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A Uintan (Late Middle Eocene) Flora and Fauna from the Uinta Basin, Utah

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THE PALEOCLIMATE AND PALEOECOLOGY OF A UINTAN (LATE MIDDLE EOCENE) FLORA AND FAUNA FROM THE UINTA BASIN, UTAH

by

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A thesis submitted to the faculty of
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GRADUATE COMMITTEE APPROVAL

Of the thesis submitted by

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This thesis has been read by each member of the following graduate committee and by majority has been found to be satisfactory.

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BRIGHAM YOUNG UNIVERSITY

As chair of the candidate's graduate committee, I have read the thesis of Stephen D. Sandau in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

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ABSTRACT

THE PALEOCLIMATE AND PALEOECOLOGY OF A UINTAN (LATE MIDDLE EOCENE) FLORA AND FAUNA FROM THE UINTA BASIN, UTAH

Stephen D. Sandau
Department of Geology
Master's of Science

Late Middle Eocene time marks one of the most dynamic periods of the Paleogene in the western interior of North America. Analysis of an extensive, new collection of plant, invertebrate, and vertebrae fossils from the Uinta Formation in the Uinta Basin, south of Myton, Utah, USA, provides evidence of environmental change. Paleobotanical specimens are preserved in late stage Uinta Lake sediments and coarse-grained fluvial sediments which are stratigraphically 650 to 660 m above the Green River Formation. Deposition rates estimates of 18 to 55 cm/kyr, for Uinta Lake sediments in the Uinta Basin suggest a period of 1.18 Ma to 3.69 Ma to deposit the thick section of lacustrine and fluvial sediments that separates the well-documented Green River Flora from this new fossil leaf assemblage, the Wells Draw flora. Prolific invertebrate trace fossils and invertebrates have a preference for areas with high to fluctuating water tables and soil moistures. The trace fossils are similar to traces of extant invertebrates found in temperate to tropical climates. A variety of reptiles, namely eight species of turtles/tortoise, one lizard (first report of *Saniwa* from the Uinta Formation), and at least two crocodilian species, are indicative of warm-temperate to subtropical climatic zones.

Flow direction data derived from sedimentary structures in sandstone channel-fills confirms previous studies which indicate the major sediment source area was to the east with a prevailing westward to northwestward flow direction. The presence of higher elevation plant material within the flora, however, implies possible hydraulic transport from the nearby Uinta Mountain highlands, located north of the basin.

The first report of *Palmoxylon* from the Uinta Formation, included in this report, corroborates the faunal indicators of a tropical climate. Physiognomical analysis of the flora yields a mean annual temperature (MAT) of 16.1°C and a mean annual precipitation (MAP) of 56 cm. Compared with older Green River flora, these new data suggest a slight drying and cooling trend toward the end of the Eocene. Leaf types also indicate possible seasonality with seasonally dry periods and an overall warm-temperate environment with extreme minima temperatures not much below freezing.

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INTRODUCTION

Early Cenozoic basins of western North America have long produced some of the richest fossil collections in the world. Paleontologists started field work in Utah's Uinta Basin as early as 1870 (Betts, 1871; Marsh, 1871, 1875a, 1875b). The Uinta Basin is located in the northeastern corner of Utah and covers approximately 31,000 km^2. The area for this study lies south-southwest of Myton, Utah, near the middle of the Uinta Basin (Figure 1).

The Middle to Late Eocene was a period of dramatic change in the climate, flora, (MacGinitie, 1969), and fauna (Black and Dawson, 1966) of North America. Although much is known about the plants and animals that existed in western North America during the Eocene, 55 to 33 million years ago, the Uintan aged flora, 46.7 to 40 Ma, within the Uinta Basin is largely unstudied. New sites have recently produced a variety of leaf, seed, stem compressions and impressions, and permineralized wood. The fossils are found in floodplain deposits and medium to coarse-grained channel sandstones in the western part of the basin where fluvial deposits interfinger with lacustrine beds of Uinta Lake. Whether these lacustrine beds belong to the Green River Formation or the Uinta Formation has been a long-standing debate (Kay, 1934; Dane, 1955; Picard, 1955; Cashion, 1982; and Bryant et al., 1989).

Along with the plants, many invertebrate, vertebrate and trace fossils were collected for this study. Together, these fossils provide important new information on the paleoenvironment and paleoecology of the late Middle Eocene Uinta Basin.

METHODS

Specimens were collected during paleontological surveys performed for the Newfield Oil Company (formally Inland Resources, Inc.). Over 43 invertebrates, 32 trace fossils (>800 observed in the field), 424 vertebrates, and >750 plant fossils were collected. Collecting was conducted in compliance with permits issued by the Bureau of Land Management (BLM) #UT-S-02-005, and the State of Utah Trust Lands Administration (SITLA). Fossil localities were documented with UTM coordinates on 7.5 minute U. S. Geological Survey topographical quadrangle maps and submitted in various paleontological reports to the state and federal agencies mentioned above. The repository for the specimens is Brigham Young University's Earth Science Museum (ESM). Fossils were prepared using standard methods and identified by comparison with specimens in the ESM, the Vernal Field House of Natural History, and literature. Samples processed for palynomorphs proved barren. Stratigraphic sections were measured using a 1.5 meter Jacob's staff and level.

Fossil leaves were categorized according to outlines provide in LAWG (1999). Although important paleoclimate information was gained from the fossil leaves, no morphotypes are assigned at this time due to the poor preservation.

Methods for determining mean annual temperature (MAT) and mean annual precipitation (MAP) are from Raunkiaer, (1934), Webb, (1959), Wilf et al., (1998), and Wilf (2000).

-Estimated MAT = $30.6P + 1.14$

error of 0.8°C P = the proportion of species in a sample with untoothed margins

(Wolf, 1979; Wing and Greenwood, 1993)

-ln (estimated MAP) = $0.548\ \mathrm{MlnA} + 0.768$

standard error = 0.359 MlnA = $\Sigma a_i p_i$, where a_i represents the seven means of the natural log areas of the Raunkiaer-Webb size categories (2.12, 4.32, 6.51, 8.01, 9.11, 10.9, and 13.1), and p_i represents the proportion of species in each category. (MlnA, is the natural logarithm of the leaf area measured in square millimeters) and mean annual precipitation (MAP, in centimeters).

GEOLOGY

In the Precambrian, 1,000 to 600 Ma, an east-west trending basin developed accommodating 7,620 m of siliclastics (Hintze, 1988) in the area now occupied by the Uinta Basin. Throughout the Paleozoic and Mesozoic deposition fluctuated between marine and non-marine environments, laying down a thick succession of sediments. With the rise of the Uinta Mountains during the early Cenozoic, the asymmetrical synclinal Uinta Basin is thought to have formed through the effects of down warping in connection with the uplift (Rasmussen et al., 1999).

Paleogene Uinta Basin sediments were deposited in lacustrine and fluvial environments. Large, shallow lakes periodically covered most of the basin and surrounding areas during Early to Middle Eocene time (Abbott, 1957). In the western part of the study area, lacustrine sediments dip 2-3 degrees to the northeast, interfingering with fluvial sediments to the east. The increase of cross-bedded, coarse-grained sandstone and conglomerates preserved in paleo-channels indicates a transition to a fluvial environment toward the end of the epoch and the last stages of Uinta Lake.

Four Eocene formations are recognized in the Uinta Basin. From oldest to youngest they are: the Wasatch, Green River, Uinta, and Duchesne River Formations (Wood, 1941). The Uinta Formation is subdivided into the Wagonhound Member

(Wood, 1934), also known as Uinta A and B (Osborn, 1895, 1929; Peterson, 1859), and the Myton Member also regarded as the Uinta C (Table 1).

Portions of the study area are covered with unconsolidated conglomeritic channel fill up to 3 meters thick, with quartzite and limestone clasts up to 30 cm in diameter. Shed off the Uinta Mountains from the north, these reworked conglomerates were deposited during an Oligocene penepalanation event some time after the deposition of the Duchesne River Formation near the end of the Eocene (Crowley, 1957). The Neogene sediments are overlain by undifferentiated Quaternary strata, which are draped over plateaus and some stream and river drainages.

Stratigraphy

Uinta Basin magnetostratigraphy data (Prothero, 1996) constrains the Uinta Formation sediments to 46.7 to 40 Ma, spanning Chrons 21n to 18r (Table 1). The Uinta Formation is present in most of the study area but interfingers with lacustrine beds on the west side, which are variably classified as the Uinta Formation or the Green River Formation (Ryder et al., 1976).

The Uinta Formation is predominantly fluvial in origin, with east/west to northwest/southeast oriented sandstone channels amid pedogenically altered, stacked, over-bank deposits. Sandstone textures range from fine- to very-coarse grained, commonly with conglomeratic channel bottoms with rip-up clasts and plant debris. Overall grain size in these channel sands deceases from east to west through the central portion of the Uinta Basin (personal observation, and Stagner, 1941). Stagner (1941) concluded that the major source area for a portion of the Uinta B (upper Wagonhound Member) to east in Colorado. His interpretation was based on channel orientation, grain size distribution, over-abundant feldspar not derived from Uinta Mountains, and a decrease in the amount of heavy minerals from east to west. Stagner, however, also detected signs of a different source area based on composition from samples taken from channel sandstones in the eastern part of the Coyote Basin. Channel sandstones from the Uinta B extend across most of the study area. A composition of 70% quartz, 22% clay and feldspar, and 8% other minerals, including rock fragments, were reported for channel sandstones in a region just east of the study area (Hamblin 1985). These sandstones can be classified as a feldspathic-arkosic-wacke.

Cross bedding and climbing ripple marks indicate streams flowed towards the northwest (Figure 2). Hamblin (1985) arrived at a similar conclusion. He noted paleo-channels striking southeast-northwest with a westerly flow direction, and concluded that they represented low-sinuosity streams which periodically changed course. Sandstone channels, being more resistant than surrounding siltstone and mudstone, are commonly exhumed in the Uinta Basin, capping hills and in some cases, preserving paleo-stream architecture. In most channels, trough cross-beds and/or planar-beds are well preserved. Sandstone colors vary in the study area from light-gray, gray, tan, brown to dark brown, yellow, green, and rust, depending on the amount of organic material and/or degree of oxidation or reduction. Finer-grained sandstone associated with proximal floodplain and splay deposits in the area are usually red to maroon.

Trace fossils (discussed below) are abundant in the sandstones. Fossil vertebrates are less common in these channel sandstones compared to their abundance in contiguous floodplain deposits.

Most overbank deposits in the area show evidence of paleosol development and are gray, drab-green, green, red, purple and maroon in color. These sediments preserve a range of trace fossils, an occasional mollusk, and most of the vertebrate fossils. As facies change to the west, sediment colors are duller, with a greater abundance of tan, brown, orange, and off-white.

Shallow lacustrine and marginal lacustrine sediments are exposed on the western half of the study area (Figure 1) where they interfinger with the fluvial and floodplain deposits from the east. These fine-grained tan, green, and off-white carbonaceous siltstones and mudstones are late stage deposits of Uinta Lake (Picard, 1957). A 5-27 cm thick ostracodal limestone bed (Figure 3) is a key marker bed for the western portion of the Uinta Basin (Dane, 1955 and Ray et al., 1956). It extends at least 19 km from Sec. 31, T 5 S, R 3 W, to Sec. 30, T 8 S, R 17 E. This resistant bed is 369 m above the Evacuation Creek Member of the Green River Formation in Petes Canyon and Wells Draw, as mapped by Dane (1955) and Ray et al. (1956). This is significant because the well-known fossil leaf beds reported by (MacGinitie, 1969) are found in the upper portions of the Parachute Creek Member to the lower beds in the Evacuation Creek Member which lie 650 to 660 below the Well Draw flora. \

TRACE FOSSILS

Trace fossils are common and are invaluable ecological and environmental indicators (Hasiotis 2002). The most abundant trace fossils are cf. *Planolites* and *Ancorichnus,* (Figure 4), which are assumed to be made by beetle and insect larvae (Hasiotis, 2002). *Edaphichnium* traces, earthworm tubes (Hasiotis, 2002), are also fairly common. Diagnostic characters are calcium carbonate fecal pellet-packed tubes (Figure

4C, 5E). Tubes diameters are usually small, 3-19 mm, but range up to 80 mm in the study area (Figure 5B, E). The large specimens were found along a bedding surface of a hard, limy-siltstone. Major trace fossils are listed in Table 2. Trace fossils on vertebrate remains are disused later in this paper. Rooting structures (Figure 4F) are also present and are important paleosol indicators. Vertebrate tracks and trackways have been reported in the area (Hamblin et al, 1999) but are not considered in this paper.

By studying traces made by extant plants and animals and comparing them to fossil equivalents, several paleoecological and environmental factors, including water table, soil moisture, oxygen levels, water salinity levels, energy of depositional events, and conditions of climate such as wind, precipitation, temperature, and seasonality can be inferred (Hasiotis, 1997). These interpretations are possible because limiting factors define where specific organisms live. Ichnology, however, is useful in paleoenvironment reconstruction only to the extent that ancient traces can be matched to recent traces and their tracemakers (Frey 1975).

Planolites is an excellent indicator of fluctuations of past water tables, soil moisture, depositional rates, duration of subaerial exposures, and soil formation (Hasiotis, 2002). Burrow orientation correlates with water table level.

The 80 mm burrows (Figure 5B, E) here assigned to *Edaphichnium* were likely made by an earthworm similar in size to the giant, extant earthworm *Megascolides australis* of Australia.

A matrix summarizing trace fossils found in the study area and correlative paleoenvironmental parameters (Table 2) reveals several patterns. On the whole, trace fossils observed in the study area are typical of traces made by extant organisms in humid to semiarid environments subject to seasonality in tropical to temperate regions. The modern trace makers live in ecological settings ranging from shallow lakes to dunes, indicating they are tolerant of fluctuating water tables. Of all of the traces listed, most favor marginal lacustrine and proximal alluvial settings, with strong tendencies towards palustrine and distal alluvial regions.

INVERTEBRATES

In contrast with the older, fine-grained lacustrine sediments of the Green River Formation, which contain innumerable invertebrate remains (Grande, 1984), the coarser-grained alluvial sediments that dominate the Uinta Formation usually preserve only mollusks and aquatic arthropods which survived moderate transport and abrasion due to their mineralized hard parts.

Four species of freshwater gastropods are recognized from the study area, (Table 2) namely: *Physa longiuscula, Biomphalaria pseudoammonius*, *B. ? storchi*, and *Goniobasis tenera* (Figure 6A-C, D-E). By far the most common species in the study area is *Biomphalaria pseudoammonius*, found in fine-grained, carbonate-rich siltstones and mudstones deposited in marginal lacustrine and palustrine settings (Figure 6B, C). Bivalves from the Uinta Formation, reported from unpublished paleontological surveys reports, most likely belong to the family Unionidae (*Plesielliptia sp.* or *Sphaerium sp.)* or the family Pisidiidae (Grande, 1984).

Ostracodes are preserved in great quantities in the ostracodal limestone marker-bed reported by Dane (1955). This bed possible contains the freshwater ostracode

Hemicyprinotus watsonensis (Figure 6F, G), a species identified by Swain (1964) from the Green River Formation in the Uinta Basin

VERTEBRATES

For more than a century numerous studies have discussed various aspects of fossil vertebrates found in Uinta Formation of the Uinta Basin, providing descriptions and faunal lists (e.g., Osborn, 1895; Scott, 1895, 1898; Douglass, 1909-1910, 1931, 1931-1933; Matthew, 1921, Burke, 1934; Gazin, 1938; Clark, 1939; Gilmore, 1915, 1946; Kay, 1957; Dawson, 1966; Black and Dawson, 1966; Black, 1968; Hamblin, 1985; Woodburn, 1987; Prothero, 1996; Gunnell and Bartels, 1999, Rasmussen et al., 1999; Thornton and Rasmussen, 2001). Hence, only a cursory treatment of selected fossil vertebrates found during the course of this study is given in this paper. Table 4 provides a list of vertebrates found recently in the study area. With the exception of *Saniwa* all have previously been reported from the Uinta Formation.

Osteichthyes

Scales of the gar, *Lepisosteus cuneatus,* are found throughout the western half of the basin in lag-deposits and basal sections of channel-fill coarse-grained sandstones. These tough, ganoin-covered scales are easily identified by their polished appearance and diamond shape. Scales and sturdy skull bone elements of *Lepisosteus cuenatus* are common in coarse channel sandstones. Partial articulated specimens, though rare, have been found in fine-grained palustrine or shallow lacustrine deposits (Figure 7A), and are preserved with hydrophyllous plants, such as cattails (*Typha*). Grande (1984) listed three fossil species of *Lepisosteus* from the Eocene lake deposits of southwestern Wyoming

(Fossil Lake and Lake Gosiute), and (Lake Uinta) from northwestern Colorado, and northeastern Utah. *Lepisosteus atrox*, the largest of the three, grew to 168 cm, and *L. simplex*, with an average length of 60 cm, are both found in deposits from Fossil Lake and Lake Gosiute. *Lepisosteus cuneatus*, the smallest of the three (Grande, 1989), ranging from 31 to 50 cm, is found only in Uinta Lake deposits. Estimated lengths from the partial specimens discovered in the study area are 35 to 45 cm, placing them in the range of *L. cuneatus* (Figure 7). Recent studies place all three of these species under the new genus *Atractosteus* (Carroll, 1988; Gayet, et al., 2002). In North and Central America, four species are found today. They range from the Great Lakes in the northeastern United States to the southernmost portions of Central America (Burton, 1969).

Two species of *Amia* (Grande, 1984) occur in Fossil Lake and Lake Gosiute, namely *Amia uintaensis* and *A. fragosa*. Grande and Bemis (1998), reassigns these two species *A. uintaensis,* and *A. fragosa*, to *Amia pattersoni* sp. *nov*., and *Cyclurus gurleyi*, respectively. Peterson (1912) reported fossil amiid material of ?*Pappichthys plicatus*, from "Horizon B and C" in the Uinta Basin above the typical Green River shales. Kay (1957) reported *Pappichys plicatus* in the Wagonhound Member of the Uinta Formation. No reference or location was given, but he was probably referring to the material reported by Peterson (1912). Cope (1873) described *Pappichys plicatus*, which was discovered on his expedition to Wyoming. Grande and Bemis (1998) list the type locality for *Pappichys plicatus* as Cottonwood Creek in southwestern Wyoming, and for the want of diagnostic martial, assign it to Amiinae indeterminate.

In the course of this study, elements from two individual amiids were found from the Uinta “B” beds in the western part of the Uinta Basin. Both specimens are large individuals represented by five to six centra. The specimen BYU 18548 includes a nearly complete occipital condyle (Figure 7B-F). The specimens, although not diagnostic to a specific level, are evidence that amiids lived in Uinta Lake, enduring into the late Middle Eocene. With the apparent absence of *Lepisosteus atrox* and *L. simplex* in Uinta Lake sediments, and judging from the size of the newly discovered amiid centra, 26-29mm, this member of the Amiidae family was the largest predatory fish in Uinta Lake.

The one extant member of the Amiidae family, *Amia calva*, is piscivorous, yet other forms from the fossil record, had flattened styliform teeth, suggesting a diet of mollusks and/or arthropods.

Amphibia

The only specimen that could be attributed to an amphibian (Figure 8E), is a single element resembling an anuran radio-ulna, possibly from a member of the Pelobatidae or Pelodytidae. Grande, (1984) reported possible pelobatids (*Eopelobates*) from the Green River Formation. The radio-ulna element found in the study area has weathered distal and proximal ends and identification below the ordinal level is not possible.

Reptilia

Reptiles are by far the most commonly vertebrates in the Uinta Formation with chelonia being dominant. Hay (1908) lists 58 species from the Eocene of North America and Gilmore (1915) lists 21 species of fossil turtle from the Uinta Formation alone. Most recently, the Uinta Formation faunal list for turtles was reduced to 8-9 likely species by Hutchison (1992). Turtle species recovered from the study are listed in Table 4. Comparing this list with others from the Uinta Basin and the Bridger Formation of southwestern Wyoming (Hutchison, 2001), *Echmatemys* is the most abundant genus during the late Middle Eocene in the intermountain west.

Pathologies on turtle shells are common in the study area (Table 5). First defined by Hutchison and Frye (2001), the turtle shell pathologies are classified as follows:

1) Pitting Type I: Circular to ovoid pits with flat bottoms.
2) Pitting Type II: Circular to ovoid pits with rounded bottoms.
3) Pitting Type III: Irregular pits and depressions with relatively discrete margins and local extent.
4) Track Type: linear and curvilinear path-like marks of relatively constant width.
5) Rot: Large areas of irregular depression or patches of dead antemortem lamellar bone.
6) Bites: Compression punctures and tapering scratches.

Possible causes of pitting on the shells are listed by Hutchison and Frye (2001), e.g., calcium and phosphate withdrawal from egg laying females, metazoan pathogens, epiphytic growths, fungal agents, bacteria, and pH levels. They also note that different pit types may only reflect developmental stages. Data from their study showed Type I and Type II pitting are predominant. Type II pitting (Figure 9B) was overwhelmingly the most common pathology (49%) from specimens included in this paper, with Type I (16%) and III (16%) being the next most common (Table 5). Rot may be caused by any of the agents mentioned above, or from damage caused by wounds from predators, and exacerbated by other means. Rot may also be a postmortem phenomenon, where portions of the shell deteriorate due to prolonged exposure before burial. Marks left by gnawing rodents harvesting calcium and phosphate from bones can also indicate extended exposure, especially in the case shown in Figure 9E. On this costal element, rodent gnawing occurs along all margins, indicating that the carapace disarticulated before gnawing and burial. Track injuries (Figure 9A), could also be related to predation damage followed by smaller parasitic or capitalizing organisms around the area of the lesion. Turtles are preyed upon by large fish, birds, crocodiles and carnivorous mammals. Bite marks (punctures or tapering gouges) on fossil turtle shells in the study area are most likely caused by crocodilians or perhaps large terrestrial carnivores (Figure 9D).

