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An *Aphelaspis* Zone (Upper Cambrian, Paibian) Trilobite Faunule in the Central Conasauga River Valley, North Georgia, USA

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ABSTRACT

Middle and Upper Cambrian strata (Cambrian Series 3 and Furongian) in the southernmost Appalachians (Tennessee to Alabama) comprise the Conasauga Formation or Group. Heretofore, the youngest reported Conasauga beds in the Valley and Ridge Province of Georgia were of the late Middle Cambrian (Series 3: Drumian) *Bolaspidella* Zone, located on the western state boundary in the valley of the Coosa River. Two new localities sited eastward in the Conasauga River Valley, yield a diagnostic suite of trilobites from the Upper Cambrian *Aphelaspis* Zone. Very abundant, polymeroid trilobites at the primary locality are referable to *Aphelaspis brachyphasis,* which is a species known previously in western North America. A second locality has produced a few identifiable specimens of the aphelaspine *Eugonocare* (*Olenaspella) separatum*. Specimens at these two localities are generally complete individuals compressed in tan mudstones. The primary locality features abundant body cluster accumulations, implying mass mortality by bioimmuration. The trilobite assemblage also includes the agnostoids *Glyptagnostus reticulatus*, *Agnostus inexpectans*, and *Aspidagnostus rugosus*, all correlated to the global Paibian agnostoid *Glyptagnostus reticulatus* Zone. These localities contain the southeastern-most Late Cambrian faunule in the Appalachians. The trilobite species and carbonate-free, mudstone lithology, lacking evidence of infaunal bioturbation and burrowing, suggest accumulation eastward of a paleotopographic shelf-to-basin break, which is interpreted to be east of the Alabama Promontory and in the Tennessee Embayment. The preservation of abundant aphelaspine specimens by bioimmuration events may have been the result of mudflows down the shelf-to-basin slope.

INTRODUCTION

Trilobites and associated biota from Middle Cambrian beds of the Conasauga Formation in northwestern Georgia have been described by Walcott, 1916a, 1916b; Butts, 1926; Resser, 1938; Palmer, 1962; Schwimmer, 1989; Schwimmer and Montante, 2007. These fossils and deposits come from exposures within the valley of the Coosa River, in Floyd County, Georgia, and adjoining Cherokee County, Alabama. Trilobite biozone associations of these Middle Cambrian biotas are of the *Glyphaspis* to *Crepicephalus* Zones of the traditional Laurentian Middle Cambrian Series.

Cambrian trilobites have not been described farther east- or southward from the above in the southern Appalachian outcrop, although the Conasauga Formation is exposed in a separate fault-bounded slice in the Conasauga River Valley (Figure 1). We report here new Upper Cambrian localities in this outcrop, containing the southeastern-most Cambrian trilobites in North America. The new trilobite assemblages include polymeroids of the Laurentian Upper Cambrian *Aphelaspis* Zone, including *Aphelaspis brachyphasis* and *Eugonocare (Olenaspella) separatum*; and coeval agnostoids of the global *Glyptagnostus reticulatus* Zone, including *Glyptagnostus reticulatus*, *Agnostus in-*

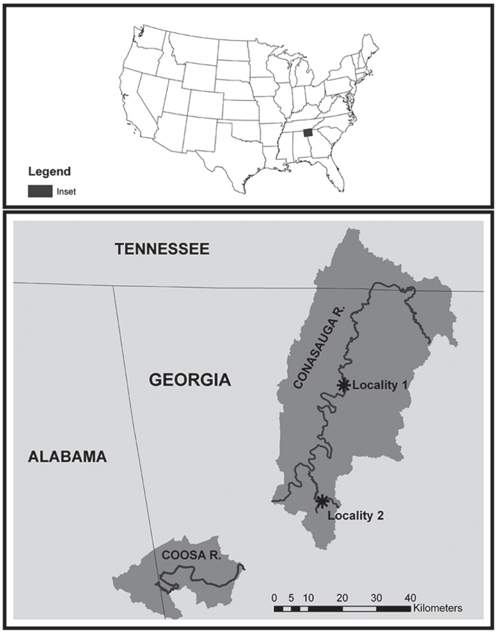

Figure 1a— Map of Conasauga Formation outcrops in Georgia with *Aphelaspis* Zone localities in the Conasauga River Valley indicated, also showing the general geographic position of the trilobite beds (discussed in text) in the proximal Coosa River Valley.

