craters; and class C contains objects which may be craters. These classes have been retained in this analysis.

Table 1 gives the percentage of craters in each class in frames 4, 7, and 11 which are common to both interpretations. The results given are the averages of several different overlap fits; the spread of the data is 10 percent for frames 7 and 11 and 25 percent for frame 4. If it is assumed that the crater commonality factors obtained for frames 4, 7, and 11 can be applied to the other frames and if we allow for the differences in the quality of the different frames, then, out of the nearly 300 craters mapped by Chapman *et al.* and the 600 mapped by Leighton *et al.* (*6*), there are only 115 to 120 common to both counts. If only frames 7 through 14 are considered, then there are about 100 craters common to both interpretations, a value which is consistent with the results obtained by Binder (*2*) and Hartmann (*3*). The comparisons also show that only 75 to 80 percent of the craters of class A, 30 percent of those in class B, and less than 10 percent of those in class C mapped by Chapman *et al.* represent real craters.

It seems that the *observed* crater density derived earlier (*2*, *3*) is essentially correct and therefore that the *observed* Martian crater density is below that of the lunar uplands by a factor of nearly 2. I would emphasize that the *actual* crater density may very well be greater than the *observed* crater density, but the evidence supporting large crater densities based on the Mariner IV photographs is questionable. The Mariner IV photographs are extremely important because they have shown the presence of a large number of craters on the surface of Mars. However, an accurate evaluation of the crater density must await improved definition.

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Podocarpus from the Eocene of North America

Abstract. *A few leafy gymnosperm shoots were found in Eocene deposits of southeastern North America. Similar fossil material from Tertiary deposits in North America has been identified as* Taxodium, Taxites, *and* Sequoia. *This new fossil material is not related to these genera but belongs to* Podocarpus *section* Stachycarpus. *This is the first fossil record of this section in North America.*

Eocene floras have been described from western Tennessee (*1*). New collections from this area have yielded gymnospermous fossils, including compressions (Fig. 1, A and B) and a whole "mummified" shoot (Fig. 1C). Some cuticular material is preserved in nearly all of the leaves.

The shoots have stout stems with spirally arranged leaves that are disposed distichously. The leaves are needle-shaped, narrowed at the base, petiolate, and have an obtuse apex. They are unequally amphistomatic (having stomata on both surfaces) (Fig. 1D); the stomata are confined to a single row on either side of the midrib and are oriented parallel to the long axis of the leaf. There are conspicuous thickened rings of cutin (Fig. 1, E and F) overlaying the accessory cells and surrounding the stomata. Thickened rings of cutin have been observed surrounding stomates in the genus *Podocarpus* (*2*).

Podocarpus has been subdivided into several sections (*3*). The species of *Podocarpus* belonging to the section *Stachycarpus* have small yewlike spirally arranged leaves that are disposed distichously (*4*). A comparison of gross morphology and fine features of the fossil cuticle to those of the cuticle of modern species in this section confirm this fossil material as *Podocarpus* section *Stachycarpus* (*5*).

Florin (*6*) described some poorly preserved material from Eocene deposits in Chile which he provisionally placed in the section *Stachycarpus*. In another paper (*7*) he mentioned, but did not describe, some fossil material which he regarded as *Podocarpus* section *Stachycarpus*. Some early Tertiary (probably Eocene) fossil material from Tasmania has been identified as *Podocarpus* section *Stachycarpus* subsection *Idioblastus* (*8*). This subsection includes modern species now living in New Caledonia and Queensland in Australia which have idioblastic sclerids (*9*). The fossil material described in this paper, two modern New Zealand species (*Podocarpus spicatus* and *P. ferrugineus*), and all the modern American species of the section *Stachycarpus* are included in the subsection *Euprumnopitys*.