In the course of this study two varanid individuals were discovered and are here tentatively identified as *Saniwa cf. ensidens* (Figure 8C-D, F) based on the smooth ventral surface, moderate elongation, and tapered form of the vertebral centra. Leidy (1870) described *Saniwa ensidens* from specimens found in sandstone blocks from the Bridger Formation in Sweetwater County, Wyoming collected by F. V. Hayden during the 1870 field season. Preparing more elements from the same blocks, Gilmore (1922) provided an amended description. Caldwell (2003) in re-examining the cranial material associated with, but not in articulation to postcranial material, reassigned it to cf. *Restes sp.* Indst. (Xenosuridae). Five other species of varanids from the Green River Basin in Wyoming were described by Marsh (1872) namely, *Thinosaurus paucidens, T. leptodus, T. crassus, T. grandis,* and *T. agilis*., and Gilmore in his 1922 paper describing fossil varanids of Wyoming, placed these five species into the genus *Saniwa*. Sullivan (1982) reported a few incomplete vertebra from the Paleocene Fort Union Formation, Carbon County, Wyoming which he referred to *Saniwa*. Kay (1953), in his faunal list for the

Uinta Basin, reports *Saniwa sp.* from the Green River Formation but does not provide a horizon or specimen number.

This is the first report of *Saniwa* from the Uinta Formation. There are two specimens. BYU 18550 consists of eight associated vertebrae pertaining to a small individual while the larger, BYU 18503 is comprised of 23 vertebrae, eight of which are articulated, along with limb fragments. Vertebrae of the latter specimen are similar in size to the extant monitor lizard *Varanus salvator*, which attains a length of over a meter.

Disarticulated crocodilian elements, such as teeth and osteoderms, are common in the Uinta Formation. The most spectacular crocodilian specimen recovered from the study area is a complete skull and jaws, BYU 18553, of a basal member of the crocodylidae, *Crocodylus affinis* (Figure 10I). Brochu (2000) indicated that *Crocodylus affinis*, despite its generic nomenclature, is not included in the crown-group *Crocodylus*, the first true member of that group appearing in the Late Oligocene or Early Miocene. Many different crocodilians have previously been described from the Paleogene basins of northwestern America, and as many as ten different species occur in the Green River Formation alone (see Brochu, 1997, 2000, and Rowe at al., 1999 for previous classifications). These papers, dealing with the phylogeny of both the alligatoroidae and crocodyloidae, have reduced the number valid Eocene species. Besides *Crocodylus affinis*, it is possible that at least two to three other crocodilians inhabited the Uinta Basin during the late mid-Eocene, namely: *Procaimanoidea utahensis, Borealosuchus wilsoni*, and *Allognathosuchus sp.* Indeed, many ventral osteoderms from numerous individuals discovered during the study closely resemble those belonging to *Borealosuchus wilsoni* (Figure 10A, E-H).

Mammalia

No in-depth discussion of the fossil mammals found during this study will be provided here. Mammalian species recently discovered in the study area (Table 4) were previously discussed in the references provided at the head of this section. However, distribution and abundance of the mammalia discovered are related here.

The majority of the mammals are from the east side of the study area, preserved in stacked paleosols. Due to the abundance of swelling montmorillonite clays fossils at the surface suffer from expansion/contraction. Thus, they are broken as well as disarticulated and it is uncommon to find well-preserved specimens. The most common mammalian taxa the small artiodactyls *Protoreodon* and *Leptotragulus*, and medium to large perissodactyls, the latter consisting of numerous unidentified brontotherid bone and tooth fragments. The great abundance of bones suggest these suggests these taxa were present in great numbers.

FLORA

Although Uinta Formation fauna has been well documented from the Uinta Basin, the flora has received little attention, primarily because the formation's paleobotanical specimens are rare and generally poorly preserved. Previously collected specimens consist of fragmentary stems and occasional leaf compressions or molds. Impressions of *Equisetum, Salix, Rhus,* and *Macginitiea* are the most common. This information is based on personal observation and from data in numerous unpublished paleontological survey reports on file with state and federal agencies that manage lands in Duchesne and Uintah Counties.

During this study, however, new localities primarily in the Wells Draw area yielded sufficient fossil plant material to merit treatment as a distinct flora, referred to here as the Uintan "Wells Draw flora" (Table 7). Leaf, stem, and seed macrofossils, and premineralized wood were collected in the study area and from various other locations from the Uinta Formation throughout the Uinta Basin. Effort made to find plant fossils from several lagoonal deposits of the Uinta Formation proved unsuccessful and most of the plants were recovered from coarse-grained channel-sandstone to finer-grained marginal lacustrine siltstone deposits. The poor preservation of fossil plant material is due to the coarse-grained nature of the sediments. The absence of plant fossils in the finer grained lacustrine sediments may have been due to unfavorable Eh and pH conditions.

In the absence of well-preserved materials, identifications are tentative. Most identifications are based on leaf outline, base, apex, and margin shape which, in a study by van Konijnenburg-van Cittert (2000), were considered generally constant characteristics. However, for the lack of well-preserved venation, a more definitive characteristic, few of the proposed taxonomic classifications are considered valid. Nevertheless, important information can be gained. The Wells Draw flora leaf types generally match those of the Green River floras (Knowlton, 1923; Cockerell 1925; Brown, 1928, 1934; MacGinitie, 1969; Grande, 1980; Manchester, 1986, 1989; Manchester et al., 1986; Call, 1994) and are similar to many of the macrofossils reported from the Late Eocene Florissant flora (Cockerell 1908; MacGinitie, 1953). The Wells Draw flora consists of two species of Equisetales, a single member of the Coniferales, 3-6 monocotyledons (including the first report of *Palmoxylon* from the Uinta Formation), and

31 species of dicotyledons (Figure 12-24). Based on a comparison to extant taxa in Table 7, the fossil flora is analogous to floras found in warm-temperate to subtropical climates in the southern United States, Mexico, South America, and southern Asia.

MacGinitie (1969) suggests that although environmental pressures over time may cause species to adapt to different habitats, a flora, taken as a whole, can be used to identify climatic conditions. Grouping of the fossil plants from the Well Draw flora into loosely constrained preferred habitats (Table 8) reveals that the majority prefer areas with high water tables, such as margins of lakes, ponds, swamps, and floodplains. Types appearing in "Groups 2 and 3" may represent material hydraulically transported in from nearby highlands to the north. It is more feasible that this material came from the Uinta Mountain highlands to the north, a relatively short distance, compared to the Douglas Creek Arch area, a considerable distance to the east, yet considered the primary source-area for the Uinta Formation (Stagner, 1941; Hamblin, 1987). If so, this would indicate that there were streams entering the basin from the north that are either not preserved or not recognized.

Petrifactions

A small number of premineralized wood specimens were collected from the Uinta Formation. Some were discovered within the study area and others roughly 77 km to the southeast along the White River, south southwest of Bonanza, Utah, in the lower Wagonhound Member (Uinta A). Specimens include three dicotyledons, two that are presently unidentified, and the other similar to, *Plataninium haydenii* (Felix) Wheeler, Scott, and Barghoorn (Figure 25). The other specimens are monocots, represented by four morphs of *Palmoxylon*.

The new *Palmoxylon* morphs (Figure 26-27) were compared to *Palmoxylon* species previously reported from the early Paleogene of the Intermountain West (Table 9). The table includes combination of physical characters of the upright axes traditionally used by various authors (e.g., Kaul, 1935; Nambudiri and Tidwell, 1998; Rao et al, 1962, 1971; Sahni, 1943, 1964; Tidwell, 1970, 1972, 1973; Tomlinson, 1961). This is the first report of *Palmoxylon* from the Uinta Basin.

DISCUSSION

Based on the sedimentological and paleontological evidence presented above a general paleoclimatic interpretation can be applied to the local area in the west central portion of the Uinta Basin during the late Middle Eocene. Low continents and warm oceans are responsible in part for equability of the climate, thus allowing warm-temperate to subtropical plants and animals to live further north than their present ranges (MacGinitie, 1969). However, recent studies contradict old interpretations of low continental surfaces (1 km) and suggest that paleoelevations in the western United States during the Late Eocene were as high if not higher (2.4- 3.5 km) than present elevations (Gregory and Chase, 1992; Gregory and McIntosh, 1996; Wolfe et al., 1998). Current elevation in the study area is 1524 to 1828 m above sea level.

Trace fossils suggest that during the late Middle Eocene, fluctuating water tables and soil moistures, like those found near marginal lacustrine and proximal alluvial environments, were dominant. Humid to semiarid conditions in temperate to tropical zones is also inferred.

Two of the gastropod species, *Physa longiuscula, Biomphalaria pseudoammonius*, and possibly *B. storchi* (Figure 6A-C, D), suggests a ponded-water habitat in poorly drained lowlands near lake margins (Hanley 1976). The fourth species, *Goniobasis tenera* (Figure 6E), is commonly linked to shoreline or offshore lacustrine habitats, although extant forms of *Goniobasis* are also found in clear, fast moving streams and rivers (Hannibal 1910). The bivalves, *Plesielliptia sp.* and *Sphaerium sp.,* both inhabit fluvial and lacustrine settings (Grande, 1984).

The ostracode marker-bed represents a period of time when the commonly saline Uinta Lake (Bradley, 1929) was freshened by an influx of water, causing its margins to transgress over the low lying floodplains. This transgression increased habitat and created diluted salinity conditions allowing this species of ostracode to flourish. Benson (1961) explained that although most freshwater ostracodes produce several broods of young in a season, large numbers of molted carapaces and separated valves can accumulate over a short amount of time. This may account for the large numbers of carapaces preserved in the marker-bed. The overwhelming dominance of 1 or 2 taxa suggests the environment was stressed such that diversity and competition was low.

The large population of fossil turtles in the Uinta Basin indicates warm-temperate to sub-tropical environment similar to Floridian conditions where many species of turtles live. Extant of the Bataguridae, Carrettochelyidae, Trionychidae, and Baenidae are all found in lacustrine and fluvial environments. Their abundance in the study area, particularly *Echmatemys* and *Apalone*, is further evidence of a marginal lacustrine to palustrine environment.

Extant monitors (varanids), similar to *Saniwa*, live in a wide variety of habitats from swamps to arid deserts in Asia, Africa, the East Indies, and Australia. The presence of this large varanid in the Uinta Basin is evidence of a carnivore in competition among the terrestrial mammalian carnivores (creodonts, mesonychids, carnivores). It must be noted, however, that some extant species are considered semi-aquatic, thus placing the varanids in competition with carnivorous fish and semi-aquatic reptiles.

Crocodilians are good climatic indicators, living in areas where the coldest-month mean temperature is >5.5°C and the mean annual temperature is >14.2°C (Markwick, 1998). The cohabitation of two or more species of these large semi-aquatic reptiles suggests a wide variety of wet environmental settings (rivers, streams, ponds, marshes, lakes, floodplains), and an abundance of prey taxa to support such a diverse predator population.

The Wells Draw flora provides additional clues to understanding the local paleoenvironmental and climatic conditions. A dominance of taxa with small leaf size in an assemblage is significant in terms of climate. *Quercus, Cedrelospermum, Macginitiea, Parvileguminophyllum, Rhus, Cardiospermum,* and *Osmanthus,* all found in this assemblage, have relatively small, thick or heavy textured leaves, and are generally associated with relatively high temperatures and low humidity. Together, they indicate possible seasonally dry periods (MacGinitie, 1969). The presence of *Allophylus, Engelhardtia*, and *Eugenia*, suggests that the extreme minima must not have reached much below freezing (MacGinitie, 1969). According to Greenwood and Wing (1995), palm is an indicator that the cold month mean temperature was greater than 5°C and the mean annual temperature was greater than10°C.

Another method of determining paleoclimatic conditions from floral assemblages uses the proportion of specimens with untoothed margins in a flora in what is referred to as leaf-margin analysis (Wolfe, 1979; Wing and Greenwood, 1993; Wilf, 1997).

Applying this method to the Wells Draw flora yields a mean annual temperature (MAT) of 16.1°C. Leaf-area analysis (Wilf et al., 1998) is used to estimate mean annual precipitation ("Methods" section this paper) and gives a (MAP) of 56 cm for the Wells Draw flora. These data show there is a decrease in annual precipitation relative to the older and stratigraphically lower Green River flora from Uinta Lake compared to estimates made by MacGinitie (1969) of 61-76 cm. This, together with tectonic factors (Carroll and Bohacs, 1999), may account for the overall regression and, finally, the demise of Uinta Lake in the Late Eocene. The data from (MAT) shows the apparent decline of the mean annual temperature, down roughly 2°C from MacGinitie's high end proposed temperature of 18.3°C. Data proposed here is in keeping with a gradual cooling through the Middle Eocene to Early Oligocene towards what was termed by Wolfe (1978) as the "Terminal Eocene Event". This Middle to Late Eocene cooling and its effect on the flora and fauna are discussed at length in Prothero and Berggren (1992).

MacGinitie (1969) noted that the slightly younger and stratigraphically higher Raven Ridge flora, differed from the Green River flora and exhibited a taxonomic shift toward the Late Eocene Florissant and Ruby River Basin floras. The same pattern is true of the Wells Draw flora. The time represented in the stratigraphic section, and the tens of thousands of years of non deposition as indicated by the paleosols, is more than enough to make a recognizable change in the flora due to environmental changes.

Varve calibration (Bradley, 1929), and gross biostratigraphic age interval calculations (Picard, 1963), which give depositional rates around 18 cm/kyr, underestimates depositional rates (Bennett, 1990). Bennett uses Milankovitch climatic forcing on the Green River Formation cycles and predicts a depositional rate of between

20 to 55 cm/kyr in various parts of the Uinta and Piceance Basins of Utah and Colorado. The 650-660 meters between the Green River and Wells Draw floras using Bradley's sedimentation rate would require 3.61-3.69 Ma to accumulate but only 1.18-3.30 Ma using Bennett's rate. Even the shortest time estimate, 1.18 Ma, is ample time to account for the floral differences.

CONCLUSIONS

The Uinta Formation of the Uinta Basin spans roughly 6.7 Ma from 46.7 to 40 Ma (Prothero, 1996). Stratigraphic data presented here agrees with previous work suggesting the Uinta Formation is primarily fluvial in origin with lesser amounts of lacustrine (late stage Uinta Lake) sediments. These lacustrine deposits interfinger with the fluvial sediments and are time equivalent, reflecting facies changes from coarse-grained fluvial sediments to the east to finer grained deposits to the west. The predominant fluvial paleo-flow was from east to west. The presence high elevation plant taxa (*Pinus, Engelhardtia, Quercus, Castanea, Mahonia, Casalpinites, Bursera, Negundo*), however was probably sourced from the nearby Uinta Mountain highlands to the north. Thus, there must have been northern tributaries draining into the primarily west flowing trunk streams. The reminder of the fossil plant types of the Wells Draw flora preferred areas with high water tables near lakes, ponds, streams, and floodplains. This flora is poorly preserved, and efforts should be made to collect more material and search for sites where preservation allows for more detailed classification. However, the flora shows distinct modifications from the older and stratigraphical lower flora of the Green River Formation. Some 650-660 meters of lacustrine deposits separate the Wells Draw flora from the Green River flora. Estimates of deposition rates within the Uinta Basin range from 18 cm/kyr to 55 cm/kyr, suggesting that the deposition of these sediments separating these two floras took anywhere from 1.182 kyrs to 3.694 kyrs. The Wells Draw flora contains leaf types that resemble those from the Green River flora as well as those of the Florissant and perhaps Ruby River Basin floras. The Well Draw flora is comparable to extant floras found in warm-temperate to subtropical zones throughout the southern United States, Mexico, South America and Southern Asia. Estimated (MAT) for this new flora is around 16.1°C with a (MAP) of 56 cm. These findings are in keeping with the sway of evidence confirming a drying out and cooling trend toward the end of the Eocene. As a whole, leaf types in the Wells Draw flora are small and appear to be thick indicating possible seasonally dry periods; with others showing that extreme minima temperatures could not have been below freezing. The discovery of palm, *Palmoxylon*, indicates that despite the cooling trend the mean annual temperature was at least >10°C.

Trace fossil and invertebrates indicate the area south of Myton, Utah, and within the study area were wet. Water tables and moisture levels, though stable for given periods of time, fluctuated as demonstrated by the transgressive and regressive lacustrine phases in the western part of the Uinta Basin. The presence of a large population of turtles, particularly *Echmatemys* and *Apalone*, are clear indicators of marginal lacustrine to palustrine environments. The presence of a disarticulated turtle costal gnawed by a rodent indicates the carapace had time to disarticulate and was subaerially exposed. The first reported varanid *Saniwa cf. ensidens* from the Uinta Formation signifies a warm environment, indicated by ranges of extant monitors. Several forms of crocodilians, *Crocodylus affinis* and possibly *Borealosuchus wilsoni,* indicate a coldest-month mean temperature is >5.5°C, and where the mean annual temperature is >14.2°C.

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Figure 1. Index map of the study area. The majority of the study area is contained within Duchesne County, the eastern edge crossing over into Uintah County, Utah.

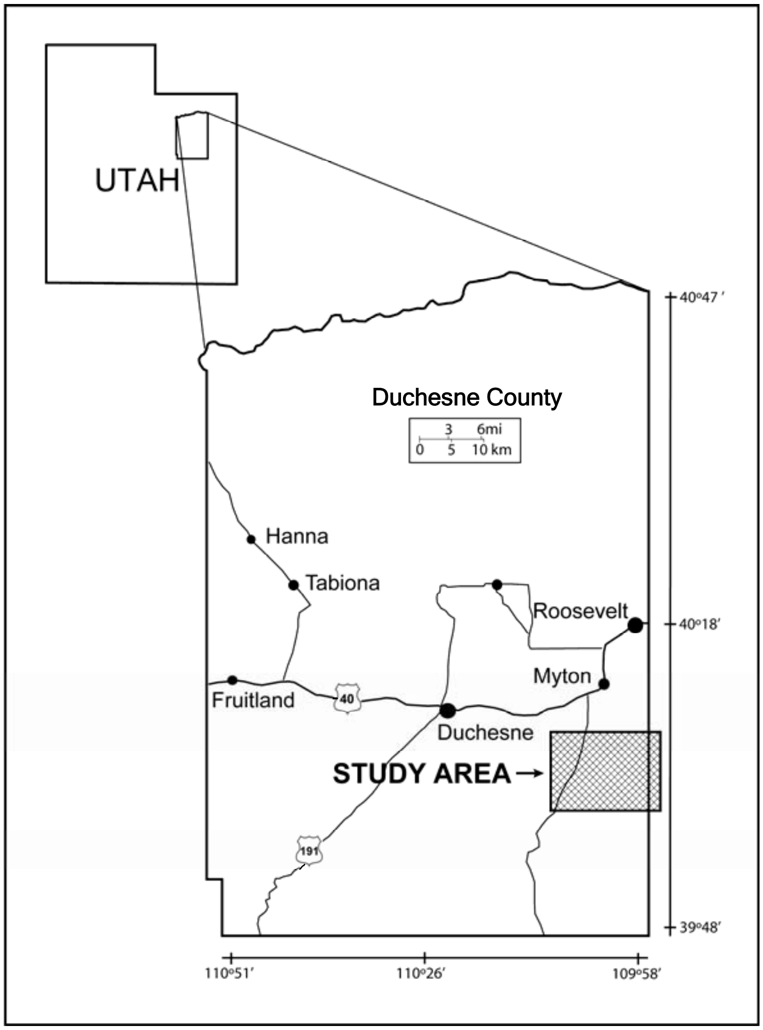
UTAH
Duchesne County
3 6mi
0 5 10 km
Hanna
Tabiona
Roosevelt
Myton
Fruitland
40
Duchesne
STUDY AREA
191
40°47′
40°18′
39°48′
110°51′
110°26′
109°58′

Figure 1.

Figure 2. Paleo-stream flow. Channel sandstones in the study area are orientated in a northwest/southeast direction. Measurements (n =58) from sedimentary structures indicates flow was west to the northwest. (Rose diagram created in RockWorks, 1999.)

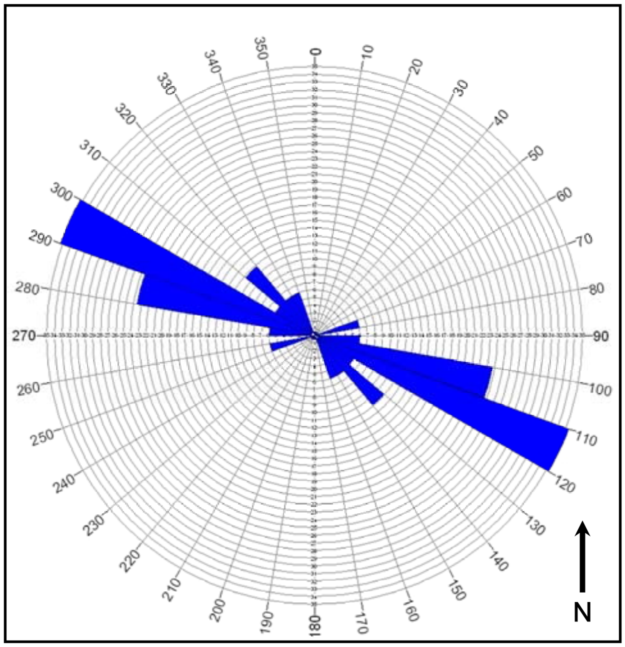
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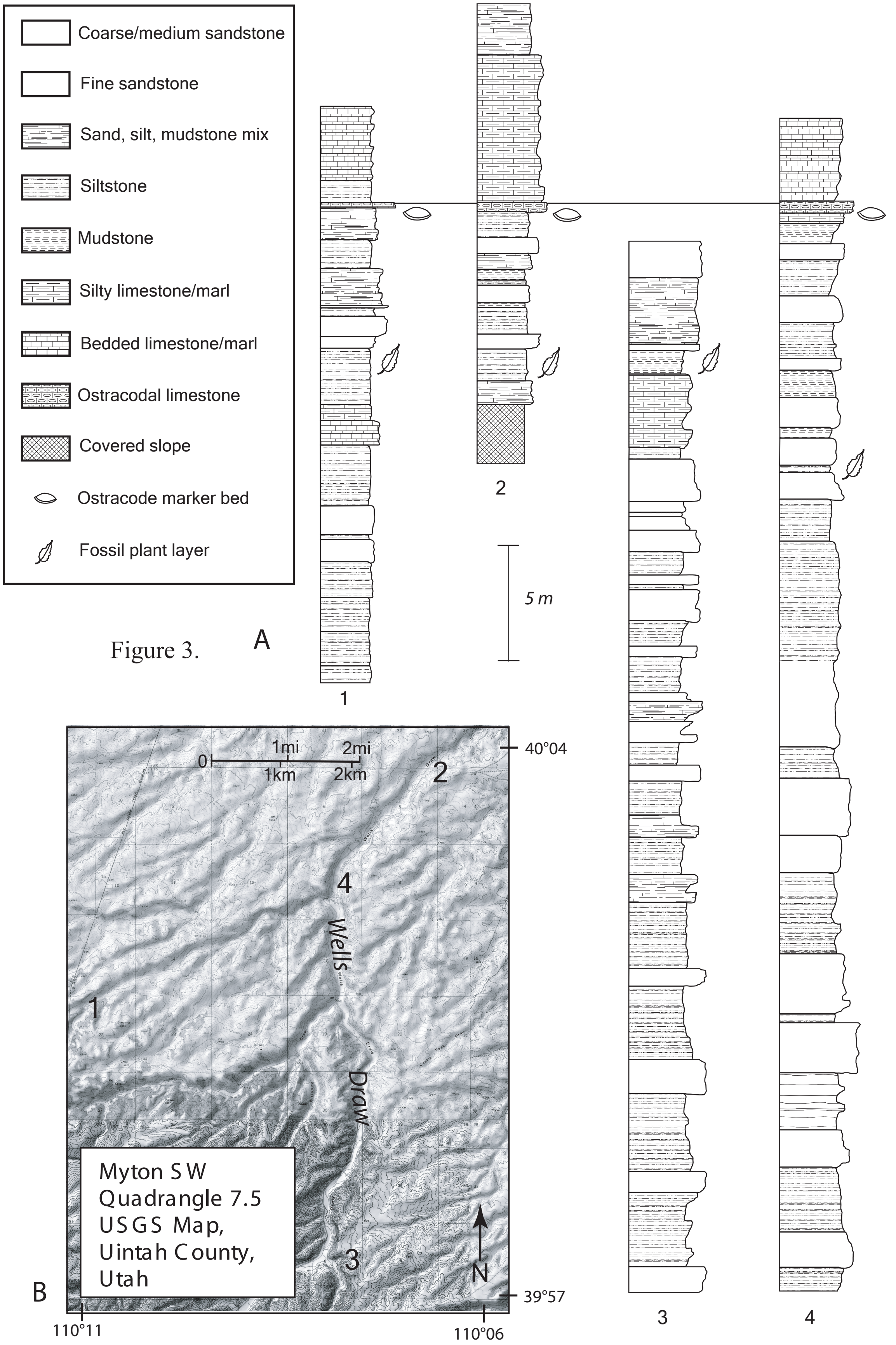
Figure 2.

