The age measured by Berger's group is 5080 ± 60 years. This result differs from ours by 820 years, about 1 standard deviation. The significance of the agreement is not in the accuracy of the cyclotron result, which does not compare with that attained by the standard decay-dating approach. For large samples that are not many half-lives old, the cyclotron technique may never match the accuracy obtainable by present radiocarbon laboratories. However, less than 150 mg of carbon was used in the measurement and most of this was used in the flushing of the manifold between sample changes; we anticipate that the amount of carbon used can be reduced by another order of magnitude. The ability to use small samples should greatly simplify the problems of selecting samples uncontaminated by recent carbon, and of dating objects too small or valuable to allow the extraction of the 1 to 10 g of carbon required in the past. If the background ^{14}C can be removed, either from the use of an external ion source or from the construction of a "clean" cyclotron, then it is possible that the full predicted sensitivity of the cyclotron technique will be achieved: 40,000 to 100,000 years for 10- to 100-mg carbon samples.

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4. Our results, including a promise to publish them, were mailed to R. Berger, W. R. Libby, and H. E. Gove on 13 December 1977, the day before we learned the date obtained by Berger's group. This report, except for the final paragraph, was written before we knew Berger's date. The need for taking such precuations is clearly expressed in F. G. Dunnington's description of his measurements of *e/m* for the electron [*Phys. Rev.* **52**, 475 (1937)].
5. We report the data in "radiocarbon years," using the standard lifetime for ^{14}C of 5570 years. The best modern estimate for the half-life is 5730 years [H. Godwin, *Nature (London)* **195**, 984 (1962)].
6. In (*3*) the group at the University of Rochester estimated the age of their Mount Shasta sample to be 5700 ± 400 years. The age measured by the U.S. Geological Survey, using decay dating, was 4590 ± 250 years, which differs from the Rochester date by about 1100 years.
7. We are grateful to R. Berger and W. R. Libby for their support and encouragement, and for supplying the blind sample. We have received important help in this work from L. W. Alvarez, H. Weiman, G. Wosniak, W. Erwin, L. Archambault, H. Dougherty, J. Yamada, and the staff of the 88-inch cyclotron at the Lawrence Berkeley Laboratory. This work was supported by the Department of Energy.

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Devonian Brachiopods from the Sillimanite Zone, Mount Moosilauke, New Hampshire

Abstract. *Devonian brachiopods, identifiable at the generic level, have been recovered from calc-silicate rocks more intensely metamorphosed and metasomatized than any other known fossil occurrence. The fossils are a key stratigraphic link between granulite facies rocks of central New Hampshire and fossiliferous rocks of western New Hampshire and Maine.*

Devonian brachiopods have been found in the sillimanite zone of the Littleton Formation, Mount Moosilauke, New Hampshire. The fauna is remarkably well preserved so that identification at the generic level is possible. The specimens are unique in that they have been metamorphosed at higher temperatures and have been subjected to more intensive metasomatism than any other known regionally metamorphosed fossils.

The fossils are significant because they paleontologically confirm Billings' (*1*) assignment of rocks of the Mount Moosilauke septum to the Devonian Littleton Formation. Furthermore, the brachiopods are a key stratigraphic link between the essentially unfossiliferous granulite facies metamorphic rocks of central New Hampshire and the fossiliferous Siluro-Devonian sections of western New Hampshire and Maine.

Generically identifiable brachiopods and a coral of late Early Silurian age have been reported from the sillimanite zone near Claremont, New Hampshire, 80 km south-southwest of the locality of the new discovery (*2*). The locality of the earlier recovery lies along the boundary between the staurolite-kyanite and sillimanite zones (*3*), presumably within the lower sillimanite zone. The fossils are preserved as coarsely crystalline calcite in a matrix consisting of quartz, diopside, grossular, and hornblende (*2*). The rocks of the older locality were metamorphosed at a lower temperature but higher pressure and have been less intensely metasomatized than the newly discovered fossils.

