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CONTENTS →

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A PRELIMINARY STUDY OF SOME SANDBIAN (UPPER ORDOVICIAN) GRAPTOLITES FROM VENEZUELA

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INTRODUCTION

The Lower Sandbian *Nemagraptus gracilis* Zone comprises one of the most widespread, and easily recognizable graptolite faunas in the Ordovician System. The base of the *N. gracilis* Zone also marks the base of the Upper Ordovician Series, and is internationally defined by the FAD of the eponymous species, with the Global Stratotype Section and Point (GSSP) located at F gels ng in Scania, southern Sweden (Bergström et al., 2000, 2009). Finney and Bergström (1986) provide a general account of the widespread record of this biozone in Europe, America, Australasia and China. In South America, graptolites of the *N. gracilis* are best known from the Argentine Precordillera (Cuyania Terrane), within the Portezuelo del Tontal, Las Aguaditas, Los Azules and Sierra de la Invernada formations in the central Precordillera, in the Yerba Loca Formation of the western Precordillera, and in the La Cantera Formation of the eastern Precordillera (see for example Borrello and Gareca, 1951 Blasco and Ramos, 1976 Brussa, 1996, 1997 Peralta, 1998 Ortega and Albanesi, 1998 Ortega et al., 2008 and references therein). *Nemagraptus gracilis* Zone faunas are rare in the Central Andean Basin, where single occurrences of only *N. gracilis* itself have been reported from three localities in Bolivia and Peru (Laubacher, 1974 Brussa et al., 2007).

In northern South America, the single known occurrence of Sandbian age graptolites, including possible specimens of *Nemagraptus* is restricted to the Caparo Formation, which crops out in the southern Mérida Andes of Venezuela, close to its tectonic boundary with the Barinas-Apure basin (Leith, 1938 Pierce et al., 1961 Shell and Creole, 1964). Recent new collecting by some of the authors (JCGM, JR, JG) has provided additional material that confirms the identification of a Sandbian graptolite fauna in the region that can be assigned to the *N.gracilis* Biozone, a fauna that is described and illustrated for the first time in this part of South America.

CONTENTS

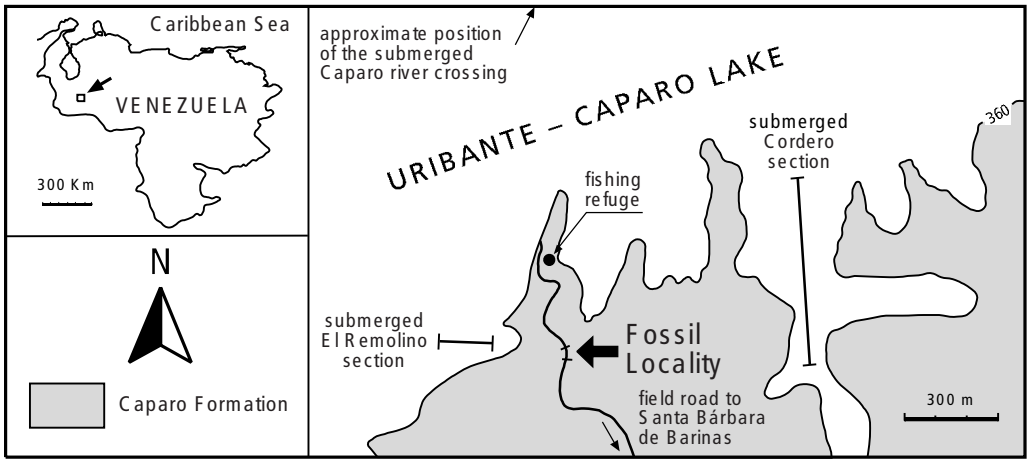


Figure 1. Sketch map of a sector south of the former Caparo River crossing, along the field road to Santa Bárbara de Barinas near the southern margin of the Uribante-Caparo Lake. Also shown are the positions of the sections (now submerged) with Ordovician fossils that were listed by Shell and Creole (1964).

