ABSTRACT: *The genus* Nummoloculina *is revised to include miliolids with a quinqueloculine embryonic stage followed by a planispiral stage, and in which there is an apertural tooth.* Nummoloculina heimi *Bonet is emended, and* Planispirina schlumbergeri *Sidebottom, 1904, and* Planispirina striata *Sidebottom, 1904, are transferred into* Nummoloculina. *The contribution of miliolids to the porosity of Cretaceous oolitic limestones is discussed.*

Revision of the genus Nummoloculina and emendation of Nummoloculina heimi Bonet

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INTRODUCTION

Steinmann (1881, pp. 31–43) erected the genus *Nummoloculina* on the basis of material from the Pliocene of Italy, with *Biloculina contraria* d'Orbigny, 1846, as the type species. Until 1952, only two other species, *Nummoloculina regularis* Philippson, 1887, from the Cretaceous of Austria, and *Nummoloculina irregularis* (d'Orbigny) [*Biloculina irregularis* d'Orbigny, 1839], from the Recent of the Falkland Islands, and one variety, *Nummoloculina contraria paradoxa* (Reuss) [*Biloculina contraria* var. *paradoxa* Reuss, 1867], from the Miocene of Poland, had beən referred to *Nummoloculina*. There have been no sections published of either *Nummoloculina irregularis* or *Nummoloculina contraria paradoxa*, so that little can be said of the internal structure of these two forms. This is unfortunate inasmuch as the criteria now used for generic and specific differentiation are based on characters best seen in sections. Although *Nummoloculina contraria paradoxa* possesses the compression along a short axis that is characteristic of *Nummoloculina* (Reuss, 1867, p. 70, pl. 1, fig. 10a–b), the writers cannot, in the absence of sections, confidently refer this variety to *Nummoloculina*. *Nummoloculina irregularis* (d'Orbigny, 1839, p. 67, pl. 8, figs. 20–21) is even more doubtfully referred to *Nummoloculina*.

Bonet (1952, text-figs. 24–25, 27–28) figured a species of *Nummoloculina* from the El Abra miliolid member of the Albian-Cenomanian El Abra formation of northern Mexico. The writers (1956) reported *Nummoloculina* from Texas, Florida, and Louisiana, as well as from Mexico. In 1956 (pp. 402–406) Bonet described the El Abra species under the name *Nummoloculina heimi*. The writers were in the process of describing the El Abra species, which is the same as that in Texas, Florida, and Louisiana, when Bonet's description of *Nummoloculina heimi* appeared. The writers find Bonet's description and illustrations inadequate for defining the species; *Nummoloculina heimi* is therefore emended in this paper. The emendation is based upon excellently preserved specimens from the El Abra miliolid member of the El Abra formation of a locality near Antiguo Morelos, Tamaulipas, Mexico (locality no. 1), and upon other specimens obtained from surface and well samples from the Lower Cretaceous limestones of Texas and Florida (localities no. 2–6).

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GEOLOGIC RANGE AND STRATIGRAPHIC VALUE OF NUMMOLOCULINA

The writers (1956) formerly believed that *Nummoloculina* ranged in the Lower Cretaceous of the United States from the Sligo limestone through the

Devils River limestone. Since that time, the writers have recognized that their specimens of *Nummoloculina* found in well cuttings from the Sligo limestone interval were actually contaminations from the *Nummoloculina*-bearing Edwards limestone, far up in the bore hole; the writers therefore know of no specimens of *Nummoloculina* from the Sligo limestone. Until records of *Nummoloculina* are reported to the contrary, the Cretaceous range of the genus in the United States is herein determined to be from the Glen Rose limestone through the Devils River limestone (Trinity-Washita), or Albian according to the European stage terminology. Recent work by Bonet (1956, pp. 403, 404) has shown that *Nummoloculina heimi* is present in Mexico in limestones ranging in age from Albian through Cenomanian.

Nummoloculina-bearing limestones occur in the Washita (Devils River limestone) of southwestern Texas only where reef conditions continued in existence from the Fredericksburg into the Washita. The El Abra formation of northern Mexico was laid down under reef conditions which continued even through the Cenomanian. Inasmuch as beds bearing abundant *Nummoloculina* in North America are restricted to or associated with reef limestones of high calcium carbonate content, these beds can be thought of as a unit well set apart from the overlying basal Upper Cretaceous beds in the United States and set apart from overlying Turonian beds in Mexico. Although the world-wide geologic range of *Nummoloculina* has been determined as Lower Cretaceous to Recent (Conkin and Conkin, 1956, p. 891), only relatively rare specimens are known from strata younger than Albian-Cenomanian.

The ecologic and stratigraphic value of *Nummoloculina* was discussed by the writers (1956, pp. 894–896) and by Bonet (1956, pp. 404, 405), and will not be considered further except to state that there is evidence available to indicate that the Lower Cretaceous limestones of Texas can be differentiated primarily on the basis of miliolids. The writers are now working on such a division of the Lower Cretaceous limestones of Texas on the basis of miliolids.

