Stratigraphic Distribution of Jacksonian (Priabonian) Echinoids in Georgia: Comparison and Suggested Correlations with Florida and the Carolinas

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The Jacksonian (Priabonian) of the southeastern United States has one of the richest echinoid faunas in the world, yet heretofore only the fauna of Florida has been adequately characterized biostratigraphically. We outline the stratigraphic distribution of Jacksonian echinoids in Georgia and compare it with the zonations used in Florida and other regions. Data come primarily from collections made in strata correlated lithostratigraphically and biostratigraphically, using micro-and macrofossils other than echinoids, with strata outside the state, particularly in peninsular Florida. Supplementary data from museum collections and published sources were subsequently added. Most species can be stratigraphically placed based upon these collections, and the pattern agrees with the distributions established in Florida. Conversely, we find support in these patterns for the use of oligopygoids in biozonation in Florida. Species not included in the primary collections were dominantly those of the upper Jacksonian Oligopygus wetherbyi *zone. We recognize these species from few individuals in residuum, from a region of active solution of the Eocene carbonates. The middle assemblage zone in Georgia, correlative with the* Oligopygus haldemani *in Florida, has a much richer fauna, including more spatangoids, than its counterpart in Florida. The Georgia strata equivalent to the* Oligopygus phelani *zone of Florida have a fauna similar to, but with lower local diversity, than correlative rocks of Florida.*

Species from southeast Georgia, previously considered middle Eocene, are better treated as Jacksonian. Two species, tentatively identified herein, are known otherwise only from the Castle Hayne Limestone of the Carolinas, and support a Jacksonian age for those strata.

INTRODUCTION

McKinney and Jones (1983) and McKinney and Zachos (1986) have recently published a biostratigraphic characterization of Eocene echinoids in Florida. Several studies of echinoid paleobiology in the region have relied explicitly upon this work (McKinney, 1984; Carter, 1987b). Carter's (1987b) discussion of the paleobiogeographic distribution of late Eocene echinoids in the southeastern United States suggested the possibility of unpreserved strata in Georgia contributing to the degree of apparent endemism between central Florida and the remainder of the Coastal Plain. This paper outlines our findings not only on the distribution of species in Georgia, but on how the distributions compare with those in Florida. We find support for the idea of stratigraphic mismatching between the regions.

Taxonomy of Eocene echinoids in the southeastern United States is well summarized in Cooke (1959), with only a few systematic modifications (Durham, 1955; Kier, 1968; Carter and Beisel, 1987) and new species (Kier, 1967; 1968; Harper and Shaak, 1974; Zachos, 1968). These are of little more than nomenclatural interest to the present study. The new taxa described in Kier (1967; 1968) are the only new species found in Georgia (see discussion below).

Echinoids have not been used extensively in the zonation of the Eocene in Georgia; only *Periarchus* species have been used at all. Pickering (1970) included a local stratigraphic zonation for the echinoids in a small region near Perry, Georgia.

In contrast, echinoids are used extensively in biostratigraphy of the Ocala Group in Florida. Early workers (Puri, 1957) used *Periarchus floridanus* (treated as a subspecies of *P. lyelli* by Cooke, 1959) to identify the lowermost portion of the sequence. Subsequently three species of *Oligopygus* have been found to be particularly useful in zonation of the entire Ocala Group (Hunter, 1976; Zachos and Shaak, 1978; McKinney and Jones, 1983), and assemblage zones for all the Ocala echinoid species have been identified (McKinney and Zachos, 1986).

MATERIALS AND METHODS

We have made extensive collections from numerous locations in the Dougherty Plain region of Georgia, both from surface exposures (quarries, stream bluffs, springs, and other natural exposures) and from water wells. We also have a small collection from the vicinity of Perry (Fig. 1). Other workers' lithostratigraphic and biostratigraphic correlations of the strata from which these collections were made are reported in Huddlestun (1981) and J. Carter (1984). These data constitute the core of the present interpretations. Figure 2 summarizes Huddlestun's (1981) lithostratigraphic and biostratigraphic relationships of the Jacksonian strata of Georgia and their correlations to the *Oligopygus* spp. zonation of central Florida. We chose the collections used in the first stage of construction of our zonation, whether our own or others', specifically from the individual units thereon. Some indication of the completeness of collections for the units is included in Figure 2. The chart in Figure 3 is primarily a range chart within these units for the species in our collections, with additional species and occurrences added from the other data sources.