Figure 3. Stratigraphic sections. **A.** Stratigraphic sections correlated by the ostracodal limestone marker-bed. Prolific fossil plant bearing layers is approximately 5 to 7 m below maker-bed. **B.** Topographic map of the Wells Draw area showing measured section localities (numbered). (Map modified from National Geographic Seamless USGS Topographic Maps of Utah, 2003.)


Coarse/medium sandstone
Fine sandstone
Sand, silt, mudstone mix
Siltstone
Mudstone
Silty limestone/marl
Bedded limestone/marl
Ostracodal limestone
Covered slope
Ostracode marker bed
Fossil plant layer
A
5 m
1
2
3
4
B
0
1mi
2mi
1km
2km
40°04
39°57
110°11
110°06
1
2
3
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Wells
Draw
N
Myton SW
Quadrangle 7.5
USGS Map,
Uintah County,
Utah

Figure 3.

Figure 4. Trace fossil. **A.** Larvae caddisfly cases *Tekonargus*, BYU 18546. **B.** Burrows of mud-loving beetles, or mole crickets *Steinichnus*, BYU 18543. **C.** Tubes of earthworms *Edaphichnium*, BYU 18544. Notice the outside of the tube is composed of carbonate rich pellets. **D-E.** Adhesive maniscate burrows of beetles cf. *Ancorichnus*, BYU 18592. **F.** Root traces in paleosol. Scale divisions are 1cm, visible pick-end of hammer is 10cm long, and the green paleosol bed in "E" is roughly 33 cm thick.

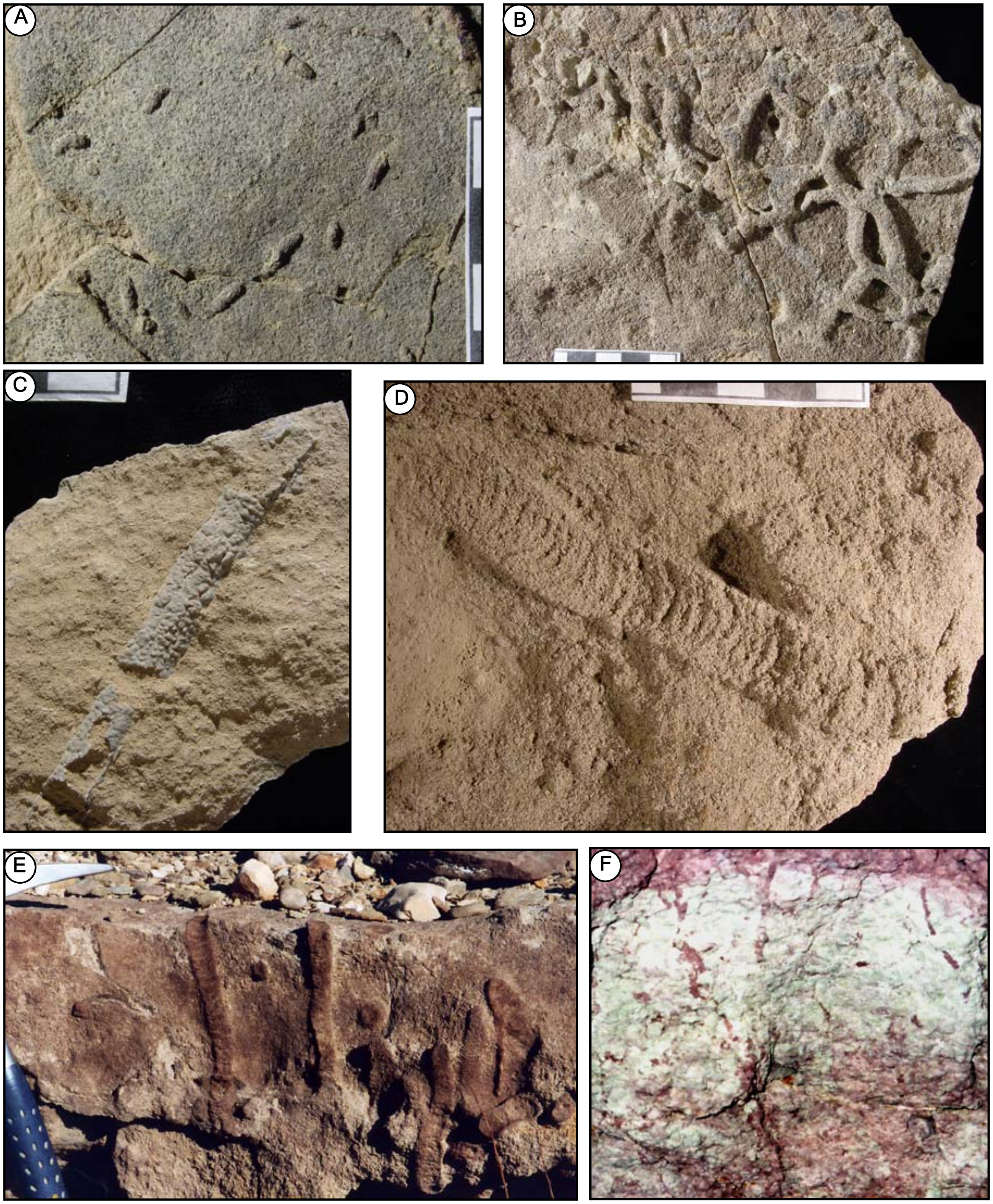


Figure 4.

Figure 5. Trace fossils. **A.** Long horizontal burrow of *Planolites*. **B.** Extremely large *Edaphichnium*, up to 8cm in diameter and well over two meters long. **C-D.** Annelid trails *Cochichnus*, BYU 18554, BYU 18593. **E.** Close up view of a tube from “B”, showing the carbonate rich pellets, typical of earthworm tube traces. Scale divisions are 1cm, and hammer is 36cm long.

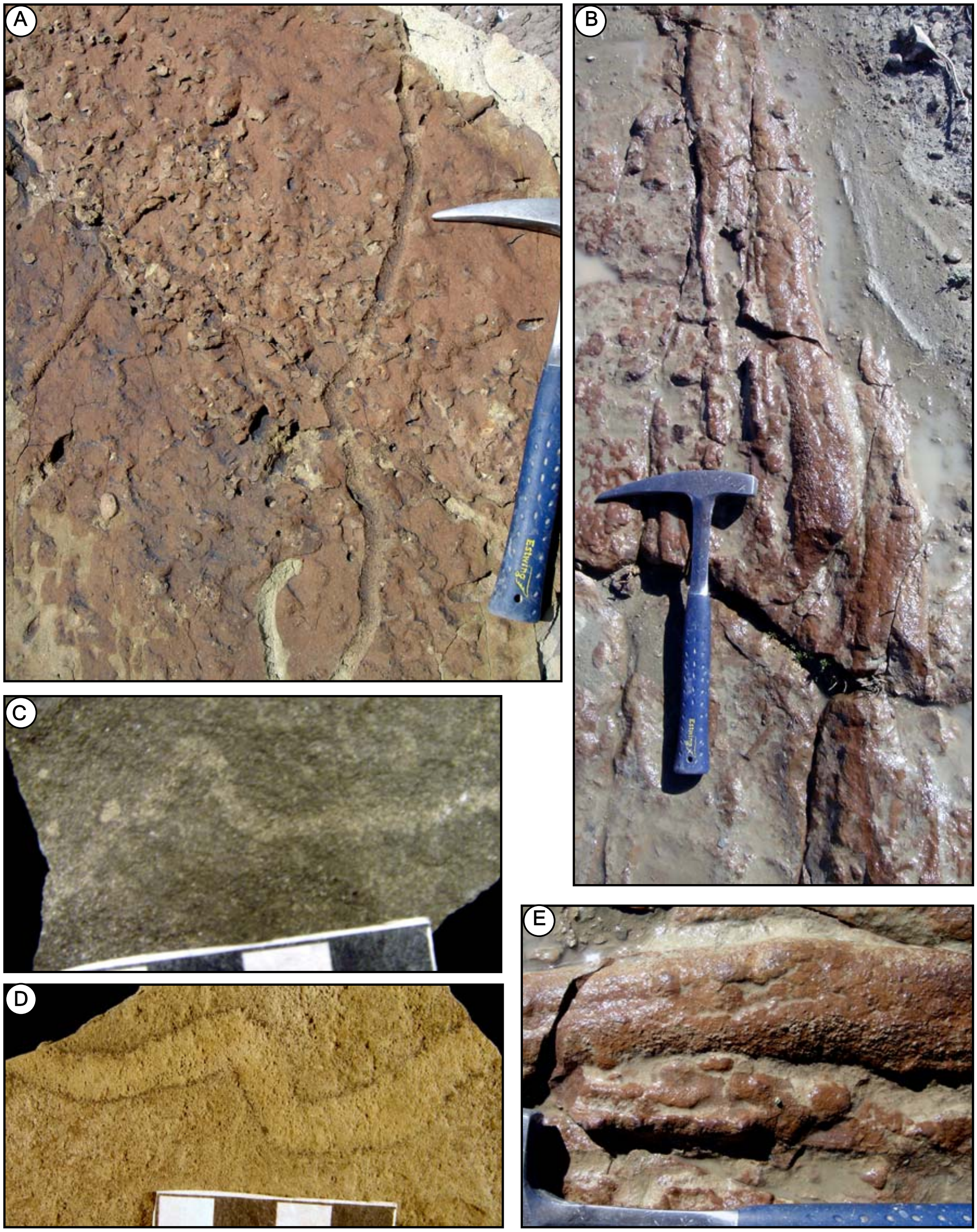


Figure 5.

Figure 6. Uinta invertebrates. **A.** *Physa longiuscula,* BYU 18504. **B.** A slab showing both *Biomphalaria pseudoammonius* and *Physa longiuscula* in close association, BYU 18552. **C.** *Biomphalaria pseudoammonius,* BYU 18505. **D.** cf. *Biomphalaria storchi,* BYU 18505. **E.** *Goniobasis tenera,* BYU 18549. **F.** Thin section of typical elliptical shaped individual ?*Hemicyprinotus watsonensis* in longitudinal view. x100.
G. Thin section of ostracodal limestone bed from the western portion of the Uinta Basin. x20.

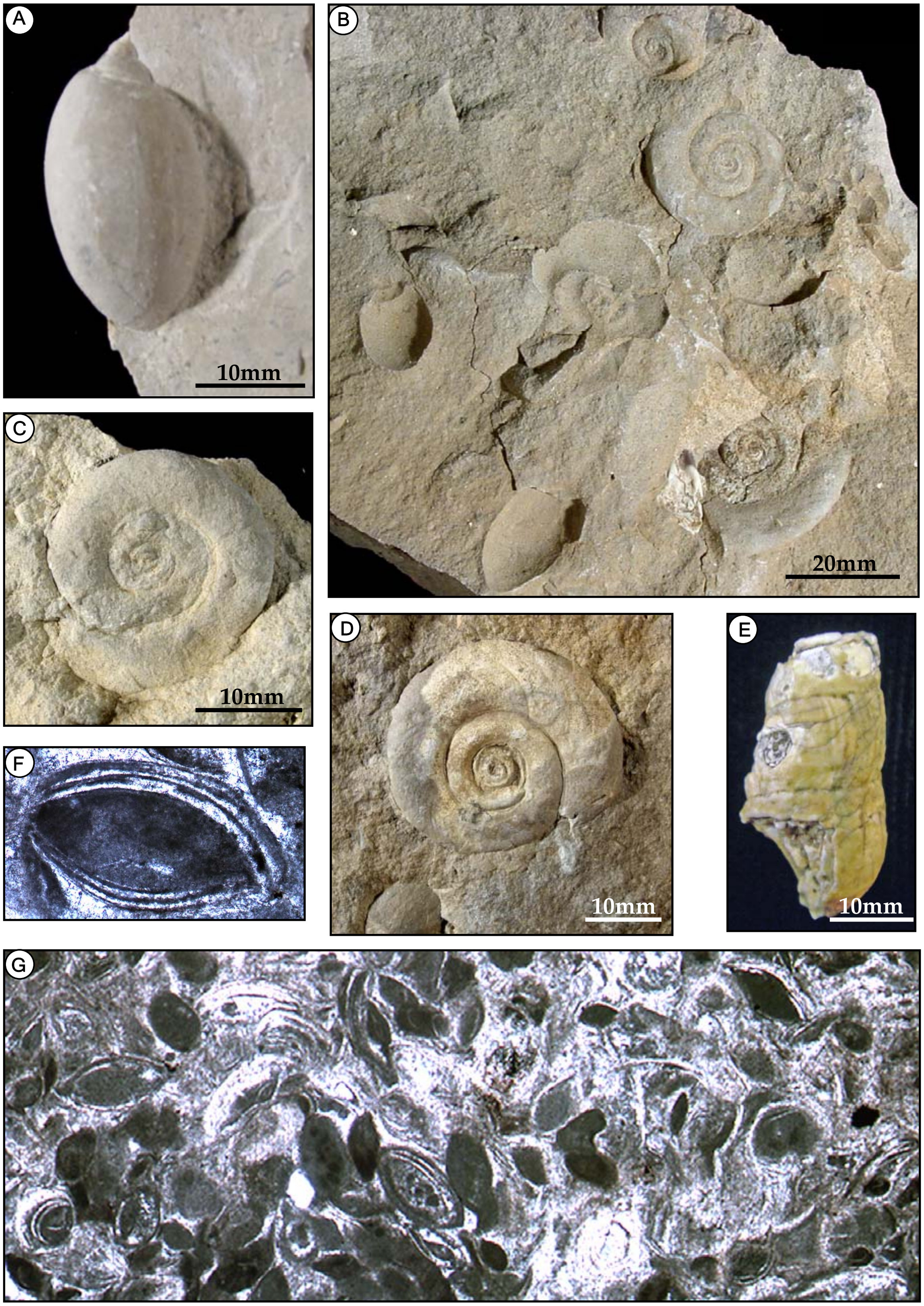


Figure 6.

Figure 7. Fish. **A.** Caudal region of *Lepisosteus cuneatus* showing caudal fin rays, BYU 18551. **B-D.** Centrum of *Amia sp.* shown in ventral “B”, anterior “C”, and posterior “D” views, BYU 18548. **E-F.** Partial occipital condyle form same amiid individual in dorsal “E” and ventral “F” views.

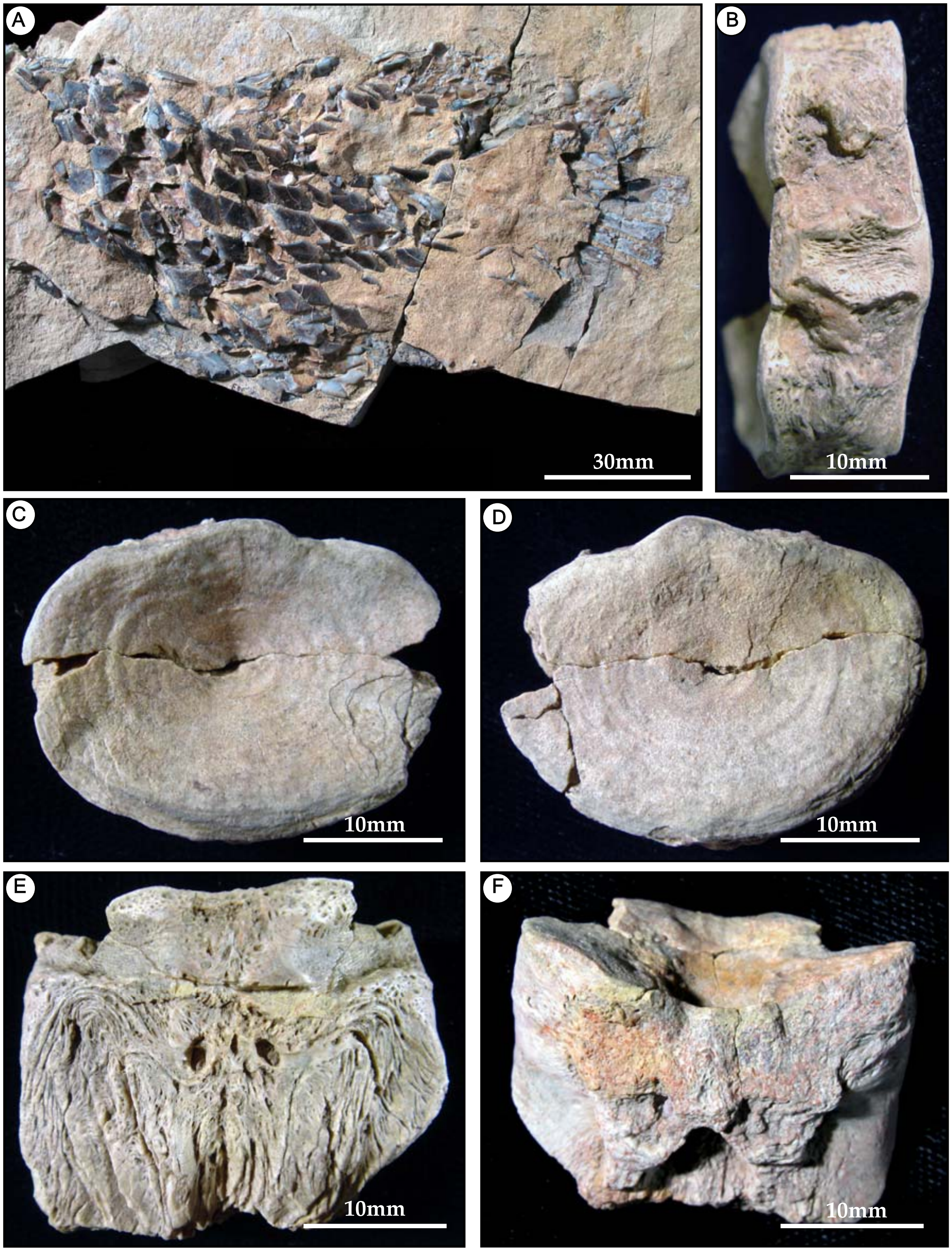


Figure 7.

Figure 8. Uinta reptiles and amphibian. **A-B.** *Apalone sp*. shown in ventral "A" and dorsal "B" view, BYU 18547. **C-D.** Vertebrae of a small varanids, *Saniwa sp.,* seen in lateral "C", and dorsal "D" view, BYU 18550. **E.** Possible pelobatid radio-ulna, cf. *Eopelobates,* BYU 18502. **F.** Eight articulated dorsal vertebrae of a large *Saniwa sp.* in dorsal view, BYU 18503.