METHODS

Many pieces of limestone from the El Abra miliolid member of the El Abra formation of Mexico (locality no. 1), from the Fredericksburg limestone of Florida (locality no. 5), and from the Devils River limestone (locality no. 2), the Edwards limestone (localities no. 3 and 4) and the Glen Rose limestone (locality no. 6) of Texas, were sectioned, polished, and examined under the microscope. Thin sections were made of polished sections that exhibited good sagittal and axial sections of *Nummoloculina heimi*. Measurements were made from the thin sections. The text-figures accompanying the present paper were drawn from photomicrographs of thin sections.

In the writers' samples, the El Abra miliolid member is composed of innumerable excellently preserved specimens of *Nummoloculina heimi*. The sagittal and axial sections produced by random sectioning of the El Abra limestone are representative of the species. The writers' sample of the Devils River limestone contain innumerable specimens of *Nummoloculina heimi*, but they are not as well preserved as the El Abra specimens; the Edwards and Glen Rose limestones of Texas, and the Fredericksburg limestone of Florida do not contain specimens of *Nummoloculina heimi* in such great abundance as do the El Abra and Devils River limestones. Weathering has obscured the external features of the free specimens observed by the writers, and since it was not possible to extract unweathered specimens from the hard limestones, little can be said of the external features of *Nummoloculina heimi*.

LIST OF LOCALITIES

1) El Abra miliolid member (upper few feet) of the El Abra formation; road cut on Pan American Highway, 3 miles south of Antiguo Morelos, Tamaulipas, Mexico.

2) Devils River limestone, upper few feet, immediately below the Del Rio shale; 26.5 miles north of Del Rio on U.S. Highway 277, Val Verde County, Texas.

3) Edwards limestone; Travis Drillers, Inc.'s no. 1 L. R. Dillon, Jr., 12 miles northeast of Luling, Caldwell County, Texas. Core from 4628–4629 feet.

4) Edwards limestone; Stanolind's no. 2 O. S. Petty, Stuart City field, 0.5 miles east of Stuart City, LaSalle County, Texas. Core from 10,008–10,013 feet.

5) Fredericksburg limestone; Humble Oil & Refining Company's no. 1 (hole no. 2) Consolidated Naval Stores, in sec. 5, T. 45 S., R. 29 E., Hendry County, Florida. Core no. 4, from 9830–9853 feet, recovered 23 feet; sample from 9845–9846 feet.

6) Glen Rose limestone; Chenoweth and Harroun's (Pagenkoph) no. 1 Max Blum, Gas Ridge field, 15 miles west of San Antonio, Bexar County, Texas. Core from 2158–2176 feet.

MILIOLIDS, OÖLITES, AND POROSITY

Several genera of miliolids are known to occur in the Sligo, Glen Rose, Edwards, and Devils River limestones of Texas and in the Fredericksburg limestone of Florida, in deposits that were laid down in shoal, back-reef, and/or inter-reef environments. In many instances rolled and eroded miliolids form the centers of oölites, around which the calcareous layers have been formed. Such oölites have been observed in the Edwards, Glen Rose, and Sligo limestones of Texas and in the Fredericksburg limestone of Florida. The writers have observed similar oölites formed around *Millerella* in the Pennsylvanian Marble Falls limestone at Marble Falls, Texas, and around *Endothyra* and *Plectogyra* in the Mississippian limestones of Indiana, Kentucky, West Virginia, and New Mexico.

The possible contribution of miliolids to porosity in oölitic limestones is not yet appreciated. Such oölitic zones have long been recognized in the Glen Rose and Sligo (Pettet zones) limestones; however, the fact that a great, but indeterminable, number of the oölites were originally miliolids is here recorded for the first time. The nature of the matrix, and the action of dolomitization and solution, control the availability of theoretical interstitial porosity in oölitic limestones such as the Sligo (Pettet zones) and the Glen Rose. In some instances, nearly hollow oölites are formed around miliolid tests that have had their internal structure almost completely destroyed, especially in the inner portions, as a result of dolomitization and solution (see pl. 1, fig. 8). In addition, there may be a certain amount of porosity due to voids originally present in the empty tests of the miliolids.

SYSTEMATIC DESCRIPTIONS

Family MILIOLIDAE

Genus **Nummoloculina** Steinmann, **emend.** Conkin and Conkin

Biloculina d'Orbigny, 1846 (part), Foram. Foss. Vienne, p. 266, pl. 16, figs. 4–6.

Nummoloculina Steinmann, 1881, Neues Jahrb. Min. Geol. Pal., vol. 1, p. 31, pl. 2, figs. 1–8.

Planispirina Seguenza. – Brady, 1884 (part), Rept. Voy. Challenger, Zool., vol. 9, p. 195, pl. 11, figs. 10–11. – Sidebottom, 1904, Manchester Lit. Philos. Soc., Mem. Proc., vol. 48, no. 5, pp. 20–21, pl. 5, figs. 9–14.

Not *Planispirina* Seguenza, 1880, R. Accad. Lincei Roma, Cl. Sci. Fis. Mat. Nat., Mem., p. 310, pl. 17, fig. 18, 18a.

