

Agglutinated foraminifera and sequence stratigraphy from the Chipaque Formation (Upper Cretaceous) of El Crucero section, Colombia, South America

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ABSTRACT: Agglutinated foraminifera from a section of the Chipaque Formation (Cenomanian-Campanian) in the Eastern Cordillera of Colombia are reported. The foraminiferal assemblage is dominated by species of the genera *Ammobaculites* and *Haplophragmoides*. The stratigraphic ranges of *Ammobaculites colombianus*, *Haplophragmoides walteri*, and *Haplophragmoides rugosus* are extended from a previously known Coniacian-Maastrichtian to a Cenomanian-Maastrichtian distribution, according to their appearance in the Chipaque Formation. Similarly, the range of *Saccamina globosa* (Cenomanian-Turonian) is extended to the Maastrichtian. The predominance of agglutinated foraminifera in the section is ascribed to undersaturation of calcium carbonate in the water column over the inner to outer shelf, due to the influx of terrigenous material. The array of parasequences composed of mudstone-sandstone couplets indicate landward and basinward coastline migrations that correspond to third order depositional sequences.

INTRODUCTION AND GEOLOGICAL SETTING

The paleoecological and chronological value of agglutinated foraminifera has increased in recent years in view of the worldwide attention they have received. Agglutinated foraminiferal assemblages of bathyal and abyssal habitats are particularly well known (e.g., Kuhnt et al. 1989; Kaminski et al. 1988; Kuhnt 1990; Gooday 1990), but there have been few paleoecological studies of neritic settings with predominantly agglutinated microfauna. Present assemblages of this type of microfauna described on shelf environments (e.g., Zheng and Fu 1990) may prove useful for accurate paleobathymetrical appraisals of ancient deposits. Although still subject to major changes in their stratigraphic ranges, the biostratigraphic use of agglutinated foraminifera in Upper Cretaceous rock successions has been stressed in various papers (Morgiel and Olszewska 1981; Kaminski et al. 1988; Kuhnt et al. 1989; Bolli et al. 1994, and references therein).

Agglutinated foraminifera from the Upper Cretaceous of north-western South America have been seldom studied. In comparison, more attention has been devoted to the planktonic and calcareous benthonic microfauna, illustrated in early works that concentrated mainly on systematics (e.g., Cushman and Hedberg 1930, 1941). More recent contributions have widened the knowledge of foraminifera as age indicators and paleobathymetric proxies in the Cretaceous of Colombia (Martínez 1989, 1995; Tchegliakova 1993; Vergara 1994). Even though species of agglutinated foraminifera in Colombia are rare, there is a growing need to evaluate their usefulness as biochronostratigraphic tools or as elements in paleoenvironmental appraisals. In spite of intense exploratory work and huge hydrocarbon discoveries in the foothills of the Eastern Cordillera (e.g., Cusiana and Cupiagua oil fields), very little is known about the foraminiferal content of strata along the eastern flank of the Cordillera and of the Llanos foothills.

Except for a recent contribution by Tchegliakova (1995), the taxonomic aspects of many agglutinated lineages recorded in Colombia are yet unknown. A single species (*Ammobaculites*

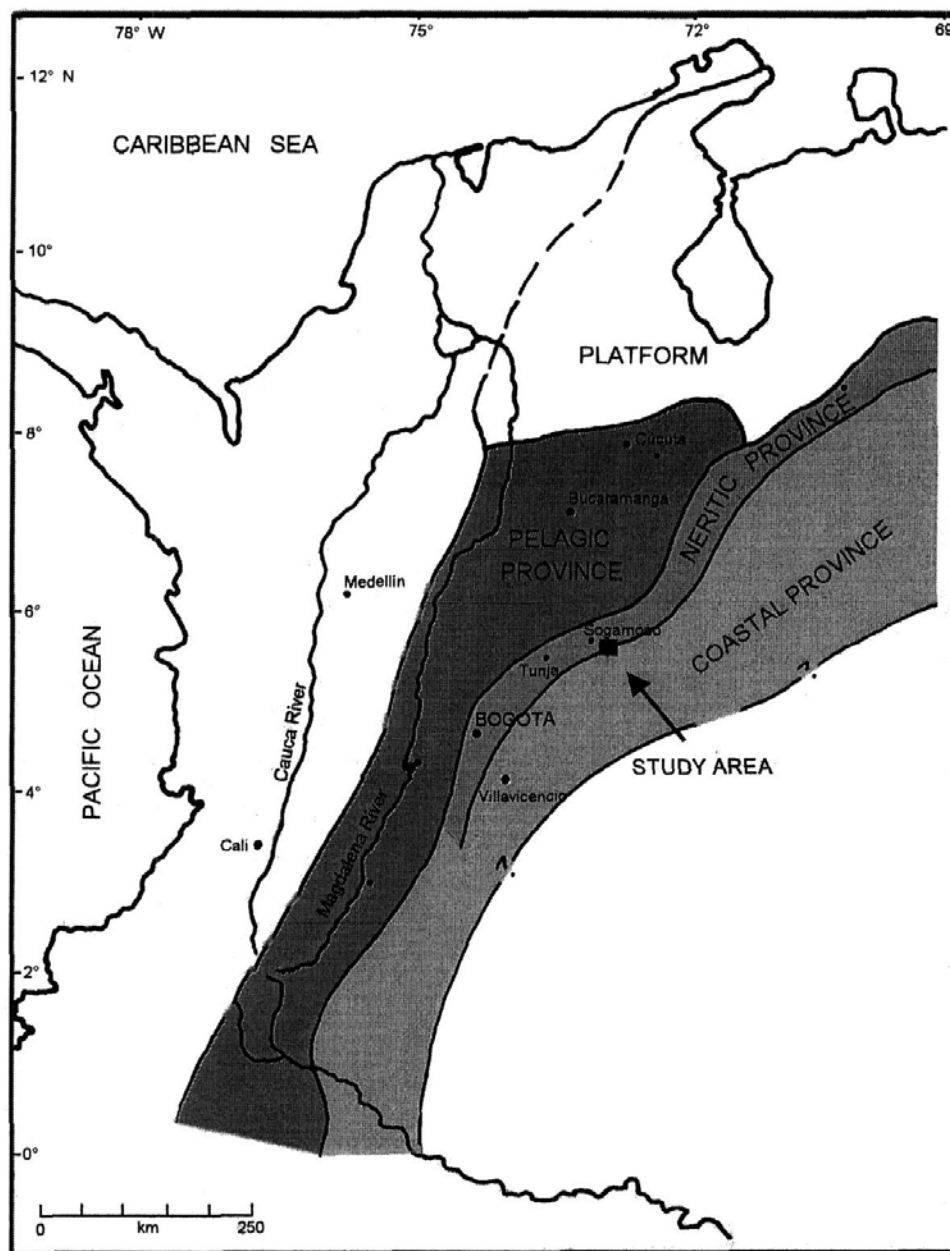
colombianus) was postulated by Petters (1955) as an index fossil. Yet, biozonations based upon benthonic species are considered of limited chronologic value in Colombia (Martínez 1989), and much work is needed to define precisely the ranges of most of the benthonic species. In this paper we intend to draw attention to the ubiquitous presence of agglutinated foraminifera in a section of the Chipaque Formation from the eastern flank of the Eastern Cordillera. Biostratigraphic aspects related to the microfaunal occurrence as well as paleoenvironmental and sequence stratigraphical considerations are discussed.

The geological setting of the present study area is believed to correspond to a supracontinental rift basin that originated in the early Mesozoic (e.g., Macía et al. 1985). During the Late Cretaceous, this setting became an epicontinental sea that extended regionally around the Guyana shield towards the west. Macellari and De Vries (1987) recognized strips of coastal, neritic and pelagic domains that developed roughly in a NE-SW trend during the Turonian to Santonian (text-figure 1). The section of the Chipaque Formation is located close to the boundary between the coastal and neritic domains depicted by Macellari and De Vries. The large extensional faults that delimit the basin reactivated during the Cenozoic, resulting in phases of episodic uplift in the present Eastern Cordillera that continued until the early Quaternary (van der Hammen 1961).

