# New Late Cretaceous leaf locality from lower Kirtland Shale member, Bisti area, San Juan Basin, New Mexico

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# New Late Cretaceous leaf locality from lower Kirtland Shale member, Bisti area, San Juan Basin, New Mexico

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This preliminary report represents the first substantial paleobotanic study of new Fruitland or Kirtland plant fossils in more than 65 yrs. The florule is the most diverse one ever found in either the Fruitland or Kirtland, and it adds substantially to the list of taxa known from these formations. The Fruitland and Kirtland floras need more paleobotanic study; cooperation from the coal companies in the area will make this possible. More precise stratigraphic delineation of floras is needed in differentiating the two formations.

The area in and around Hunter Wash, near the site of the Bisti Trading Post, in west-central San Juan Basin, has been actively investigated by geologists and paleontologists for almost 70 yrs (for example, Bauer, 1917; Bauer and Reeside, 1921; Gilmore, 1917; Clemons, 1973; Hutchinson, 1981). Within the immediate region, rocks of the Lewis Shale (Late Cretaceous), Pictured Cliffs Sandstone, Fruitland Formation, and Kirtland Shale are exposed (table 1). The Bisti–Fruitland coal field, upon which this area lies, is estimated to contain 1,870 million metric tons of subbituminous, low-sulfur coal beneath less than 250 ft of overburden and is the greatest undeveloped reserve in the San Juan Basin (Shomaker, 1971). To better understand the stratigraphic record and depositional environments of the rocks containing these resources, detailed field investigations were made near the old Bisti Trading Post (Fig. 1). These involved stratigraphic sedimentologic and paleontological studies (Hunt and others, 1981). During the course of these investigations a new leaf locality was found in the Fruitland–Kirtland sequence.

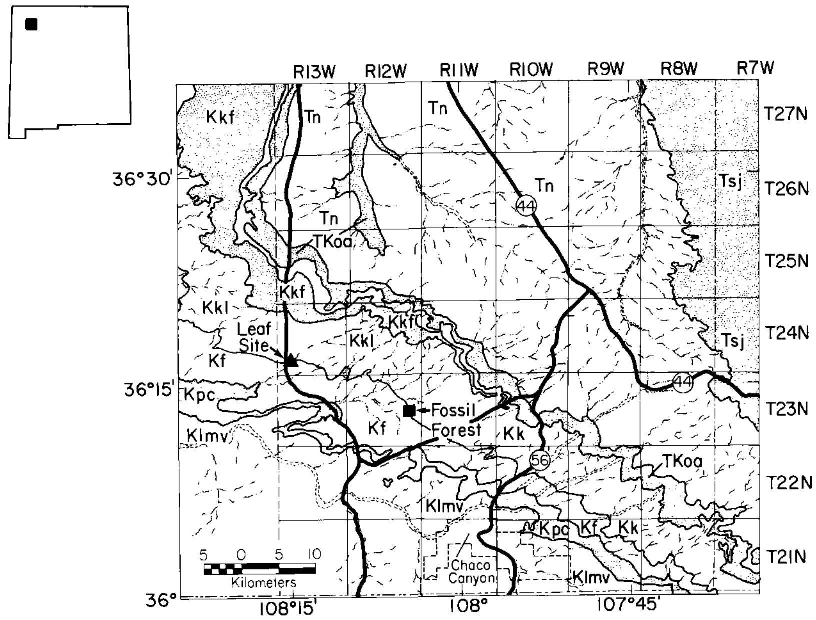


FIGURE 1—GEOLOGICAL MAP OF AREA IN VICINITY OF LEAF LOCALITY. Also shown is Fossil Forest, a fossiliferous area currently being studied by the authors and others. **Klmv,** Lewis Shale; **Kpc,** Pictured Cliffs Sandstone; **Kf,** Fruitland Formation; **Kk,** Kirtland Shale; **Kkl,** lower shale member of Kirtland Shale; **Kkf,** Farmington Sandstone Member of Kirtland Shale; **TKoa,** Ojo Alamo Sandstone; **Tn,** Nacimiento Formation; **Tsj,** San Jose Formation.