Type species: Biloculina contraria d'Orbigny, 1846 (original designation, by Steinmann, 1881; Miocene, Austria).

In 1880 (p. 310) Seguenza erected the genus *Planispirina*, with *Planispirina communis* Seguenza, 1880, as the type species. There has been much confusion regarding possible relationships between *Nummoloculina* and *Planispirina*. Brady (1884, pp. 192–196) placed *Nummoloculina* in synonymy with *Planispirina;* in recent years other writers, such as Glaessner (1945, p. 119), have considered that *Nummoloculina* may be congeneric with *Planispirina*. Cushman (1948, p. 179), however, clearly distinguished *Nummoloculina* from *Planispirina*, especially on the basis of the presence in *Nummoloculina* of an apertural tooth and quinqueloculine embryonic chambers.

The generic definition of *Nummoloculina* accepted by recent workers can be summarized as follows: A miliolid genus with quinqueloculine embryonic chambers that are followed by planispirally arranged whorls coiled about a short axis and divided into several chambers; aperture with a tooth. The accepted definition of *Planispirina* can be summarized as follows: An ophthalmidiid genus (and thus planispiral throughout) with a tendency to a rectilinear mode in the last chambers, giving a crosier-like form to the test; whorls divided into several chambers; aperture *Cornuspira*-like, with no tooth.

One of the main sources of confusion between the two genera *Nummoloculina* and *Planispirina* has been the failure of workers to recognize that *Nummoloculina* may have, in the megalospheric form, a completely planispiral test like that of *Planispirina*. Philippson (1887, p. 167) made the first observation concerning the planispiral nature of *Nummoloculina*, in his description of *Nummoloculina regularis*, which follows:

> "Die von Steinmann beobachteten Embryonalwindungen, die nicht in einer Ebene liegen, fanden sich nicht vor; stets beginnt das Gehäuse mit einer relativ großen kugeligen Anfangskammer (Megasphäre nach Munier-Chalmas et Schlumberger, Bull. Soc. Géol. France, 3e sér., t. XIII, p. 276). An einem Exemplar fand sich die von denselben Forschern als 'Polymorphisme initial' and zwar als 'Etat initial triloculinaire' bei *Idalina antiqua* beschriebene Erscheinung vor (loc. cit., p. 296), indem die auf die Megasphäre folgenden ersten Windungen in verschiedenen Ebenen angeordnet sind, so daß der Horizontalschnitt (Fig. 7) diese ersten Umgänge mehr oder weniger quer durchschneidet, während die folgenden regelmäßig in der Ebene ihrer Spirale getroffen sind. Dieser Polymorphismus kann nicht mit den von Steinmann geschilderten Embryonalwindungen verwechselt werden, welche an Stelle der Megalosphäre liegen, während sich diese letztere in unserem Falle wohl erhalten im Innern jener ersten *Triloculina*-ähnlichen Windungen zeigt."

Subsequent workers have overlooked Philippson's important observations on the planispiral nature of *Nummoloculina regularis*. However, the fact that *Nummoloculina regularis* is not completely planispiral in all members of the population studied by Philippson is shown by at least one of Philippson's type specimens, which was described by Philippson as containing milioline embryonic chambers (probably very early quinqueloculine chambers, initiating the quinqueloculine pattern). The writers independently arrived at

TABLE 1

MEASUREMENTS OF *Nummoloculina heimi* FROM THE EL ABRA MILIOLID MEMBER OF THE EL ABRA LIMESTONE, LOCALITY NO. 1

Specimen	Form	Height in mm.	Diam. of pro-loculus in mm.	No. of quinque-loculine chambers	No. of whorls	Septa per whorl (number in parentheses is number of septa inferred for incomplete final whorl)						
						1st	2nd	3rd	4th	5th	6th	7th
1	micro.	0.70	0.033	4–5	3	6	7	10				
2 (text-fig. 6)	micro.	0.83	0.053	4	$3\frac{2}{3}$	6	8	10	7 (11)			
3 (text-fig. 7; pl. 1, fig. 2)	micro.?	1.00	0.026	2	4	4	5	6	8			
4	micro.	1.03	0.053	6	$3\frac{3}{4}$	5	10	12	11 (15)			
5 (text-fig. 5; pl. 1, fig. 3)	micro.	1.33	0.030	3	$5\frac{1}{8}$	6	9	9	11	15	2(16)	
6	micro.	1.50	0.027	6	$4\frac{1}{2}$	4	7	10	11	6 (12)		
7	megalo.	0.53	0.078	8	$1\frac{1}{2}$	3	2 (4)					
8	megalo.	0.80	0.073	10	$2\frac{1}{2}$	3	5	2 (5)				
9	megalo.	0.83	0.079	10	$2\frac{2}{3}$	2	4	4 (6)				
10 (text-fig. 4)	megalo.	0.86	0.093	0	4	3	3	5	7			
11 (text-fig. 3)	megalo.	0.93	0.068	7	3	4	5	6				
12	megalo.	0.93	0.066	5	$3\frac{1}{2}$	2	2	4	3 (6)			
13 (text-fig. 2; pl. 1, fig. 5)	megalo.	1.03	0.093	5	$3\frac{1}{4}$	3	5	4	2 (8)			
14	megalo.	1.43	0.079	4	$5\frac{1}{3}$	2	4	4	6	7	4(10)	
15 (text-fig. 1; pl. 1, fig. 1)	megalo.	1.53	0.093	7	$5\frac{2}{3}$	2	4	4	6	7	7(10)	
16	megalo.?	1.83	?	4?	$6\frac{1}{2}$	?	5	6	7	10	10	15?
17 (text-fig. 8; pl. 1, fig. 4)	megalo.	1.00	0.073	10	3							
18	megalo.	1.23	0.103	6	4	(Axial sections, septa not seen)						
19 (text-fig. 9; pl. 1, fig. 6)	megalo.	1.26	0.073	?	6							
20	megalo.	1.43	0.073	9	$4\frac{1}{2}$							
21	?	2.06	?	?	7							