Most additional data were taken from Cooke (1959). We sorted his species by locality, and found that in some cases associations of species reported by

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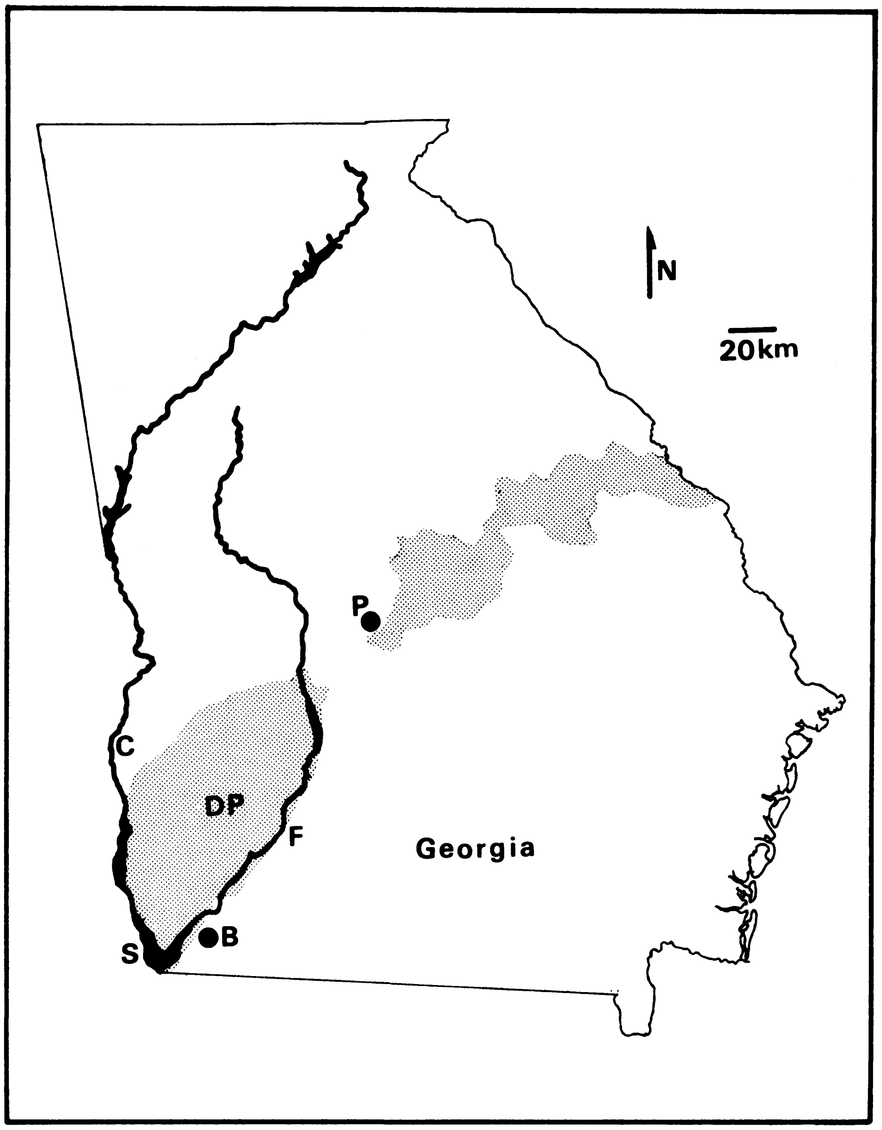

FIGURE 1—Outline map of Georgia showing generalized outcrop pattern of Eocene rocks (light shading) and geographic features mentioned in the text. B—Bainbridge; P—Perry; DP—Dougherty Plain; C—Chattahoochee River; F—Flint River; S—Lake Seminole.

