We have not measured the merging rate in this study, for we cannot be certain that the particle injection rate is linearly proportional to the merging rate. However, it is difficult to conceive of a mechanism whereby the injection rate depends on a rectified interplanetary electric field while the merging rate does not. Thus, it appears that the merging rate is effectively zero for northward magnetic fields. Further support for this contention is provided by the fact that perturbation in the horizontal component of polar cap magnetograms, presumably caused by antisolar convection driven by the merging process, also drops to zero for northward magnetic fields (*11*). Thus, the available observational data support the popular assumption about the dependence of merging on the direction of the interplanetary magnetic field, that the terrestrial magnetosphere acts as a rectifier. We would expect the Jovian (*12*) and Mercurian (*13*) magnetospheres to behave in a similar manner.

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Lepidopteran Leaf Mine from the Early Eocene Wind River Formation of Northwestern Wyoming

Abstract. *A lepidopteran mine, probably of* Phyllocnistis, *on a leaflet impression of* Cedrela *(Meliaceae) discovered in late early Eocene strata near Dubois, Wyoming, is the earliest record of leaf mining and of the Phyllocnistidae. Considerable prior evolution of the mining habit, antiquity of the* Cedrela-Phyllocnistis *relationship, and subtropical climatic conditions are indicated.*

A single lamina bearing the track of a serpentine mine was found during the course of paleobotanical collecting in 1969 in the Sheridan Pass area southwest of Dubois, Wyoming (Fig. 1) (*1*). Subsequent examination led to the identification of the lamina as a leaflet of the genus *Cedrela* and of the mine as a probable member of the modern genus *Phyllocnistis*.

The leaflet bearing the mine occurs in a 0.6-m-thick bed of light gray, tuffaceous, microcross-to-parallel laminated claystone and siltstone apparently deposited in a swamp (*2*). This bed contains a rich and diverse megafossil plant assemblage laterally equivalent to the Coyote Creek flora of the Fish Lake Quadrangle to the east (*2*). The bed containing this flora is part of what Rohrer (*2*) calls the "lower volcaniclastic unit" (Fig. 1) and is tentatively correlated with the upper part of the Wind River Formation in the DuNoir and East Fork areas lying to the east. In the vicinity of Sheridan Pass the lower volcaniclastic unit consists of approximately 365 m of volcanic granulite, sandstone, siltstone, and claystone, with minor amounts of conglomerate. A "variegated unit," which is also tentatively correlated with the Wind River Formation, conformably underlies the unit, while an unconformity separates the lower volcaniclastic unit from an overlying "upper volcaniclastic unit." This latter sequence is tentatively correlated with the Tepee Trail Formation of the DuNoir area (*2*).

The Coyote Creek flora appears to lie stratigraphically above the level of the Wind River flora in the DuNoir area, where associated beds contain vertebrate fossils of Lost Cabin age (*2, 3*). A lapilli tuff found 46 to 49 m above the Coyote Creek floral unit gives an uncertain potassium-argon age of 50 million years (*2*). Fossil floras and a potassium-argon age from a bentonite bed in the upper volcaniclastic unit in the Kisinger Lakes Quadrangle to the north give ages of middle Eocene and 49.3 million years, respectively (*2, 4*). Thus, the Coyote Creek flora appears to date from the Lost Cabin provincial substage of the late early Eocene, between 50 and 51 million years ago (*5*).

A number of examples of leaflets and whole leaves identical in internal architecture to the mined lamina occur in the leaf bed at the locality and in correlative units (Fig. 2). These indicate that the lamina is part of a compound leaf with five to seven leaflets. Leaflet shape ranges from symmetrical (for terminals) to slightly asymmetrical (for laterals) and elliptic to