There have been no previous reports of leafy shoots of *Podocarpus*, section *Stachycarpus*, from the fossil record of North America. Previously, similar gymnosperm material with spirally arranged leaves from Tertiary deposits in North America has been identified as *Taxodium, Taxites,* and *Sequoia* (*1, 10*). *Metasequoia* is not generally confused with these genera because of its subopposite leaf arrangement. On the basis of gross morphology alone, this fossil material can not easily be distinguished from *Taxodium, Taxites* (*Taxus*), and *Sequoia.* However there are unique features of the cuticle which identify it as *Podocarpus*. The stomata of *Taxodium* are oriented in a random fashion on the lower surface of the leaves; those of *Taxus, Sequoia,* and *Podocarpus* are oriented parallel to the long axis of the leaves. The epidermal cells and accessory cells of *Taxus* are conspicuously papillate; those of *Podocarpus* are not. Thickened rings of cuticle are lacking in *Sequoia;* they are prominent in this fossil material and to some extent in *Podocarpus*. Because the leafy shoots of these genera cannot easily be differentiated when they lack cone material, the use of cuticular analysis is essential to the identification of fragmentary fossil leafy shoots. Until the fine features of the cuticle were carefully compared the material described in this paper was thought to belong to the genus *Sequoia* (*11*). Thus it is very possible that the reason no previous reports of fossils of *Podocarpus* section *Stachycarpus* have been made in North America is that identifications of leafy shoots of gymnospermous material have been made on the basis of gross morphology alone and this genus and section has not been considered when identifications have been made.

There are several reports of *Podocarpus* pollen from Mesozoic sediments of North America (*12*) and one report of *Podocarpus* wood from Eocene sediments in Washington (*13*). The pollen record of *Podocarpus* is believed not to extend into Tertiary sediments of North America (*14*). However, there is some indication from the pollen rec-

