sive sequences. In Alabama (*17*) and Georgia (*12, 18*), opaline claystones are overlain by regressive sand units which complete the record of what may be considered classic transgressive-regressive depositional cycles.

Our evidence makes it necessary to revise presently accepted paleoenvironmental interpretations and models of Eocene coastal lithofacies. For instance, Reynolds' (*2*) proposal of restricted back-bay coastal lagoons as sites of cristobalite deposition is incompatible with the open marine environment we demonstrate. His model of direct chemical precipitation of cristobalite from circulating bottom waters, therefore, is invalid and unnecessary in view of the fact that the immediate silica source was diatomite rather than volcanic ash. Similarly, the Twiggs Clay of Georgia should be considered not a regressive unit composed of detrital clastics (*18*) of a deltaic complex (*19*) but rather a diatomaceous member of a transgressive sequence which also includes the time-equivalent outer shelf marls and limestones illustrated by Carver (*12*) in his figure 3. We believe such reinterpretations will aid (i) location of additional deposits of economically important fuller's earth in the coastal plain and (ii) more faithful reconstruction of Eocene paleoenvironments of deposition in the western Atlantic-Caribbean area.

With respect to the source of the diatomite deposits, profuse blooms of siliceous plankton along the continental shelves at various times during the Eocene could have been stimulated by nutrients supplied by favorable ocean current systems. Ramsay (*20*) presents a paleocurrent model which explains high Eocene siliceous plankton productivity not only in the Gulf of Mexico and Caribbean but also in the North Atlantic where the horizon A cherts formed. Our data, which include a failure to detect textural or structural features that would suggest ash deposition, are compatible with Ramsay's model. Some zeolites do occur in Eocene coastal plain deposits, and these may owe their origin to the deposition of various types of volcanic ash; nevertheless, these ashes were certainly not as volumetrically important as mineralogists (*1, 2, 10*) have suggested. Any ash deposition was apparently incidental to rather than causative of a general pattern of biogenic silica deposition (*21*), as indicated by the fact that the times of formation of the Paleocene Grampian Hills member of the Nanafalia formation and of the Upper Eocene Twiggs Clay (15 m thick) are not coincident with the schedule of rhyolitic volcanic activity in the Caribbean defined by Gibson and Towe (*1*) and Mattson and Pessagno (*3*). We conclude, therefore, that the opaline claystones of the coastal plain, which are all essentially identical in hand specimen, mineral content, and microstructure, owe their unusual character to a biogenic mode of deposition.

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21. Gibson and Towe's interesting suggestion (*1*) that rhyolitic volcanic activity could possibly stimulate high productivity of siliceous plankton in deep-sea areas has yet to be substantiated by independent evidence. Nevertheless, any such activity on a regional scale in the Caribbean, even if it did somehow serve as a stimulus, would be entirely inadequate to account for the extensive Eocene chert deposits which have now been encountered by the Deep Sea Drilling Project in the Pacific, Indian, and Southern ocean basins as well as in the Atlantic and Caribbean.
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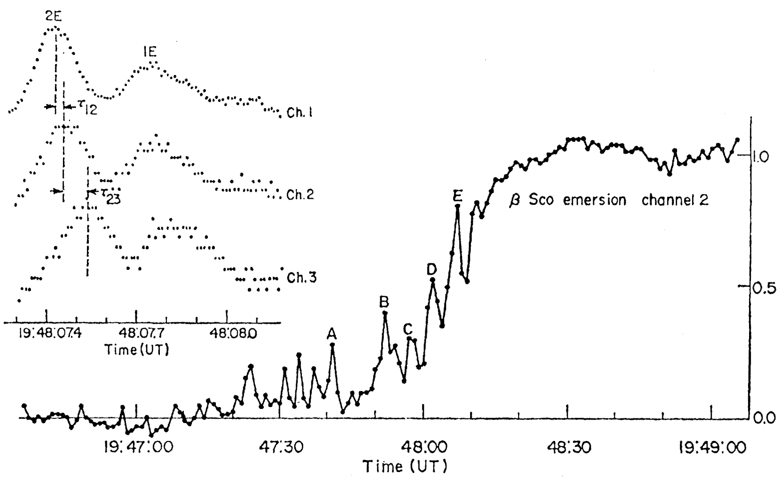
21 December 1973