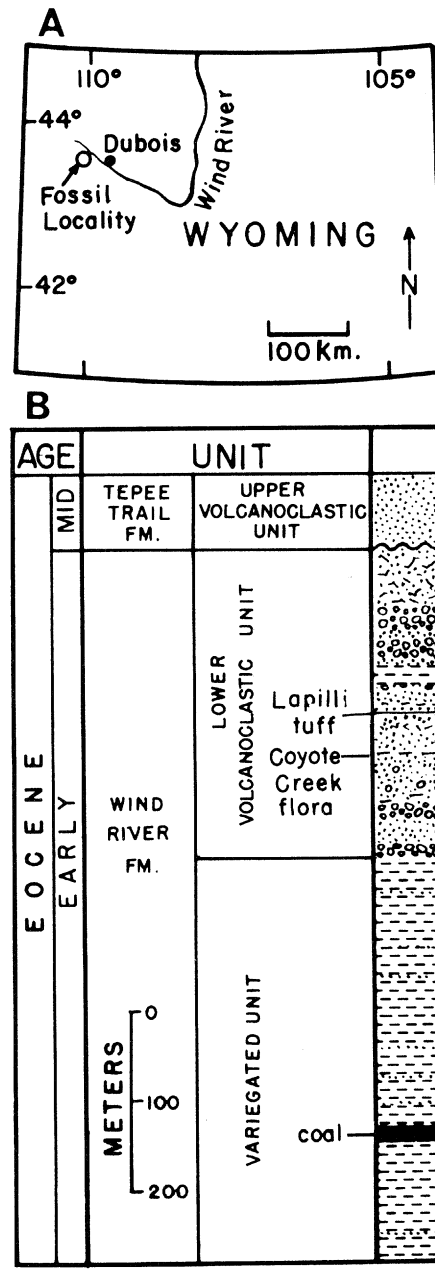

Fig. 1. Geographic location (A) and stratigraphic setting (B) of the leaf mine locality. The mine was found at the level of the Coyote Creek flora. Stratigraphic section and correlations after Rohrer (*2*).

wide elliptic or rarely narrow ovate; the ratio of length to width is 1.5 to 2.5, with length up to 12 cm and width to 6.1 cm; apices are acuminate, bases obtuse, and margins entire (*6*). Leaflets have short petiolules, a chartaceous texture, and lack any visible glands.

The following characters were important in determining the identity of the mined leaf: secondary veins pinnate in 9 to 12 pairs, relatively straight until close to the margin, where they turn abruptly upward and form somewhat irregular, angular brochidodromous arches. The inner branch of the secondary, which forms the arch, joins the superadjacent secondary at an acute angle, and an outer branch runs into a strongly developed series of looped higher-order veins just inside the leaflet margin. Intersecondary veins are present in some leaflets. Tertiary veins are irregularly percurrent, with simple, irregularly convex courses. The abaxial angle of the tertiary vein origin is acute in all cases, while the adaxial angle is right in 50 percent, acute in 30 percent, and obtuse in 20 percent of the cases. Quaternary veins are predominantly orthogonal and quinternaries random; marginal ultimate venation has strongly developed loops forming a fimbrial vein.

Of the six dicot subclasses (*7*), entire-margined, pinnately compound leaves with this morphology are limited to the Rosidae, and in particular to the superorders Rosanae and Rutanae as well as the orders Rhamnales and Oleales. Within these rosid taxa only the family Meliaceae of the Rutanae displays a combination of characters including an indeterminate leaflet arrangement and angular brochidodromous arches with an outer secondary branch merging with looped marginal venation so strong as to appear to be a fimbrial vein. Within the extant Meliaceae brochidodromous secondaries are common in *Swietenia* and relatively rare in the closely related genus *Cedrela*, in which eucamptodromy predominates. However, only *Cedrela* shows the same pattern of intercostal venation, particularly the angle of tertiary vein origin and course of intersecondaries.

The mine starts on the leaflet margin, runs to the midvein, then generally parallels the secondary veins (Fig. 2). It does not cross the midrib and transects the secondary veins only marginally where they are weak. Terminally, the mine is a narrow blotch, and pupation occurred in this area. Frass is placed somewhat loosely at the center of the mine throughout its length. Most features of this mine are typical of the genus *Phyllocnistis* Zeller (Lepidoptera: Phyllocnistidae). Becker (*8*) demonstrated a current association between *Phyllocnistis meliacella* Becker and species of *Cedrela* and *Swietenia* in Costa Rica. Mines of at least two additional neotropical *Phyllocnistis* species were found on leaflets of *Cedrela* in the U.S. National Herbarium. The fossil mine differs from those of these three species by its disconnected frass pattern, whereas the contemporary *Phyllocnistis* mines have frass centrally compacted throughout most of their length.

Phyllocnistis is a tineoid lepidopteran with highly specialized larval feeding habits. The larva is a flattened, apodal sap feeder in the first three instars, becoming cylindrical and nonfeeding in the fourth instar (*9*). Pupation occurs in a chamber at the end of the mine. The frass pattern of the fossil mine implies that at this stage in the evolution of the genus cells as well as sap were consumed.

The few fossils of microlepidoptera are mainly larval mines (*10*). A poorly preserved larval head capsule was found in Late Cretaceous Canadian amber (*11*). Although the family placement of this specimen cannot be determined, the rounded head capsule and position of the mouth parts indicate that the larva was an external feeder. Scales attributed to adult Micropterygidae were found in the Middle Cretaceous Harz Formation of West Germany (*12*). Adult Lepidoptera of Oecophoridae and Tineidae were reported from Oligocene Baltic amber (*13*).