PREVIOUS DATA AND LOCATION OF THE STUDIED MATERIAL

The discovery of fossils in the old "Caparro-Bellavista series" (Christ, 1927) within the Caparo Block of the Mérida Andes of Venezuela, was described by Terry (1935, p. 692) as occurring near the Caparo River crossing (currently submerged under Uribante-Caparo Lake), along an abandoned field road from Mucuchachí to Santa Bárbara de Barinas. His fossil collection, belonging to the Sinclair Exploration Company, was later studied by Leith (1938), who described three new fossil species including the graptolite *Dicranograptus* "*caparroensis*" (a junior synonym of *D. ramosus* Hall), a trilobite ("*Cryptolithus*" *terryi*) and a bivalve (*Allonychia*? *brevirostris*). Leith (1938) also listed an "?Orthoid brachiopod" and an "undetermined pelecypod".

Four additional fossiliferous sections were found by Pierce et al. (1961, fig. 8) and Shell and Creole (1964, figs. 2 and 3): two of them recorded as adjacent to the Caparo River crossing (El Remolino and Cordero creeks, neither in existence today), a third along the Lirán creek (about 17.4 km northeast of the old Caparo River crossing), and the fourth in the upper valley of the Caparo River, about 19.5 km northeast from the Lirán creek. These authors also listed the occurrence of Ordovician trilobites, graptolites, brachiopods, bryozoans, crinoids and questionable corals in several beds within the Caparo Formation, and considered all the fossil localities to be of late Mohawkian (early "Caradocian") age. A partial review of the original trinucleid trilobite material from these collections reassigned specimens of *Cryptolithus terryi* to the genera ?*Salterolithus* (Dean in Shell and Creole, 1964), *Onnia* (see the redescription of *O. terryi* by Whittington, 1954) or *Reuscholithus* (Hughes et al., 1975 Hughes, 1980). More recent research at the type section of the Caparo Formation was presented by Benedetto and Ramírez Puig (1982) and Gutiérrez-Marco et al. (1992), with few new paleontological discoveries.

Shell and Creole (1964) reported two separate lists of graptolites collected from locality no. 5 at the Lirán creek, which formerly yielded *Dicranograptus ramosus* and *Didymograptus* sp. (Pierce et al., 1961, p. 358). A sample taken at the same section by the Shell de Venezuala company yielded the following taxa (identifications by I. Strachan): cf. *Nemagraptus* sp., *Climacograptus peltifer*, *C.* cf. *parvus*, *C.* aff. *antiquus*,

CONTENTS

Climacograptus sp., *Orthograptus* sp., *Glyptograptus* cf. *teretiusculus*, *Cryptograptus* sp., *Dicranograptus* cf. *caparroensis*, *Dicranograptus* sp., cf. *Dicranograptus* sp., cf. *Didymograptus* sp., *Amphigraptus* cf. *divergens* and cf. *Thamnograptus* sp., in association with some trilobites, brachiopods and bryozoans. Additionally, a sample collected by the Creole Petroleum company from the same section, yielded *Dicranograptus caparroensis*, *D. nicholsoni*, *Dicranograptus* sp. and some trilobites (identifications by A. Boucot and G.A. Cooper). The age in both cases was established as "Middle" Ordovician (Caradoc). The original graptolite material collected by Shell and Creole (1964) was briefly reviewed by Rickards (in Hughes, 1980, p. 11) who recognized the taxa *Dicranograptus caparroensis* Leith, *Dicranograptus* sp., *Orthograptus amplexicaulis* (Hall), *O.* ?*quadrimucronatus* (Hall), *Corynoides* sp. and *Acanthograptus* sp., assigning the assemblage to "Caradoc age, probably Longvillian or younger."

However, according to the maps associated with the above mentioned data, there are two clearly separated graptolite collections coming from Lirán creek: one apparently made by H.C. Arnold for the Company Shell de Venezuela, and the other was probably made by W.R. Smidth for the Creole Petroleum Corporation. Moreover, the detailed map of Pierce et al. (1961, fig. 8) shows that the Lirán creek section comprises two distinct fossiliferous localities separated by more than two hundred meters. As a consequence of these statements, we cannot be sure that all the graptolite data mentioned in the two previous papers came from a single locality and horizon, and thus Rickards s review and age designation (in Hughes, 1980) of the Lirán creek graptolite fauna is based on separate collections that could be of different ages. Unfortunately, due to the low water level present during the field research of January 2011, navigation to the mouth of the Lirán Creek, a tributary of the Caparo River proved impossible. Thus, we were unable to recollect that section and clarify its age relationships.