TABLE 1—UPPER CRETACEOUS (CAMPANIAN TO MAASTRICHTIAN) STRATIGRAPHIC UNITS IN AREA OF HUNTER WASH.

| Stratigraphic unit | Thickness | |
|---|---|---|
| Ojo Alamo Sandstone | 20 m | |
| Naashoibito Member | 20 m | |
| Upper shale member | 30 m | nonmarine |
| Kirtland Shale | | |
| Farmington Sandstone Member | 120 m | |
| Lower shale member | 250 m | |
| Fruitland Formation | 50 m | ———— |
| Pictured Cliffs Sandstone | 25 m | final marine |
| Lewis Shale | 20 m | regression from San Juan Basin |

## Geologic background

The Upper Cretaceous rocks of the Western Interior were deposited in or near an epeiric sea that extended from the Gulf of Mexico to the Arctic Ocean. This seaway, approximately 3,000 mi in length and 1,000 mi in width, divided the North American landmass into two large continental areas. The San Juan Basin lay on the western margin of the seaway and was intermittently inundated by the advances and retreats of the sea (Fassett and Hinds, 1971).

The Pictured Cliffs Sandstone represents delta-front and barrier beach deposits (Erpenbeck, 1979; Cumella, 1981) of the final retreat of the Campanian seaway from the region. Coal deposits of varying thickness and lateral extent and other organic-rich sediments were laid down in a variety of delta-plain and back-barrier environments (Erpenbeck, 1979). The upper portions of the Fruitland Formation and the overlying Kirtland Shale lack well-developed coal deposits that are present in the lower Fruitland. Preliminary analyses of Fruitland and Kirtland brackish and freshwater molluscan faunas indicate a progressive trend toward fresh-water environments. This trend implies increasing distance from the Pictured Cliffs shoreline (Hartman, 1981).

Both the Fruitland and Kirtland shale were named by Max Bauer in 1916 for exposures along the San Juan River in northwest San Juan County, New Mexico. Lindsay and others (1981) suggested that the Kirtland Shale be renamed the Kirtland Formation as Kirtland rocks are predominantly siltstones and not shales. The Fruitland Formation is dominantly composed of interbedded coals, sandstones, and shales. Three members of the Kirtland Shale are recognized: the lower shale member overlain by the Farmington Sandstone Member in turn overlain by the upper shale member (Bauer, 1917; Reeside, 1924). The contact between the lower shale member and the Fruitland Formation is imprecise although many boundaries have been suggested (Fassett and Hinds, 1971, p. 19). Lindsay and others (1981) suggest, rightly in our view, the presence of a transition zone between the uppermost Fruitland and lower Kirtland Shale. The leaf locality reported here is 8.2 m (27.1 ft) above the highest coal contact of O'Sullivan and others (1972) and Scott and others (1979) and 5.1 m (16.8 ft) below the top of a red-brown tabular sandstone, the boundary of Dane (1936) and Hutchison (1981). Pending more precise delineation of the boundary this locality is assigned to the lower shale member of the Kirtland Shale.

LOCALITY DESCRIPTION—The locality occurs in the SW¼NE¼ sec. 32, T. 24 N., R. 13 W. (Fig. 1) within a measured section of 19.37 m (63.9 ft) of channel sandstones and overbank deposits consisting of carbonaceous and noncarbonaceous mudstones and siltstones (appendix A; Fig. 2). The locality is just below the shoulder of a hill and has been protected from weathering by an overlying resistant siderite concretion. Although the mudstones are highly weathered where not covered by the concretion, the deposit seems to be a lens-shaped pocket that extends laterally about 3.5 m (11.6 ft).

TABLE 2—COMPOSITION OF FLORA.

Filicophyta (ferns)
  Polypodiaceae
    *Asplenium* sp.
    *Woodwardia* ? *crenata*
  Salviniaceae
    *Salvinia* sp.
Coniferophyta (conifers)
  Taxodiaceae
    *Sequoia cuneata*
Anthophyta (flowering plants)
  Monocotyledonae
    Cyperaceae
      *Cyperacties* sp.
  Dicotyledonae
    Salicaceae
      *Salix lancensis*
      *S.* sp. A
      *S.* sp. B
    Juglandaceae
      *Carya antiquorum*
    Fagaceae
      *Dryophyllum subfalcatum*
    Moraceae
      *Ficus baueri*?
      *F. crossii*
      *F. planicostata*
    Platanaceae
      *Platanus raynoldsii*
    Menispermaceae
      *Menispermites belli*
    Magnoliaceae
      *Magnolia cordifolia*
    Lauraceae
      *Laurophyllum coloradensis*
      *L. wardiana*
      *L. salicifolium*
    Leguminosae
      *Leguminosites*
    Rhamnaceae
      *Rhamnus* sp.
      *Zizyphus* sp.
    Vitaceae
      *Cissus marginata*
    Dilleniaceae
      *Dillenites cleburni*
    Myrtaceae
      *Myrtophyllum torreyi*
Taxonomic Position Uncertain
  *Carpites baueri*
  *C. lancensis*
  *C.* sp.
  *Ficus*? *trineruis*
  *Rhamnus minutus*
  unidentified influorescence

