

Popovia johnrolandi n.sp., a new smaller agglutinated foraminifera from northern Venezuela: a biostratigraphic example of the second law of thermodynamics

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ABSTRACT

We describe a previously unrecognised species of *Popovia*, here named *Popovia johnrolandi* n.sp. from the Miocene of Eastern Falcon state in Venezuela. The internal complexity of this new species increased through the Serravalian from Zone N10 to N14. This apparent trend towards increasing internal complexity reflects increasing entropy through time, and is here interpreted as an evolutionary adaptation to life within an oxygen minimum zone.

INTRODUCTION

Neogene sediments from upwelling areas are important targets for petroleum exploration, and micropalaeontological analysis provides a useful tool for exploration (Jones, 1996). However, in the low-latitude basins of the Atlantic the stratigraphic record of calcareous microfossils, which are conventionally used for correlation, can be sporadic. Planktonic foraminifera are often poorly preserved. In such conditions the only microfossil group suitable for small scale stratigraphic appraisal is the agglutinated foraminifera. These microfossils enjoy a prestigious history, extending back to the 19th century with the studies of Grzybowski (see Kaminski *et al.*, 1993) and continuing into the 1980s through the endeavours of George Seiglie and co-workers (Seiglie & Baker, 1982, 1983; Seiglie *et al.*, 1986).

Our micropalaeontological examination of Neogene sediments from northern Venezuela (Preece, 1999) reveals the presence of a cosmopolitan agglutinated foraminiferal assemblage. In this study we report the presence of a new species of *Popovia* in northern Venezuela which displays increasing morphological complexity through time. This study emphasises the utility of detailed analysis of agglutinated foraminiferal lineages for potential fine-scale stratigraphic studies.

SAMPLE LOCATION AND STRATIGRAPHY

The name "Agua Salada Series" was coined in 1919 by M.L. Thomas in private petroleum consulting reports (Thomas, 1924). In 1937 Hedberg referred to it as the "Agua Salada Group". The type section of the Agua Salada Group lies within the El Mene de Acosta, in Falcon state, Venezuela (Figure 1).

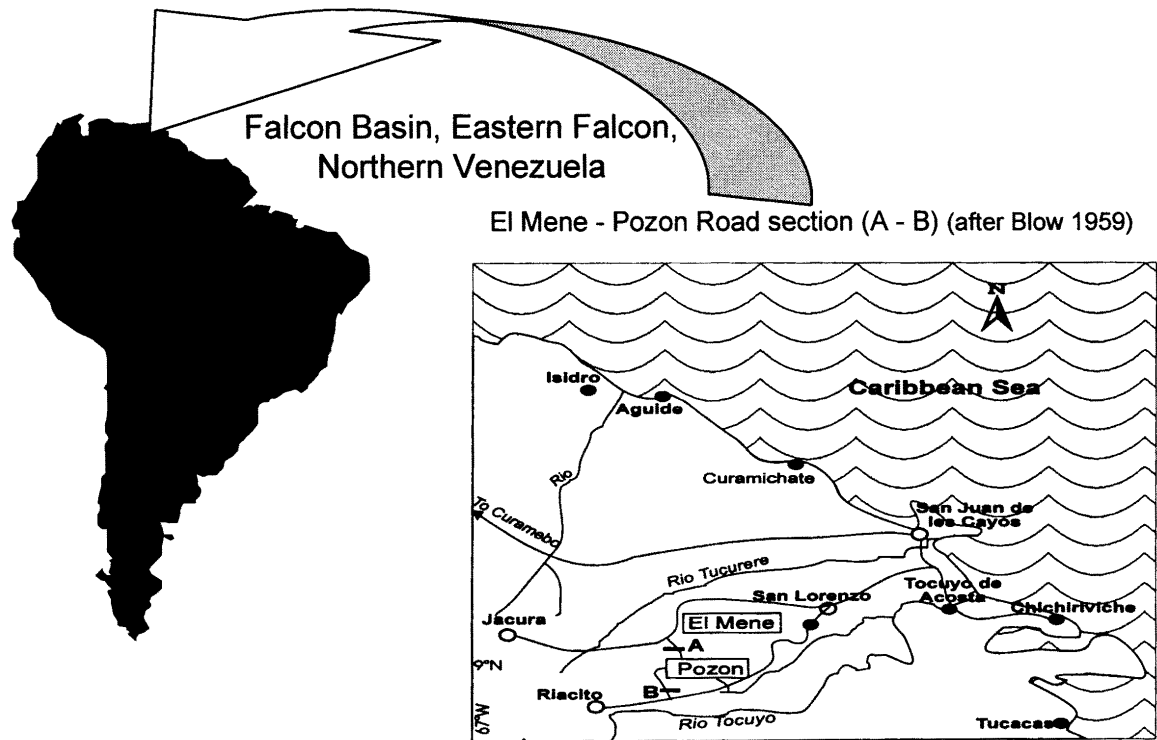
The type sections of the Agua Salada Group are approximately 1442 m thick, and are of Late Oligocene to Late Miocene age. The group is lithologically subdivided into the San Lorenzo and Pozon Formations on the basis of lithology (Figure 2).

