Reports

Delaware River: Evidence for Its Former Extension to Wilmington Submarine Canyon

Abstract. *Seismic-reflection profiles indicate that during the Pleistocene the Delaware River flowed across the continental shelf east of Delaware Bay and emptied into Wilmington Submarine Canyon. The ancestral valley (width, 3 to 8 kilometers; relief, 10 to 30 meters) is buried, is not reflected in the surface topography, and probably predates the formation of the present canyon head.*

During times of lowered sea level, the rivers along the east coast of the United States flowed across the subaerially exposed continental shelf. The ancestral channels of these rivers were subsequently buried or partially obliterated by erosion during sea-level transgressions. As a result, only a few channels have been traced across the shelf. For the area between Cape Cod and Cape Hatteras, these include Block Channel (*1*), Hudson Channel (*2*), and Great Egg Channel (*3*). The former path across the shelf of one of the largest rivers in this area, the Delaware, has not been defined.

Until now, the location of the ancestral Delaware River valley has not been known with certainty. On the basis of the bathymetry, it has been suggested that the Delaware River once flowed southeastward across the shelf and emptied near or between Baltimore Canyon and Washington Canyon (*4*). However, recently reported seismic-reflection profiles of the inner shelf (*5*) show that the ancestral valley is buried and lies north of the bathymetric channel off the mouth of Delaware Bay. The study reported here extends the inner-shelf survey and shows that the Delaware River also traversed the middle and outer shelf and flowed into Wilmington Submarine Canyon.

We collected seismic-reflection profiles along 1400 km of track line between the seaward limit of the inner-shelf survey and the shelf edge during cruises of the R.V. *Mt. Mitchell* in 1974 and the R.V. *Atlantis II* in 1975 (Fig. 1). The 3.5-khz, Uniboom (400- to 4000-hertz band pass), and Sparker (180- to 420-hertz band pass) acoustic systems were used during the study. Navigational control for all track lines was provided by Loran-C.

Eleven crossings (either complete or partial) define the path of the buried valley across the middle and outer shelf (Fig. 1). The valley trends southeastward to a water depth of about 40 m and then proceeds toward the east to the head of Wilmington Canyon. It is sinuous along the easternmost part, but the actual number of meanders cannot be determined from the data available at present.

The characteristics of the valley differ between the middle and the outer shelf. Across the middle shelf (Fig. 2, profiles 1 through 8), the valley has a broad flat bottom, a width of 4 to 8 km, a relief of 10 to 15 m, and a gradient of less than 0.03°. Across the outer shelf, the valley is more V-shaped in profile, is narrower (3 to 4 km wide) and deeper (relief, 30 m), and has a steeper gradient (0.09°) (Fig. 2, profiles 9 through 11). Between profile crossings, the thalweg consistently increases in depth. A large buried trough underlies the valley near the head of Wilmington Canyon (Fig. 2, profile 11).

The trend, size, shape, and gradient of the valley suggest that it comprises a single drainage system. In particular, the change in gradient between the middle and outer shelf parallels a change in the regional dip of the shelf as deduced from other subbottom reflectors in the area.