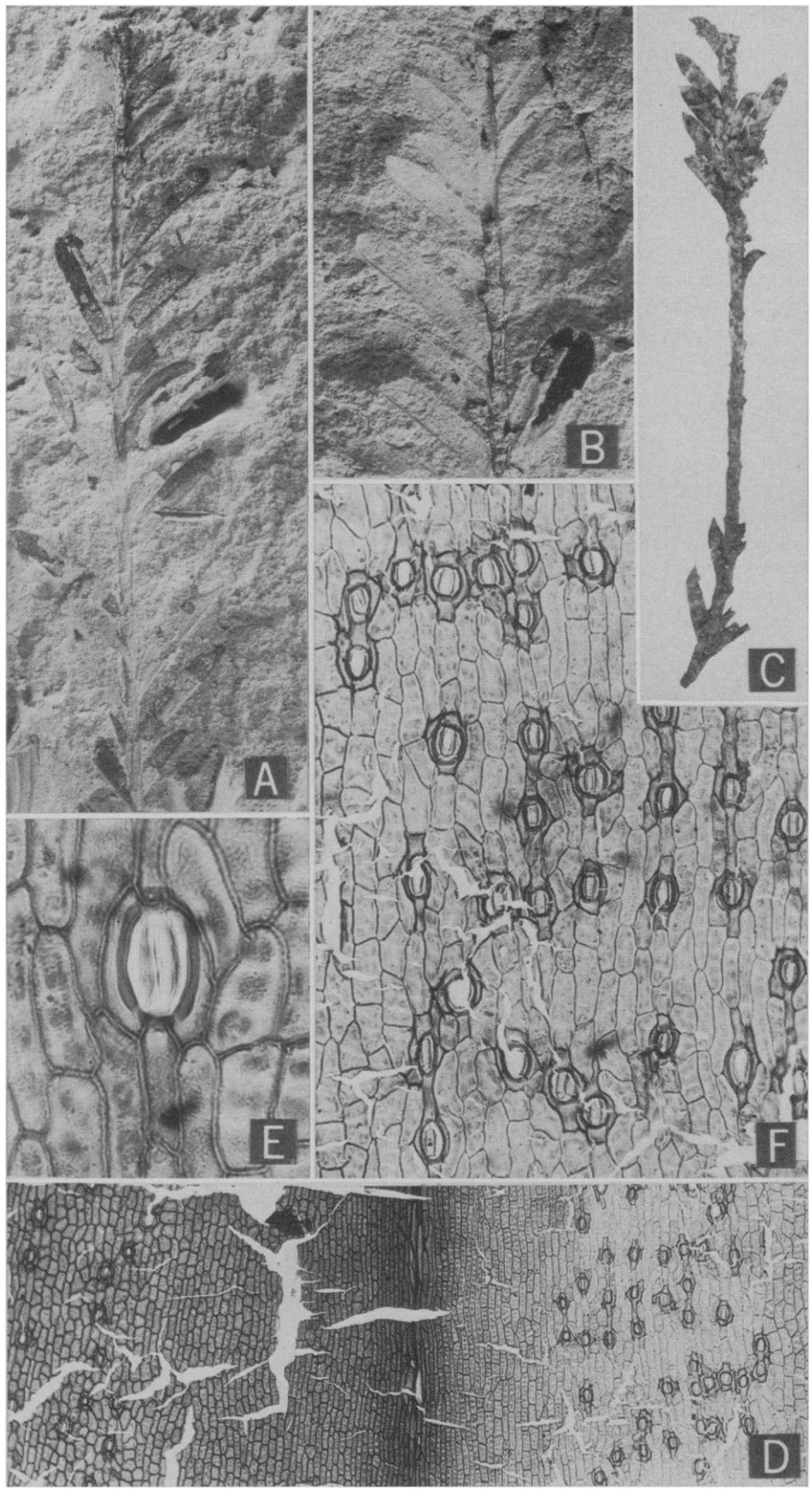

Fig. 1. Fossil *Podocarpus*. (A) Compression of leafy shoot of *Podocarpus*; W1183 (× 2). (B) Impression of *Podocarpus* leafy shoot, opposite half of specimen seen in A; W1183′ (× 3). (C) "Mummified" leafy shoot of *Podocarpus*; NP 1354 (× 1.9). (D) Upper epidermis on the left and lower epidermis on the right showing only one of the two rows of stomata found on each surface of the leaves. This illustrates the unequal amphistomatic conditions characteristic of this fossil material (× 75). (E) Single stomatal apparatus from the lower epidermis of specimen seen in C, illustrating the thickened ring of cutin overlaying the accessory cells (× 530). (F) Lower epidermis of the specimens illustrated in A and B (× 160).

ord (*15*) that *Podocarpus* was present in the Mississippi embayment area during the early Tertiary. The megafossil record now supports this idea.

Florin (*16*) recognizes 11 species in the section *Stachycarpus*, six in the New World, and five in the Old World; Buchholz and Gray (*4*, *9*) recognize five species in the New World and five in the Old World. The present range of the section is along the western side of the South Pacific where it occurs south from Stewarts Island, through New Zealand, and north to New Caledonia and Queensland and along the eastern side of the Pacific in Chile, Bolivia, Peru, Venezuela, and north into Central America (*16*). All of the American species of this section are hypostomatic (having stomata on the lower surfaces) but there are some species on the extreme western range of the section which have unequally amphistomatic leaves (*4*), as observed in the fossil material. Thus, the fossil material from the middle Eocene of North America seems most related to those species of *Podocarpus* section *Stachycarpus* now confined to the South Pacific. Buchholz (*17*) proposed in 1948 that the ancestors of the section *Stachycarpus* migrated across the southern Pacific from west to east. The close affinity of the morphology of the fossil material with the two species of the subsection *Euprumnopitys* now living in New Zealand suggests that the American species, all belonging to this subsection, may be evolutionary modifications of a form similar to the species now restricted to New Zealand. A migration across the southern Pacific from west to east with subsequent spreading of these early podocarps through South and North America and a later extinction and isolation of segments of this population would explain the origin of the modern species of *Podocarpus* section *Stachycarpus* now found in the New World.

Buchholtz (*17*) suggests that podocarps were much more widely distributed throughout the Northern Hemisphere in the past. However, Florin (*16*) does not accept this hypothesis but considers the podocarps which are now found in the Northern Hemisphere to have "invaded limited parts of the northern hemisphere only in late geologic times." The Eocene *Podocarpus* described in this paper and the numerous reports of *Podocarpus* pollen from Mesozoic sediments in widely scattered areas of the Northern Hemi-

sphere are remnants of a once much more northern extension of *Podocarpus* rather than a recent northernmost extension of a southern element.

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Mode-Locked Lasers: Measurements of Very Fast Radiative Decay in Fluorescent Systems

Abstract. *A mode-locked laser was used to measure fluorescence decay down to 80 picoseconds. Measurements on the fluorescence of methylene blue quenched with potassium iodide demonstrate the effectiveness of the method. Fluorescence decay times of chlorophyll b (3.87 ± 0.05 nanoseconds) and c-phycocyanin (1.14 ± 0.01 nanoseconds) in vitro and chlorophyll a in the green alga* Chlorella pyrenoidosa *(1.14 to 1.6 nanoseconds) compare well with some of the existing data.*

