with a 5-W, continuous argon-ion laser. Only one fragment of the sanidine melted to a clear glass bead (93Z0406, Table 1). Nevertheless, radiogenic argon yields were appreciable (1.23×10^{-13} to 5.13×10^{-13} mol). Most fragments were heated with the laser for less than 1 s, but a few were heated for 5 min. Reheating of the sanidine (93Z0408 and 93Z0411, Table 1) showed that most of the argon was expelled during the initial 1-s heating episode. The neutron fluence within the radiation package was measured by the analysis of five to seven lots of sanidine crystals of each fluence-monitor packet. Each age determination of the sanidine from the M-1 core hole was made by the melting of single fragments (~0.3 mg). For additional internal calibration, 12 K-T boundary tektites from Beloc, Haiti, were irradiated in the same package, and they yielded a weighted mean age of 64.6 ± 0.1 Ma at the 95% confidence level for the standard error of the mean. This $^{40}Ar/^{39}Ar$ age is nearly identical to that of K-T tektites (64.5 Ma) reported in (*6*). The gas released from the samples was cleaned with Zr-Al and Zr-V-Fe getters, and the isotopic composition of the argon released was analyzed with an ultra-sensitive, rare-gas mass spectrometer. Ages were calculated with the use of the decay constants of R. H. Steiger and E. Jäger [*Earth Planet. Sci. Lett.* **36**, 359 (1977)].

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Mississippian Fossils from Southern Appalachian Metamorphic Rocks and Their Implications for Late Paleozoic Tectonic Evolution

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Fossils of *Periastron reticulatum* Unger emended. Beck recovered from the Erin Slate of the Talladega slate belt of Alabama establish that these rocks have a Mississippian (Kinderhookian-Tournaisian) age. The Talladega slate belt, the southwestern extension of the western Blue Ridge belt, was interpreted to have been affected by regional dynamothermal metamorphism and coeval deformation as a result of the Acadian orogeny. This fossil find indicates that metamorphism and deformation of the Talladega belt occurred after the Early Carboniferous (Alleghanian), requiring a reevaluation of tectonic interpretations of the southernmost Appalachians.

The Talladega belt is the westernmost crystalline thrust sheet in the southernmost exposed Appalachians and lies between the foreland fold-thrust belt to the northwest and the eastern Blue Ridge to the southeast (Fig. 1). Southeast-dipping, post-metamorphic fault systems form both upper and lower boundaries. Low-grade metasedimentary and metavolcanic rocks are interpreted to range from Late Precambrian to Devonian in age, on the basis of radiometric determinations and lithostratigraphic and biostratigraphic correlations with fossiliferous units in the foreland (*1*). Fossiliferous units include the Cambrian Jumbo Dolomite (*2*), the Silurian–Early Devonian Lay Dam Formation (*2*), the Early Devonian Jemison Chert (*2–4*), and the controversial Erin Slate that has been argued as either Early Devonian (*2*) or "probably Pennsylvanian" (*5*). Metasedimentary rocks in the Talladega belt contain no evidence of polymetamorphism (*6*). The time of dynamothermal metamorphism has been interpreted to be Devonian, coeval with Acadian orogenesis, on the basis of K-Ar whole rock ages on slate and the presence of an Early Devonian megafaunal assemblage from chert (Jemison Chert) near the stratigraphic top of the sequence (*6, 7*). An early 20th-century report of "probable" Pennsylvanian plant fossils from the Erin Slate (*5*), which overlies the Jemison, has been questioned because of the inability of subsequent investigators to replicate previous material. This inconsistency has led to the conclusion that these Carboniferous fossils are exotic (*2*).