PREVIOUS STUDIES

Foraminifera from the Agua Salada Group were initially studied by Cushman (1929) and Cushman & Renz (1941), who began the description of foraminifera from Eastern Falcon. Cushman & Renz erected seven foraminiferal zones that spanned the Upper Oligocene to Middle Miocene. This work was continued by Renz (1948) who first monographed what is now termed the "Agua Salada Fauna". Renz remarked that the Agua Salada Group is "very rich throughout in foraminifera", and outlined a succession of biostratigraphical units and subunits based on the ranges of benthic foraminifera. The Agua Salada Fauna was re-evaluated by Blow (1959), who studied samples collected from the type section along the El Mene - Pozon road section in eastern Falcon. Blow established a zonation based on planktonic foraminifera for the section that was then correlated to the benthic foraminiferal zones of Renz (Figure 2). Subsequent studies of the Agua Salada Fauna from the type area include the work of Diaz de Gamero (1977, 1985a,b), Bolli *et al.* 1994, and Preece (1999).

MATERIAL & METHODS

Fifty-seven outcrop samples from the El Mene - Pozon road section in eastern Falcon were examined for foraminifera. The samples ranged in age from Burdigalian to Tortonian, and reflect deposition in an upper to middle bathyal environment.



El Mene - Pozon, Eastern Falcon, Northern Venezuela (after Blow 1959)

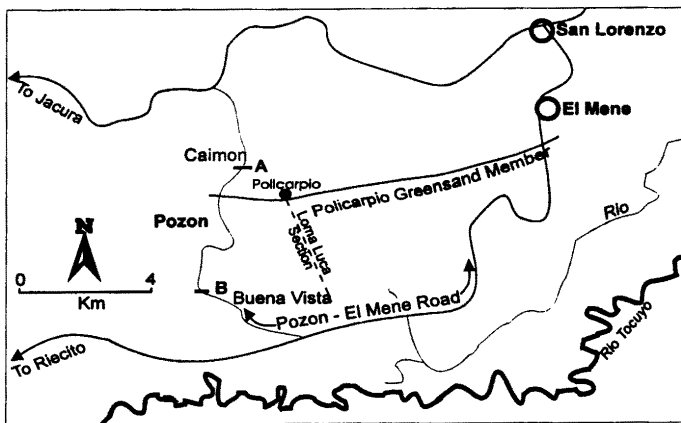


Figure 1. Study Location in Eastern Falcón, northern Venezuela.

Foraminifera were picked and mounted on cardboard slides. Light microscope photographs were made in immersion using a Zeiss SV-11 photomicroscope. Sketches were made using a camera lucida.

SYSTEMATICS

Family Cyclamminidae Marie, 1941

Subfamily Alveolophragmiinae Saidova, 1981

Genus *Popovia* Suleymanov, 1965

Popovia johnrolandi Preece, Kaminski & Dignes
n.sp.