Cooke from individual localities represented assemblages consistent with the assemblage zones recognized in Florida, or with those recognized during our first-stage analyses. Such data were added to the core data set we accumulated. Other localities (or groups of geographically closely spaced localities—Cooke's locality data are not always of optimal precision) from Cooke contained either no stratigraphically certain species, or stratigraphically diverse species. Such localities contribute nothing to our zonation. Other literature sources were generally used only if the identifications could be verified with plates or examination of the specimens in museum collections. Toulmin's (1977) collections were checked at the Alabama Geological Survey. Some of Pickering's (1970) collections were examined at the Georgia Geological Survey. Huddlestun and Hetrick (1986) contributed in a minor way for one easily identified species (not checked).

A few records we used were from specimens in the collections of the Alabama, Florida, and Georgia Geological Surveys that have never been reported in the literature.

Our total data set includes 160 records from approximately 50 localities, mostly but not universally within the Dougherty Plain. This number included only those species reported in the literature which we actually used, for instance not including the localities we discarded from Cooke's monograph. Twenty nine species are treated. Roughly half of these records are from our own collections, which are the most sound geographically, stratigraphically, and taxonomically.

Our first order assessment of the zonation in Georgia agrees well with the assemblage zones recognized in Florida (compare our Figure 3 with figure 2 of McKinney and Zachos, 1986). Taking this agreement as an indication of the applicability of the Florida zonation in Georgia, we have added some rare species and occurrences to our diagram which we could not fit in on during our initial assessment *(Amblypygus americanus, Oligopygus phelani,* and *Eurhodia trojana).*

Multivariate analyses as in McKinney and Zachos (1986) were performed, but analyses using our entire data matrix failed to produce any pattern in either q-mode or r-mode analyses. Extensive pruning of the data, discarding small samples, produced clusters in agreement with the pattern in Figure 3. However, in order to get these results we had to discard all the samples except the most diverse five or six—the ones used to manually construct the chart anyway. Because of this we assume that numerical analysis is superfluous in this case. In addition, we arguably would have done extensive damage to the data set by deleting so many data.

RESULTS

We recognize a three-fold stratigraphic subdivision of the Jacksonian echinoid fauna of Georgia (Fig. 3) similar to that recognized in Florida (McKinney and Zachos, 1986). The Clinchfield, lower Tivola, and basal Williston (*sensu* Huddlestun, 1981) correspond with the *Oligopygus phelani* zone of Florida; the Muckalee member of the Williston, and