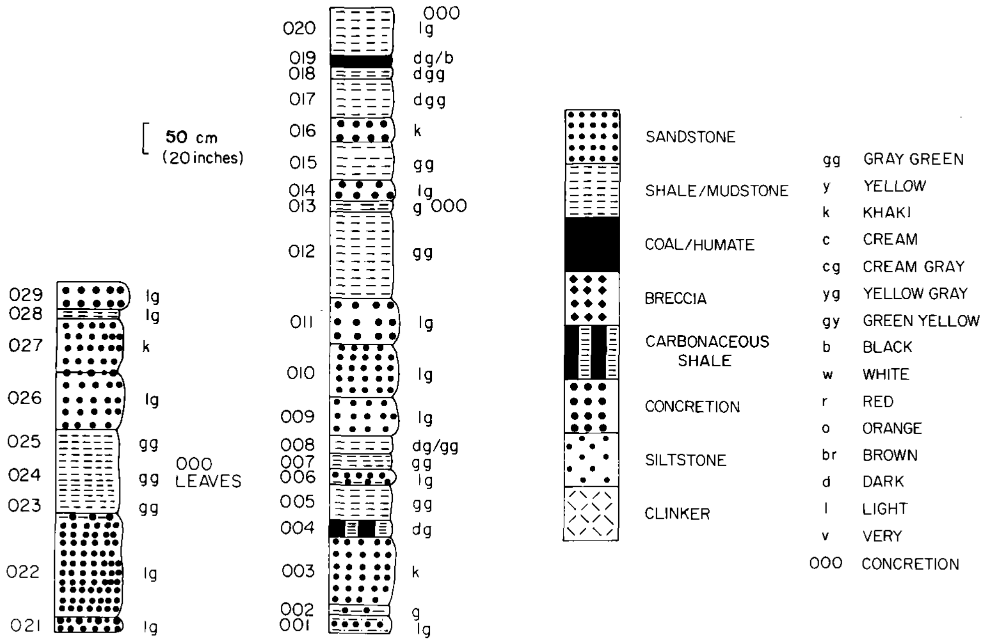


FIGURE 2—DIAGRAMMATIC REPRESENTATION OF MACROSTRATIGRAPHIC SECTION IN WHICH LEAF LOCALITY LIES.

Fossil leaves are preserved in light-brown compressions that vary in quality of preservation from fair to good. Rare, small, poorly preserved gastropods and bivalves are found in association with the leaves and these specimens will be studied by J. Hartman, University of Minnesota. The environment of deposition was a meandering stream that periodically flooded interchannel areas, creating transient swamps and ponds.

PREVIOUS STUDIES—Although the Fruitland Formation and, to a much lesser extent, the Kirtland Shale are rich in plant fossils, remarkably little paleobotanic work has been done. The only studies are by Knowlton (1917) and Lee (1917). Subsequent publications only have listed additional taxa (O'Sullivan and others, 1972; Kues and others, 1977; Tidwell and others, 1981). Based on published studies, Fruitland and Kirtland floras are inseparable. The new locality described below represents by far the largest sample of a local flora yet described.

**Floral composition**

The plant taxa identified are listed in table 2. Only a few ferns occur in Fruitland–Kirtland floras (Tidwell and others, 1981), and the florule discussed here contains only three genera: *Asplenium, Woodwardia,* and *Salvinia. Salvinia* (plate 1, fig. 1; all further references to plate figures will be made by the notation fig. and the number) is interesting because it is an aquatic, floating fern that requires open water.

The only conifer in the florule is *Sequoia cuneata,* which bears short, lancelike leaves on young branches and scalelike leaves on older branches. *Sequoia cuneata* is thought to have been a dominant element of late Cretaceous peat swamps in the Rocky Mountain region (Parker, 1976). This florule is severely impoverished in conifers, which represent only 3.2% of the assemblage as opposed to 12.3% for the entire Fruitland–Kirtland flora (table 3).