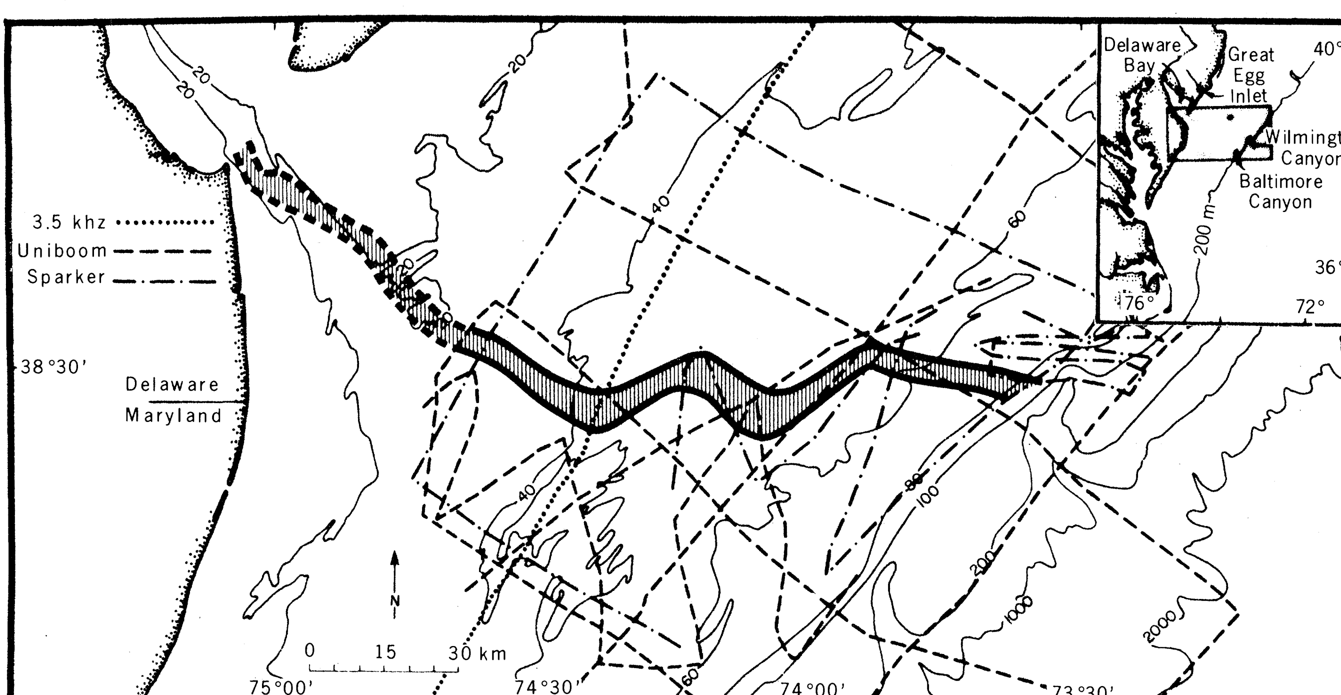

Fig. 1. Trace of the ancestral Delaware River valley (hatched) across the continental shelf, including bathymetry (*9*), cruise tracks, types of seismic profiles, and index map. The dashed part of the valley trace was inferred from (*5*). Depth contours are in meters.

Differences in the size and shape of the valley may be consequences of this change in gradient. Our profiles do reveal another buried valley to the north that coincides with the trace of the Great Egg Channel between Great Egg Inlet and Wilmington Canyon (*3*) and that intersects the ancestral Delaware River valley at a water depth of about 55 m. At the confluence of the two valleys, the Great Egg Channel is 30 to 50 m shallower than the Delaware River valley.

The gradient of the former Delaware River valley is similar to that of other buried valleys. Both Hudson Channel (*2*) and Great Egg Channel (*3*) have average slopes of 0.05° or less. An increase in gradient across the outer shelf was also noted for Hudson Channel (*2*).

The ancestral Delaware River probably contributed to the development of Wilmington Canyon. The canyon may have been eroded or modified by the downslope movement of fluvial detritus when the river debouched into the canyon head. At that time, however, the head of the canyon may have extended to the west rather than to the north, as it does now. This alteration in direction is indicated by the fact that the trend of the ancestral shelf valley is perpendicular to the trend of the present canyon head (Fig. 1) and by the presence of the large buried trough that underlies the valley near the canyon (Fig. 2, profile 11). Faulting (*6*), canyon-head erosion (*2*), and changes in sediment supply may have subsequently altered the canyon morphology.