Plate 1, Figs 1-6; Plate 2, Figs 1-6; Plate 3, Figs 1-4;
Plate 4, Figs 1-4

Description. Test small, compressed, with rounded periphery. Coiling planispiral, evolute. Chambers increase rapidly in height and width, with the

ultimate chamber much enlarged. Juvenile specimens display simple chamber interiors, adult specimens are more complex, displaying hemisepta and chamberlets. In the ultimate stage transverse septa and pillars may develop. The ontogenetic increase in complexity is mirrored by phylogeny, with the gradual increase in complexity through time. Wall medium to finely agglutinated, characteristically reddish brown in colour, with a high proportion of cement (originally organic, but now silicified). Aperture not observed.

Derivation of name. Patronymic, in honour of Professor John Roland Haynes in recognition of his unwavering commitment, enthusiasm, and contributions to the advancement of Micropalaeontology.

Deposition of types. Holotype (pl. 2, fig. 6a,b) and paratype (pl. 2, fig. 4a,b) are deposited in the micropalaeontological collections of The Natural

Lithostratigraphy		Biostratigraphy		
		Renz (1948)	Blow (1959)	
Agua Salada Group	Poizon Formation	Huso Clay Member	<i>Elphidium poeynamum</i> zonule	<i>Globigerinoides bulloides</i> zone
			<i>Textularia panamaensis</i> zonule	
			<i>Vaginulopsis superbis</i> zonule	<i>Sphaeroidinella seminulina</i> zone
			<i>Lenticulina senni</i> zonule	
	Husito Clay Member	<i>Marginulopsis basispinosus</i> zone	<i>Globorotalia menardii menardii</i> / <i>Globorotalia nepenthes</i> zone	
		<i>Valvulineria herricki</i> zone	<i>Globorotalia mayeri</i> zone s.l.	<i>G. mayeri</i> / <i>G. nepenthes</i> subzone <i>G. mayeri</i> / <i>G. lenguaensis</i> subzone
		<i>Globorotalia fohsi</i> zone	<i>Globorotalia fohsi</i> zone s.l.	<i>Globorotalia fohsi robusta</i> zone
				<i>Globorotalia fohsi lobata</i> zone
	<i>Globorotalia fohsi fohsi</i> zone			
	<i>Globorotalia fohsi barisasensis</i> zone			
San Lorenzo Formation	Policarpio Greensand Member	<i>Siphogenerina transversa</i> zone	<i>Globigerinatella insueta</i> zone s.l.	<i>G. insueta</i> / <i>G. trilobus</i> subzone
	Menecito Clay Member	<i>Lenticulina wallacei</i> zone		<i>G. insurta</i> / <i>G. trilobus</i> subzone
	El Salto Sand Member	<i>Uvigerinella sparicostata</i> zone	<i>Catapsydrax stainforthi</i> zone	<i>Catapsydrax dissimilis</i> zone

Figure 2. Correlation of foraminiferal zonation of Renz (1948) with the planktonic foraminiferal zonation of Blow (1959), eastern Falcon, after Blow (1959).

History Museum London. The holotype is registered as PF67073. A paratype specimen is registered as PF67074.. Additional specimens are housed in the Kaminski Collection at UCL.

Type level. Middle Miocene.

Remarks. This species displays a tendency towards increasing complexity of the internal wall structure with time. Between Zones N10 and N14, the species develops hemisepta, pillars, and become internally subdivided. Early forms of this species with straight hemisepta projecting inward from the outer wall are replaced by forms with simple branching hemisepta, which may gently curve. Later forms possess hemisepta that begin to anastomose, and acquire transverse septa that form what appear to be chamberlets. The hemisepta may bifurcate and have bulbous terminations. Finally, the stratigraphically youngest individuals possess very complex septa, and individual chambers may be difficult to discern from one another. This phylogenetic trend towards increasing complexity is mimicked by ontogeny: early chambers are comparatively simple, while the latter ones are more complex.

