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Pleistocene to Holocene benthic foraminiferal assemblages from the Peruvian continental margin

Zeynep Erdem and Joachim Schönfeld

ABSTRACT

The benthic foraminiferal inventory and their assemblage composition was documented along five sediment cores from the Peruvian margin between 3°S and 18°S at water depths of 500 to 1250 m, covering the lower boundary of today's Oxygen Minimum Zone (OMZ). Emphasis was given to certain time intervals during the last 22 thousand years when different climatic and oceanographic conditions prevailed than today. In total three agglutinated and 186 calcareous species were recognised. *Bolivina costata, Bolivinita minuta, Cassidulina delicata* and *Epistominella exigua* were most abundant. The foraminiferal distributions revealed a marked change in assemblage composition particularly at the deeper cores during and after the deglaciation. The diversity declined and *Bolivina* species became dominant. These changes took place gradually over several millennia, and high-frequency fluctuations were not recorded. This pattern provides evidence for rather stable ecological conditions and sluggish changes in bottom water circulation during the last deglaciation.

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INTRODUCTION

The present study focuses on benthic foraminifera from the continental margin off Peru in order to broaden our knowledge of Southeast Pacific foraminifera and their response to changing environmental conditions during the last glacial-interglacial transition. Today, the Peruvian margin is bathed by one of the strongest oxygen minimum zones (OMZs) in the world (e.g., Paulmier and Ruiz-Pino, 2009). Sediments underneath the Peruvian OMZ sustain rich foraminiferal faunas with a high population density and low diversity, similar to other oxygen depleted environments in the Arabian Sea or California borderland basins (Sen Gupta

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and Machain-Castillo, 1993; Mallon et al., 2012; Cardich et al., 2015). The low-oxygen tolerant foraminiferal faunas are almost entirely composed of calcareous species (Gooday, 2003), because agglutinated species are less tolerant to hypoxic conditions and thus prefer oxygenated conditions (Bernhard and Sen Gupta, 1999; Gooday and Rathburn, 1999; Gooday et al., 2000; Levin et al., 2002). Large miliolids were also reported being restricted to higher bottom water oxygen concentrations (in Arabian Sea >16 µmol/kg; Caulle et al., 2014) and suggested as a proxy for rapid ventilation of oxygen-depleted environments (den Dulk et al., 2000). In particular, species of the family Bolivinitidae are tolerant to the suboxic conditions, and they occur in large numbers in the Peruvian OMZ (Phleger and Soutar, 1973; Khusid, 1974; Manheim et al., 1975; Ingle et al., 1980; Resig, 1981; Heinze and Wefer, 1992). *Bolivina* species, for instance, have shown an oxygen related distribution pattern (Mallon et al., 2012). Using this background information, we investigated the benthic foraminiferal distribution at different sediment cores recovered from the base of the Peruvian OMZ covering the last 22 thousand years. The aim of the study was to explore a) whether there are principle differences between Recent faunas and Pleistocene assemblages, b) the timing, frequency, and magnitude of faunal changes in the core records, and c) if and how they mirror changes in the climate and ocean systems during the last deglaciation.

Recent benthic foraminifera from the Peruvian and Chilean shelf and margin were previously documented by Bandy and Rodolfo (1964), Phleger and Soutar (1973), Khusid (1974), Ingle et al. (1980), Resig (1981), Resig (1990), Schönfeld and Spiegler (1995), Figueroa et al. (2005), Morales et al. (2006), Tapia et al. (2008), Cardich et al. (2012), Mallon (2012), Mallon et al. (2012), and Cardich et al. (2015). Some studies focused on living (rose Bengal stained) foraminiferal faunas (Tapia et al., 2008; Cardich et al., 2012; Mallon, 2012; Mallon et al., 2012; Cardich et al., 2015), but most of them considered dead or subfossil assemblages in near-surface sediments. The records of Pleistocene and Holocene foraminiferal assemblages are limited to a few sediment cores, mostly from the centre of the OMZ. Only a few of those studies provided plates and detailed taxonomic references (Resig, 1990; Schönfeld and Spiegler, 1995).

Benthic foraminifera have served as important tools for palaeoenvironmental studies due to their global distribution, high levels of adaptation, short generation times, quick response to environmental changes, and good preservation of their tests in the fossil record (e.g., Alve and Bernhard, 1995; Van der Zwaan et al., 1999; Murray, 2006). They have been widely used in palaeoenvironmental reconstructions either by applying indicator species or groups (Lutze et al., 1986; Smart et al., 1994; Asteman and Nordberg, 2013; Alve et al., 2016), assemblage composition in general (Schmiedl et al., 2003; Jennings et al., 2004; de Nooijer, 2007; Mendes et al., 2012; Moffitt et al., 2014) or the elemental and isotopic chemistry of their shell calcite (e.g., Mackensen et al., 1993; Elderfield et al., 1996; Lear et al., 2000; Waelbroeck et al., 2002). This attribution of certain species and chemical response of their shell to environmental parameters has been the subject of a long and controversial debate (e.g., Van der Zwaan et al., 1999; Gooday, 2003). One of the biggest challenges of foraminiferal proxy studies is a correct and well-documented taxonomy. Recent publications using benthic foraminifera as palaeoproxies rarely unveil the application of classical taxonomy methods, e.g., working strictly quantitative, preparing Plummer cell slides, providing high quality images, and annotated taxonomical reference lists quoting more than just the type references (Schönfeld et al., 2012). This process is lacking either because of time limitations during a project or because of the expenses to have access to classical taxonomy literature or the Ellis and Messina catalogues. Because of such limitations, we rely more and more on electronic sources, which eventually lead to mistakes in species determinations (Erdem, 2015). In this study, we therefore emphasised the taxonomic documentation by providing both, high quality optical and Scanning Electron microscope (SEM) images.

REGIONAL SETTING

The Peruvian continental margin is characterised by strong upwelling, high productivity, and pronounced oxygen minimum conditions in the water column. The oxygen minimum zones (OMZs) are defined as regions with dissolved oxygen concentrations of <0.5 ml/l = ~<22 µmol/kg (Helly and Levin, 2004; Fuenzalida et al., 2009). The Peruvian OMZ covers the continental slope and the shelf with its thickest part between 5°S and 15°S and 50 to 750 m water depths (Figure 1; Karstensen et al., 2008; Fuenzalida et al., 2009; Paulmier and Ruiz-Pino, 2009; Czeschel et al., 2012). The strength and extension of the Peruvian OMZ is maintained by the combination of a sluggish ocean circulation

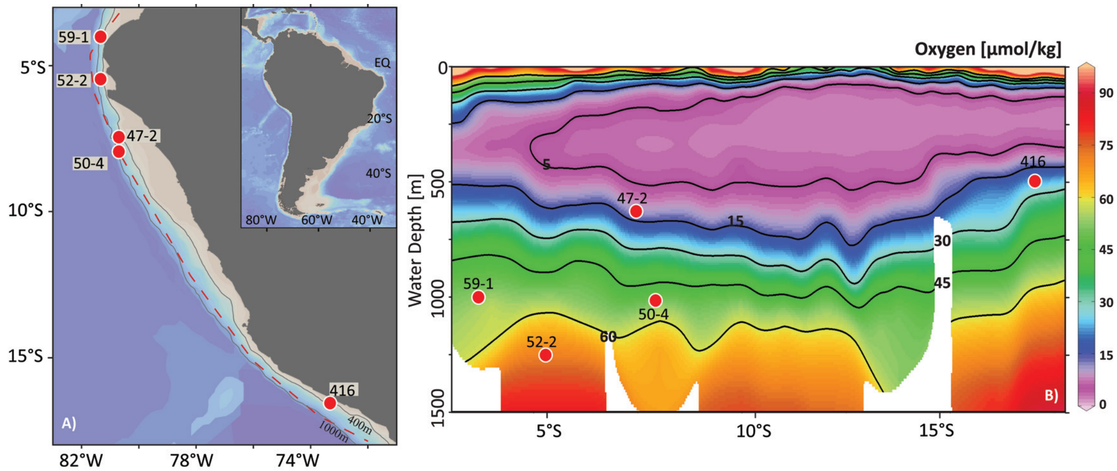

FIGURE 1. A) Map of the research area showing the core locations. The dashed line shows the approximate position of the section in B) depth vs latitude section showing the dissolved oxygen concentrations and the core locations. Oxygen data were taken from a CTD compilation after Schönfeld et al. (2015). Contour lines indicate the dissolved oxygen concentration interval. Prepared by ODV Software (Schlitzer, 2010)

and high primary productivity in the surface waters, leading to increased organic carbon export and enhanced consumption of dissolved oxygen in the water column (Wyrtki, 1962; Fuenzalida et al., 2009; Schönfeld et al., 2015; Dale et al., 2015).

The Peruvian margin is tectonically active and the continental shelf extends down to about 600 m depth in places (Krissek et al., 1980; Strub et al., 1998). Between 7°S and 10°30'S, the shelf is broad with a pronounced shelf break and a steep continental slope (Reimers and Suess, 1983; Suess et al., 1987; Reinhardt et al., 2002). Further south, between 11 and 14°S, the shelf break is less pronounced (Reimers and Suess, 1983) and the shelf is narrower and deeper as compared to the northern part. The continental slope becomes steep again south of 15°S towards the Chilean margin, and the shelf is even narrower with a pronounced shelf break (Krissek et al., 1980). Due to these topographic alternations, the hydrodynamics of near-bottom waters play an important role for sedimentary processes at different latitudes and water depths. Active winnowing and reworking are observed in sediment cores obtained from the shelf between 11-14°S and from the slope south of 14°S (Reimers and Suess, 1983). The sedimentary record is characterised by marked unconformities and extended periods of non-deposition (Erdem et al., 2016). The sediments are predominantly olive green to dark grey green silts and clays with glauconitic sand and phosphorite layers. Laminations are observed within the OMZ whereas around the OMZ foraminifera bearing, bioturbated silty clays are found (Pfannkuche et al., 2011). Sediments from intense upwelling areas south of 10°30'S and within the OMZ are organic-rich, diatom bearing silty clays (Krissek et al., 1980; Suess et al., 1987; Wefer et al., 1990; Pfannkuche et al., 2011; Erdem et al., 2016). The sediment cores considered in the present study were obtained from the mid continental slope and from the lower oxic - suboxic boundary of the Peruvian OMZ between 500 and 1250 m depth where records with a longer stratigraphic reach or even continuous core sequences were found (Figure 1).

MATERIALS AND METHODS

In total, five sediment cores were considered in this study and they were recovered in 2008 during *R/V Meteor* cruise M77, Legs 1 and 2. They were located between 3°S and 18°S from water depths of 500 m to 1250 m (Table 1 and Figure 1). In reference to today's dissolved oxygen concentrations, the shallower two cores, core 47-2 and core 416, were located within the OMZ and other three cores, 59-1, 52-2, and 50-4, were located outside the OMZ (Figure 1). The sediment cores were split half, described and preliminary information was gathered on board (Pfannkuche et al., 2011). The age model of the core 59-1 was based on radiocarbon dating from planktonic foraminifera species *Neogloboquadrina dutertrei* performed at the Leibniz Laboratory for Radiometric Dating and Stable Isotope Research, University of Kiel (CAU). The ages were later calibrated applying the Marine09 marine calibration set (Reimer et al., 2009) with a reservoir age correction of 200±15

TABLE 1. The metadata of the sediment cores used in this study.

Cruise	Core name	Year	Lat (S)	Long (W)	Water depth (m)	Reference; Age model
M77/2	059-PC1	2008	03°57.01'	81°19.23'	997	Mollier-Vogel et al., 2013
M77/2	052-PC2	2008	05°29.01'	81°27.00'	1249	Erdem et al., 2016
M77/2	047-PC2	2008	07°52.01'	80°31.36'	626	Erdem et al., 2016
M77/2	050-PC4	2008	08°01.01'	80°30.10'	1013	Erdem et al., 2016
M77/1	416-GC4	2008	17°28,13'	71°52,62'	505	Erdem et al., 2016

years (Mollier-Vogel et al., 2013). Age models of the other cores were based on radiocarbon dating of planktonic foraminifera species *N. dutertrei* (cores 52-2, 50-4 and 47-2) and benthic foraminifera species *Planulina limbata* (core 416) that were performed at the Beta Analytic Inc., Florida (Erdem et al., 2016). The ages were calibrated applying the Marine13 marine calibration set (Reimer et al., 2013). Reservoir age corrections were done according to the marine database (calib.qub.ac.uk/marine/) ranging from 89 to 338 years for this region (Erdem et al., 2016).

After the age models were established, they revealed rather incomplete records. Due to the erosion in the region and hiatus in the sedimentary record we were not able to compare all time intervals in all cores (Figure 2). The Last Glacial Maximum (LGM) was documented by four cores (52-2, 50-4, 47-2 and 416), the deglaciation was documented in northern part by four cores (59-1, 52-2, 50-4 and 47-1) whereas the Holocene was documented only in the northernmost cores (59-1 and 52-2). We therefore focused on specific time intervals that are represented in as many cores as possible, in particular the Last Glacial Maximum (LGM; 20-22 cal ka BP), the Heinrich Stadial-1 (HS1; 15-17.5 cal ka BP) the Bølling Allerød/Antarctic Cold Reversal (BA/ACR; 13-14.5 cal ka BP), the early Holocene (EH; 8-10 cal ka BP), and the late Holocene (LH; 3-5 cal ka BP) (Figure 2).