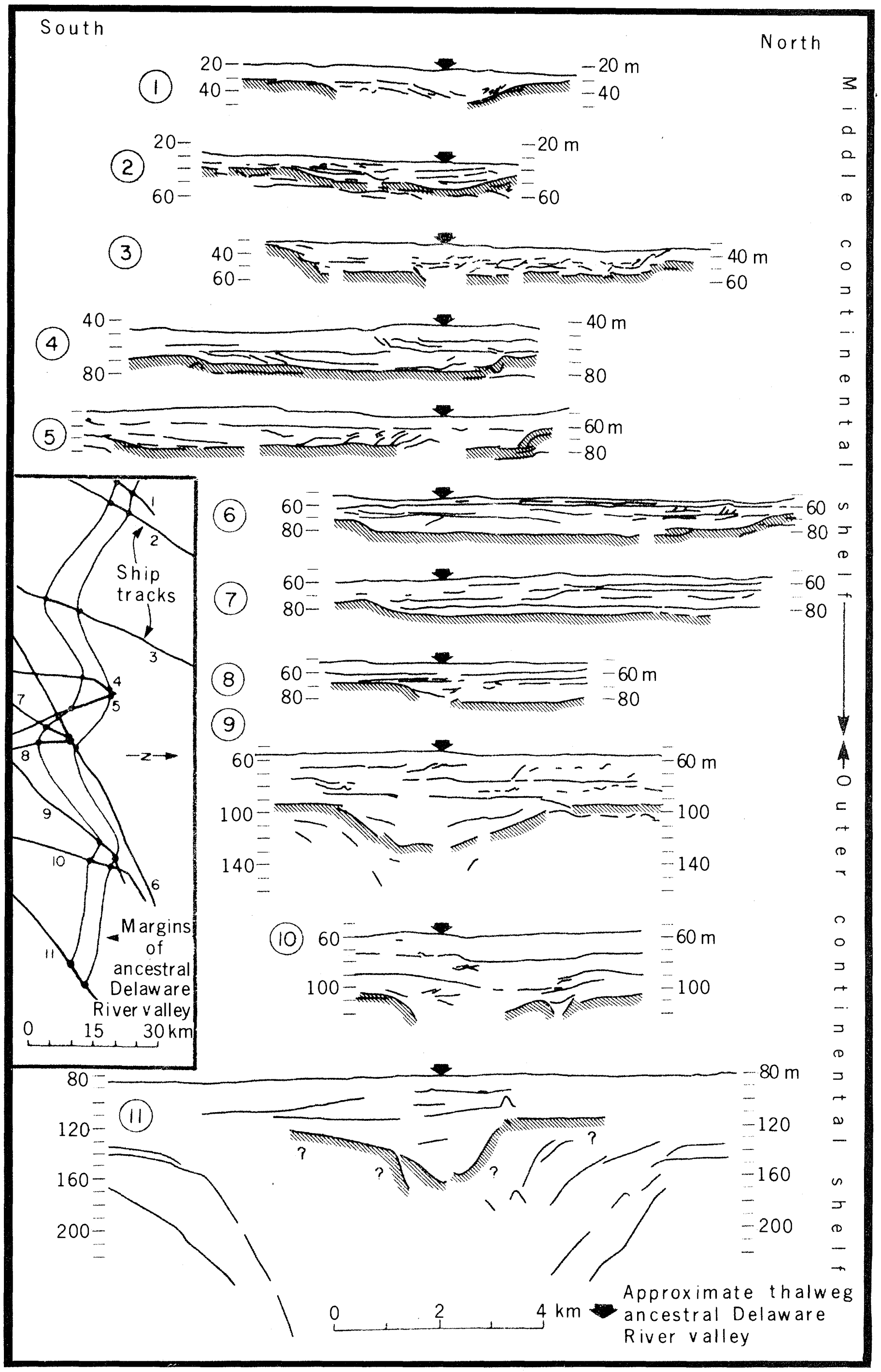

Fig. 2. Line drawings of 11 selected acoustic profiles across the ancestral Delaware River valley. Profiles have been adjusted to the same horizontal scale, have a vertical exaggeration of about 25:1 (assuming a sound velocity in the sediments of 1500 m/sec), and do not show variations in the intensity of the reflectors. The depth in meters below the sea surface is shown at the ends of each profile. Locations of the profiles along the valley trend are shown on the index map. Hatched lines outline the valley floor in the cross sections.