The fossils are located in the cascades of Beaver Brook, on the southwestern wall of Kinsman Notch, Mount Moosilauke 7-$^1/_2$′ quadrangle in New Hampshire. The bed of fossils (5 to 10 cm thick) is the innermost layer within a banded, tan or pink, calc-silicate unit (20 to 30 cm thick) that is interbedded with gray mica schist. The shells are aligned parallel to the bedding of the rock, are thoroughly disarticulated, little sheared, and unbroken. The rocks containing the fossils were correlated by Billings (*1*) with the Littleton Formation. The contact between the Littleton Formation and the Kinsman Quartz Monzonite is located 200 m east of the fossil locality.

The fauna recognized in the initial sample processed for fossils is as follows: *Acrospirifer* cf. *A. murchisoni; Leptocoelia* cf. *L. flabellites; Atrypa* cf. *A. "reticularis"; Leptostrophia* or *Protoleptostrophia* sp.; and a high-spired gastropod similar to *Loxonema*. The *Acrospirifer* is coarsely plicate and larger than similar-shaped spiriferids of Silurian age. *Leptocoelia sensu stricto* is known only from beds of Oriskany and Esopus age in the Northern Appalachians. *Atrypa* is not found in beds younger than early Late Devonian (Frasnian), nor earlier than late Lower Silurian (Upper Llandovery). Marine fossils of post-Early Middle Devonian (Onondaga, Eifelian) age are unknown in New England. Fossiliferous beds of Esopus age are rare in the Northern Appalachians, but beds of Oriskany age are widespread. Therefore, it is likely that the Beaver Brook fossils are of Oriskany age although an Esopus age cannot be ruled out.

The fossil shells consist of either calcite and quartz or wollastonite, calcite, and quartz. Impressions of the shells are composed of either grossular, diopside, and sphene, or grossular, diopside, sphene, and zoisite. The mica schists with which the fossils are interbedded contain the assemblage quartz–biotite–muscovite–andalusite–sillimanite (fibrolite)–staurolite (retrograde)–garnet–tourmaline–ilmenite (*4*). The Kinsman Quartz Monzonite is made of quartz–plagioclase (oligoclase–andesine)–potash feldspar–biotite–muscovite (*1*). Metamorphism of the fossils took place at a pressure of ≤3.8 kbar and a temperature of 625° ± 25°C; these conditions are estimated on the basis of the presence of the mineral assemblages listed above and their experimental calibration (*5*). Chemical metasomatism of the fossils included silicification of the shells during diagenesis or low-grade metamorphism followed by loss of CO_2 during high-grade metamorphism according to the reaction

$$CaCO_3 + SiO_2 = CaSiO_3 + CO_2$$

(calcite) (quartz) (wollastonite)

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The whole rock oxygen isotopic composition ($\delta^{18}O$) of the fossil bed varies from +11.83 to +12.13 per mil (*6*) along the outcrop length of the bed. Comparison of these values with those measured on unaltered or silicified Devonian brachiopods (*7*) shows that the fossils have been depleted by 12 per mil as a consequence of metamorphism.

The correlation by Billings (*1*) of the rocks of the Mount Moosilauke septum with the Littleton Formation was based, in part, on the identification of a brachiopod collected 5 km west of the Beaver Brook locality (*8*). The phyletic identification of the form has been questioned, however (*9*). The discovery of the Beaver Brook fossils and their stratigraphic age assignment completely confirms Billings' original correlation. The probable Oriskany age of the Beaver Brook fossils suggests that much of the Littleton Formation may be older than the Schoharie age rocks of the type area (*9*). The older age of the rocks in the Mount Moosilauke septum is compatible with what is known of lithostratigraphy in the Devonian of New England: the rhythmically banded and laminated clastic beds prevalent in the Mount Moosilauke septum are similar in appearance to those of the Oriskany age Sebomook Formation of northern Maine (*10*).

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11. We thank F. L. Steele, of the Society for the Protection of New Hampshire Forests, for permission to collect specimens. C. V. Guidotti discovered the fossils during a field trip led by D. Rumble. J. M. Stonehouse, G. Carlson, and F. S. Spear helped collect samples. One of us (A.J.B.) was supported by NSF grant DES74-22051 to Oregon State University.