In its type area, the Erin Slate is a variably deformed black slate that stratigraphically overlies the Cheaha Quartzite across a gradational contact and underlies the Chulafinnee Schist (Fig. 2). The upper contact with the Chulafinnee is interpreted as a thrust fault (*8*). The interpretation of the Erin-Chulafinnee contact as gradational and conformable; the discovery of the fossil *Veryhachium*, a long-ranging (Silurian to Carboniferous) marine acritarch from the Erin Slate; and the correlation of the Chulafinnee with the Jemison Chert (*9*) have

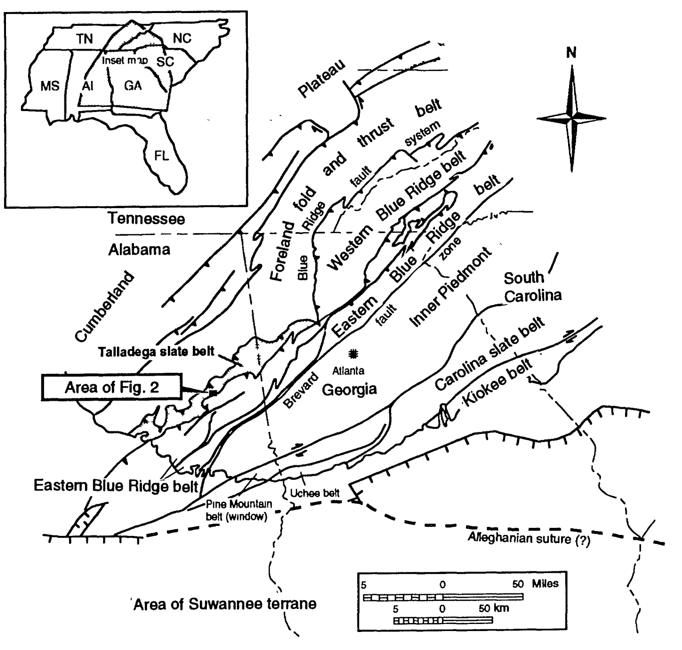

Fig. 1. Generalized tectonic map of the southern Appalachians [modified from (*8*) and (*29*)].

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led to the hypothesis that the age of the Erin is Silurian to Early Devonian (*10*).

Within the last 5 years, six well- to poorly preserved fossil plant specimens have been collected from two localities in the Erin Slate (Fig. 3) (*11*). The specimens occur in "concretions, usually lens shaped" (*5*), as noted by earlier workers. The fossils have various orientations within the phyllite matrix, are smooth or slightly textured, range from nearly circular to fusiform in the shape of their transverse section, and rarely possess the metamorphic foliation of the matrix. Most fossils are carbonaceous; samples are overmature (Rock-Eval Pyrolysis S2 peaks are absent), and organic carbon ranges from 1.79 to 2.32% (*12*).

Two well-preserved specimens (Fig. 4) (*13*) have been identified as *Periastron reticulatum* Unger emend. Beck (*14*). Several other specimens contain only the more resistant cortex and are probably of the same taxon. The anatomy of *Periastron* is unique in the paleobotanical record. Plant axes are characterized by a more or less median row of vascular bundles, variable in number, that lie in a plane approximately parallel to the transverse axis of elliptical specimens. The cortex contains conspicuous aerenchyma and longitudinal lacunae (air chambers), whereas the outer cortex consists of sclerenchymatous tissues in which secretory ducts are embedded (*14*). Plant axes are believed to represent petioles, although one of the specimens (121388.1) appears to be a main axis (Fig. 4B) with a divergent lateral petiole bearing the characteristic *Periastron* anatomy (Fig. 4C).