The anthophyta (angiosperms or flowering plants) are the dominant element of the florule, comprising 87.1% of the identical species (table 2). Monocots are represented by a few specimens assignable to the genus *Cypercites.* In general, monocots are less common in this florule than elsewhere in the Fruitland–Kirtland. On the other hand, 26 species of dicots, representing 15 genera and 13 families, are present in the florule. The willow family (Salicaceae) is represented by *Salix lancensis* (fig. 2) and two undetermined species (figs. 3 and 4). For the oak family (Fagaceae), the only species present is the extinct *Dryophyllum subfalcatum* (figs. 5 and 6). This is the first report of *Dryophyllum* from the Kirtland Shale. The genus *Dryophyllum* is common in Late Cretaceous floras of the Rocky Mountains but has still to be found in the Fruitland Formation (Tidwell and others, 1981). Three species of figs (Family Moraceae) occur in the florule: *Ficus vaueri, F. crossii,* and *F. planicostata. Ficus planicostata* (figs. 7 and 8) is by far the most frequently encountered species in the collection, with specimens ranging in size from 1.5 x 2.5 cm (.6 x 1.0 inches) to 6.2 x 9.3 cm (2.5 x 3.7 inches). *Menispermites belli* (fig. 9) is the only member of the moonseed family (Menispermaceae) in the florule. The laurela (Fauraceae) are represented by *Laurophyllum coloradensis, L. wardiana* (fig. 10), and *L. salicifolium* (fig. 11). Of the family Dilleniaceae, only *Dillenites cleburni* (fig. 12) is present. The buckthorn family (*Rhamnaceae*) has one species each from the genera (*Rhamnus*) and Zizyphus in the florule, but the exact species affinity for the specimens is yet to be determined. The remaining dicot families in the florule are each represented by a single species and include: *Carya antiquorum* of the Juglandaceae (walnut family), *Platanus raynoldsii* of the Platanaceae (sycamore family), *Magnolia cordifolia* of the Magnoliaceae, *Leguminosites* sp. of the Leguminosae (pea family), *Cissus marginata* of the Vitaceae (grape family), and *Myrtophyllum torreyi* of the Myrtaceae (myrtle family).

In terms of numbers of specimens, the most frequently encountered dicot genera in the florule are, in decreasing order of abundance:

*Ficus*
*Laurophyllum*
*Dryophyllum*
*Salix*
*Myrtophyllum*
*Rhamnus*
*Menispermites*

Three kinds of seeds have been recovered from the locality. They are *Carpites baueri* (fig. 13), *C. lancensis,* and *C.* sp. (fig. 14). Two species of dicotyledonous leaves and an ☞

TABLE 3—PERCENT OF FLORA SPECIES IN STUDY AREA COVERED IN THIS STUDY COMPARED TO TOTAL FRUITLAND-KIRTLAND (Tidwell and others, 1981).