Measurements of the decay times of radiative emission provide information regarding energy transfer processes that follow electronic excitation. One of the main difficulties in making accurate determinations of decays is the lack of light sources that can produce both high-intensity and fast-decaying pulses. By exploiting the existence of stable, sustained interference in time between the optical frequencies of laser emission (*1*), one can produce high-intensity pulses with fast rise and fall time; these can be as short as tens of picoseconds in broad-band lasers. Such pulses are difficult or impossible to generate with conventional flash sources. Use of high peak power and sharp pulse shape resulting from locking of longitudinal laser modes has been reported (*2*). We have used a mode-locked He-Ne laser as the excitation source to measure fluorescence decay times as short as 80 psec and have compared the phase-delay method of measurement (*3*) with direct measurement of decay (*4*). Measurements were carried out on dyes and photosynthetic samples.

The components of the measuring apparatus are shown in Fig. 1. The He-Ne laser, oscillating at the fundamental intermode frequency separation of 102.207 Mhz and emitting at 6328 Å, was conventionally constructed and consisted of a 100-cm discharge section, 4 mm inside diameter. The maximum average output power was on the order of 10 mw, whereas mode-locked average power was only a few milliwatts. The laser was operated at an average power as low as 0.4 mw mode-locked for many of the measurements. The average intensity of the laser irradiation was 10^5 erg cm^{-2} sec^{-1}. No special optical shielding precautions were necessary in these measurements because of the collimation and relatively narrow band of the laser light.

For direct measurement of fluorescence decay, the components included a He-Ne laser, a 1-cm^2 glass cuvette, an optical filter, a photomultiplier (RCA 7102), and a sampling oscilloscope (Tektronix 661) with camera attachment. The fluorescence was observed at right angles to the incident laser light. For the phase-delay measurement, the components and geometry were the same as those used for the direct measurement of decay, except that the sampling oscilloscope was no longer used as the monitor. Part of the incident laser beam was deflected to another photomultiplier serving as reference. The signals from the two photomultipliers were passed through a low-pass electrical filter and then into a phasemeter. The phasemeter was nulled with scattered laser-radiation (with calcium carbonate suspended in water as scatterer) emanating from the same point as the sample fluorescence. The intensity of scattered light was made comparable to that of fluorescence by use of neutral density filters.

Materials known to have very short fluorescence lifetime (τ) were chosen to demonstrate the effectiveness of this method. In particular, fluorescence lifetime of methylene blue at room temperature is measured as a function of potassium iodide concentration (Fig. 2). The results are reliable to within ±2 percent for the higher values, approximately ±10 percent for 0.1 nsec, and ±20 percent for the lowest value (80 psec). The inaccuracy for the lower decay times results from the lower fluorescence yield and a consequent decrease in the signal-to-noise ratio. To our knowledge, no measurements of τ for methylene

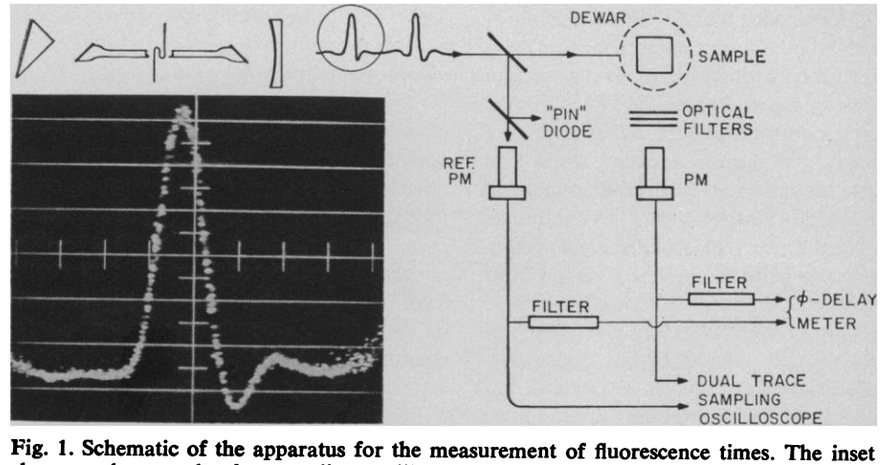

Fig. 1. Schematic of the apparatus for the measurement of fluorescence times. The inset shows a photograph of a sampling oscilloscope trace representing a mode-locked laser pulse (1 nsec/div).