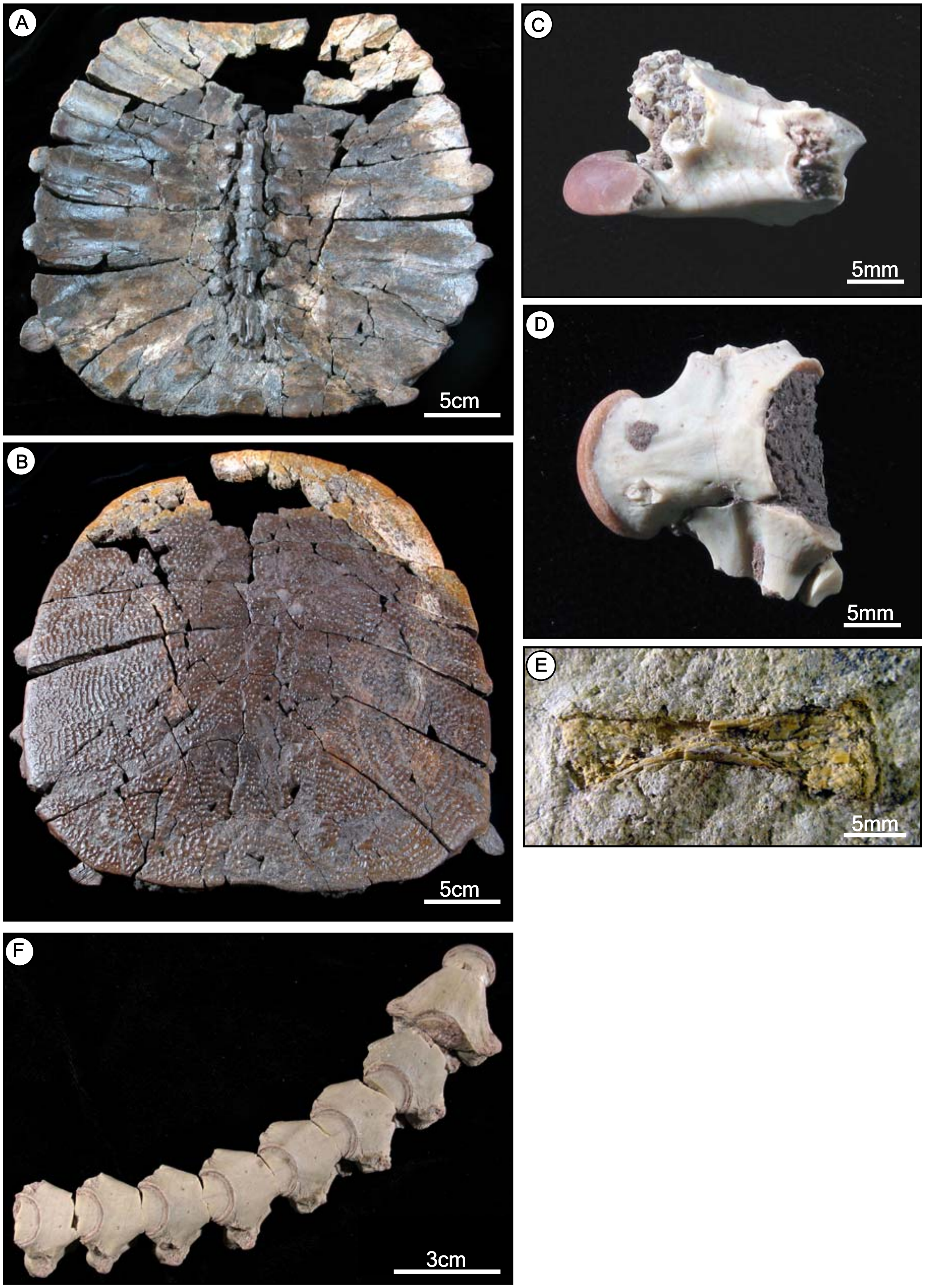


Figure 8.

Figure 9. Pathologies and taphonomic markers. **A.** Track injury on epiplastron and hyoplastron of *Baena arenosa,* BYU 18533. **B.** Type I and II pitting on a partial *Echmatemys callopyge* plastron, BYU 18516. **C.** Extensive pitting on neural of *Echmatemys sp.,* BYU 18538. **D.** Bit marks “tapered gouge” on carapace fragment, BYU 18507. **E.** Mammal harvesting, “rodent gnawing” around the margins of a costal bone from a trionychid, *Apalone sp.,* BYU 18532. Terminology after Hutchison and Frye (2001).

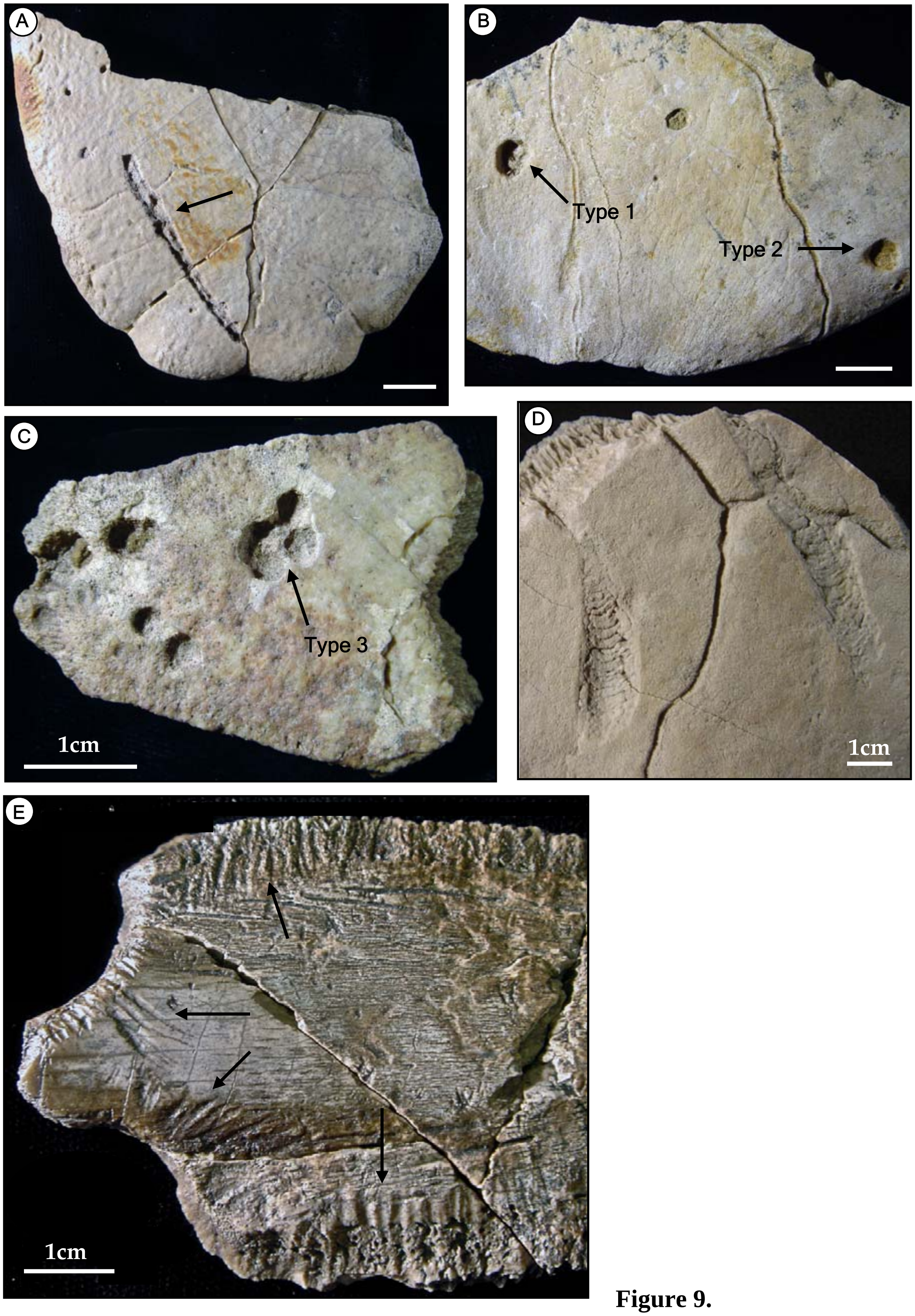


Figure 9.

Figure 10. Crocodilians. **A, E-H.** Various (ventral osteoderms) possibly from *Borealosuchus wilsoni,* BYU 18529. **B-C.** Skull element "B" and osteoderm "C" from small *Borealosuchus sp.,* BYU 18501. **D.** Left femur presumably from the same individual as the scutes in "A, E-H", BYU 18500. **I.** Skull of *Crocodylus affinis*, dorsal view, BYU 18553.

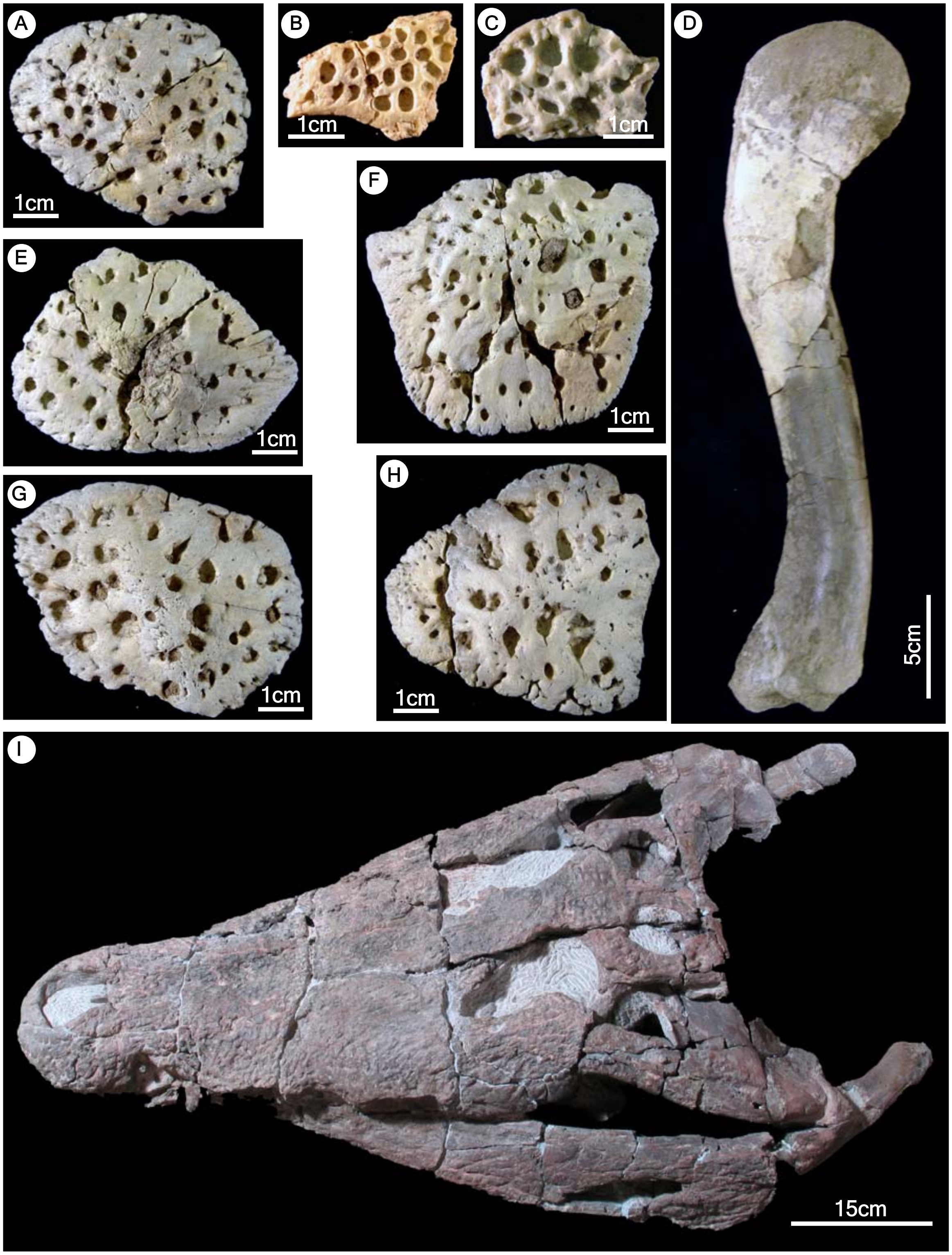


Figure 10.

Figure 11. *Phoenicites, Equisetum,* ?*Pinus*. **A.** Monocot blade (? *Phoenicites*), BYUPB 1288. **B.** *Equisetum sp.* stem base, BYUPB 1106. **C.** Joint impression of *Equisetum cf. tipperarense* Berry, BYUPB 1353. D. Possible *Equisetum* bulbils. BYUPB 1111. **E.** *Equisetum sp.* joint impression, BYUPB 1089. **F.** *Equisetum sp.* stem sections showing multiple joints, BYUPB 1006. **G-H.**, Specimen and line drawing highlighting the small blades with prominent midvein (?sedge), BYUPB 1313. **I.** Large joint of *Equisetum cf. winchesteri* Brown, BYUPB 1133. **J-K.** Positive and negative of a winged seed of (?*Pinus*), BYUPB 1233. **L-M.** Possible strobilous of *Equisetum,* BYUPB 1182. Drawing illustrates possible sporangia along the structure.

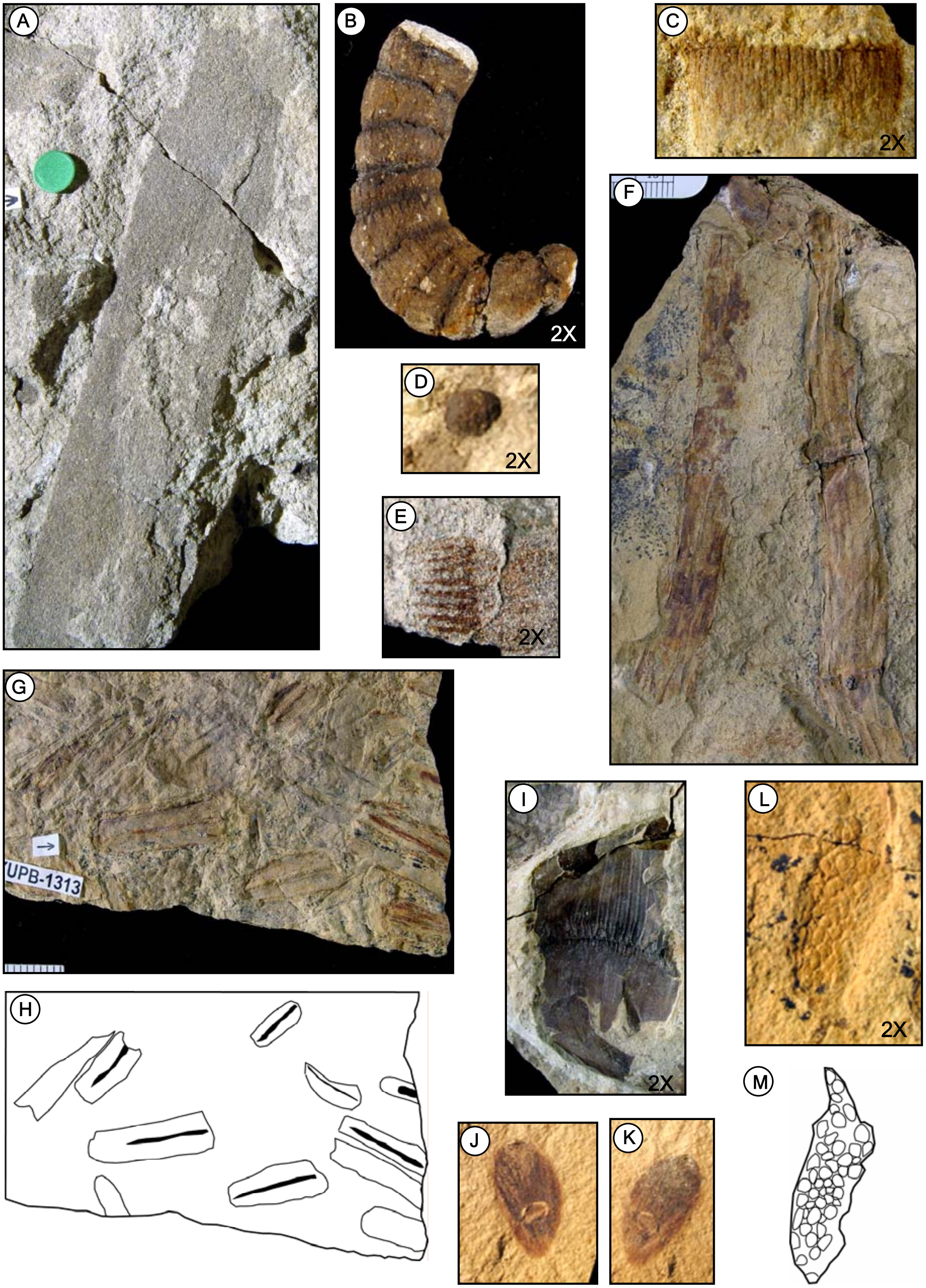


Figure 11.

Figure 12. *Salix, Populus, Allophylus*. **A.** Unidentified leaf, BYUPB 1295. **B.** cf. *Salix cockerelli* Brown, BYUPB 1337. **C.** cf. *Populus cinnamomoides* (Lesquereux) MacGinitie, BYUPB 1392. **D.** cf. *Salix longiacuminata* Knowlton, BYUPB 1049. **E.** Unidentified leaf, BYUPB 1382. **F.** cf. *Salix longiacuminata* Knowlton, BYUPB 1024. **G.** Unidentified leaf, BYUPB 1069. **H.** cf. *Salix coloradica* MacGinitie, BYUPB 1290. **I.** cf. *Allophylus flexifolia* (Lesquereux) MacGinitie, BYUPB 1386.

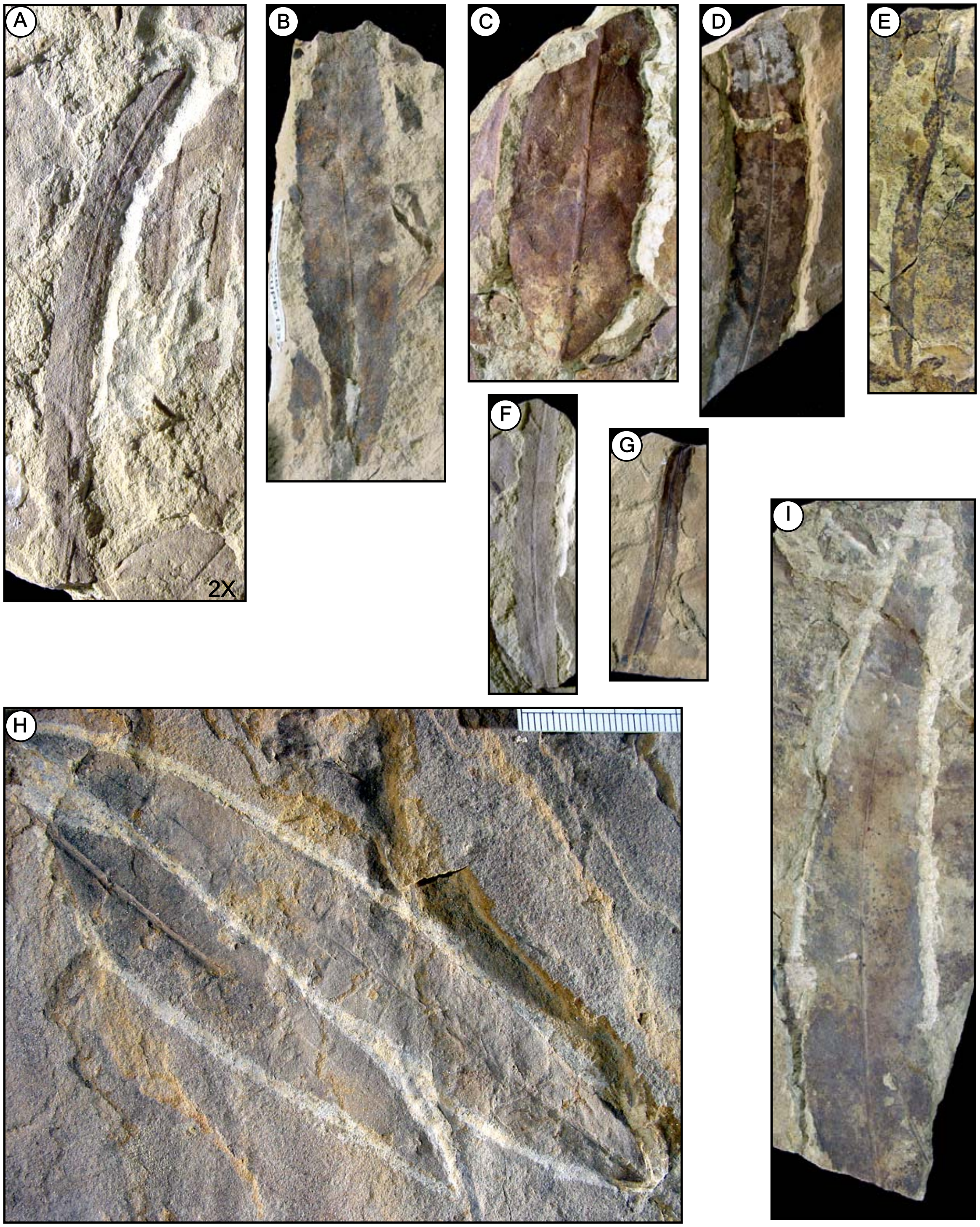


Figure 12.

Figure 13. *Populus,* Fagaceae, *Macginitiea*. **A-B.** Blade with long petiole and tertiary veins as illustrated, *Populus wilmattae* Cockerell, BYUPB 1245. **C.** *Populus wilmattae* Cockerell, BYUPB 1155. **D.** cf. Fagaceae, BYUPB 1458, unidentified leaf (large blade), BYUPB 1177. **E.** Six-lobed *Macginitiea wyomingensis* (Knowlton, Cockerell, MacGinitie) Manchester, BYUPB 1478. **F.** cf. *Salix,* BYUPB 1463.

