detect trail odors. In the first, the ability of *P. basizonus* females to detect their own odor was observed. The experimental arena provided a substrate similar to the forest floor, in which the parasitoids habitually search for hosts. The sand floor of a tray (60 by 60 by 5 cm) was covered with lichens, *Cladonia* spp. It was dimly illuminated from above with a central, shaded 100-watt lamp. The arena was ventilated through the tray walls. A barricade was placed across the middle of the arena at right angles to two sides. A female was liberated in one half of the tray, and the whole tray was covered with an acrylic plastic sheet. When the female had searched the litter for 5 to 6 hours, it was captured and the barricade was removed. The female was released again in the center of the tray and the amount of time it spent in each half of the arena was recorded. Observations on a female released in a fresh tray acted as a control. Study periods of up to 1¾ hours were necessary to establish a change in behavior.

A second experiment provided a more rapid assay for trail recognition. The arena was simpler and smaller. A tray (60 by 27 by 5 cm) was illuminated as before and lined with a sand base on which two plastic rings (15 cm in diameter and 5 cm in height) were placed 10 cm apart. The tray was covered as before. This closed the rings to form two cages within the tray. One cage was used as a control. A female parasitoid was introduced to the other cage and was allowed to search for 2 to 3 hours. The parasitoid and the two plastic rings were then removed. A sheet of thin plastic was placed over the arena top and the course of a newly introduced female was traced for 15 to 30 minutes onto the plastic in ink. These tracings showed the number of times a parasitoid entered the treatment or control area without changing its course (apparent nonrecognition). They also showed the times it approached but did not enter the control or treatment area and those entrances that occurred after clearly defined changes in the course of the parasitoid (apparent recognition). Only trails within 1.25 cm (the approximate length of a parasitoid) of the cage perimeter were used in the analysis (*7*). This method could not be used for testing self-recognition because females became hyperactive after being confined in the small cage.

In experiment 1, 19 female *P. basizonus* of unknown age were tested. Seven individuals avoided the area that they had already searched and 12 did not (Fig. 1). The latter individuals may have been too old to recognize trail odors; in the second experiment, age proved to be an important factor. Experiment 2 established that females of the same species could recognize each other until after they were 6 days old (Fig. 1). Under natural conditions, females could probably recognize this odor throughout their life span. In the laboratory, where they were kept in small cages before the experiment, the substrate and atmosphere probably became saturated with the trail odor. Here acclimation to high concentrations could have raised the level of response to a threshold higher than the concentrations reached in the experiments. Females were able to detect the odor 4.5 hours after another female had been present (Fig. 1).

One test was made on each of all possible combinations of four coexisting species of ichneumonid parasitoid that attack the same host. Conspecific, congeneric, and intergeneric recognition of trails was evident (Table 1).

The behavior of the parasitoids suggests that the odor acts as an irritant. The longer they remain in an enclosed space, the more they wipe their antennae and mouthparts with their forelegs, a mild form of the behavior seen in the presence of the irritant vapor of ethyl acetate. They tend to move more rapidly with time (*6*) and remain close to the perimeter of the tray.

These results provide an explanation for the interference between searching parasitoids observed in several sets of data analyzed by Hassel and Varley (*8*).

Since female parasitoids can recognize and avoid the presence of others, the maximum level of their abundance in a given habitat may be determined by the concentration of the trail odor, rather than by the density of hosts, in that area. Therefore, parasitoid numbers would reach their peak while the host population continued to rise, allowing the host to escape the large mortality caused by parasitoids. Although the efficiency of individual parasitoids may be increased, the mortality caused in the host population is decreased. However, as females are compelled to emigrate from an area with a high parasitoid density because of their avoidance behavior, new host populations can be colonized and the survival probability of the parasitoid species improved.

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Pre-Cretaceous Flowering Plants: Further Evidence from Utah

Abstract. *Palm roots discovered in place in the Jurassic Arapien Shale Formation are further evidence for pre-Cretaceous flowering plants.*

Petrified palm logs comprising two species of *Palmoxylon*, as reported (*1*) from the Middle Jurassic Arapien Shale Formation near Redmond, Utah, were excavated from undisturbed beds within this formation. These represent the first definite flowering plants known from strata of pre-Cretaceous age. Three criteria are necessary in order to substantiate the validity of a proposed pre-Cretaceous Anthophyta. First, the collection site must be Jurassic or earlier in age. Second, it must be demonstrated that the fossil was collected in place. Third, the fossil must be unquestionably related to the Anthophyta (Magnoliophyta).

Jurassic invertebrate fossils have been collected near the localities of both palm roots (*Rhizopalmoxylon*) and *Palmoxylon simperi*. These include forms previously described by Reeside

(2) and Imlay (3), especially *Pentacrinus asteriscus* which is known only from Jurassic strata (4, 5). Rigby (4), in studying the fossils, also noted a similarity between the oolitic bed in which these fossils occur and a comparable bed from the lower portion of the Jurassic Carmel Formation.

Younger formations were searched for the presence of palm axes that may have rolled down upon the Arapien Shale. No evidence of petrified palm specimens was discovered above the Arapien. Of these younger formations, the Green River Formation (Eocene) received particular emphasis because of its well-known angiospermous flora. Palms, however, do not constitute a major or typical aspect of the Green River flora. Knowlton (6) states, "The [leaf compressional] species of *Geonomites* and *Sabal* are very rare—in fact, are known only from the type material—but the form referred to *Flabellaria* [leaf compression] was very abundant at one locality. . . ." No petrified woods, including palms, have been reported in this formation from Utah.