| | Species for total Fruitland–Kirtland | Species this report | Percent this report | Percent of total Fruitland–Kirtland |
|---|---|---|---|---|
| Filicophyta | 9 | 3 | 9.7 | 12.3 |
| Osmundaceae | 2 | | | 2.7 |
| Schizaeaceae | 2 | | | 2.7 |
| Cyathaceae | 1 | | | 1.3 |
| Polypodiaceae | 3 | 2 | 6.5 | 4.1 |
| Salvinaceae | 1 | 1 | 3.2 | 1.3 |
| Coniferophyta | 9 | 1 | 3.2 | 12.3 |
| Araucariaceae | 2 | | | 2.7 |
| Cupressaceae | 1 | | | 1.3 |
| Taxodiaceae | 5 | 1 | 3.2 | 6.8 |
| Incertae sedis | 1 | | | 1.3 |
| Anthophyta | 55 | 27 | 87.1 | 75.3 |
| Monocotyledonae | 11 | 1 | 3.2 | 15.0 |
| Sparganiaceae | 1 | | | 1.3 |
| Cyperaceae | 1 | 1 | 3.2 | 1.3 |
| Palmae | 6 | | | 8.2 |
| Araceae | 1 | | | 1.3 |
| Pontederiaceae | 1 | | | 1.3 |
| Cannaceae | 1 | | | 1.3 |
| Dicotyledonae | 44 | 26 | 83.9 | 60.2 |
| Salicaceae | 2 | 36 | 9.7 | 2.7 |
| Juglandaceae | 1 | 1 | 3.2 | 1.3 |
| Fagaceae | 2 | 1 | 3.2 | 2.7 |
| Moraceae | 9 | 3 | 9.7 | 12.3 |
| Lauraceae | 4 | 3 | 9.7 | 5.5 |
| Platanaceae | 2 | 1 | 3.2 | 2.7 |
| Nymphaeceae | 1 | | | 1.3 |
| Cercidiphyllaceae | 1 | | | 1.3 |
| Menispermaceae | 1 | 1 | 3.2 | 1.3 |
| Magnoliaceae | 2 | 1 | 3.2 | 2.7 |
| Saxifragaceae | 1 | | | 1.3 |
| Leguminosae | 2 | 1 | 3.2 | 2.7 |
| Rhamnaceae | 2 | 2 | 6.5 | 2.7 |
| Vitaceae | 2 | 1 | 3.2 | 2.7 |
| Dillenaceae | 1 | 1 | 3.2 | 1.3 |
| Myrtaceae | 2 | 1 | 3.2 | 2.7 |
| Cornaceae | 1 | | | 1.3 |
| Bignoniaceae | 1 | | | 1.3 |
| Caprifoliaceae | 1 | | | 1.3 |
| Incertae sedis | 6 | 6 | 19.4 | 8.2 |
| TOTAL | 73 | 31 | 100 | 100 |

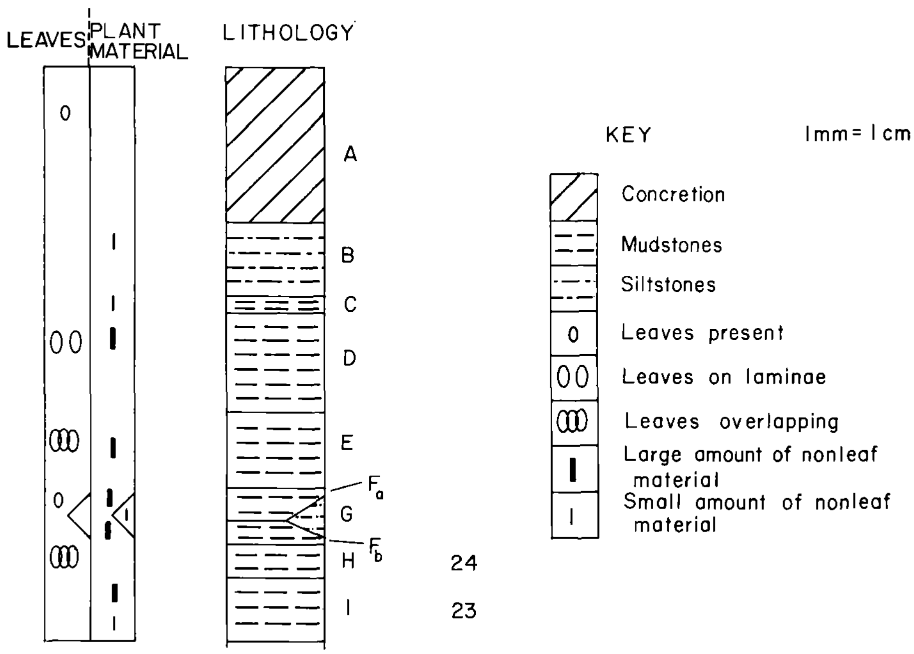


FIGURE 3—MICROSTRATIGRAPHY OF PLANT LOCALITY.

inflorescence (fig. 15) cannot be assigned with certainty to any known taxon.

Clearly, the remains of dicots are the predominate element in the florule. They make up 83.9% of the florule as compared with 60.2% for the known Fruitland–Kirtland flora (table 3).

### Depositional environment

Based on the presence of aquatic gastropods and bivalves, the fern *Salvinia,* and the fine-grained texture of the sediments containing the fossils, the deposition probably took place in open, standing water (Fig. 3). Presumably small lakes or ponds existed on the floodplains between stream channels. Lower in the rock sequence, Fruitland interchannel areas were occupied by coal swamps. In contrast, in the Kirtland, swamps were far less well represented, suggesting better drained conditions during Kirtland time. The standing water or pond in which the leaves were deposited must have had a high sedimentation rate to retain compressions of such complete and well preserved leaves. The higher energy, coarser grained sediments (see B and G of appendix B) significantly contain only poorly sorted, broken plant fragments and no leaves. Ninety-three measurements of the long axes of leaves and stems were made and indicate current directions with a northeast-southwest trend (Fig. 4).