Volume-defined samples of 10 to 20 cc were taken from the working halves of the cores at 10 cm spacing that corresponds to a resolution of 300 to 500 years. The samples were wet-sieved on a 63 μm screen immediately after sampling, except for cores 47-2 and 59-1, which were sampled previously by others. The residues were oven-dried at 40°C. They were later split with an Otto microsplitter in order to attain aliquots with a similar total number of ca. 300 specimens per sample (Murray, 2006). All benthic foraminifera from the >63 μm size fraction were dry picked from the aliquots, col-

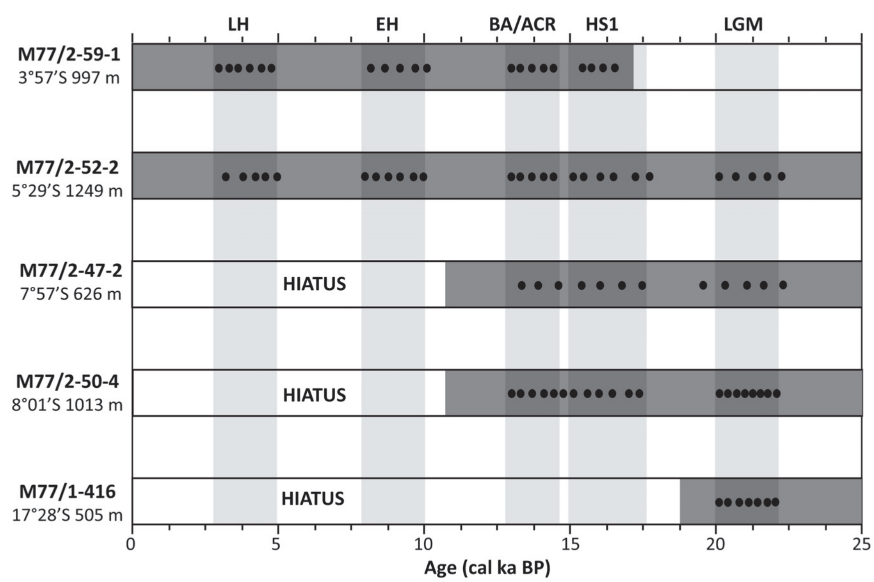

FIGURE 2. Schematic description of the focused time intervals and samples considered regarding to the benthic foraminifera study at each core.

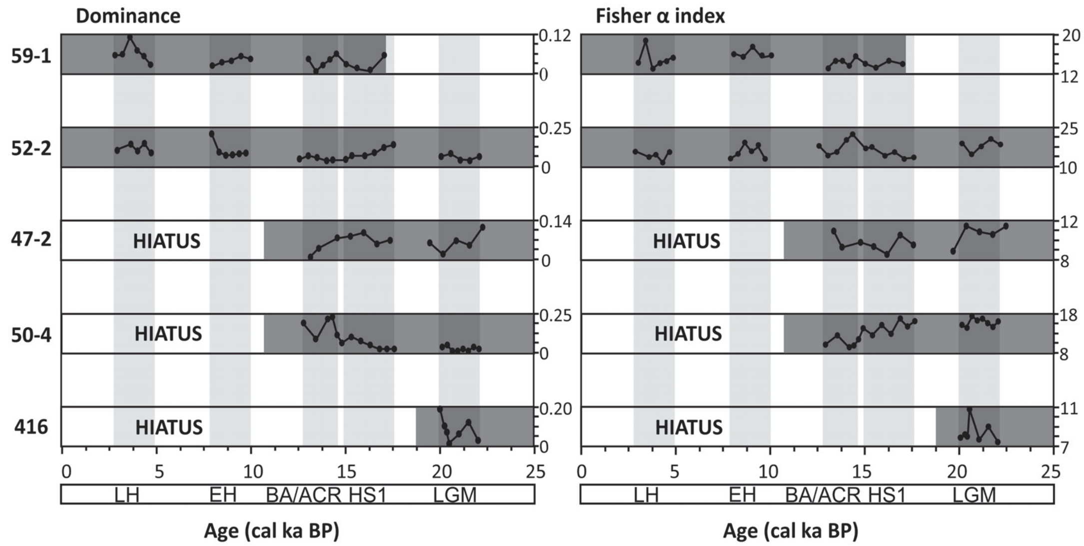

FIGURE 3. Dominance and Fisher α diversity indices calculated for each sample and core. Note that the scale bars are different.

lected in Plummer cell slides, sorted by species, fixed with glue and counted. The species were determined after Natland (1950); Barker (1960); Uchio (1960); Smith (1964); Boltovskoy and Theyer (1970); Coulbourn (1980); Ingle et al. (1980); Resig (1981); Loeblich and Tappan (1988); Whittaker (1988); Resig (1990); Figueroa et al. (2005); Mallon (2012), and the Ellis and Messina Catalogues. Relative abundances (%) were calculated for each sample (Appendix). The most abundant species with >5 % relative abundance (Table 2) and common species that were observed in most of the cores (at least in three cores) were imaged with a CamScan 44/EDX scanning electron microscope and a Keyence VHX-700 FD digital camera at the Institute for Geosciences, Kiel University. The Fisher α diversity index and dominance was calculated from the census data using the software Palaeontological STatistics (PAST) Version 3.11 (Hammer et al., 2001). The Fisher α index assumes that the abundance of species follows the log series distribution and is calculated through the gradient of relationship between the number of species and individuals in a sample (Fisher et al., 1943).

RESULTS

A total of 189 species were identified in all the sediment cores. Three of them were agglutinated species (*Dorothia goesii*, *Martinottiella communis*, and *M. nodulosa*). They were observed only in the deep cores 59-1, 52-2, and 50-4. Relative abundances of the agglutinated species showed highest values in core 52-2 (up to 2.2 %) during the late Holocene and were less than 0.5 % in other two cores (Appendix). Total relative abundance of the miliolids showed a similar trend *(Pyrgo depressa, P. lucernula, P. murrhyna, P. serrata, Quinqueloculina seminulum, Q. triangularis)*. They were observed at a few samples with percentages less than 1.5 % from the deep cores, predominantly during the LGM period, whereas in the shallow cores specimens of *Quinqueloculina* species were observed only at one sample in each core (47-2 and 416; Appendix). Overall, diversity was higher at the deeper cores 59-1, 52-2, and 50-4 as indicated by the Fisher α index (Figure 3). It showed values between 8 and 25 at these cores whereas at the shallower cores the values ranged from 7 to 11 and from 8 to 12 at core 416 and 47-2, respectively. The diversity showed a decreasing trend during the deglaciation at cores 47-2 and 50-4, from values 12 and 18 to around 8. The dominance measured in all samples showed that certain time intervals were dominated by specific species. It showed different trends in each core. The highest values (up to 0.25) were observed at cores 50-4 and 52-2 during the deglaciation and the Holocene.

In the present study, we mainly focused on 38 common species with relative abundances of more than 5 % observed at least at one sample in each core (Table 2). These species constitute at least 70 % of whole benthic foraminiferal assemblages

TABLE 2. List of the most abundant species with >5 % relative abundance observed in each sediment core. The most abundant and common species are indicated bold. * species without image.

Species name	Occurrence				
	59-1	**52-2**	**50-4**	**47-2**	**416**
Alabaminella weddellensis	0-6			absent	absent
Anomalinoides minimus	0-5		absent		absent
Bolivina costata		**1-43**	**5-45**	**16-26**	
Bolivina interjuncta var. bicostata	0-7				0-5
Bolivina pacifica	0-6	0-5	0-6		
Bolivina plicata		absent			0-6
*Bolivina quadrata**	0-7		absent		absent
Bolivina seminuda var. *humilis*			1-7	0-6	1-23
Bolivina spissa	0-5	0-7			absent
Bolivinita minuta	**0-30**	**0-20**	**0-10**	**0-6**	
cf Buccella peruviana			0-5	2-9	
Bulimina exilis			0-6		
Bulimina pagoda		0-7			absent
Buliminella elegantissima					0-22
Cassidulina auka	absent	0-6	0-6		2-38
Cassidulina carinata	0-9	0-24	0-11		
Cassidulina delicata	**3-14**	**5-21**	**3-14**	**6-16**	
*Cassidulina laevigata**		0-14			absent
Cassidulina minuta	0-9			0-9	absent
Cibicides mckannai		0-7		absent	absent
Epistominella afueraensis			0-7		0-27
Epistominella exigua	**5-23**	**0-33**	**0-13**		**0-6**
*Epistominella obesa**	0-5		0-15	2-16	
Epistominella pacifica	0-6	0-8	0-8		0-34
Epistominella smithi	0-6	0-12	0-7	absent	absent
Fursenkoina fusiformis		0-5	0-5		
Gyroidina rothwelli	0-5				2-14
*Nonionella auris**					0-15
Planulina limbata					0-7
Pseudoparella sp.			0-18	4-14	absent
*Pseudoparella subperuviana**			0-15	3-14	0-18
Uvigerina auberiana	0-8	0-11			absent
Uvigerina bifurcata	absent	0-9		absent	absent
Uvigerina peregrina		0-10			0-6
Uvigerina semiornata	0-5	3-17	0-7		
Uvigerina striata					0-5
*Virgulina cornuta**			0-6		
Virgulina spinosa	0-21	absent		absent	absent

in the samples (Appendix). This percentage drops to 60 % in the samples from cores 59-1 and 52-2 where the Fisher α index showed relatively high values (Figure 3). The most abundant and common species observed in the cores are *Bolivina costata, Bolivinita minuta, Cassidulina delicata,* and *Epistominella exigua.* Overall trends showed that the most abundant taxa belong to the genera *Bolivina, Cassidulina, Epistominella,* and *Uvigerina* (Figure 4; Appendix).

On species level, these taxa showed differences between the sediment cores depending on the core location. In particular core 416, only the LGM is represented, was obtained from the southernmost and shallowest station. The distributional pattern was distinctly different from the other cores. *Cassidulina auka* showed highest percentages (up to 40 %) in this core whereas it was absent in all samples from core 59-1 and less than 5 % in other three cores (52-2, 50-4, and 47-2). Instead, *C. delicata* showed high percentages (up to 25 %) in the northern cores, particularly in core 59-1 ranging between 5 and 20 %. A similar difference was observed in the distribution of *Bolivina costata.* This species was observed with highest percentages ranging from 0 to 50 % in the cores between latitudes 5-8°S (cores 52-2, 50-4, and 47-2). *Bolivina costata* was observed at only one sample from core 416 and two samples from core 59-1. In core 59-1, other smaller *Bolivina* species, such as *B. pacifica* (Figure 4) and *B. quadrata* (Appendix) showed percentages reaching up to 6 % during the deglaciation, particularly during the period BA/ACR. Their abundance decreased to percentages around zero during the Holocene. In core 416, *B. seminuda* var. *humilis* represents the genus with percentages ranging from 0 to 30 %. *Epistominella exigua* was observed in all cores with highest percentages in the northern cores. Its abundance reached up to 25 % in core 59-1, 40 % in core 52-2 and 15 % in core 50-4 during the HS1. It showed a similar decreasing trend during the deglaciation in cores 50-4 and 52-2. Instead, *Epistominella obesa* and *E. pacifica* were more frequent in the shallower cores 47-2 and 416, respectively. Beside the differences between taxa from the same genus, some species showed high abundances and distinct differences between cores. *Bolivinita minuta* was observed in high numbers in the northern cores, showing an increase during the BA/ACR (Figure 4). At core 59-1, it remained the most abundant species throughout the Holocene with percentages reaching up to 30 %, whereas in core 52-2, its abundance decreased distinctly from 20 % in the BA/ACR to 2 % in the Holocene. Its abundance did not exceed 5 % in core 416 similar to its distribution in other cores during the LGM. *Pseudoparella subperuviana* showed low percentages (<5 %) in the northern and deep cores 59-1 and 52-2, whereas its abundance reached up to 20 % in other cores (Figure 4). Inversely, *Uvigerina auberiana* was abundant in the northern and deep cores, showing an increasing trend from the HS1 to LH with percentages ranging from 0 to 8 % in core 59-1 and from 0 to 15 % in core 52-2. *Uvigerina auberiana* was low in abundance in cores 50-4 and 47-2, and absent from the southernmost core 416. In addition, the smaller species *Anomalinoides minimus* and *Alabaminella weddellensis,* which were not mentioned as common species in earlier studies, were found with proportions exceeding 5 % in core 59-1 during the Holocene (Figure 5). Both species were absent in core 416 and not abundant in other cores. *Buliminella elegantissima* and *Nonionella auris* showed high abundances of 21 % and 9–15 %, respectively, in samples 140 cm and 180 cm from core 416 (Figure 6). They were absent from other samples of this core, and likewise were absent or did show only low numbers in other cores.