The valley may have formed during the late Pleistocene. If the valley resulted from the southward redirection of the ancient Schuylkill River (*7*) when Great Egg Channel was abandoned (*3*), then the ancestral Delaware River valley probably is younger than the early Pleistocene. That the valley is younger than Great Egg Channel is supported by the absence of depressions within the sediments 30 to 50 m above the floor of the Delaware River valley at the confluence of the two channels on the outer shelf. When the valley formed, sea level was 120 to 160 m lower than it is now (Fig. 2, profile 11). A wave-cut bench has been observed in the Wilmington Canyon area at water depths of 128 to 146 m (*6*). This bench has been interpreted as the 35,000-year-old Nichols shoreline (*8*).

The results presented here support the contention by Belknap *et al.* (*5*) that tracing former fluvial valleys from the present bathymetry on the shelf can be misleading. Our profiles show that the trace of the ancestral Delaware River valley is not reflected by the modern bathymetry of the middle and outer shelf.

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Occultation of ϵ Geminorum by Mars: Evidence for Atmospheric Tides?

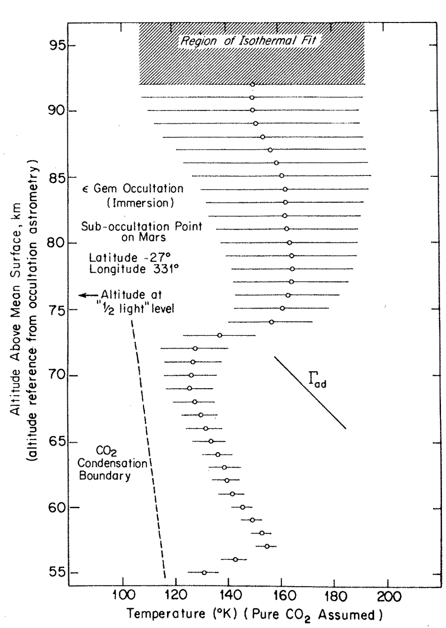
Abstract. *Temperature profiles of the martian atmosphere have been derived from airborne observations of the 8 April 1976 occultation of ϵ Geminorum. Within the altitude range from 50 to 90 kilometers, these profiles show peak-to-peak variations of 35°K with a vertical scale of 20 kilometers and represent evidence for strong tides in the martian atmosphere. However, more information is necessary to conclusively rule out a radiative explanation for the temperature variations.*

The martian occultation of ϵ Geminorum (visual magnitude = +3.1, spectral class G8Ib) on 8 April 1976 was observed with the 91-cm telescope aboard the National Aeronautics and Space Administration Kuiper Airborne Observatory, the first occultation observations made with this facility (*1*). High-quality light curves for both immersion and emersion were obtained simultaneously at three wavelengths (0.37, 0.45, and 0.75 μm) with a time resolution of 4 msec. A similar occultation of β Scorpii by Jupiter on 13 May 1971 yielded temperature and number density profiles of the jovian atmosphere (*2*), as well as a measurement of its He abundance (*3*). From our ϵ Gem occultation data we have obtained temperature, pressure, and number density profiles of the martian atmosphere and information about its composition from a differential refractivity measurement. Our result indicated that no more than 30 percent Ar (and N_2) is mixed with pure CO_2 (*4*) and is consistent with the low abundance of Ar and N_2 obtained by the Viking entry probe (*5*). In addition, we have obtained the wavelength dependence of the extinction of the martian atmosphere from the first observation of the central flash—a bright feature in the light curve that was recorded when ϵ Gem was aligned with the center of Mars (*1*). We report here the temperature profiles deduced from the occultation data, which were obtained above the martian coordinates 27°S, 331°W (immersion) and 28°N, 152°W (emersion) and cover an altitude range of about 50 to 90 km above the mean surface. These results are compared with those of Viking 1 (*5*) and with theoretical predictions of thermally driven tides in the martian atmosphere (*6*). The details of our observations, data analysis procedures, and other results are given elsewhere (*4*).