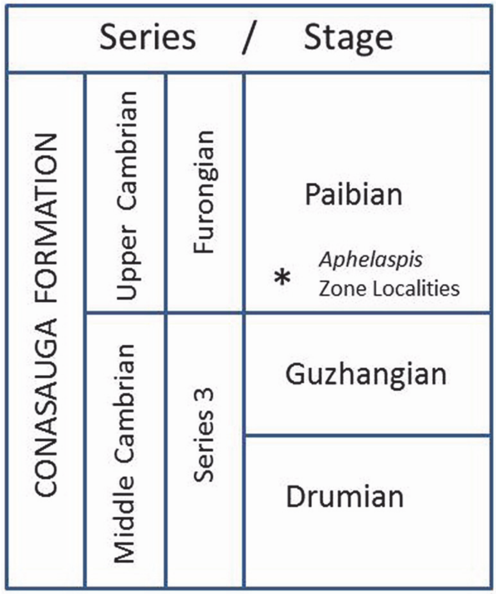

Figure 1b—correlation chart showing the stratigraphic position of the *Aphelaspis* faunule. (Correlation chart based on Babcock and Peng, 2007, and Ogg, 2009).

expectans, and *Aspidagnostus rugosus*.

In contrast with most prior reports of Upper Cambrian trilobites from the Southern Appalachians (e.g. Butts, 1926; Resser, 1938; Palmer, 1962; Rasetti, 1965), specimens collected in the new localities are preserved in mudstones as compressed, typically complete individuals, with intact librigenae. At Locality 1 (Figure 1a), *Aphelaspis* specimens are very abundant, with intact librigenae, associated in "body clusters" (*sensu* Whittington, 1997b), and commonly surrounded by decay-gas induced iron oxide halos (Schwimmer and Montante, 2007). These new trilobite localities contain relatively few agnostoids, but enough species are present (as indicated above) to be clearly referable within the global Cambrian agnostoid-based stratotype system (Peng and Robison, 2000; Babcock and others, 2007; and see discussion in "Biostratigraphy"). In addition to extending the southeastern geographic range of Upper Cambrian strata in the southern Appalachians, the occurrence of a well-demarcated *Aphelaspis* assemblage with the globally-correlative agnostoid *Glyptagnostus reticulatus* Zone provides well-dated Upper Cambrian sites in the south-easternmost Appalachians.

GEOLOGIC SETTING

The localities here are in the Conasauga Formation in Murray and Gordon Counties, northwestern Georgia. This study area (Figure 1a) is in the Appalachian Valley and Ridge Province, characterized by series of northeast-trending, ridge-forming Paleozoic thrust faults and transforms, with relatively low valleys floored with less-resistant strata sandwiched between fault boundaries. The mudstones of the Conasauga Formation form two such valleys (Figure 1a), and the two localities discussed here lie in the broad valley of the Conasauga River, situated between the East Coosa and Cartersville Faults (Thomas and others, 2000; Thomas and Bayona, 2005). Locality 1 is a riverside outcrop on the Conasauga River in Murray County, in the vicinity of Chatsworth, Georgia, on the eastern side of the Conasauga River Valley. This locality has an approximately 4.0 meter-thick exposure of abundantly fossiliferous, tan-to-olive, flaggy-bedded mudstones exposed on the banks of the river and in ancillary drainages. Polymeroid trilobites are very abundant at this site, and include numerous individuals with attached librigenae. Locality 2, which is now covered, was a commercial borrow-pit excavation in the vicinity of Calhoun, Georgia, in southernmost Gordon County, exposing approximately 6.0 m of olive-green mudstones with a relatively sparse trilobite fauna. This locality is in the southwestern-most edge of the Conasauga River Valley.

The Conasauga Formation in northwestern Georgia spans much of the Middle Cambrian (Schwimmer, 1989, Schwimmer and Montante, 2007) through the lowermost Upper Cambrian (Figure 1b). Collections for this report are from exposures in the upper portion of the Conasauga Formation in Georgia. The Conasauga in its entire geographic range, extends down to the base of the Middle Cambrian, up through most of the Upper Cambrian, and is mapped from central Alabama, across northwestern Georgia, to eastern Tennessee and southwestern Virginia (Palmer, 1971; Hasson and Hasse, 1988; Osborne and others, 2000), reaching local thicknesses exceeding 1000 m. Across the entire exposure, the Conasauga represents multiple depositional environments forming on the marine shelf and in shelf-edge basins along the salients and recesses of the Laurentian margin of the Cambrian Iapetus Ocean. These paleoenvironments include shallow-water peritidal clastic wedges, admixed outer shelf carbonates and shales, and algal carbonate shoals on the shelf-to-basin boundaries (Hasson and Haase, 1988).

