eroded before the first deposits of the Mancos were laid down. It appears probable, therefore, that the Dakota(?) was the source of the *Tempskya* collected by Hess.

The locality (loc. 32) at which Read collected *Tempskya* is about 15 miles south of the area in which Hess made his collection. Therefore, judging by the nearness of the two localities, the Hess specimen probably also came from the middle coal-bearing member of the Dakota Sandstone.

During 1944, W. L. Stokes collected a specimen of *Tempskya knowltoni* from the lower part of the Dakota Sandstone at locality 34 in Grand County. The specimen was described and illustrated by Brown in 1950.

Colorado.—A specimen of *Tempskya* was collected in Montezuma County, Colo., at locality 35 by R. Clare Coffin. Although its stratigraphic position is unknown, it probably came from the middle coal-bearing member of the Dakota Sandstone, which is known to contain *Tempskya* elsewhere on the Colorado Plateau.

New Mexico.—In 1956, J. D. Strobell reported the occurrence of *Tempskya* in the basal beds of the Dakota Sandstone in northwestern New Mexico at locality 36. In 1961, Strobell and Read returned to the locality and made additional collections of *Tempskya.* A stratigraphic section of the rocks exposed at this locality is as follows:

Section of Dakota Sandstone 6 miles north of Bitlabito Trading Post, San Juan County, N. Mex., in E½SE¼ sec. 1, T. 31 N., R. 21 W., Pastora Peak quadrangle

[Measured by J. D. Strobell, Sept. 1961]

	Feet
Top of section, top of pediment.	
19. Covered by pediment gravel float. Consists of Mancos Shale and pediment gravel. Laterally to the south on the east and west sides of this ridge Mancos Shale is exposed and *Gryphaea* shells are abundant	20

Section of Dakota Sandstone 6 miles north of Bitlabito Trading Post, San Juan County, N. Mex., in E½SE¼ sec. 1, T. 31 N., R. 21 W., Pastora Peak quadrangle—Continued

	Feet
Dakota Sandstone:	
18. Sandstone, crosslaminated, ripple-marked; has more marine aspect than the lower sandstones	4
17. Covered, dark-gray shale exposed by digging	7
16. Sandstone and sandy shale, forms cliff laterally	7
15. Gray to black carbonaceous shale, lower part covered	15
14. Sandstone and sandy claystone	5
13. Coaly black shale containing thin beds of very fine grained white sandstone bearing root casts (like ganister)	23
12. Covered interval containing 2-ft bed of sandstone at top; coaly shale exposed by digging in lower part	11
11. Sandstone, thin-bedded, platy, poorly sorted	2
10. Shale, sandy, greenish-gray, passing laterally into coaly shale, and containing some beds of sandstone 1 to 2 ft thick	6
9. Sandstone and coarse conglomerate, containing silicified wood and plant impressions. This ledge caps the cliff and contrasts with the lighter colored underlying unit. Traced laterally it ranges from 2 to 8 ft in thickness and forms a broad bench to the south where *Tempskya* was found in it in NW¼NW¼, sec. 12, T. 31 N., R. 21 W. (USGS fossil plant loc. 9787)	6
Total Dakota Sandstone	86
Morrison Formation:	
8. Sandstone, weathers light with greenish cast, fine-grained, clayey, limonitic; forms cliff below the thin dark resistant basal ledge of the Dakota Sandstone	20
7. Claystone, dark-gray, weathers pale green	3
6. Sandstone, thin-bedded, crosslaminated, light-tan	2
5. Claystone, sandy, some tendency to weather puffy, weathers pale greenish; two thin beds of sandstone near top	6
4. Conglomeratic sandstone, light-tan, matrix fine grained and clayey, pebbles mostly less than 1 inch, few as much as 2 inches, in middle part of unit; some angular red chert pebbles one-fourth to one-half inch possibly from underlying Brushy Basin Shale Member; fluvial type of crossbedding	5
3. Claystone, dark-gray, greenish-weathering, very argillaceous and not at all puffy like next unit below	21
(Units 3 through 8, 57 feet thick, may represent the Burro Canyon Formation.)	
2. Puffy bentonitic light-gray claystone and siltstone; thickness estimated	30
1. Bright-red silty claystone, somewhat bentonitic and puffy, not measured.	
Base of measurements, not base of exposures.	

The lower two members of the Dakota Sandstone on the Colorado Plateau were considered to be of middle Early Cretaceous (Aptian) age by Cobban and Reeside (1952a). However, the finding of *Tempskya* in the middle coal-bearing member of the Dakota suggests to the authors that at least a part of this member is of Albian Age.

MEXICAN GEOSYNCLINE

MOJADO FORMATION

The two new species of *Tempskya* described in this paper, *Tempskya reesidei* and *Tempskya zelleri,* occur in the Mojado Formation [1] southwest of Deming, N. Mex., at localities 40 and 41. Details of the stratigraphy of the occurrences and lists of the marine fossils associated with *Tempskya* are given in the part of this report written by Zeller, so only the following brief summary is given here.

The mollusks, smaller Foraminifera, and gastropods found in rocks above and below those containing *Tempskya* were examined by several paleontologists. From their findings, it is apparent that the part of the Mojado Formation that contains the marine fossils and *Tempskya* is of late Fredericksburg (middle Albian) to late Washita (late Albian) age.

ATLANTIC COASTAL PLAIN

PATAPSCO FORMATION

Specimens of the first American *Tempskya* to be described, *T. whitei* Berry, were collected at locality 42 in the valleys of Stony Run and Deep Run, southeast of Annapolis, Anne Arundel County, Md. The type specimen and others are from the Patapsco Formation which, in the Maryland Geological Survey's volume on the Lower Cretaceous (Clark and others, 1911), was classed as the uppermost formation of the Potomac Group (Lower Cretaceous). E. W. Berry, in discussing the age of the relatively large flora of the Patapsco Formation, said (1911a, p. 160):

> Moreover, the latter flora [Albian of Portugal] closely parallels the Patapsco, in that both mark the first abundant appearance of undoubted dicotyledons and a persistence of a considerable number of the earlier Cretaceous types, which survive in both the Patapsco flora and that of the Albian of Portugal.
>
> On the basis of this close similarity between these two floras on opposite sides of the Atlantic, and the fact that both mark the first abundant appearance of Dicotyledonae, and the further fact that the Patapsco formation is overlain unconformably by the Raritan formation, carrying an abundant and unmistakably Cenomanian flora, the Patapsco formation is considered of Albian age. The unconformity which separates the Patapsco formation from the underlying

[1] This name as formally used by Zeller (1958c) is herewith adopted for usage by the U.S. Geological Survey.

Potomac beds is believed to represent all or nearly all of the time interval represented by the Aptian stage of European geology.

Apparently, until 1948, there was general agreement in regard to the Early Cretaceous age of the three units of the Potomac Group. However, in that year Anderson (1948, p. 14–16, 23, 84–85, 92–94, 97–102) and Vokes (1948, p. 129–133) suggested that the two upper units of the Potomac Group, the Arundel and the Patapsco Formations, are of early Late Cretaceous (Cenomanian) age. As evidence, they cited marine mollusks obtained from a well core, correlation from the well to the outcrops by means of heavy-mineral studies, and reevaluation of certain old data. Dorf reviewed all the evidence in 1952 and concluded that such an age assignment was unsubstantiated because (p. 2176):

1. The invertebrate fossils from the Maryland Esso well, dated as Cenomanian by Vokes, were recovered from sediments which cannot be definitely correlated on a lithologic basis with either the true Arundel or Patapsco formations along the outcrop.
2. The age of the subsurface beds, referred to as the "Patapsco-Arundel section," is not necessarily the same as the age of the true Arundel and Patapsco formations along the outcrop.
3. Organic remains, both floral and faunal, collected from along the outcrop of the Arundel and Patapsco formations indicate that these formations are more reasonably assignable to the Lower Cretaceous series, not the Upper Cretaceous.

Spangler and Peterson (1950) also assigned a Late Cretaceous age to the Arundel and Patapsco Formations on the basis of some sauropod remains that had been found in the Arundel. However, Dorf (1952, p. 2177) stated that "Present-day authoritative opinion still maintains that the Arundel vertebrate fauna is Early Cretaceous***."

A reanalysis of the Potomac Group floras was made by Dorf, who concluded (1952, p. 2177) that "the Patuxent and Arundel floras are essentially similar associations comparable in age and composition with the Wealden flora of England, which is at present considered of Neocomian age. The Patapsco flora *** appears to be comparable in age and composition with the Albian floras of Portugal."

Although the Maryland Department of Geology, Mines, and Water Resources has accepted Anderson and Vokes' proposed age reclassification of the Patapsco and Arundel Formations, others, including the U.S. Geological Survey, continue to consider the Potomac and Arundel to be of Early Cretaceous age (Richards and others, 1957). The authors of this account also consider the *Tempskya*-bearing part of the Patapsco Formation to be of latest Early Cretaceous (Albian) age.

REWORKED SPECIMENS

Arizona.—A waterworn specimen of *Tempskya* sp. was collected in 1950 by Phil F. Van Cleave, Chief Naturalist, Petrified Forest National Park, from a gravel bed exposed just above the Moenkopi Sandstone near Holbrook, Ariz., at locality 37(R). These gravels are probably of middle Pleistocene age and consist of material derived from all the formations in the area drained by the Little Colorado River, according to Maurice E. Cooley (written commun., 1962). Thus, the original source could have been the Dakota Sandstone of Early Cretaceous age which is widely exposed in the drainage area of the Little Colorado.

Nebraska.—Mr. N. H. Niles has collected four fragments of *Tempskya* sp. from loose boulders eroded from the Chadron Formation of Oligocene age in Dawes County, Nebr., at locality 28(R). In addition to *Tempskya,* fragments of other plants including *Cycadeoidea* have also been found among the boulders. All the boulders, including the specimens of petrified wood, are well rounded, indicating that they have probably been transported by streams for a considerable distance before they were deposited in the Chadron.

Arnold (1958, p. 134), who described this occurrence and the specimens of *Tempskya* sp., believed that "these silicified plants were eroded from the Lakota Sandstone during the early part of the Oligocene Epoch and that they were carried [from the area of the hogback of Lakota around the Black Hills] by swift streams over the intervening 50 miles to the site where they were found." He suggested that the Lakota is the source, because in the Black Hills it contains cycadeoids that are also silicified. However, the specimens found in Nebraska may have been derived instead from the lower part of the Graneros Shale which is exposed along the south rim of the Black Hills and is a time equivalent of the Aspen Shale, Thermopolis Shale, and other formations that elsewhere contain *Tempskya.*

New Mexico.—A small specimen of *Tempskya* sp. was collected by L. F. Brady during the early 1940's from the gravel beds of Quaternary age about a mile and a half northeast of Grants, N. Mex., at locality 38(R). The gravels consist mostly of material derived from the conglomerate in the lower part of the Chinle Formation (Upper Triassic). However, the specimen of *Tempskya* probably came from the part of Dakota Sandstone of Early Cretaceous age which is well exposed within a mile or less of the collecting locality. This part of the Dakota is known to contain *Tempskya* sp. about 150 miles northwest of Grants. The specimen was originally identified by R. W. Chaney and is now in the collections of the Museum of Northern Arizona at Flagstaff, Ariz.

At least one specimen of *Tempskya* sp. has also been collected from stream gravel in the valley of Rio Puerco about 30 miles northwest of Albuquerque at locality 39(R). The precise locality is not clear because the specimen was found by an amateur rock collector. The gravels of the Rio Puerco valley contain abundant petrified plant material derived from several formations ranging in age from Late Jurassic to Paleocene. Strata assigned to the Dakota Formation are present and are known to contain petrified plant material. However, the Mesaverde and some of the Paleocene rocks also contain plants. It can only be surmised that the material is from the Dakota.

North Carolina.—The new specimens of *Tempskya* reported from North Carolina by West (1968, 1970) came from what are probably Quaternary gravel deposits. Although the specimens are undoubtedly reworked, they are of some note because they constitute the second reported occurrence of *Tempskya* east of the Mississippi River. The position of these localities is not shown on the index map (fig. 3).

Oregon.—In 1914, J. T. Pardee collected two specimens of *Tempskya* from the gravels in a placer pit on Lightning Creek, 1 mile north of Greenhorn, Baker County, Ore., at locality 7 (R). Additional specimens of *Tempskya* sp. have been obtained by members of the Oregon Geological Survey and others in the vicinity of this locality in both Baker and Grant Counties from this same placer deposit. Apparently these gravels are also the source of the specimens of *Tempskya* sp. that are so highly prized by local rock collectors. The age of the placer deposit has not been established but appears to be of pre-Mascal (Miocene) age.

Very little is known about Cretaceous stratigraphy in this general area. Therefore it can only be suggested that the material may have been initially derived from Cretaceous rocks, and, judging by the abundance of material, the source was probably not too distant.

Wyoming.—Read and Brown (1937, p. 127) reported the finding of a specimen of *Tempskya* in terrace gravels in southwestern Wyoming at locality 23(R), as follows:

> One small water-worn specimen of *Tempskya minor* was collected by R. W. Brown in June, 1930 from a gravel terrace in the valley of the westward-flowing Twin Creek near the town of Fossil, in T. 21 N., R. 117 W., Wyoming. * * * The debris of this gravel terrace includes, besides other rocks, some pebbles of igneous rock, no outcrop of which occurs within the present drainage basin of Twin Creek. The gravel has therefore not been derived entirely from the Tertiary bedrock on which it lies, but a portion must have come from some exterior source. The specimen of *Tempskya*, if the diagnosis of the stratigraphic significance of the species is correct, came from Cretaceous deposits. * * * The nearest area of outcrop of such deposits to the point where the specimen was found is across the low divide and in the townships next to the east, where Bear River, Aspen, and Frontier beds occur just east of Kemmerer. The inference that the specimen came from this area seems to be reasonable, but it involves the necessity of explaining some changes in drainage which the writers believe have taken place but the elucidation of which they deem not within their present undertaking.

Arnold (1945, p. 30–31) described the occurrence of *Tempskya wyomingensis* in northern Wyoming at locality 25(R). Here the specimens were found on the valley floors of Beaver Creek and its tributaries northeast of Greybull, Big Horn County, Wyo. Although the source of the specimens has not been determined, Arnold mentioned that they only occur where the Morrison Formation is exposed in the area and that they are usually associated with dinosaur bone fragments, gastroliths, and occasional cycad fragments. The authors of this paper suggest that the Mowry Shale or Thermopolis Shale is also a possible source of *T. wyomingensis* at this locality, as both formations are exposed in the area. The intervening Cloverly Formation also could be the source, as it also is exposed in the area and locally contains plants.

Several small specimens of petrified material, reportedly resembling *Tempskya*, have been collected from a conglomerate of Late Cretaceous age in the Jackson Hole area at locality 24(R) (Love and others, 1948, p. 25). The conglomerate underlies the Pinyon Conglomerate of Paleocene age and has been referred to the Mesaverde Group by Foster (1947). However, the specimens of plant material and the pebbles in the conglomerate are well rounded to subangular and obviously have been reworked from older formations. The *Tempskya* specimens may have been derived from either the Mowry Shale or Thermopolis Shale which are exposed in the area and which contain *Tempskya* elsewhere.

STRATIGRAPHY AND AGE OF THE *TEMPSKYA*-BEARING ROCKS OF SOUTHERN HIDALGO COUNTY, NEW MEXICO

By Robert A. Zeller, Jr.

INTRODUCTION

The specimens of *Tempskya* discovered in southern Hidalgo County, N. Mex. (fig. 5), by the author are closely associated with an Early Cretaceous marine fauna that is rich in short-ranging fossils, the stratigraphic distributions of which have been accurately established in terms of both the Texas Coastal Plain and European sequences. Such an opportunity to date plant fossils by using a marine fauna is rare; therefore, the biota is of fundamental importance in establishing the age of *Tempskya*.

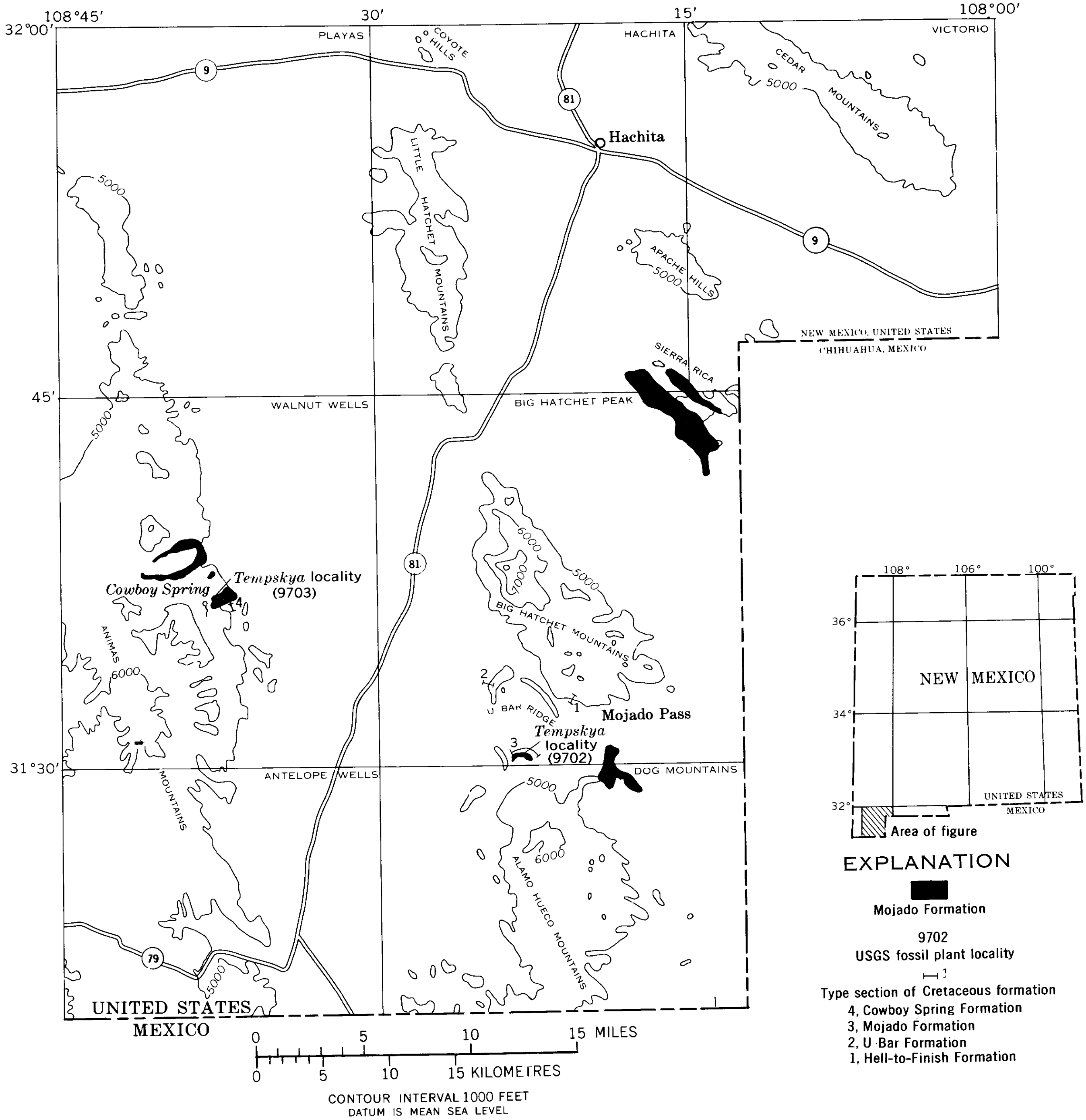


Figure 5.—Location of the known exposures of the Mojado Formation, known *Tempskya* localities, and the type sections of the several Cretaceous formations mentioned in this report.