Occurrence. El Mene - Pózon Road section, Eastern Falcon, northern Venezuela. Sporadic occurrence in the *R. spinulosa*/*E. poeyanum* and *T. panamaensis* zonules. Greater frequency through the *V. herricki* to *S. transversa* Zones, with an acme in the *V. herricki* Zone.

DISCUSSION & CONCLUSIONS

Popovia johnrolandi n.sp. displays a morphological trend through time that provides us with a biostratigraphic example of the second law of thermodynamics. The taxon displays a clear propensity towards increasing complexity of wall structure through time. This evolutionary development follows four distinct stages (Figure 3):

- Stage 1. Simple straight septa, mostly developed in the outer whorl
- Stage 2. Development of hemisepta, mostly in the second whorl, but may also be present in the early chambers. Evidence for neotony
- Stage 3. Hemisepta bifurcate and anastomose, and develop bulbous terminations. Transverse septa form chamberlets.

Stage 4. Most complex stage. Chambers become so complex internally that they become difficult to discern. Pillars and canal-like structures develop.

This evolutionary trend is mimicked in some individuals by their ontogeny. Early chambers are comparatively simple and latter ones are increasingly complex. Of particular interest is the increasing frequency of this taxon within an assemblage that reflects dysoxic conditions in the studied section. It is most common in assemblages containing "deep-infaunal" r-selected forms such as *Reophax*, which suggest low-oxygen conditions.

The apparent evolutionary development of complex inner structure among organically-cemented deep-water agglutinated foraminifera is regarded to be a response to changing oceanographic conditions. Seiglie *et al.* (1986) have pointed out that Early Miocene to Recent diversification episodes among alveolar forms have occurred in deep-water environments, while earlier episodes were shallow-water phenomena. A number of taxonomically separate lineages developed alveoles and complex inner structure during the Early Miocene, which suggests this is a morphological character which can be "switched on" given the necessary environmental conditions, for example as a response to the development of a strong oxygen minimum zone.

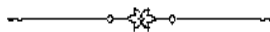
We regard the trend towards increasing entropy in *Popovia johnrolandi* n.sp. between Zones N10 and N14 to be coincident with the intensification of the OMZ in northern Venezuela at the time. Increasing complexity of the agglutinated wall is considered to be a means to increase the surface area to volume ratio, to facilitate gaseous exchange under low oxygen conditions. Having reached maximum complexity, the taxon then disappeared from the section in N14, when a change to a predominantly calcareous assemblage was observed. Its disappearance in the section reflects a return to more well-oxygenated conditions.