Temperature profiles were obtained from the occultation light curves with a new inversion procedure (*7*). This method is mathematically equivalent to standard inversion techniques (*2, 8*) but has the advantage that error bars (calculated from the known noise in the light curve) can be assigned to the temperature profiles. Thus we can have confidence in separating those features in the temperature profiles that are caused by the martian atmosphere from the variations arising from the noise in the light curve.

The temperature profiles obtained are given in Figs. 1 and 2. The profiles are for the light curves at 0.45 μm, the channel with the best signal-to-noise ratio; the profiles from our other two channels agree within their errors. The upper boundary condition for the inversion is determined by an isothermal fit to the upper part of the light curve, indicated by the shaded region at the top of Figs. 1 and 2. The temperatures and their error bars are obtained from the inversion calculation matched to the boundary condition. For each temperature point the error bars represent ± 1 standard deviation expected from the noise in the light curve. Neighboring temperature points agree better than the error bars because the noise affecting the points is correlated (*7*). The inversion calculation is terminated when the uncertainty in the lower base line of the light curve produces an error as large as the random error.

Both the immersion and emersion profiles show peak-to-peak temperature variations of 35°K, much larger than variations expected from random noise. Temperature maxima occur at an altitude of about 55 to 60 km on both profiles. The mean temperature of the emersion profile is somewhat warmer than the mean



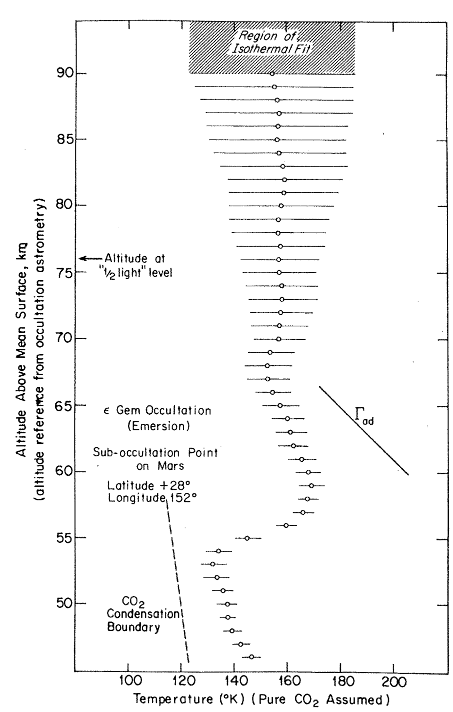


Fig. 1 (left). Temperature profiles for immersion. The plotted points and their error bars were obtained from the immersion light curve for a pure CO_2 atmosphere. A correction for the small amount of N_2 and Ar present would lower the temperatures about 3°K. The uncertainty in the altitude scale is ± 5 km, and an altitude of 65 km corresponds to a number density of 2.0×10^{14} cm^{-3}. The shaded region represents the uncertainty in the temperature obtained from the isothermal fit used to establish the boundary condition for the inversion calculation. The largest temperature gradients are subadiabatic ($\Gamma_{ad} = -5$°K km^{-1}). The wavelike structure strongly suggests the presence of tides in the martian atmosphere. At the time of the occultation, the martian subsolar latitude was + 19.2° and the planetocentric longitude of the sun (L_s) was 51.6°. Immersion occurred above the suboccultation point on Mars at about 0330 local solar time. Fig. 2 (right). Temperature profile for emersion, which occurred above the suboccultation point on Mars at about 1530 local solar time. For details, see the legend for Fig. 1.