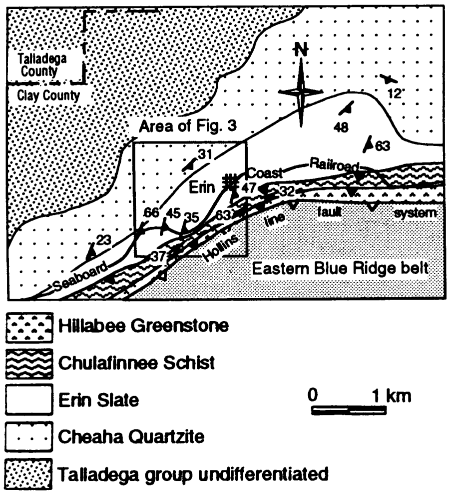

Fig. 2. Geologic map of a northwestern part of Clay County, Alabama, where the Erin Slate outcrops. Numbers indicate depth of cleavage. Open triangles, Hollins line fault. Closed triangles, other faults.

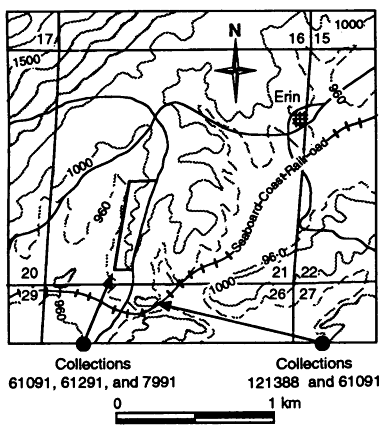

Fig. 3. Locality map with collection sites indicated where permineralized plant axes of *Periastron* have been collected (NE1/4, NW1/4, sec. 28, T19S, R7E, Clairmont Springs 7.5-min quadrangle). Contour measurements are given in feet.

The biostratigraphic age of *Periastron* is restricted. It is known from the Lower Carboniferous (Tournaisian TN1–TN2) (*14, 15*) Unterculm at Saalfeld, Germany (*16*); the "Lydinnes" Formation (middle to upper Tournaisian) of the Montagne Noire, France (*17*); and the New Albany Shale (Kinderhookian) in Kentucky (*16*). An Early Mississippian age is assigned to the formation because of the presence of *Periastron* in the Erin Slate. This age is compatible with the microfossil assemblage (*10*), as well as the lycopsid cones described in the early twentieth century (*5*).

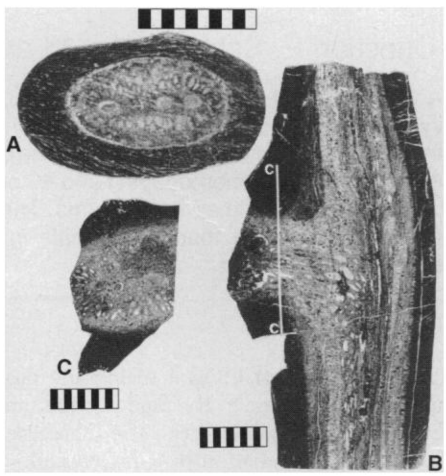

Fig. 4. (**A**) Transverse section of *P. reticulatum* Unger emend. Beck (specimen 61091.35) in which a medial row of four vascular bundles can be seen surrounded by aerenchymatous tissue and lacunae. (**B**) Median longitudinal section of a main axis of *P. reticulatum* (specimen 121388.1) in which a lateral axis can be seen to depart. Section C-C is illustrated in Fig. 4C. (**C**) Incomplete transverse section of the lateral axis of specimen 121388.1 containing four medially arranged vascular bundles. Two vascular bundles are conspicuous (on the left), and two additional vascular bundles occur to the right. The vascular bundle row is surrounded by aerenchymatous tissue and lacunae. A phyllitic matrix adheres to all axes. All scale bars are 10 mm.

On the basis of the megafloral assemblage described herein, prograde metamorphism and the attendant ductile deformation that affected the Talladega slate belt did not occur before the Early Mississippian. An upper age for this event is found in the subsurface to the southwest where the Talladega belt is truncated by Late Triassic graben-bounding faults (*18*). Although this evidence conflicts with previous interpretations of metamorphism and tectonism in the Talladega belt (*1*), it is not incompatible with reported radiometric ages from the belt that extend into the Early Mississippian (*7, 19*).