LOCATION AND METHODS

The stratigraphic section of El Crucero is located in the province of Boyacá along the highway connecting Sogamoso to Yopal at the Llanos foothills, close to Lake Tota (text-figure 2). The section was described previously in an unpublished thesis by Alzate and Bueno (1994). Regional mapping of the area, carried out by Ingeominas and published as Sheet 192 (Ulloa et al. 1973), shows that the measured section occurs on the eastern limb of the El Crucero anticline (text-figure 2).

Approximately 480m of the Chipaque Formation that outcrop in this section together with the main lithological characteristics are shown in text-figures 5 and 6 (see text-figure 4 for captions).



TEXT-FIGURE 1

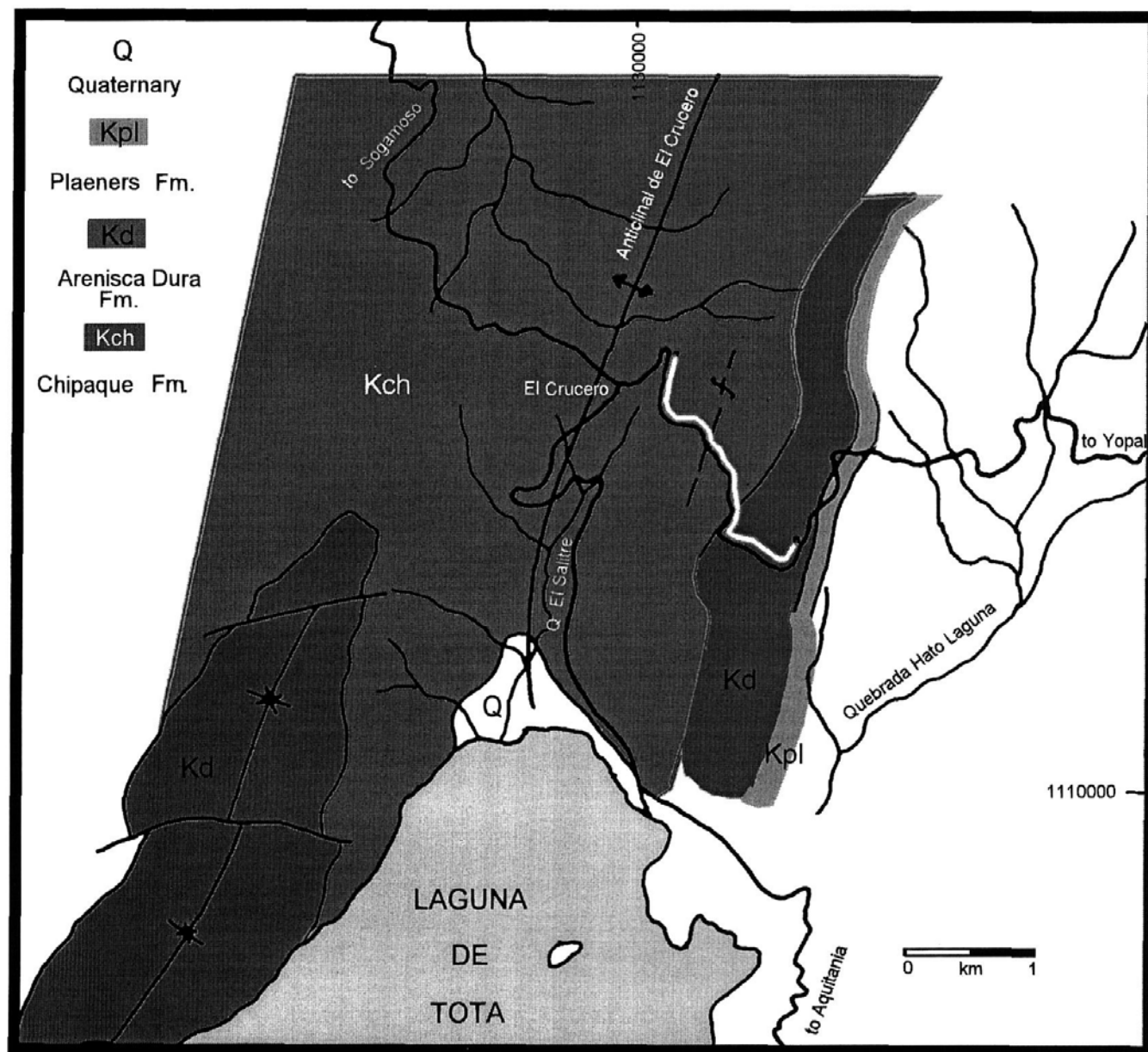
Paleogeography of eastern Colombia and western Venezuela during the Late Cretaceous (Turonian and Santonian). Modified after Macellari and De Vries (1987). Box shows location of text-figure 2.

The base of the unit is not exposed and the measured sections include the basal part of the overlying Arenisca Dura Formation. Folding and faulting are of minor importance and the distortion of the stratigraphical succession could be estimated in certain cases. For instance, at m 240, nearly 20m of section are likely repeated by thrusting.

The section of the Chipaque Formation was sampled for foraminifera, palynology and organic geochemistry. Fresh rock exposures with no signs of weathering facilitated the sampling. Samples were prepared for foraminifera by soaking them in Quaternary-O prior to conventional washing with a 0.063mm mesh sieve. Due to the little amount of individuals recovered no quantitative treatment was approached. The palynological study was undertaken by Bioss Ltda., whereas geochemical analyses were performed at Ecopetrol-ICP (Bucaramanga).

Stratigraphic succession of the Chipaque Formation

Text-figure 3 shows the nomenclatural equivalencies of the Chipaque Formation based on prior publications of the unit along the eastern flank of the Eastern Cordillera. The name Chipaque was introduced by Hubach (in Kehr 1933), and later described in Hubach (1958). The Chipaque Formation in the study area lies conformably on the Une Formation (Aptian-Cenomanian) and is conformably overlain by the Arenisca Dura Formation (Campanian) of the Guadalupe Group. This is the concept of the Chipaque Formation (*sensu* Renzoni 1962) that we use herein. In the Llanos foothills, the Chipaque Formation has similar stratigraphic relations, but lies beneath the sandstones of the Palmichal Group (Campanian-Paleocene). In the Cocuy area in the northern part of the Eastern Cordillera, the Chipaque Formation is overlain by the La Luna Formation of Santonian to Campanian age (Etayo-



TEXT-FIGURE 2

Location and main geological features of the stratigraphic section of El Crucero, after Ulloa et al. (1973). White line shows measured section along the road Sogamoso-Yopal.

Serna 1985; Fabre 1985). Thus, the Chipaque Formation in our study area is not synonymous to that of the Cocuy area, whose equivalent upper facies (Santonian-Campanian) are denoted as the La Luna Formation in the latter region.

The lithology of the Chipaque Formation in the study area consists essentially of light to dark gray shales exhibiting even and undulating laminae. The shales alternate with thick to medium-thick layers of sandstone and siltstone bearing mostly wavy lamination. Phosphates and less commonly glauconite are present in the sandstones, which are composed of fine to very fine grained sand. Bioturbation commonly homogenizes the sandstone bodies, thus burrows usually are unidentifiable. The most frequent fossils are foraminifera; macrofossils are rare. Of stratigraphic significance are bentonite laminae in the lower part of the

section. An angular truncation of shale beds associated with a clay layer rich in plant remains occurs at m 138 (Text-figure 5).

Biostratigraphy and stratigraphic ranges of the microfauna

The early age determinations of the Chipaque Formation were furnished by Julivert (1968), who, apparently based on data from Bürgl, placed the base of the Cenomanian stage approximately coincident with the lower contact to the Une Formation, whereas the upper limit of the Chipaque Formation fell within the Senonian. However, Etayo Serna (1964) previously questioned the coincidence of the Une-Chipaque lithological limit with the base of the Cenomanian, as well as the stratigraphic value of the bivalve *Exogyra squamata* as an indicator for the base of the Turonian. In the Cocuy area (northern part of the Eastern Cordillera), the Chipaque Formation ranges from the Cenomanian

pearing in strata of probable Cenomanian age. In Ecuador, similar lineages occur in the late Santonian or early Campanian (Durán and Salazar 1986). This allows to discard the age-indicative character of *A. colombianus* and to extend its range well into the "middle Cretaceous".