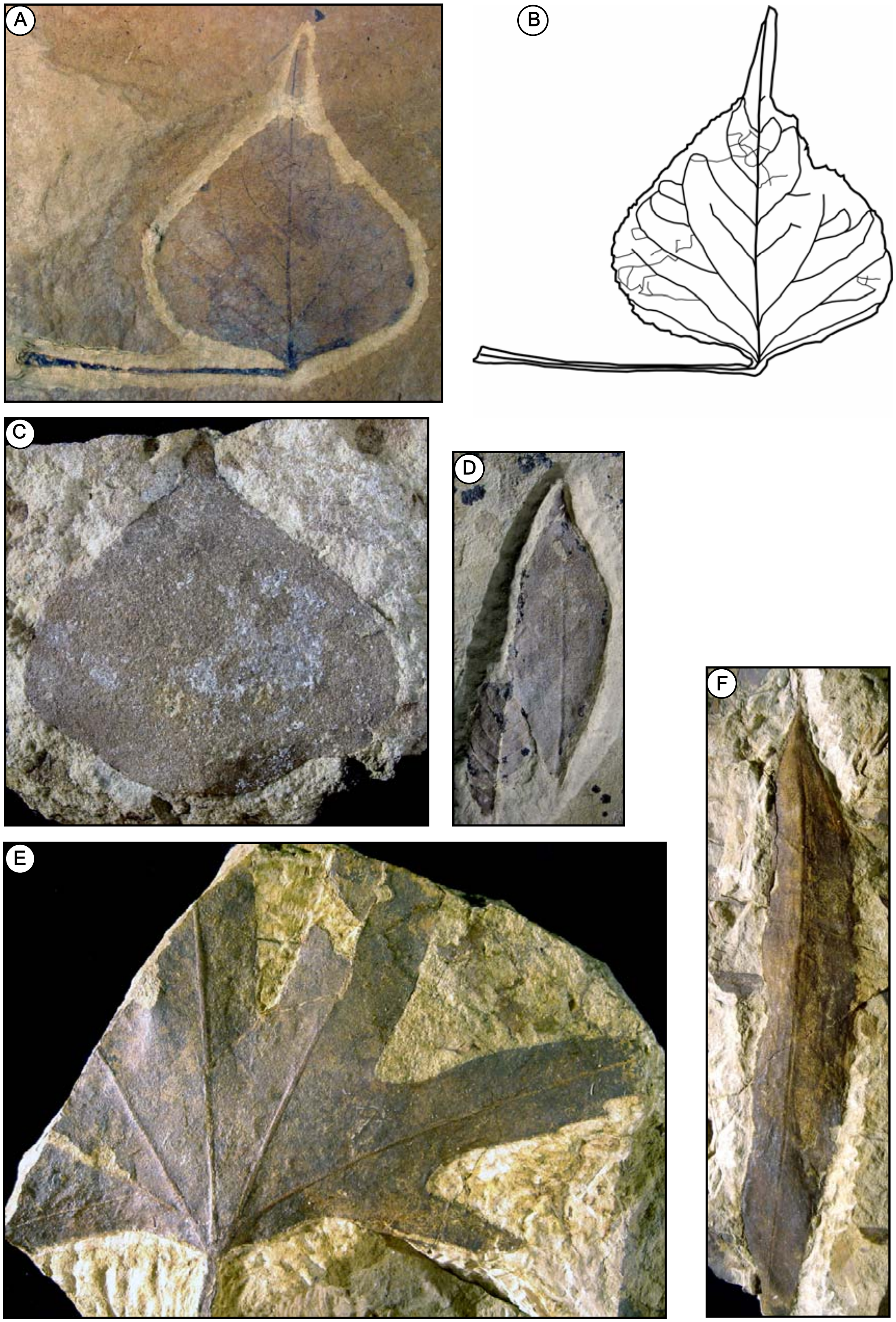


Figure 13.

Figure 14. Juglandaceae, *Cardiospermum, Robinia, Rhus, Castanea*. **A-B.** Four leaves attached to rachis, cf. Juglandaceae, BYUPB 1391. **C-D.** Partial blade and illustration of *Cardiospermum coloradensis* (Knowlton) MacGinitie, BYUPB 1401.
E-F. *Cardiospermum coloradensis* (Knowlton) MacGinitie, BYUPB 1398. **G.** *Cardiospermum coloradensis* (Knowlton) MacGinitie, BYUPB 1397. **H.** cf. *Robinia lesquereuxi* (Ettingshausen) MacGinitie, BYUPB 1383. **I.** cf. *Rhus nigricans* (Lesquereux) Knowlton, BYUPB 1236. **J-K.** cf. *Castanea dolichophyiia* Cockerell, BYUPB 1271.

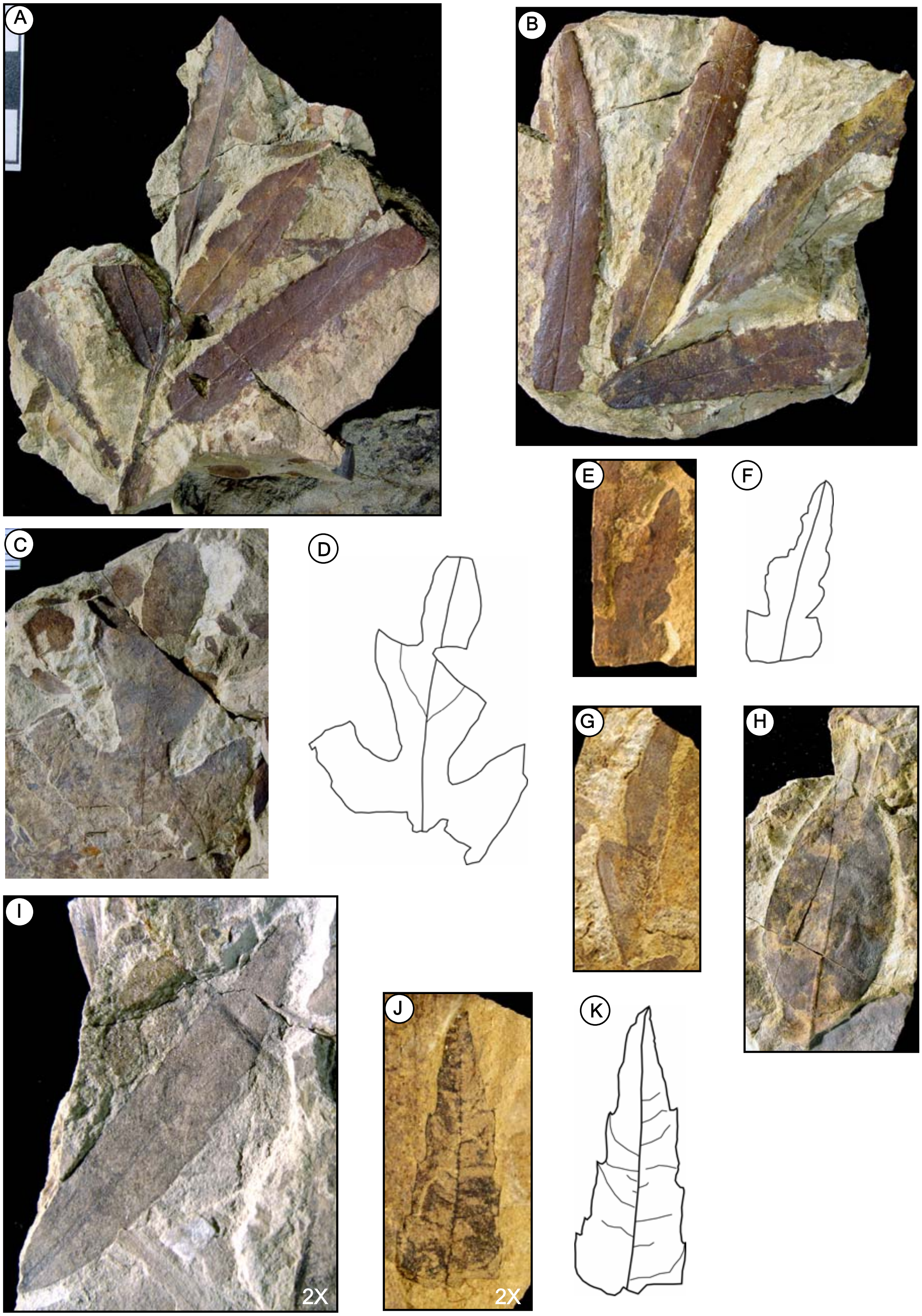


Figure 14.

Figure 15. *Rosa, Cedrelospermum,* ?*Quercus*. **A-B.** Craspedodromous venation (Fagaceae?), BYUPB 1224. **C.** Unidentified leaf, BYUPB 1395. **D-E.** (*Salix?*), BYUPB 1267. **F-G.** cf. *Rosa hilliae* Lesquereux, MacGinitie, BYUPB 1327. **H.** cf. *Cedrelospermum nervosum* (Newberry) Manchester, BYUPB 1364. **I.** Short thick blade with undulate margins (?*Quercus*), BYUPB 1172. **J.** cf. *Cedrelospermum nervosum* (Newberry) Manchester, BYUPB 1225. **K.** Unidentified leaf, BYUPB 1127. **L-M.** Unidentified leaf, line drawing showing wandering venation, BYUPB 1128. **N.** Blade with crenate margins (Ulmaceae?), BYUPB 1400. **O.** Crenate to rounded-serrate margined unidentified leaf (Ulmaceae?), BYUPB 1365. **P.** Unidentified leaf, BYUPB 1367.

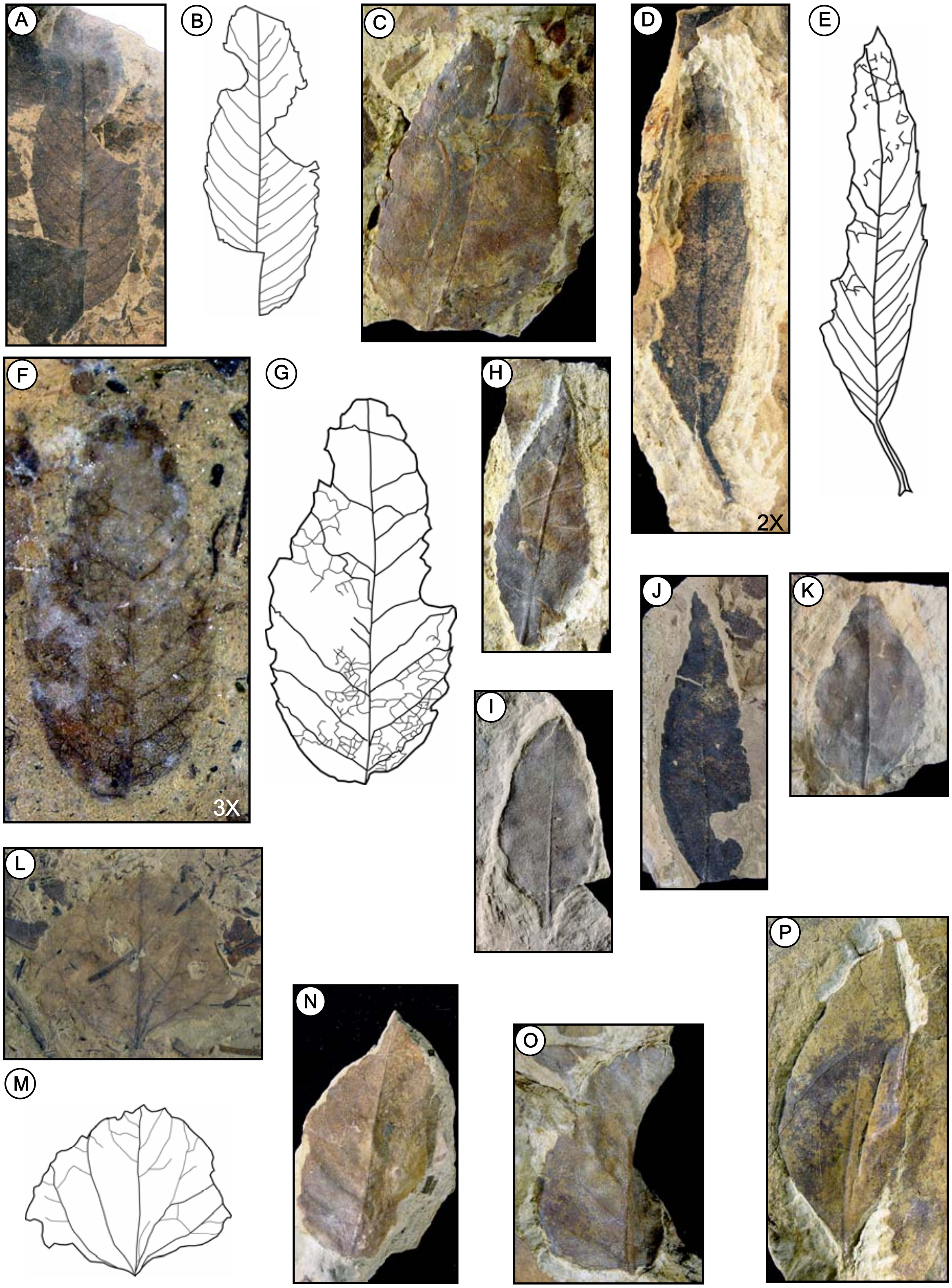


Figure 15.

Figure 16. *Cederlospermum, Bursera, Allophylus, Mahonia, Cedrela*. **A-B.** Blade with short petiole and visible secondaries illustrated in drawing, cf. *Cederlospermum,* BYUPB 1284. **C.** Large leaf with crenate margins cf. *Bursera inaequalateralis* (Lesquereux) MacGinitie, BYUPB 1428. **D.** Unidentified leaf, BYUPB 1445. **E.** Leaf with asymmetrical base, cf. *Allophylus felifolia* (Lesquereux) MacGinitie, BYUPB 1437. **F.** Unidentified leaf, BYUPB 1422. **G.** cf. *Mahonia marginata* (Lesquereux) Arnold, BYUPB 1470. **H.** Legume, BYUPB 1331. **I.** Unidentified leaf, BYUPB 1048. **J.** cf. *Cedrela,* BYUPB 1252. **K.** cf. *Allophylus felifolia* (Lesquereux) MacGinitie, BYUPB 1425.

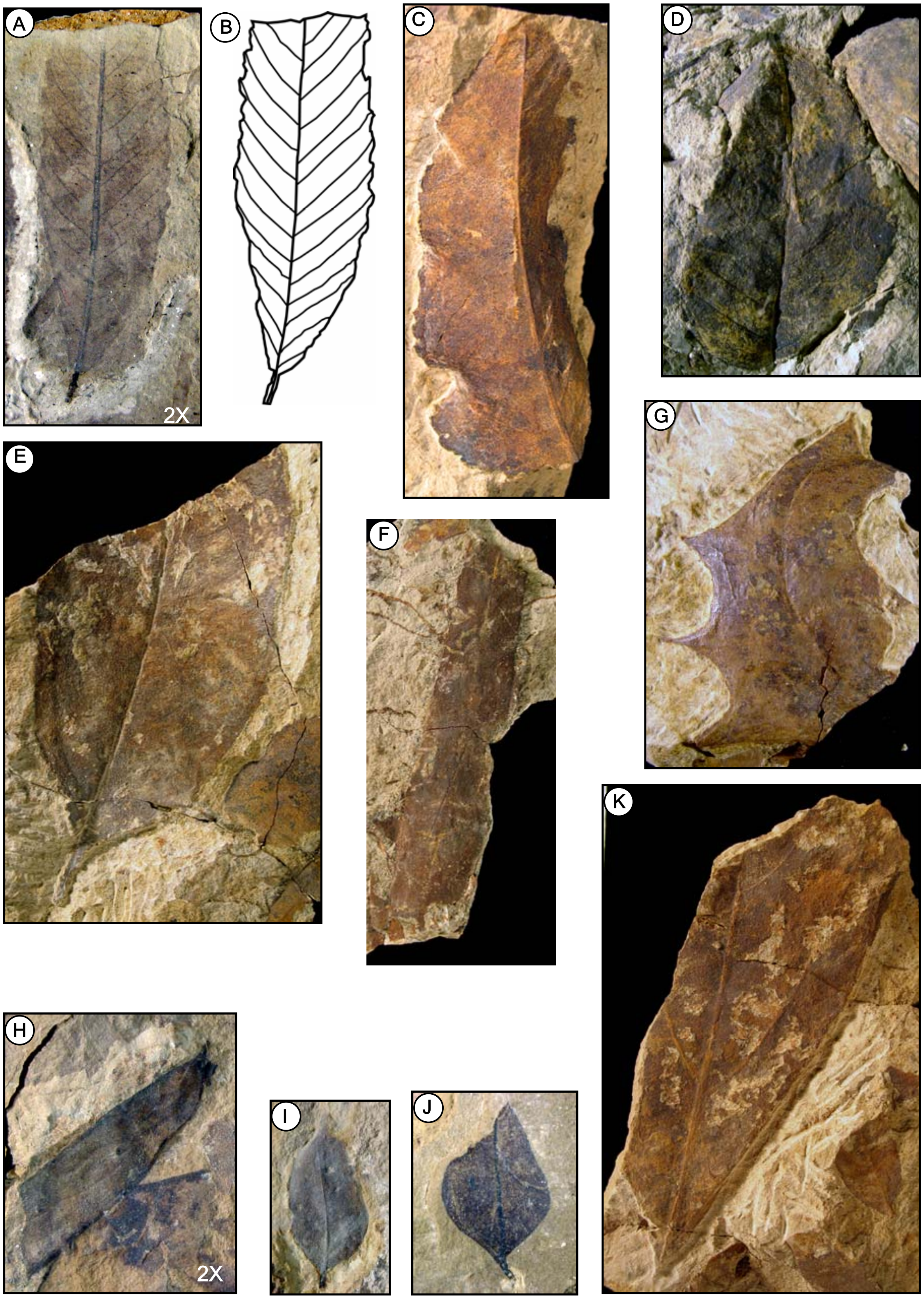


Figure 16.

Figure 17. *Macginitiea*. Variation in leaf types in *Macginitiea wyomingensis* (Knowlton and Cockerell) Manchester. **A.** Two long serrate lobes, BYUPB 1194. **B.** Possible five-lobed small unserrated leaf, BYUPB 1407. **C.** Miniature five-lobed blade with basal serrations, BYUPB 1228. **D.** Large blade with short blunt lobes, BYUPB 1430. **E.** Six-lobed leaf with reduced basal lobes, BYUPB 1442. **F.** Slender (six?)-lobed leaf with basal serrations, BYUPB 1018.

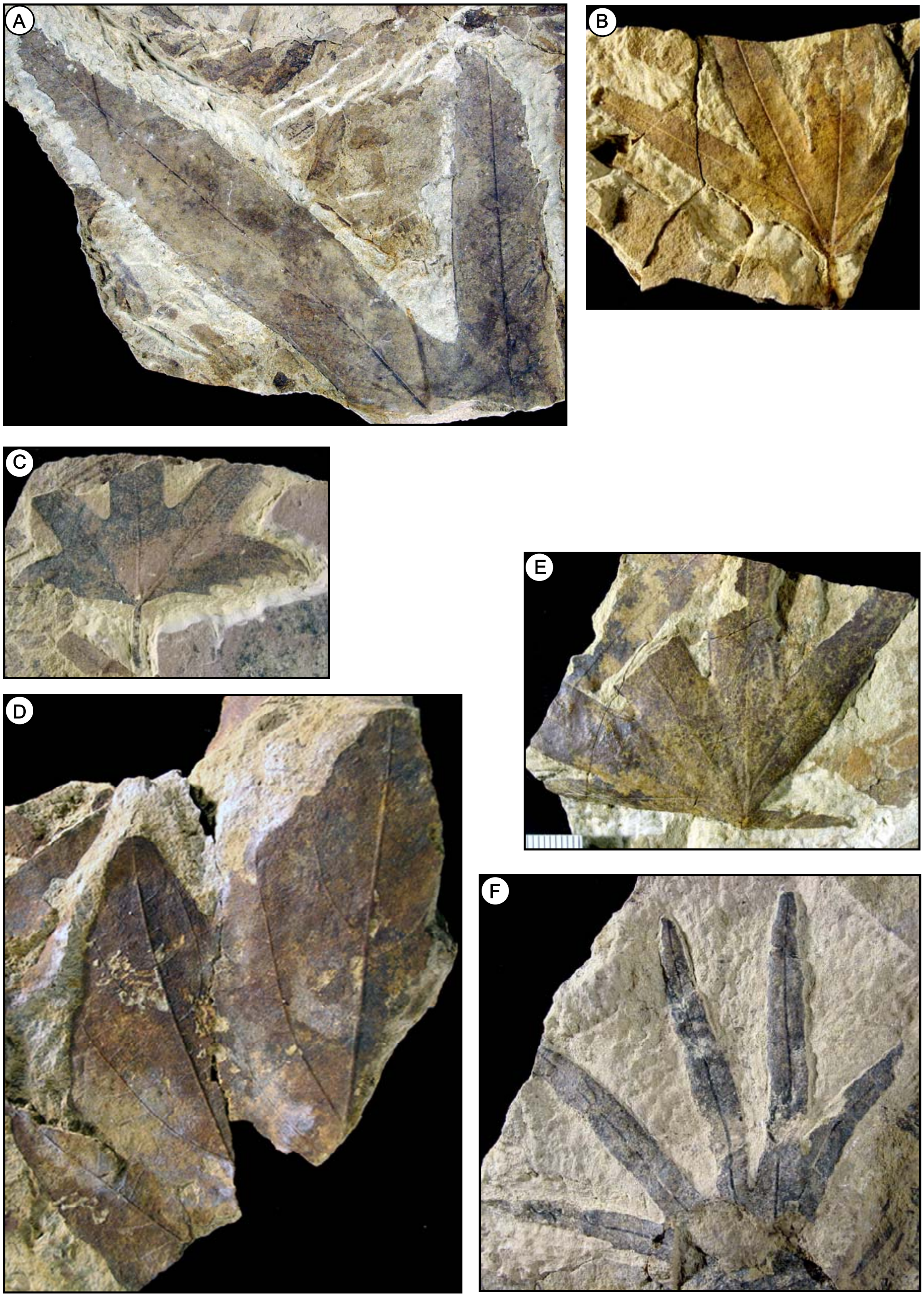


Figure 17.

Figure 18. *Macginitiea*. **A.** Several leaf morphologies of *Macginitiea wyomingensis* (Knowlton and Cockerell) Manchester, BYUPB 1418. **B-C.** Negative and positive of an inflorescence of *Macginitiea wyomingensis* (Knowlton and Cockerell) Manchester, BYUPB 1129. **D.** Six-lobed *Macginitiea wyomingensis* (Knowlton and Cockerell) Manchester, BYUPB 1431.