The construction of the La Honda dam in 1986 flooded the area in 2003, producing the Uribante-Caparo Lake and submerging the sections of the Caparo Formation located south (El Remolino) and west (Cordero creek) of the former Caparo River crossing (after the latter was proposed as the best reference section for the unit by Shell and Creole, 1964). A recent review of the existing outcrops above the water level along the former Cordero creek, provided some brachiopod and trilobite finds in sandstone and weathered ironstone, but no graptolites. However, a careful examination of original type section of the Caparo Formation, placed along the trail from the Uribante-Caparo Lake to Santa Bárbara de Barinas, led to the rediscovery of several fossiliferous beds, partially listed by Benedetto and Ramírez Puig (1982) and Gutiérrez-Marco et al. (1992). In addition to badly preserved remains of *Dicranograptus*, and uncommon specimens of *Amphigraptus* and dendroids, which occur through more than 30 m of strata, a reasonably well preserved graptolite assemblage was discovered in a 20 cm thick bed of laminated shale located in the trail itself (geographic coordinates S7 52 56 W71 16 13" H 392 m). This bed yielded a fairly abundant fauna of *Archiclimacograptus* specimens, along with uncommon *Hustedograptus*, *Nemagraptus*, and the same *Dicranograptus* species found in stratigraphically lower horizons. A preliminary description of this assemblage is is presented below.

THE GRAPTOLITE ASSEMBLAGE

Occurrence

The Caparo Formation graptolites are preserved as organic films on dark argillaceous shales frequently weathered to yellow to grey colours in the section. These shales are intercalated with lighter colored

CONTENTS

laminae consisting of thin bands with a sandy texture that are very rich in transported fossils, such as dissociated sclerites of trinucleid and calymenacean trilobites, isolated valves of orthid and organophosfatic brachiopods, small fragments of ramose bryozoans and graptolites, crinoid columnals, and a few smooth ostracods. Our sedimentological interpretation is that the graptolite-bearing beds represent distal turbidites, an analysis in agreement with the occurrence of some "deep-water" olenid trilobites (*Porterfieldia*, *Triarthrus*?) with the graptolites at the Lirán creek (Shell and Creole, 1964 Hughes, 1980).