This chapter summarizes the stratigraphy of the Mojado Formation and presents marine fossil evidence regarding the age of the formation and the fossil fern *Tempskya*.

Prior to my work, few geologic studies had been made in southern Hidalgo County. Darton (1928a, b) recognized the existence of rocks of Early Cretaceous age in the region, and Lasky (1947) studied the Lower Cretaceous rocks of the Little Hatchet Mountains.

The writer began detailed geologic mapping and stratigraphic study of the rocks in the Big Hatchet Peak quadrangle, Hidalgo County, N. Mex., in 1951. The project was eventually enlarged to include detailed and reconnaissance geologic mapping throughout most of southern Hidalgo County and study of the stratigraphy of the Cretaceous System in much of southwestern New Mexico and adjoining areas in Arizona, Texas, and Mexico. Results of this work have been published in several reports (Zeller and Read, 1956; Dane and Bachman, 1961; Zeller, 1958a, b, c; 1965; Zeller and Alper, 1965).

CRETACEOUS STRATIGRAPHY

Lasky (1947) divided the stratified Lower Cretaceous rocks of the Little Hatchet Mountains into seven formations. As they could not be correlated with described formations elsewhere in the region, he gave them new names.

South of the Little Hatchet Mountains, the Lower Cretaceous rocks are divisible into three formations, but as they cannot be correlated at present with the formations in the Little Hatchet Mountains, only 20 miles to the north, or with any other described formations in the region, the writer has given them new names (Zeller, 1958c). In ascending order they are the Hell-to-Finish Formation,[2] U-Bar Formation,[2] and Mojado Formation. The three names have been used by Dane and Bachman (1961), and the units later were described in detail by Zeller (1965).

Along the east flank of the Animas Mountains west of the Big Hatchets, the U-Bar and Mojado Formations are recognized. However, because of local erosion during earliest Cretaceous time, the Hell-to-Finish Formation is missing, and the U-Bar Formation is thin and rests upon deeply eroded Permian rocks. Here the Mojado Formation is overlain conformably by another formation of Early or Late Cretaceous age, the Cowboy Spring Formation,[2] which was described in detail in a report on the geology of the Walnut Wells quadrangle by Zeller and Alper (1965).

Hell-to-Finish Formation.—The Hell-to-Finish Formation, named for a stock tank, is exposed in a limited area on the southern flank of the Big Hatchet Mountains. The type section is in secs. 2 and 11, T. 32 S., R. 15 W. It rests with erosional unconformity upon carbonate rocks of Permian age and is overlain conformably by the U-Bar Formation. Rock types are primarily red shale and arkosic sandstone. A 30-foot basal bed of conglomerate is composed of chert pebbles derived from the underlying Permian strata. The formation has a measured thickness of 1,274 feet in the type section where it is most completely exposed. The rocks are relatively nonresistant, and elsewhere thicknesses cannot be determined. The age of the Hell-to-Finish is not definitely known because of the lack of fossils. However, it is believed to be of Early Cretaceous age because the upper beds are transitional with the lowest strata of the U-Bar Formation, which is known to be of Early Cretaceous age.

U-Bar Formation.—This unit is named for U-Bar Ridge, a prominent arcuate ridge southwest of the Big Hatchet Mountains; it is the erosional remnant of a resistant limestone reef folded into a broad syncline. The type section is a composite of several sections, but the main exposures are on the northwestern part of U-Bar Ridge. The formation consists mostly of marine limestone. The lower and middle parts are thin-bedded fossiliferous limestone with some thin beds of claystone; the upper part is massive reeflike limestone which is 500 feet thick on the northern part of U-Bar Ridge and which thins southeastward. Thin limestone beds above the reef form the uppermost part of the formation, and these are interbedded in a transition zone with sandstone typical of the overlying Mojado Formation. The total thickness of the formation in the type area is about 3,500 feet, and 6 miles to the southeast a similar thickness has been noted. In Sierra Rica (fig. 5) only the upper part of the formation is exposed. In the central Animas Mountains, the U-Bar Formation is thinner than in the composite type section and rests unconformably upon Permian rocks. Marine invertebrate fossils indicate a late Aptian Age for the lower part of the formation, an early to middle Albian Age (Glen Rose) for the middle part, and a middle Albian Age (Fredericksburg) for the uppermost beds including the reef.

Mojado Formation.—This unit is named for Mojado Pass, which is the broad low area between the main mass of the Big Hatchet and the Alamo Hueco Mountains. The type section is south of the Big Hatchet Mountains along the north flank of the

[2] This name is herein adopted for usage by the U.S. Geological Survey.

low hill in sec. 20, T. 32 S., R. 15 W., and has a measured thickness of 5,195 feet. Here the unit can be divided into two parts, the lower consisting of 4,110 feet of nearly unfossiliferous sandstone and shale, and the upper composed of 1,085 feet of sandstone and shale and a few thin beds of impure and coquina limestone and calcareous sandstone rich in marine fossils. The formation has also been recognized northeast of the Big Hatchets in Sierra Rica and west of the Big Hatchets in the Animas Mountains. The age of the Mojado probably extends through most of Fredericksburg (middle Albian) time and nearly all of Washita (late Albian) time, although the ages of the base and top of the formation are not precisely known.

In the lower part of the formation sandstone occurs in fairly thin lensing beds. Its crosslamination is pronounced. Its fresh color is gray, and its weathered color, though predominantly brown, ranges from white through many shades of brown, depending upon various concentrations of limonitic pigment. Sand grains are angular to subangular and medium to fine. Most of the sandstones are composed almost entirely of quartz grains, but a few contain sufficient quantities of detrital ferromagnesian minerals and rock fragments to be classed as graywackes. Many beds are weakly cemented, but some are strongly cemented with calcite. Intervals between sandstone beds, though usually concealed, consist of beds of clay and silt and their more indurated counterparts, shale and siltstone. Contacts between argillaceous units and sandstone beds commonly show channel or cut-and-fill structures. Several unconsolidated clay beds evidently represent fossil soil zones. Although this part of the Mojado is not conspicuously fossiliferous, fossil wood and pelecypod remains are found in a few beds. Except for rare oyster-bearing beds, the lower part of the type Mojado Formation appears to be of continental origin.

Lithologically, the upper part of the formation is much like the lower in that brown-weathered sandstone and interbedded shale and clay beds predominate. However, it differs from the lower part by having beds of calcareous sandstone, brown-weathered quartzose and silty limestone, and brown-weathered coquina limestone, all of which are rich in marine fossils. The thin bed bearing *Tempskya zelleri* is between two such marine beds. These fossiliferous beds include the diagnostic biota described later. The proportion of calcareous beds increases upwards to the uppermost exposure of the formation, beyond which the beds are concealed by alluvium. Most beds of the upper part were probably deposited under continental conditions, but the fossiliferous calcareous beds represent brief periods of marine flooding.

From the type section, the Mojado Formation is sporadically exposed for about 7 miles to the east-southeast. It is shown on the Dog Mountains quadrangle map (Zeller, 1958a) as Cretaceous sandstone (Ks), although the upper part of the formation containing the characteristic biota is not exposed beyond the type section.

The lithology of the Mojado Formation exposed along the eastern foothills of the Animas Mountains about 16 miles northwest of the type section is similar to that of the formation at its type section. The actual thickness of the Mojado cannot be determined here because alluvium covers the middle part of the formation and conceals a known fault. However, a carefully estimated thickness making allowance for the fault suggests that in the Animas Mountains the Mojado is as thick as it is at the type section. Here the layers that contain the same biota found at the type section are overlain by about 1,000 feet of interbedded sandstones and shales of the Mojado Formation.

In Sierra Rica the Mojado Formation had originally the same lithology as at the type section. However the introduction of silica, probably from nearby post-Early Cretaceous monzonite intrusions, caused alteration of the sandstone to hard quartzite and the shale to resistant hornfels. This section has not been measured or studied in detail. However, 4,000 to 5,000 feet above the base of the formation, calcareous beds are found which contain a marine fauna including many of the forms found in the late Albian biota of the type Mojado, including the diagnostic foraminifer *Cribratina texana* (Conrad) Sample. This fauna has not been studied by specialists.

The brief periods of marine flooding, which occurred during the time of deposition of the upper part of the Mojado in the Big Hatchet area and during which the biota was deposited, also occurred in the areas of the Animas Mountains and Sierra Rica.

LATE ALBIAN BIOTA IN THE MOJADO FORMATION

Marine invertebrate fossils are closely associated with specimens of *Tempskya* in the type section of the Mojado Formation and on the east side of the Animas Mountains (fig. 5). Collections of the invertebrates were examined by several paleontologists; summaries of their findings are included in the following discussion, and the relative positions of the collections are shown on the stratigraphic sections (fig. 6).

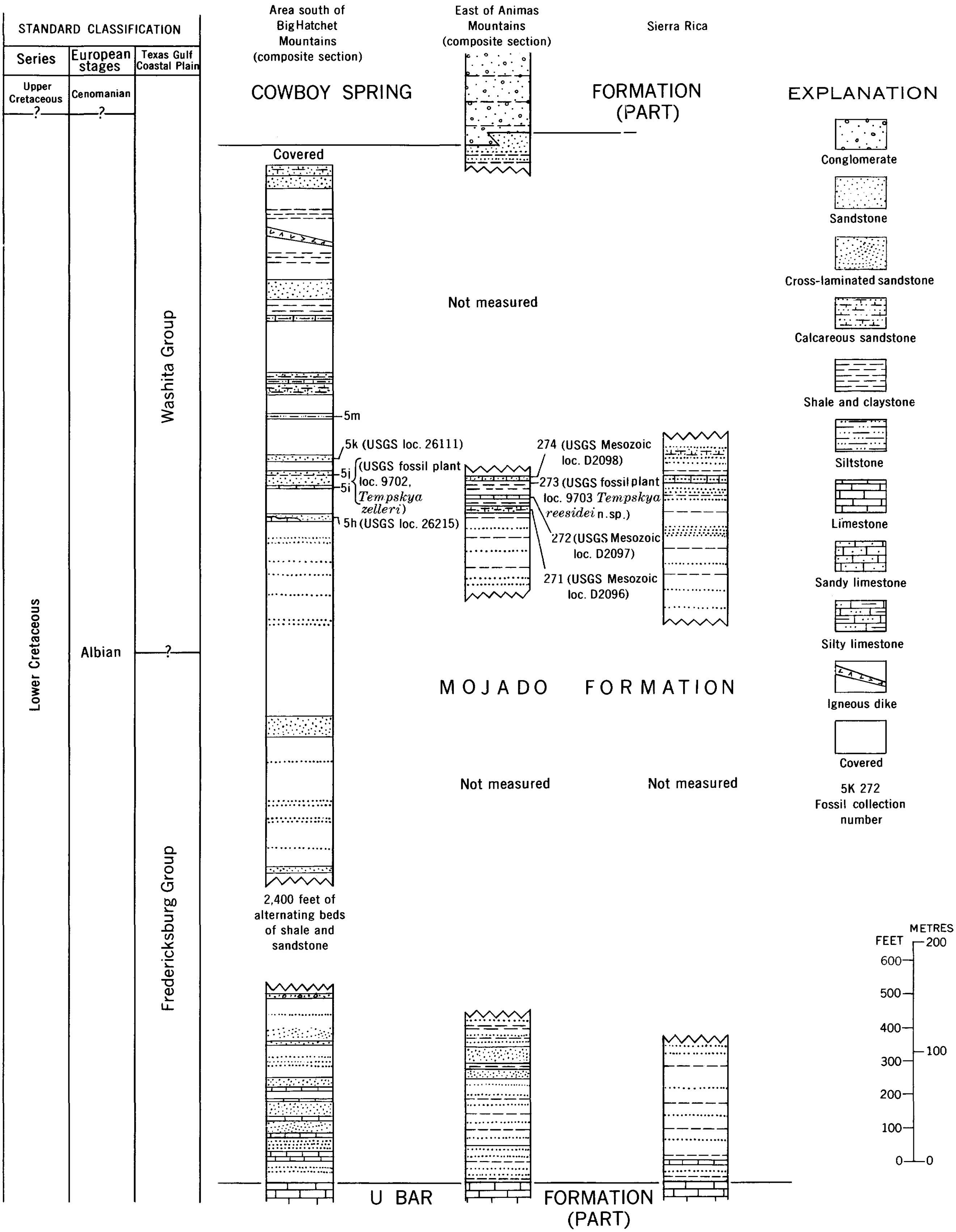


FIGURE 6.—Stratigraphic sections of the Mojado and adjacent formations in the southern part of Hidalgo County, N. Mex.

BIOTA IN THE TYPE MOJADO FORMATION IN MOJADO PASS

The marine fossils collected from beds near those bearing *Tempskya* in the upper part of the type Mojado Formation came from the following localities:[3]

Locality	*Descriptions*
5h	Approximately 140 ft stratigraphically below the bed containing *Tempskya zelleri.*
5i	About 30 ft below the *T. zelleri*-bearing bed.
5j	In a bed about 5 ft below the bed containing *T. zelleri.*
5k	About 30 ft above the *T. zelleri*-bearing bed.
5m	Approximately 120 ft above the *T. zelleri*-bearing bed.

At locality 5h (USGS loc. 26215), a collection was made by John B. Reeside, Jr., Charles B. Read, and the writer. It was studied by Reeside (written commun., 1956) who concluded that it "would*** be of Washita age." He identified the following forms in the collection:

Pelecypods:
- *Arca*? sp.
- *Ostrea perversa* Cragin
- *Plicatula*? sp.
- *Brachydontes*? sp.
- *Protocardia texana* (Conrad)
- "*Tellina*" sp.

Gastropod:
- *Cassiope*? sp.

Several collections of gastropods were studied by Norman F. Sohl of the U.S. Geological Survey, who identified the following forms in the collections (written commun., 1955):

Locality 5i
- *Nerita* sp.
- *Turritella seriatimgranulata* Roemer
- *Nerinea* cf. *N. geminata* Stanton
- *Pyrazus (Echinobathyra)* cf. *P. pecoense* (Stanton)
- *Cassiope* sp.

Mixed collection from localities 5i, 5j, 5k, 5m
- *Turritella seriatimgranulata* Roemer
- *Pyrazus (Echinobathyra)* cf. *P. pecoense* (Stanton)

Sohl made the following comments concerning the fossils and the age significance:

> *Turritella seriatimgranulata* Roemer ranges through both the Fredericksburg and lower Washita. The specimens here placed in this species bear a closer resemblance to those assigned by Stanton to the variety *gainsvillensis* of the lower Washita than to the holotype from the Walnut clay. The specimens of *Nerinea* do not preserve the external ornamentation in sufficient detail for confident identification but in shape, whorl profile and sutural characteristics appear close to the type of *N. geminata* found in the Edwards limestone. *Pyrazus* (*Echinobathyra*) *pecoense* (Stanton) also occurs in the Edwards limestone.
>
> The known stratigraphic ranges of the individual species substantiates a Fredericksburg age assignment and further suggests that the sandstone may be of late Fredericksburg (Middle Albian) age correlative with the Edwards formation of Texas.

A collection of mollusks from locality 5k was studied by Norman F. Sohl, who identified the following forms (written commun., 1956):

Pelecypods:
- *Breviarca* sp.
- *Ostrea* sp.
- Pelecypods indet.

Gastropods:
- *Nerita* (*Theilostyla*?) sp.
- *Turritella seriatimgranulata* Roemer
- *Pyrazus* (*Echinobathyra*) n. sp.
- *Cassiope* cf. *C. hyatti* Stanton
- *Pseudonerinea* sp.?
- *Nerinea* cf. *N. geminata* Stanton
- *Aptyxella* (*Nerinoides*) n. sp.
- *Acteonella*? sp.

Sohl commented as follows concerning the collection and its age significance:

> Many of the mollusks are new forms and others specifically indeterminate. In addition a restricted age identification on the basis of the mollusks is difficult due to the lack of published information as to the total range of the few species previously described. Taken collectively the identifiable material ranges in age from late Fredericksburg to early late Washita.
>
> *Breviarca* has never been identified in the Lower Cretaceous but is known from the Woodbine of Texas, and its presence in the Washita would not necessarily be inconsistent. Among the gastropods, as noted in the report of November 23, 1955, *Turritella seriatimgranulata* Roemer has a wide range but the specimens in these collections appear to be closest to Stanton's variety *gainsvillensis* from the lower Washita. *Pyrazus* (*Echinobathyra*) n. sp. is close to *Cerithium pecoense* Stanton from the Fredericksburg of the Quitman Mountains area but differs in having a slimmer outline and additional sculpture elements. *Cassiope* cf. *C. hyatti* Stanton compares rather well with the paratype from the Purgatoire Formation (Washita) of Mesa Tucumcari, N. Mex.. *Nerinea* cf. *N. geminata* Stanton externally is similar to Stanton's variety *glabra* of the Edwards but internally is closer to *N. shumlensis* Stanton from the upper part of the Devils River Limestone (Georgetown). The remainder of the identifiable material has little in common with previously described species.
>
> The two most abundant species in the fauna are *Turritella seriatimgranulata* and *Pyrazus* (*Echinobathyra*) sp. The latter is typically a littoral to estuarine, brackish-water form. A shallow water nearshore environment of deposition is in keeping with the remainder of the assemblage as well as the physical wear and breakage exhibited by much of the material and detrital nature of the sediment.

An ammonite in a collection from locality 5k was recognized as belonging to the genus *Engonoceras* by Alexander Stoyanow. Specimens of the ammonite were examined by Reeside, who reported as follows on the fossil (written commun., 1956):

> The ammonite seems to me to be *Engonoceras serpentinum* (Cragin), which has been reported from the Pawpaw and seems to be only of late Washita age. The material is good and the identification should be reliable.

[3] Originally the fossil collections made from particular beds were assigned specific collection numbers by Zeller. The additional collections made later by Reeside, Read, and Zeller from the same beds were assigned the same collection numbers used by Zeller. For purposes of this report, the collection numbers will be referred to as locality numbers.