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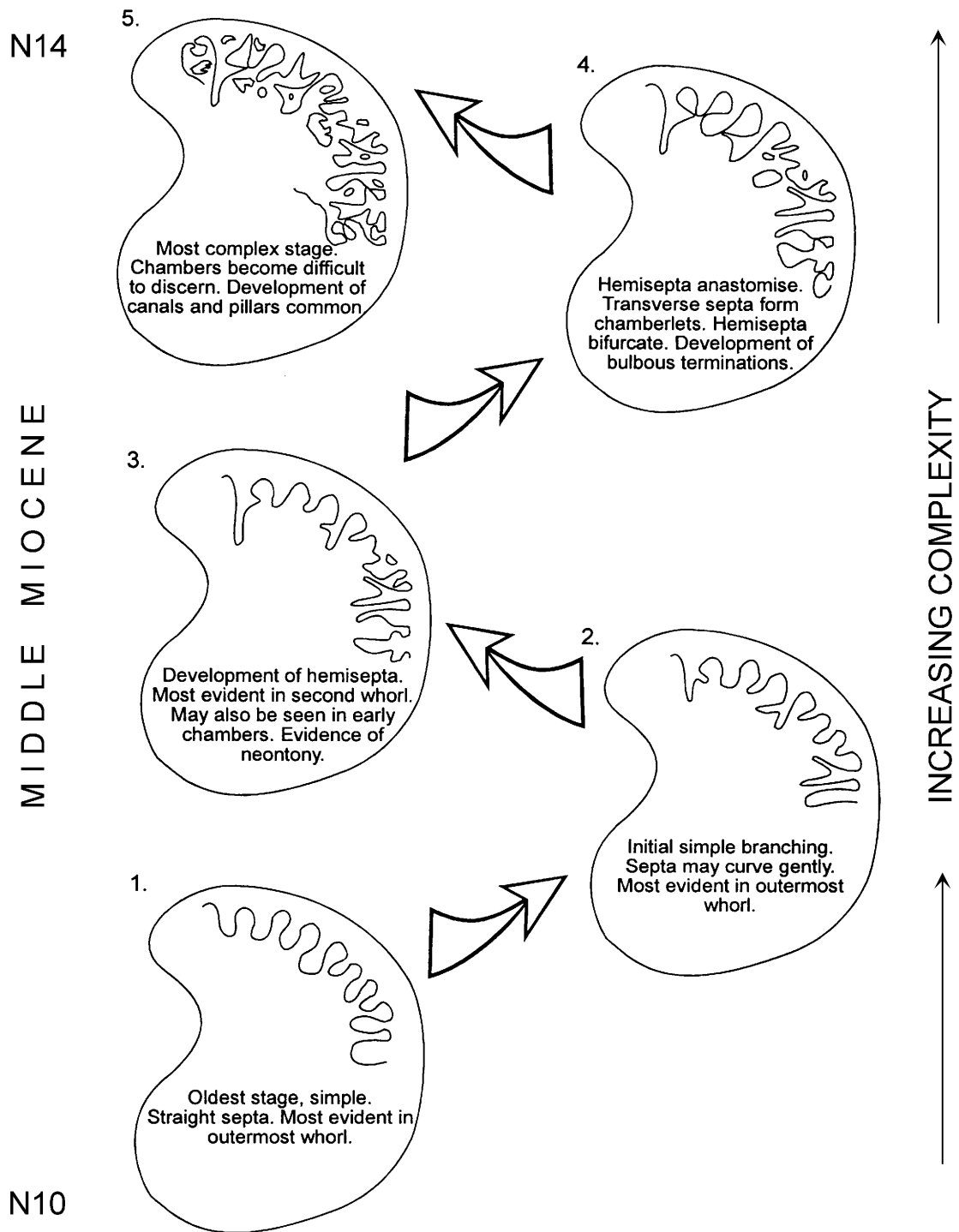


Figure 3. Morphological evolution of *Popovia johnrolandi* n.sp. with reference to standard Middle Miocene chronostratigraphy.