Jovian Atmosphere: Structure and Composition between the Turbopause and the Mesopause

Abstract. *The occultation of the star Beta Scorpii by Jupiter was observed at high time resolution in three wavelength channels. The results imply a temperature of 220°K at an altitude in the Jovian atmosphere corresponding to 10^{14} molecules per cubic centimeter, and temperature fluctuations of 2° to 10°K over vertical scales of 2 to 10 kilometers. They suggest that the vertical eddy diffusion coefficient near the turbopause has a lower limit of 7×10^5 square centimeters per second, and that the turbopause lies above the altitude where the density is 5×10^{13} molecules per cubic centimeter. Below the turbopause, the ratio of hydrogen to helium is consistent with cosmic abundances.*

On 13 May 1971, the planet Jupiter occulted the multiple star system Beta Scorpii. The visual magnitude of Beta Scorpii A is 2.76, and an occultation of so brilliant a star by Jupiter is estimated to occur once every 10^3 years (*1*). We observed the occultation event with the 152-cm Rockefeller reflector of Boyden Observatory (Bloemfontein, South Africa), with a three-channel photometer having the following central wavelengths: channel 1, 3530 Å; channel 2, 3934 Å; channel 3, 6201 Å. The time resolution of the observations was 0.01 second. A detailed description of the instrumentation has been published elsewhere (*2*). While the occultation event was widely observed



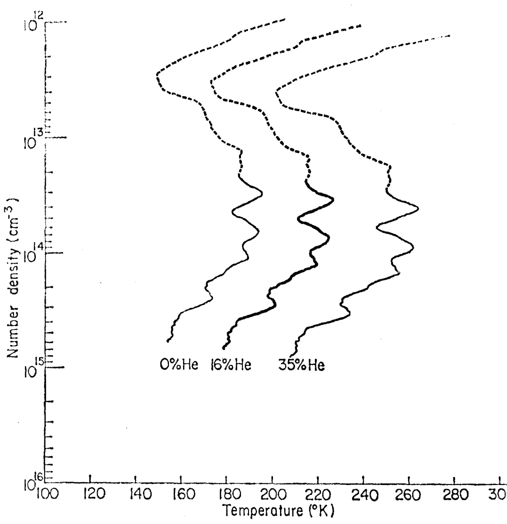


Fig. 1 (left). Light curve for the emersion of Beta Scorpii (β *Sco*) at a time resolution of 1.0 second. The unit level is determined by setting the star's full intensity equal to one. Some of the prominent spike groups are labeled. (Inset) Records of spike group E at high time resolution (0.01 second). The time delays (τ_{12} and τ_{23}) between spike arrival in the different channels are caused by differential refraction in the Jovian atmosphere. Fig. 2 (right). Temperature profiles derived from the channel 2 data for three assumed compositions of the Jovian atmosphere, spanning the range deduced from these observations. As explained in the text, the upper portions of the profiles, shown dashed, are uncertain. The wiggles in the profiles correspond to spikes in the light curve.

(*3*), no other observations were performed either at several wavelengths or with high time resolution. Both immersion and emersion were observed.

Figure 1 shows the channel 2 emersion observations, which are marked, even at the 1-second time resolution shown, by very high amplitude spikes. These spikes are intrinsic to the Jovian atmosphere and are not due to detection system noise or to scintillation in the earth's atmosphere. The clearest evidence for this is the fact that the spikes occur in all three channels, but are systematically displaced in time as a function of channel wavelength (Fig. 1, inset). This result is consistent with dispersion physics, and can be used to deduce the variation of the real part, n_r, of the refractive index of the Jovian atmosphere with wavelength, and thereby to extract compositional information. Likewise, the general shape of the ingress and egress curves can, through the physics of differential refraction in a planetary atmosphere, be deconvolved to derive the refractivity ($n_r - 1$) as a function of altitude (*4*). With an estimate of composition, the refractivity curve can be converted (*4*) into a relation between temperature, T, and number density, n.