A collection of fossils was made by Reeside, Read, and the writer from locality 5k. In the collection (USGS. loc. 26111) Reeside identified the forms listed below (written commun., 1956):

Foraminifera:
- *Cribratina texana* (Conrad), probably including *Polychasmina pawpawensis* Loeblich and Tappan

Pelecypods:
- *Nucula* sp.
- *Yoldia* sp.
- *Ostrea perversa* Cragin
- *Lopha quadriplicata* (Shumard)
- *Neithea texana* (Roemer)
- *Camptonectes inconspicuus* (Cragin)
- *Plicatula* sp.
- *Lima*? sp.
- *Anomia*? sp.
- *Cardium* aff. *C. kansasense* Meek
- *Protocardia texana* (Conrad)
- *Cyprimeria gigantea* Cragin
- "*Tellina*" sp.
- *Cymbophora*? sp.
- *Corbula* sp.

Scaphopods:
- *Cadulus*? sp.
- *Dentalium* sp.

Gastropods:
- "*Lunatia*," several species
- *Turritella seratimgranulata* Roemer
- *Anchura* aff. *A. mudgeana* White
- *Cinulia*? sp.

Cephalopod (ammonite):
- *Engonoceras serpentinum* (Cragin)

Worm:
- *Serpula* sp.

Reeside commented on these fossils as follows:

The collection of invertebrates (26111) 30 feet above the horizon of fossil plant remains confirms the indication of the ammonite previously examined that the level is about the age of the late Washita in terms of the Texas sequence, and late Albian in terms of the European stage sequence. Some of the fossils have sufficiently marked characters to permit fairly assured determination. Others suggest generic assignment that seems well assured, but do not warrant the effort to find a rational specific name. Others permit only a guess at a generic assignment or are completely indeterminable. The fauna is certainly an extensive one and though the matrix is extremely hard and tough would be worth further study.

The most abundant forms in the collection are the foraminifera, the *Camptonectes*, and the *Cyprimeria*. In previous reports N. F. Sohl has listed forms from the horizon of silicified gastropods that lies below the plant remains. These are in reasonable agreement with an assignment to a late Albian age.

Arenaceous Foraminifera are found throughout the entire faunal zone from which the above-described faunas were collected, including localities 5h through 5m. Examples of these forms were studied by Ruth Todd, who reported on them as follows (written commun., 1955):

These arenaceous Foraminifera range from cylindrical individuals to flattened ones (as much as 3 to 1). In the cylindrical individuals the aperture consists of a group of openings between the sand grains at the top of the final chamber. In the flattened individuals the aperture consists of a string of slits at the top of the final chamber. Two generic names have been applied to forms like these: *Cribratina* Sample, 1932[4] for the cylindrical ones and *Polychasmina* Loeblich and Tappan 1946 for the flattened ones. So far as I can determine, cylindrical and flattened specimens have not previously been found occurring together. Their presence together here, with numerous examples of gradational forms from cylindrical to flattened, throws doubt upon the validity of the generic separations as resting upon flattening of the test and consequent rearrangement of apertural pores.

Comparisons have been made with types of *Cribratina texana* (Conrad) and *Polychasmina pawpawensis* Loeblich and Tappan and all these specimens can be included in these two species. It seems likely, however, that the earlier name, *C. texana*, should be used for all the specimens.

Without settling the question of whether one or two genera are represented here, the following notes include the age indications given by both *Cribratina texana* and the genus *Polychasmina* (which is represented by only one species).

Cribratina texana (Conrad):
- In Grayson, Weno, and Maness? of Washita age (Frizzell, 1954, p. 58)
- In Washita group (except Fort Worth); Fredericksburg and Trinity records doubtful (Lozo, 1944, p. 547–548)
- In strata of upper Albian age in Colombia (Petters, 1954, p. 134)

Polychasmina pawpawensis Loeblich and Tappan:
- In Pawpaw and Weno of Washita group (Loeblich and Tappan, 1946, p. 242–243)

The above records of occurrences elsewhere seem to indicate Washita equivalent for the age of the strata containing these large arenaceous Foraminifera.

Because of the widespread occurrence of *Cribratina texana* in other exposures of the Mojado in the region, the writer has relied heavily upon this form for dating rocks in which it is found. To confirm further the known range of this form, he wrote to Esther R. Applin, who replied as follows (written commun., 1959):

regarding the vertical range of *Cribratina texana* (Conrad), I have seen specimens of *Cribratina texana* only in outcrop samples of sediments of Washita age in Texas and, so far as I know, this fossil is restricted in its range to the upper half of the Washita group. In Texas it has been reported from the Grayson marl and the Weno clay and some questionable specimens were also recorded from the Maness shale.

BIOTA IN THE MOJADO FORMATION OF THE ANIMAS MOUNTAINS

In the upper part of the Mojado Formation on the east side of the Animas Mountains (near center of

[4] In the original "Report on Referred Fossils" prepared by Ruth Todd, the name *Haplostiche* was applied to the cylindrical Foraminifera mentioned here. Since then, however, paleontologists have come to restrict the name *Haplostiche* to Foraminifera that have a single terminal aperture (Loeblich and Tappan, 1964, p. C220). Those having multiple apertures, like the Foraminifera discussed here are then referred to *Cribratina* Sample, 1932. Therefore, in order to bring the present report into line with current practice, the authors have changed the name of the fossil formerly called *Haplostiche* to *Cribratina* wherever it appears in the report. The authors of this report are grateful to W. A. Cobban and Harlan Bergquist for pointing out this change in nomenclature.

sec. 13, T. 31 S., R. 18 W.), the writer made two collections of marine invertebrate fossils from beds stratigraphically beneath those containing *T. reesidei* and one collection from the beds above. These collections were studied by W. A. Cobban (written commun., 1959). They contain several forms that were also recognized in the type Mojado, as noted above; these are indicated by an asterisk (*) in the following lists.

The collection of fossils from USGS Mesozoic locality D2096, about 65 feet below the *T. reesidei*-bearing bed, contains the following forms:

Foraminifera:
  **Cribratina texana* (Conrad)
Pelecypods:
  **Lopha* cf. *L. quadriplicata* (Shumard)
  Trigonia cf. *T. emoryi* Conrad
  **Protocardia texana* (Conrad)
  Corbula basiniformis Adkins
Scaphopods:
  **Cadulus* sp.
  **Dentalium* sp.
Gastropod:
  Drepanochilus kiowana (Cragin)
Cephalopod (ammonite):
  **Engonoceras serpentinum* (Cragin)

Cobban concluded that "The pelecypods, gastropod, and ammonite suggest a late Comanche (Washita) age (late Albian)" for this collection.

In a collection from USGS. Mesozoic locality D2097, about 40 feet below the bed containing *T. reesidei,* the following forms were identified:

Pelecypods:
  **Ostrea* sp.
  Exogyra sp.
  Trigonia emoryi Conrad
  **Protocardia texana* (Conrad)
Gastropods:
  Turritella kansasensis Meek
  Actaeonella sp.
Cephalopod (ammonite):
  **Engonoceras serpentinum* (Cragin)

According to Cobban, "This fauna suggests a Washita age."

The following fossils were collected from USGS. Mesozoic locality D2098, about 20 feet above the bed containing *T. reesidei*:

Foraminifera:
  Cribratina texana (Conrad)
Pelecypod:
  **Protocardia texana* (Conrad)
Gastropod:
  Drepanochilus kiowana (Cragin)

Cobban considered that this collection is "a Washita fauna."

CONCLUSIONS REGARDING THE AGE OF THE BIOTA

The age determinations of the different elements of the marine fauna associated with *Tempskya* spp. in the Mojado Formation are in close agreement. At the type locality, the pelecypods and gastropods in localities 5h, i, and j (stratigraphically below the bed containing *T. zelleri*) range in age from late Fredericksburg to early late Washita; the ammonite and the mollusks from locality 5k (stratigraphically above the beds containing *T. zelleri*) are of late Washita age; Foraminifera from localities 5h, k, and m are also of Washita age. On the east side of the Animas Mountains, two collections of Foraminifera and mollusks from the beds overlying those containing *T. reesidei* are also of Washita age. Thus, it is evident that these faunas range in age from late Fredericksburg to late Washita in terms of the Texas Coastal Plain classification and are of late Albian Age according to European terminology. It can be further concluded that the *Tempskya* spp. in the Mojado Formation are of the same age.

Cowboy Spring Formation.—The Cowboy Spring Formation is named for Cowboy Spring in the Animas Mountains. The type locality is in sec. 13 and 24, T. 31 S., R. 18 W., and in secs. 18 and 19, T. 31 S., R. 17 W. The basal beds intertongue with the upper beds of the Mojado Formation. The formation consists of limestone cobble-and-boulder conglomerate and a few thin beds of shale. A limestone conglomerate of Tertiary age rests with angular unconformity upon the Cowboy Spring Formation; rock types of the two formations are so similar that they are difficult to distinguish. Although the total thickness of the Cowboy Spring Formation has not been measured at the type locality, it is at least 500 feet. Because the cobbles and boulders were apparently derived from a nearby source, the formation is probably restricted to the area near its present exposures. No fossils have been found in the Cowboy Spring Formation, but it is believed to be of very late Albian Age because of its intertonguing relationships with the underlying Mojado and because its lithology suggests rapid deposition. However, it could possibly be of very early Cenomanian (early Late Cretaceous) Age.

SYSTEMATIC DESCRIPTIONS

Division PTEROPHYTA
Family TEMPSKYACEAE

Genus TEMPSKYA Corda, 1845

The following are the more important references to the genus.

1845. *Tempskya* Corda, p. 81.
1911. *Tempskya* Corda: Kidston and Gwynne-Vaughn, p. 1–20.

1924. *Tempskya* Corda: Seward, p. 485–507.
1937. *Tempskya* Corda: Read and Brown, p. 108–112.
1947. *Tempskya* Corda: Andrews and Kern, p. 119–186.
1970. *Tempskya* Corda: Andrews, p. 485–487.

The first clearcut generic diagnosis of the genus *Tempskya* was prepared by Kidston and Gwynne-Vaughan (1911, p. 13) and is as follows:

Stems of small diameter, erect, dichotomous, and embedded in a felted mass of their own adventitious roots. Dorsiventral, with the leaves in two rows on one side of the stem and roots alone on the opposite side. Vascular system of stem a solenostele. Leaf trace departs as a single strand. Roots diarch.

Seward (1924), Read and Brown (1937), and Andrews and Kern (1947) have more recently discussed the generic characteristics of *Tempskya* at some length. In consequence, it is unnecessary to elaborate in this report. However, a concise account appears to be appropriate in view of the fact that much of the older literature is not readily available to many workers.

Stem.—The stems of *Tempskya* are dorsiventral and are characterized by solenosteles. The protoxylem is exarch or slightly immersed. Both the pith and the cortex are characterized by variable amounts of parenchyma and sclerenchyma, the distribution patterns of which appear to have some value in specific taxonomy. The stem system is freely dichotomous and is sheathed in a thick and very dense felt of adventitious roots.

A well-preserved to poorly preserved endodermis constitutes the inner and outer limits of the stele. A very thin layer of pericycle and phloem occurs both on the exterior and interior of the stele and together with the endodermis wraps around the terminations of the steles when they are gapped during the emission of leaf traces. Because of the nature of the preservation of the material, it is rarely, if ever, possible definitely to separate the pericycle from the phloem. The xylem cylinder is exarch. In most species the protoxylem appears to form a continuous or nearly continuous band on the exterior, but in some it is discontinuous and occurs as discrete strands. Variable quantities of xylem parenchyma occur interspersed with the tracheids in the metaxylem.

Leaf trace and phyllodium.—Leaf traces are given off from the stele in the manner characteristic of solenostelic types of ferns and are in two ranks. The stele below the point of emission thins primarily by reduction of the width of the xylem strand and finally gaps, permitting the departure of a thin, broad, and inverted U-shaped strand which is completely encircled by a thin layer of phloem and pericycle bounded by the endodermis. The gap is quickly closed above the point of departure. As the strand passes through the cortex, cortical tissues are disposed around the foliar stele in the same manner that they are developed in the stem, except that the thicknesses of the zones diminish. As they emerge into the phyllopodia, the terminations of the inverted U become enlarged and recurved. The xylem, except at the terminations, is rarely more than two cells thick, and in some instances, as shown in plate 12, figure 1, it is only one cell thick. Midway on the dorsal surface of the stele as the strand continues outward, a depression or furrow forms. Both the leaf traces and the phyllopodia are rather small, as might be expected in view of the size of the parent stems. In consequence, the fronds of *Tempskya* were undoubtedly rather small.

Root.—The adventitious roots that sheath the stems and phyllopodia of *Tempskya* are diarch and characterized by relatively large steles. The cortex is characterized by a narrow inner layer of parenchyma beyond which is a thick zone of sclerenchyma. In well-preserved specimens a layer of large-celled parenchyma lies on the exterior of the sclerenchyma; this has a tendency to become lacunar as a result of the breaking down of some of the cell walls. Sheathing this layer are smaller and thicker walled cells of the epidermal zone. In some specimens, well-preserved root hairs are present, which, as in the case of modern plants, are outgrowths from the epidermis.

False trunk.—The most striking characteristic of the genus *Tempskya,* and the feature that serves to set it apart from most of the other ferns, is the false trunk or "stem." When viewed with the eye directly or under a hand lens, specimens of *Tempskya* are seen to be an aggregate of stems, phyllopodia, and adventitious roots. The roots parallel to subparallel the course of the stems and are so numerous that they form a dense felt which apparently in life served to bind the branching stem system into a massive stem or trunklike body.

According to Andrews and Kern (1947) the parts of the false trunks they examined may be classified into bases, discs, and tips. To some extent, as these authors point out, this differentiation is interpretative. The bases of some flare slightly at the very bottom, have a knobby lower surface, and consist entirely of roots. Disc specimens are massive columnar segments of false trunks with many well-preserved true stems as well as abundant adventitious roots. At least in some cases, the true stems are penetrated by the adventitious roots. The specimens interpreted as tips are reported to "taper rather abruptly to a blunt apex" (Andrews and Kern, 1947, p. 121). Such specimens are interpreted as the terminal parts of false trunks.

Although Andrews and Kern questioned the existence of dorsiventral false trunks, it has not been clearly demonstrated that radial symmetry of false trunks is a constant characteristic of the genus *Tempskya*. In fact one of the new fossils from New Mexico seems to indicate the reverse.

One of the new discoveries that throws additional light on the general morphology of the false trunks is the paratype (USNM 167547) of *T. reesidei*. The specimen is approximately 62 cm long and is tapered similarly to and is quite reminiscent of the holotype of *T. knowltoni*. (See figs. 8 and 9; pl. 3, fig. 3.) The upper part of this specimen is radially symmetrical (fig. 9*A*) and contains some well-preserved stems. The tip or lower part of the specimen contains remains of only three stems; these have been penetrated by many adventitious roots. (See fig. 9*B*.)

The occurrence of an additional obconical false trunk must be taken seriously into account. It certainly demonstrates that *Tempskya* showed this growth form, at least occasionally, substantiating the idea that the holotype of *T. knowltoni*, which is dorsiventral, represents an entire false trunk and not a segment as Andrews and Kern (1947) thought. This in turn seems to indicate that radially symmetrical false trunks were not a constant characteristic of the genus.

Growth habit.—The growth habit of *Tempskya* has been a matter of speculation for many years. As noted, Kidston and Gwynne-Vaughn (1911) discussed the subject and prepared a reconstruction that Stopes published in 1915. (See fig. 1 of this report.) Later Seward (1924), Read and Brown (1937), and Read (1939) considered the problem, but it was not until 1947 that a new restoration was attempted. In that year, Andrews and Kern analyzed all the information available about the growth habit of *Tempskya* and published the somewhat different reconstruction reproduced here as figure 2.

Andrews and Kern (1947) showed that in material they identified as *T. wesselii*, the courses of some of the branches of the stem system were somewhat oblique, as though passing to the margins of the false trunks below the apices. They interpreted this emergence at lower levels as indicating that the false trunks were invested by fronds for some distance below the apical area of the composite organ. As a result, the reconstruction of a radially symmetrical *Tempskya* published by Andrews and Kern shows the upper two-thirds of the false trunk bearing several irregular clusters of fronds. (See fig. 2.) Thus, it contrasts somewhat with the restoration published by Stopes. (See fig. 1.)

Although the authors of this report do not entirely agree with the interpretation that the false trunks bore fronds well below the apices, the situation noted by Andrews and Kern has also been observed in *T. reesidei*. There appears to be little if any evidence of such marked divergences in the other well-preserved species of the genus, and in *T. zelleri* the stems appear to be confined to the central area of the false trunk. In view of the fact that fern fronds are rather ephemeral organs, it would follow, should Andrews and Kern's interpretation be correct, that the branched stem system must have been more rapidly growing than is common in ferns. It seems more likely that the leaves were confined to an apical crown at any given time, somewhat as suggested by Stopes, rather than loosely distributed along the margins of more than half of the false trunks.

Andrews and Kern (1947, p. 133) pointed out that although paleobotanists like to compare fossil plants with modern ones, we may, in the case of *Tempskya*, be "dealing with a different mode of increase in the diameter of the trunk, as well as a highly unique physiological setup with regard to photosynthesis and transportation of fluids." Ordinarily, the stems of tree ferns, palms, and cycads, all of which have certain physiological and architectural similarities to the false trunks of the tempskyas, are characterized by crowns or apical growths of large and usually compound leaves or fronds. In *Tempskya*, however, it is rather unlikely that the fronds ever reached a length much greater than 30 cm, because the diameters of the phyllopodia in *Tempskya* are much smaller than the diameters of similar organs in tree ferns, cycads, and palms. On the basis of this characteristic Andrews and Kern believed that the *Tempskya* false trunks must have had many more fronds than do modern tree ferns, cycads, and palms in order to have achieved the necessary balance of photosynthesis.

Although we do not attempt a restoration here, we would like to make a few comments about the growth habit of *Tempskya*. To begin with, as it is generally agreed that most, and probably all, specimens of *Tempskya* are the remains of single plants rather than of a colony of ferns, then the massive and complexly branched stem systems must have originated from single stems. In addition, the individual stems are dorsiventral. In consequence, the young plants must have been horizontal and must have developed the unusual upright characteristic only after sufficient massiveness through branching had been achieved so that the composite or false trunk was sufficiently strong to support itself completely or partly. Both the holotype of *T. knowltoni* and the paratype (USNM 167547) of *T. reesidei* are interpreted as parts of false trunks immediately adjacent to the very young plant. In other words, they probably represent an early stage in the development of the plant while the growth was still horizontal. The specimens referred to as bases by Andrews and Kern quite possibly were fairly low in the false trunk and formed after the plant attained an upright stance; they must have been above the broadly rounded terminations discussed above.

Tempskya reesidei Ash and Read, n. sp.

Plates 1–4; figures 7–9

Diagnosis.—False trunks large, 10–30 cm in diameter, radially symmetrical; individual stems usually 3–5 mm in diameter; internodes long, usually showing one or two, rarely three, leaf traces in a transverse section; cortex two layered, outer layer of parenchyma cells with dark contents, about 10 cells wide, inner layer narrow, about five cells wide, composed of small, thick-walled sclerenchyma cells, inner layer containing irregular, elongate "island like" bodies of parenchyma; outer endodermis present; pericycle and phloem thin; xylem with little interspersed parenchyma; interior phloem and endodermis present; pith composed of an outer layer of sclerenchyma and a center composed of parenchyma and large sclerenchyma cells. Adventitious roots randomly oriented.