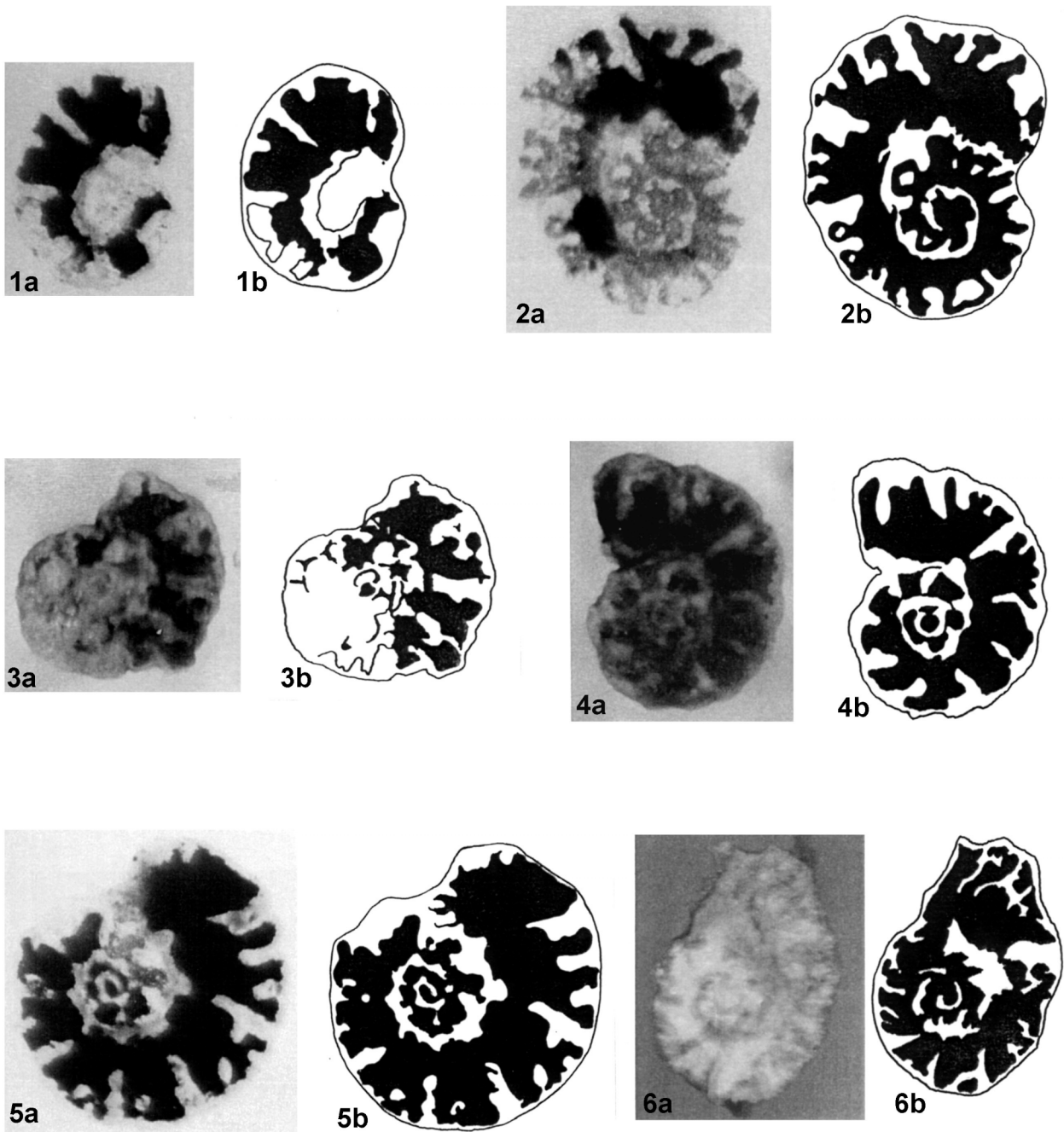


Plate 1. *Popovia johnrolandi* n.sp. Transmitted light images and line drawings; all figures x85. Morphologically simple forms. **1a,b.** Primitive juvenile, sample 2702; **2a,b.** Primitive megalosphaeric form with simple hemisepta, sample 2702; **3a-6b.** More complex microsphaeric individuals from sample 2617.