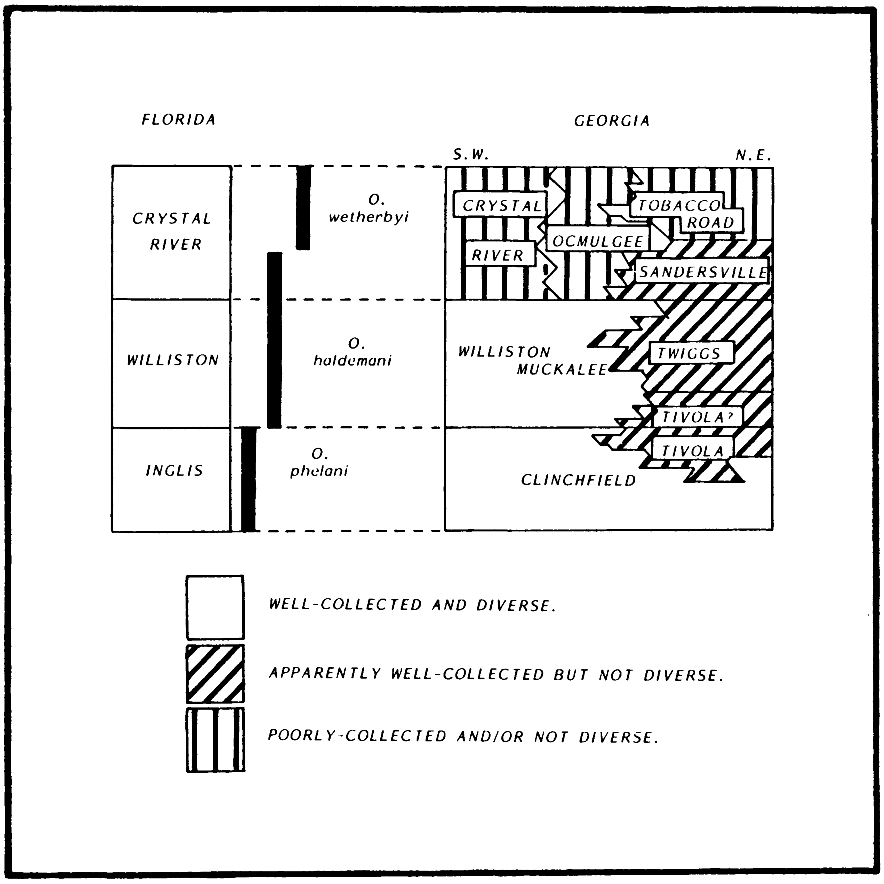

FIGURE 2—Lithostratigraphic and biostratigraphic relationships of the Eocene strata discussed in the test. Modified from Huddlestun (1981) and McKinney and Jones (1983).

upper Tivola correlate with the *O. haldemani* zone; and the residua in the Dougherty Plain (?Crystal River), Sandersville, and Tobacco Road correlate with the Florida *O. wetherbyi* zone. The correlation of the upper Tivola and Muckalee does not agree with Huddlestun's (1981) assessment.

Comparison of our chart (Figure 3) with that of McKinney and Zachos (1986, figure 2) reveals only one complete inconsistency. *Dixieus dixie* is known from a test fragment from the Clinchfield Sand in a well in southwest Georgia, whereas in Florida it is restricted to younger parts of the Ocala.

The Muckalee Member of the Williston in the Dougherty Plain is much richer in species, including a number of spatangoids, than the equivalent *O. haldemani* zone of Florida. A number of these species are either very rare or unknown from central Florida (e.g. *Macropneustes mortoni, Brissopatagus alabamensis*—Carter, 1987a and in prep.). The *O. phelani* and *O. wetherbyi* zones have been called "echinoid biosomes" to contrast them with the relatively echinoid-poor *O. haldemani* zone ("miliolid biosome" and "pectinid biosome"—Zachos and Shaak, 1978).

In Florida the uppermost part of the Ocala is richest in echinoid diversity, but in Georgia this is the least diverse. As mentioned above, this probably is a result of the poor preservation of the uppermost Ocala in the Dougherty Plain. This low-lying physiographic province of Georgia is a region of extensive active solution (Cooke, 1943; Beck and Arden, 1983). Quarries and natural outcrops (principally stream bluffs) in the region generally expose middle and lower zone rocks. Our collections and those we have examined at the Georgia Geological Survey include upper zone species only from residual chert on the surface of the Plain. Most of the upper zone species reported by Cooke (1959) are apparently from similar exposures, though a couple of his localities in the vicinity of Bainbridge, on the Chattahoochee and Flint Rivers were apparently *in situ* exposures of this zone. These localities are now covered by the floodwaters of Lake Seminole.

Of the three species of *Oligopygus* used in biostratigraphy in Florida, only *O. haldemani* is found in any abundance in Georgia. We have found several specimens at one locality, and only one specimen at a second—the most diverse locality we know of in the state. At the most diverse locality of the proper age reported by Cooke (1959), which we have also collected intensely, no specimens have ever been found. Pickering (1970) reports *O. wetherbyi* from the vicinity of Perry, but all the specimens so labeled in Pickering's collections at the Georgia Geological Survey are in fact *O. haldemani.* Possibly the rocks of the proper age in Georgia are too muddy (Branch and Carter, 1985) for this species (McKinney, 1984) except at a few localities. *Oligopygus phelani* is known in Georgia from three specimens from a well in the Dougherty Plain. We have one internal mold of *O. wetherbyi* from residuum and have seen a couple of specimens in a core from the edge of the Suwannee Strait which may be this species. The Alabama Geological Survey has one specimen from residuum. Thus the oligopygoids are of limited practical use in the state.