The abundance of medium-sized angiospermous leaves with entire or nearly entire margins and drip points may indicate a warm-temperate to subtropical climate during late Fruitland and early Kirtland time.

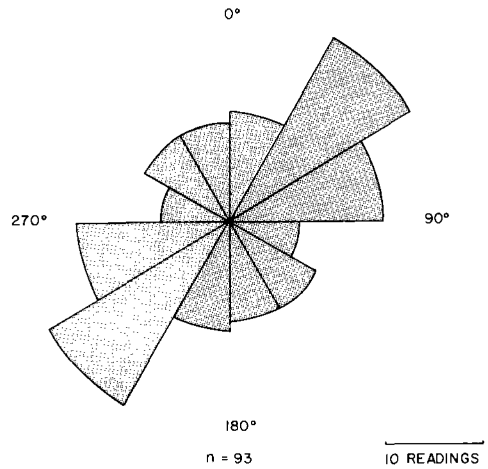


FIGURE 4—ROSE DIAGRAM OF ORIENTATION OF 93 STEM AND LEAF FRAGMENTS FROM LOCALITY.

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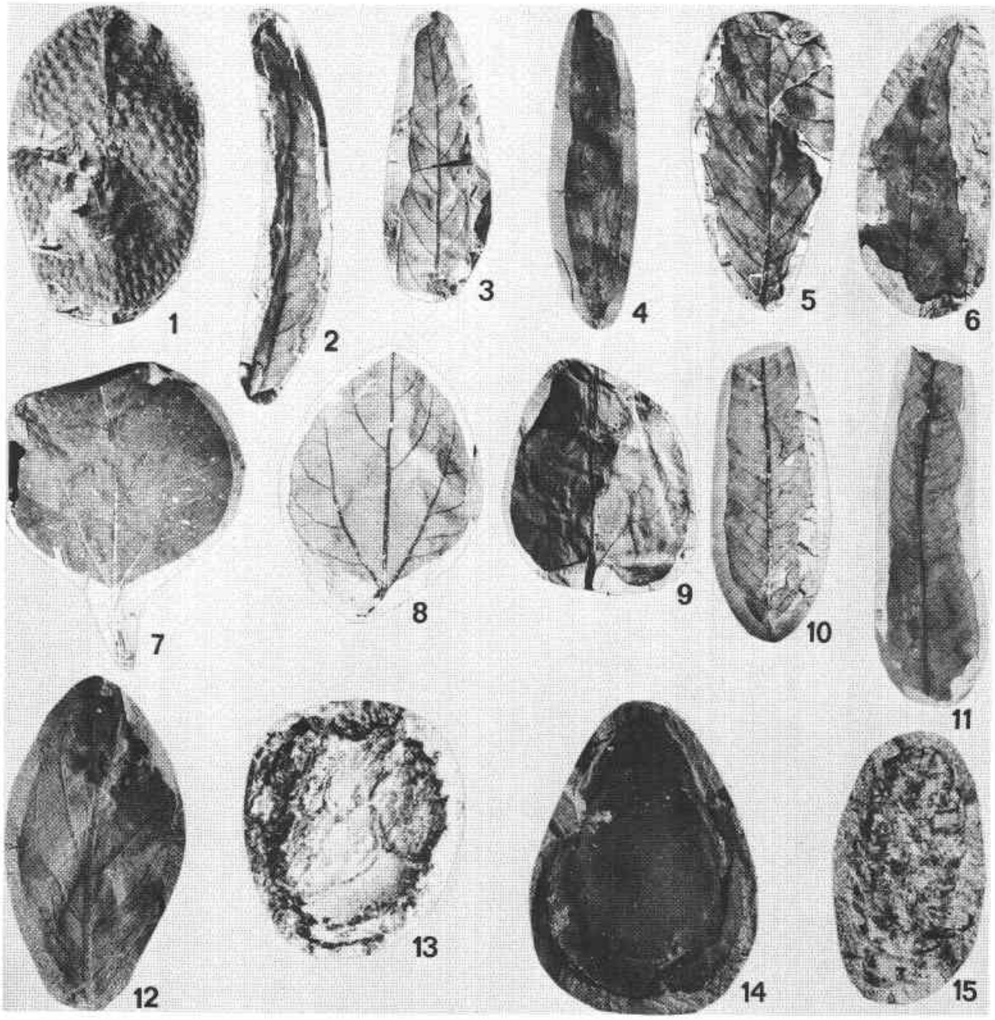