While a few spikes have greater peak intensity than the unocculted star, showing that ray crossing occasionally occurs, such instances are rare. We will in general assume that the spikes are due to vertical density layering. More particularly, the spikes may be due to the upward propagation of gravity waves, or perhaps to atmospheric scintillation on Jupiter. In the earth's atmosphere such vertical density layering apparently ceases above the turbopause, and this can be understood in terms of the physics of gravity wave propagation (*5*).

Since spikes are observed at least as high as $n = 5 \times 10^{13}$ cm^{-3} (Fig. 2) we deduce that the turbopause lies above this level and that the vertical eddy diffusion coefficient $K_v \geqq 7 \times 10^5$ cm^2 sec^{-1}. Wallace and Hunten (*6*) derived an upper limit $K_v \leqq 10^6$ cm^2 sec^{-1} from rocket observations of the Lyman-alpha brightness of Jupiter. However, recent Pioneer 10 measurements (*7*), performed with much superior angular resolution, imply a substantially lower brightness and a correspondingly higher and less restrictive upper limit on K_v.

A numerical inversion of the light

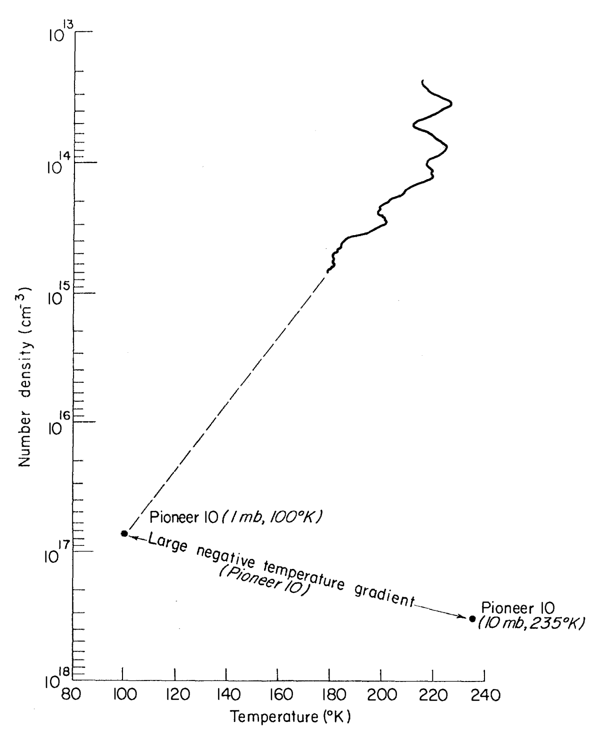


Fig. 3. Comparison of the Beta Scorpii results for 16 percent helium with preliminary Pioneer 10 S-band occultation measurements (*16*). Two Pioneer 10 points are shown (heavy dots); between them a large negative temperature gradient was observed. The dashed line represents a linear extrapolation of the Beta Scorpii results; the extrapolation proves to be consistent with both data sets, and represents a very rough measure of the atmospheric profile near the Jovian mesopause.

curves, in which the information contained in the spikes is preserved, has been carried out (*2*). The resulting plot of n versus T, for three assumed values of the hydrogen-to-helium ratio blanketing the expected range (see below), is shown in Fig. 2 for emersion. Our emersion observations correspond to a Jovian latitude of 58°S at a time just after local sunrise. The upper or dashed portions of these curves are entirely unreliable, and reflect the distance for the solutions to converge depending on the initial assumed boundary conditions (*4*). Within the errors of observation the results shown in Fig. 2 are consistent with ingress and egress observations on all channels. The results are reliable between 10^{15} cm^{-3} and almost 10^{13} cm^{-3}.