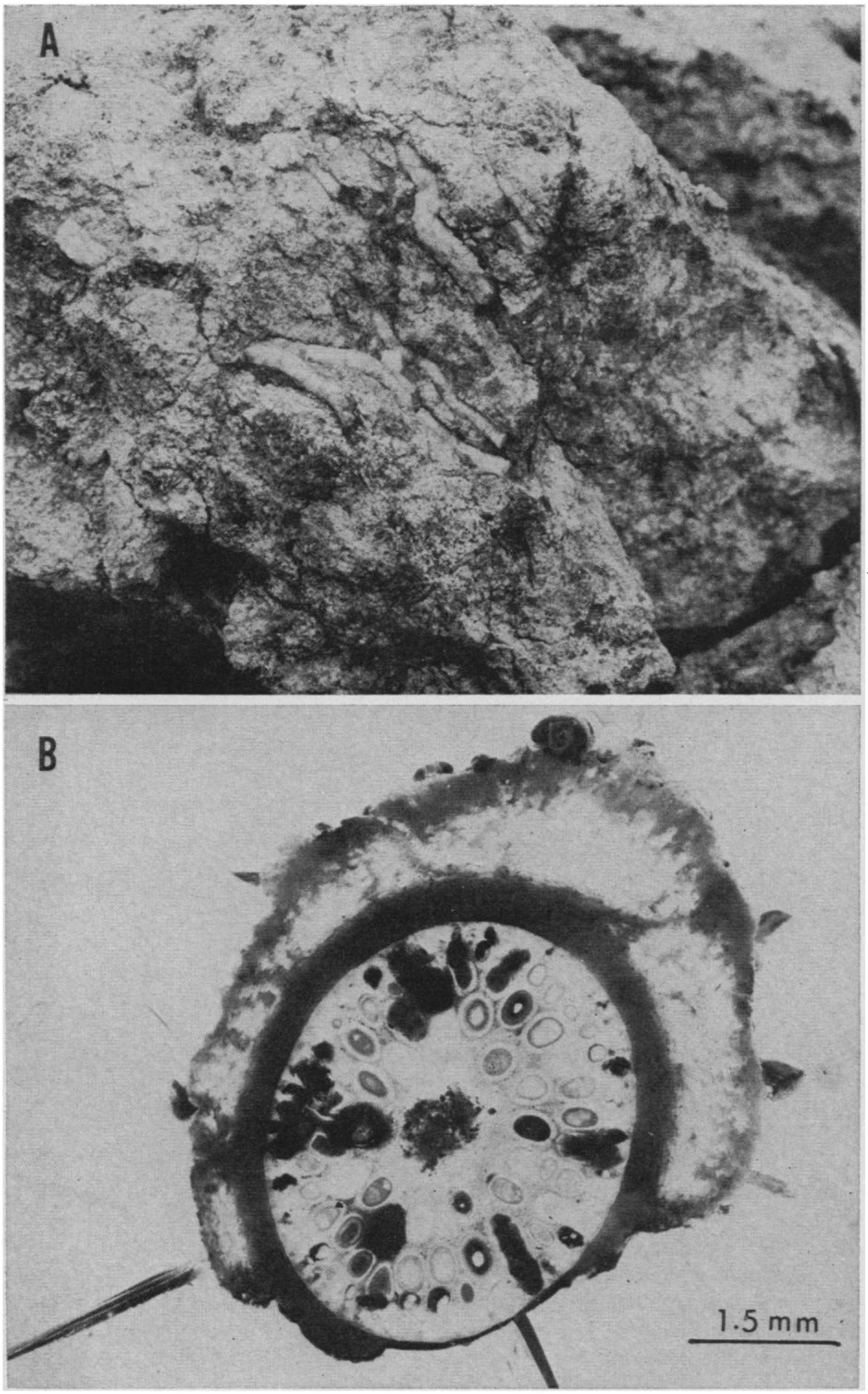

Fig. 1. Palm roots from the Jurassic Arapien Shale of central Utah. (A) Roots in growth position embedded in a sandstone bed. (B) Cross section of a root illustrating typical anatomical construction of a palm root.

The Arapien Shale is unconformably overlain near the palm localities by Tertiary (possibly Miocene) volcanic rocks. Thus, the Green River Formation and other possible Cretaceous and Jurassic formations (3) were eroded from above the Arapien Shale prior to the extrusion of these volcanic rocks. It is very doubtful that palm logs, even if present in the Green River Formation, could have survived the intervening millions of years of weathering and erosion.

Well-preserved palm roots imbedded in growth position within sandstone beds of the Arapien Shale (Fig. 1) have recently been collected. These roots vary in size from the diameter of a pin to several centimeters and may be traced laterally within the sandstone beds, where they form a network of small and large roots typical of a living arborescent monocot. At least three species of palm roots (*Rhizopalmoxylon*) are present in this formation. Axelrod (7) reviewed the collecting sites of both the palm stems and roots with us. He suggested that rather than roots being found in only one sandstone bed, the palm roots were present in several sandstone horizons, each of which indicates a distinct period of flooding and deposition. These roots demonstrate that palm trees, and thus flowering plants, were growing over an extended period of time in central Utah during the deposition of the Arapien Shale Formation.

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