PLATE 1—REPRESENTATIVE SPECIMENS: 1) *Salvinia* sp., x 4.62; 2) *Salix lancensis,* x 0.99; 3) *Salix* sp. A, x 1.32; 4) *Salix* sp. B, x 1.32; 5, 6) *Dryophyllum subfalcatum,* 5–base, 6–apex, both x 0.33; 7, 8) *Ficus planicostata,* 7–x 0.53, 8–x 1.65; 9) *Menispermites belli,* x 1.32; 10) *Laurophyllum wardiana,* x 0.40; 11) *Laurophyllum salicifolium,* x 0.99; 12) *Dillenites cleburni,* x 1.98; 13) *Carpites baueri,* x 9.24; 14) *Carpites* sp., x 2.64; and 15) unidentified influorescence, x 3.63.

## APPENDIX A—MEASURED SECTION; MEASURED BY A. HUNT AND J. MENACK, JULY 1980, USING A BRUNTON COMPASS AND JACOB'S STAFF.

**Total thickness—16.84 m (55.9 ft)**

| Unit No. | Description | Thickness (cm) | (*inches*) |
|---|---|---|---|
| 029 | White sandstone, medium-grained; about 15% organic clasts | 41 | *16* |
| 028 | Light-gray mudstone; finely divided sand-sized plant fragments | 18 | *7* |
| 027 | Olive sandstone, fine-grained; with about 5% organic matter; olive laminae alternate with light-gray fine-grained laminae | 92 | *37* |
| 026 | White sandstone, medium-grained; about 10% organic clasts overall but with plant-rich laminae; grades upward into 027 | 96 | *38* |
| 025 | Gray-green mudstone; 5–10% organic matter; very rare occurrences of leaf fragments | 148 | *59* |
| 024 | Gray-green mudstone; with abundantly preserved leaves just below a sideritic concretionary layer forming a protective cap; leaf-bearing horizon laterally discontinuous | 148 | *59* |
| 023 | Sandy mudstone, gray-green; little organic material present | 48 | *19* |
| 022 | White sandstone, fine- to medium-grained; crossbedded laminae; less than 10% plant debris but locally more carbonaceous; locally red-brown color developed; iron staining in some laminae; fines upward into 023 | 18 | *7* |
| 021 | White sandstone, fine-grained; 5–10% plant debris in thin laminations; grades upward into 022 | 20 | *8* |
| 020 | Light-gray mudstone with less than 5% organic matter; dark-brown sideritic concretions present | 82 | *33* |
| 019 | Dark-gray (weathered) to black, lignitic horizon; very friable with amber blebs 1–2 mm in diameter; dull coal | 18 | *7* |
| 018 | Dark-gray-green shale; rich in plant debris (20–30%) | 20 | *8* |
| 017 | Dark-gray mudstone; lacks plant debris or carbonaceous material, grades upwards into 018 | 66 | *26* |
| 016 | Olive sandstone, fine-grained | 40 | *16* |
| 015 | Gray-green mudstone; occasional occurrences of plant debris in carbonaceous pockets | 64 | *26* |
| 014 | White sandstone, medium-grained; well indurated and prominent ledge former | 36 | *14* |
| 013 | Gray mudstone; with about 15% organic debris | 18 | *7* |
| 012 | Gray-green mudstone, very carbonaceous (50–60%); very deep, deep weathering developed (45 cm); characterized by development of vegetation along the outcrop of this unit | 147 | *59* |
| 011 | White sandstone, fine- to medium-grained; about 20% plant fragments in matrix; approximately 10% clay in thin laminae less than 1 mm thick and clay pebbles up to 2 cm x 1 cm; poorly developed ripple marks | 78 | *31* |

(*continued on p. 48*)

## Pajarito fault zone

(*continued from p. 41*)

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## Late Cretaceous leaf locality

(*continued from p. 45*)

APPENDIX A (*continued*)