As well as being the oldest example of a leaf miner (*14*), this find is the first evidence of the Phyllocnistidae in the fossil record. In addition, it demonstrates an extant insect-host relationship that had become established 50 million years ago and carries with it the implication that this relationship must have been preceded by considerable coevolution of leaf-mining

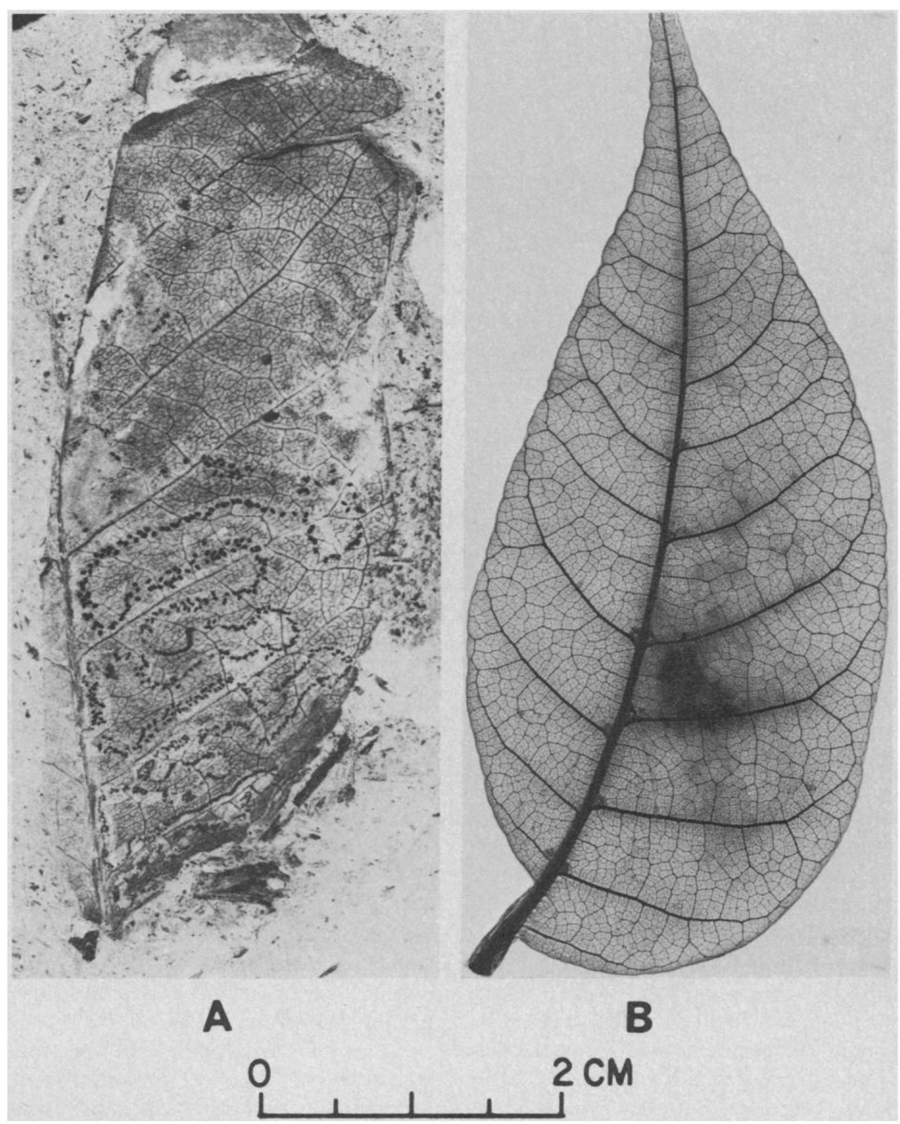

Fig. 2. (A) Fragment of a fossil *Cedrela* leaflet with a mine of *Phyllocnistis* (U.S. National Museum specimen 208538). (B) Leaflet of the living species *Cedrela mexicana* included for comparison. [Photograph by James P. Ferrigna, Division of Paleobotany, Smithsonian Institution]

Lepidoptera and plant hosts. Finally, the presence of this pair of forms now restricted to the tropics and subtropics reinforces the impression from the total Wind River flora (*15*) that this area of the central Rocky Mountains was subject to a humid, subtropical climate in the late early Eocene.