The high diversity of the *O. haldemani* zone equivalent in Georgia is partly due to the inclusion of five species which are found primarily in the *O. wetherbyi* zone in Florida (the late Ocala shallow association of McKinney and Zachos, 1987). Our examinations of hand samples and a limited number of thin sections of the sediments containing these faunas suggest similar substrate conditions—the rocks in both cases are poorly washed biopelsparites. This suggests that during the range of *O. haldemani* environmental conditions were already quieter and more stable, conditions Florida did not attain until the

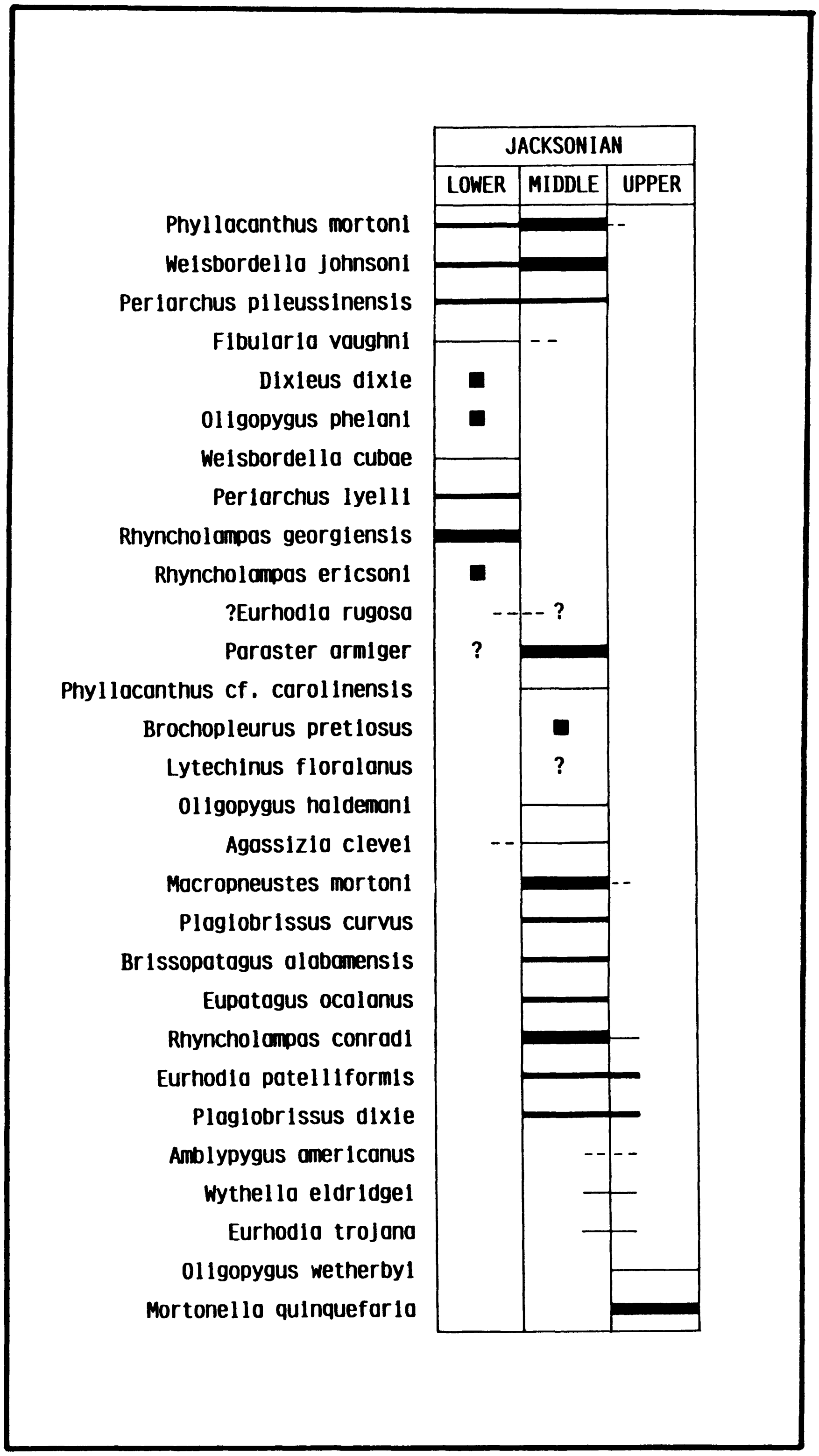

FIGURE 3—Range chart for late Eocene echinoid species in Georgia.

time of *O. wetherbyi*. Two possible inferences from this are important. First, the paucity of *O. haldemani* in Georgia may reflect a paucity of area of suitable substrate, emphasizing the importance of environmental control on species of this genus stressed in the evolutionary scenario of McKinney (1984). Second, if these substrata were indeed similar to those preferred by *O. wetherbyi* later in the Jacksonian of Florida, then the absolute lack of that species in these rocks suggests that its stratigraphic distribution in Florida is very much temporally (and not environmentally) controlled. This supports its qualifications for use in biozonation.