DISCUSSION

Benthic foraminifera generally show a low diversity and a high dominance in oxygen depleted environments (e.g., Phleger and Soutar, 1973; Sen Gupta and Machain-Castillo, 1993; Bernhard and Sen Gupta, 1999). The shallow cores 47-2 and 416 were recovered from the edge of the modern OMZ and due to the erosion, observations regarding to the temporal variations was limited to LGM in core 416 and to LGM and the deglaciation in core 47-2. The dominance and diversity indices did not reveal distinct differences throughout the time intervals considered in core 47-1. However, the deeper core 50-4 from the same latitude indicated a distinct decrease in diversity and an increase in dominance during the deglaciation. This pattern might indicate a relatively stable bottom water oxygenation around today's 600 m water depth, and a thickening of the oxic–suboxic boundary in greater depths at these latitudes. On the other hand, the dominance and diversity measures from the northern cores indicated fluctuating trends during the deglaciation rather than a distinct diversity decline as in core 50-4. That trend in core 50-4 was mostly related to the relative abundance of *Bolivina costata*, which showed a distinct increasing trend during the deglaciation and reaching up to 45 % of

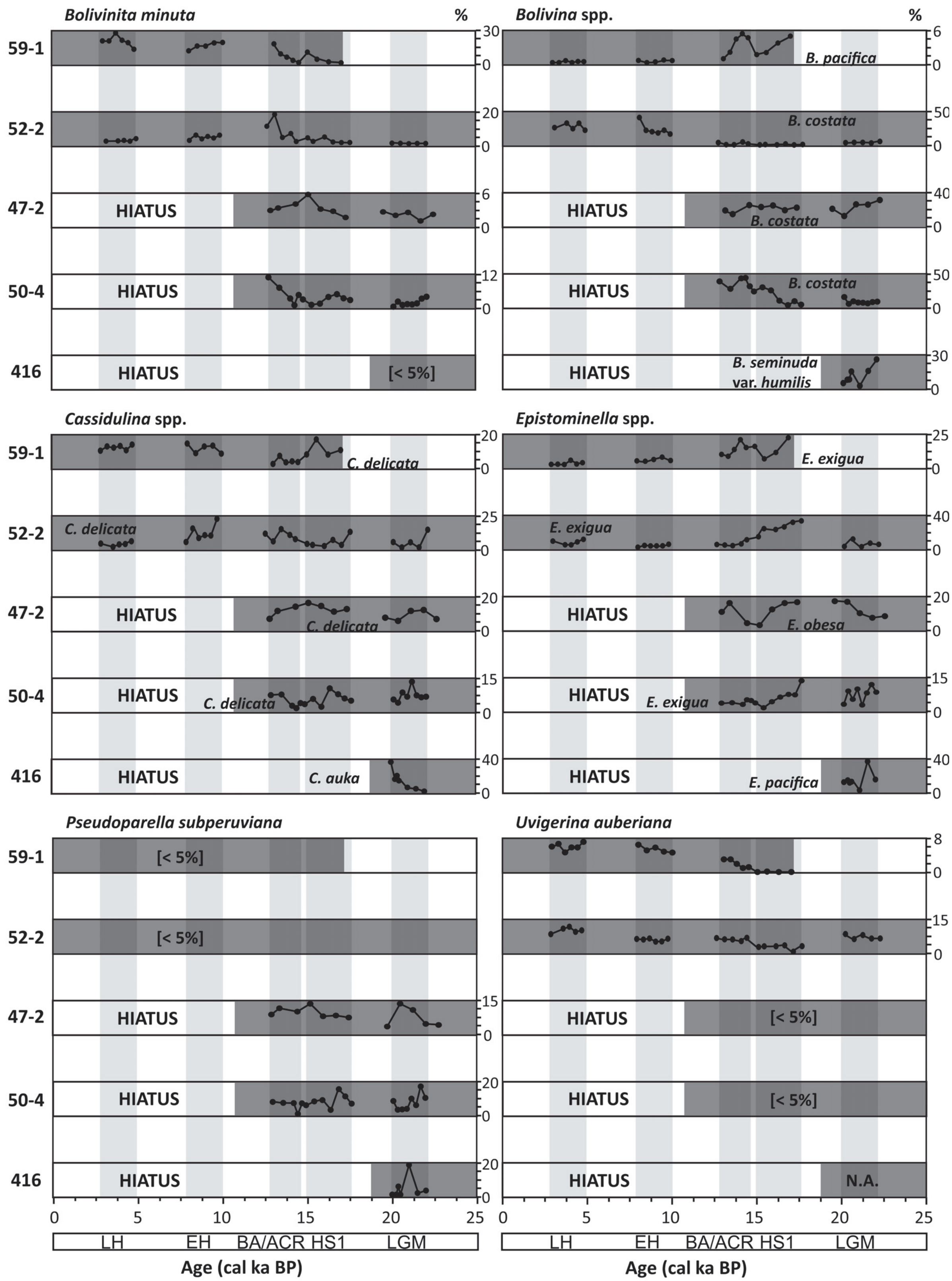

FIGURE 4. Downcore distributions of the most abundant species (>5% relative abundance) observed in the sediment cores. N.A.: in case of absence of the species. Note that the scale bars are different.

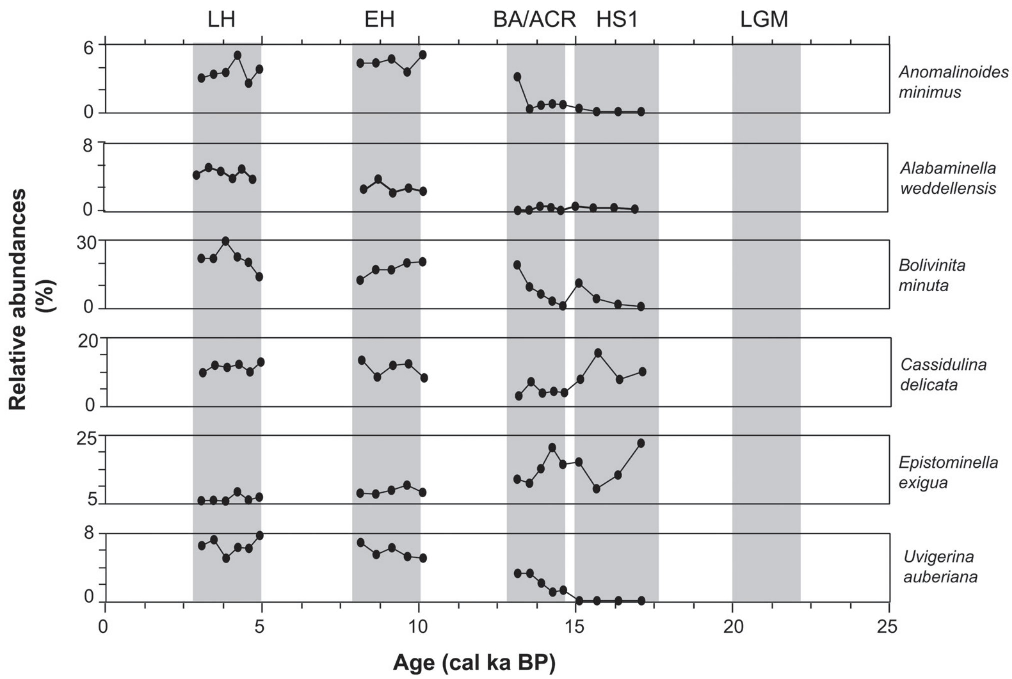

FIGURE 5. Downcore distributions of *A. minimum*, *A. weddellensis*, *B. minuta*, *C. delicata*, *E. exigua* and *U. auberiana* observed in core M77/1-59-1. Note that the scale bars are different.

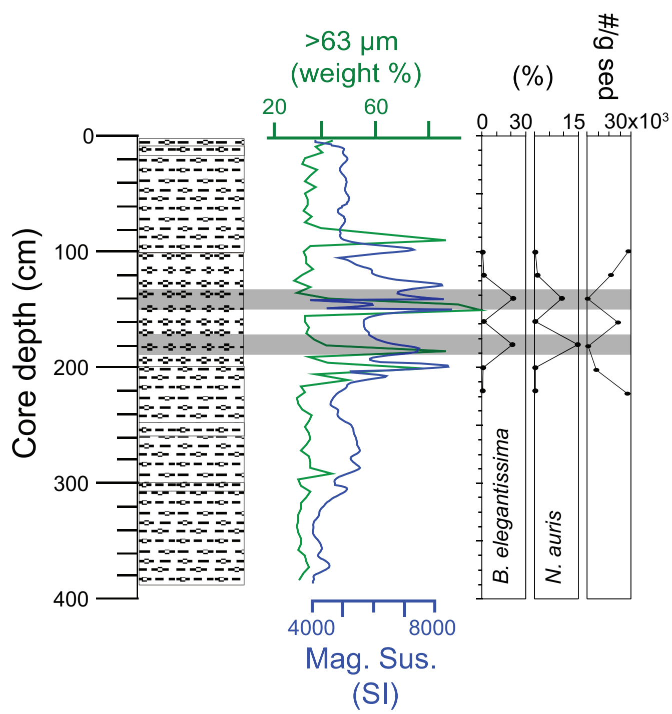

FIGURE 6. Visual description of core M77/1-416 with magnetic susceptibility (SI) measurements and < 63 µm (weight %) information. Relative abundances of given species are potentially in relation with the downslope transported material.

whole assemblage during the BA/ACR. In the core 52-2, however, *Epistominella exigua* reached up to 40 % during the HS1 and dominated the whole assemblage, which is reflected in both, low diversity and high dominance.

In overall distributional patterns, *Bolivina costata* was one of the most abundant species, but its occurrence was limited to sediment cores between 5°S and 8°S. Not much is known about the ecology of *B. costata*, as well as its distribution in the global oceans. Previous observations off Peru reported its tolerance to oxygen minimum conditions (Khusid, 1974; Resig, 1981; Mallon et al., 2012) and even to sulfidic pore waters (Cardich et al., 2015). Another downcore application from the Peruvian margin used this species as high upwelling and low oxygen indicator (Heinze and Wefer, 1992). Its distribution also has been thought to be limited to the continental shelf offshore Peru, where it has been used as a proxy for sea-level fluctuations (Resig, 1990). New observations on living (rose Bengal stained) benthic foraminifera from the region indicated that *B. costata* also occurred in the deeper parts of the Peruvian margin (Mallon, 2012). Its distribution in core 50-4 indicated an increasing trend from 10 % to 45 % during the deglaciation. The deeper core 52-2 from 5°S revealed similar changes but during a later period, the Holocene (Figure 4). This species could be an indicator of the deoxygenation in the bottom waters at these core sites offering the conclusion of a gradually expanding OMZ with the onset of the deglaciation. This is also supported by the disappearance of the miliolids and the agglutinated species in core 50-4 with the onset of the deglaciation (Appendix).

Epistominella exigua has been associated with pulsed supply of phytodetritus (Gooday, 1993; Smart et al., 1994; Thomas and Gooday, 1996). It was observed at few samples in shallow cores 47-2 and 416. The abundances increased during the deglaciation in the northern cores but with different magnitudes. It showed high abundances in core 52-2 during HS1 followed by a distinct decrease towards the end of the deglaciation. In contrast, the *E. exigua* abundance fluctuated around similar values during the whole deglaciation in the northernmost core 59-1. The southern core within these three cores, 50-4, showed a different pattern. The proportions of *E. exigua* fluctuated during the LGM indicating high detritus fluxes to the sea floor at this time. The following trend of high abundances during HS1 and decreasing proportions during the deglaciation shows similarities with the distribution in core 52-2 although with much less proportions. These temporal and proportional differences indicate that different surface water processes (e.g., upwelling, surface productivity) have taken place above the core locations since the LGM. The northern part of the 5°S might have been under influence of the Equatorial upwelling system instead of the Peruvian coastal upwelling. The significant drop of the *E. exigua* proportions in the core 52-2 and its continuous occurrence in core 59-1 during the BA/ACR could be interpreted as a northward shift of the upwelling cell and a subsequently high surface productivity during the deglaciation. Furthermore, the negative correlation trend, which is observed between abundances of *E. exigua* and *Bolivinita minuta,* deserves attention. Even though the ecology of the latter species is yet largely unknown, other *Bolivinita* species are always observed in association with sustained organic matter input (Sarkar and Gupta, 2014 and references therein). *Bolivinita minuta* is one of the common species in the OMZ on the shelf and tolerant to low bottom water oxygen conditions (Ingle et al., 1980; Resig, 1990; Mallon et al., 2012). The species is not, however, as abundant as *Bolivina costata* within the OMZ core (dissolved oxygen concentrations <5 µmol/kg; Mallon et al., 2012). Its slightly increasing trend at the end of the BA/ACR period is observed in all cores from the northern part of the region and could be related to environmental changes in relation to climatic changes during the Younger Dryas, which is often not observed in the Southern Hemisphere records (Broecker et al., 2010; Shakun and Carlson, 2010). Additionally, this slight increase is also in accordance with the distributional pattern of *Anomalinoides minimus* in core 59-1, which might be an indication of short-term ventilation at intermediate depths. *Anomalinoides minimus* was previously observed and described from the Mediterranean Sea (Vismara Schilling and Parisi, 1981). Its size does not exceed 150 µm. The distribution of *A. minimus* in the Mediterranean Sea was reported in co-occurrence with *Epistominella exigua* and *Eponides pussillus* and in association with sapropels suggesting a high recolonization potential of deep-sea areas following anoxic periods (Schmiedl et al., 2003 and references therein). In the open oceans, these small opportunistic species are reported as indicators of enhanced phytodetritus input to the sea floor (e.g., Gooday, 2003). *Anomalinoides minimus* co-occurred with *Alabaminella weddellensis, Bolivinita minuta,* and *Uvigerina auberiana* in the core 59-1 (Figure 5). The decreasing trend of *E. exigua* together with the increase of other species increased might be related to changes in food-composition or their (of *A. weddellensis, B. minuta* and *U. auberiana)* low tolerance of the low oxygenation in the bottom waters during the deglaciation. *Epistominella exigua* is potentially much more tolerant to low oxygen concentrations and may have benefited from less competition. High productivity and low bottom water oxygen conditions during the deglaciation were reported for the Eastern Equatorial Pacific (Pedersen, 1983; Hendy and Pedersen, 2006), which supports this idea. It should also be kept in mind that core 59-1 has been under the influence of major riverine input (Mollier-Vogel et al., 2013). According to their results, the terrestrial input decreased during the deglaciation and increased during the late Holocene. Since the benthic foraminiferal information is not continuous, we cannot assess the influence of terrestrial material with certainty.