BIOSTRATIGRAPHY

Trilobites from both new localities are assigned to the *Aphelaspis* Zone (Figure 1b), which is coeval with the lowermost biozone of the global of the Furongian Series (= Upper Cambrian in traditional Laurentian nomenclature: Ludvigsen and Westrop, 1985). The Conasauga sites in consideration are assigned to the *Aphelaspis* Zone based on the co-occurrence of *Aphelaspis brachyphasis*, and *Eugonocare* (*Olenaspella) separatum* (Palmer, 1962, 1965; Pratt, 1992).

The base of the A*phelaspis* Biozone is biostratigraphically equivalent to the first appearance of the agnostoid *Glyptagnostus reticulatus* (Babcock and others, 2005). This species is the eponym of the biozone that comprises the lowest unit of the global Paibian Stage (Gradstein and others, 2005; Babcock and Peng, 2007), which is penecontemporaneous with the Laurentian Steptoean Stage (Ludvigsen and Westrop, 1985; Peng and others, 2004). The new Conasauga sites include three agnostoid species common to the *Glyptagnostus reticulatus* Zone (Peng and Robison, 2000), including *G. reticulatus* itself. Therefore, these Conasauga sites include age-specific genera and species incorporated in both Laurentian polymeroid- and global agnostoid trilobite chronostratigraphic zone concepts.

SYSTEMATIC PALEONTOLOGY

Repository and Terminology

Specimens described and figured are curated and housed in the Cambrian Research collections (CSU€) of Columbus State University, Columbus, Georgia. Descriptions of polymeroid trilobites follow Whittington (1997a); agnostoid morphology also incorporates basic terminology from Öpik, 1967, as modified by Whittington and Kelly, 1997, and Peng and Robison, 2000. To protect fragile fossil sites, only general localities are given here and in Figure 1a: precise locality coordinates are available for qualified research by contact with the first author.

Order Agnostida Salter, 1864
Subfamily Agnostinae M'Coy, 1849
Agnostus Brongniart, 1822
Agnostus inexpectans Kobayashi, 1938
Figure 2.1

Referred Material— CSUꞒ-07-4-1, a complete exoskeleton, part and counterpart; CSUꞒ-07-4-2, an incomplete cephalon.
Occurrence— Locality 1, Murray County, Georgia (see Figure 1a).
Diagnosis—Cephala with moderate to deep median preglabellar furrow, transglabellar furrow relatively shallow, glabellar furrows F1 and F2 well-incised, subtending distinct M2 and M3. Pygidium slightly expanded posteriorly, posteroaxis not touching border furrow, F1 continuous across pygidial axis, F2 weakly demarcated around axial node.
Discussion—Peng and Robison (2000) provded a complete review of this genus and species, including its various reassignments between *Innitagnostus* and *Agnostus.* The agnostoids in the sites to be discussed here tend to be poorly preserved at the microscopic level, and also tend to split from the enclosing matrix with the exoskeleton adhering to one part of the sediment, and the internal cast on the counterpart. The complete individual of *Agnostus inexpectans* figured here (Figure 2.1) has the better preservation on the internal cast.

The specimen figured here, although poorly preserved, shows the characteristic cephalic and pygidial furrows and lobation. Palmer (1962) reported specimens of *A. inexpectans* from the Conasauga Formation in Cedar Bluff, Alabama, located approximately 80 km west of the locality discussed here. *Agnostus inexpectans* is among the most cosmopolitan of Asian, Australian and Laurentian Upper Cambrian agnostoids.