GLYNN COUNTY WELL, SOUTHEAST GEORGIA

Kier (1968) reported six echinoid species from a well in Glynn County, on the Georgia coast. Two of these species, *Leniechinus herricki* and *Pentedium curator,* are unique to this locality. *Echinocyamus bisexus* is known also from the Castle Hayne Limestone of the Carolinas (Kier, 1980) from Kier's "late zone." My preliminary assessment of the stratigraphic distribution of the Castle Hayne species places it within the upper "zone 3" or "zone 4" of Zullo and Harris (1986, 1987) which these authors argue is Jacksonian. *Fibularia alabamensis* is fairly common in the Jacksonian of the Gulf Coast (Cooke, 1959; Toulmin, 1977). The last two species were not certainly assigned by Kier, but he stated that they were quite similar to two Jacksonian species—*Periarchus lyelli* from the Gulf Coast and the Carolinas, and *Durhamella floridana* from central Florida.

Kier (1980) treated these species as Claibornian, but presented no evidence for such as assignment except a supposed lithostratigraphic correlation with the Lake City Limestone of central Florida. The echinoids, in contrast, suggest a Jacksonian age. None of these species allows a more precise stratigraphic assignment than this, so they are not included in Figure 3.

SPECIES SHARED WITH THE CAROLINAS

Worsley and Laws (1986) and Zullo and Harris (1986, 1987) have recently suggested that the Castle Hayne and equivalent strata of the Carolinas are in part Jacksonian, and not entirely Claibornian as is generally held. Based upon the echinoids, and presumably his experience with other taxa, Cooke (1959) refused to assign the Castle Hayne to either stage. Kier (1980) treated all these strata as Claibornian, but provided no argument for such an assignment. The highly endemic fauna of this region (Carter, 1987b) is the cause of this uncertainty. Our collections from the middle zone of the Ocala in Georgia contain two taxa which we treat as species shared with the Carolinas. Interambulacral test fragments, with attached half-ambulacra, of a cidaroid species other than the common *Phyllacanthus mortoni* are known from two localities in the Dougherty Plain. These fragments are identical with *P. carolinensis* as figured in Kier (1980). Though Cooke (1959) treated this species as a synonym of *P. mortoni* the differences are obvious at a glance. Unfortunately *P. carolinensis* is known in the Carolinas only from the holotype, and its locality and exact stratigraphic position are not known.

In addition, we collected a longitudinal third of an elongate cassiduloid from a quarry near Perry. The specimen does not include any of the characters necessary for a positive identification, but it does have a distinctly longitudinally depressed oral surface as is often the case with species of *Eurhodia* (Carter and Beisel, 1987) and it is too elongate to be any of the cassidulids known from the Eocene of the southeast. It is too large to be *Eurhodia patelliformis*, and so we tentatively assign it to *E. rugosa* whose shape we infer it shares. This latter species is common throughout the Castle Hayne of the Carolinas, including that portion which is debatably Jacksonian.

Other species from the Castle Hayne with Jacksonian affinities in Georgia include *Echinocyamus bisexus* (discussed above); *Dixieus dixie* (from the "late zone" of Kier, 1980); *Periarchus lyelli* (also from Kier's "late zone" and zones "3" and "4" of Zullo and Harris, 1986, 1987); and *Rhyncholampas carolinensis* (also from Kier's "late zone," and treated as a subspecies of *R. conradi* by Cooke, 1959). Cooke (1942) mentioned a specimen of the latter species from the Ocala of Florida, but dropped it from his 1959 monograph. Kier (1980) reported being unable to find the specimen at the USNM.

These occurrences of Castle Hayne echinoid species from Jacksonian rocks in Georgia lend further support to the suggested reassignment of the upper Castle Hayne to that stage (Zullo and Harris, 1986; 1987).

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