Cassidulina delicata is one of the common species of upper-middle bathyal assemblages (500–1 000 m) offshore Peru and Chile (Ingle et al., 1980; Resig, 1981) and offshore California (Bandy, 1953; Zalesny, 1959; Uchio, 1960). It occurred dominantly together with *Epistominella pacifica, E. smithi,* and *Bolivinita minuta.* Off Chile, Ingle et al. (1980) related this assemblage to the influence of Antarctic Intermediate Waters (AAIW). *Cassidulina delicata* is also reported as low oxygen tolerant species (Douglas and Heitman, 1979; Sen Gupta and Machain-Castillo, 1993). In our core samples, *C. delicata* is one of the most abundant species and our findings agree with the previous observations. It was observed with percentages more than 5 % in all cores except core 416. Nonetheless, *C. delicata* did not show distinct changes along the cores, and thus the species' distribution was seemingly not influenced by the same environmental factors as the other species.

The recent occurrence of *Buliminella elegantissima* and *Nonionella auris* is known to be limited to the continental shelf (e.g., Ingle et al., 1980; Resig, 1990; Mallon, 2012). Comparing their abundances with sedimentological information and physical properties measured at core 416, it emerged that their occurrence matched with levels showing evidences of re-deposition (Figure 6). In particular, high values of magnetic susceptibility (SI) together with an increase in sand content (weight % >63 µm) at the same core depths were considered as indicators of the downslope transport. The foraminiferal data from these core depth levels should therefore be taken with caution.

CONCLUSIONS

Five sediment cores from the lower boundary of the Peruvian OMZ were investigated with emphasis on certain time intervals during the last 22 thousand years. Benthic foraminiferal inventory and assemblage composition of the size fraction >63 µm was assessed throughout the considered time intervals. In total, 189 species were identified. The most abundant species were *Bolivina costata*, *Bolivinita minuta*, *Cassidulina delicata,* and *Epistominella exigua*. The assemblage composition did not show abrupt changes or fluctuations during the periods studied. The most distinct changes were increasing relative abundances of *B. costata* and *B. minuta* in the deeper cores during and after the deglaciation, suggesting a gradual decrease of bottom water ventilation. The overall faunal changes were gradual providing evidence for relatively stable ecological conditions along the Peruvian margin at intermediate water depths since the LGM.

TAXONOMIC REFERENCE LIST

Type references are given for each species identified. Angular brackets refer to figures.

Alabaminella weddellensis = *Eponides weddellensis Earland*, 1936. [Figures 7.12, 8.24].

Angulogerina angulosa = *Uvigerina angulosa* (Williamson, 1858). [Figure 9.4].

Angulogerina carinata (Cushman, 1927).

Anomalinoides minimus (Vismara Schilling and Parisi, 1981). [Figures 7.4-5, 8.14, 8.20].

Bolivina advena (Cushman, 1925).

Bolivina advena Cushman var. *striatella* Cushman, 1925.

Bolivina alata = *Valvulina alata* (Seguenza, 1862).

Note: This species was denominated as *Bolivina pseudobeyrichi* Cushman and the species name *Bolivina alata* (Seguenza) is considered to have priority. [Figures 10.10, 11.10].

Bolivina albatrossi Cushman, 1922.

Bolivina argentea Cushman, 1926a. [Figure 10.5].

Bolivina costata d'Orbigny, 1839. [Figures 12.1, 8.8].

Bolivina doniezi Cushman and Wickenden, 1929.

Bolivina interjuncta = *Bolivina costata* d'Orbigny var. *interjuncta* Cushman, 1926a. [Figures 10.1, 11.1].

Bolivina interjuncta Cushman var. *bicostata* = *Bolivina costata* d'Orbigny var. *bicostata* Cushman, 1926a, illustrated in Cushman, 1937.

Note: The description and images provided by Uchio (1960) as *Bolivina subargentea* are also similar to what is observed in the sediment samples in this study, but the specimens observed in the sediment cores are too small in size compared to those reported by Uchio (1960). The appearance and struc-

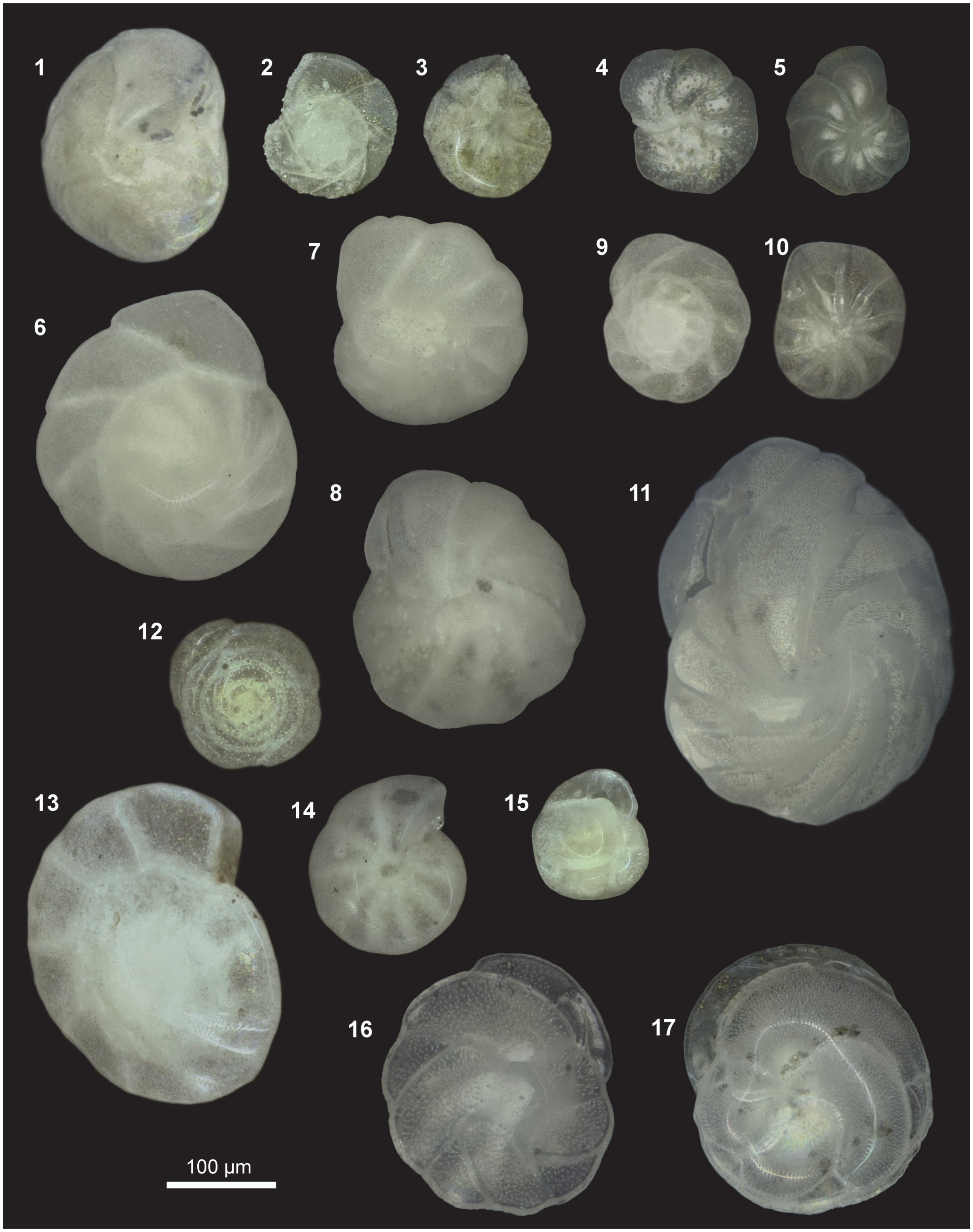

FIGURE 7. Optical microscope images; scale bar equals 100 µm. 1. *Epistominella pacifica* umbilical view 47-2; 128 cm, 2. *Epistominella exigua* spiral view 52-2; 450 cm, 3. *Epistominella exigua* umbilical view 52-2; 450 cm, 4. *Anomalinoides minimus* spiral view 59-1; 523 cm, 5. *Anomalinoides minimus* umbilical view 59-1; 523 cm, 6. *Epistominella obesa* spiral view 50-4; 100 cm, 7. *Epistominella obesa* spiral view 50-4; 100 cm, 8. *Epistominella obesa* umbilical view 50-4; 100 cm, 9. cf. *Buccella peruviana* spiral view 50-4; 230 cm, 10. cf. *Buccella peruviana* umbilical view 47-2; 113 cm, 11. *Cassidulina auka* 416; 100 cm, 12. *Alabaminella weddellensis* spiral view 52-2; 270 cm, 13. *Gyroidina subtenera* spiral view 52-2; 270 cm, 14. *Gyroidina subtenera* umbilical view 52-2; 230 cm, 15. *Cassidulina minuta* 52-2; 120 cm, 16. *Cassidulina carinata* 50-4; 210 cm, 17. *Cassidulina delicata* 47-2; 128 cm.

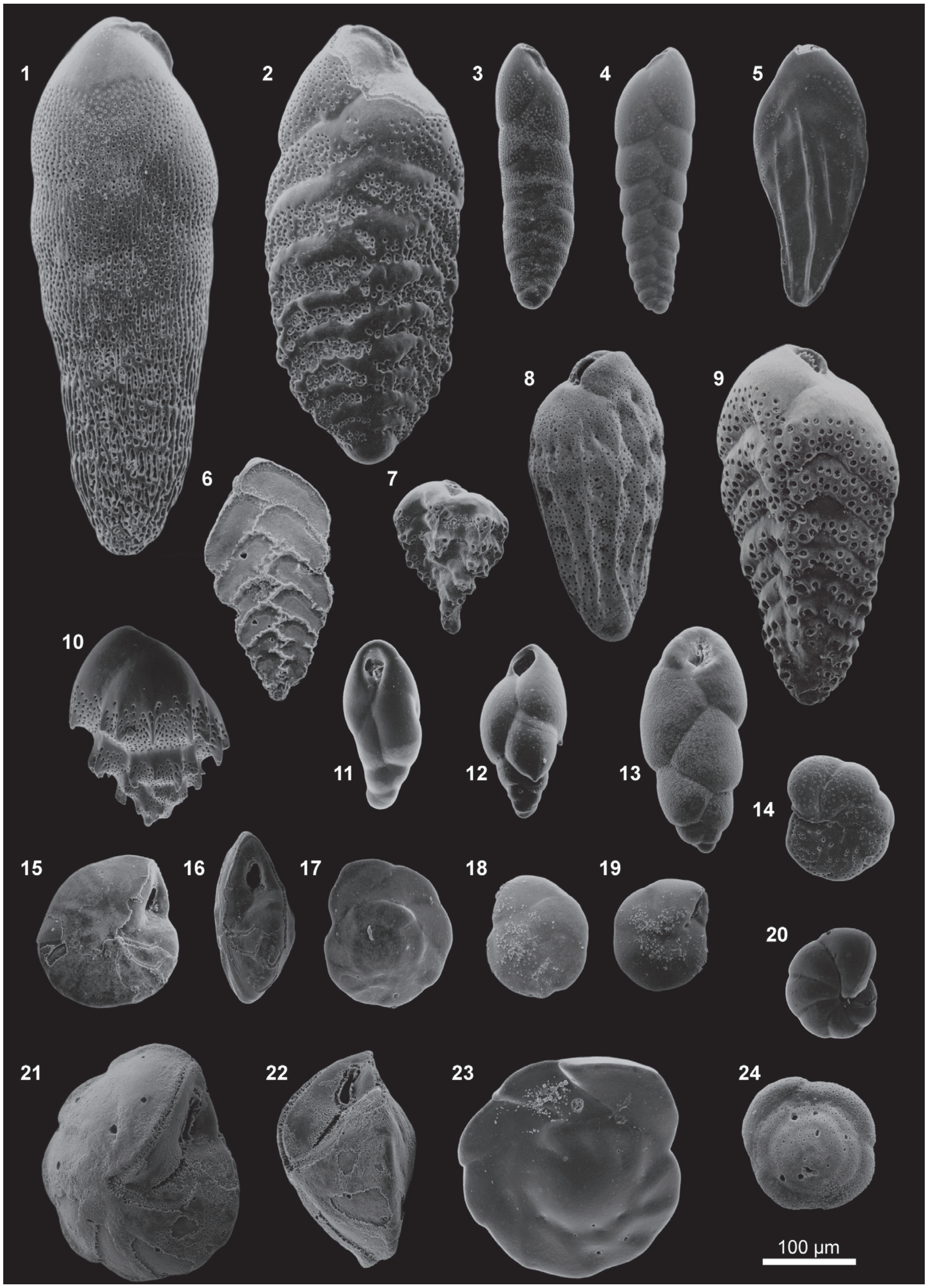

FIGURE 8. SEM images; scale bar equals 100 µm. 1. *Bolivina seminuda* 416; 200 cm, 2. *Bolivina* cf. *seminuda* var. *humilis* 416; 200 cm, 3. *Bolivina seminuda* var. *humilis* 47-2; 113 cm, 4. *Bolivina pacifica* 52-2; 270 cm, 5. *Bolivina interjuncta* var. *bicostata* 52-2; 520 cm, 6. *Bolivinita minuta* 52-2; 270 cm, 7. *Bolivina* aff. *tortuosa* 59-1; 523 cm, 8. *Bolivina costata* 52-2; 270 cm, 9. *Bolivina ordinaria* 47-2; 128 cm, 10. *Bulimina pagoda* 52-2; 520 cm, 11. *Fursenkoina fusiformis* 50-4; 230 cm, 12. *Virgulina spinosa* 59-1; 963 cm, 13. *Fursenkoina glabra* 50-4; 230 cm, 14. *Anomalinoides minimus* spiral view 59-1; 523 cm, 15. cf. *Buccella peruviana* umbilical view 47-2; 113 cm, 16. cf. *Buccella peruviana* peripheral view 47-2; 113 cm, 17. cf. *Buccella peruviana* spiral view 50-4; 230 cm, 18. *Epistominella exigua* spiral view 52-2; 450 cm, 19. *Epistominella exigua* umbilical view 52-2; 450 cm, 20. *Anomalinoides minimus* umbilical view 59-1; 523 cm, 21. *Epistominella afueraensis* umbilical view 416; 200 cm, 22. *Epistominella afueraensis* peripheral view 416; 200 cm, 23. *Epistominella afueraensis* spiral view 416; 200 cm, 24. *Alabaminella weddellensis* spiral view 52-2; 270 cm.