the fact that *Nummoloculina* (as represented by *Nummoloculina heimi*) may possess a completely planispiral test as a result of skipping the early quinqueloculine stage of development in the megalospheric form (see Tables 1–3, 5). This phenomenon also occurs in *Spiroloculina* (Cushman, 1948, p. 179).

As the writers interpret and emend the genus, *Nummoloculina* includes miliolids having quinqueloculine embryonic chambers (although these chambers may be absent in the megalospheric form), followed by planispiral whorls divided into chambers; the apertural tooth may be of different shapes in different species, and may even be bifid. The generic character that invariably distinguishes *Nummoloculina* from *Planispirina* is the presence of an apertural tooth in *Nummoloculina* and the absence of an apertural tooth in *Planispirina.*

In view of the generic definitions of *Planispirina* and *Nummoloculina* as here emended, the figures of *Planispirina schlumbergeri* Sidebottom, 1904 (p. 20, pl. 5, figs. 9–11) and of *Planispirina striata* Sidebottom, 1904 (p. 21, pl. 5, figs. 12–14) demonstrate clearly that these two species must be removed from *Planispirina* and must be placed in *Nummoloculina. Nummoloculina schlumbergeri* possesses milioline embryonic chambers and a bifid apertural tooth. *Nummoloculina striata* possesses a planispiral or nearly planispiral test and has a broad flat tooth in the aperture.

Nummoloculina heimi Bonet, **emend.** Conkin and Conkin
Plate 1, figs. 1–10; text-figures 1–25

Nummoloculina sp., LEUPOLD, 1941, in HEIM, Eclogae Geol. Helv., vol. 33, no. 2, p. 324, text-fig. 5.

Nummoloculina sp., BONET, 1952, Asoc. Mexicana Geol. Petr., Bol., vol. 4, no. 5–6, p. 181, text-figs. 24–25, 27–28.

Nummoloculina sp., CONKIN AND CONKIN, 1956, Amer. Assoc. Petr. Geol., Bull., vol. 40, no. 5, p. 890, text-fig. 3.

Nummoloculina heimi BONET, 1956, Asoc. Mexicana Geol. Petr., Bol., vol. 8, no. 7–8, pp. 402–406, pls. 3–4.

Bonet's description of *Nummoloculina heimi* is as follows:

"*Descripción.* – Concha discoidea, de unas 900–1000 micras de diámetro, ligeramente bicóncava, con una anchura cerca del borde de unas 200 a 350 micras. Paredes muy gruesas, de espesor desigual (30 a 90 micras en distintas partes del mismo individuo). Los grandes ejemplares de cerca de 1 mm. de diámetro, en corte sagital muestran de 4 a 6 vueltas de espira además de las cámaras centrales. La última vuelta de espira tiene alrededor de 10 cámaras; los ejemplares pequeños, de tamaño mitad, presentan cuatro vueltas de espira y solamente 4–6 cámaras en la vuelta terminal; cámaras cónicas, alargadas con su extremo proximal estrechado y el terminal bruscamente truncado, de tal manera que la pared espiral presenta aspecto de rueda dentada. No se han observado los caracteres apertu-rales, pues a pesar de ser una especie abundantísima y muy frecuente todos los ejemplares conocidos se conservan en calizas compactas.

TABLE 2

MEASUREMENTS OF *Nummoloculina heimi* FROM THE DEVILS RIVER LIMESTONE, LOCALITY NO. 2

Specimen	Form	Height in mm.	Diam. of pro-loculus in mm.	No. of quinque-loculine chambers	No. of whorls	Septa per whorl (number in parentheses is number of septa inferred for incomplete final whorl)						
						1st	2nd	3rd	4th	5th	6th	7th
22	micro.	0.53	0.026	8	1	4						
23	micro.	0.56	0.039	6	$2\frac{1}{4}$	4	7	?				
24	micro.	0.93	0.039	4?	$3\frac{1}{2}$	4	7	10	7 (14)			
25 (text-fig. 12; pl. 1, fig. 7)	micro.	1.33	0.039	5	4	5	7	9	11			
26	micro.	1.60	0.033	?	4?	?	9	12	15			
27	?	2.16	?	?	6 plus	?	?	12?	12?	15?	20?	
28	megalo.	1.20	0.080	0	$4\frac{1}{3}$	1	4	7	8	4 (9)		
29	megalo.	1.32	0.070	0	$5\frac{1}{4}$	0	3	5	6	8	2 (8)	
30 (text-fig. 10)	megalo.	1.88	0.065	0	$6\frac{1}{2}$	1	3	6	7	8	9	6 (12)
31 (text-fig. 13)	?	1.33	?	?	5							
32	micro.	1.33	0.053	0	6	(Axial sections, septa not seen)						
33	megalo.	?	0.112	?	?							
34 (text-fig. 11)	megalo.	1.86	0.110	0	7							