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Jupiter: Its Infrared Spectrum from 16 to 40 Micrometers

Abstract. *Spectral measurements of the thermal radiation from Jupiter in the band from 16 to 40 micrometers are analyzed under the assumption that pressure-broadened molecular hydrogen transitions are responsible for the bulk of the infrared opacity over most of this spectral interval. Both the vertical pressure-temperature profile and the molecular hydrogen mixing ratio are determined. The derived value of the molecular hydrogen mixing ratio, 0.89 ± 0.11, is consistent with the solar value of 0.86.*

The abundance of H_2 and He in the Jovian atmosphere has a direct influence on a number of astronomical problems. Jupiter's low atmospheric temperature and great mass prevent even the lightest atoms from escaping from the top of the atmosphere. Therefore, Jupiter as a whole is a sample of the elemental abundance at the time of the formation of the planet. Modern theories of explosive nucleosynthesis show that most of the He presently in the universe was formed during the Big Bang (*1*). Further, it has been shown that the relative abundance of H_2 and He depends strongly on the temperature and density during the early stages of the evolution. To the extent that the Jovian atmosphere is representative of the planet as a whole, a measure of the H_2 mixing ratio $\alpha_{H_2} = N(H_2)/[N(H_2) + N(He)]$, where $N(x)$ is the number density of x in the atmosphere, is useful for the determination of the conditions during the early stages of the Big Bang. There are, however, several effects which may systematically distort the atmospheric value of α_{H_2}.

Opik has suggested a model for the formation of Jupiter in which first "hydrogen snow" collects to form a core and then a He-rich atmosphere is captured (*2*). Salpeter has suggested that there may be internal differentiation with the He sinking toward the center of the planet, resulting in a H_2-rich atmosphere (*3*).

We observed Jupiter on the nights of 14 November and 16 November 1973 and 21 January 1974, using a 31-cm telescope mounted on the National Aeronautics and Space Administration Ames Research Center Lear jet. The aircraft was flown to an altitude of 14 km (45,000 feet). At this altitude about 3 to 10 precipitable micrometers of water remain above the observer. The telescope viewed the source at elevation angles between 14° and 28°. The spectral scans were made with two different grating spectrometers cooled to liquid helium temperatures (*4*). These instruments employ an Ebert-Fastie spectrometer (12.5-cm focal length) with two detectors in the focal plane. Instrument 1 has a Ge : Cu photoconductor to scan the 16- to 28-μm band, and a Ge : Ga photoconductor covers the range from 20 to 40 μm. The resolution of the two channels is 0.5 and 1.0 μm, respectively. Instrument 2 has two Ge : Cu photoconductors and covers the range from 16 to 28 μm with a 2.7-mm entrance aperture corresponding to 4.7 minutes of arc. Jupiter had a diameter of about 0.5 minute of arc during the observing periods. The chopping frequency was 48 hertz.

We determined the instrumental response by normalizing spectra of the moon and Mars as if they were blackbody radiators at 350° and 240°K, respectively. The instrumental profile determined in this way is consistent with the laboratory profile and the absorption expected by the atmosphere. It was used to normalize the Jupiter data. The resulting spectrum (Fig. 1a) shows the presence of three absorption features at 18, 23.5, and 28 μm. The first and last are, respectively, the $J = 1$ and $J = 0$ rotational transitions of H_2. The 23.5-μm feature shown in Fig. 1a may be due to sulfur, silicate dust, or complex hydrocarbons in the atmosphere (*5*). However, recent data of greater resolution and signal-to-noise ratio indicates that the brightness temperature falls smoothly from a maximum at 21 μm to a broad minimum around 28 μm. The regions of the spectrum used to determine the ratio of H_2 to He are substantially unchanged. However, the reality of the 23.5 μm is somewhat in doubt. A discussion of all the observational data will be given by Pollack *et al.* (*6*).

The observed spectrum of Jupiter contains information about both a portion of its vertical temperature structure and its ratio of He to H_2. Before describing our numerical method for deriving this information, we describe the physical connection between these quantities and the observed spectrum. The brightness temperature found at a given wavelength is approximately equal to the value of the physical temperature in the Jovian atmosphere at an optical depth of unity. As the wavelength changes, the altitude at which the optical depth is unity also varies. Thus, spectral observations over a range of wavelengths provide information on the temperature conditions over a corresponding range of altitudes in the atmosphere. For the spectral band measured, H_2 is the principal source of opacity. The Jovian atmosphere is probed from pressures of about 0.15 to 0.6 atm, a region which includes a temperature minimum and the top of the convection zone.

In carrying out the analysis described below, we excluded data close to the 23.5-μm feature. In addition to opacity due to the rotational and translational transitions of H_2, we allowed for opacity due to NH_3, which is important only at the long-wavelength edge of our data. We carried