Family Clavagnostidae Howell, 1937
Genus *Aspidagnostus* Whitehouse. 1936
Aspidagnostus rugosus Palmer, 1962
Figures 2.2-2.4

Referred Material— CSUꞒ-07-4-8, complete individual; CSUꞒ-07-4-9, CSUꞒ-07-4-11, cephala; and CSUꞒ-07-4-10, CSUꞒ-07-4-12, pygidia.
Occurrence—Locality 1, Murray County, Georgia.
Diagnosis—Cephala with sagittally short glabella, edges slightly swollen at M3, genae with irregular, radial scrobiculae with moderately deep furrows, preglabellar medial furrow may be poorly distinct because of cross furrows. Pygidium with elevated, spinose axial nodes, slightly to moderately scrobiculate pleurae, F1 slightly constricted at lateral edges but not subtending distinct M1.
Discussion—*Aspidagnostus* is an easily recognizable, biostratigraphically-useful genus because of the unique pygidial medial spine. The specimens here are very small and poorly preserved, but nevertheless readily identifiable to genus and species.

This species was first identified by Palmer, 1962, in the Conasauga Formation at Cedar Bluff Alabama, in addition to localities in the Great Basin. Subsequently it is has been recognized nearly globally, co-occurring with other agnostoids of the *Glyptagnostus reticulatus* Zone. Pratt (1992) noted that *Aspidagnostus rugosus* occurs in the lowest Steptoean to latest Marjuman strata. Therefore, we assume that the assemblage in study may be likewise constrained to the very oldest portion of the *G. reticulatus* biozone.

Family Indeterminate
Subfamily Glyptagnostinae Whitehouse, 1936
Genus *Glyptagnostus* Whitehouse, 1936
Glyptagnostus reticulatus (Angelin, 1851)
Figures 2.5-2.8

Referred Material—CSUꞒ-07-4-3, CSUꞒ-07-4-5, CSUꞒ-07-4-7 pygidia; CSUꞒ-07-4-4, CSUꞒ-07-4-6, cephala; plus numerous additional specimens.
Occurrence—Locality 1, Murray County, Georgia
Diagnosis—Complexly scrobiculate agnostoids with narrow border furrows, cephalon