**Total thickness—16.84 m (55.9 ft)**

| Unit No. | Description | Thickness (cm, | *inches*) |
|---|---|---|---|
| 010 | White sandstone, medium-grained; with large plant fragments up to 5 cm²; well indurated and forms characteristic popcorn surface texture upon weathering; some hoodoo (columns or pinnacles) development | 89 | *36* |
| 009 | White sandstone, fine-grained; about 5% plant debris concentrated in laminae. Undulating bedding finely developed; well indurated with fine laminations and mud partings | 60 | *24* |
| 008 | Dark gray-green mudstone with 15–20% plant debris up to 3.5 cm²; coarsens upward | 30 | *12* |
| 007 | Gray-green mudstone with about 5% plant fragments and stems; grades upward into 008 | 28 | *11* |
| 006 | Sandstone, white, medium-grained; with large fragments of plants up to 5 cm²; about 10% plant content | 25 | *10* |
| 005 | Mudstone, gray-green; with approximately 10% carbonaceous debris; coarsens upwards into 006 | 61 | *24* |
| 004 | Carbonaceous mudstone, dark-gray; up to 40% plant debris is up to 2 cm² poorly sorted; coarsens upwards; becomes much less carbonaceous laterally (about 10%) | 28 | *11* |
| 003 | Olive sandstone, medium-grained; with some iron staining along bedding planes; 5–10% plant debris | 117 | *47* |
| 002 | Gray siltstone; 5% plant debris; iron staining in fractures | 18 | *7* |
| 001 | White sandstone; fine-grained lenses of sand rich in carbonized plant debris and silt lacking plant debris; lenses subparallel to bedding; fines upward into 002; much lateral variation in plant debris content (5–20%) | 30 | *12* |

APPENDIX B—MEASURED SECTION.

| Unit No. | Description | Thickness (cm, | *inches*) |
|---|---|---|---|
| A | Concretion, dark-brown; siderite with veins of barite; rare, poorly preserved leaf impressions extend laterally 1.8 m (5.9 ft) | 35.6 | *14.2* |
| B | Siltstone, gray-green; scattered subrounded plant fragments; well-sorted, averaging 5 mm (.2 inches) in diameter | 15.2 | *6.1* |
| C | Mudstone, gray-green; a few scattered stem fragments; poorly sorted up to 3 x 5 cm (1.2 x 2 inches) | 3.8 | *1.5* |
| D | Mudstone, gray-green; occasional horizons with leaves 3 cm (1.2 inches) in length and also horizons of poorly sorted stems up to 1.3 x 2 cm (.5 x .8 inches) | 22.8 | *9.1* |
| E | Mudstone, gray-green; many jumbled leaves, many of which overlap; leaves subcomplete 2–5 cm (.8–2 inches) in length, small fragments up to 5 mm (.2 inches) in length; poorly sorted stem fragments 1–5 cm (.4–2 inches) in length and up to .75 cm (.3 inches) wide; slickensides up to 39 cm (16 inches) in length, leaves on laminae averaging .3 cm (.12 inches) apart | 17.8 | *7.1* |
| F | Mudstone, gray-green; scattered leaves few in number: (a), lens of few scattered complete leaves grades laterally into stems and poorly sorted small plant fragments, but no leaves; stems 5–10 cm (2–4 inches) long and up to 1 cm (.4 inches) wide, fragments are subrounded 2–.25 mm (.08–.01 inches) in diameter; (b) same as lateral, stem-rich portion of (a), sharp contact with plant-rich portion of (a) | a) 7.6<br>b) 5.0 | *3.0*<br>*2.0* |
| G | Lateral from (a) and (b) siltstone, yellow-green; few broken plant fragments (no leaves); lens-shaped cross section 7 x 60 x 15 cm (2.8 x 24 x 6 inches) | 7.0 | *2.8* |
| H | Mudstone, gray-green; full of overlapping complete leaves that cover 100% of surface on laminae about every .5 cm (.2 inches); intervening layers produce complete leaves not overlapping | 7.7 | *3.1* |
| I | Mudstone, gray-green; large stems 5–10 cm (2–4 inches) long and 1 cm (.4 inches) wide, also many small stem pieces, subrounded from 3 to 8 mm (.12 to .32 inches) in diameter | 15.2 | *3.1* |
| J | Grades down with less stem to subrounded fragments less than 2 mm (.08 inches) in diameter to unfossiliferous gray-green mudstone | 45.9 | *18.4* |

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