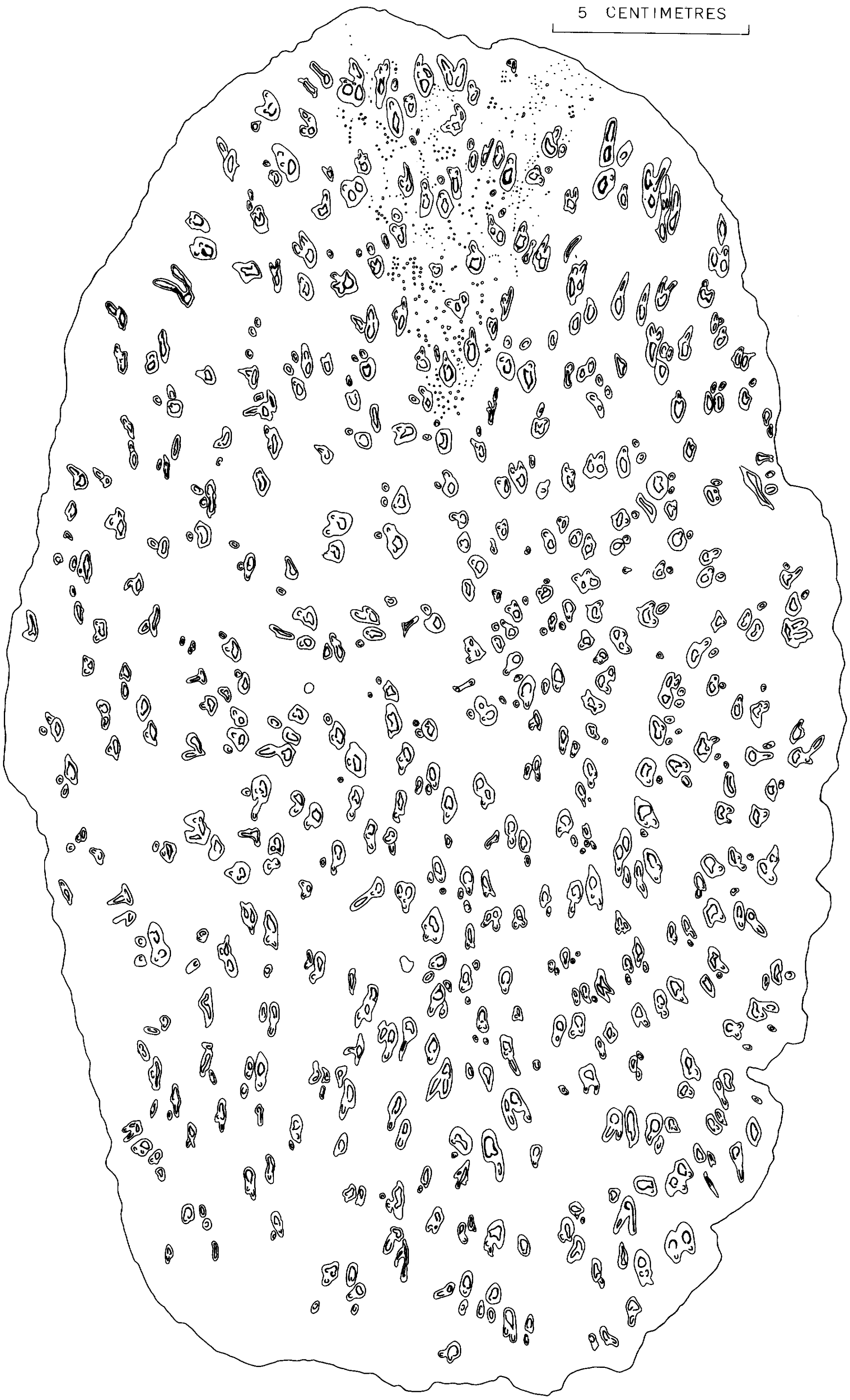
Description.—The holotype of *T. reesidei* n. sp. is a false trunk ranging in diameter in the apical part from about 20.5×11 (circumference of 52.5 cm) to 27.5×16.2 cm (circumference of 71.3 cm) near the base of the preserved part of the false stem. As indicated in figure 7, the false trunk is characterized by more than 425 stems sheathed in a loose mass of adventitious roots. The stems, in general, are radially disposed. In the central area of the false trunk, most of the stems are vertical in their orientation. However, it is apparent that the stems in the peripheral zone have a pronounced tendency to be obliquely oriented and to trend outward to the margin of the false trunk (pl. 1, fig. 1). Many leaf traces and bases are visible in the diagram (fig. 7), and many phyllopodia may be seen. In the section very few, if any, of the stems are penetrated by adventitious roots of *Tempskya*. Consequently, we suggest that the stems may have been functional at a distance of at least a meter below the apical area of the false trunk. Although in certain details the stems are not strictly equally dichotomous, the variations are sufficiently minor that for general purposes the branching can best be described as equally dichotomous. It also appears from the abundance of leaf traces, bases, and phyllopodia related to the various stems at any given level that the stems are characterized by long internodes. Equally apparent from the section is the fact that the departure of the leaves from the stem must have approached a right angle, in comparison with the very acute angles characteristic of most other American species of *Tempskya*.

Figure 8 is a reconstruction of the paratype of the species that was found in place and removed by the writers. This specimen is also shown on plate 3, figure 3. The fossil is irregularly tapered and is reminiscent of the specimen of *T. knowltoni* described by Seward (1924). Cuts were made in this specimen at two levels, as indicated in figure 8. The larger slice, approximately through the middle of the specimen, is shown diagrammatically in figure 9*A*. Some stems are shown in the false trunk with a rather imperfect radial symmetry. Present and of interest are foreign objects indicated at d. The position of two of these is also shown in the profile (fig. 8). Both the stems and the foreign vegetative bodies, which are fragmentary stems of a woody dicotyledonous plant, are penetrated by the adventitious roots of *Tempskya* and are sufficiently broken down (morphologically) so that the details of structure can be ascertained in only a general way.

The section illustrated in figure 9*B* was cut approximately 5 cm from the tip of the horn-shaped specimen; it has only three stems in it, and again these are penetrated by many roots.

Plate 1, figures 1 and 2, illustrate the anatomy of *Tempskya reesidei* at rather low magnification. It is apparent that the stems are solenostelic and are dorsiventral. The leaf traces depart in two ranks from the stem on one side, and adventitious roots are derived at random on the rest of the stem surface. The leaf traces, bases, and phyllopodia are characterized by U-shaped steles that are rather broad and short in cross section. A considerable amount of sclerenchyma is evident in both the stem and phyllopodia. The stems are sheathed in a mass of adventitious roots, many of which are divergent from the courses of the stem so that they form a tangled mass. In addition, the stems are sheathed by a thick mat of dermal emergences or epidermal hairs.

The general characteristics of transverse and slightly oblique sections of *T. reesidei* n. sp. are illustrated on plates 1–4. Several leaf traces and


5 CENTIMETRES

bases are shown in various stages of development. The epidermal area cannot be clearly identified, although its approximate position is marked by "e" on plate 4. When examined in detail, the mass of homogeneous matted tissues on the exterior is seen to be a dense and relatively thick zone of epidermal hairs.

Beneath the dermal zone is an outer cortical zone of parenchyma. This reaches a maximum width of approximately 10 cells and in most stems is poorly preserved. The cells are large in cross section and appear to have been filled with protoplasm originally, as there is carbonaceous material embedded in the silica that now constitutes the filling of the cells. The inner margin of the outer cortex abuts irregularly against a narrow zone of small sclerenchyma cells. This sclerenchyma zone is rarely more than five cells in diameter, and because of the small size of the cells it is only about one-third the width of the outer cortex. Within this zone of sclerenchyma is a second layer of parenchyma poorly preserved but apparently similar to the outer cortex. In cross section this zone of parenchyma is slightly wider than the bounding sclerenchyma on the exterior and is seen to be discontinuous, inasmuch as the outer sclerenchyma zone bridges the parenchyma at several points so that the parenchyma areas lie as elongate "island like" bodies within sclerenchyma. On the interior of the parenchyma and constituting a zone only slightly narrower in cross section than the outer sclerenchyma, is a zone of inner sclerenchyma similar to the outer zone and connecting with it, as is apparent on plate 1, figure 2. This in turn is bounded by poorly preserved or ill-defined endodermis. Judging from the thin layer of tissues between the outer face of the xylem ring and the endodermis, little, if any, pericycle is present. In fact, all the tissues in this zone originally may have been elements of the phloem and are so indicated by the symbol "ph" on plate 4.

The xylem cylinder is exarch and is rarely wider than six cells. A small amount of xylem parenchyma is present, but most of the cells, except for the protoxylem, are scalariform tracheids. On the exterior of the xylem ring is the interior phloem and a vaguely marked interior endodermis. The margin of the pith is marked by a zone of sclerenchyma which reaches a maximum width of about five cells and within which are the remnants of large sclerenchyma cells.

Figure 7 shows that in every section of a true stem there is evidence of leaf emergence in one stage or another, and several stages are usually apparent. A very early stage in the origin of leaf trace is seen on plate 1, figure 2. The xylem strand, as well as the accompanying inner and outer zones of the stele, has thinned and bulges outward slightly. A somewhat more advanced stage is shown on plate 4 where the stele has been gapped and the inverted U-shaped trace emerges at a rather oblique angle. The steepness of the angle is indicated by the fact that the stelar cells in the stem are cut in cross section, whereas those of the trace are oblique.

On plate 3, figure 2, more advanced stages in leaf-trace emission are shown. The inverted U-shaped xylem strand is slightly swollen at the terminations and also has a tendency to bend inward in cross section. It is enveloped by phloem and endodermis.

On plate 3, figure 1, the leaf base, that is, that zone in emission of the foliar trace just prior to detachment, is shown. The shape of the stele is that of a low inverted U, the terminations of which bend slightly inward. The stele is sheathed by tissues similar to those that constitute the cortex of the parent stem, and also similar to those that constitute the pith.

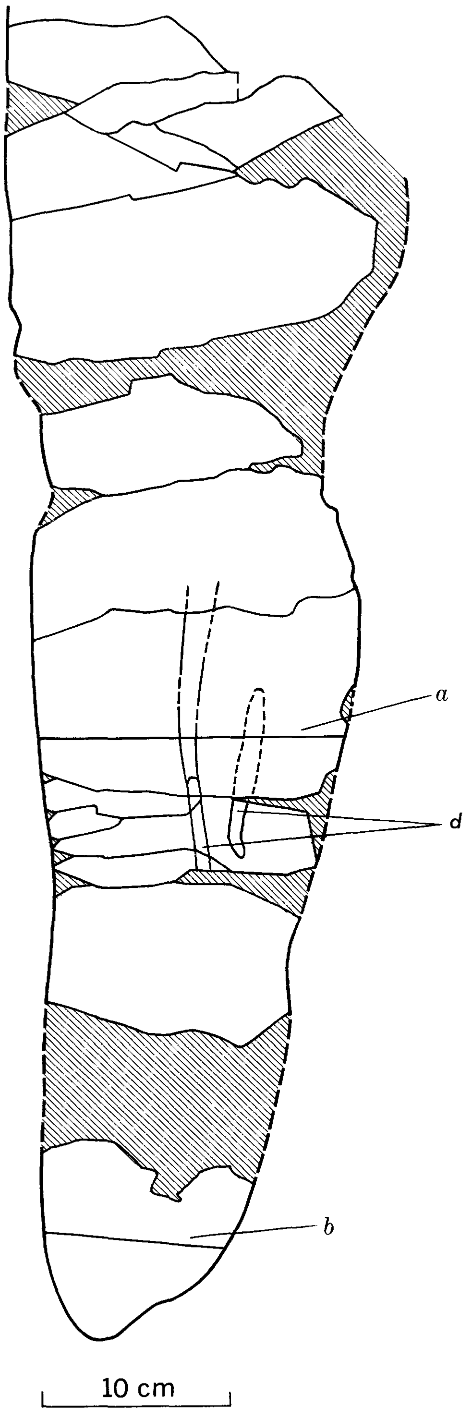
Phyllopodia are very common in *T. reesidei*, n. sp., as figure 7 shows. These are similar to the leaf bases and consist of a sheath of poorly preserved epidermis with dermal hairs, beneath which is an outer parenchymatous cortex and an inner mixed sclerenchymatous and parenchymatous cortex. The stelar tissues are arranged in an inverted U-shaped strand that has invaginated terminals, and the xylem is exarch. Most of the phyllopodia appear to pass outward from the parent stem at rather oblique angles, for in planes that show the stems in transverse section, the phyllopodia are usually cut diagonally, as shown on plate 2.

The roots are diarch and exarch and are limited

FIGURE 7.—Cross section of the false trunk of the holotype of *Tempskya reesidei* n. sp. showing the distribution and radial orientation of the stems. Note that they are transversely sectioned near the middle of the specimen, but are cut more and more obliquely as the margins are approached. The figure also indicates that the internodes are long, because just a few (usually two) departing leaf traces are associated with each stem. In contrast, the stems of *T. wesselii* usually have only one associated leaf trace and very long internodes, and the stems of *T. grandis* often have three to five associated leaf traces and short internodes. The low frequency of free petioles in the false trunk is typical of *T. reesidei.* Adventitious roots are present throughout the section between the stems, but for simplification only the vertically oriented ones are shown in a small part of the illustration. USNM 167546g.

by a well-defined endodermis, beneath which are small areas of phloem. The cortex appears to be entirely sclerenchymatous, and an outer lacunar zone has not been observed. In contrast to the other species described in this report, only a few of the roots of *T. reesidei* are oriented parallel to the parent stems (pl. 3, fig. 1). Most are oriented outwardly in a random fashion so that a dense tangle of these organs apparently was present in life.

Remarks.—The species is named for John B. Reeside, Jr., who took great interest in the stratigraphic range of *Tempskya* for many years before his death in 1958.



Material.—Holotype: USNM 167546. Paratype: USNM 167547.

Distribution.—This species occurs in the Mojado Formation on the east flank of the Animas Mountains, Hidalgo County, N. Mex., at USGS fossil plant locality 9703.

Tempskya zelleri Ash and Read, n. sp.

Plates 5–7; figure 10

1956. *Tempskya minor* Read and Brown: Zeller and Read, p. 1804.

Diagnosis.—False trunks small to medium, as much as 17 cm in diameter, radially symmetrical; individual stems usually 3–8 mm in diameter, distinctly angular in cross section; internodes very long, usually showing one, rarely two or three, leaf traces in a transverse section; cortex three-layered, outer layer narrow, composed of parenchyma, middle layer wide, composed of sclerenchyma, inner layer wide, composed of parenchyma; outer endodermis present; outer pericycle and phloem thin; xylem exarch with little interspersed parenchyma; inner phloem, inner pericycle, and endodermis present; pith consisting of thin outer layer of parenchyma and a central area of sclerenchyma. Free petioles rare. Adventitious roots usually vertically oriented.

Description.—The largest specimen of *T. zelleri* that has been collected is about 17 cm by 11 cm in diameter; it is illustrated diagrammatically in figure 10. Thirty-two stems are present and are oriented so that the false trunk has a crude radial symmetry. The stems are all in a central zone in the false trunk, on the exterior of which is a rindlike area made up entirely of adventitious roots. The stems are all vertical or nearly vertical in their orientation in the false trunk, are small, and are equally dichotomous. The low number of leaf traces associated with each stem suggests relatively long internodes, longer than in *T. reesidei* Ash and Read.

FIGURE 8.—Reconstruction of the basal part of the false trunk of the paratype of *Tempskya reesidei* n. sp. Fragments of the specimen that were recovered are shown unpatterned and the missing parts are patterned. The position of the cross sections in figures 9*A* and *B* are indicated by the straight lines at *a* and *b*, respectively. Places where stems of woody dicotyledonous plants adhered to the exterior of this false trunk of *T. reesidei* when it was alive are indicated by d. Solid lines show the present extent of this foreign vegetative material, and the dashed lines delineate the impressions they made on the surface of the false trunk by other parts of these same woody stems. USNM 167547.

FIGURE 9.—Cross sections of the false trunk of the paratype of *Tempskya reesidei* shown in figure 8; USNM 167547. *A*, Section cut through about the middle of the specimen (at *a* in fig. 8), showing the comparatively large number and orientation of the stems and the remains of three foreign vegetative bodies (d). Compare the number of stems in this section with the three in the section cut through the basal part of the fossil shown in figure 9*B*. Adventitious roots are not shown in the figure although they are abundant in the section. *B*, Section cut through the basal part of the specimen (at *b* in fig. 8). Note the rarity of stems in this section. The bulk of the false trunk at this level is composed of adventitious roots, but simplification they are not shown.

The most characteristic feature of all specimens of this species that have been examined is the angular nature of both the steles and the stems when viewed in cross section. It was at first thought that this angularity might be due to crushing of the plant material during the processes of sedimentary loading and postdepositional deformation of the containing rocks in the Big Hatchet Mountains. However, as is indicated by the diagram (fig. 10), the largest specimen is nearly equidimensional in cross section, and there is no apparent relationship between the small amount of flattening that may be inferred and the orientation of the stems. In addition, the tissues of the stem, as will be shown at a later point, are not crushed or deformed any more than in other species of *Tempskya* that do not show the angular characteristics that seem to mark this form. In consequence, the writers are forced to assume that the angularity is characteristic of the species, just as it is a characteristic of some genera and species of modern ferns.