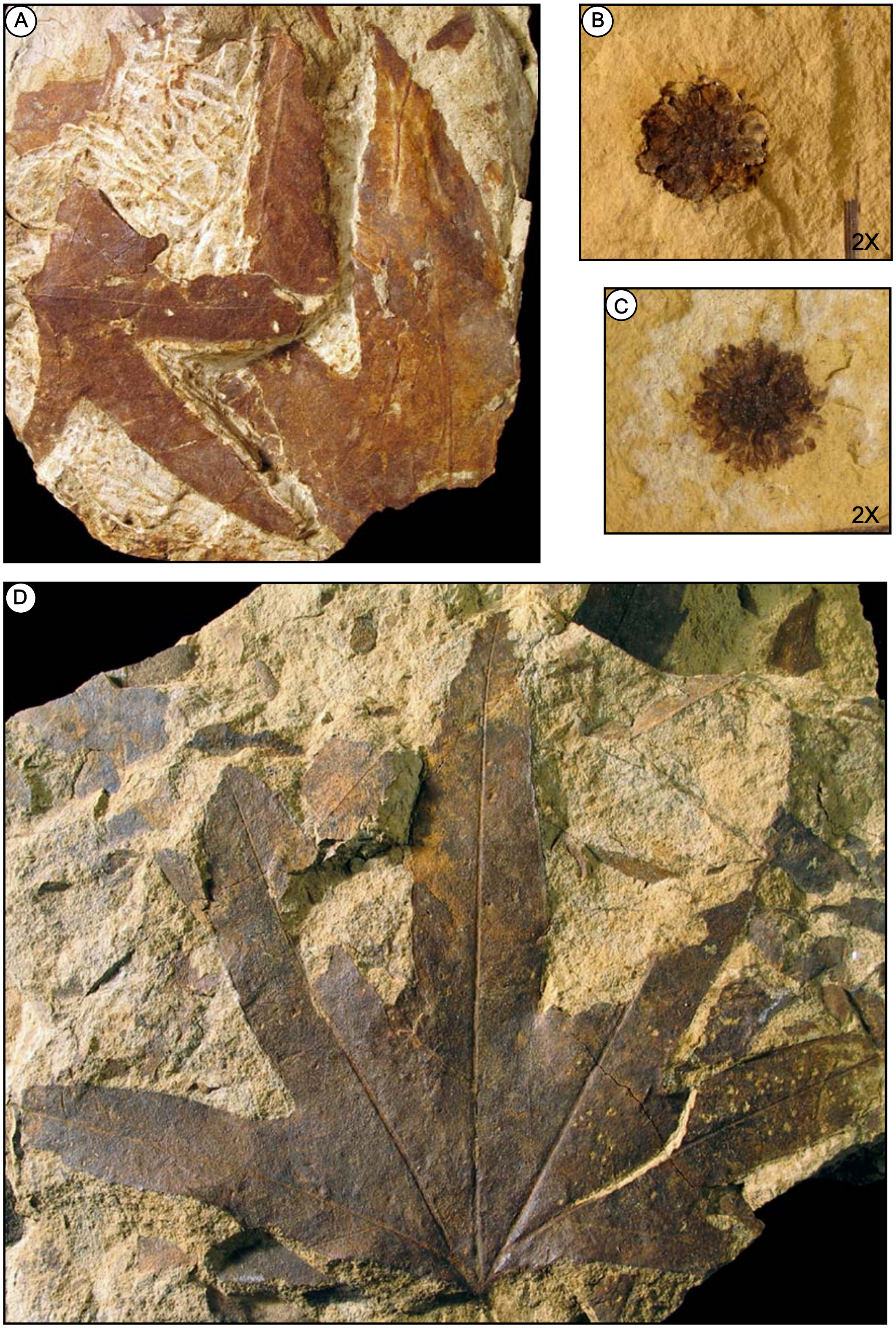


Figure 18.

Figure 19. *Caeslpinites, Quercus, Gymnocldus, Osmanthus, Eugenia*. **A.** Unidentified leaf, BYUPB 1379. **B.** cf. Leguminosae, BYUPB 1363. **C.** Unidentified leaf, BYUPB 1358. **D.** cf. *Caeslpinites falcate* MacGinitie, BYUPB 1385. **E.** cf. Leguminosae, BYUPB 1378. **F.** Unidentified leaf, BYUPB 1357. **G.** cf. *Quercus cuneatus* MacGinitie, BYUPB 1475. **H.** cf. *Quercus cuneatus* MacGinitie, BYUPB 1444. **I.** cf. *Gymnocldus hesperia* (Brown) MacGinitie, BYUPB 1377. **J-K.** cf. *Osmanthus praemissa* (Lesquereux) Cockerell MacGinitie, BYUPB 1452. **L-M.** Mid portion of a blade, cf. *Eugenia americana* (Lesquereux) MacGinitie, BYUPB 1454. **N-O.** Basal portion of the same leaf with illustration, cf. *Eugenia americana* (Lesquereux) MacGinitie, BYUPB 1454. **P.** Unidentified leaf, BYUPB 1465. **Q.** cf. *Parvileguminophyllum,* BYUPB 1091.

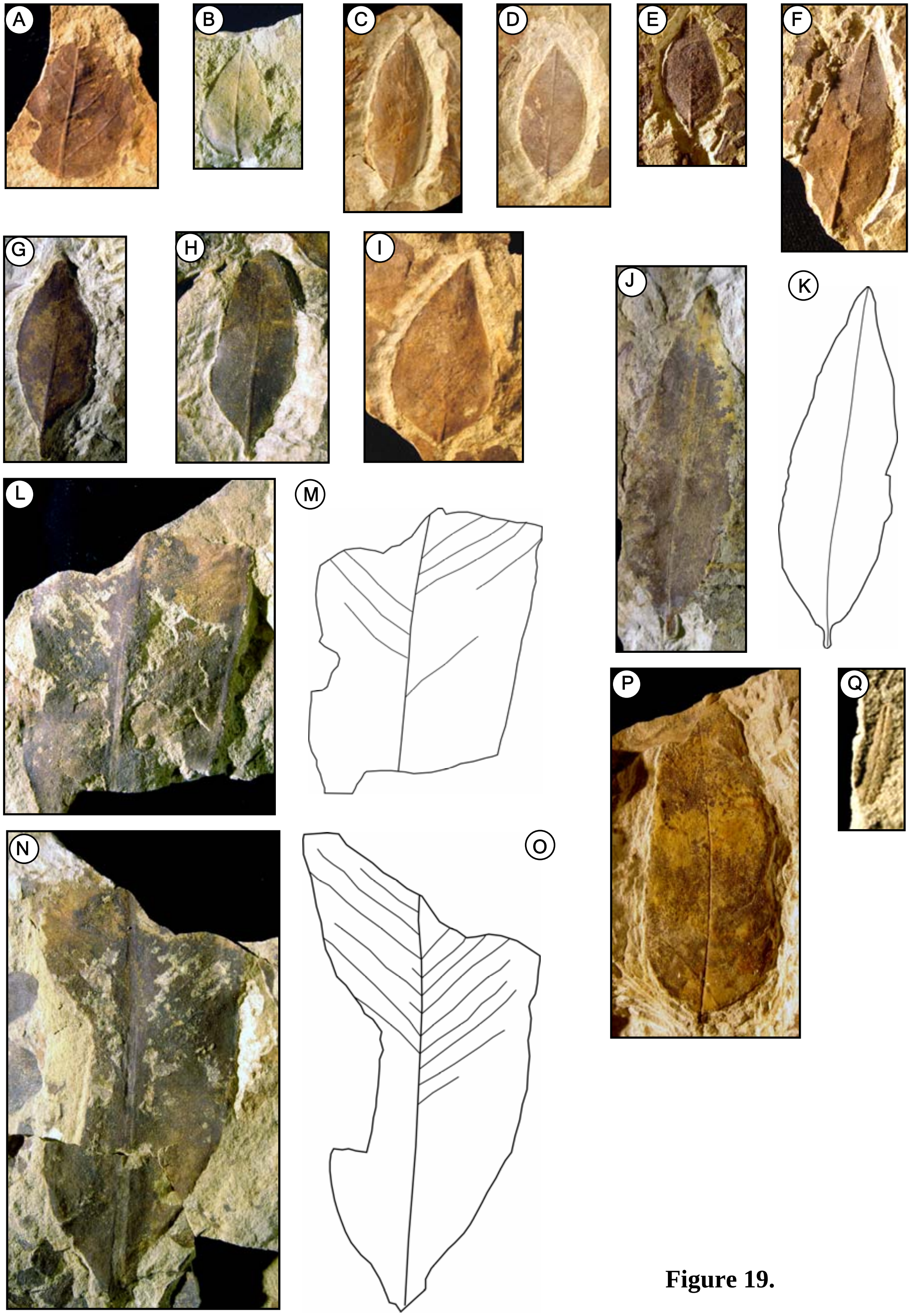


Figure 19.

Figure 20. *Acer?, Sapindus*. **A.** Palmate blade with petiole. Drawing illustrates visible veins (?*Acer*), BYUPB 1159. **B-C.** Lobe impression showing tertiary veins, BYUPB 1159. **D-E.** Positive and negative of a single lanceolate blade cf. *Sapindus coloradensis* Cockerell, BYUPB 1340.

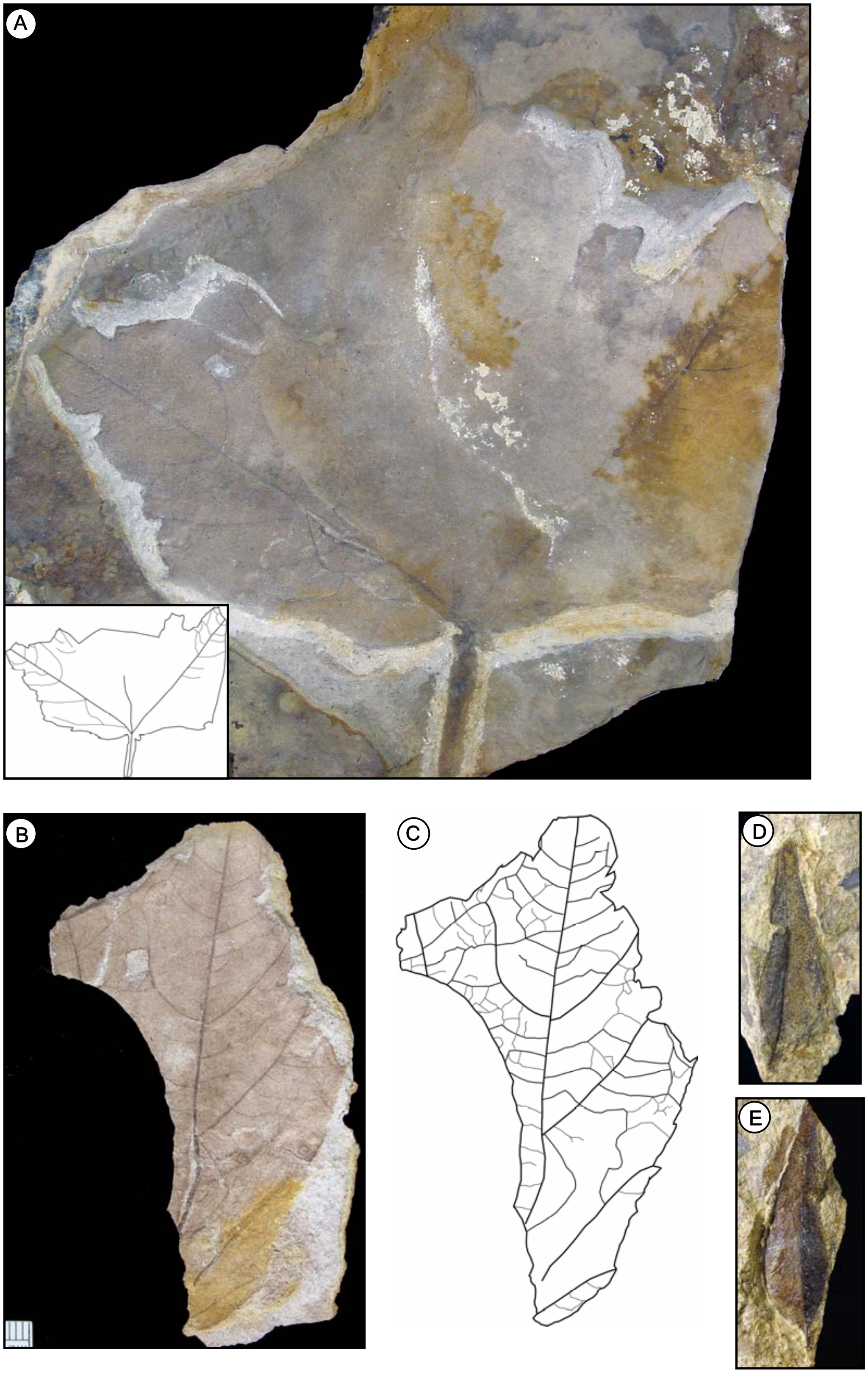


Figure 20.

Figure 21. *Vitis, Osmanthus, Robinia, Swartzia*. **A-B.** Blade illustrated with secondary and tertiary veins, cf. *Vitis,* BYUPB 1399. **C.** Unidentified leaf, BYUPB 1175. **D-E.** Leaf with acrodromous like venation, (?Tiliaceae), BYUPB 1083. **F.** Unidentified leaf, BYUPB 1142. **G.** cf. *Osmanthus praemissa* (Lesquereux) Cockerell, BYUPB 1415. **H.** Unidentified, BYUPB 1412. **I.** cf. *Robinia lesquereuxi* (Ettingshausen) MacGinitie, BYUPB 1345. **J.** cf. *Swartzia wardellii* Macginitie, BYUPB 1414. **K.** (?*Leguminosites*), BYUPB 1438.

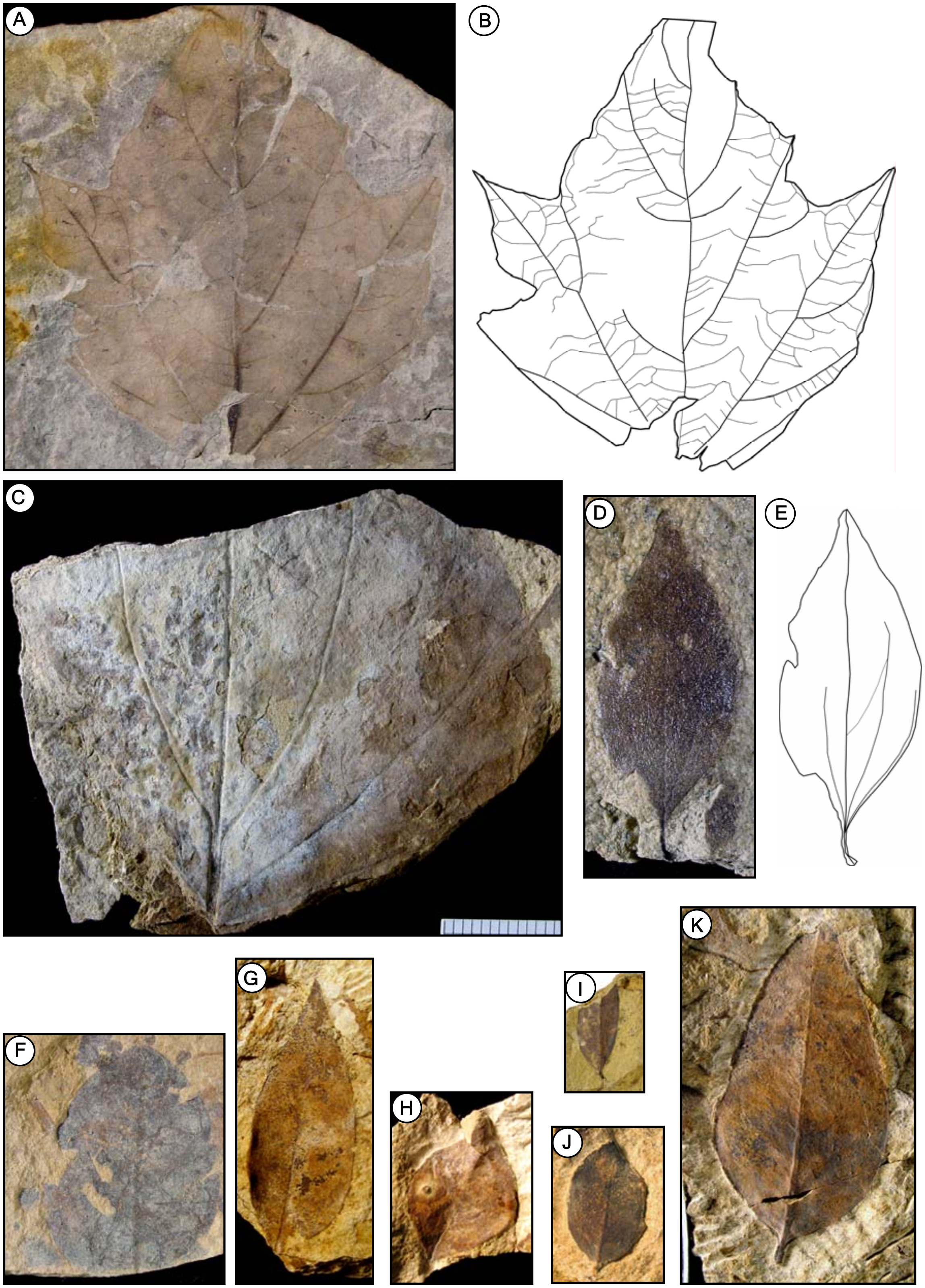


Figure 21.

Figure 22. *Vitis, Rhamnus, Triumfetta*. **A-B.** Large blade with petiole, cf. *Vitis,* BYUPB 1399. **C.** cf. *Rhamnus,* BYUPB 1067. **D.** cf. *Triumfetta ovata* MacGinitie, BYUPB 1329.

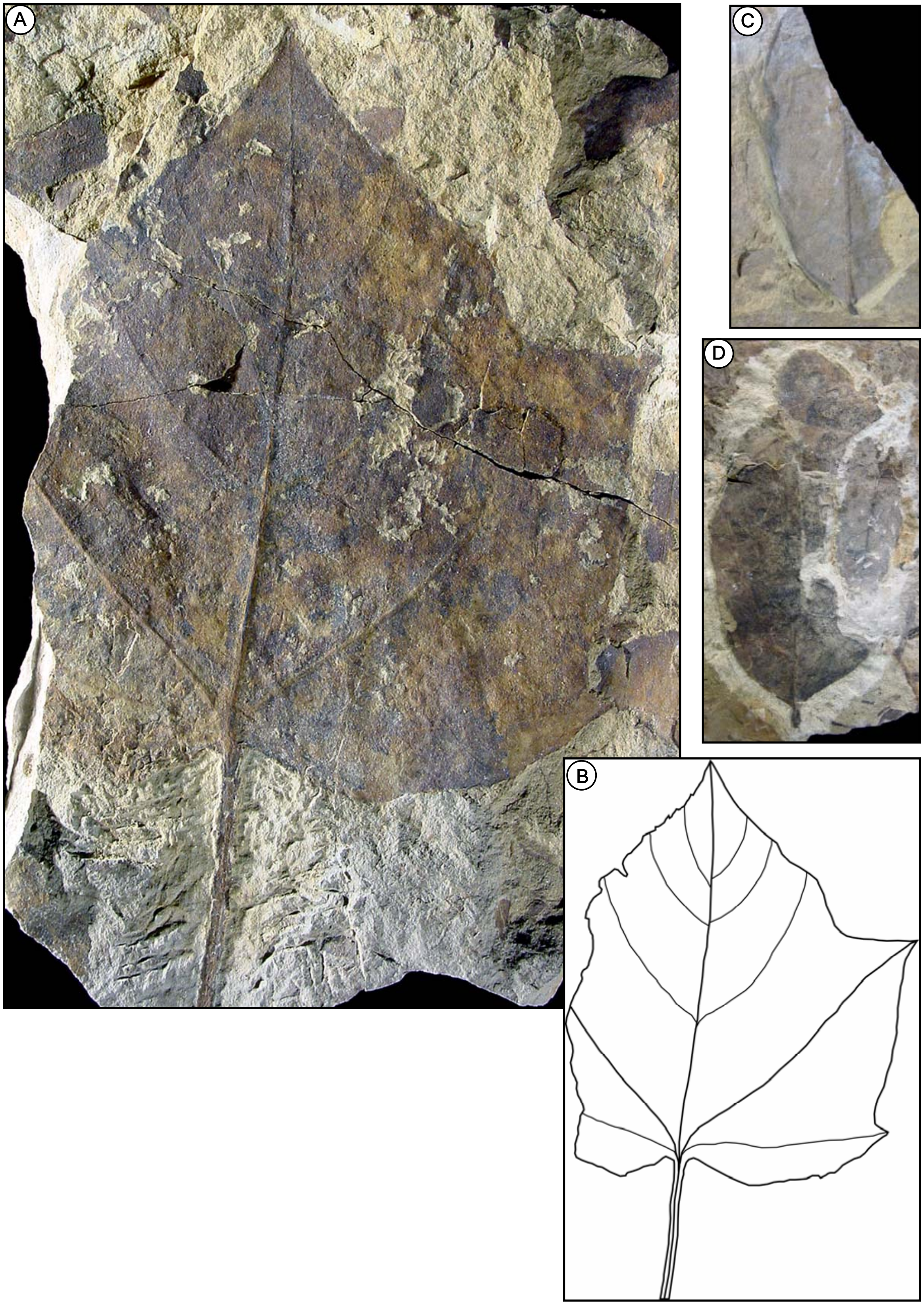


Figure 22.

Figure 23. *Grewiopsis, Negundo, ?Lomatites, ?Acer*. **A-B.** cf. *Grewiopsis,* BYUPB 1251. **C-D.** Unidentified leaf, BYUPB 1374. **E-F.** cf. *Negundo fremontensis* Berry, BYUPB 1316. **G-I.** Unidentified leaf, BYUPB 1405. **J-K.** (?*Lomatites*), BYUPB 1256. **L-M.** (?*Acer*), BYUPB 1245.