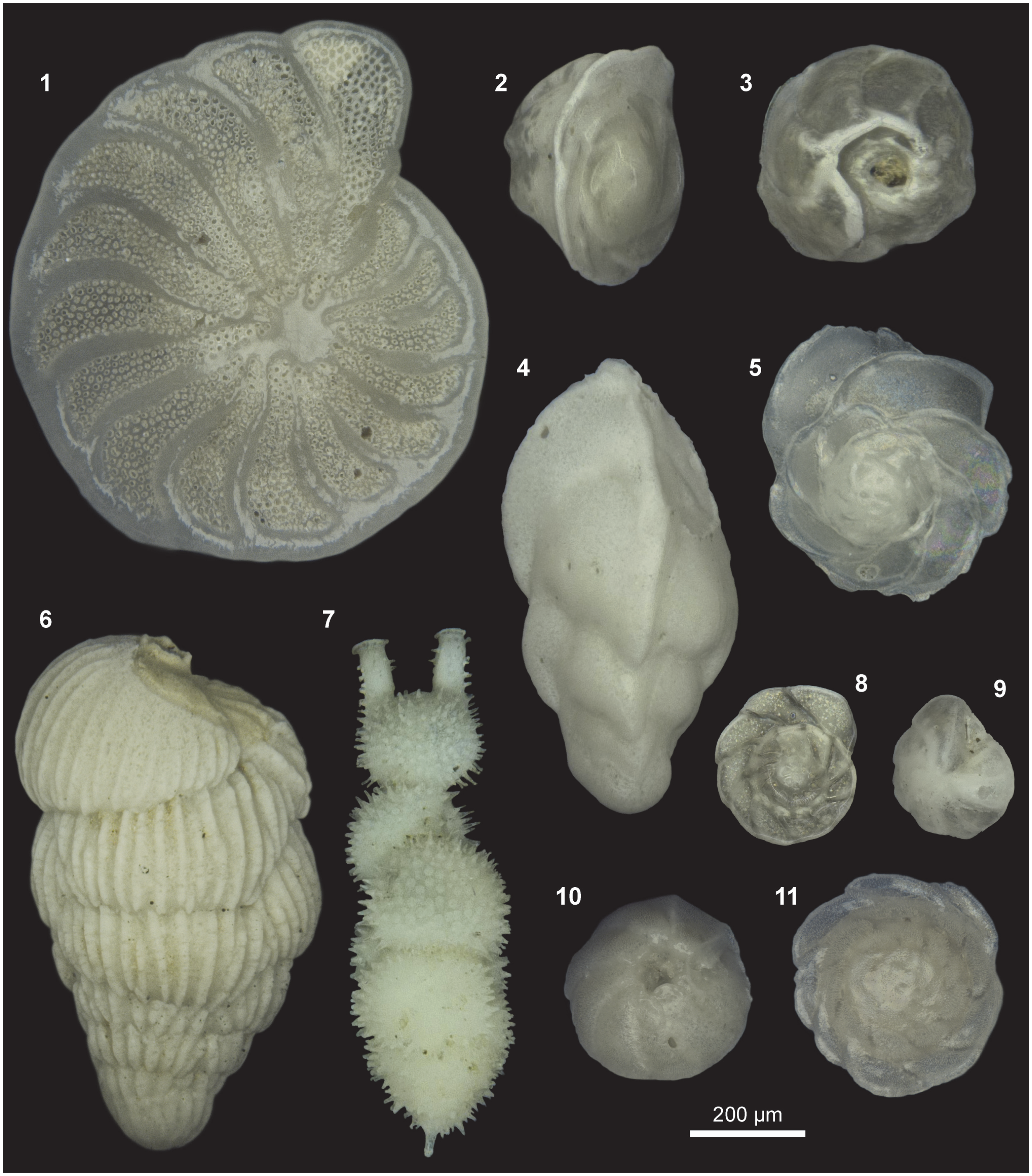

FIGURE 9. Optical microscope images; scale bar equals 200 µm. 1. *Planulina limbata* umbilical view 416; 100 cm, 2. *Epistominella pacifica* 416; 200 cm, 3. *Epistominella pacifica* umbilical view 416; 200 cm, 4. *Angulogerina angulosa* 50-4; 100 cm, 5. *Epistominella smithi* spiral view 50-4; 210 cm, 6. *Uvigerina striata* 416; 200 cm, 7. *Uvigerina hispida* 52-2; 120 cm, 8. *Epistominella afueraensis* spiral view 416; 200 cm, 9. *Epistominella afueraensis* umbilical view 416; 200 cm, 10. *Gyroidina rothwelli* umbilical view 416; 100 cm, 11. *Gyroidina rothwelli* spiral view 416; 100 cm.

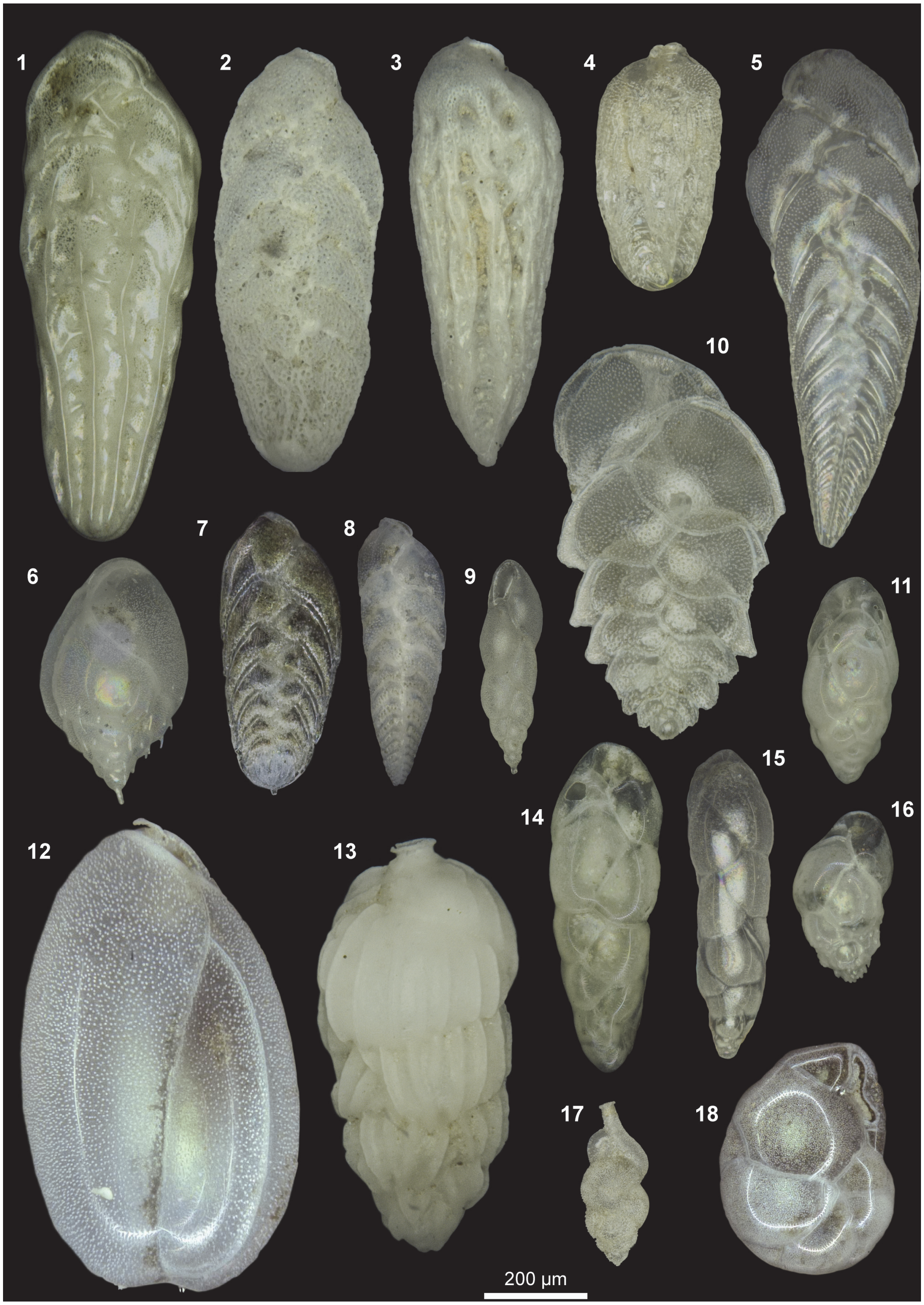

FIGURE 10. Optical microscope images; scale bar equals 200 µm. 1. *Bolivina interjuncta* 47-2; 168 cm, 2. *Bolivina subadvena* 47-2; 113 cm, 3. *Bolivina plicata* microspheric form 416; 200 cm, 4. *Bolivina plicata* macrospheric form 416; 100 cm, 5. *Bolivina argentea* 50-4; 350 cm, 6. *Praeglobobulimina spinescens* 47-2; 168 cm, 7. *Bolivina spissa* macrospheric form 52-2; 520 cm, 8. *Bolivina spissa* microspheric form 47-2; 128 cm, 9. *Stainforthia complanata* 50-4; 210 cm, 10. *Bolivina alata* 50-4; 110 cm, 11. *Buliminella tenuata* 50-4; 100 cm, 12. *Globobulimina pacifica* 52-2; 230 cm, 13. *Uvigerina peregrina* 416; 200 cm, 14 – 15. *Bulimina exilis* 50-4; 100 cm & 350 cm, 16. *Buliminella curta* var. *basispinata* 50-4; 350 cm, 17. *Uvigerina auberiana* 50-4; 350 cm, 18. *Cassidulina crassa* 52-2; 520 cm.