The general characteristics of the stems are illus-

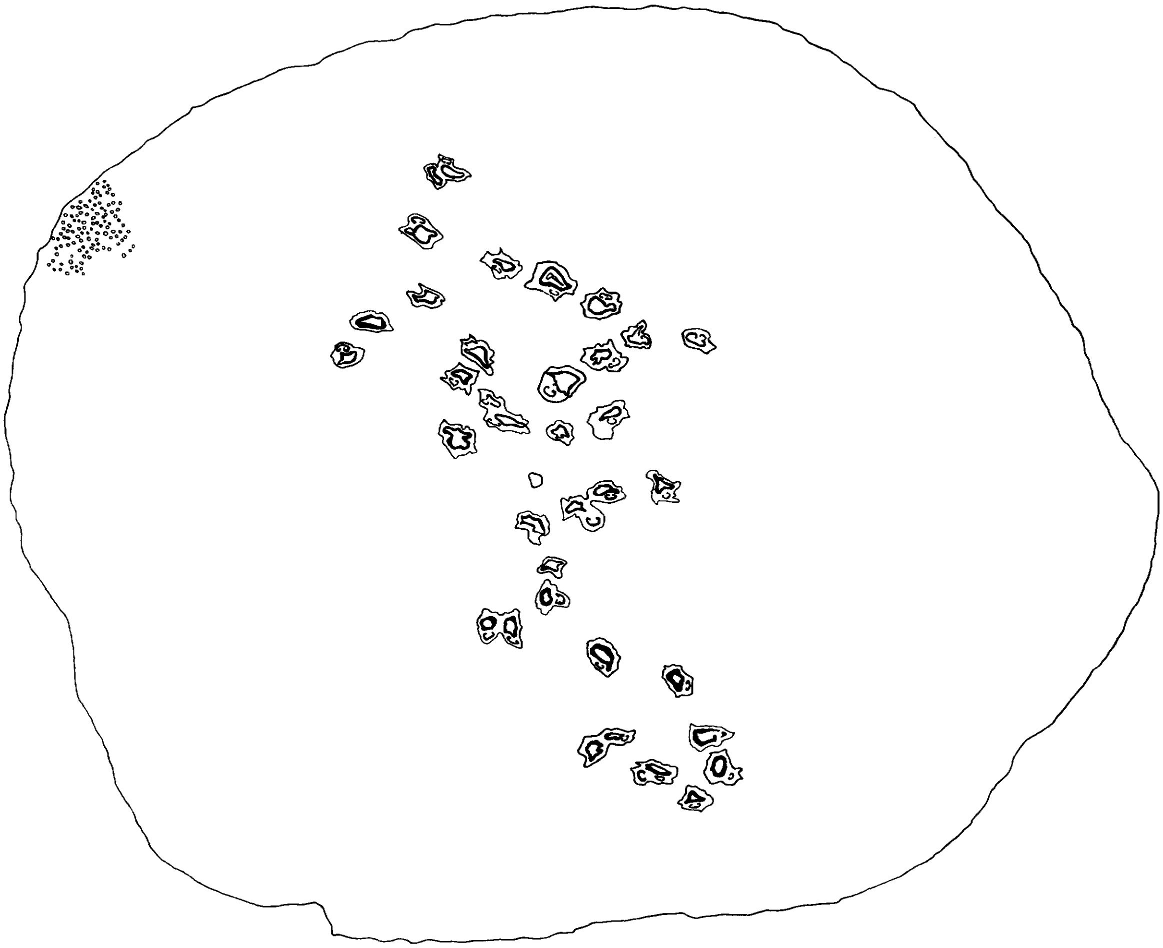


FIGURE 10.—Cross section of the false trunk of the holotype of *Tempskya zelleri* n. sp. showing the distribution and crude radial orientation of the stems. In this specimen they are concentrated more or less near the middle of the false trunk and generally are transversely sectioned, contrasting in both of these features with *T. reesidei* n. sp. Compare the diagram with the cross sections of *T. reesidei* n. sp. (figs. 7 and 9*A*). Another significant feature of the species that can be seen in the figure is the angularity of the stems which contrasts with the rounded stems of *T. reesidei* n. sp. and all the other known species of the genus. Adventitious roots are present throughout the section, but for simplification they are shown as small circles in a part of the illustration. USNM 167543.

trated on plates 5 and 6. They are dorsiventral and give off leaf traces in two ranks. Only rarely is more than one leaf trace seen in a single transverse section associated with a single stem. (See plates 5 and 6.) In consequence, it may be assumed that the internodes are somewhat longer than in *T. reesidei*. From the point of their inception the leaf traces are seen to be oblique in comparison with the orientation of the stem, so it may be assumed that they pass out from the parent stem at rather low angle to the stem.

In the stems examined, the epidermis is rarely preserved. The outer cortex appears to be a zone about one-fifth the width of the entire cortex. It is poorly preserved and parenchymatous. The middle cortex consists of sclerenchyma, which judging from the sizes of the lumens, may be stone cells, and is at least three times the thickness of the outer cortex. It is usually dark brown, and the lumens appear to be nearly closed. Bordering the middle cortex is the inner cortex which is at least twice the width of the outer cortex and on the average slightly narrower than the middle cortex. The inner cortex is thinner walled than the middle cortex and appears to be parenchyma. The endodermis is fairly well defined in this species, and internal to it is a very thin zone of pericycle and phloem. These tissues are all illustrated on plate 7. The xylem is exarch and, like *Tempskya minor*, the protoxylem appears to be a series of clusters rather than a continuous ring. One especially prominent cluster of protoxylem is seen on plate 7. It will be noted on this plate that adjacent to the prominent protoxylem, large metaxylem cells extend to the interface of the xylem and phloem. The xylem is from four to as many as eight cells wide. It is characterized by an abundance of small-celled xylem and parenchyma interspersed with the scalariform tracheids. A narrow zone of inner phloem and pericycle within the xylem ring is bounded by the inner endodermis. The pith is characterized by a thin outer ring of parenchyma and a central area of sclerenchyma.

Leaf traces cut at low levels are shown on plate 6, figure 3 (upper left), and others cut at higher levels are on plate 6, figure 2. The leaf traces depart at a very low angle from the xylem ring and from the stem in general. Thus, on plate 6, figure 3, the xylem ring of the stem is in cross section except for the part that is bulging into a leaf trace. In this protrubence the tracheids are slightly oblique. At a still higher level (pl. 6, fig. 3; pl. 7), the same obliqueness may be noted. The leaf traces are inverted U shaped with invaginated or recurved ends. The xylem is two or three cells wide except at the terminations, where knoblike bulges cause it to be as much as six cells wide. The xylem is completely surrounded by phloem, a thin zone of pericycle, and the endodermis. The inner cortex within the inverted U of the stele is a very thin zone of parenchyma, and the middle cortex is a thick zone of sclerenchyma. The cortex on the exterior of the inverted U of the stele consists of a much thicker inner parenchymatous zone and a somewhat thinner sclerenchymatous middle cortex.

Phyllopodia are rarely seen in specimens attributed to this species.

The roots are diarch and exarch, have only a few tracheids, are sheathed by a thin zone of phloem and pericycle, and the stele is bounded by a very well defined endodermis (pl. 7). The cortex appears to be almost entirely sclerenchymatous. No evidence of an outer lacunar cortex was observed in the roots of this species. The long axes of the adventitious roots of *T. zelleri* appear to be oriented parallel to the long axes of the stem in most cases. Exceptions, of course, occur at the point of departure of the adventitious roots from the stem where the long axes are at nearly right angles. The orderly orientation of the adventitious roots in this species contrasts strongly with the random orientation of the roots, with the resultant tangle that appears to be so characteristic of *T. reesidei.*

Remarks.—The species is named for Robert A. Zeller, Jr., who collected many of the specimens on which this species and *T. reesidei* n. sp. are based and who was an authority on the geology of southwestern New Mexico before his untimely death in 1970.

Material.—Holotype: USNM 167543. Paratypes: USNM 167541, 167542, 167544.

Distribution.—*T. zelleri* occurs in the Mojado Formation south of the Big Hatchet Mountains, Hidalgo County, N. Mex., at USGS fossil plant locality 9702.

COMPARISONS OF THE SPECIES OF *TEMPSKYA*

At present, nine species of *Tempskya* have been described from North America. These are *Tempskya grandis* Read and Brown, *T. knowltoni* Seward, *T. minor* Read and Brown, *T. reesidei* Ash and Read, *T. superba* Arnold, *T. wesselii* Arnold, *T. whitei* Berry, *T. wyomingensis* Arnold, and *T. zelleri* Ash and Read. In addition, several species are known in Europe, and two of these, *T. rossica* Kidston and Gwynne-Vaughan and the new *Tempskya* from England are based on very well preserved material. The following discussion is restricted to the well-preserved species in North America and to *T. rossica.* The several European species that are based on poorly preserved material, and *T. whitei* Berry, which is also known only from poor specimens, are mentioned only incidentally.

False trunks.—The several species of the genus *Tempskya* are tentatively classified into two groups according to the symmetry of the false trunks, one being characterized by dorsiventral false trunks and the other by radially symmetrical false trunks. *T. knowltoni* and *T. minor* continue to be the only known species that have dorsiventral false trunks. The radially symmetrical group now includes *T. grandis, T. rossica, T. superba, T. wesselii, T. wyomingensis,* and the two new species described here, *T. reesidei* and *T. zelleri.*

Stems.—It was suggested by Read and Brown

(1937) and again by Arnold (1945) that variations in dispositions of tissues in the cortex of the stems must have systematic value. The writers agree with the earlier findings and place emphasis on the cortical characteristics.

Two groups of *Tempskya* may be recognized on the basis of the disposition of tissues in the cortex, the first characterized by a simple cortex consisting of inner parenchymatous, middle sclerenchymatous, and outer parenchymatous zones. the outer parenchymatous zone, in some cases, being reduced to only a few cells in thickness. The second group is characterized by an inner mixed zone of parenchyma and sclerenchyma, a middle sclerenchymatous, and an outer parenchymatous zone. Parenthetically, the usage of the terms inner, middle, and outer zones of the cortex does not mean that these are homologous tissues (Arnold, 1945). As here used, the terms simply refer to position with respect to the epidermis and to the stele.

The group characterized by the simple three-layered type of cortex includes *T. zelleri, T. knowltoni, T. minor*, and *T. rossica*. Idealized diagrams of the stems of these species are shown in figure 11, and anatomical details of *T. zelleri* are illustrated on plates 5–7. Details of *T. knowltoni* are shown on plate 8 and those of *T. minor* on plate 9. In these four species, the cortex is characterized by an inner zone of parenchyma, a middle zone of sclerenchyma, and an outer zone of parenchyma. The relative widths of these zones probably are fairly constant, but the exact widths are probably functions of relative sizes of the stems.

In the second group, characterized by mixed tissues in the inner cortex, several architectural patterns as viewed in cross sections appear to be of specific value. Diagrams of the stems of *T. reesidei, T. grandis, T. wyomingensis, T. wesselii*, and *T. superba* are also shown in figure 11. Anatomical details of *T. reesidei* are illustrated on plates 1–4, whereas those of *T. grandis* are shown on plate 10, those of *T. wyomingensis*, on plate 11, those of *T. wesselli*, on plate 12, and those of *T. superba*, on plate 13.

In *Tempskya grandis* and *T. superba* an irregular and discontinuous band of sclerenchyma divides the inner and dominantly parenchymatous cortex into three bands, as is indicated in the diagrams. In *T. reesidei, T. wesselii*, and *T. wyomingensis* the inner cortex is characterized by inner and outer zones of sclerenchyma separated by a continuous or discontinuous band of parenchyma. According to Arnold (1945), in *T. wesselii* and *T. wyomingensis* these bands of sclerenchyma are actually stone cells. In *T. reesidei* the middle belt of parenchyma is discontinuous by reason of radial bands of sclerenchyma that connect the inner and outer continuous zones of sclerenchyma. In *T. wesselii* and *T. wyomingensis*, the middle zone of parenchyma is continuous, according to Arnold (1945).

Epidermal emergences that appear to be simple hairs are characteristic of at least two species, *Tempskya zelleri* and *T. minor*. Because the epidermis is rarely preserved in most stems, such structures may have occurred in other species.

Except for differences in diameters, the steles of all species are fairly similar in their characteristics, although there are some slight differences. For instance, the protoxylem in most species appears to form a continuous or nearly continuous band on the exterior of the xylem cylinder, whereas in *T. zelleri* and *T. minor* it is discontinuous and occurs as discrete strands.

Earlier it was thought by one of the writers that variations in amounts of xylem parenchyma might be of value in separating some of the species (Read and Brown, 1937). Arnold (1945) discussed this problem and was inclined to question the value of this criterion. After reviewing the matter on the basis of new material in hand as well as the material earlier described, the writers are now inclined to agree with Arnold. The xylem is rarely more than 9–10 cells wide and is usually less.

The morphological details of the leaf traces and phyllopodia are in general similar, except for the envelopment of the epidermis. At present, except for the variations in cortex, the writers are unable to recognize any differences in these organs in the various known species.

One observation of possible value has been made, however, regarding the presence or absence of preserved phyllopodia. In most species these organs are rarely noted, and in some, as *T. knowltoni*, they have not been reported, whereas, in *T. reesidei* they are quite abundant.

The pith in all known species of *Tempskya* consists of two zones. The outer zone is parenchymatous or a mixture of parenchyma and sclerenchyma. In general, it is similar to, but thinner than, the inner cortex of the stem. The inner or central zone of the pith in all species is sclerenchyma and similar to the sclerenchyma of the middle cortex, although somewhat thicker walled.

All investigators of the morphologic characteristics of the genus *Tempskya* have formally or informally used stem diameter as a basis for specific separation. However, as Arnold (1958) has pointed out, the use of diameter as a character trait always raises a question whether exceedingly large specimens that are otherwise similar to smaller stems may simply be indicative of very robust individuals. Thus, *T. superba* Arnold appears to be identical in all respects with *T. grandis* Read and Brown, but the stem diameter in *T. superba* is approximately twice that of *T. grandis*. Nevertheless, in the absence of data to the contrary, the writers are of the opinion that stem diameters are a valid criterion for distinguishing species.

Earlier, Read and Brown (1937) expressed the opinion that stem diameter and length of internodes might correlate directly. At that time, *Tempskya grandis* and *T. rossica* were the only two large-stemmed species known (>4 mm in diameter), and both of them are characterized by relatively short internodes. Similarly, *T. knowltoni* and *T. minor* were the only small-stemmed (<4 mm in diameter) types known, and both are characterized by relatively long internodes. *T. wesselii* is in stem size somewhat larger in general than *T. knowltoni* and *T. minor*, but as indicated elsewhere, it is characterized by very long internodes comparable in length to those of *T. zelleri* n. sp.

T. wyomingensis is intermediate in average diameter between *T. grandis* and *T. superba*, but it has short internodes. *T. reesidei* n. sp. has small stems and relatively long internodes, whereas *T. zelleri* n. sp., which also has small stems, has very long internodes. It is thus apparent that there is no correlation between stem diameter and length of internodes (Arnold, 1945).

Roots.—The roots of all known species of *Tempskya* appear to be similar, if not identical. In most species the outer cortex is unknown. However, in *T. minor* and *T. wesselii*, several observers (Read and Brown, 1937; Arnold, 1945; Andrews and Kern, 1947) have noted an outer lacunar cortex (pl. 9, fig. 3) as well as a well-defined epidermis bearing simple root hairs. We believe that these observations have been made on exceedingly well-preserved specimens and that the outer lacunar zone in the cortex is probably characteristic of all species.

In general, the adventitious roots of all species parallel or subparallel the long axes of the stems. However, in one species, *T. reesidei*, a relatively high percentage of roots clearly do not parallel the courses of the stems (pl. 3, fig. 1). The importance of this characteristic in the specific concept of *T. reesidei* can only be evaluated after material from many localities has become available.

SYNOPSIS

In an earlier report on *Tempskya* (Read and Brown, 1937) an effort was made to summarize the distinctions of the better known species. This grouping of salient characteristics seems to have been helpful to some of the investigators who have worked on *Tempskya* in more recent years. Accordingly, a new synopsis has been prepared which includes the better known species of the genus.

I. Individual stems of false trunk medium to large (5–15 mm) in cross-sectional diameter. The inner parenchymatous layer of the cortex containing continuous and (or) discontinuous bands of sclerenchyma. Much parenchyma in the xylem ring. False trunks have radial symmetry.
   - A. Inner parenchymatous layer of cortex and exterior of pith contains a single discontinuous and irregular band of sclerenchyma. Internodes short, permitting much overlapping (3–5) of leaf bases.
     1. Individual stems, 10–15 mm in cross-section diameter ---------------------------------- *Tempskya superba*
     2. Individual stems medium, 4–6 mm in cross-section diameter ---------------------------- *Tempskya grandis*
   - B. Inner parenchymatous layer of cortex contains two bands of sclerenchyma separated by a continuous or discontinuous band of parenchyma. The outer band of sclerenchyma is continuous, and the inner band may be either continuous or discontinuous. Exterior of pith does not contain a band of sclerenchyma. Internodes long to very long, permitting very slight to slight overlapping (1-3) of leaf bases.
     1. The two bands of sclerenchyma in the inner parenchymatous layer of cortex are connected locally by strands of sclerenchyma, giving an impression of "islands" of parenchyma surrounded by sclerenchyma. Internodes are long, permitting slight overlapping (2–3) of leaf bases ------------------------- *Tempskya reesidei*
     2. The two bands of sclerenchyma in the inner parenchymatous layer of cortex are completely separated from each other by a continuous band of parenchyma.
        - a. Internodes very long, permitting only very slight overlapping (1–2) of leaf bases. Individual stems 4.0–5.0 mm in cross-sectional diameter---------- *Tempskya wesselli*
        - b. Internodes medium in length, permitting slight overlapping (2–3) of leaf bases. Individual stems 6.0–8.0 mm in cross-sectional diameter----- *Tempskya wyomingensis*

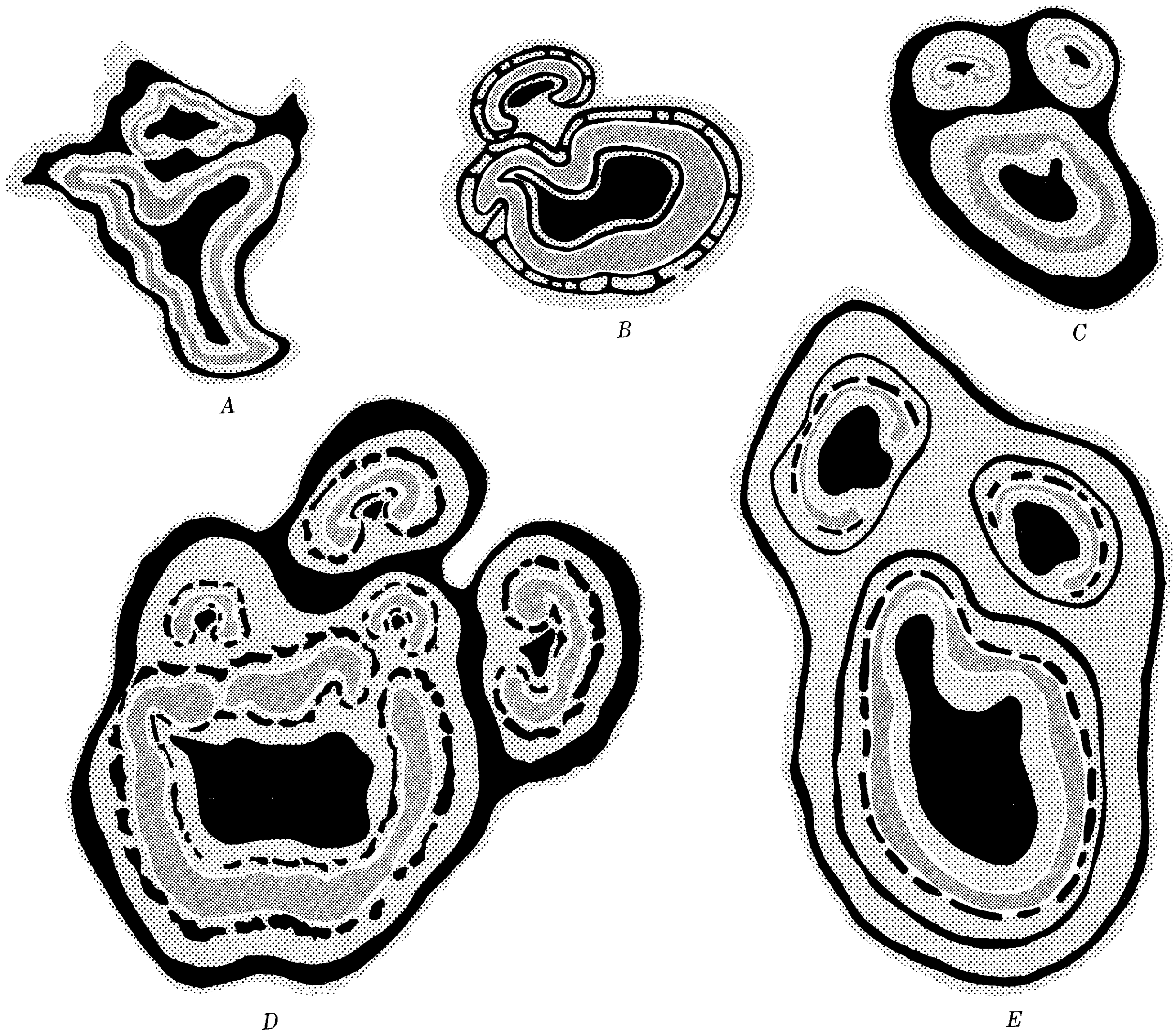


FIGURE 11.—Diagrammatic sketches of the stems of the well-known species of *Tempskya*. Cortical sclerenchyma and similar tissues in the pith are shown as black; xylem of the stele is shown by the dark stipple pattern; the parenchyma is shown by a light stipple pattern; and phloem and pericycle are shown by clear bands. All × 10 except *I* which is × 8. *A*, *Tempskya zelleri*. Adapted from slides of the type specimen. *B*, *T. reesidei*. Adapted from slides of the type specimen. *C*, *T. minor*. Adapted from Read and Brown, 1937, pl. 36, fig. 3, and slides of the type specimen. *D*, *T. grandis*. Adapted from Read and Brown, 1937, pl. 33, fig. 4, and slides of the type specimen. *E*, *T. wyomingensis*. Adapted from Arnold, 1945, pl. 10, fig. 1, and slides of the type specimen. *F*, *T. rossica*. Adopted from Kidston and Gwynne-Vaughan, 1911, pl. 2, fig. 10. *G*, *T. knowltoni*. Adapted from Read and Brown, 1937, pl. 32, fig. 1, and slides of the type specimen. *H*, *T. wesselii*. Adapted from Arnold, 1945, pl. 8, fig. 1, and slides of the type specimen. *I*, *T. superba*. Adapted from Arnold, 1958, pl. 2, fig. 2, and slides of the type specimen.