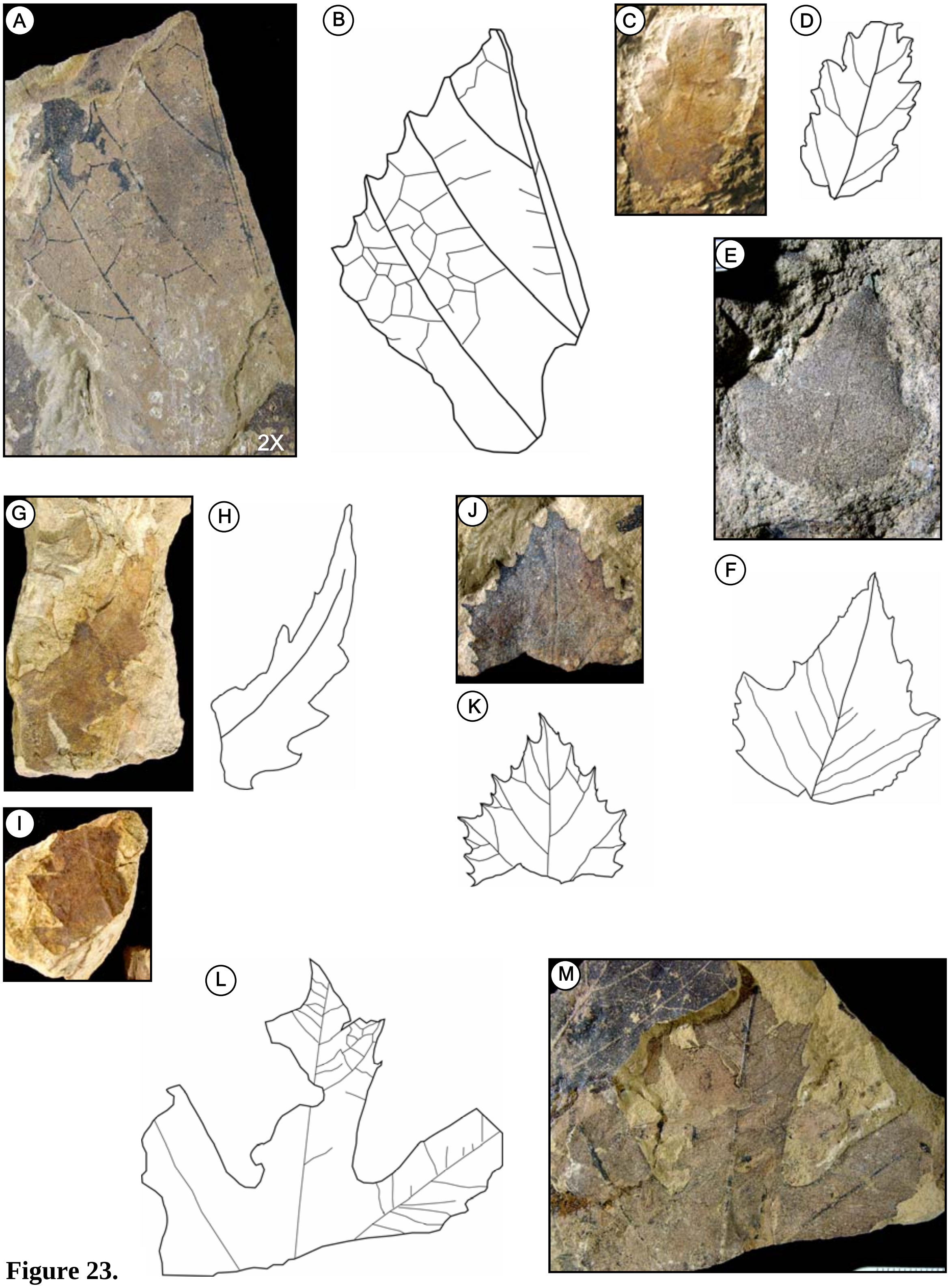


Figure 23.

Figure 24. Dicotyledon wood. **A.** Transverse section showing vessel distribution of an unidentified dicotyledon, BYUPB 1479. x20. **B.** Cross sectional view of a line of parenchyma cells, BYUPB 1479. x200. **C.** Unidentified dicotyledon in transverse view, BYUPB 1481. x20. **D.** Miltseriate rays in tangential view, BYUPB 1481. x100. **E.** Broad and narrow rays in secondary xylem with the widening of the rays in late wood development, cf. *Plataninium haydenii* (Felix) Wheeler, Scott, and Barghoorn, BYUPB 1480. x20. **F.** Tangential section through the same specimen showing the broad and the narrow rays, BYUPB 1480. x20. Note that the rays are arranged in an aggregate fashion with few to none imperforate tracheary elements to divide them. The arrow points towards the junction of two rays where imperforate tracheary elements are missing.

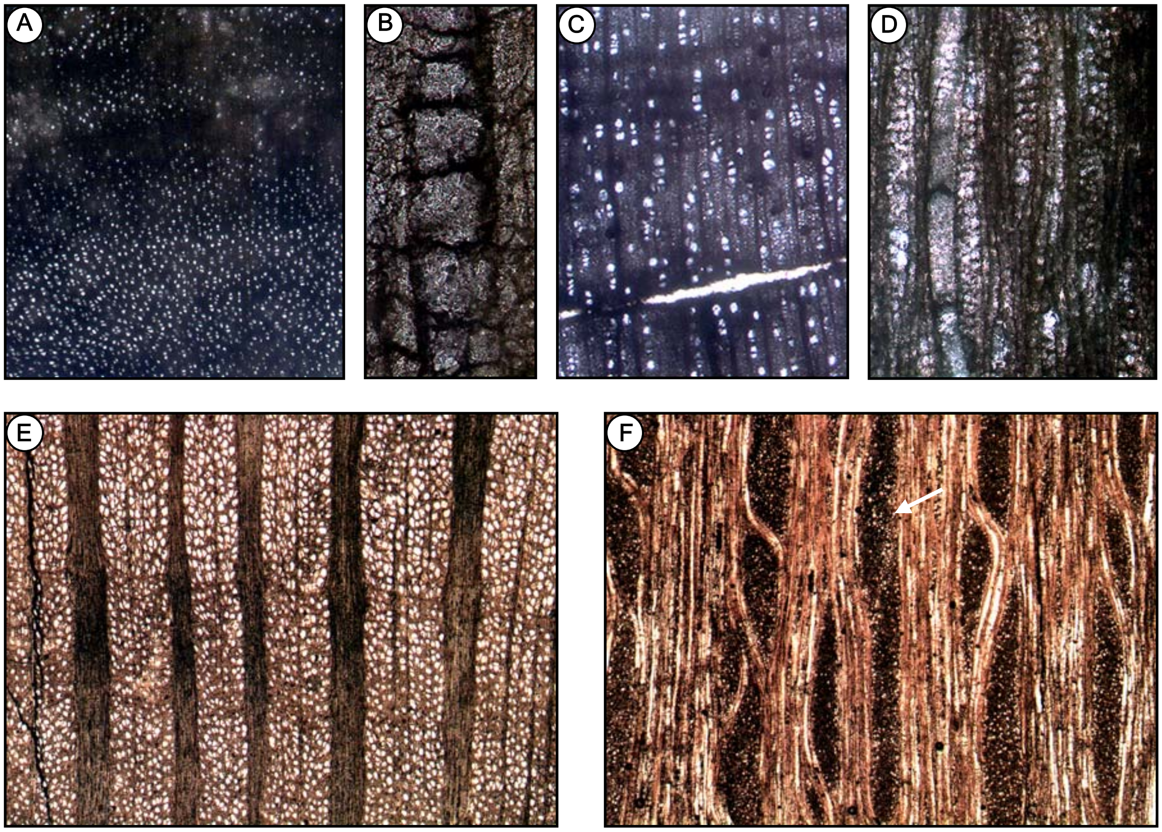


Figure 24.

Figure 25. Uinta Formation *Palmoxylon*. **A.** Transverse section though the central zone showing the close proximity of vascular bundles and the well-defined fibrous bundles, BYPB 1482. Note absence of preserved ground parenchyma. x20. **B.** Typical vascular bundle from the central zone, BYPB 1482. The linear void beneath the bundle cap outlines the medial sinus, showing the location of the non-preserved phloem. x100. **C.** Longitudinal view of a scalariform perforation plate and scalariform thickening on smaller vessel element, BYPB 1483. x100. **D.** Fibrous bundle with prominent stegmata, BYPB 1482. x200. **E.** View shows the distribution of vascular and fibrous bundles from the central zone, BYPB 1483. x20. **F.** Deformed scalariform thickening, BYPB 1483. x100. **G.** Vascular bundle surrounded by fibrous bundles, BYPB 1483. x100.

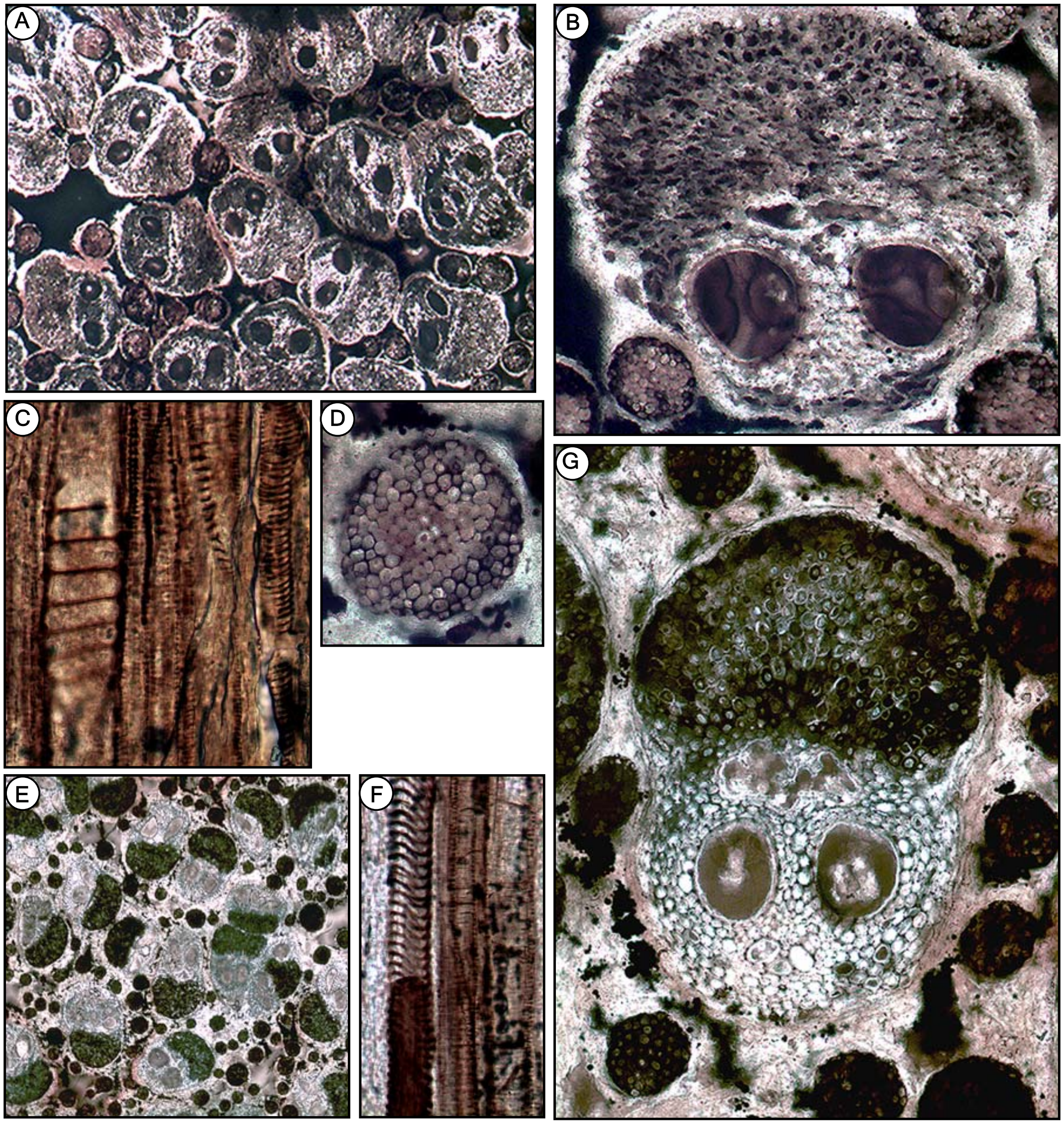


Figure 25.

Figure 26. Uinta Formation *Palmoxylon*. **A.** Orientation and distribution of vascular bundles in subdermal zone (left) and the central zone (right), BYUPB 1485. x20. **B.** Typical vascular bundle in the central zone, BYUPB 1485. x100. **C.** Vascular bundle from the subdermal zone, BYUPB 1485. x100. **D.** Transectional view of the central zone showing the randomly oriented vascular bundles, BYUPB 1484. x20. **E.** Vascular bundle displaying layers of tabular parenchyma, BYUPB 1484. x100. **F.** Longitudinal section showing scalariform wall thickening, BYUPB 1485. x200. **G.** Vessel elements showing joining perforation plates, BYUPB 1484. x100. **H.** Scalariform perforation plate of a vessel in longitudinal view, BYUPB 1484. x100. **I.** Scalariform thickenings on vessel wall, BYUPB 1484. x100.

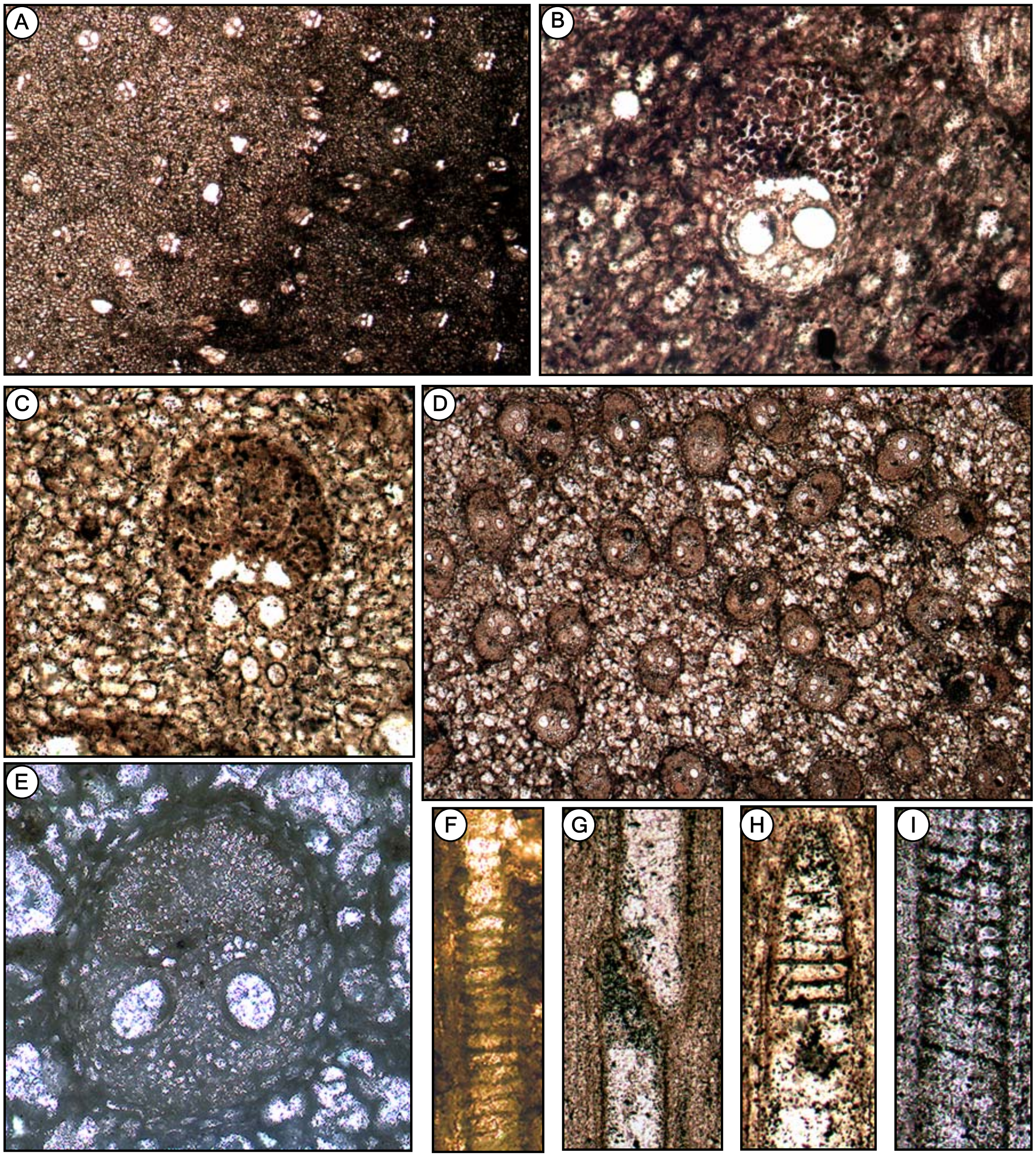


Figure 26.

Table 1. Geologic time table and Uinta Basin stratigraphy. (Magnetostratigraphic data after Prothero, 1996; stratigraphy modified from Jones, 1957 and MacGinitie, 1969; terminology after Ray et al., 1956, and Andersen and Picard, 1972.)

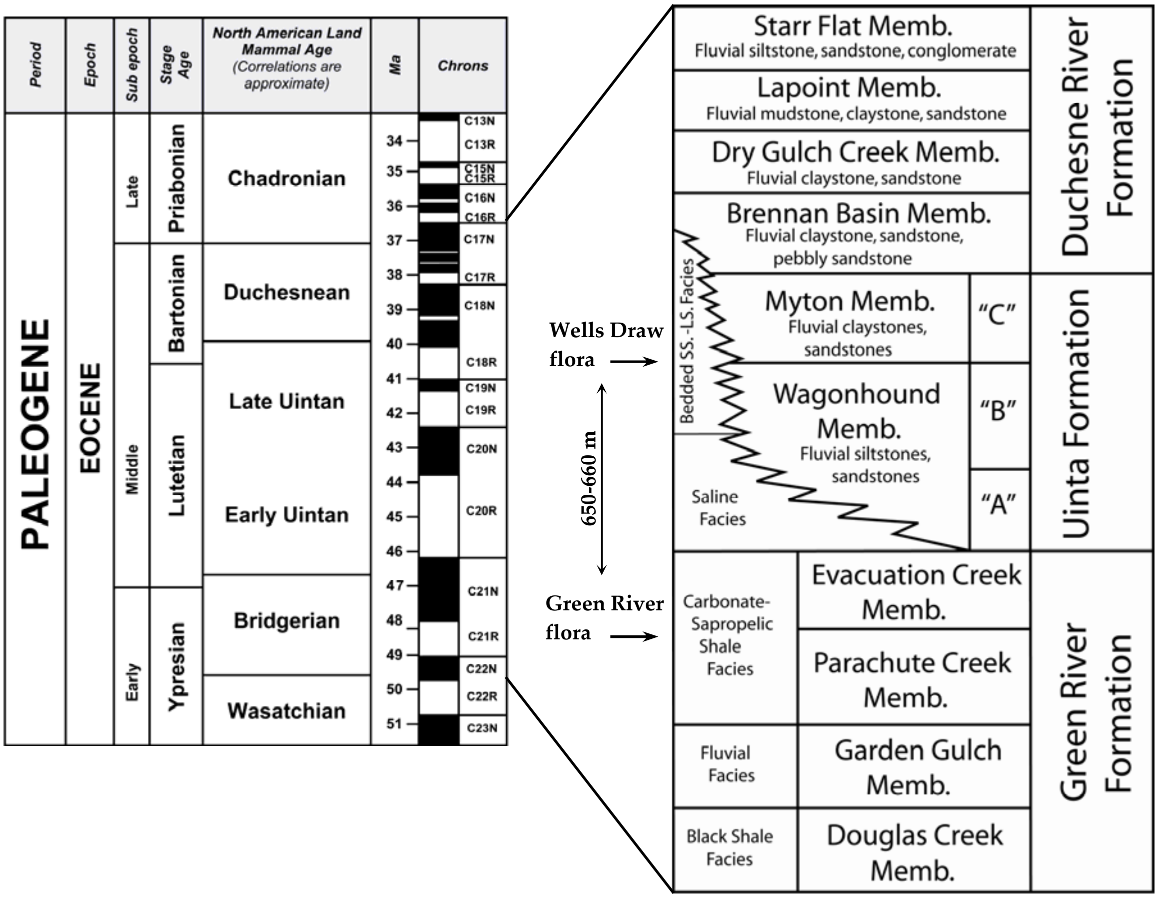

Period
Epoch
Sub epoch
Stage Age
North American Land Mammal Age (Correlations are approximate)
Ma
Chrons
PALEOGENE
EOCENE
Late
Middle
Early
Priabonian
Bartonian
Lutetian
Ypresian
Chadronian
Duchesnean
Late Uintan
Early Uintan
Bridgerian
Wasatchian
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
C13N
C13R
C15N
C15R
C16N
C16R
C17N
C17R
C18N
C18R
C19N
C19R
C20N
C20R
C21N
C21R
C22N
C22R
C23N
Starr Flat Memb.
Fluvial siltstone, sandstone, conglomerate
Lapoint Memb.
Fluvial mudstone, claystone, sandstone
Dry Gulch Creek Memb.
Fluvial claystone, sandstone
Brennan Basin Memb.
Fluvial claystone, sandstone, pebbly sandstone
Duchesne River Formation
Bedded SS.-LS. Facies
Myton Memb.
Fluvial claystones, sandstones
"C"
Wagonhound Memb.
Fluvial siltstones, sandstones
"B"
"A"
Saline Facies
Uinta Formation
Wells Draw flora
650-660 m
Green River flora
Carbonate-Sapropelic Shale Facies
Evacuation Creek Memb.
Parachute Creek Memb.
Fluvial Facies
Garden Gulch Memb.
Black Shale Facies
Douglas Creek Memb.
Green River Formation

Table 1.

Table 2. Ichnotaxa. Well drained soils (low water table); fluctuating soil moisture and water table levels; high soil moisture or water table (at or above ground). Environmental and climatic data based on Hasiotis (2002).

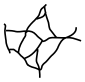
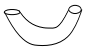
Ichnotaxonomy	Trace		Trace-maker	Environmental and climatic setting																		
				Wet ⟷ Dry																		
				Shallow lacustrine	Palustrine	Marginal lacustrine	Proximal alluvial	Distal alluvial	Paleosol	Interdune	Dune	Well drained	Fluctuating	High	Tropical	Subtropical	Temperate	Cold temperate		Humid	Semiarid	Arid
Cf. *Planolites* & *Ancorichnus*	burrows		beetles			x	x	x	x											x	x	x
Cochlichnus	trails		nematodes, annelids	x	x	x	x						x	x	x	x	x	x	x	x	x	x
Haplotichnus	trails		insect larvae	x	x	x	x						x	x	x	x	x					
Ants nest	chambers, galleries		ants			x	x	x	x	x		x	x		x	x	x	x	x	x	x	x
Steinichnus	burrows		mud-loving beetle, or mole cricket		x	x	x						x		x	x	x	x	x	x	x	
Tekonargus	cases		larvae of caddisflies	x	x	x	x	x					x		x	x	x		x	x	x	
Edaphichnium	tubes		earthworms			x	x	x	x				x	x	x	x	x		x	x	x	
Arenicolites	U-shaped tubes		insect larvae (chironamids, or mayflies)	x	x	x	x	x					x		x	x	x	x	x	x	x	
Scolica	trails		snails	x	x	x	x	x				x	x		x	x	x	x	x	x	x	x
Cocoons	casts		wasps			x	x	x	x	x	x	x			x	x	x	x	x	x	x	x
Roots	traces		shrubs, trees	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x
Tracks	molds/ casts		birds, mammals	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x
			Totals	7	8	12	12	9	6	4	2	5	10	4	11	11	11	8	10	11	11	7

Table 2.