Similarly, *Haplophragmoides walteri* is reported herein from Cenomanian through Senonian rocks of the Chipaque Formation. In view of this, a wider range than Coniacian to Eocene (Morgiel and Olszewska 1981) applies. *Haplophragmoides walteri* seems to be common in the Maastrichtian Umir Formation of Colombia (Tchegliakova 1995). In addition, *Haplophragmoides rugosus* was reported from the Taylor (Campanian) and Navarro (Maastrichtian) stages by Cushman (1946); we found it in strata of most probable Turonian age.

Facies types and paleoenvironmental considerations

In the section studied there are mainly two facies types represented by the mudstones (shales) and very fine to fine-grained sandstones. The sand/shale ratio is used to infer open sea deposits (outer shelf) and transition zone episodes (see Reinson 1992), as shown in the stratigraphic columns (text-figures 5 and 6).

The shales of the Chipaque Formation in the El Crucero section contain a variety of indicators of probable prodelta type shales. Towards the base of the unit, there are abundant plant remains that suggest a proximity to fluvial mouths. As described before, the sandstone banks exhibit undulose laminae, are homogenized by bioturbation, and contain sporadic macrofossil remains. These sandstone interbeds correspond generally to shoreface environments brought about by pulses of terrigenous input, whose relation to sea level will be discussed later. At intervals (e.g., 230-285m), a nearly equal proportion of sandstones and shales is ascribed to the lower shoreface and distal lower shoreface (see van Wagoner et al. 1992: fig. 3A), the latter denoted here as a transition zone.

We believe that most of the organic matter bearing mudstones were deposited in inner to outer shelf environments. However, anoxic conditions did not develop thoroughly and thus the organic matter quantity expressed as total organic carbon averages only 0.76%. The decomposition of organic matter was favored by oxygen bearing currents that brought fine sandstones from the continent located to the east. The presence of an oxygenated sediment-water interface is supported by the presence of *Planolites* and *Thalassinoides* type burrows and the common wavy, discontinuous lamination of the mudstones resulting from bioturbation in some intervals. However, mudstones commonly exhibit a parallel, even lamination that indicates poor oxygenation at the ocean bottom (e.g., Demaison and Moore 1980, among others). In general, the characteristics of the population meet the dysaerobic to quasi-anaerobic bottom conditions outlined by Koutsoukos et al. (1990: Table II) especially concerning the low diversity, high dominance (*Ammobaculites* and *Haplophragmoides*) and muddy substrate.

The paleoenvironmental significance of the benthonic foraminifera of the Chipaque Formation is summarized as follows. Douglas (1979) restricted agglutinated dominated biofacies to marginal marine-estuarine or to abyssal deposits beneath the carbonate compensation depth. The latter biotope is discounted here due to the presence of shelf organic matter bearing mudstones and shallow-water sandstones, and because of the regional epicontinental setting.

The living conditions of the infaunal genera discussed below help to shed light on the paleoenvironment. For instance, species of *Haplophragmoides* dwell preferably within bathyal or marsh settings, whereas *Ammobaculites* and *Reophax* are more tolerant to environmental constraints, living from lagoons to bathyal zones (Murray 1991). The microfaunal assemblage of the Chipaque Formation is comparable to the *Haplophragmoides* association described by Morris (1971), where the species *H. excavatus* (= *H. walteri*) also occurs abundantly, as well as other genera of foraminifera reported here. Morris interpreted his mudstone related assemblage to belong to nearshore open marine environments. This comparison is also supported by the very rare planktonic foraminifera and the lack of calcareous benthonics in our samples.

Recent weathering is a possible causal factor for the rarity of calcareous foraminifera, but the climatic regime around the El Crucero section differs little or nothing from that prevalent in other Cretaceous sections of the Eastern Cordillera, for instance near Tausa or Gámeza, where calcareous foraminifera are locally abundant and other fossils such as ammonites are present as casts (Tausa section; Föllmi et al. 1992; Martínez 1995). Therefore, we believe paleoenvironmental factors controlled the composition of the foraminiferal assemblage, in particular, the carbonate availability.

Calcium carbonate undersaturation in the water column can account for the extreme paucity of calcareous fossils (cf. Hesse and Butt 1976). Undersaturation in CaCO_3 at the inferred very shallow position of the El Crucero section in the basin may be explained by high continental runoff, a hypothesis that is also supported by the lack of carbonate banks or concretions in this section of the Chipaque Formation. In addition, the proximity of river mouths generated turbidity in the water column that hampered the biological crystallization of CaCO_3 , thus providing a favorable environment for agglutinated foraminifera (cf. Boltovskoy and Wright 1976).

Sliter and Baker (1972) included *Haplophragmoides*, *Trochammina* and *Spiroplectammina*, among others, within the inner shelf fauna in their biofacies model. Planktonic foraminifera such as *Hedbergella* and *Heterohelix* (sample 131294-03) are considered to belong to the epipelagic zone (Sliter 1972; Hart and Bailey 1979). Similarly, dinoflagellates occur in only one sample (131294-17), and they are subordinated to large amounts of spores and angiosperm pollen grains.

Deeper dwelling organisms or planktonic foraminifera of intermediate to deep layers are sparse, even in the pelagic facies of the Magdalena Valley (see text-figure 1). Elements such as paleogeography, water-column anoxia, or basin shallowness are pointed out by Vergara (1994) to account for their scarceness. Since such elements were important in more distal parts of the basin, shallow water microfauna and the predominance of terrestrial-derived palynomorphs in the eastern, more proximal sections, is easily predictable.

Sequence stratigraphy of El Crucero section; possible relation to the microfauna

The following interpretation is intended primarily to place the location of the microfauna in a sequence stratigraphic context, based mostly on the facies types discussed above. Parasequences were identified and outlined according to the guidelines of van Wagoner et al. (1992). In the Chipaque Formation, the parasequences coarsen upward, tend to be a few meters thick, and are

delimited by flooding surfaces of shale overlying sandstones with sharp contacts. They resemble the idealized parasequences illustrated by van Wagoner et al. (1992: figs. 3A, 3B), especially in the geometry of the beds, but without vestiges of trough cross bedding or hummocky stratification within the sandstones.

The contact between the littoral sandstones of the Une Formation and overlying marine shales of the Chipaque Formation was observed in other outcrops (e.g. Quebrada Potrerogrande, Choachí) and is interpreted as a transgressive surface. The accommodation space generated by flooding during the Cenomanian lasted a long time, probably more than 10 m.y., and enabled deposition of more than 480m of predominantly marine mudstones. Within the Chipaque Formation, cycles that correspond to third order sequences could be delineated as follows.

The transgressive systems tract of the first sequence is observed in Cenomanian rocks (text-figure 5), where the parasequence stacking pattern shows progressive thinning of the sandstone banks, thus indicating a retrogradation of the coast line. The occurrence of thin bentonite layers preserved in the lower part of the Chipaque Formation is worth mentioning because of their appearance close to the Cenomanian-Turonian boundary in Colombia, where maximum flooding took place (Villamil and Arango-Pardo, in press). We picked a bentonite bed at m 85, close to which bivalves and foraminifera are present (see text-figure 5), to separate the transgressive systems tract from the highstand systems tract because it coincides with a marked change in the parasequence stacking pattern. This change represents the end of a period of coastal retrogradation and the beginning of aggradation. Thus, a period of condensation is suggested close to this change, and may be detected in more basal sections based on fossils (Villamil and Arango-Pardo, in press). Upsection, in the interval between m 90 and m 150, the stratigraphic record exhibits an aggradational array of parasequences that represents a period of sea level stability ("still-stand") prior to the regressive trend of the highstand systems tract.