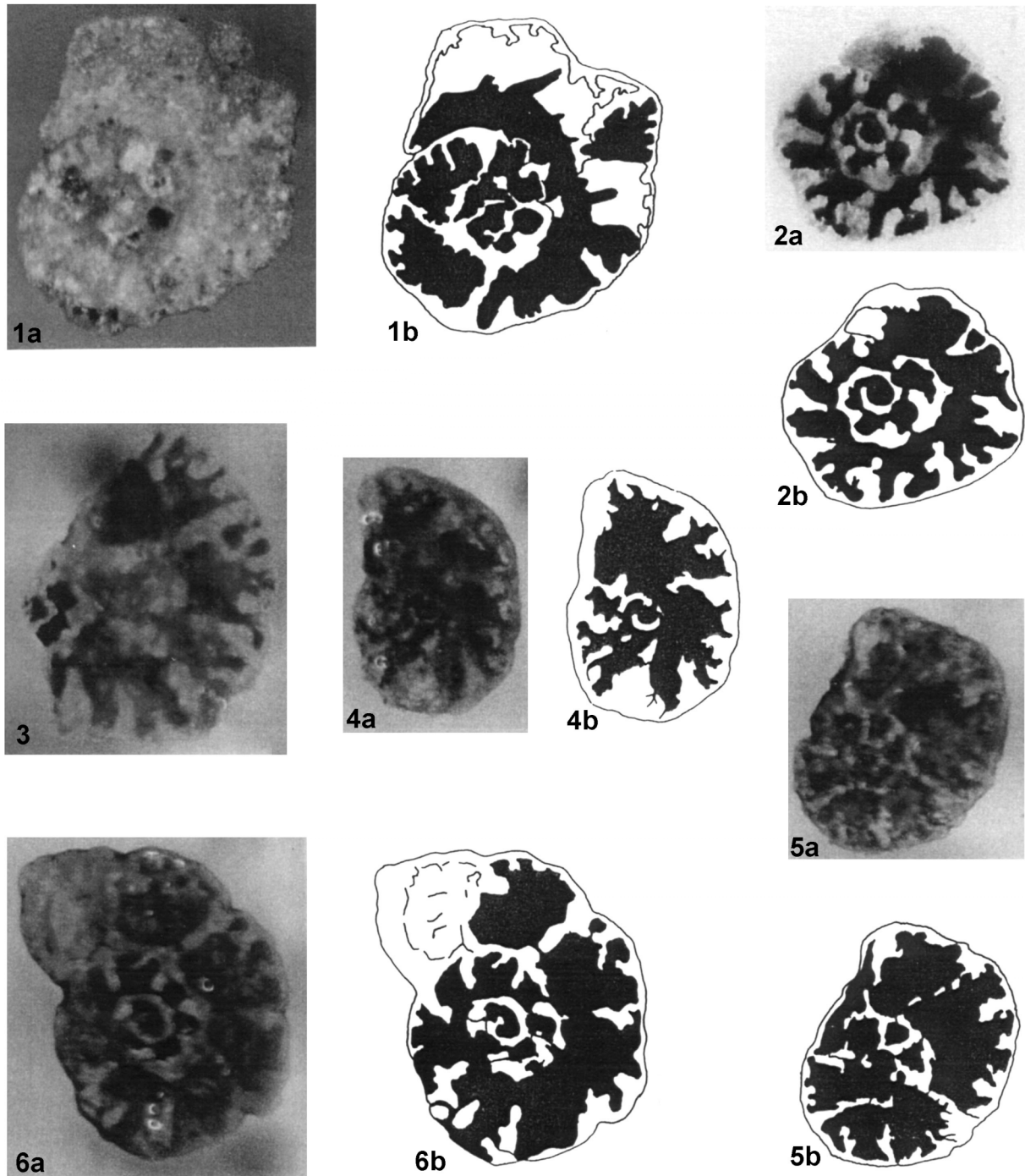


Plate 2. *Popovia johnrolandi* n.sp. Transmitted light images and line drawings; all figures $\times 85$. Individuals with hemisepta that display increasing morphological complexity. **1a,b.** Megalosphaeric individual, sample 2612. **2a,b.** Megalosphaeric individual, hemisepta with bulbous projections develop in the second whorl, sample 2611; **3.** Partial specimen; **4a,b.** Microsphaeric form, with more complex hemisepta in the second whorl, sample 2614; **5a-6b.** Megalosphaeric individuals, with hemisepta but still possessing clearly delimited chambers, sample 2614.