"*Variación.* – En una misma población pueden observarse muchas variaciones de detalle de tal manera que resulta difícil encontrar dos ejemplares exactamente iguales; esta variación real se acentúa aparentemente al considerar la variedad de aspectos que resultan de la distinta orientación de los planos de sección. No obstante, todos los individuos presentan una semejanza general de modo que no hay dificultad en su identificación. Algunos ejemplares de forma irregular parecen haber sufrido un crecimiento desigual a causa del contacto con otros individuos. Ya se ha apuntado la existencia de dos formas que difieren, entre otras cosas, en el tamaño; ignoramos cuál puede ser su significación taxonómica y biológica."

In his description, Bonet did not recognize megalospheric and microspheric forms, nor did he realize the planispiral nature of *Nummoloculina heimi* in the megalospheric form. Although Bonet's plates show *Nummoloculina heimi* as it often appears in randomly oriented sections of the El Abra limestone, the specimens figured are inadequate for revealing essential details of the nature of the species.

Bonet evidently neglected to figure or designate a holotype for *Nummoloculina heimi.* The writers can only assume that the two plates given by Bonet (1956, pls. 3–4) contain many syntypes. Inasmuch as neither of these plates illustrates complete axial or sagittal sections of specimens, nor do all the individuals together supply satisfactory information on which to base the specific concept of *Nummoloculina heimi*, the writers are basing their description and emendation of *Nummoloculina heimi* on their own hypotypes, many of which are deposited in various institutions in the United States and other countries. These hypotypes must form the basis of the present definition of *Nummoloculina heimi*, although they are secondary types. The writers do not feel disposed to choose one of Bonet's figured specimens as a lectotype. Any subsequent type designation is left to the discretion of the original author. The main objective in emending *Nummoloculina heimi* is to show the true nature of the species and to establish its definition on a firm morphologic basis.

Emended description: Test free, biconcave to biconvex discoidal. Greatest thickness about one-quarter to one-half the height; height of largest measured specimen 2.16 mm.; height of smallest measured specimen 0.43 mm. Test consists of a proloculus, which measures from 0.026 to 0.053 mm. in the microspheric form and 0.056 to 0.112 mm. in the megalospheric form, followed by from one to ten more or less precisely arranged quinqueloculine embryonic chambers (which may be absent in the megalospheric form), and then followed by as many as seven somewhat involute, compressed planispiral whorls coiled at an angle to the axis of the quinqueloculine chambers, and divided by short septa into several chambers (as few as one to four chambers in the innermost whorl of megalospheric forms, but as many as sixteen and perhaps twenty chambers in the outer whorl of microspheric forms). Aperture, as observed in thin or polished sections, appears to be a low arch with a small, rather stocky tooth; the apertural tooth and former apertural teeth can be seen clearly in sagittal sections, but are rarely seen in axial sections.

Microspheric and megalospheric forms are readily distinguished on the basis of the size of the proloculus, and also by the fact that the microspheric form has up to five times as many chambers (usually, however, about twice as many chambers) per planispiral whorl as the megalospheric form, especially in the outer whorls (see Table 4). The greater number of chambers per whorl in the microspheric form gives these chambers a much less elongate appearance in sagittal section than the chambers of the megalospheric form (compare text-figs. 1 and 5). Furthermore, only the megalospheric form may possess a completely planispiral test.

TABLE 3
MEASUREMENTS OF *Nummoloculina heimi* FROM THE EDWARDS LIMESTONE (LOCALITIES NO. 3 AND 4), FREDERICKSBURG LIMESTONE (LOCALITY 5) AND GLEN ROSE LIMESTONE (LOCALITY 6)