Between m 150 and m 180 a new phase of retrogradational coast line is indicated in the parasequence pattern showing a progres-

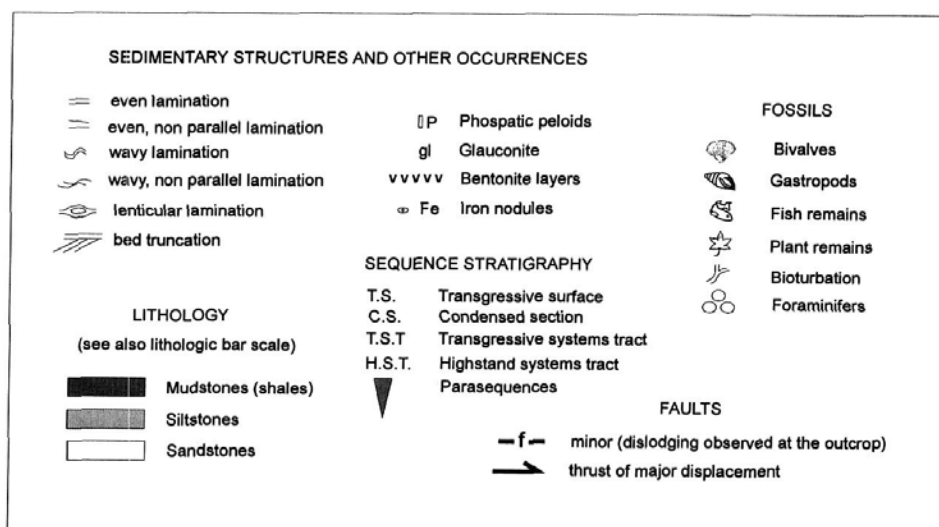
sive decrease in sandstone layers. This interval corresponds to the transgressive systems tract of sequence 2. The flooding surface at m 150 is accompanied by the only planktonic foraminifera and calcispheres recorded, few agglutinants and the occurrence of phosphate nodules (see text-figure 5). Superimposed over this transgressive interval the succession shown in the lower part of text figure 6 represents the highstand systems tract.

A third sequence probably occurs between m 250 and 430, but its elements and the recognition of clear parasequence stacking patterns cannot be precised because of the uncertainty caused by the covered intervals in this part of the Chipaque Formation (text-figure 6). However, above m 430 there is evidently another retrogradational interval that depicts the lower part of sequence 4. The maximum flooding of this fourth sequence is probably associated with the increasing number of foraminifera found in sample 131294-21, close to the top of the unit, where the Chipaque Formation grades slowly into the Arenisca Dura Formation. We envisage the lowermost portion of the latter unit as the highstand systems tract of sequence 4.

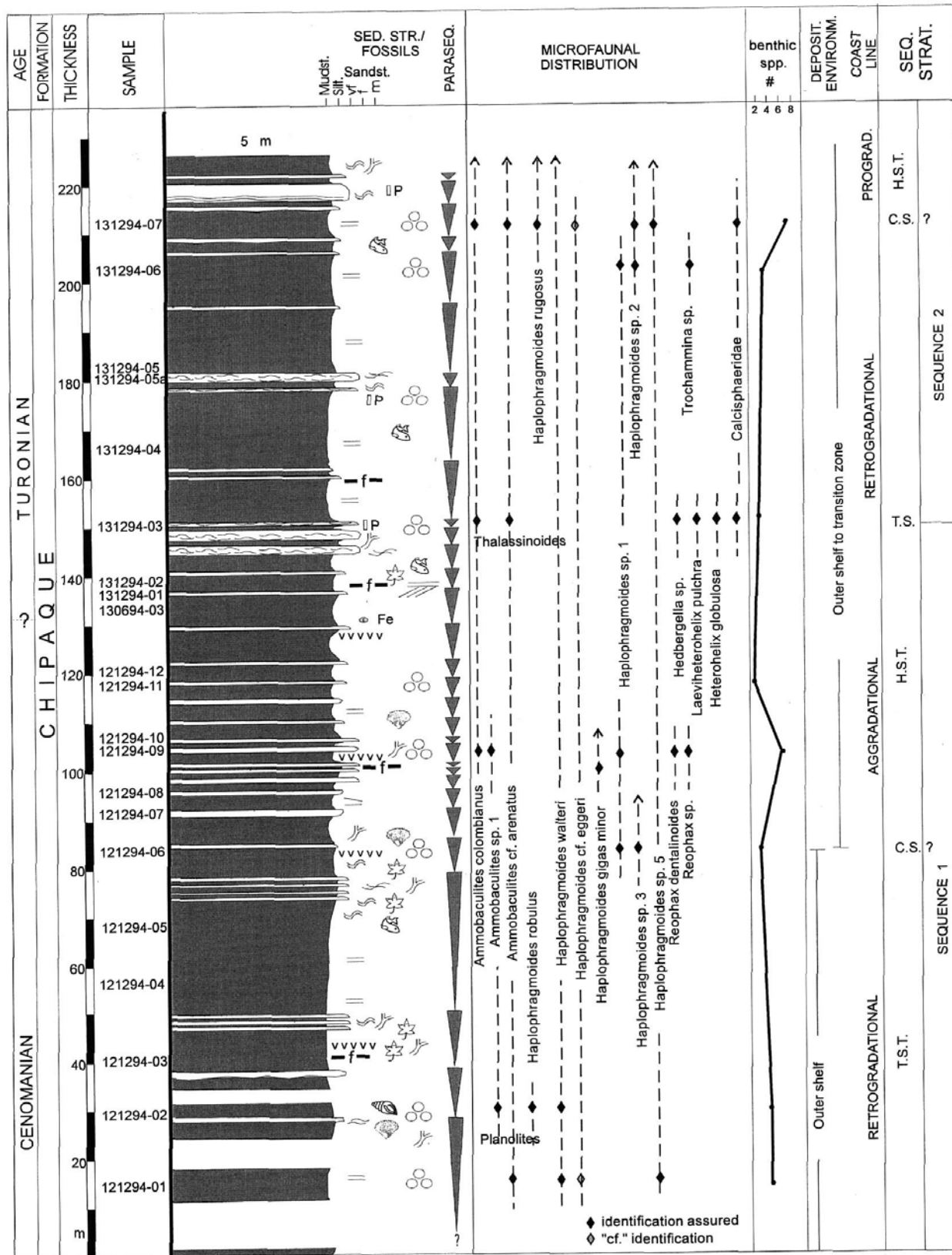
In two of the cases (sequences 2 and 4) the largest populations of foraminifera were used to infer the maximum flooding episodes, also in agreement with the parasequence stacking pattern. We also note the presence of *Ammobaculites colombianus* in samples close to or at the inferred flooding surfaces. Conversely, in sequence 1 the maximum flooding is deduced from the parasequence analysis and shows no microfaunal diversification.

DISCUSSION AND CONCLUSIONS

The evident dominance of the agglutinated foraminifera and the very little planktonic microfossils encountered owe to the high terrigenous input of the depositional system, which benefited the proliferation of the former. The most marked insights related to the occurrence of the foraminifera in the sequence stratigraphical framework seem to be speciation and the particular occurrence of *Ammobaculites colombianus* during periods of maximum flooding.



TEXT-FIGURE 4
Key for the stratigraphic columns in text-figures 5 and 6



TEXT-FIGURE 5
Stratigraphic column, microfaunal distribution and sequence stratigraphic elements of the lower half of the Chipaque Formation, El Crucero section.

The parasequence stacking patterns observed allowed the identification of third order sequences within the Chipaque Formation. The unit was thought to represent one transgression-regression cycle within the Upper Cretaceous, starting in the Cenomanian of the Chipaque Formation and ending in the Santonian-Campanian of the La Luna Formation, as outlined by Fabre (1985) in the Cocuy area. This cycle is evidently of second order according to the ranking of Haq et al. (1988), allowing the presence of further sequences of higher order such as those delineated in this paper. Further discussion of the sequence stratigraphy of the Upper Cretaceous of eastern Colombia is beyond the scope of this paper.

The agglutinated foraminifera from the Chipaque Formation are closely related to the faunal populations recorded in the Eastern Cordillera of Colombia (Martínez 1989; Tchegliakova 1995) in account of the considerable number of species common to this study. Similar or identical species of the genera *Ammobaculites* and *Haplophragmoides*, by far the most abundant in our samples, are widely known from California (Sliter 1968) and Texas (Cushman 1946) to Venezuela (Sellier de Civrieux 1952) and Argentina (Malumíán and Náñez 1986). Conversely, when comparing the species of this genera in the above mentioned works with the Caribbean assemblages compiled by Bolli et al. (1994), the number of common species is rather low. An even lesser affinity of our agglutinated faunas to the ones reported by Koutsoukos et al. (1990) and Koutsoukos and Bengtson (1993) for the Sergipe Basin in Brazil can be perceived, although the contrary applies for calcareous benthonic foraminifera, which show great affinity to those reported elsewhere in Colombia (see references above). Therefore it is unlikely that free intermingling of the biota between the Caribbean Sea or Atlantic Ocean and the Andean basins became restricted, but possibly differing depositional environments and facies control of the fauna were responsible for the occurrence of our peculiar population of shelf dwelling agglutinants.