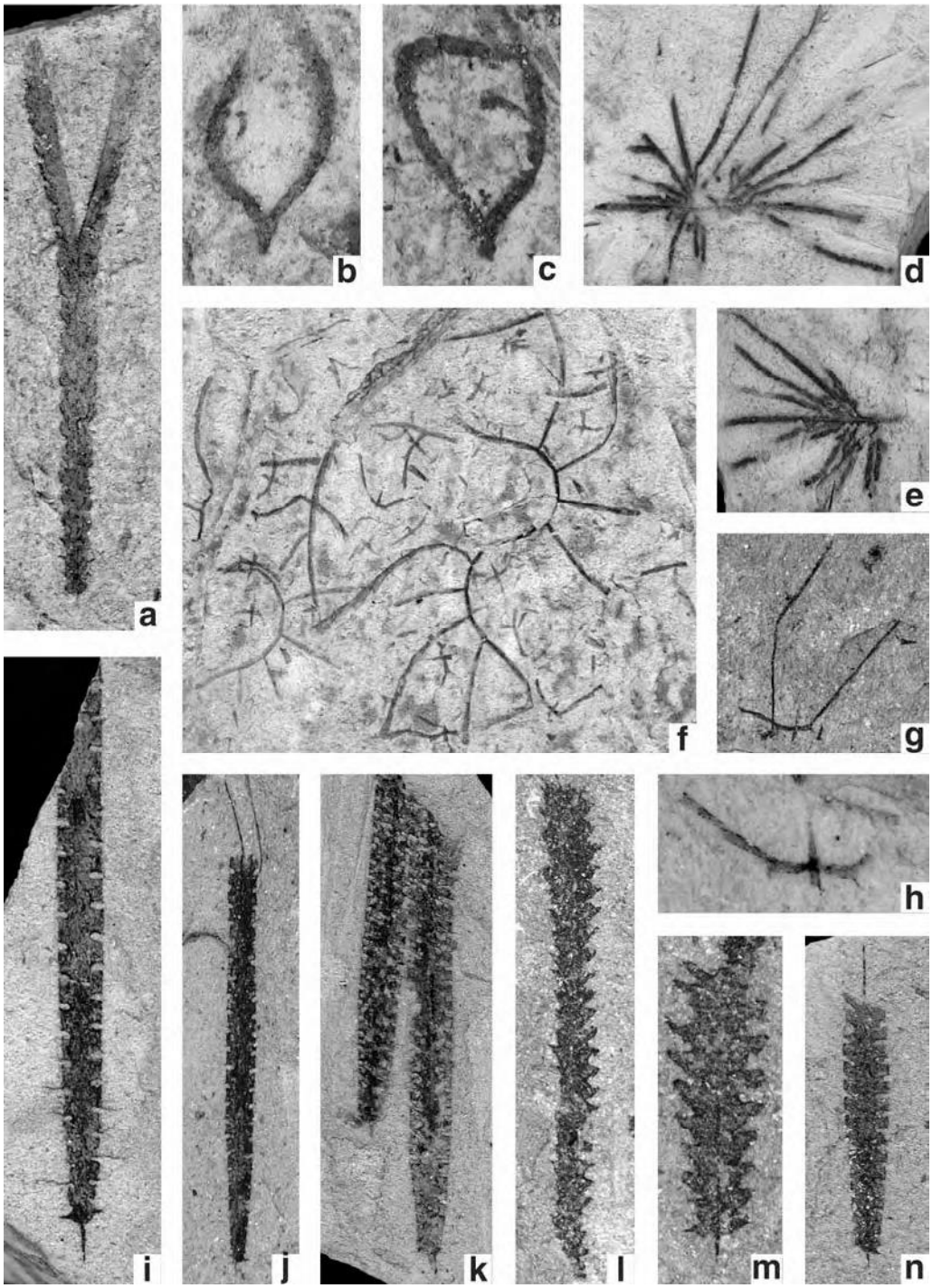
Transported fragments of benthic graptolites belong to the genera *Dictyonema*, *Desmograptus* (both recorded from the section by Gutiérrez-Marco et al., 1992), and another undetermined form resembling *Callograptus* or *Dendrograptus*. All the specimens are too fragmented for species level identification.

Taxonomic notes

1. *Nemagraptus gracilis* (Hall) was fully re-described and illustrated from both flattened and isolated specimens by Finney (1985). Our specimens (Figs. 1f–h) fully agree with Finney s (1985) description.
2. *Dicranograptus ramosus* (Hall). Ruedemann (1947) provided a full description of Hall s (1847) species, noting that it is characterized by a very long biserial portion (13 to 18 thecal pairs) and a narrow axial angle between the uniserial stipes. Topotypical and other specimens collected by one of the junior author (DG) exhibit similar variability in the length of the biserial portion and also have mesial spines on the first 2 to 5 thecal pairs. Leith (1938) differentiated *Dicranograptus caparroensis* n. sp. from *D. ramosus* based on the former having greater sigmoidal curvature to the ventral thecal walls, a slightly longer biserial portion (17 as opposed to 15 mm), and a slightly larger axial angle (40 as opposed to 30 degrees). An examination of Leith s (1938) figures and our new specimens (Fig. 1a) indicates that all the Venezuelan material falls within the range of variation exhibited by other specimens of *D. ramosus*. In South America, *D. ramosus* has also been recorded from the *C. bicornis* Zone of the Argentine Precordillera (Cuerda et al., 1998 Toro and Brussa, 2003).
3. *Dicranograptus furcatus* (Hall). Several small species of *Dicranograptus* that have short, spinose, biserial portions (3 – 8 thecal pairs) and exhibit pronounced torsion in the uniserial stipes have been described from Sandbian strata in the eastern United States and Great Britain (e.g., *D. contortus* Ruedemann, *D. furcatus* (Hall), and *D. ziczac* Lapworth). Our specimens exhibit a very short (3 – 4 thecal pairs), spinose, biserial portion, and short, curved, uniserial stipes that form the start of spiral loops (Figs. 1b–c). The Venezuelan specimens best fit the descriptions for *D. furcatus* (Hall), which is also the name that maintains priority if future studies demonstrate that any of these taxa are synonymous with one another. The Venezuelan material confirms earlier but questionable records of this species from South America that were listed as *D.* cf. *furcatus* from the *N. gracilis* Zone of the central Precordillera, Argentina (Ortega et al., 2008).
4. *Amphigraptus divergens* (Hall). Specimens of *Amphigraptus* exhibit two stipes that diverge from the sicula at approximately 180 degrees from each other, and also bear distinctive paired cladia. The Venezuelan specimens (Figs. 1d–e) agree with Ruedemann s (1947) description and no other species of *Amphigraptus* are known from Sandbian age strata. This rare but characteristic graptolite was