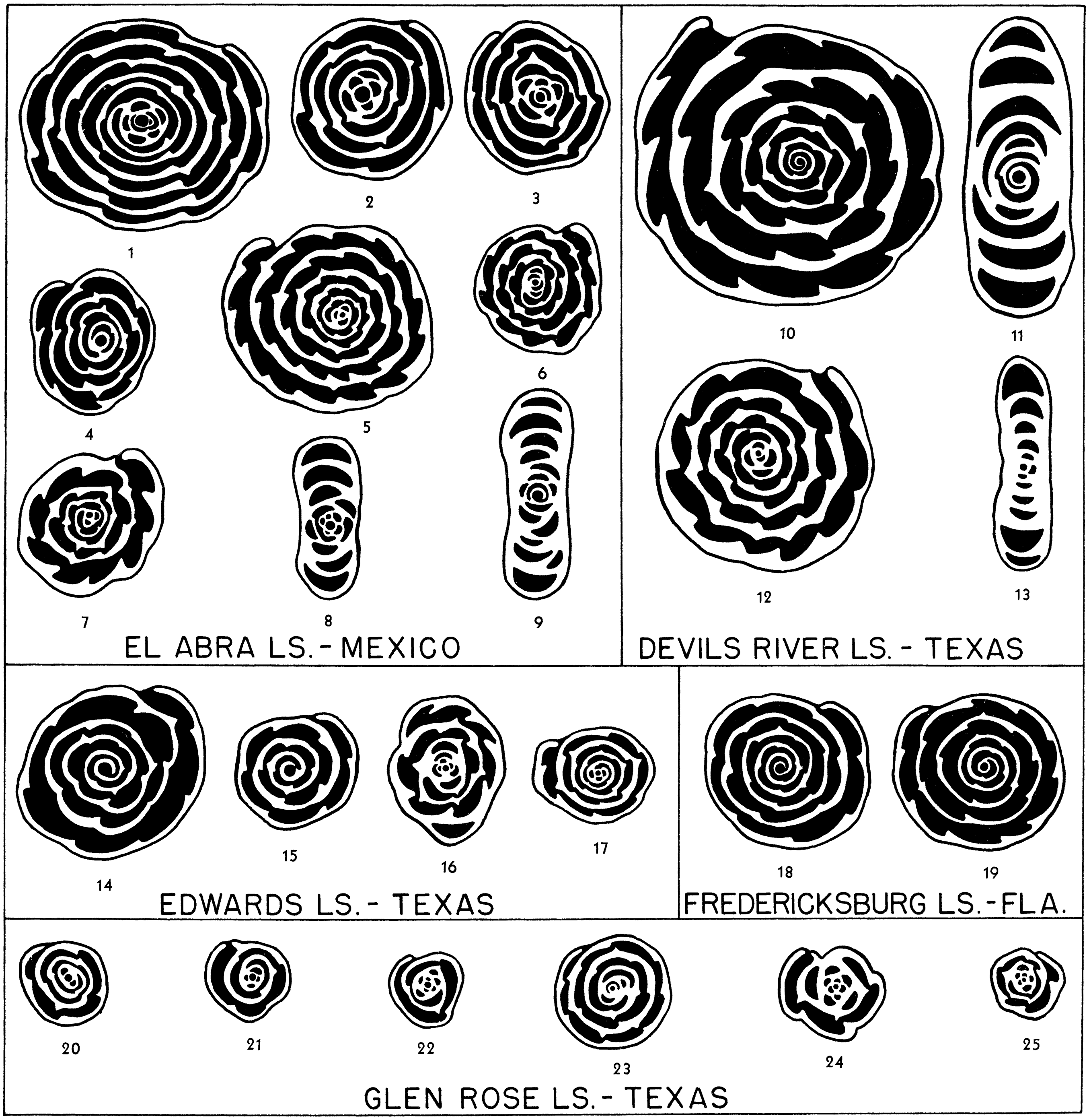
Loc.	Specimen	Form	Height in mm.	Diam. of pro-loculus in mm.	No. of quinque-loculine chambers	No. of whorls	Septa per whorl (number in parentheses is number of septa inferred for incomplete final whorl)				
							1st	2nd	3rd	4th	5th
3	35	micro.	0.76	0.046	8	1½	7	4 (8)			
	36 (text-fig. 16)	micro.	0.84	0.040	8	1¾	6	6 (8)			
	37 (text-fig. 15)	megalo.	0.74	0.084	0	3	3	5	6		
	38	megalo.	1.03	0.079	1	4	3	5	6	8	
	39 (text-fig. 14; pl. 1, fig. 10)	megalo.	1.16	0.110	0	4¼	1	5	6	7	2 (8)
	40	?	1.53	?	?	5					
	several axial sections		0.93–1.16	0.026–0.053	?	3–5½					
4	41 (text-fig. 17)	megalo.	0.73	0.066	3	3¾	3	5	5	7 (9)	
5	42 (text-fig. 19; pl. 1, fig. 8)	megalo.	1.06	0.084	0	5	2	3	5	7	9
	43 (text-fig. 18)	megalo.	1.06	0.090	0	5	2	4	6	6	8
	44	?	1.20	?	?						
	45	?	1.33	?	?						
6	46 (text-fig. 24)	micro.	0.63	0.042	10	1	4				
	47 (text-fig. 25)	micro.	0.43	0.035	6	1½	4	4 (8)			
	48 (text-fig. 23)	micro.	0.73	0.046	4	2½	4	6	5 (10)		
	49 (text-fig. 22; pl. 1, fig. 9)	megalo.	0.43	0.056	7	1½	2	2 (4)			
	50 (text-fig. 21)	megalo.	0.50	0.070	4	2	2	3			
	51 (text-fig. 20)	megalo.	0.50	0.069	2	2¾	3	3	4 (6)		
	a few larger specimens		0.93–1.00								