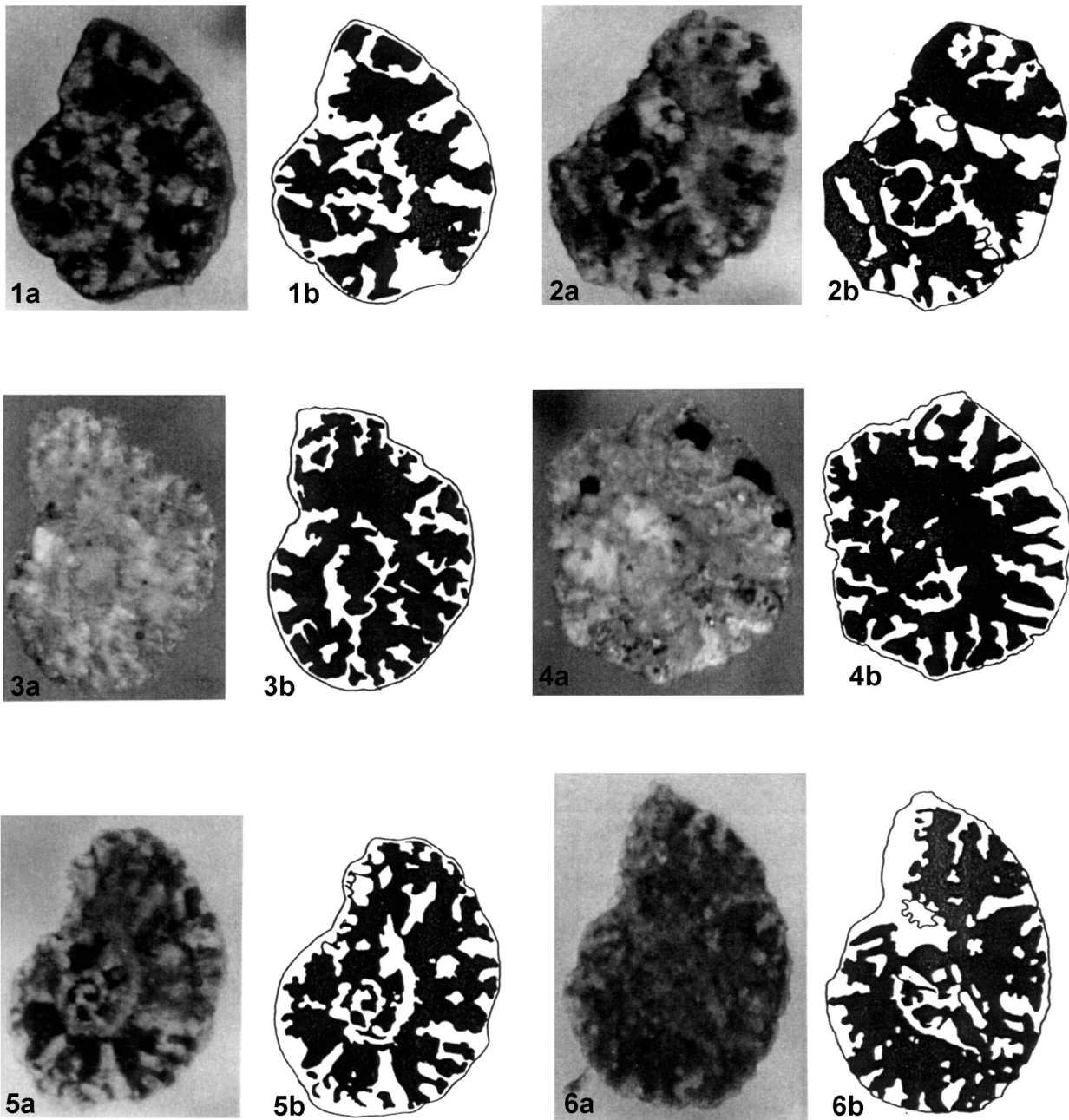


Plate 3. *Popovia johnrolandi* n.sp. Transmitted light images and line drawings; all figures $\times 85$. Individuals with hemiseptae that bifurcate, anastomose, and detach, yielding more poorly defined chambers. **1a,b.** Microsphaeric form, sample 2613. **2a,b.** Megalosphaeric form, sample 2613. **3a-4b.** Microsphaeric forms, sample 2612. **5a-6b.** Microsphaeric forms, sample 2610.