From the time delay of spikes in the three channels and the shape of the light curves, we are able to determine the composition of the Jovian atmosphere in this density range, assuming it is well mixed—that is, assuming that our observations apply to the region below the turbopause (*8*). We also assume that the atmosphere at this level is composed only of hydrogen and helium. The refractivities, spectroscopic abundances, and vapor pressures of all other plausible constituents show them to make a negligible contribution. A careful error analysis gives a ratio of refractivities in emersion channel 3 to emersion channel 2 of 0.9713 ± 0.0015. From the best available laboratory and quantum theoretical estimates of the refractivity of H_2 and He (*8*) the derived mean molecular weight is $2.32^{+0.30}_{-0.32}$, which corresponds to a helium fraction by number of $0.16^{+0.19}_{-0.16}$. The errors correspond to 1 standard deviation. Our compositional results are consistent with spectroscopic limits on helium on Jupiter (*9*), with solar spectroscopic ratios (*10*), with solar wind ratios (*10*), and with the expectations from big bang nucleosynthesis (*11*). They are inconsistent with the results deduced from the earlier occultation of Sigma Arietis by Jupiter (*12*), with the results of some lower quality observations of the Beta Scorpii event (*13*), and with inhomogeneous accretion models of Jupiter in which a massive accretion of helium occurs around a hydrogen core (*14*).

Between 10^{13} and 10^{14} cm^{-3} the atmosphere appears to first order to be isothermal, although the spike-related temperature fluctuations of 2° to 10°K are real. At altitudes below 10^{14} cm^{-3} a positive temperature gradient is indicated. Recent theoretical models of the Jovian thermosphere and mesosphere put the mesopause within an order of magnitude of the 10^{14} cm^{-3} level (*15*), that is, within the range of our measurements. However, from our measurements combined (Fig. 3) with preliminary Pioneer 10 results (*16*), it appears likely that the temperature minimum occurs at lower altitudes, somewhere between 10^{16} and 10^{17} cm^{-3}.

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Purgatorius, an Early Paromomyid Primate (Mammalia)

Abstract. *Fragmentary mandibles of* Purgatorius unio *Van Valen and Sloan from the Puercan (approximately early Paleocene), Garbani Locality, Montana, preserve associated postcanines. Their morphology indicates that this mammal was an early paromomyid primate and suggests that primate ancestry does not include currently known members of the palaeoryctid and leptictid Insectivora or of the Condylarthra.*

For many years the oldest records of Primates were from Torrejonian (approximately middle Paleocene), North American localities. In 1965 *Purgatorius* (*1*) was described and its species, Puercan *P. unio* and latest Cretaceous *P. ceratops*, greatly extended the order's paleontostratigraphic range. *Purgatorius unio* has been known hitherto from about 50 isolated teeth found at the type locality, Purgatory Hill, McCone County, Montana. *Purgatorius ceratops* is represented by an isolated, lower molar found at Harbicht Hill, McCone County. Because of this limited and fragmentary sample, problems inherent to identification of isolated teeth, and dental similarities to contemporaneous condylarths, the phylogenetic relationships of *Purgatorius* have been debated (*2*).

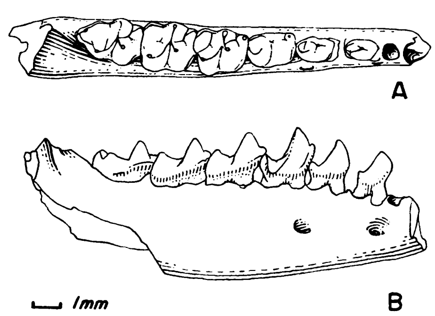

Fig. 1. *Purgatorius unio* (specimen UCMP 107406). (A) Occlusal and (B) labial views of right mandible showing alveoli of the canine (posterior rim) and P_1, and P_2 to M_3.

The postcanine dentition of *P. unio* is now additionally documented by 13 dentulous, fragmentary mandibles, a fragmentary maxillary, and more than 50 isolated teeth from the Garbani Locality, about 30 km north of Jordan, Garfield County, Montana, and about 80 km west of Purgatory Hill (*3*). This site, discovered by paleontologists from the Natural History Museum of Los Angeles County, is now being studied jointly with members of the