Our fossils provide additional evidence to support a more fundamental role than was previously thought for the Alleghanian orogeny in the western part of the southern Appalachians. Recent discoveries of Silurian to Early Carboniferous fossils in the western Blue Ridge have been used to support the lithostratigraphic correlations between the Talladega slate belt and the western Blue Ridge belt and indicate that metamorphism must be no older than Early Carboniferous (*20, 21*). However, the fossils from the western Blue Ridge are poorly preserved and have not been independently confirmed, and considerable debate exists as to the age range they represent (*22*). The Silurian to Early Carboniferous time frame is consistent with the time we propose for the Talladega slate belt. Recent $^{40}Ar/^{39}Ar$ dating of amphibolite-facies rocks of the central and eastern Piedmont of the southern Appalachians also indicates that large areas previously considered to have been affected by Taconic or Acadian metamorphism and deformation actually cooled below argon closing temperatures during the Carboniferous and Permian (*23, 24*) and may have been metamorphosed then.

Amphibolite-facies rocks of the southernmost Piedmont in Alabama and Georgia are the most proximal surface exposures to the proposed suture with Gondwanan crust of the Suwannee terrane (*18, 25*) (Fig. 1). Work has shown that these rocks attained amphibolite-facies conditions during the late Paleozoic (*26*). These data are consistent with interpretations of the timing of collision between the Suwanee terrane and ancestral North America (*24*). Seismic reflection data indicate a southeast dip for the suture in this region (*27*); therefore, the southernmost Alabama and Georgia Piedmont rocks occur in the footwall block to the suture. The apparently widespread nature of the Alleghanian event indicates that the Late Paleozoic was a time of major tectonometamorphism in the southeastern United States resulting from the final assembly of Pangea (*28*).

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12. Samples of organic-rich elliptical-elongate structures and carbonaceous rinds of permineralized plant fossils were analyzed by Rock-Eval pyrolysis at the Institut Français du Pétrole (IFP nos. 121388.1 and 121388.16; A. Y. Huc, written communication).
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Structure at 2.5 Å of a Designed Peptide That Maintains Solubility of Membrane Proteins

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A 24–amino acid peptide designed to solubilize integral membrane proteins has been synthesized. The design was for an amphipathic α helix with a "flat" hydrophobic surface that would interact with a transmembrane protein as a detergent. When mixed with peptide, 85 percent of bacteriorhodopsin and 60 percent of rhodopsin remained in solution over a period of 2 days in their native forms. The crystal structure of peptide alone showed it to form an antiparallel four-helix bundle in which monomers interact, flat surface to flat surface, as predicted.

The structures of integral membrane proteins are of interest to the field of structural biology, but they have been less than amenable for determination by x-ray crystallography. Crystals of at least 20 membrane proteins have been obtained (*1*), but in only a few cases have the crystals been of suitable quality to permit the resolution of atomic structure (*2*). With the hypothesis that small-molecule detergents, as required to solubilize membrane proteins, are in some way responsible for the disorder within the crystals (*3*), we attempted to design homogeneous peptides as detergents, "peptitergents" that would lead to a more homogeneous, well-ordered complex for crystallography. Peptitergents are amphipathic peptides designed to sequester the hydrophobic membrane-spanning region of membrane proteins by packing around the protein in a rigid, well-ordered, parallel α-helical arrangement. The first peptitergent, PD_1, was designed, synthesized, and crystallized by itself and found to form an antiparallel four-helix bundle, a structure that is of interest from the point of view of de novo protein design. It also interacted with the integral membrane proteins bacteriorhodopsin and rhodopsin to maintain the majority of protein in solution for several days (Fig. 1). In contrast, PD_1 did not maintain PhoE porin solubility.

The peptide was designed as a 24-residue amphipathic α helix (Fig. 2) with a hydrophobic surface 30 Å in length, long enough to traverse the membrane-spanning region

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