In view of the extremely long stratigraphic ranges of many agglutinated foraminifera, the extension of the biochrons from the Maastrichtian to the "middle" Cretaceous is not very surprising. Species of *Haplophragmoides*, for instance, are difficult to distinguish morphologically (e.g., *H. rugosus*, *H. calcula*) and the obvious tendency is to lump specimens into general categories, until distinct features and shorter stratigraphic ranges are proven.

TAXONOMIC NOTES

Ammobaculites colombianus Cushman and Hedberg
Plate 1, figure 19

Ammobaculites colombiana n. sp. CUSHMAN and HEDBERG 1930, p. 68, pl. 9, figs. 4a,b (holotype).

Ammobaculites colombianus Cushman and Hedberg.—CUSHMAN and HEDBERG 1941, p. 83, pl. 21, fig. 3. —TCHEGLIAKOVA 1995, p.118, pl. 5, fig. 2

Remarks: This species is easily recognized due to its conspicuous uncoiling, the curved final chambers, the raised sutures, and its very thin test (see also Tchegliakova 1995).

Range: Cenomanian to Maastrichtian, as stated in this work (see above).

Ammobaculites subcretaceus Cushman and Alexander
Plate 2, figure 10

Ammobaculites subcretaceus Cushman and Alexander.—CUSHMAN 1946: 23, pl. 3, figs. 18-20. —WIGHTMAN 1990: 755, pl. 1, figs. 11-13. —BOLLI ET AL. 1994: 78-79, fig. 20/34

Range: Late Albian to early Cenomanian (Bolli et al. 1994); occurs in sample 131294-11

Ammobaculites cf. *arenatus* Cushman
Plate 2, figure 2

Remarks: The specimen illustrated probably represents a juvenile form of *A. arenatus* because adult forms are longer than wider. Its large size with considerable cement content seems to be diagnostic (Cushman 1946). We have also observed larger individuals in other samples, which correspond more surely to *A. arenatus*.

Ammobaculites sp.
Plate 1, figure 7

Remarks: This form seems to represent an intermediate form between *A. colombianus* and the longer *A. coprolithiforme*.

Bathysiphon sp.
Plate 1, figure 3

Remarks: The specimen is a finely agglutinated long tube without constrictions. It is comparable to some foraminifers illustrated by Malumíán and Náñez (1986: pl. V, fig. 4) and Kaminski et al. (1988: pl. 1, fig. 2-3) that were not ascribed to any particular taxon. It is tentatively assigned to the present genus but we are aware it may belong in the genus *Nothia* (see below).

Haplophragmoides calcula Cushman and Waters
Plate 2, figures 1, 8

Haplophragmoides calcula n. sp. CUSHMAN and WATERS 1927, p. 83, pl. 10, fig. 5 a,b (holotype). —CUSHMAN 1946, p. 19-20, pl. 2, figs. 11, 12

Remarks: Tchegliakova (1995) suggested synonymy between *H. calcula* and *H. rugosus*. According to the original definitions of both species, *H. calcula* bears a coarser grain size than *H. rugosus*, which is true for our specimens also.

Range: the biochron seems to extend from the Austin (Coniacian-Santonian) to the Navarro (Maastrichtian) according to Cushman (1946). In this work it appears in the upper part of the Chipaque Formation in Senonian strata.

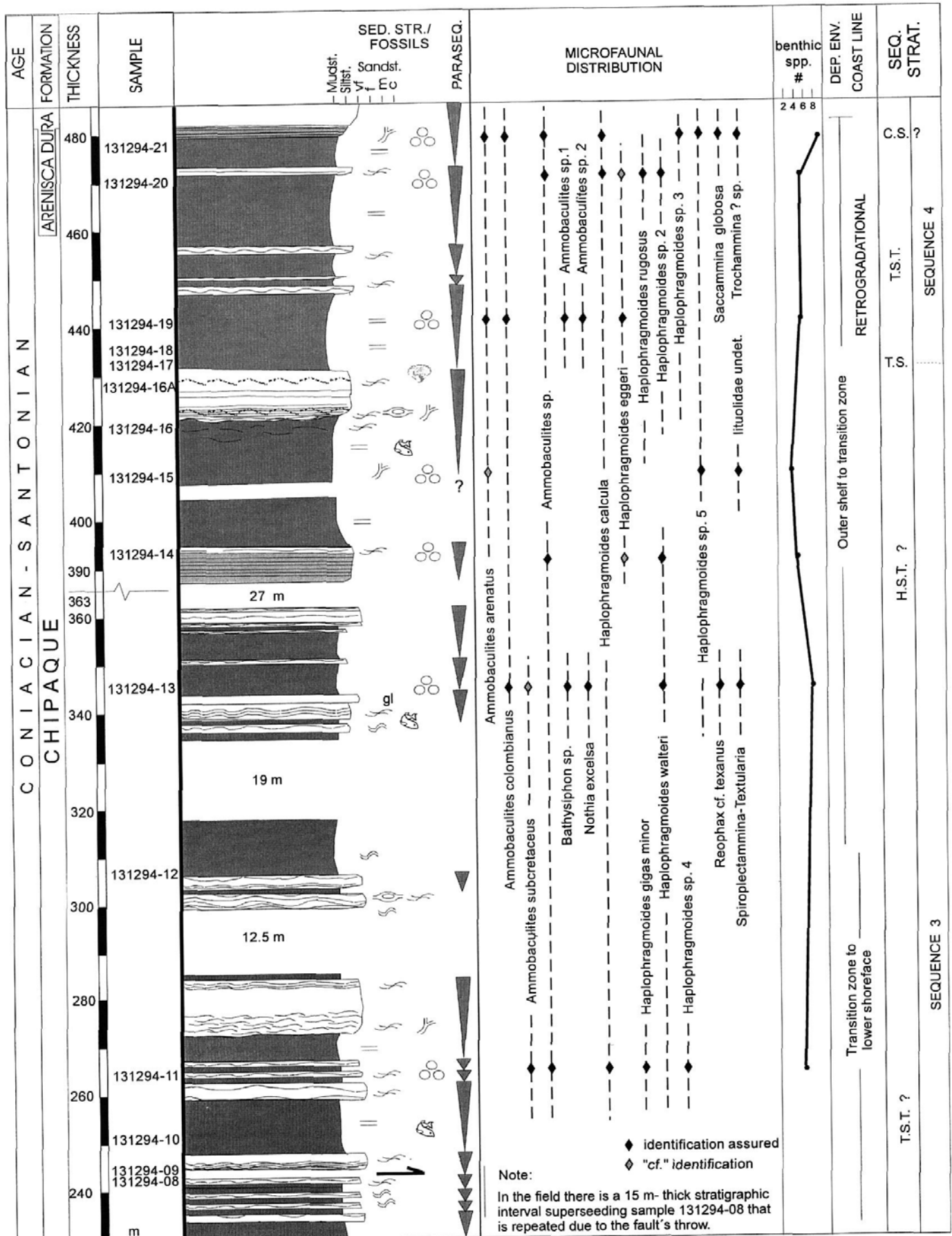
Haplophragmoides gigas minor Nauss
Plate 1, figure 12

Haplophragmoides gigas minor NAUSS, n. var., 1947, p. 338-339, pl. 49, fig. 10 (holotype).—MORGIEL and OLSZEWSKA 1981, p.10, pl. 3, fig. 1.—MALUMÍÁN 1986, p. 485, lám. XII, fig. 5a-b.—MALUMÍÁN and NÁÑEZ 1986, p. 517, lám. II, figs. 2-3

Haplophragmoides minor Nauss.—WIGHTMAN 1990, p. 752-753, pl. 1, figs. 3-4

Remarks: *Haplophragmoides gigas minor* is smaller and finer grained than the holotype of *H. gigas* Cushman. Its similarity to the specimen of the genera *Feurtillia* illustrated by Loeblich and Tappan (1964; fig. 144/1) is evident, but it differs in the subacute contour of the present species, which is also biconvex in the lateral view.

Neagu (1990) defined a similar form, *H. falcatosuturalis*, which differs from *H. gigas minor* in the lenticular instead of compressed shape of the test, but is probably a synonym of much of the forms reported above.