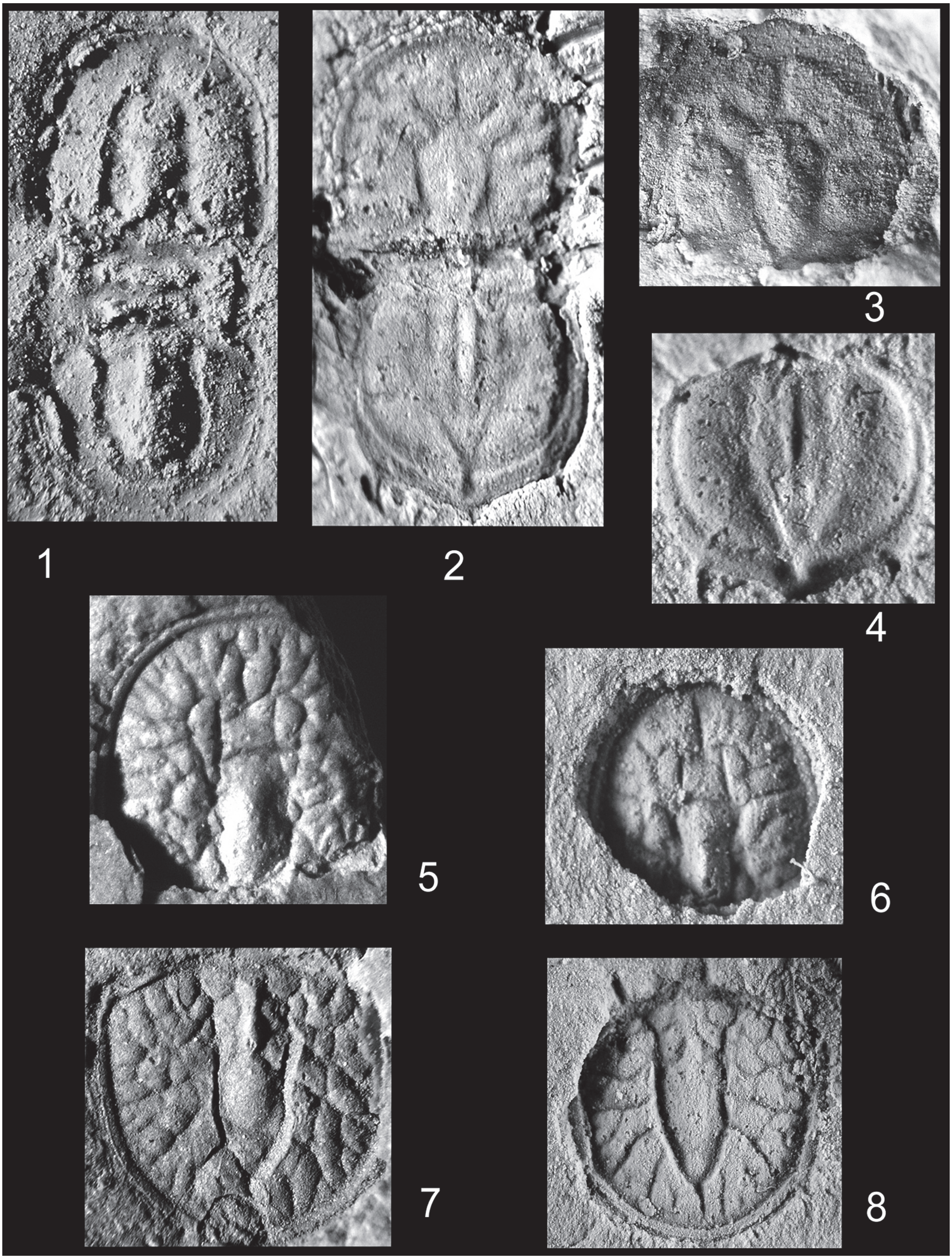

Figure 2—Agnostoid trilobites from Locality 1. *1*, *Agnostus inexpectans* Kobayashi, internal cast of complete individual, CSU€-07-4-1, x18. *2-4, Aspidagnostus rugosus* Palmer. *2*, complete individual, CSU€-07-4-8, x16; *3*, cephalon, CSU€-07-4-9, *4*, external mold of pygidium, CSU€-07-4-10, both x20. *5-8, Glyptagnostus reticulatus* (Angelin). *5-6* cephala, CSU€-07-4-4, x17, CSU€07-4-6, x15; *7-8*, pygidia CSU€-07-4-3, CSU€-07-4-5, both x15.

with subquadrate anteroglabella, median preglabellar furrow present, basal lobes elongate. Pygidium with tapering axis constricted at M2, not touching border furrow, posterior median furrow present. In some specimens the pattern of rugae is multi-order, forming a nodulose pattern.

Discussion—This is arguably the most distinctive and recognizable agnostoid genus known because of the elaborate and specifically variable scrobiculation on cephala and pygidia. The genus has been discussed exhaustively through one and one-half centuries of literature, and often split into multiple species and subspecies based on the variable patterns of furrows (Shergold, 1982; Pratt, 1992; Peng and Robison, 2000). Species of *Glyptagnostus* are particularly useful, globally distributed guide fossils, and comprise two biozones in the Late-Middle to early-late Cambrian, of which the specimens here denote the younger biozone. It is significant to biogeographic implications of the Conasauga fauna in study (in discussion to follow) that Pratt (1992) noted (p. 87): "…species of *Glyptagnostus* are distributed in slope and deeper shelf lithofacies…."

Resser (1938) and Palmer (1962) described specimens of *Glyptagnostus* from the Conasauga Formation at Cedar Bluff, Alabama, located approximately 100 km southwest of the site of specimens here. Because these had relatively less intensely scrobiculate pygidia, Resser referred the Conasauga Formation specimens to a new species, *G. angelini*, which Palmer (1962) revised as a subspecies, *G. reticulatus angelini.*

Subsequent authors (Pratt, 1992; Peng and Robison, 2000) have observed that the intensity of scrobiculation varies both ontogenetically and temporally in the *Glyptagnostus reticulatus* clade, with geologically older and more juvenile individuals less ornamented. Therefore, it is currently accepted that *G. reticulatus* comprises a single variable species with an apparent cline in complexity of ornamentation that may be useful to delimit the stratigraphic age of specimens. The specimens illustrated here (Figures 2.5-2.8) are mature individuals that show the average intensity of furrows for the stratigraphically older representatives of the species.