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Fallopian Tube Isthmic Mucus and Ovum Transport

Abstract. *The oviduct isthmus is capable of transporting spermatozoa and ova in opposite directions. A column of tenacious mucus that occupies the lumen of the rabbit oviduct isthmus during estrus may permit sperm transport. After ovulation the mucus disappears, with subsequent efflorescence of cilia, which probably assist transport of ova to the uterus.*

Ovulation in the estrous rabbit normally occurs between 9.5 and 14 hours after coitus or the injection of exogenous luteinizing hormone (*1*). Ova reach the ampullary-isthmic junction (AIJ) less than 10 minutes after being released (*2*). Paralysis of the ampullary musculature with a β-receptor agonist has no effect on ampullary transit time (*3*), implying that cilia provide the most important propellant force. Spermatozoa, having begun to reach the ampulla well before ovulation, are present in large numbers by 10 hours after coitus (*4*). Fertilization normally takes place in the ampulla.

Whether or not fertilization has occurred, the ovum or zygote is delayed at the AIJ for 24 to 36 hours before entering the isthmus (*5*). The tubal isthmus, located between the site of fertilization and the site of implantation, needs the unique capability of effecting sequentially the transport of spermatozoa and ova in opposite directions. Progression of the egg along the isthmus is gradual and, although there is no evidence for any specific delay at the uterotubal junction, ova do not normally arrive in the uterus until 66 to 72 hours after ovulation (*5, 6*).

High doses of exogenous estradiol can prolong the delay at the AIJ (*5*), a process known as tube locking (*7*). In contrast, administration of progesterone 24 to 48 hours before ovulation accelerates ovum transport by reducing both the delay at the AIJ and isthmic transit time (*5*). The physiological basis for the isthmic delay is not known (*6, 8*). Adrenergic nerves supply the thick muscular wall of the isthmus (*9*) and it seems that both stimulatory (α) and inhibitory (β) adrenergic receptors are present (*10*). Exogenous estrogen increases the noradrenalin content in the oviduct, and, conversely, the tube-locking effect of estradiol may be overcome by the concomitant administration of an α-receptor blocking agent and progesterone (*11*). However, destruction of adrenergic nerves with 6-hydroxydopamine, depletion of noradrenalin with reserpine, or anatomical denervation have no deleterious effect on the reproductive capacity of the rabbit (*10*). It has therefore been concluded that the muscular activity of the oviduct has a minimal influence on isthmic ovum transport (*7, 10*).

Segments of oviduct isthmus were removed from eight normal adult New Zealand White rabbits and from five rabbits in which ovulation had been induced with human chorionic gonadotrophin (hCG). These segments were prepared for scanning electron microscopy by fixation with 3 percent glutaraldehyde, dehydration in acetone, critical-point drying with CO_2, and shadow-casting with gold. The appearance of ampullary and fimbrial mucosa from these rabbits is generally similar to that of the human fallopian tube (*12*), except for a greater predominance of ciliated cells in the rabbit, and cilia always appear prominent and erect.

When care was taken not to disturb the mucosal surface by, for example, excessive washing, oblique sections through the oviduct isthmus of the estrous rabbits revealed the presence of dense and tenacious mucus (Fig. 1A). This mucus typically obliterates the tubal lumen, but in areas in which it is absent secretory cells are conspicuous; they have tall distended apices bearing prominent microvilli, and often demonstrate apocrine secretory activity (Fig. 1B). The ciliated cells are indistinct; cilia droop randomly and may be caught in the strands of mucus.

Twenty-four hours after ovulation was induced with hCG (100 units, intravenously), much of the viscous mucus had disappeared. Previously agglutinated cilia were prominent and erect, and the apices of the secretory cells appeared sunken in comparison. In three rabbits in which progesterone was administered (2.5 mg in oil, intramuscularly) 24 hours before the hCG injections, a maneuver that accelerates isthmic ovum transport (*5*), the cilia were even more prominent, and ciliated cells dominated the isthmic mucosa (Fig. 1C). This situation was similar to that seen 48 and 72 hours after injection of hCG alone. In contrast, the isthmic mucosa of three rabbits injected simultaneously with estradiol cyclopentylpropionate (250 μg, intramuscularly) and hCG, a regime that causes tube locking (*5*), showed persistent secretory cell dominance and ciliary depression.

In 1958, Greenwald (*13*) demonstrated the prominence of rabbit isthmic ciliated cells 3 days after coitus by conventional

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