TEXT-FIGURE 6
Stratigraphic column, microfaunal distribution and *sequence stratigraphic* elements of the upper half of the Chipaque Formation, El Crucero section.

Range: Albian to Cenomanian according to Morgiel and Olszewska (1981). The last occurrence was reported near to the Cenomanian/Turonian boundary by Kuhnt et al. (1989). In the Chipaque Formation the species occurs in strata ascribed to the Cenomanian.

Haplophragmoides robus Montanaro-Gallitelli
Plate 1, figure 18

Haplophragmoides robus Montanaro-Gallitelli.- LOEBLICH and TAPPAN, 1964, p. C223, fig. 135/ 2a-c (lectotype designated)

Remarks: This taxon is easily mistaken for specimens of *Ammobaculites*, as we believe is the case with a specimen shown by Durán and Salazar (1986: pl. 1, fig. 4) from Ecuador. In our opinion, however, the position of the last chamber does not represent a true uncoiling but instead shows a tendency to become involute, characteristic proper of *Haplophragmoides*.

Range: described from the Upper Cretaceous of the Apennines (Loeblich and Tappan 1964). In this work in sample 121294-02.

Haplophragmoides rugosus Cushman and Waters
Plate 2, figure 6

Haplophragmoides rugosa Cushman and Waters.- CUSHMAN 1946, p. 20, pl. 2, figs. 18, 19

Haplophragmoides rugosus Cushman and Waters.- TCHEGLIAKOVA, 1995, p. 116, lám. 3, fig. 2a,b (with list of synonyms)

Remarks: Differs from other species of *Haplophragmoides* in the subspherical chambers and the sand of angular shape that agglutinates. As in many other coarse-grained agglutinated foraminifera, the sutures can seldom be seen.

Range: Cushman (1946) reports it in the North American Navarro and Taylor stages. In samples 131294-07 and -20 of the Chipaque Formation.

Haplophragmoides walteri (Grzybowski)
Plate 1, figure 11

Trochammina walteri n.sp. GRZYBOWSKI 1897; holotype reproduced in Kaminski et al., 1993 (Eds.): p. 111, pl. 11, fig. 31

Haplophragmoides excavata Cushman and Waters.- CUSHMAN and HEDBERG 1941, p. 82, pl. 21, fig. 1

Haplophragmoides glabra Cushman and Waters. - CUSHMAN 1946, p. 20, pl. 2, fig. 16, 17

Haplophragmoides excavata Cushman and Waters.- MELLO, 1971, p. 30-34, pl. 4, figs. 1-6

Haplophragmoides walteri (Grzybowski).- MORGIEL and OLSZEWSKA 1981 p. 10, pl. 3, fig. 15.- KAMINSKI ET AL. 1988, p. 189, pl. 5, figs. 14, 15.- CHARNOCK and JONES 1990, p. 171, pl. 6, figs. 3-4; pl. 17, fig. 2.- KAMINSKI and GEROCH 1993, p. 263, pl. 10, figs. 3a-7c

Asanospira walteri (Grzybowski).- BOLLI ET AL. 1994, p. 74, fig. 19/33-34, 40

?*Haplophragmoides walteri* (Grzybowski).- TCHEGLIAKOVA 1995, p. 115-116, lám. 3, fig. 1a,b

Remarks: Apart from the above listed synonyms, Kaminski et al. (1988) believed specimens compared to *H. glabra* are an early variety of *H. walteri*. *Haplophragmoides glabra* has been widely documented possessing intraspecific variability, as demonstrated by Mello (1971), who emended the species of Cushman and Waters and defined new forms. However, we note that his form *Haplophragmoides walteri kirki* differs considerably from the form *H. w. excavata* and should not be lumped together in the same species. The species illustrated herein in plate I (fig. 11) should correspond to an intermediate form between the varieties *excavata* and *beta* of Mello (1971: pl. 4, fig. 6). We fol-

lowed the proposal of Tchegliakova (1995) to lump together some species of difficult differentiation and of little stratigraphic value. Even so, the lobulated outline and type of sutures in specimens of *H. walteri* illustrated by Tchegliakova are unusual. Concerning the use of the genus *Asanospira* for this species, this genus differs from *Haplophragmoides* in the lenticular form and subangular periphery, among others (Loeblich and Tappan 1988), which is not observed in our specimens of *H. walteri*. Furthermore, Charnock and Jones (1990) argued that the siliceous composition of the wall, which gave rise to *Asanospira*, may be a diagenetic rather than a genetic feature, thus not justifying its retention.

Range: The first occurrence was reported in the Coniacian by Morgiel and Olszewska (1981), though restricted to the Santonian to Early-Middle Miocene in the North Sea by Charnock and Jones (1990). In the El Crucero section it occurs in Cenomanian and Senonian strata of the Chipaque Formation.

Haplophragmoides cf. eggeri (Cushman)
Plate 1, figures 4, 10

Remarks: The specimens illustrated are similar to those of Cushman (1946), who highlighted the degree of fossilization as a factor of variability. In our specimens an apparent involute coiling, the shape of the last chamber and the grain size all point towards *H. eggeri*. Although it is similar to the specimen identified by Malumián and Nández (1986: pl. I, fig. 19) as *H. cf. eggeri*, it is also similar to other specimens ascribed by the same authors to *H. walteri* (pl. X, figs. 5-6 and 9-10).

Range: Taylor and Navarro stages in North America (Cushman 1946), in Patagonia it is reported from the Cerro Toro Formation of Cenomanian-Turonian to Campanian-Santonian age (see table 1 of Malumián and Nández 1986).

***Haplophragmoides* sp. 1**
Plate 1, figure 15

Remarks: *Haplophragmoides* sp. 1 bears affinity to an Ecuadorian specimen described by Durán and Salazar (1986) and a Colombian one by Martínez (1987: pl. 10, fig. 5). Specimens are morphologically similar in the samples studied, and its discrimination is eased by the raised sutures and the medium to coarse grain size of the agglutinated material.

***Haplophragmoides* ? sp. 2**
Plate 1, figure 17; plate 2, figure 14

Remarks: This is another unknown species, assigned tentatively to *Haplophragmoides*. It agglutinates well-sorted sand grains and its profile is clearly biconvex.

***Haplophragmoides* sp. 3**
Plate 1, figure 14

Remarks: This species is the thinnest of this genera encountered in our samples.

***Haplophragmoides* sp. 4**
Plate 2, figure 9

Remarks: It may represent *H. rugosa*, but it differs in having an inflated last chamber.

***Haplophragmoides*? sp. 5**
Plate 1, figure 13

Remarks: The illustrated specimen is assigned tentatively to *Haplophragmoides* based on its planispiral profile and fine to medium grain size. In other samples, we attribute specimens with agglutinated material having slightly larger grain size, better sorting, and a hyaline quartz composition to the same taxon.

***Hedbergella* sp.**

Plate 1, figure 2a, b

Remarks: A *Hedbergella* with five chambers in the last whorl and a low trochospire; differs from *H. delrioensis* in the lower trochospire.

Range: sample 131294-03 of the Chipaque Formation (Turonian).

***Heterohelix globulosa* (Ehrenberg)**

Plate 1, figure 1

Textularia globulosa- EHRENBURG 1839 (pars): 135, pl. IV, figs. ?I(B), ?IV (B), VII(B), VIII(B) (holotype)

Heterohelix globulosa (Ehrenberg 1839).- VERGARA 1994, p. 113: pl. 2, fig. 2 a-b, 3; pl. 6, fig. 9 (with list of synonyms)

Remarks: According to the revision of the heterohelidae by Nederbragt (1991), *H. globulosa*, *H. striata* and *H. reussi* are lumped together into *H. globulosa*. On the basis of our material, these species are, in fact, difficult to separate from each other. However, we are aware that to use the three mentioned taxa may be useful because of their stratigraphic value (Sliter, wr. comm.)

Range: Turonian to Maastrichtian (Nederbragt 1991). Abundant in the upper Cretaceous of the Upper Magdalena Valley, Colombia.

***Laeviheterohelix pulchra* (Brotzen)**

(not illustrated)

Güembelina pulchra n.sp.- BROTZEN 1936, p. 121-122, pl. IX, fig. 3; non pl. IX, fig. 2 (holotype)

Laeviheterohelix pulchra (Brotzen).-NEDERBRAGT 1991, p. 352, 354, pl. 6, fig. 1

Range: Turonian to late Campanian (Nederbragt, 1991). Abundant in the Turonian and Coniacian of the Upper Magdalena Valley (Vergara, 1994); herein in sample 131294-03.