Order Ptychopariida Swinnerton, 1915
Suborder Ptychopariina Richter, 1933
Family Pterocephaliidae Kobayashi, 1935
Subfamily Aphelaspinae Palmer, 1960
Genus *Aphelaspis* Resser, 1935
Aphelaspis brachyphasis Palmer, 1962
Figures 3.1-3.7

Referred Material— CSUЄ-07-2-1, CSUЄ-07-5-5, complete holaspides with intact librigenae; CSUЄ-07-5-6, larger holaspis with intact librigenae, missing posterior segments and pygidium; CSUЄ-07-2-3, cephalon exposing ventral sclerites; CSUЄ-07-2-4, partial late-stage meraspis missing pygidium; CSUЄ-07-2-7, CSUЄ-07-2-8, pygidia.

Occurrence—Locality 1, Murray County, Georgia.

Diagnosis—Ptychopariina with co-equal preglabellar field and border, librigenae separated by a narrow rostral plate, natant hypostome clearly detached skeletally from the doublure, short preglabellar field with indistinct border furrow; short, stout genal spines reaching posteriorly no farther than the second thoracic segment and laterally extending from the thorax at relatively large angles. Pygidia relatively wider (tr.) than long, with three poorly demarcated axial rings plus indistinct posteroaxis.

Discussion—This *Aphelaspis* species is extraordinarily abundant in Locality 1 and commonly preserved with intact librigenae and found in a wide variety of size classes, including meraspides. Many species of *Aphelaspis* have been recognized, many of which are dubious: over-splitting of the genus is evident in various literature sources: for example, Rasetti (1965) recognized fifteen species of *Aphelaspis* in Tennessee, including eleven of which he erected in that single publication. Among the many (and variable) described species of *Aphelaspis*, the broad, strongly divergent spines combined with the short, indistinctly segmented pygidium closely conform with the type specimens from Nevada in Palmer (1962), as well as material tentatively referred in Pratt (1992). The specimens from the Conasauga Formation are flattened but complete, and therefore some