Table 3. Invertebrates. Typical habitats are listed for each genus. Classification after Hanley (1974) and Scott (1961)

Class	Family	Genus/Species	Environmental Indication
Bivalvia	Unionidae	*Plesielliptia sp.*	fluvial and lacustrine setting
	Pisidiidae	*Sphaerium sp.*	fluvial and lacustrine setting
Gastropoda	Pleuroceridae	*Goniobasis tenera* Hall	offshore or shoreline lake settings
	Physidae	*Physa longiuscula* Meek and Hayden	poorly drained lowlands around lake margins
	Planorbidae	*Biomphalaria storchi* Russell	poorly drained lowlands around lake margins
		Biomphalaria Pseudoammonius Schlotheim	poorly drained lowlands around lake margins
Ostracoda	Cypridinae	?*Hemicyprinotus* W*atsonensis* Swain	varied, still to running water, streams, ponds, and lakes

Table 3.

Table 4. Vertebrate faunal list. Late Middle Eocene Uinta Formation taxa recently found south and southwest of Myton, Utah in the Uinta Basin. (Classification after Gunnell and Bartels, 1999.)

- OSTEICHTHYES
  - Lepisosteiformes
    - Lepisosteidae
      - *Lepisosteus cuneatus* Cope, 1877
  - Amiiformes
    - Amiidae
      - *Amia ?pattersoni* Grande and Bemis, 1998
- AMPHIBIA
  - Anura
    - ? Pelodytidae
- REPTILIA
  - Chelonia
    - Baenidae
      - *Baena arenosa* Leidy, 1870
      - *Chisternon undatum* Leidy, 1871
    - Carrettochelyidae
      - *Pseudoanosteiria pulchra* Clark, 1932
    - Trionychidae
      - *Apalone sp.*
    - Bataguridae
      - *Echmatemys callopyge* Hay, 1908
      - *Echmatemys uintensis* Hay, 1908
    - Testudinidae
      - *Xerobates uintensis* Gilmore, 1916
      - *Hadrianus sp.*
  - Squamata
    - Varanidae
      - *Saniwa cf. ensidens* Leidy, 1870
  - Crocodylia
    - Crocodylidae
      - *Crocodylus affinis*
      - *Borealosuchus wilsoni* Mook (Brochu), 1997
- MAMMALIA
  - Carnivora
    - ?Miacidae
  - Artiodactyla
    - Agriochoeridae
      - *Protoreodon pumilus* Marsh, 1875
      - *Protoreodon petersoni* Gazin, 1955
    - Protoceratidae
      - *Leptotragulus sp.*
    - Camelidae
      - ?*Poebrodon kayi* Gazin, 1955
  - Perissodactyla
    - Equidae
      - *Epihippus sp.*
    - Rhinoceroyoidea
      - *Hyrachyus*
    - Hyracodontidae
      - *Triplopus*
    - Brontotheriidae
      - *Dolichorinus sp.*
      - *Diplacodon sp.*
      - *?Metarhinus*
      - *Protitanotherium ?emarginatum* Hatcher, 1895
  - Rodentia
    - Paramyidae
      - ?*Mytonomys robustus* Peterson, 1919

Table 4.

Table 5. Turtle diversity. Turtle specimens collected from the Uinta Formation south of the Myton, Utah.

Taxa	# and % of individual’s collected	
	family	genus
Baenidae	11(11%)	
Baena sp.		7(7%)
Baena arenosa		3(3%)
Chisternon undatum		1(1%)
Carettochelyidae	1(1%)	
Pseudoanosteiria pulchra		1(1%)
Trionychidae	29(28%)	
Apalone sp.		29(28%)
Bataguridae	56(55%)	
Echmatemys sp.		41(40%)
Echmatemys callopyge		9(9%)
Echmatemys uintensis		6(6%)
Tesudinidae	5(5%)	
Xerobates uintensis		1(1%)
Hadrianus sp.		4(4%)
TOTAL	**102**	

Table 5.

Table 6. Pathologies and taphonomic markers. Note that more than one pathology or taphonomic marker can occur on a single individual. For examples of various pathologies and/or taphonomic marks, see Figure 9. Terminology after Hutchison and Frye (2001).

Taxa	(# and % of individuals)	Pathologies/Taphonomic markers						
		Bites	Harvesting	Rot	Track Injuries	Type I Pitting	Type II Pitting	Type III Pitting
Baena sp.	(7)$_{11\%}$					1		
Baena arenosa	(3)$_{4\%}$		1		1	1		1
Echmatemys sp.	(41)$_{62\%}$				2	1	14	1
Echmatemys callopyge	(6)$_{9\%}$		1	1		1	5	3
Echmatemys uintensis	(9)$_{14\%}$	1			1	3	2	2
Totals	66 individuals 43 pathologies	(1)$_{2\%}$	(2)$_{5\%}$	(1)$_{2\%}$	(4)$_{9\%}$	(7)$_{16\%}$	(21)$_{49\%}$	(7)$_{16\%}$

Table 6.

Table 7. Floral list. Organs: **A**, axis/wood; **C**, cone; **Ca**, calyx; **F**, foliage. Habitat: **Nc**, Northwest California; **Sa-Nch**, Southern Arizona- Northwestern Chihuahua; **Sap**, Southern Appalachians; **Esmm**, Eastern Sierra Madre, Mexico; **Nar**, Northwestern Argentina; **Sc-j**, Southern China-Japan; and **Ct**, Central Texas. (Modified after Wilf et al., 1998, and MacGinitie, 1969)

Taxon	Organs	Similar Living Species	Habitat
Sphenophyta			
EQUISETALES			
Equisetum tipperarense Berry	A		
Equisetum winchesteri Brown	A	*Equisetum giganteum* Lesquere	Nar
Coniferophyta			
Coniferales			
PINACEAE			
Pinus sp.	C		
Angiospermophyta			
Monocotyledonae			
TYPHACEAE			
Typha lesquereuxi Cockerell	A	*Typha latifolia* Linne	Sap, Esmm
PALMAE			
Phoenictie	F		
Palmoxylon sp.	A		
Dicotyledonae			
SALICACEAE			
Populus cinnamomoide (Lesquereux) MacGinitie	F	*Populus angustifolia* Rydberg	Sa-Nch
Populus wilmattae Cockerell	F	*Populus dimorpha* Brandegee	Sa-Nch
Salix cockerelli Brown	F	*Salix nigra* Marshall	Esmm, Nar
Salix coloradica MacGinitie	F	*Salix bonplandiana, nigra*	Sa-Nch,Ct
Salix longiacuminata Knowlton	F	*Salix fluviatilis* Standley	Sc-j
JUGLANDACEAE			
Engelhardtia uintaeensis MacGinite	F	*Engelhardtia guatemalensis* Standley	Esmm
FAGACEAE			
Quercus cuneatus MacGinitie	F		
Castanea dolichophylla Cockerell	F	*Castanea esquinii, henryi*	Sc-j
ULMACEAE			
Cedrelospermum nervosum (Newberry) Manchester	F	*Zelkova serrata* Makino	Sc-j
BERBERIDACEAE			
Mahonia marginata (Lesquereux) Arnold	F	*Mahonia beali* Carriere	Sc-j
LAURACEAE			
Ocotea coloradensis (Brown) LaMotte	F	*Phoebe mexicana* Meissner	Esmm
PLATANACEAE			
Macginitiea wyomingens (Knowlton and Cockerell) Manchester	A, F, Ca	*Platanus racemosa* Nuttall	Nc
ROSACEAE			
Rosa hilliae Lesquereux	F	*Rosa palustris*	Sap
LEGUMINOSAE			
Casalpinites falcate MacGinitie	F	*Albizzia lebbeck* (Linne) Bentham	Esmm
Gymnocladus hesperia (Brown) MacGinitie	F	*Gymnocladus dioicus* (Linne) K. Kunth	Sap
Parvileguminophyllum sp.	F	*Cassia spectabilis* de Candolle	Esmm
Robinia lesquereuxi (Ettingshausen) MacGinitie	F	*Robinia pseudoacacia, neomexicana*	Sap, Ct
Swartzia wardellii MacGinitie	F		
BURSERACEAE			
Bursera inaequalateralis (Lesquereux) MacGinitie	F	*Bursera tomentosa* (Jacquin) Triana & Planchon	Esmm
MELIACEA			
Cedrela lancifolia (Lesquereux) Brown	F	*Cedrela chinensis, mexicana*	Sc-j
ANACARDIACEAE			
Rhus nigricans (Lesquereux) Knowlton	F	*Rhus typhina* Torner	Sap
ACERACEAE			
Negundo fremontensis Berry	F		
SAPINDACEAE			
Cardiospermum coloradensis	F	*Cardiospermum microcarpum*	Sa-Nch
Sapindus coloradensis Cockerell	F		
Allophylus flexifolia (Lesquereux) MacGinitie	F	*Allophylus rasemosus* (Linne) Radlkofer	Nar
RHAMNACEAE			
Rhamnus	F		
VITACEA			
Vitis sp.	F		
TILIACEAE			
Grewiopsis	F		
Triumfetta ovata MacGinitie	F		
MYRTACEAE			
Eugenia americana (Lesquereux) MacGinitie	F	*Eugenia (Jambos) jambos* Linne	Sc-j
OLEACEAE			
Osmanthus praemissa (Lesquereux) Cockerell	F	*Osmenthus americanus* Bentham & Hooker	Sap

Table 7.

Table 8. Preferred habitats. **Group 1**, vegetation favoring marginal lacustrine, pluvial, floodplains and swampy areas, high water tables. **Group 2**, vegetation inclined to hills, terraces, alluvial fans and south-facing slopes in area up to 610 m. (2,000 ft.) above lake level. **Group 3**, plants inhabiting elevation 457-1219 m. (1,500-4,000 ft.) above lake level along tributaries and larger streams adapted to live in mesic conditions. (Adapted from MacGinitie, 1969)

Taxon	Preferred Habitat		
	Group 1	Group 2	Group 3
Equisetum tipperarense	X		
Equisetum winchesteri	X		
Pinus sp.		X	
Typha lesquereuxi	X		
Populus cinnamomoide	X		
Populus wilmattae	X		
Salix cockerelli	X		
Salix coloradica	X		
Salix longiacuminata	X		
Engelhardtia uintaeensis			X
Quercus cuneatus		X	
Castanea dolichophylla		X	
Cedrelospermum nervosum	X		
Mahonia marginata		X	
Ocotea coloradensis	X		
Macginitiea wyomingens	X		
Casalpinites falcate		X	
Gymnocladus hesperia	X		
Parvileguminophyllum	X		
Swartzia wardellii	X		
Bursera inaequalateralis		X	
Rhus nigricans	X		
Negundo fremontensis			X
Cardiospermum coloradensis	X		
Sapindus coloradensis	X		
Allophylus flexifolia	X		
Eugenia americana	X		
Osmanthus praemissa	X		
Totals	20	6	2

Table 8.

Table 9. *Palmoxylon* diagnostic features. Species of *Palmoxylon* from Utah and Wyoming (**CZ**, central zone; **SDZ**, subdermal zone; **SD**, dermal zone). Four newly discovered specimens appear at the bottom of the table. (Modified from Nambudiri and Tidwell 1998)

Species	Fibrous bundle density (no/cm^2)	Fibrous bundle size (µm) diameter	Vascular bundle density (no/cm^2)	Vascular bundle size (µm)	Stenzel's class	f/v ratio	Stegmata	Median sinus	Vessels
Palmoxylon edenense	CZ: 350	Numerous, CZ: 52-104	CZ: 85	CZ: 700-900× 500-600	Reniformia	CZ: 3×5:1 to 3:1	Absent	Shallow	Bivascular, MX 78-91 µm in CZ
			SDZ: 100	SDZ: 600-700× 400-500		SDZ: 5:1			
			DZ: 250	DZ: 600-800× 280-470		DZ: 7:1			50 µm in DZ PX CZ: 25-35 µm
Palmoxylon colei	CZ: 290	CZ: 78-120	CZ: 115	CZ: 500-600× 500-600	Reniformia	CZ: 2×5:1 to 3:1	Present	Slightly indented	Bivascular, in SDZ and DZ rarely trivascular MX in CZ-65 85 µm SDZ/MX 75 µm DZ/ MZ: 52 µm PZ/CZ 30-40 µm
			SDZ: 160	SDZ: 600-750× 500-650	Some bundles in SDZ are sagitate	SDZ: 6:1			
Palmoxylon contortum	Not known	Numerous sclerotic bundles, CZ: 40-50	CZ: 350	CZ: 320-400× 300-500	Not known	CZ: 1:1 to 1:1×5	Absent	Present	Bivascular, MX 55µm
Palmoxylon gustavsonii	Not known	Numerous, CZ:150-250	CZ: 67	CZ: 800-950× 750	Reniformia	CZ: 1:1, 1×5:1 or 1:1×2	Absent	Shallow	Bivascular, occasionally trivascular MZ 155-200 µm
			SDZ: 84	SDZ: 1250× 1000		SDZ: 1:2, rarely 1:1			
Palmoxylon macginitiei	Not known	Numerous	CZ: 104	CZ: 450-500× 600-700	Reniformia	CZ: 1×5:1 to 2×1:1	Absent	Shallow concave	Bivascular, sometime 3 or 1 to 2 metaxylem vessels MZ/ CZ: 29-47 µm MX/SDZ MX/ DZ: 52-70 µm
			SDZ: 140	SDZ-SD: 600× 420		SDZ: 3×1:1			
Palmoxylon hebbertii	CZ: 40	Numerous, CZ: 129-370	CZ: 22	CZ: 925×815	Reniformia	CZ: 1×8:1 to 2×3:1	Absent	Shallow to absent	Bivascular with 2 metaxylem and 3-7 protoxylem vessels CZ: 50-92 µm
	SDZ: 10		SDZ: 14	SDZ: 470×765		SDZ: 2×4:1			
Palmoxylon simperi	CZ: 132	CZ: 60-190	CZ: 53	CZ: 120-200× 740-930	Reniformia	CZ: 2×5:1	Absent	Rounded to angular	Bivascular, sometimes 3 or 4 metaxylem (1000 µm long)
Palmoxylon pristina	Not known	CZ: 40-59	CZ: 63	CZ: 600-800× 450-680	Reniformia	CZ: 1×7:1 to 2×7:1	Absent	Very Shallow	Bivascular, occasionally 3 metaxylem, 3-5 protoxylem
Palmoxylon BYUPB 1482	CZ: 193	CZ: 107-281	CZ: 134	CZ: 570-855× 300-825	Reniformia	CZ: 1:1×1	Present	Shallow to absent	Bi and trivascular with 4-7 uncommon, CZ: 106-194µm
Palmoxylon BYUPB 1483	CZ: 441	CZ: 87-204	CZ: 99	CZ: 525-1000× 390-650	Reniformia	CZ: 1:1×2 to 1:1	Absent	Shallow	Bi and trivascular with 4-6 uncommon, CZ: 136-291× 58-203 µm
Palmoxylon BYUPB 1484	Not known	CZ: 39-87	CZ: 82	CZ: 450-1000× 260-470	Reniformia	CZ: 1:1×6 to 1:1×2	Absent	Shallow to absent	Bivascular, trivascular uncommon CZ: 68-146 µm
Palmoxylon BYUPB 1485	Not known	CZ: 29-78	CZ: 220	CZ: 290-760× 290-515	Reniformia	CZ: 1:1 to 1×4:1	Absent	Shallow	Bivascular, 3-4 vessels CZ: 59-107 µm
		SDZ: 39-78	SDZ: 275	SDZ: 310-560× 195-400		SDZ: 1:1×1 to 1×4: 1			SDZ: 49-107 µm

Table 9. *continued*

Species	Auricular sinus	Auricular lobe	Ground general parenchyma	Tabular parenchyma	Radiating parenchyma	Locality	Horizon	Authors
Palmoxylon edenense	Shallow or absent	Rounded	Elongated and compact parenchyma cells	One or two layers around bundle sheath	Around the vascular tissues	Eden Valley, Wyoming	Green River Formation (Eocene)	Tidwell et al. (1973)
Palmoxylon colei	Shallow or absent	Rounded	Thin-walled compact parenchyma cells	One or two layers of tabular parenchyma around bundle sheath	Radiating parenchyma around the vascular tissues	Eden Valley, Wyoming	Green River Formation (Eocene)	Tidwell et al. (1973)
Palmoxylon contortum	Shallow or absent	Rounded	Compact, thin-walled columnar parenchyma	Tabular parenchyma around the bundle sheath	Absent	Eden Valley, Wyoming	Green River Formation (Eocene)	Tidwell et al. (1973)
Palmoxylon gustavsonii	Absent	Rounded	Thin-walled compact isodiametric cells lacking lacunae	Encasing the bundle sheath as well as the vascular tissues	Absent	Redmond, Utah	Dipping Vat Formation (Eocene)	Tidwell et al. (1972)
Palmoxylon macginitiei	Unknown	Rounded	Compact parenchyma	Tabular parenchyma around the bundle sheath	Around the vascular tissues	Eden Valley, Wyoming	Green River Formation (Eocene)	Tidwell et al. (1971, 1972)
Palmoxylon hebbertii	Rounded to a point	Rounded	SDZ: Compact, radially expanded, lacuna small or absent	Tabular and radiating parenchyma around the bundles in SDZ	Around the vascular bundles only in SDZ	Dog Valley, Utah	Golden Ranch Formation (Oligocene)	Nambudiri and Tidwell (1998)
Palmoxylon simperi	Prominent	Rounded	Compact, thin-walled radially expanded with small, narrow longitudinal lacunae ensheathed among parenchyma cells	Unknown	Around the vascular bundles	Redmond, Utah	Dipping Vat Formation (Eocene)	Tidwell et al. (1970)
Palmoxylon pristina	Absent	Rounded	Compact, thin walled, non-expanded	Tabular sheath around bundles	Unknown	Redmond, Utah	Dipping Vat Formation (Eocene)	Tidwell et al. (1970)
Palmoxylon BYUPB 1482	Rounded to a point	Sub-angular	Absent	Two or three layers around bundle sheath and vascular tissue	Absent	Uinta Basin, Utah Sec. 26, T 8 S, R 17 E.	Uinta Formation "Uinta C" (Eocene)	This paper
Palmoxylon BYUPB 1483	Absent	Rounded	Thin-walled compact parenchyma	Three layers around bundle sheath and vascular tissue, 2 layers are uncommon around vascular tissue	Absent	Uinta Basin, Utah Sec. 26, T 8 S, R 17 E.	Uinta Formation "Uinta C" (Eocene)	This paper
Palmoxylon BYUPB 1484	Shallow to absent	Rounded	Irregular to columnar elongate parenchyma	Two to five layers around the bundle sheaths and vascular tissue	Absent	Uinta Basin, Utah Sec 17, T 10 S, R 24 E.	Uinta Formation "Uinta A" (Eocene)	This paper
Palmoxylon BYUPB 1485	Absent	Rounded	Thick to thin-walled columnar parenchyma	? 1-2 layers of tabular parenchyma around the whole vascular bundle	Absent	Uinta Basin, Utah T10 S, R 24 E.	Uinta Formation "Uinta A" (Eocene)	This paper

Table 9. *continued*

Species	Auricular sinus	Auricular lobe	Ground general parenchyma	Tabular parenchyma	Radiating parenchyma	Locality	Horizon	Authors
Palmoxylon edenense	Shallow or absent	Rounded	Elongated and compact parenchyma cells	One or two layers around bundle sheath	Around the vascular tissues	Eden Valley, Wyoming	Green River Formation (Eocene)	Tidwell et al. (1973)
Palmoxylon colei	Shallow or absent	Rounded	Thin-walled compact parenchyma cells	One or two layers of tabular parenchyma around bundle sheath	Radiating parenchyma around the vascular tissues	Eden Valley, Wyoming	Green River Formation (Eocene)	Tidwell et al. (1973)
Palmoxylon contortum	Shallow or absent	Rounded	Compact, thin-walled columnar parenchyma	Tabular parenchyma around the bundle sheath	Absent	Eden Valley, Wyoming	Green River Formation (Eocene)	Tidwell et al. (1973)
Palmoxylon gustavsonii	Absent	Rounded	Thin-walled compact isodiametric cells lacking lacunae	Encasing the bundle sheath as well as the vascular tissues	Absent	Redmond, Utah	Dipping Vat Formation (Eocene)	Tidwell et al. (1972)
Palmoxylon macginitiei	Unknown	Rounded	Compact parenchyma	Tabular parenchyma around the bundle sheath	Around the vascular tissues	Eden Valley, Wyoming	Green River Formation (Eocene)	Tidwell et al. (1971, 1972)
Palmoxylon hebbertii	Rounded to a point	Rounded	SDZ: Compact, radially expanded, lacuna small or absent	Tabular and radiating parenchyma around the bundles in SDZ	Around the vascular bundles only in SDZ	Dog Valley, Utah	Golden Ranch Formation (Oligocene)	Nambudiri and Tidwell (1998)
Palmoxylon simperi	Prominent	Rounded	Compact, thin-walled radially expanded with small, narrow longitudinal lacunae ensheathed among parenchyma cells	Unknown	Around the vascular bundles	Redmond, Utah	Dipping Vat Formation (Eocene)	Tidwell et al. (1970)
Palmoxylon pristina	Absent	Rounded	Compact, thin walled, non-expanded	Tabular sheath around bundles	Unknown	Redmond, Utah	Dipping Vat Formation (Eocene)	Tidwell et al. (1970)
Palmoxylon BYUPB 1482	Rounded to a point	Sub-angular	Absent	Two or three layers around bundle sheath and vascular tissue	Absent	Uinta Basin, Utah Sec. 26, T 8 S, R 17 E.	Uinta Formation "Uinta C" (Eocene)	This paper
Palmoxylon BYUPB 1483	Absent	Rounded	Thin-walled compact parenchyma	Three layers around bundle sheath and vascular tissue, 2 layers are uncommon around vascular tissue	Absent	Uinta Basin, Utah Sec. 26, T 8 S, R 17 E.	Uinta Formation "Uinta C" (Eocene)	This paper
Palmoxylon BYUPB 1484	Shallow to absent	Rounded	Irregular to columnar elongate parenchyma	Two to five layers around the bundle sheaths and vascular tissue	Absent	Uinta Basin, Utah Sec 17, T 10 S, R 24 E.	Uinta Formation "Uinta A" (Eocene)	This paper
Palmoxylon BYUPB 1485	Absent	Rounded	Thick to thin-walled columnar parenchyma	? 1-2 layers of tabular parenchyma around the whole vascular bundle	Absent	Uinta Basin, Utah T10 S, R 24 E.	Uinta Formation "Uinta A" (Eocene)	This paper