Figure 2. Sandbian graptolites from the Caparo Formation, Venezuelan Andes. a, *Dicranograptus ramosus* (Hall), x 3.3 b–c, *Dicranograptus furcatus* (Hall), both x 3 d–e, *Amphigraptus divergens* (Hall), x 0.7 and x 1.6, respectively f–h, *Nemagraptus gracilis* (Hall), x 3.5, x 3.8 and x 8, respectively i–k and n, *Archiclimacograptus meridionalis* (Ruedemann), x 5.2 (i), x 3 (j-k) and x 3.6 (n) l–m, *Hustedograptus vikarbyensis* (Jaanusson), x 3.3 and x 6.2, respectively.

CONTENTS



CONTENTS

previously recorded in South America only from the Upper Ordovician of the Argentine Precordillera (Cuerda, 1979).

5. *Hustedograptus vikarbyensis* (Jaanusson). Jaanusson (1960) described a new species of "*Glyptograptus*" (now *Hustedograptus* Mitchell, 1987), "*G.*" *vikarbyensis*, from the Furudal Limestone (*Hustedograptus teretiusculus* Zone) on land, Sweden. *Hustedograptus vikarbyensis* was differentiated from the more commonly cited *H. teretiusculus* by its narrower rhabdosome and more symmetrical proximal end – i.e., the first two thecae form a symmetric "w" shape with their upward facing apertures occuring at approximately the same level (Jaanusson, 1960 Maletz, 1997). Our specimens (Fig. 1l–m) agree completely with Jaanusson s (1960) description of the specimens from Sweden. In South America, *H. vikarbyensis* has also been recorded from the *H. teretiusculus* Zone of the central Precordillera, Argentina (Ortega et al., 2008).
6. *Archiclimacograptus meridionalis* (Ruedemann). This genus currently comprises two distinct sets of species (Mitchell, 2007), a more primitive group that has strongly introverted apertures (e.g., *Archiclimacograptus decoratus* and *A. sebyensis*) and a derived group with nearly horizontal, semi-circular apertures (e.g., *A. meridionalis* and *A. antiquus*). The Venezuelan specimens have thecae with straight ventral walls and relatively shallow, horizontal, semi-circular apertures (Figs. 1i–k, n), and clearly belong to the derived group. Their dimensions (rhabdosomes widen from about 0.8 mm at the second thecal pair to 1.3 – 1.5 mm distally, and having 11 – 13 thecae in 10mm proximally) fit most closely to *Archiclimacograptus meridionalis* (Ruedemann). The slightly fusiform shape of the rhabdosome also agrees with the morphology of *A. meridionalis*. Our specimens also resemble *A. antiquus* (Lapworth), but tend to be narrower with shorter thecae than the latter species. In South America, another possible record of *A. meridionalis* comes from the *N. gracilis* Zone of the central Precordillera, Argentina (Ortega et al., 2008).
7. *Cryptograptus* sp. Several fragmentary specimens of *Cryptograptus* occur in our collection. These are not well enough preserved for a species level identification.

Biostratigraphy

Our new collections from the Caparo Formation along the trail from the Uribante-Caparo Lake to Santa Bárbara de Barinas contain a fauna that is referable to the *Nemagraptus gracilis* Zone. The presence of the eponymous species along with *Dicranograptus ramosus*, *D. furcatus*, and *Archiclimacograptus meridionalis* clearly indicate a Sandbian age for the strata. Although many of the taxa range up into the upper Sandbian, the complete absence of *Climacograptus bicornis* or any astogenetic Pattern G orthograptids (e.g., *Orthograptus calcaratus* group species) indicate that a lower Sandbian (*N. gracilis* Zone) age assignment is most appropriate.

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CONTENTS

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CONTENTS