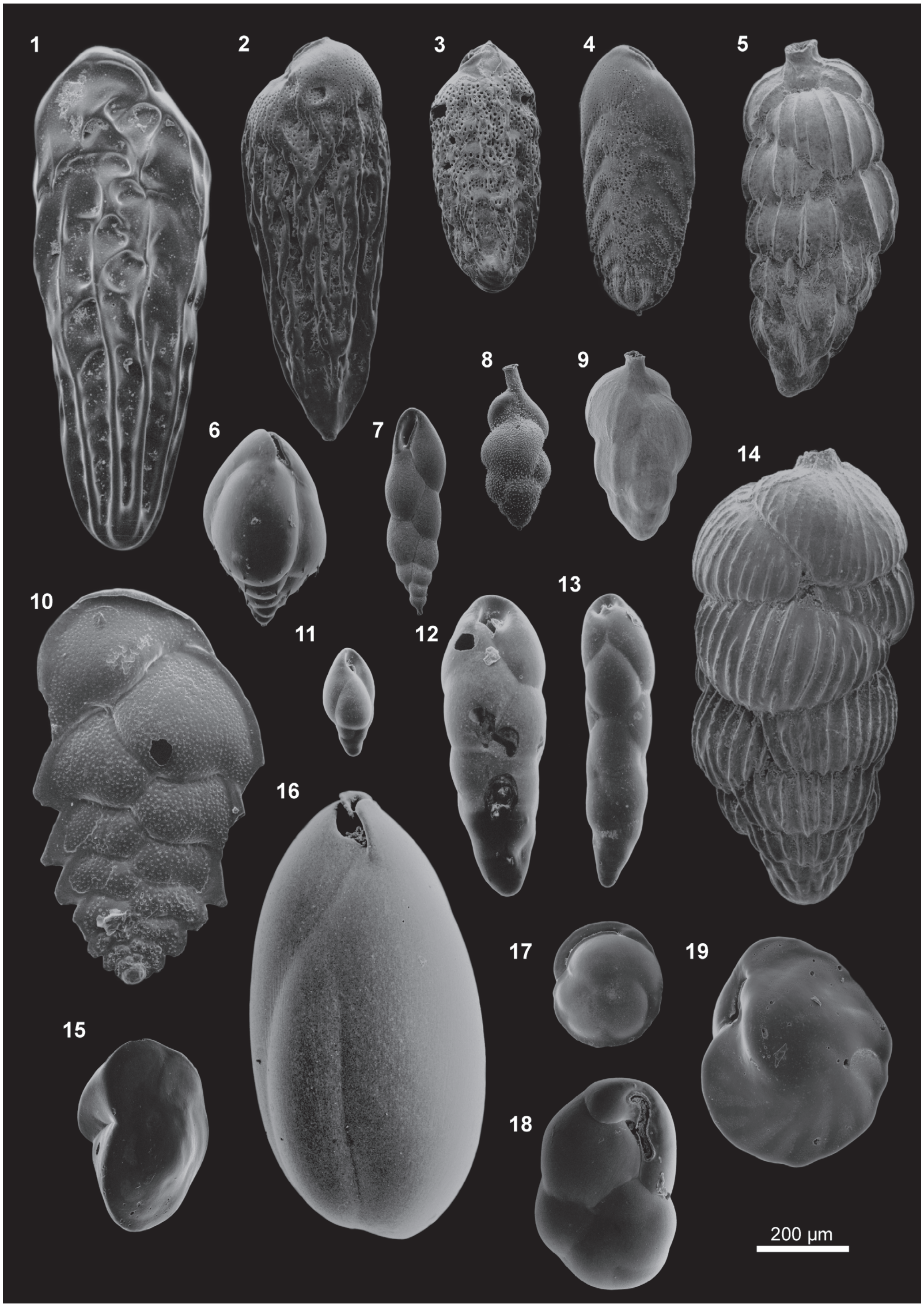

FIGURE 11. SEM images; scale bar equals 200 μm. 1. *Bolivina interjuncta* 47-2; 168 cm, 2. *Bolivina plicata* microspheric form 416; 200 cm, 3. *Bolivina plicata* macrospheric form 416; 100 cm, 4. *Bolivina spissa* 52-2; 520 cm, 5. *Uvigerina peregrina* 416; 200 cm (different specimen depicted in optical microscope and SEM image), 6. *Praeglobobulimina spinescens* 47-2; 168 cm, 7. *Stainforthia complanata* 50-4; 210 cm, 8. *Uvigerina auberiana* 50-4; 350 cm, 9. *Uvigerina semiornata* 52-2; 230 cm, 10. *Bolivina alata* 50-4; 110 cm, 11. *Buliminella* cf. *curta* 50-4; 100 cm, 12.-13 *Bulimina exilis* 50-4; 100 cm & 350 cm, 14. *Uvigerina striata* 416; 200 cm, 15. *Hoeglundina elegans* 52-2; 500 cm, 16. *Globobulimina pacifica* 52-2; 230 cm, 17. *Cassidulina delicata* 47-2; 128 cm, 18. *Cassidulina crassa* 52-2; 520 cm, 19. *Cassidulina auka* 416; 100 cm.

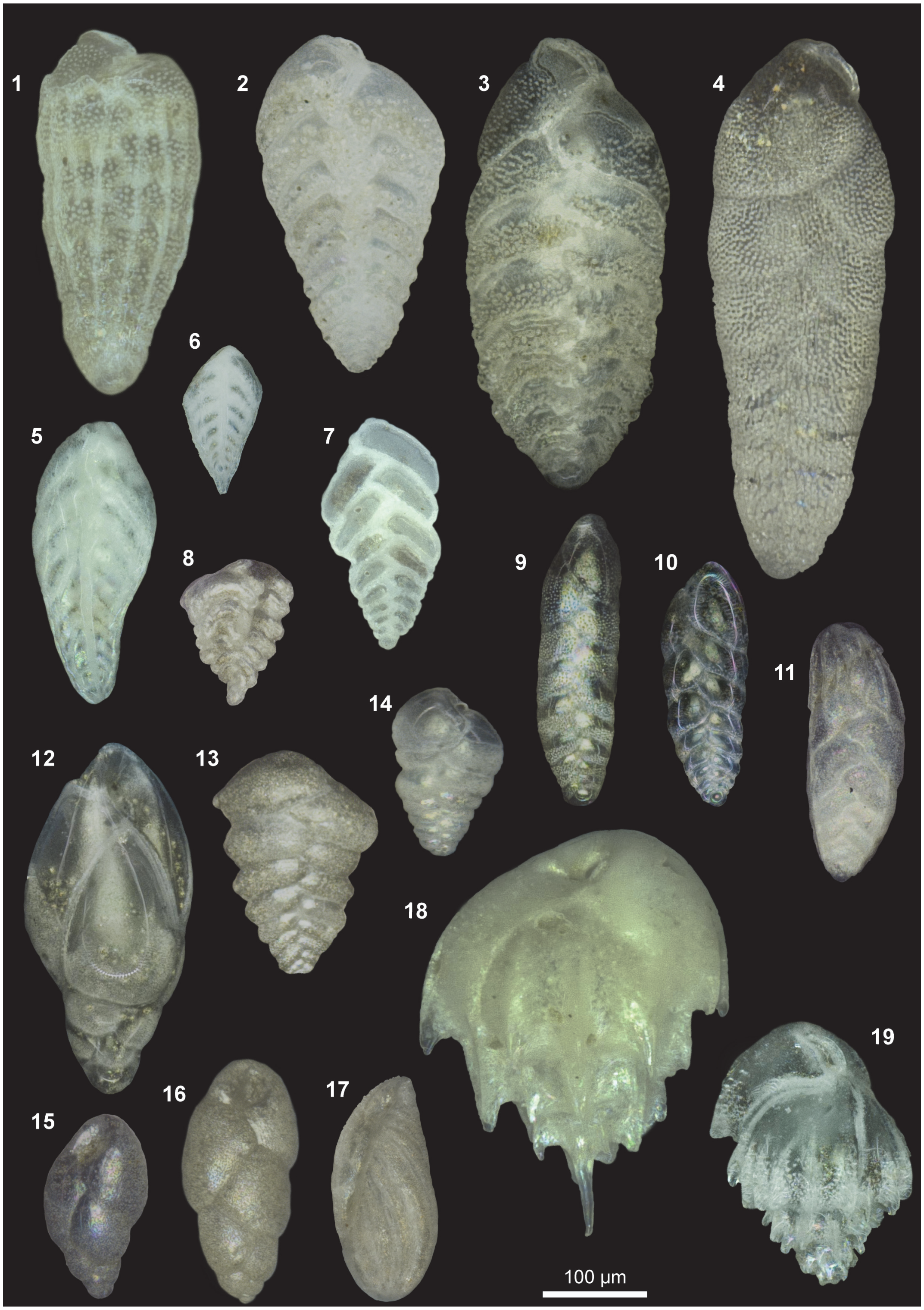

FIGURE 12. Optical microscope images; scale bar equals 100 µm. 1. *Bolivina costata* 52-2; 270 cm 2. *Bolivina ordinaria* 47-2; 128 cm, 3. *Bolivina* cf. *seminuda* var. *humilis* 416; 200 cm, 4. *Bolivina seminuda* 416; 200 cm, 5-6. *Bolivina interjuncta* var. *bicostata* 52-2; 520 cm and 450 cm, 7. *Bolivinita minuta* 52-2; 270 cm, 8. *Bolivina* aff. *tortuosa* 59-1; 523 cm, 9. *Bolivina seminuda* var. *humilis* 47-2; 113 cm, 10. *Bolivina pacifica* 52-2; 270 cm, 11. *Bolivina tongi* var. *filacostata* 59-1; 523 cm, 12. *Buliminella* cf. *curta* 50-4; 100 cm, 13. S*uggrunda eckisi* 50-4; 110 cm, 14. *Suggrunda porosa* 47-2; 128 cm, 15. *Fursenkoina fusiformis* 50-4; 230 cm, 16. *Fursenkoina glabra* 50-4; 230 cm, 17. *Buliminella elegantissima* 416; 180 cm, 18. *Bulimina mexicana* 52-2; 520 cm, *Bulimina pagoda* 52-2; 520 cm.

ture of the costae are the most similar to the *Bolivina interjuncta* Cushman var. *bicostata* Cushman. The costae are not easily recognised because of the small size but they are unquestionably visible at SEM images. [Figures 12.5-6, 8.5].

Bolivina minima Phleger and Parker, 1951.

Bolivina ordinaria Phleger and Parker, 1952. [Figures 12.2, 8.9].

Bolivina pacifica = *Bolivina acerosa* Cushman var. *pacifica* Cushman and McCulloch, 1942. [Figures 7.10, 12.4].

Bolivina plicata d'Orbigny, 1839. [Figures 10.3-4, 11.2-3].

Bolivina quadrata Cushman and McCulloch, 1942.

Bolivina semicostata Cushman, 1911.

Bolivina seminuda Cushman, 1911. [Figures 12.4, 8.1].

Bolivina seminuda Cushman var. *humilis* Cushman and McCulloch, 1942.

Note: *Bolivina seminuda* Cushman var. *humilis* showed huge variations in the samples similar to those provided as type figures. [Figures 12.9, 8.3].

Bolivina cf. *seminuda* Cushman var. *humilis*

Note: This species is similar to the type specimen figured in Cushman and McCulloch (1942, pl. 26, fig. 1a) and it has projections and acute periphery in early chambers similar to *Bolivina minima* but it is not as flat and compressed as *B. minima*. Considering overall appearance, inflated later chambers, structure of the aperture, and the appearance of the pores, it is considered as a variation of *B. seminuda* var. *humilis* and could be merged into this group. [Figures 12.3, 8.2].

Bolivina serrata = *Bolivina subadvena* Cushman var. *serrata* Natland, 1938.

Bolivina spissa = *Bolivina subadvaena* Cushman var. *spissa* Cushman 1926a. [Figures 10.7, 11.4].

Bolivina subadvena Cushman, 1926a. [Figure 10.2].

Bolivina subaenariensis Cushman, 1922.

Bolivina tongi Cushman var. *filacostata* Cushman and McCulloch, 1942. [Figure 12.11].

Bolivina tortuosa Brady, 1881 p. 57, illustrated by Brady, 1884.

Bolivina aff. *tortuosa*

Note: The almost 90° twisted feature and coarse pores of this species are similar to *Bolivina tortuosa* though the specimens found in the sediment samples are really small in size, not exceeding 150 µm in length and they are compressed. [Figures 12.8, 8.7].

Bolivinita minuta = *Bolivina minuta* Natland, 1938 [Figures 12.7, 8.6].

cf. *Buccella peruviana* = *Rotalina peruviana* d'Orbigny, 1839.

Note: Except the appearance of the aperture, other features are similar to those described in the type reference. *Buccella plana* of McCulloch, 1977 exhibits similar features but the appearance of the aperture is different in the specimens of our samples. [Figures 7. 9-10, 8.15-17].

Bulimina denudata = *Bulimina pagoda* Cushman var. *denudata* Cushman and Parker, 1938.

Bulimina exilis = *Bulimina elegans* d'Orbigny var. *exilis* Brady, 1884.

Note: Most of the taxonomical studies from Eastern Pacific denominate this species as *Buliminella tenuata* Cushman or *Bulimina exilis* var. *tenuata* Cushman. The species name *Bulimina exilis* Brady 1884 is considered to have priority though. [Figures 10.14-15, 11.12-13].

Bulimina marginata d'Orbigny 1826.

Bulimina mexicana = *Bulimina inflata* Seguenza var. *mexicana* Cushman, 1922. [Figure 12.18].

Bulimina pagoda Cushman, 1927. [Figures 12.19, 8.10].

Bulimina rostrata Brady, 1884.

Bulimina striata d'Orbigny, 1826.

Buliminella curta Cushman, 1925. [Figures 12.12, 11.11].

Buliminella curta Cushman var. *basispinata* Stewart and Stewart, 1930. [Figure 10.16].

Buliminella elegantissima = *Bulimina elegantissima* d'Orbigny, 1839 [Figure 12.17].

Buliminella tenuata = *Buliminella subfusiformis* var. *tenuata* Cushman, 1927

Note: Not *Bulimina tenuata* Cushman. In our samples, this species is small in size and has an aperture with tooth. [Figure 10.11].

Cancris auriculus = *Nautilus auricula* Fichtel and Moll, 1798.

Cancris carmenensis Natland, 1950.

Cancris inflatus = *Valvulina inflata* d'Orbigny, 1839.

Cassidulina auka Boltovskoy and Theyer, 1970 [Figures 7.11, 11.19].

Cassidulina carinata = *Cassidulina laevigata* d'Orbigny var. *carinata* Silvestri, 1896 [Figures 7.16, 13.15].

Cassidulina corbyi Cushman and Hughes, 1925.

Cassidulina crassa d'Orbigny, 1839 [Figures 10.18, 11.18]

Cassidulina delicata Cushman, 1927

Note: We followed the suggestion of Uchio (1960) and included *Cassidulina cushmani* Stewart and Stewart, 1930 into the range of variability of this species. [Figures 7.17, 11.17].

Cassidulina depressa Asano and Nakamura, 1937.

Cassidulina laevigata d'Orbigny, 1826.

Cassidulina minuta Cushman, 1933. [Figure 7.15].

Cassidulina pulchella d'Orbigny, 1839.

Chilostomella ovoidea Reuss, 1850.

Cibicides aknerianus = *Rotalina akneriana* d'Orbigny, 1846.

Cibicides elmaensis Rau, 1948.

Cibicides floridanus = *Truncatulina floridana* Cushman, 1918.

Cibicides mckannai Galloway and Wissler, 1927 [Figure 13.2].

Cibicides spiralis Natland, 1938.

Cibicidoides dispars = *Truncatulina dispars* d'Orbigny, 1839.

Cibicidoides mundulus = *Truncatulina mundula* Brady, Parker, and Jones, 1888.

Cibicidoides wuellerstorfi = *Anomalina wuellerstorfi* Schwager, 1866 [Figure 13.1].