***Nothia excelsa* (Grzybowski)**

Plate 1, figure 16

Dendrophrya excelsa n. sp. GRZYBOWSKI 1897; holotype reproduced in Kaminski et al., 1993 (Eds.), p. 104, pl. 10, figs. 1-4.- MORGIEL and OLSZEWSKA 1981, p. 7, pl. 1, figs. 5-6

Dendrophrya ex gr. *excelsa* Grzybowski.- KAMINSKI ET AL. 1988 (pars), p. 182, pl. 1, fig. 4, ? fig. 5

Rhabdammina excelsa (Grzybowski).- CHARNOCK and JONES 1990, p. 152-153, pl. 1, figs. 26-27; pl. 3, fig. 24

Nothia excelsa (Grzybowski) emend. Geroch and Kaminski.- KAMINSKI and GEROCH 1993, p. 245-247, pl. 1, figs. 2-6, 15a,b

Remarks: It is likely that some incomplete specimens may be regarded as *Bathysiphon* or other tube-like relatives. This is suggested by comparing the specimen of Kaminski et al. (1988) in pl. 1, fig. 4 with the one of pl. 1, fig. 3 of these authors, the latter referred to as *Bathysiphon*. Our specimen is broken but its branching is evident. According to Kaminski and Geroch (1993) most specimens are straight rather than branched or twisted. The use of the genus *Nothia* for this species is preferred from *Rhabdammina* and *Dendrophrya* by Geroch and Kaminski (in Kaminski and Geroch 1993) because of the absence of the initial

basal chamber or centre of attachment proper of the latter two genera.

Range: Upper Cretaceous to Eocene according to Morgiel and Olszewska (1981), although the greatest range reported is Turonian-Oligocene, in the North Sea (Charnock and Jones 1990). Occurs in sample 131294-13 in this work (Senonian)

***Reophax dentalinoides* (Reuss) Cushman**

Plate 1, figure 8; plate 2, figure 12

Reophax dentalinoides (Reuss) Cushman.- CUSHMAN 1946, p.16, pl. 1, figs. 24-25

Remarks: It differs from other species of this genera by its elongate test and the grain size, predominantly arenaceous wall material. The specimens illustrated herein are comparable to a specimen illustrated by Tchegliakova (1995, lám 5, fig. 1) and referred to as *R. cf. dentalinoides*.

***Reophax cf. texanus* Cushman and Waters**

Plate 2, figure 4

Remarks: The figured specimen exhibits a terminal aperture, and arenaceous agglutinated material with clay matrix, that resembles *Reophax texanus* Cushman and Waters.

***Reophax* sp.**

Plate 1, figure 9

Remarks: We assigned the illustrated specimen to *Reophax* in view of its uniserial agglutinated test, and apparent horizontal sutures. The specimen may only be partially preserved.

***Planularia* sp.**

(not illustrated)

Remarks: The specimen corresponds to the same unnamed species documented by Cushman and Hedberg (1941: pl. 21, fig. 15).

***Pyramidina proluxa* (Cushman and Parker)**

Plate 1, figure 5

Bulimina proluxa n.sp. Cushman and Parker 1935, p. 98-99, pl. 15, figs. 5 a,b (holotype).- VERGARA 1994, p. 128, pl. 4, fig. 13; pl. 5, fig.15 (with list of synonyms)

Remarks: Sliter (1968) pointed out its typical triangular section and Cushman and Parker (1935) its aperture away from the junction of the third preceding chamber as diagnostic.

Range: The species occurs abundantly in the Senonian of the Upper Magdalena Valley (Vergara, 1994). In this study we found a few specimens in the Plaeners Formation near Gámeza.

***Saccamina globosa* Crespin**

Plate 2, figure 7

Haplophragmoides sp. A.- MARTÍNEZ 1987, pl. 10, fig. 5

Saccamina globosa Crespin.- BOLLI ET AL. 1994, p. 66-67, fig. 18.12-13

Remarks: The presence of a faint umbilicus in some specimens has probably led to determinations within *Haplophragmoides*. Its elongate termination is asymmetric, and differs from the flask-shaped, symmetric *Lagenammina grzybowskii*.

Range: Cenomanian-Turonian (Bolli et al., 1994) to Maastrichtian (Martínez 1987). Herein, *S. globosa* is present near the top of the Chipaque Formation in probable Campanian age strata.

***Spiroplectammina-Textularia* sp.**

Plate 1, figure 6

Remarks: We used this connotation to refer to biserial agglutinated specimens observed under water with a crossed suture arrangement. These features are no longer visible in the SEM photographs after metallic coating.

***Trochammina* sp.**

Plate 2, figure 3

Remarks: The figured specimen is assigned to *Trochammina* due to the presence of a low trochospire, finely agglutinated test, and globular chambers, of which the last protrudes towards the umbilical side.

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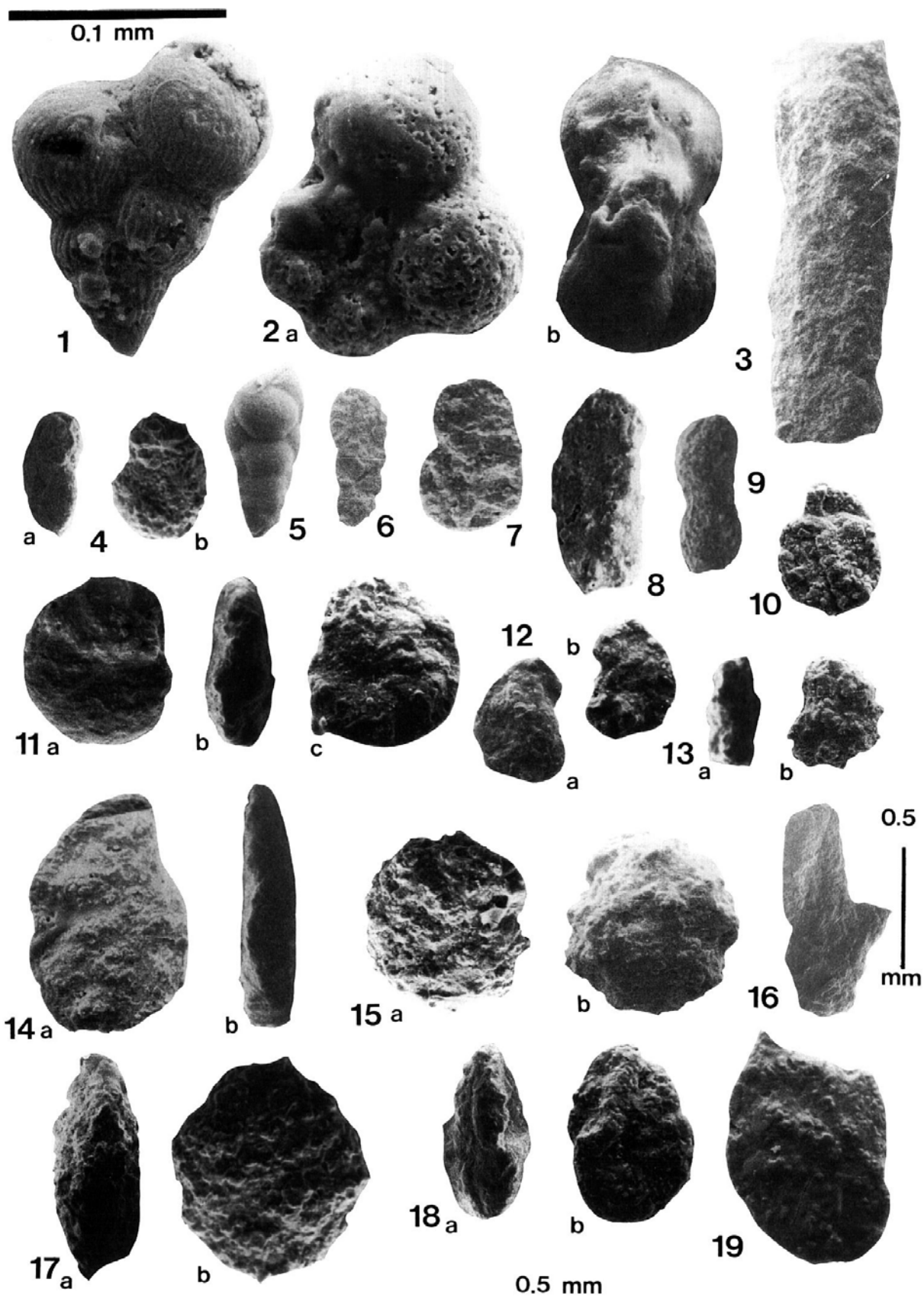
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PLATE 1

Scale: the upper bar (0.1mm.) is valid for numbers 1 and 2; the bar at the lower right (0.5mm.) for number 16, and the lower bar (0.5mm.) for the rest of the foraminifera.