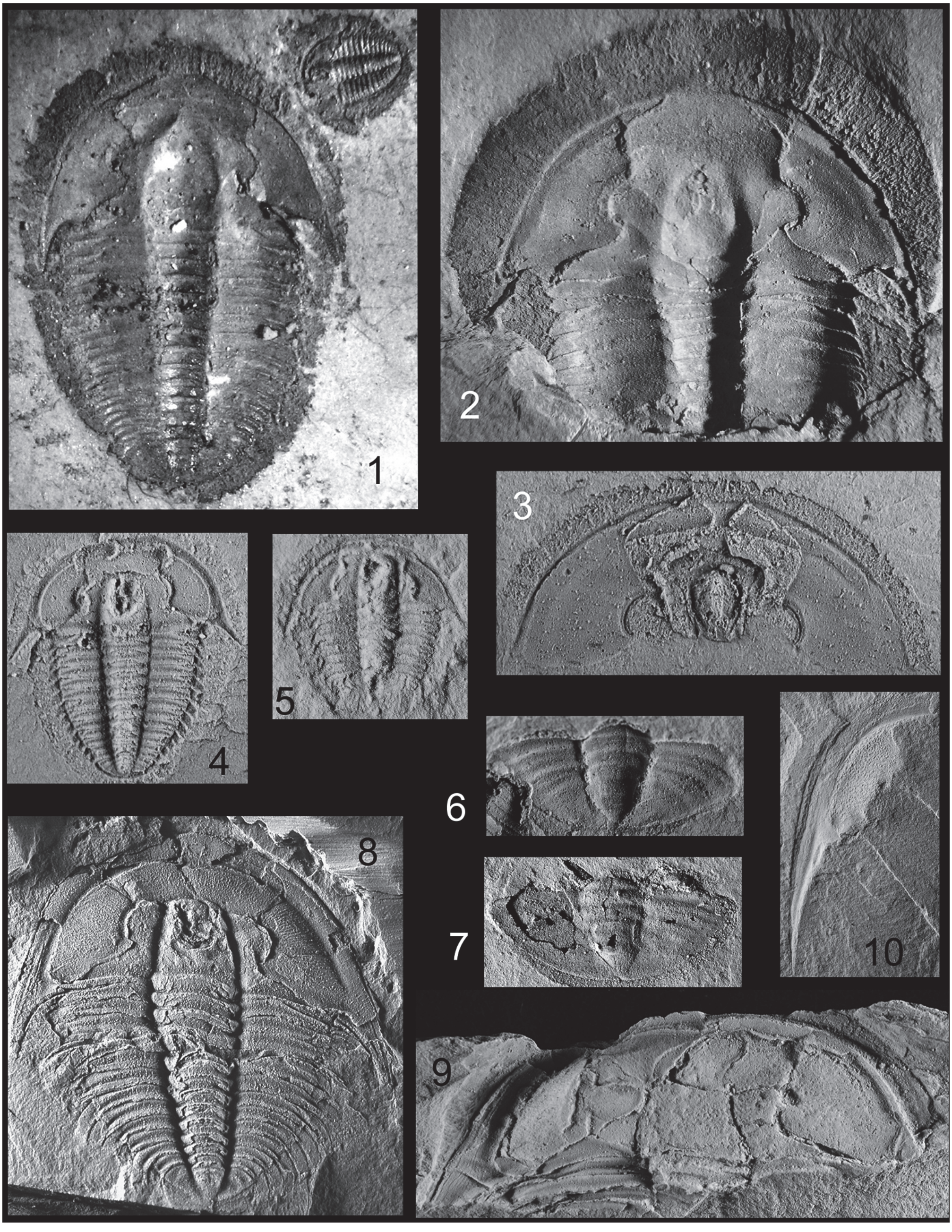

Figure 3—Ptychopariine trilobites from Localities 1 and 2. *1-7*, *Aphelaspis brachyphasis* Palmer, from Locality 1; *1, 2*, larger holaspides with attached librigenae, showing iron-oxide halos; *1,* CSU€-07-2-1, *2*, CSU€-O7-5-6, both x5.5; *3*, ventral view of cephalon, showing labrum and rostral plate, CSU€-07-2-3, x7.5; *4*, small holaspis with attached librigenae, CSU€-07-5-5, x5; *5,* partial meraspis, CSU€-07-2-4, x10; *6,7*, pygidia; *6*, CSU€-07-2-7, x3.5; *7*, CSU€-07-2-8, x5. *8-10*, *Eugonocare (Olenaspella) separatum* (Palmer), from Locality 2; *8,* holaspis with intact librigenae, CSU€-07-3-1, x3.5; *9*, cephalon and anterior thorax of larger individual, CSU€-07-3-5; *10*, isolated librigena, CSU€-07-3-6, both x2.

features comparable with the holotype may be exaggerated or distorted, such as the lateral spread of the genal spines and the width of the pygidium. This is the first occurrence of this species in the eastern continent.

Genus *Eugonocare* Whitehouse, 1939
Eugonocare (Olenaspella) separatum (Palmer, 1962)
Figures 3.8-3.10

Referred Material—CSU€-07-3-1, complete holaspis; CSU€-07-3-4, larger cephalon and partial thorax; CSU€-07-3-5, isolated librigena.
Occurrence—Locality 2, Gordon County, Georgia.
Diagnosis—Aphelaspinae with transversely wide cranidia, equally wide librigenae with broad margin, wide, deep, marginal furrow. Preglabellar field long (sag.), slightly inflated, with fine radiating striations. Genal spines long and broad, reaching posteriorly to the sixth thoracic segment. Thoracic segments with deep interpleural furrows, terminating in relatively long marginal spines. Pygidium relatively small with five segments and a single pair of marginal spines on the anterior segment.
Discussion—The specimens here retain the librigenae, showing the proportionately large size of the cephala. However, the preservation of some individuals incorporates distortion of the claystone matrix (e.g. Figure 3.9), skewing the body proportions. Most generic and specific descriptions of *Eugonocare* sp. are based on isolated cranidia, free cheeks and pygidia, and complete individuals such as figured here are relatively rare. It is therefore notable that the thorax shows segments with deep interpleural furrows and elongate marginal spines. The marginal spines, in particular, are confluent with the diagnostically spinose morphology of the anterior pygidium. Identification of *Eugonocare separatum* in the Conasauga Formation further extends the geographic range to eastern North America. Peng (1992) recognized three subgenera of *Eugonocare*, including *Eugonocare* (*Olenaspella*), which in his concept comprises a distinct North American subgenus. The specimens discussed here clearly conform to that morphology, whether or not the subgeneric classification is necessary.