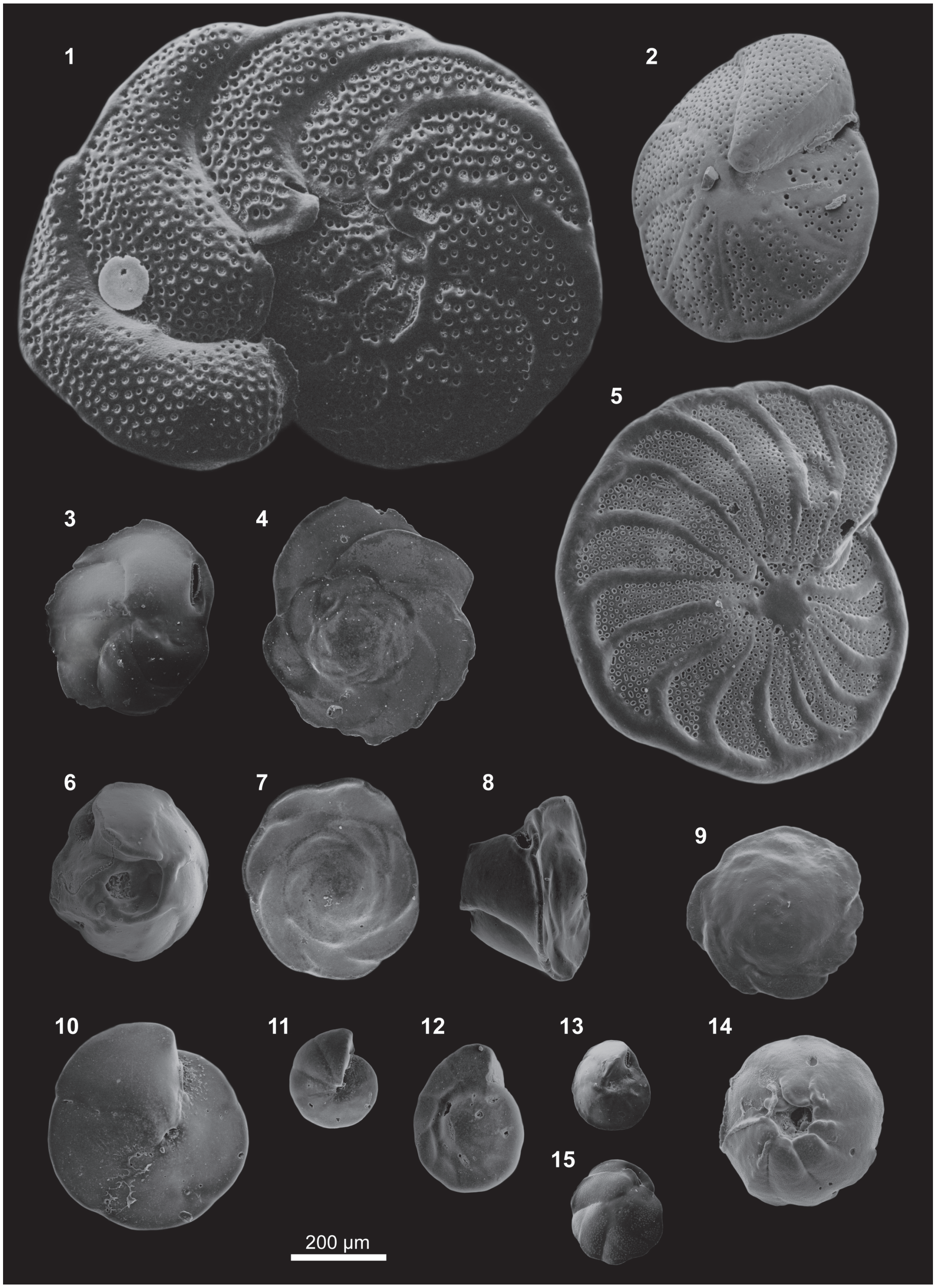

FIGURE 13. SEM images; scale bar equals 200 µm. 1. *Cibicidoides wuellerstorfi* spiral view 52-2; 500 cm, 2. *Cibicides mckannai* umbilical view 52-2; 230 cm, 3. *Epistominella smithi* umbilical view 50-4; 210 cm, 4. *Epistominella smithi* spiral view 50-4; 210 cm, 5. *Planulina limbata* umbilical view 416; 100 cm, 6. *Epistominella pacifica* umbilical view 416; 200 cm, 7. *Epistominella pacifica* spiral view 416; 200 cm, 8. *Epistominella pacifica* peripheral view 416; 200 cm, 9. *Gyroidina rothwelli* spiral view 416; 100 cm, 10. *Oridorsalis umbonatus* umbilical view 52-2; 230 cm, 11. *Gyroidina subtenera* umbilical view 52-2; 230 cm, 12. *Gyroidina subtenera* spiral view 52-2; 270 cm, 13. *Epistominella pacifica* umbilical view 47-2; 128 cm, 14. *Gyroidina rothwelli* umbilical view 416; 100 cm, 15. *Cassidulina carinata* 50-4; 210 cm.

Dentalina advena = *Nodosaria advena* Cushman, 1923.
Discorbis micens Cushman, 1933.
Discorbis peruvianus = *Rosalina peruviana* d'Orbigny, 1839.
Dorothia goesii = *Textularia goesii* Cushman, 1911.
Ehrenbergina pupa = *Cassidulina pupa* d'Orbigny, 1839.
Epistominella afueraensis McCulloch, 1977.

Note: The acute periphery and keeled appearance of chambers discriminates this species from *Epistominella obesa*. [Figures 9.8-9, 8.21-23].

Epistominella exigua = *Pulvinulina exigua* Brady, 1884. [Figures 7.2-3, 8.18-19].
Epistominella obesa Bandy and Arnal, 1957.

Note: Bandy and Arnal (1957) described this species as similar to *Pulvinulinella bradyana* Cushman, 1927 but with more inflated chambers. In the sediment samples, it is difficult to distinguish these two species. Based on the structure of the aperture they are treated here together as *Epistominella obesa.* [Figures 7.6-8].

Epistominella pacifica = *Pulvinulinella pacifica* Cushman, 1927.

Note: In our samples this species exhibited variations such as size, keel type, or transparency. Specimens of *Epistominella* sp. figured by Resig (1981) and Coulbourn (1980) are similar to those observed in the studied sediment samples and, therefore are considered to be in the range of intraspecific variability. [Figures 9.2-3, 7.1, 13.6-8, 13.13].

Epistominella smithi = *Pulvinulinella smithi* Stewart and Stewart, 1930. [Figures 9.5, 13.3-4].
Eponides pusillus Parr, 1950.
Fissurina alatifundata McCulloch, 1981.
Fissurina alveolata = *Lagena alveolata* Brady, 1884.
Fissurina annectens = *Lagena annectens* Burrows and Holland, 1895.

Note: Type reference given by Jones, 1895.

Fissurina exculpta = *Lagena exculpta* Brady, 1881, p. 61, illustrated by Brady, 1884.
Fissurina kerguelenensis Parr, 1950.
Fissurina laevigata Reuss, 1850.
Fissurina marginata = *Vermiculum marginatum* Montagu, 1803, illustrated by Walker and Boys, 1784.
Fissurina orbignyana Seguenza, 1862.
Fissurina semimarginata = *Lagena marginata* (Montagu) var. *semimarginata* Reuss, 1870.
Fursenkoina fusiformis = *Bulimina pupoides* d'Orbigny var. *fusiformis* Williamson, 1858 [Figures 12.15, 8.11].
Fursenkoina glabra = *Bulimina patagonica* d'Orbigny var. *glabra* Cushman and Wickenden, 1929 [Figures 12.16, 8.13].
Globobulimina affinis = *Bulimina affinis* d'Orbigny, 1839.
Globobulimina glabra Cushman and Parker, 1947.
Globobulimina hoeglundi Uchio, 1960.
Globobulimina ovula = *Bulimina ovula* d'Orbigny, 1839
Globobulimina pacifica Cushman, 1927 [Figures 10.12, 11.16].
Globocassidulina paratortuosa = *Cassidulina paratortuosa* Kuwano, 1954.
Globocassidulina subglobosa = *Cassidulina subglobosa* Brady, 1881.
Gyroidina altiformis = *Gyroidina soldanii* d'Orbigny var. *altiformis* Stewart and Stewart, 1930
Gyroidina gemma Bandy, 1953.
Gyroidina lamarckiana = *Rotalina lamarckiana* d'Orbigny, 1839.
Gyroidina neosoldanii Brotzen, 1936.
Gyroidina nitidula = *Rotalia nitidula* Schwager, 1866.
Gyroidina polia = *Eponides polius* Phleger and Parker, 1951.
Gyroidina quinqueloba Uchio, 1960.
Gyroidina rothwelli Natland, 1950. [Figures 9.10-11, 13.9, 13.14].
Gyroidina soldanii d'Orbigny, 1826.
Gyroidina subtenera = *Rotalia subtenera* Galloway and Wissler, 1927 [Figures 7.13-14, 13.11-12].
Hanzawaia bertheloti = *Rosalina bertheloti* d'Orbigny, 1839.
Hanzawaia mexicana Lankford, 1973.
Hoeglundina elegans= *Rotalia (Turbinuline) elegans* d'Orbigny, 1826 [Figure 11.15].
Lagena amphora Reuss, 1863.
Lagena distoma Parker and Jones, 1864.
Lagena elongata = *Miliola elongate* Ehrenberg, 1845.
Lagena gracillima = *Amphorina gracillima* Seguenza, 1862.
Lagena hispidula Cushman, 1923.
Lagena laevis = *Vermiculum laeve* Montagu, 1803.
Lagena lateralis Cushman, 1913a.
Lagena meridionalis = *Lagena gracilis* Williamson var. *meridionalis* Wiesner, 1931.
Lagena semistriata = *Lagena striata* (Montagu) var. *semistriata* Williamson, 1848.
Lagena squamosa = *Vermiculum squamosum* Montagu, 1803.
Lagena striata = *Oolina striata* d'Orbigny, 1839.
Lagena substriata Williamson, 1848.
Lagena sulcata = *Serpula (Lagena) sulcata* Walker and Jacob, 1798.
Lagena sulcata (Walker and Jacob) var. *pecularis* Cushman and McCulloch, 1950.
Lagena sulcata (Walker and Jacob) var. *striatopunctata* Parker and Jones, 1865.
Lagena williamsoni Harvey and Bailey, 1854.
Lagenosolenia inflatiperforata McCulloch, 1977.
Laticarinina pauperata = *Pulvinulina repanda* Fichtel and Moll var. *menardii* d'Orbigny subvar. *pauperata* Parker and Jones, 1865.
Lenticulina convergens = *Cristellaria convergens* Bornemann, 1855.
Lenticulina limbosa = *Cristellaria (Robulina) limbosa* Reuss, 1863.
Martinottiella communis = *Clavulina communis* d'Orbigny, 1846.
Martinottiella nodulosa = *Clavulina communis* d'Orbigny var. *nodulosa* Cushman, 1922.

Melonis affinis = *Nonionina affinis* Reuss, 1851.
Melonis barleeanum = *Nonionina barleeana* Williamson, 1858.
Melonis pompilioides = *Nautilus pompilioides* Fichtel and Moll, 1798.
Nonion commune = *Nonionina communis* d'Orbigny, 1846.
Nonion pizarrensis Berry var. *basispinata* Cushman and Moyer, 1930.
Nonionella cf. auricula Heron-Allen and Earland, 1930.
Nonionella auris = *Valvulina auris* d'Orbigny, 1839.
Nonionella iridea Heron-Allen and Earland, 1932.
Nonionella labradorica = *Nonionina labradorica* Dawson, 1860.
Nonionella miocenica Cushman, 1926b.
Nonionella stella = *Nonionella miocenica* Cushman var. *stella* Cushman and Moyer, 1930.
Nonionella turgida = *Rotalina turgida* Williamson, 1858.
Nonionoides grateloupii = *Nonionina grateloupii* d'Orbigny, 1826.
Oolina apiculata Reuss, 1851.
Oolina globosa = *Vermiculum globosum* Montagu, 1803
Oolina truncata = *Lagena truncata* Brady, 1884.
Oridorsalis umbonatus = *Rotalina umbonata* Reuss, 1851. [Figure 13.10].
Planulina limbata Natland, 1938. [Figures 9.1, 13.5].
Planulina ornata = *Truncatulina ornata* d'Orbigny, 1839.
Praeglobobulimina ovata = *Bulimina ovata* d'Orbigny, 1846.
Praeglobobulimina spinescens = *Bulimina pyrula* d'Orbigny var. *spinescens* Brady, 1884 [Figures 10.6, 11.6].
Pseudoparella subperuviana = *Pulvinulinella subperuviana* Cushman, 1926b.
Pseudoparella sp.

Note: Small juvenile specimens with large umbilicus. They potentially belong to *Pseudoparella* group but as indicated in the note for *Epistominella obesa,* the differences reported between these two species are difficult to discriminate in our samples.