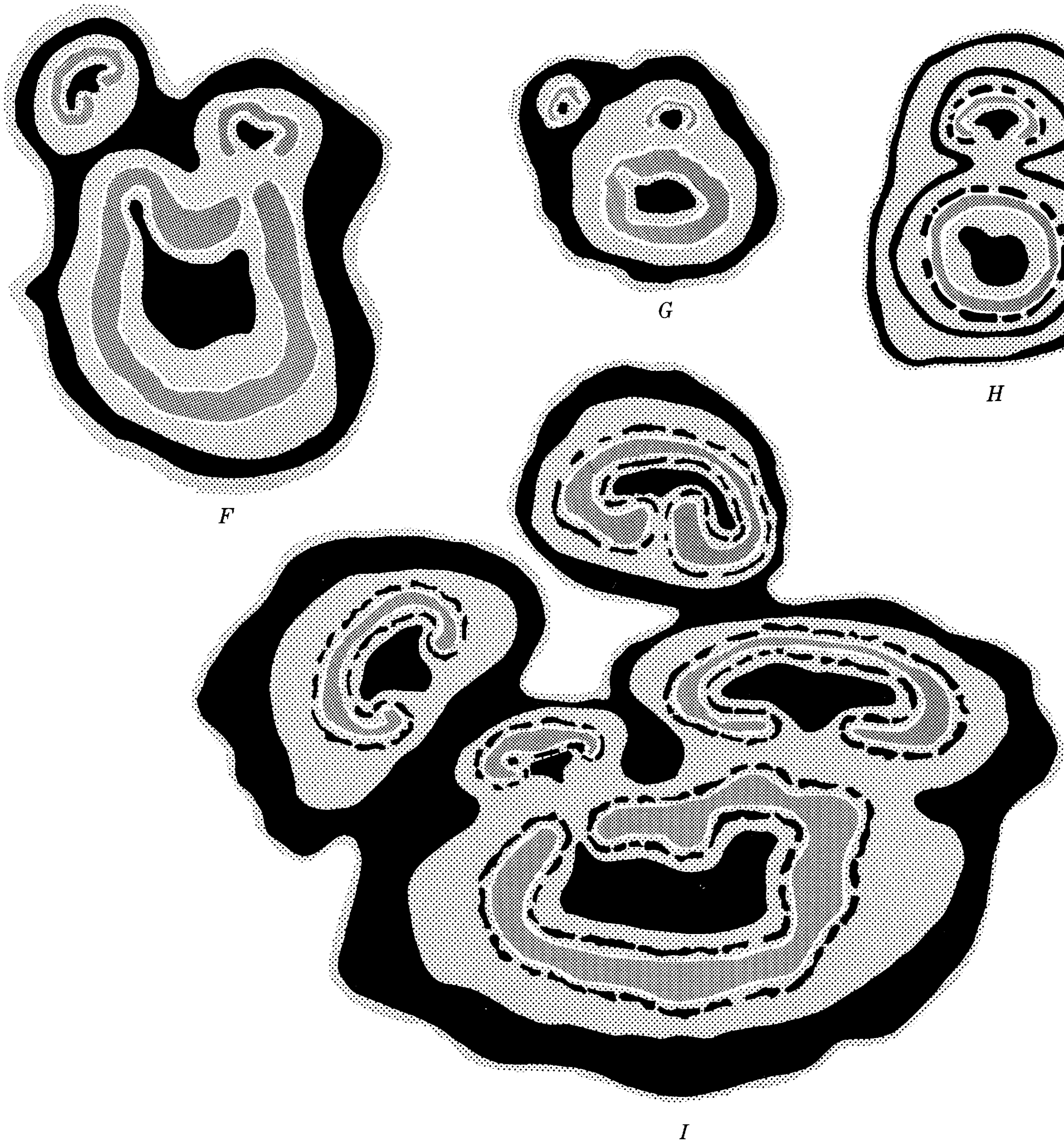


FIGURE 11.—(Continued.)

II. Individual stems of false trunk small to medium (2.5–8.0 mm) in cross-sectional diameter. The inner parenchymatous layer of the cortex does not contain continuous or discontinuous layers of sclerenchyma. Little parenchyma in the xylem ring. False trunks have either dorsiventral or radial symmetry.

A. Individual stems and steles angular in cross section, approximately 3–8 mm in diameter. Internodes very long, permitting only very slight overlapping (1–2) of leaf bases -- *Tempskya zelleri*

B. Individual stems and steles round to subround in cross section. Internodes long, permitting slight overlapping (2–3) of leaf bases.

1. Petioles common in false trunks; stems approximately 2.0–3.5 mm in diameter. False trunks are dorsiventral--------------------- *Tempskya minor*

2. Petioles rare in false trunks. Stems are approximately 2.5–7.0 mm in diameter. False trunks are dorsiventral or radially symmetrical.

a. False trunk dorsiventral. Xylem exarch. Xylem ring containing little if any parenchyma. Stems are 2.5–3.5 mm in diameter ----------------- *Tempskya knowltoni*

b. False trunk radially symmetrical. Xylem exarch or possibly slightly immersed in some specimens. Xylem ring containing much parenchyma. Stems are 6.0–7.0 mm in diameter ------------------- *Tempskya rossica*

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INDEX

[Italic page numbers indicate descriptions and major references]

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PLATES 1-13

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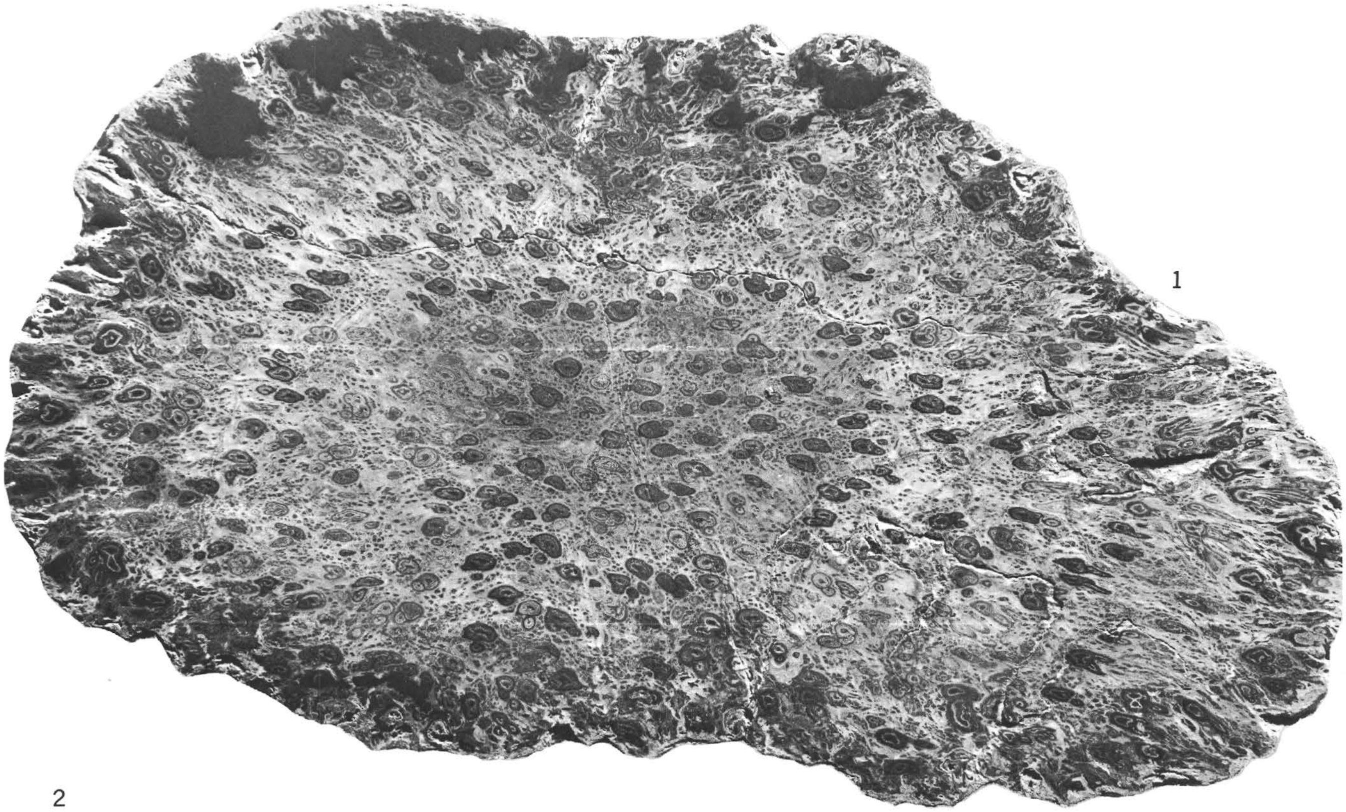
PLATE 1

FIGURES 1, 2. *Tempskya reesidei* Ash and Read, n. sp. (p. 25).

From USGS fossil plant locality 9703.

1. Cross section of the false trunk of the holotype showing the radial distribution of stems. The section is also shown in figure 7. Note that the stems are cut transversely in the central part of the false trunk whereas they are cut rather obliquely near the exterior. USNM 167546f, × 3/4.
2. Two stems and associated leaf traces in the central part of the false trunk. A petiole has just separated from the left-hand stem, and a leaf trace is in an advanced stage of separating from the same stem, as indicated by the protuberance that has formed on the stem. A leaf trace that is nearly free is associated with the right-hand stem. The pronounced thinning of the stele in the same stem indicates that another leaf trace is in the process of forming. The "islands" of parenchyma in the inner cortex show as light irregularly shaped areas just outside of the steles. A few adventitious roots that are randomly oriented are noticeable in the picture. Slide USNM 167546a, × 5.



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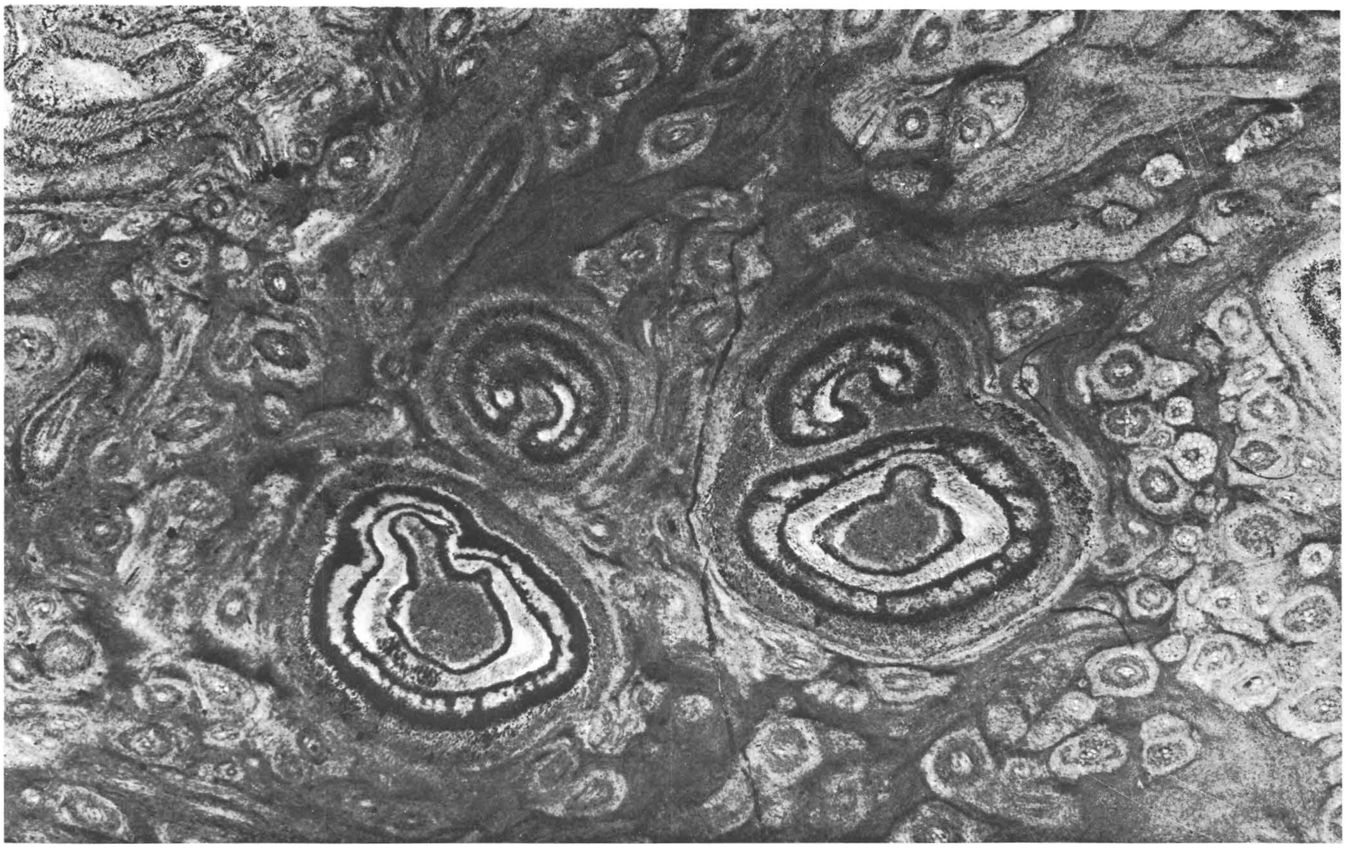


TEMPSKYA REESIDEI ASH AND READ, N. SP.

PLATE 2

Tempskya reesidei Ash and Read, n. sp. (p. 25).

From USGS fossil plant locality 9703.

Cross section a short distance away from the center of the false trunk. Here the stems are somewhat obliquely oriented, and the petioles are at a more oblique angle. Slide USNM 167546b, × 5.

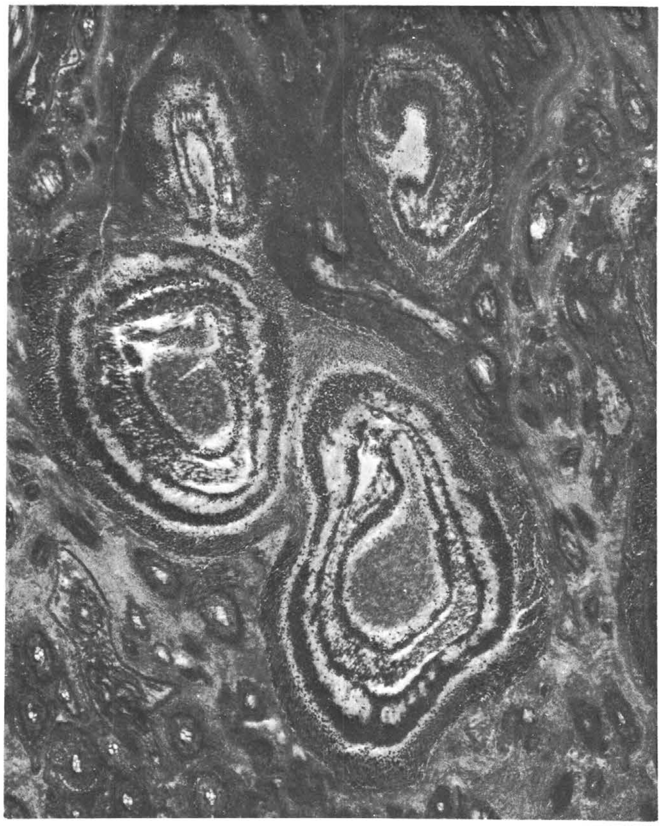
TEMPSKYA REESIDEI ASH AND READ, N. SP.

PLATE 3

FIGURES 1–3. *Tempskya reesidei* Ash and Read, n. sp. (p. 25).

From USGS fossil plant locality 9703.

1. Cross section of two stems which are in the process of dividing. A leaf trace has started to separate from the left-hand stem, whereas a free petiole has just formed above the right-hand stem, and a leaf trace has begun to form on the same stem. The "islands" of parenchyma in the inner cortex that are typical of this species are clearly visible in some places. Note, especially in the upper right-hand corner, that the long axes of some of the roots extend horizontally or at random, rather than vertically as they do typically in *T. zelleri* and other species of *Tempskya*. Slide USNM 167546c, × 10.
2. A stem that has just begun to divide into two stems. The process of dividing has not progressed as far in this example as in the stem shown in figure 1, so the stem is only slightly bilobed. A leaf trace has started to form from the right-hand lobe and a free petiole is just above the narrowed part of the stem. It probably arose from this same stem at a lower level. In most of this view, the long axes of the adventitious roots are oriented vertically, although a few can be seen that are randomly oriented. Slide USNM 167546d, × 10.
3. The basal part of the false trunk of the paratype. This is a view of the side opposite that shown in figure 8. Compare with the picture of the holotype of *T. knowltoni* given by Seward (1924, pl. 16, fig. 1). USNM 167547, about × ⅓.