TAPHONOMY AND BIOGEOGRAPHY

Preservation of Complete *Aphelaspis* and *Eugonocare*

Specimens of *Aphelaspis* and *Eugonocare* from both localities contain a majority of individuals with intact librigenae (see, for example, Figures 3.1-3.4, 3.8, 3.9). Such fossils represent dead trilobites rather than molted exuviae, since the librigenae of ptychopariines were typically separated during exuviation along the facial sutures (Whittington, 1997b), and are almost always found in molts separated from the cranidia. At locality 1 complete *Aphelaspis* individuals are very abundant and frequently occur as multiples, sometimes overlapping, within decimeter-scale slabs. Such occurrences are termed “body clusters” in Whittington, 1997b, and represent death assemblages (versus “molt clusters” representing marine current sorted exuviae accumulations). Given the abundance of apparently dead individuals, combined with the well sorted, fine-grained enclosing lithology, it is inferred that the *Aphelaspis* specimens here were killed and preserved by episodes of rapid immuration in mudflows, most likely on the outer marine shelf or a deeper marine basin environment.

It is also significant that many of the complete (thus dead) specimens are surrounded by iron oxide (goethite) halos (see, e.g., Figure 2.1). These oxides are the final event in a preservational-depositional sequence (Schwimmer and Montante, 2007) which begins with precipitation of pyrite around the decaying organism (Borkow and Babcock, 2003; Popa and others, 2004). Pyrite is commonly precipitated when decay gases cause locally reducing conditions in iron and sulfur-rich marine waters, which subsequently oxidizes to ferrous oxides when the sediment is exposed at any later time to higher oxygenated groundwater or subaerial environments. In addition to authigenic sulfide deposition, we infer there was locally low oxygen conditions in the Conasauga Formation based on the near absence of burrow traces in the Conasauga Valley mudstones containing the complete *Aphelaspis* specimens: the absence of significant infaunal traces implies low oxygen conditions especially below the sediment-water interface.

Similar pyrite deposition and goethite replacement around intact trilobite specimens was reported in nearby late Middle Cambrian trilobite assemblages (*Bolaspidella* Zone) in the Coosa Valley in Georgia (Schwimmer and Montante, 2007). In both the latter and present situations, the mode of trilobite preservation (intact librigenae and oxides halos) apparently resulted from the combination of relatively low-oxygen conditions below the sediment-water interface, and well-sorted mud sedimentation on the outer marine shelf. These similar marine conditions, found in two closely-spaced trilobite chronozones (*Bolaspidella* and *Aphelaspis* Zones) suggest that stable marine conditions persisted on the extreme southwestern continental shelf-edge.

Paleobiogeography

The Conasauga River Valley localities discussed here are the southeastern most exposures of Upper Cambrian strata in the southern Appalachian region. The nearest Upper Cambrian trilobite faunal locality (which correlates very well biostratigraphically with the Conasauga Valley localities) is at Cedar Bluff, Alabama, in the Coosa River Valley (Palmer, 1962; Butts, 1926), located approximately 75 km to the west. The palinspastically reconstructed distance between these localities was substantially greater in the Cambrian, and also involves some clockwise rotation (Thomas and Bayona, 2005) since there are several transform detachments and thrust fault zones intervening between the localities. The Late Cambrian separation between these *Aphelaspis* faunal sites reconstructs to approximately 145 km on the Cambrian marine shelf.

It is noteworthy in this context that the respective Cedar Bluff, Alabama, and Conasauga Valley, Georgia, assemblages have identical agnostoids, but that the abundant *Aphelaspis brachyphasis* of the Conasauga Valley were not reported at Cedar Bluff (Palmer, 1962). The muddy, low-oxygen sedimentary and taphonomic conditions inferred for the Conasauga Valley localities, suggest that these deposits accumulated on the distal edge of the shelf or in a relatively deep intrashelf basin. In contrast, Palmer (1962) reported the strata at Cedar Bluff, Alabama (located northwestward, toward the mid-continent) to be composed of interbedded shales and thin-bedded limestones. This slight sedimentary and faunal change from west (Cedar Bluff, Alabama) to east (Conasauga Valley), may reflect the paleotopographic break (Thomas and others, 2000) from the Alabama Promontory shelf edge (then, due northwest) across the transform to deeper water in the Tennessee Embayment (then, to the southeast). Carrying this argument one step further, we may also infer that the species *Aphelapsis brachyphasis*, which was apparently absent at Cedar Bluff, may have been endemic to the deeper, basinal marine environment represented in the Conasauga Valley localities.

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