TABLE 4
RANGE IN MEASUREMENTS OF *Nummoloculina heimi*

Character	Microspheric forms	Megalospheric forms
Height	0.53–2.16 mm.	0.43–2.06 mm.
Diameter of proloculus	0.026–0.053 mm.	0.056–0.112 mm.
Septa per whorl		
1st whorl	4–7	0–4
2nd whorl	6–10	2–6
3rd whorl	9–12	4–8
4th whorl	11–15	6–9
5th whorl	12–15	7–10
6th whorl	12–16 (20?)	8–10

TABLE 5
COMPARISON OF THE SPECIES OF *Nummoloculina*

Species	Height	Quinque-loculine chambers	Whorls	Septa (or chambers)
N. heimi	0.43–2.16 mm.	0–10	up to 7	8–16 (20?) in 6th whorl
N. contraria	about 2.0 mm.	?	5 or 6	6 chambers in 6th whorl
N. regularis	about 0.2–0.3 mm.	0–3?	5½–10	3 in outer whorl
N. schlumbergeri	1.44–1.76 mm.	6 or more	3½	2 in inner, 3 in outer whorls
N. striata	1.0 mm.	2	4	2 in inner, 3 in outer whorls



EXPLANATION OF TEXT-FIGURES 1–25

Nummoloculina heimi Bonet, emend. Conkin and Conkin, all × ca. 28; 1–4, sagittal sections of megalospheric forms: 4, a completely planispiral form; 5–6, sagittal sections of microspheric forms; 7, sagittal section of microspheric form showing less than the usual number of chambers per whorl; 8–9, axial sections: 9, showing a rather irregular embryonic portion similar to that in text-figure 11; 10, sagittal section of megalospheric form; 11, axial section of megalospheric form; 12, sagittal section of microspheric form; 13, axial section, walls thickened; 14–15, sagittal sections of megalopheric forms, planispiral throughout; 16, sagittal section of microspheric form; 17, sagittal section of megalospheric form; 18–19, sagittal sections of megalospheric forms, planispiral throughout; 20–22, sagittal sections of megalospheric forms: 21, showing an especially well developed apertural tooth; 23–25, sagittal sections of microspheric forms.

Measurements of *Nummoloculina heimi* are given in Tables 1–3. Table 4 gives the ranges of measurements of specimens studied for this paper.

Comparison: *Nummoloculina heimi* differs from all other species of *Nummoloculina* in the large number of chambers per whorl (see Table 5), but it has its closest affinities with *Nummoloculina contraria.*

Discussion: There is great variation in the number of quinqueloculine embryonic chambers following the proloculus in *Nummoloculina heimi* (see Tables 1–3); in some of the megalospheric forms of *Nummoloculina heimi* the quinqueloculine stage is completely absent. This absence would seem to place these forms in *Planispirina*, except for the presence of teeth in these forms and the fact that there are only one or two "quinqueloculine" chambers in some other specimens of *Nummoloculina heimi* (Table 3, specimen 38; text-figs. 7, 20).

Large individuals of *Nummoloculina heimi* consisting of six or even seven planispiral whorls, such as those shown in text-figures 1 and 10, are generally found only where there are abundant specimens present, as in the limestones with very high calcium carbonate content of the El Abra and Devils River formations. In an area of 36 sq. mm. in a thin section of the El Abra limestone, sixty specimens of *Nummoloculina heimi* were counted, of which fifty are small specimens, six are of medium size, and only four are large. Only a few large specimens of *Nummoloculina heimi* were found in the other limestones. The Edwards limestone (containing frequent *Nummoloculina heimi*) and the Glen Rose limestone (containing rare *Nummoloculina heimi*) have a less pure calcium carbonate matrix, and the specimens of *Nummoloculina heimi* in these formations are not abundant; hence, large specimens are rare. Large specimens were noted occasionally in the Edwards and Glen Rose limestones, but unfortunately these individuals were not cut in such a way as to allow measurements other than their approximate height (see Table 3).

Text-figures 1–25 illustrate the variation seen in *Nummoloculina heimi.* Considered by themselves, the megalospheric forms shown in text-figures 10 and 22, for example, would not seem to belong to the same species; however, a gradation between these specimens is clearly seen in text-figures 14, 4 and 20.

Deposition of types: Fifteen hypotypes are deposited in the Cushman Foraminiferal Collection of the U. S. National Museum, Washington, D. C., nos. 626226–626240. Hypotypes are also deposited in the type collections of the following institutions: Bureau of Economic Geology, University of Texas, Austin, Texas, no. 20269; Department of Geology Museum, University of Cincinnati, Cincinnati, Ohio, no. 34531; Florida Geological Survey, Tallahassee, Florida, no. S–4642; Paleontological Research Institution, Ithaca, New York, nos. 25315–25316; Amt für Bodenforschung, Hannover, Germany, no. 2205; and Geological Department, British Museum (Natural History), London, England, nos. P 41688 and P 41689.