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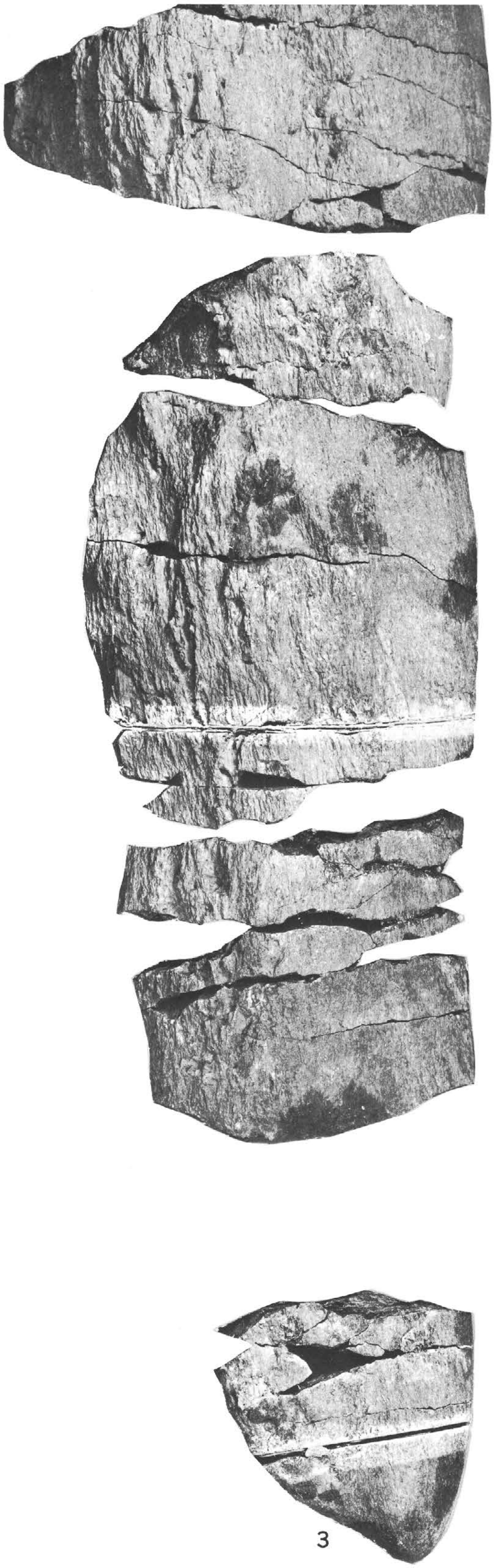

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TEMPSKYA REESIDEI ASH AND READ, N. SP.

PLATE 4

Tempskya reesidei Ash and Read, n. sp. (p. 25).

From USGS fossil plant locality 9703.

A stem and two associated leaf traces. The leaf trace in the upper left is nearly free, whereas the other is in a much less advanced stage of departure, and the leaf gap in the stele is beginning to close. Note that the stelar cells in the stem are cut transversely, whereas those in the leaf traces are cut on oblique angle. The "islands" of parenchyma surrounded by sclerenchyma in the inner cortex of the stem are clearly visible in this section. e, approximate position of the epidermal area; ph, phloem. Slide USNM 167546e, × 25.

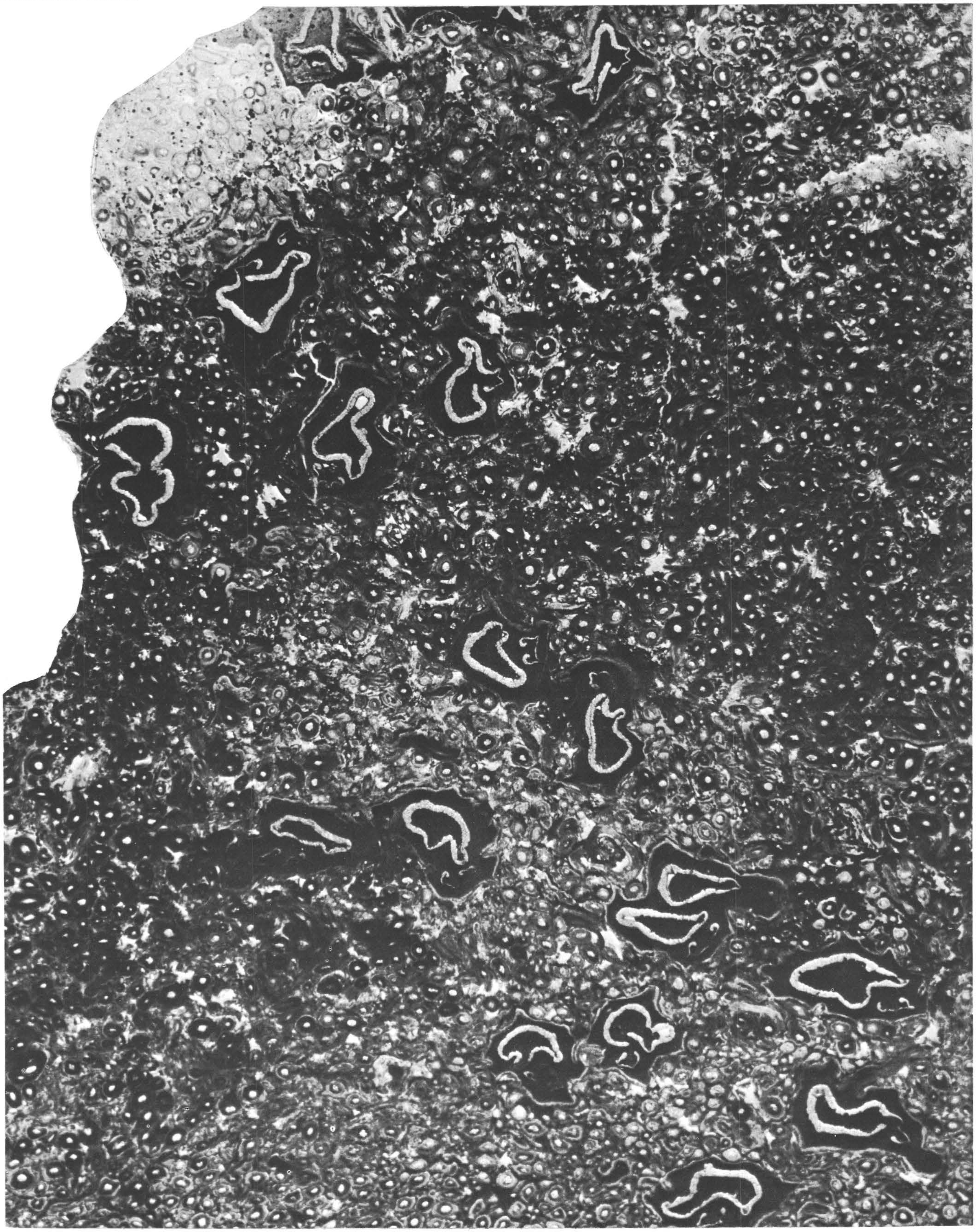
TEMPSKYA REESIDEI ASH AND READ, N. SP.

PLATE 5

Tempskya zelleri Ash and Read, n. sp. (p. 28).

From USGS fossil plant locality 9702.

General view of part of the false trunk of the holotype showing the distribution and orientation of the stems. Note that only one departing leaf trace is associated with most stems. Two exceptions are near the figure margin in the upper left. Each of these contains one leaf trace that is in an advanced stage of departure and another that is in an earlier stage. This feature indicates that the internodes are fairly long in comparison with those of *T. grandis*. Also note the fact that there are no free petioles in this section, a characteristic of the species. Slide USNM 167543b. × 5.



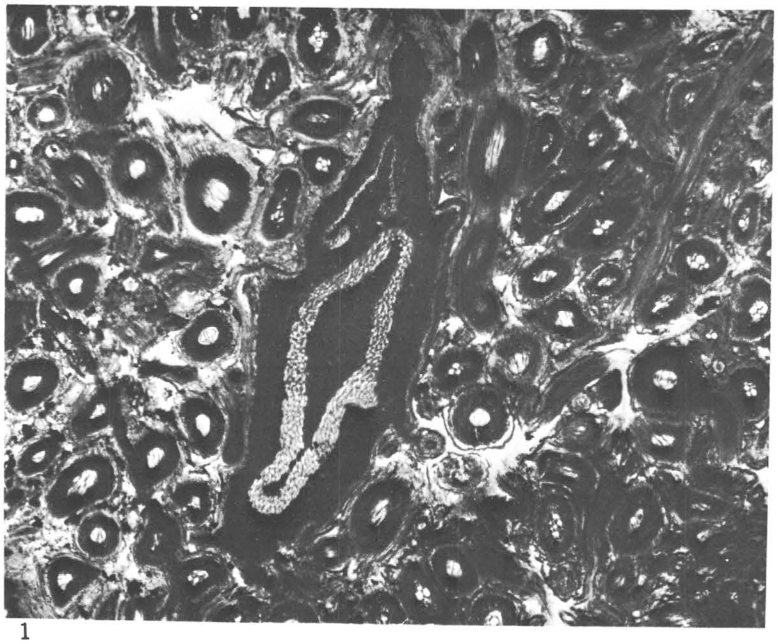
TEMPSKYA ZELLERI ASH AND READ, N. SP.

PLATE 6

FIGURES 1–3. *Tempskya zelleri* Ash and Read, n. sp. (p. 28).

Slide USNM 167543a, × 10. From USGS fossil plant locality 9702.

1. Cross section of a stem in which the xylem of the leaf trace is free and the leaf gap in stem has closed but the cortex of the stem and leaf trace is still united. Note the typical knoblike bulges at the ends of the xylem in the leaf traces in this and the other figures on the plate. Practically all the adventitious roots in the figures are cut transversely, indicating that they are vertically oriented, as is usual in this species.
2. Another stem in the false trunk. The xylem of one leaf trace is now free, and a second one is in the early stages of departure to the left.
3. Six stems with leaf traces in various stages of departure. A stem that is in the process of bifurcating is in the lower left of the figure.



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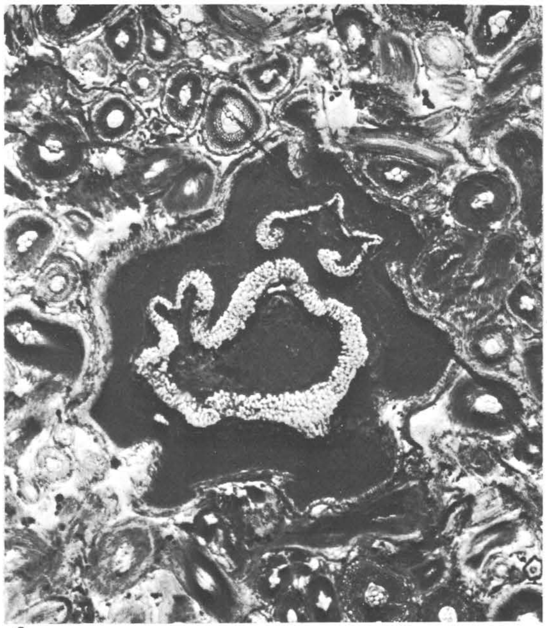

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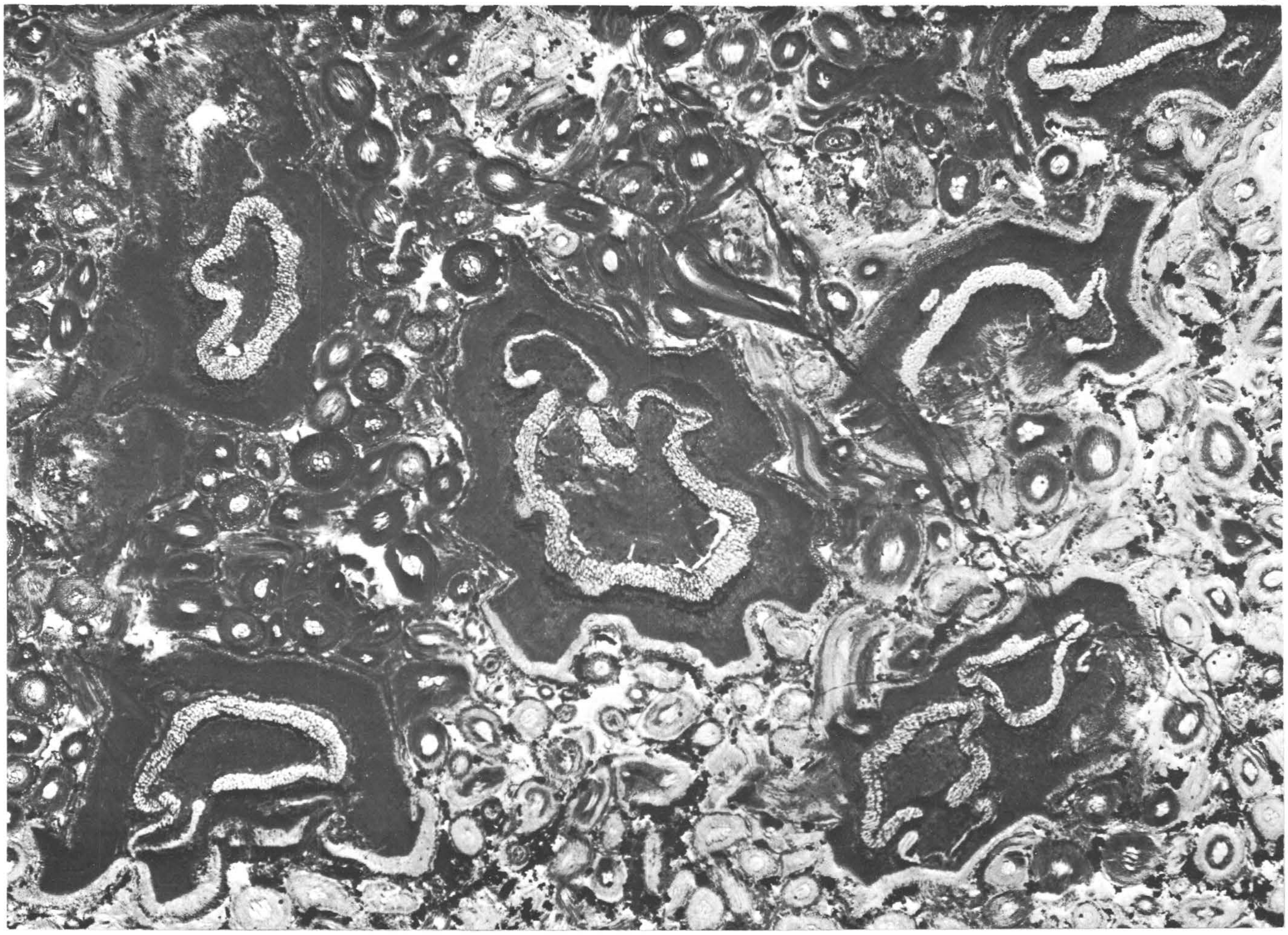


TEMPSKYA ZELLERI ASH AND READ, N. SP.

PLATE 7

Tempskya zelleri Ash and Read, n. sp. (p. 28).

From USGS fossil plant locality 9702.

Transverse section of a stem containing two departing leaf traces. One leaf trace at the upper left is in an advanced stage of departure, although the associated leaf gap in the stele is still present. A second leaf trace which has just begun to form is at the upper right. A leaf gap has formed at the left side of the trace, whereas the xylem of the trace and stele are still united at the right. The knoblike bulges at the ends of the xylem in the left-hand leaf trace are well developed. Angularity of the stem is particularly noticeable in this view. A few of the adventitious roots are randomly oriented, although most are vertically oriented as is characteristic of this species. Slide USNM 167543a, × 25.

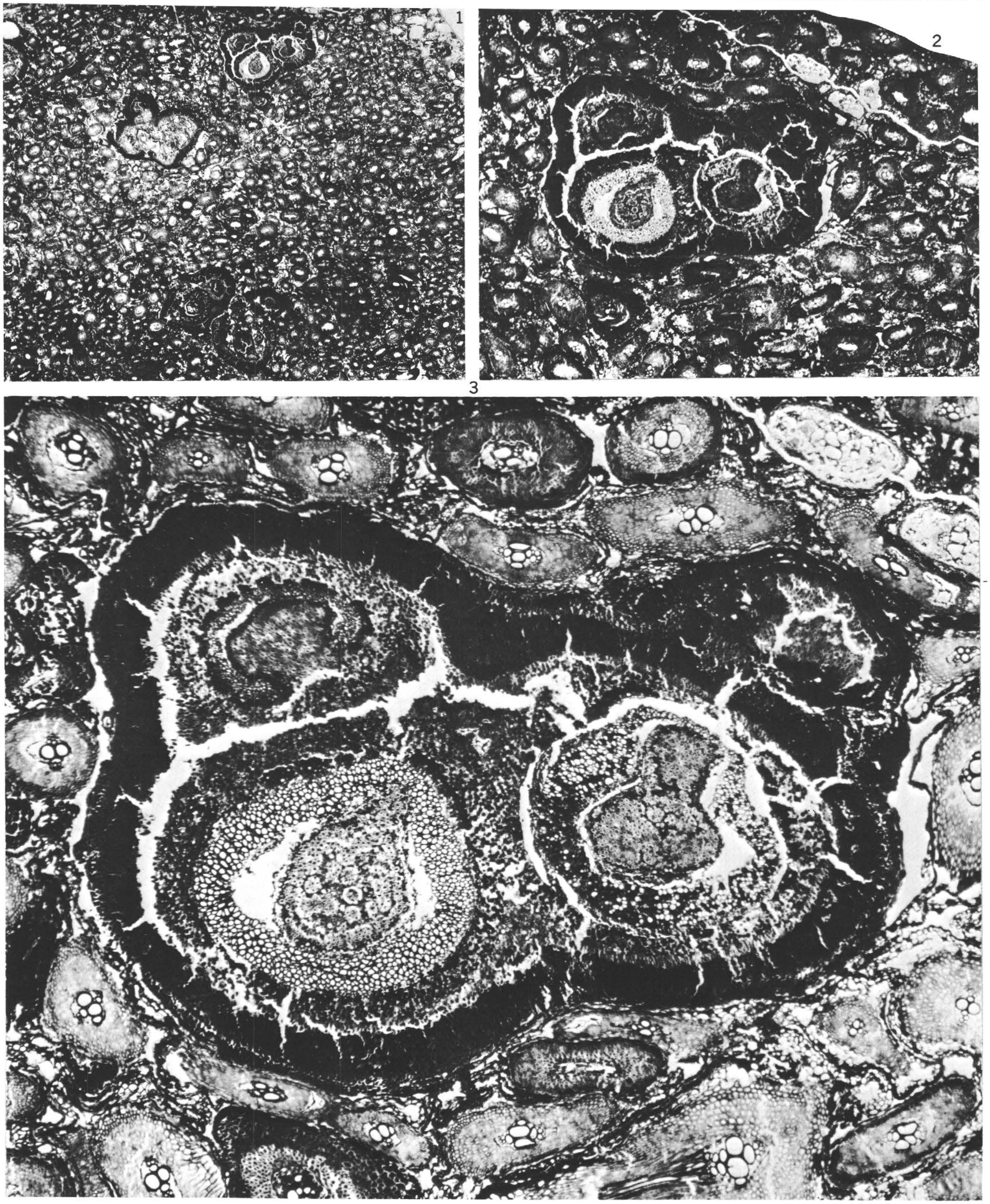
TEMPSKYA ZELLERI ASH AND READ, N. SP.