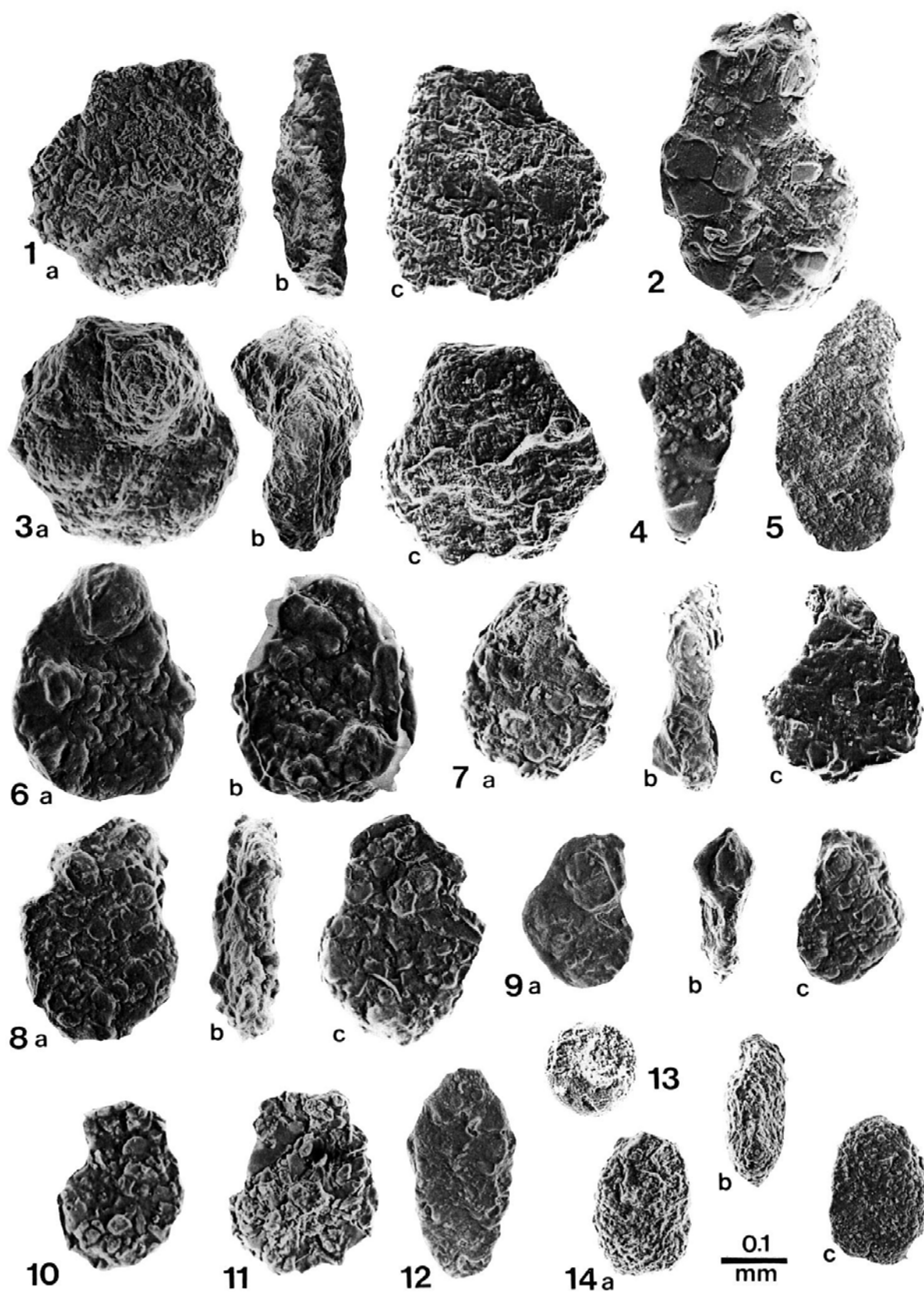
- 1 *Heterohelix globulosa* Ehrenberg, sample 131294-03
- 2 *Hedbergella* sp., sample 131294-03. a. Umbilical view; b. Lateral view
- 3 *Bathysiphon* sp., sample 131294-13
- 4 *Haplophragmoides* cf. *eggeri* Cushman, sample 131294-14. a. Lateral view; b. Umbilical view
- 5 *Pyramidina prolixa* Cushman and Parker, sample 151294-05
- 6 *Spiroplectammina-Textularia* sp., sample 131294-14
- 7 *Ammobaculites* sp., sample 131294-14
- 8 *Reophax dentalinoides* Reuss, sample 121294-09
- 9 *Reophax* sp., sample 121294-09
- 10 *Haplophragmoides* cf. *eggeri* Cushman, sample 121294-02
- 11 *Haplophragmoides walteri* Grzybowski, sample 121294-02. a. Umbilical view; b. Lateral view; c. Umbilical view
- 12 *Haplophragmoides gigas minor* Nauss, sample 121294-09. a. Spiral view; b. Umbilical view
- 13 *Haplophragmoides* ? sp. 5, sample 131294-07. a. Lateral view; b. Umbilical view
- 14 *Haplophragmoides* sp. 3, sample 131294-09. a. Umbilical view; b. Lateral view
- 15 *Haplophragmoides* sp. 1, sample 131294-07. a. Umbilical view; b. Spiral view
- 16 *Nothia excelsa* Grzybowski, sample 131294-14
- 17 *Haplophragmoides* ? sp. 2, sample 131294-07. a. Lateral view; b. Umbilical view
- 18 *Haplophragmoides robulus* Montanaro-Gallitelli, sample 121294-02. a. Lateral view; b. Spiral view
- 19 *Ammobaculites colombianus* Cushman, sample 121294-09



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PLATE 2
Scale: 0.1mm

- | | |
|---|---|
| <p>1 <i>Haplophragmoides calcula</i> Cushman and Waters, sample 131294-20. a. Umbilical view; b. Lateral view; c. Umbilical view</p> <p>2 <i>Ammobaculites</i> cf. <i>arenatus</i> Cushman, sample 210295-07</p> <p>3 <i>Trochammina</i> sp. a. Spiral view; b. Lateral view; c. Umbilical view, sample 131294-06</p> <p>4 <i>Reophax</i> cf. <i>texanus</i> Cushman and Waters, sample 131294-13</p> <p>5 <i>Spiroplectammina-Textularia</i> sp. sample 131294-13</p> <p>6 <i>Haplophragmoides rugosus</i> Cushman and Waters, sample 131294-14. a. Spiral view; b. Umbilical view</p> <p>7 <i>Saccamina globosa</i> Crespín, sample 131294-21. a. Spiral view; b. Lateral view; c. Umbilical view</p> | <p>8 <i>Haplophragmoides calcula</i> Cushman and Waters, sample 131294-11. a. Spiral view; b. Lateral view; c. Umbilical view</p> <p>9 <i>Haplophragmoides</i> sp. 4, sample 131294-03. a. Umbilical view; b. Lateral view; c. Umbilical view</p> <p>10 <i>Ammobaculites subcretaceus</i> Cushman and Alexander, sample 131294-11</p> <p>11 <i>Ammobaculites</i> cf. <i>subcretaceus</i> Cushman and Alexander, sample 131294-13</p> <p>12 <i>Reophax dentalinoides</i> Reuss, sample 121294-09</p> <p>13 <i>Calcisphaeridae</i> undet., sample 131294-03</p> <p>14 <i>Haplophragmoides</i> sp. 2, sample 121294-09. a. Spiral view; b. Lateral view; c. Umbilical view</p> |
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