PLATE 1

All figures approximately × 40 except where noted. All specimens of *Nummoloculina heimi* Bonet, emend. Conkin and Conkin. (Much more detail can be seen with a microscope than can be seen in these photomicrographs.)

1 Sagittal section of megalospheric form from the El Abra miliolid limestone, locality 1 (same as text-fig. 1), showing clear calcite matrix and abundance of specimens.

2 Sagittal section of megalospheric form from locality 1 (same as text-fig. 7).

3 Sagittal section of microspheric form from locality 1 (same as text-fig. 5).

4 On right, axial section from locality 1 (same as text-fig. 8).

5 Sagittal section of megalospheric form from locality 1 (same as text-fig. 2).

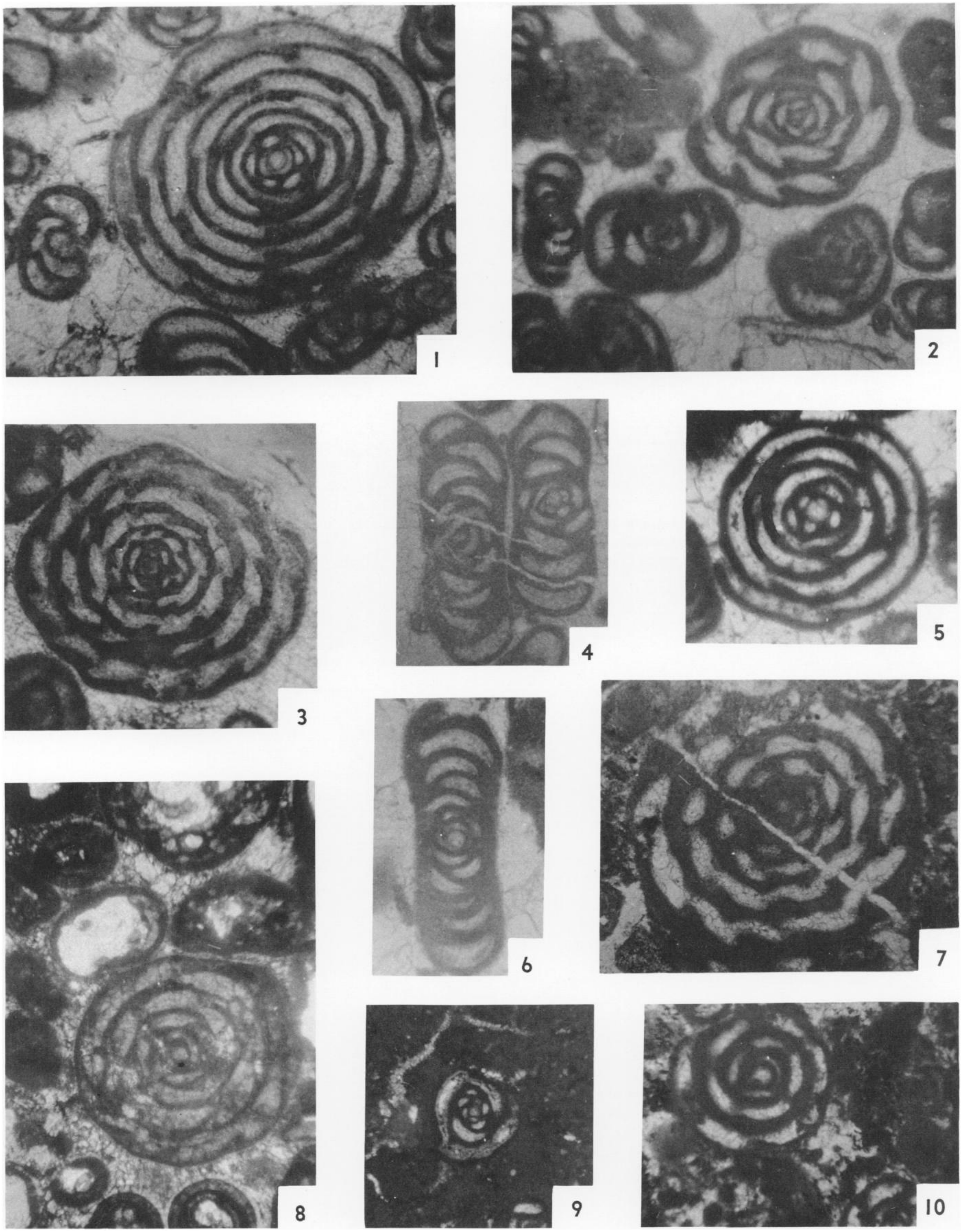
6 Axial section from locality 1 (same as text-fig. 9).

7 Sagittal section of microspheric form from the Devils River limestone, locality 2 (same as text-fig. 12), showing relatively poor preservation as compared with the El Abra specimens.

8 Sagittal section of megalospheric form from the Fredericksburg limestone of Florida, locality 5 (same as text-fig. 19), showing oölites formed of miliolids.

9 Sagittal section of megalospheric form from the Glen Rose limestone, locality 6 (same as text-fig. 22).

10 Sagittal section of megalospheric form from the Edwards limestone, locality 3 (same as text-fig. 14), × 27.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