PLATE 8

FIGURES 1–3. *Tempskya knowltoni* Seward, 1924 (p. 4).

1. General view of part of the false trunk showing several pairs of stems imbedded in a groundmass of adventitious roots. Note the absence of free petioles in the section. They are characteristically rare in the false trunk of this species as they are in *T. zelleri* n. sp. and *T. rossica*. The dense, thick sclerotic cortex that is typical of *T. knowltoni* is evident in this figure and the others on the plate. The occurrence of just one or two leaf bases with each stem indicates fairly long internodes and contrasts with *T. grandis* where there are often four or more leaf bases with a single stem. Slide USNM 39266 (section V), × 3.

2, 3. Cross section of a pair of stems that are in the process of dividing. Note that there is one departing leaf trace with each stem and that both have a protuberance marking the beginning of a second leaf trace. The excellent preservation of most tissues in this fossil is well illustrated in figure 3. Both from slide USNM 39266 (section V); 2, × 10; 3, × 25.

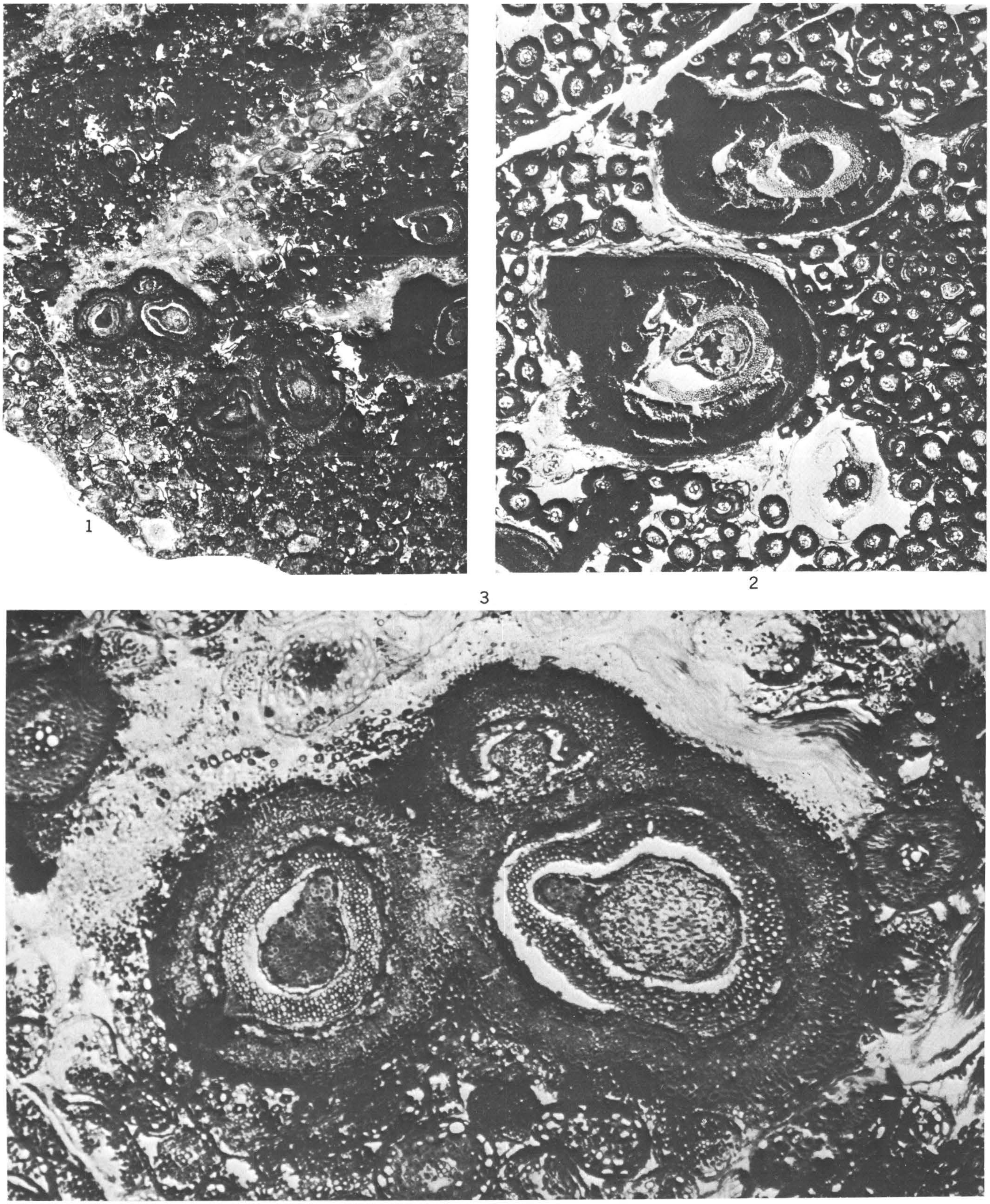


TEMPSKYA KNOWLTONI SEWARD

PLATE 9

FIGURES 1–3. *Tempskya minor* Read and Brown, 1937 (p. 4).

1. Part of the false trunk showing the general distribution of the small stems typical of this species imbedded in a groundmass of adventitious roots. The occurrence of only one or two departing leaf traces with each stem suggests that the internodes are fairly long and are comparable in length with those in *T. rossica*, *T. knowltoni*, and *T. wyomingensis*. Slide USNM 39260c, × 5.
2. Two stems in which the xylem cylinder is well preserved. Slide USNM 39254a, × 10.
3. Two stems that are in the process of dividing. Apparently dividing of the stem began at a slightly lower level. A departing leaf trace is present at the upper left of the right-hand stem. The protuberance on the side of each stele marks the beginning of a leaf trace. Slide USNM 39260c, × 25.

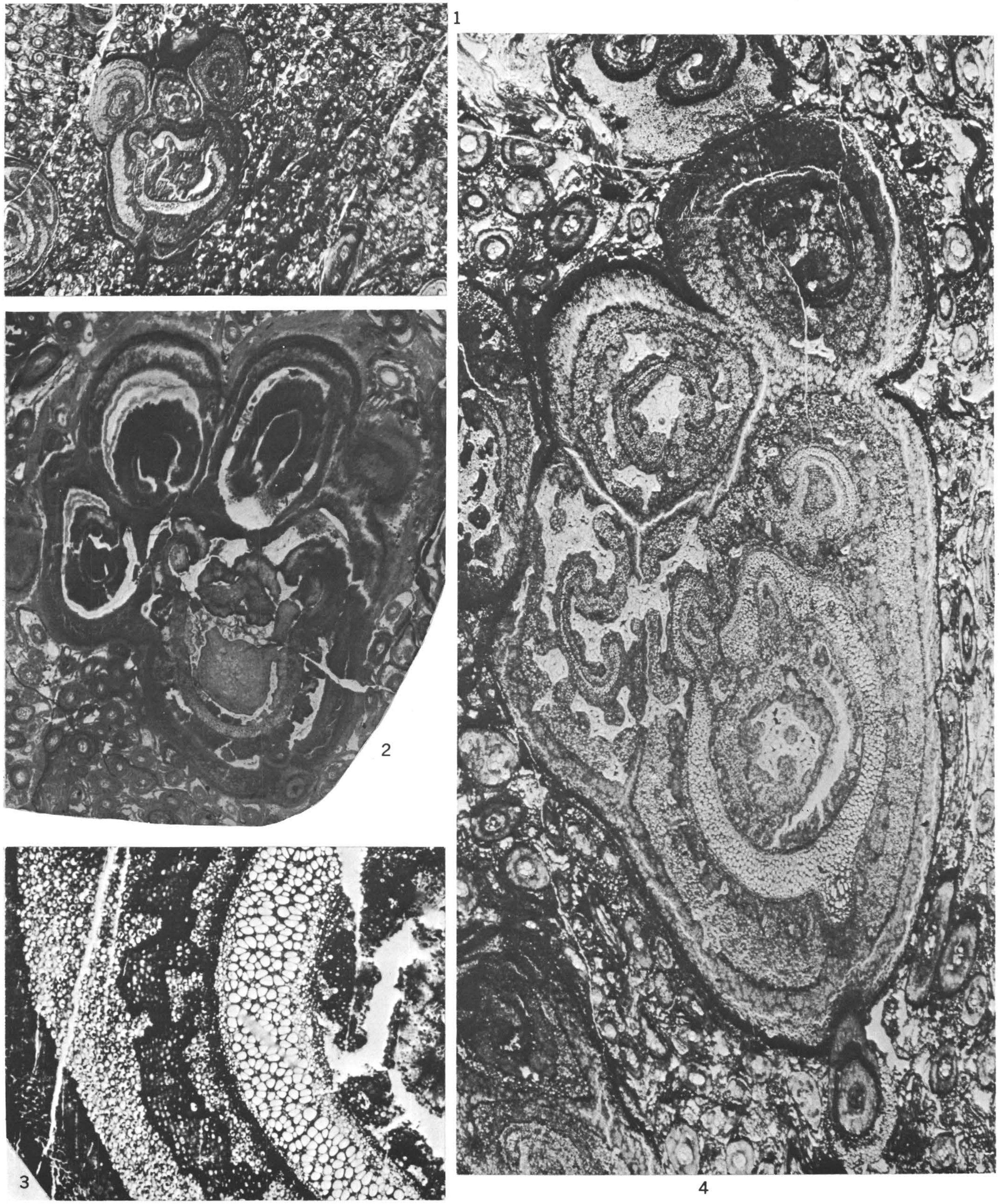


TEMPSKYA MINOR READ AND BROWN

PLATE 10

FIGURES 1–4. *Tempskya grandis* Read and Brown, 1937 (p. 4).

1. Transverse section of a stem with three leaf traces in various stages of departure and two leaf-trace protuberances. At least one of the traces is free or practically so. Note the comparatively large number of departing leaf traces and leaf-trace protuberances associated with each stem on this plate. This demonstrates that the internodes are fairly short in *T. grandis,* contrasting strongly with *T. wesselii* and *T. zelleri* which have long internodes and usually only one leaf trace and possibly one leaf-trace protuberance associated with each stem. Slide USNM 39267p, × 3.
2. A stem with several departing leaf traces and leaf-trace protuberances. Slide USNM 39164b, × 5.
3. Part of the side of a stem showing the three-layered cortex. The discontinuous and irregular band of sclerenchyma in the inner cortex near the stele is exceptionally well preserved in this specimen, although a similar band of sclerotic tissue in the pith is not as clear. Slide USNM 39267i, × 25.
4. Cross section of a stem which has at least six departing leaf traces. The one on the left edge of the photograph has just become free of the stem, whereas near the center of the photograph the stele of another has just separated from the stele of the stem. Near the bottom of the picture an adventitious root is inserted on the stem. Slide USNM 39267j, × 25.



TEMPSKYA GRANDIS READ AND BROWN

PLATE 11

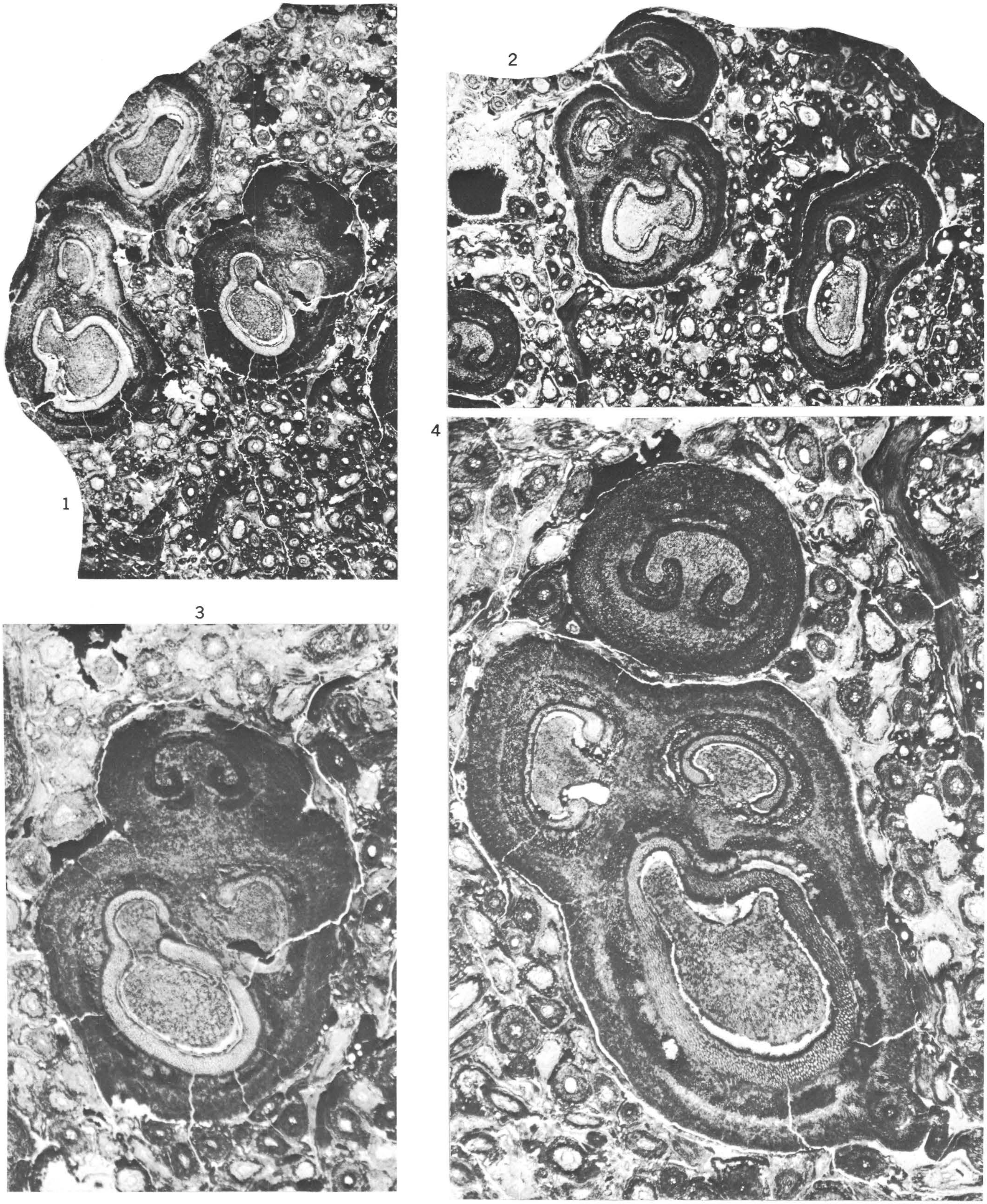
FIGURES 1–4. *Tempskya wyomingensis* Arnold, 1944 (p. 5).

All figures are from the holotype (No. 23400) in the Museum of Paleontology, University of Michigan.

1,2. Two general views of part of the false trunk showing several stems with departing leaf traces and two free petioles surrounded by a groundmass of adventitious roots which are mainly vertically oriented. Note that two or more departing leaf bases are attached to each stem in these and the other figures on the plate, indicating that the nodes are fairly long. × 5.

3. A rather small stem from which three leaf traces are in the process of departing. This same stem is shown in figure 1. × 10.

4. A somewhat larger stem with twc departing leaf traces and one free petiole that evidently just separated from the stem. The outer continuous band of sclerenchyma is clearly visible, but the inner discontinuous band is not as clear. The two protuberances above the stele mark the beginning of a leaf trace. × 10.



TEMPSKYA WYOMINGENSIS ARNOLD

PLATE 12

FIGURES 1–3. *Tempskya wesselli* Arnold, 1944 (p. 5).

All figures are from slides made from the holotype (23399) in the Museum of Paleontology, University of Michigan.

1. A stem from which a leaf trace is in the process of separating. The two continuous bands of sclerenchyma separated by a complete band of parenchyma are clearly visible surrounding the stems and the leaf traces in all figures on the plate. In the example shown in this figure the leaf gap has closed, the bands of sclerenchyma are still complete, and there is a gap in the parenchymatous layer where the inner band of the leaf trace is still fused with the inner band of the stem. Most of the adventitious roots in this figure are cut transversely. An exception is the root that is cut more or less tangentially at the lower left. × 25.
2. General view of a part of the false trunk showing the distribution and remains of four stems in a groundmass of adventitious roots. The stem near the left side of the photograph has been penetrated by several roots. The stem near the center is shown in figure 1. × 5.
3. A stem from which a leaf trace is in the process of separating. In this example the separation has not proceeded quite as far as in figure 1 and a leaf gap is still present. An adventitious root which probably arose from the stem is at the lower right imbedded within the band of parenchyma. The root is cut transversely and probably is vertically oriented. A second adventitious root that is in the process of separating from the stem is at the lower left. It is cut tangentially and apparently is horizontally oriented. The xylem of the root is not connected with the xylem of the stem, but the sclerenchyma bands of the stem cortex are connected with the sclerenchymatous cortex of the root. × 10.

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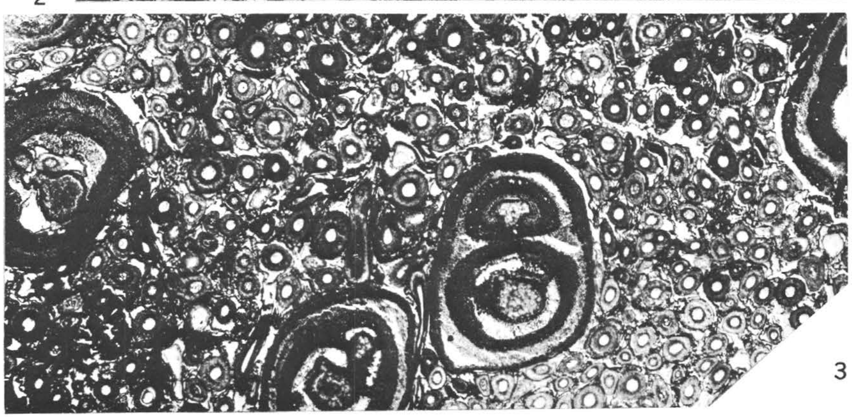

3

TEMPSKYA WESSELLI ARNOLD

PLATE 13

Tempskya superba Arnold, 1958 (p. 5).

A stem with three leaf bases in various stages of departure.

Short internodes in this species are responsible for this noteworthy feature of *T. superba.* The remains of several adventitious roots are visible including one that is in the process of separating from the right side of the stem. Although this fossil is not very well preserved, the thick band of parenchyma in the inner cortex and the discontinuous, irregular band of sclerenchyma that characteristically surrounds the vascular cylinder in this species are visible in a few places, × 10. The figure is from a slide (USNM 167545a) made from the holotype (34561) in the Museum of Paleontology, University of Michigan.

TEMPSKYA SUPERBA ARNOLD