Pullenia bulloides = *Nonionina bulloides* d'Orbigny, 1846.
Pullenia elegans Cushman and Todd, 1943.
Pullenia quinqueloba = *Nonionina quinqueloba* Reuss, 1851.
Pullenia subcarinata = *Nonionina subcarinata* d'Orbigny, 1839.
Pyrgo depressa = *Biloculina depressa* d'Orbigny, 1826.
Pyrgo lucernula = *Biloculina lucernula* Schwager, 1866.
Pyrgo murrhyna = *Biloculina murrhina* Schwager, 1866.
Pyrgo serrata = *Biloculina serrata* Bailey, 1861.
Quinqueloculina seminulum = *Serpula seminulum* Linné, 1758.
Quinqueloculina triangularis d'Orbigny, 1846.
Stainforthia complanata = *Virgulina schreibersiana* Czjzek var. *complanata* Egger, 1893. [Figures 10.9, 11.7].
Suggrunda eckisi Natland, 1950. [Figure 12.13].
Suggrunda porosa Hoffmeister and Berry, 1937. [Figure 12.14].
Uvigerina cf. *acuelata* d'Orbigny, 1846.
Uvigerina auberiana d'Orbigny, 1839. [Figure 10.17, 11.8].
Uvigerina bifurcata d'Orbigny, 1839.
Uvigerina canariensis d'Orbigny, 1839.
Uvigerina curticosta = *Uvigerina pigmea* d'Orbigny var. *curticosta* Cushman, 1927.
Uvigerina excellens Todd, 1948.
Uvigerina hispida Schwager, 1866.
Uvigerina peregrina Cushman, 1923. [Figures 10.13, 11.5].
Uvigerina semiornata d'Orbigny, 1846. [Figure 11.9].
Uvigerina senticosa Cushman, 1927
Uvigerina striata d'Orbigny, 1839. [Figures 9.6, 11.14].
Valvulineria araucana = *Rosalina araucana* d'Orbigny, 1839.
Valvulineria bradyana Fornasini, 1900.
Valvulineria californica Cushman, 1926b.
Valvulineria glabra = *Valvulineria vilardeboana* (d'Orbigny) var. *glabra* Cushman, 1927.
Valvulineria cf. *involuta* Cushman and Dusenburry, 1934.
Valvulineria minuta Parker, 1954.
Valvulineria cf. *olssoni* Redmond, 1953.
Valvulineria rugosa = *Rosalina rugosa* d'Orbigny, 1839.
Virgulina apertura Uchio, 1960.
Virgulina bradyi Cushman, 1922.
Virgulina bramlettei Galloway and Morrey, 1929.
Virgulina cornuta Cushman, 1913b.
Virgulina pauciloculata Brady, 1884.
Virgulina schreibersiana Czjzek, 1848.
Virgulina spinosa = *Virgulina schreibersiana* Czjzek var. *spinose* Heron-Allen and Earland, 1932. [Figure 12.12].

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APPENDIX.

Relative abundances calculated for each sample and core.
Part 1.

M77/2-59-1	**late Holocene**						**early Holocene**					**BA/ACR**					**Heinrich Stadial-1**			
Species / Age (cal yr BP)	**3024**	**3413**	**3801**	**4178**	**4531**	**4877**	**8098**	**8596**	**9095**	**9594**	**10093**	**13112**	**13504**	**13867**	**14230**	**14569**	**15080**	**15643**	**16330**	**17065**
Alabaminella weddellensis	4.85	5.96	5.45	4.50	5.77	4.17	3.03	4.35	2.64	3.10	2.67	0.00	0.00	0.38	0.00	0.00	0.44	0.00	0.00	0.00
Anomalinoides minimus	3.00	3.34	3.50	5.03	2.54	3.79	4.33	4.35	4.70	3.53	5.08	3.11	0.23	0.57	0.69	0.63	0.29	0.00	0.00	0.00
Bolivina interjuncta var. *bicostata*	0.57	0.73	0.00	0.53	0.46	0.19	0.43	1.16	1.17	1.21	1.60	6.99	3.97	4.39	3.45	2.83	5.84	4.05	4.84	3.93
Bolivina pacifica	0.00	0.00	0.39	0.00	0.23	0.19	0.43	0.00	0.15	0.52	0.40	0.78	2.10	4.77	5.86	5.03	1.61	2.02	3.96	5.36
Bolivina quadrata	0.14	0.00	0.00	0.00	0.00	0.00	0.87	0.87	1.03	1.03	1.60	4.50	3.50	6.87	1.38	2.83	1.75	0.00	3.96	3.39
Bolivinita minuta	21.83	21.80	29.57	22.49	20.09	13.64	12.12	16.81	16.74	19.83	20.32	18.94	9.11	5.92	2.76	0.63	10.80	3.85	1.32	0.36
Cassidulina carinata	2.71	3.78	5.06	6.08	8.31	5.11	5.19	8.70	6.75	6.21	6.42	5.28	5.37	7.63	0.00	1.89	4.38	7.29	8.79	4.82
Cassidulina delicata	9.70	11.92	11.28	12.17	9.93	12.88	13.42	8.41	11.89	12.33	8.16	2.80	7.01	3.63	4.14	3.77	7.74	15.59	7.69	10.00
Cassidulina minuta	8.27	4.22	0.00	1.59	4.85	2.27	0.00	4.06	1.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00
Epistominella afueraensis	0.00	0.00	1.56	0.00	0.00	4.36	1.30	5.80	2.94	1.47	1.07	2.95	1.87	0.19	0.00	0.63	0.00	0.00	0.66	0.00
Epistominella exigua	5.56	5.67	5.45	8.20	5.77	6.63	7.79	7.54	8.66	10.17	8.02	11.96	10.75	15.08	21.38	16.35	17.08	9.11	13.19	22.68
Epistominella obesa	2.57	3.05	1.56	3.70	5.08	0.95	0.00	0.00	0.00	1.81	0.94	0.78	3.74	2.10	4.48	3.14	2.77	3.24	1.76	1.61
Epistominella pacifica	0.71	1.45	0.39	0.00	0.00	0.00	0.00	0.00	1.17	0.95	2.67	0.00	2.57	6.30	5.52	0.00	2.19	2.02	1.76	0.89
Epistominella smithi	0.00	0.00	0.00	0.00	0.23	0.19	0.00	0.29	0.00	0.00	0.00	4.97	5.84	0.00	0.00	4.40	3.50	2.83	5.71	5.00
Gyroidina rothwelli	1.14	1.16	1.95	1.06	0.69	0.95	0.87	3.19	1.47	2.41	2.81	4.97	5.37	5.15	4.14	3.14	3.21	4.66	0.88	1.61
Uvigerina auberiana	6.56	7.27	5.06	6.35	6.24	7.77	6.93	5.51	6.31	5.26	5.08	3.26	3.27	2.10	1.03	1.26	0.00	0.00	0.00	0.00
Uvigerina semiornata	2.85	1.60	1.56	3.97	5.08	4.73	3.90	2.61	3.08	1.12	3.21	2.64	1.64	0.76	0.00	1.57	1.90	0.81	2.86	1.25
Virgulina spinosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.47	1.87	7.06	6.21	20.44	1.17	0.61	0.88	0.00
Miliolids	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.09	0.27	0.16	0.00	0.00	0.00	0.00	0.29	0.00	0.66	0.18
Other calcareous	29.24	28.05	27.24	24.34	24.48	32.20	39.39	26.38	29.96	28.88	29.68	25.47	31.78	27.10	38.97	31.45	34.60	43.93	41.10	38.93
Agglutinated	0.14	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total number specimens	701	688	257	378	433	528	231	345	681	1160	748	644	428	524	290	318	685	494	455	560
Total number species	57	71	40	48	51	56	45	50	67	70	63	52	51	54	43	49	56	49	52	53

Part 2A.

M77/2-52-2	late Holocene					early Holocene					
Species / Age (cal yr BP)	**3130**	**3845**	**4202**	**4559**	**4917**	**8097**	**8486**	**8839**	**9192**	**9546**	**9899**
Bolivina costata	27.12	33.88	25.50	33.81	23.13	42.46	22.96	20.85	18.98	23.13	17.32
Bolivina spissa	4.24	4.47	6.19	3.57	3.06	6.36	4.14	3.64	4.92	6.22	5.08
Bolivinita minuta	1.69	1.88	2.23	1.67	3.40	2.21	5.80	3.24	4.92	3.84	5.77
Bulimina pagoda	0.00	0.71	0.99	1.43	0.68	0.41	0.59	0.81	0.00	0.00	0.00
Cassidulina carinata	0.00	1.65	1.73	0.95	4.08	0.00	1.78	0.00	0.51	0.73	1.39
Cassidulina delicata	7.63	5.88	7.18	7.38	8.84	8.44	15.50	10.53	12.03	11.83	20.55
Cassidulina laevigata	0.85	0.00	0.00	0.48	0.00	0.28	0.00	0.81	0.00	0.00	0.00
Cibicides mckannai	0.42	3.29	2.72	2.38	1.02	4.43	1.54	3.64	4.24	3.22	2.54
Epistominella exigua	7.63	3.06	2.97	6.67	9.86	0.00	2.25	1.62	1.69	1.76	3.70
Epistominella pacifica	1.69	4.47	0.00	0.00	3.40	1.38	6.51	6.28	7.29	6.95	2.54
Epistominella smithi	3.39	4.24	7.43	6.67	3.06	2.35	0.00	0.00	0.00	0.93	2.77
Uvigerina auberiana	7.63	9.88	10.64	8.57	9.18	5.67	5.44	5.87	4.58	4.67	5.77
Uvigerina bifurcata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62	0.00
Uvigerina peregrina	0.00	0.94	0.00	0.00	0.00	0.00	1.18	1.21	1.19	0.83	0.00
Uvigerina semiornata	8.05	6.82	8.42	8.10	6.12	5.39	5.56	8.91	10.85	4.67	3.46
Miliolids	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.34	0.00	0.23
Other calcareous	28.39	16.94	21.78	16.19	22.11	19.92	25.80	31.78	27.80	30.08	28.41
Agglutinated species	1.27	1.88	2.23	2.14	2.04	0.55	0.95	0.81	0.68	0.52	0.46
Total number specimens	236	425	404	420	294	723	845	494	590	964	433
Total number species	45	48	50	41	48	53	62	67	60	77	46

Part 2B..

M77/2-52-2	**BA/ACR**					**Heinrich Stadial-1**						**Last Glacial Max**				
Species / Age (cal yr BP)	**12714**	**13177**	**13641**	**14143**	**14465**	**15147**	**15469**	**16151**	**16653**	**17155**	**17657**	**20168**	**20670**	**21172**	**21674**	**22176**
Bolivina costata	4.35	1.15	1.00	5.23	2.34	0.88	1.35	0.90	2.24	0.74	1.38	4.15	4.60	4.56	3.66	6.04
Bolivina spissa	4.35	3.93	2.99	3.35	2.05	4.84	2.12	4.30	2.52	1.98	2.75	0.98	1.02	1.45	0.37	0.15
Bolivinita minuta	11.84	19.86	4.23	6.90	1.46	3.96	1.54	4.52	1.12	0.74	0.79	0.37	0.26	0.00	0.18	0.15
Bulimina pagoda	1.21	0.69	1.00	1.05	0.88	1.10	0.19	0.00	0.84	0.50	0.79	5.73	3.32	6.01	3.84	6.50
Cassidulina carinata	2.42	2.08	6.97	4.60	4.39	4.84	3.08	0.45	3.36	4.95	2.75	8.29	23.27	9.12	10.42	7.28
Cassidulina delicata	12.80	8.78	15.17	12.13	9.94	7.47	6.92	6.33	9.52	6.93	13.75	8.41	5.63	8.29	5.67	14.86
Cassidulina laevigata	0.00	0.00	0.25	0.00	0.00	0.00	0.38	1.36	0.00	0.00	2.36	0.98	0.00	3.11	6.95	14.09
Cibicides mckannai	4.59	6.70	6.72	3.56	1.46	3.30	1.15	2.26	1.12	0.99	1.96	1.95	0.26	1.66	0.18	1.24
Epistominella exigua	3.38	2.77	1.99	4.18	9.36	13.19	23.27	22.17	25.49	31.19	33.01	0.98	10.23	0.62	5.12	3.56
Epistominella pacifica	4.11	5.08	8.21	2.51	0.88	3.52	6.35	3.62	2.24	1.98	1.96	0.00	0.00	0.21	1.10	2.17
Epistominella smithi	6.28	8.08	1.74	8.58	11.40	6.81	4.62	3.85	4.48	6.44	1.77	10.12	5.88	4.97	4.02	2.32
Uvigerina auberiana	6.04	5.54	5.47	4.81	6.14	2.42	2.69	2.71	3.08	0.50	2.75	7.68	5.63	7.25	5.85	5.88
Uvigerina bifurcata	0.00	1.15	0.00	1.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.63	3.07	8.91	0.00	0.00
Uvigerina peregrina	0.00	0.92	0.00	1.26	0.88	0.66	0.58	2.04	0.28	0.00	0.00	2.32	4.09	5.60	10.05	5.73
Uvigerina semiornata	7.00	5.54	11.44	4.60	7.60	10.55	4.23	6.11	8.68	5.69	6.29	17.20	5.88	6.53	3.66	6.04
Miliolids	0.00	0.46	0.00	0.42	0.29	0.22	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.31	0.37	0.00
Other calcareous	30.92	25.87	32.84	35.15	40.35	35.82	40.96	38.69	34.17	37.38	26.92	26.10	26.85	31.40	38.57	23.84
Agglutinated species	0.72	1.39	0.00	0.42	0.58	0.44	0.58	0.45	0.84	0.00	0.79	0.12	0.00	0.00	0.00	0.15
Total number specimens	414	433	402	478	342	455	520	442	357	404	509	820	391	965	547	646
Total number species	60	50	53	69	67	59	63	50	51	45	50	76	50	75	73	70

Part 3.

M77/2-50-4	BA/ACR						Heinrich Stadial-1						Last Glacial Max							
Species / Age (cal yr BP)	**12873**	**13502**	**14131**	**14377**	**14622**	**14868**	**15359**	**15850**	**16341**	**16832**	**17215**	**17598**	**20095**	**20359**	**20623**	**20900**	**21178**	**21455**	**21733**	**22010**
Bolivina costata	39.30	28.85	43.63	44.31	32.44	25.06	30.97	26.58	12.08	5.85	11.38	6.52	17.22	7.60	11.18	9.43	9.13	8.30	10.14	10.71
Bolivina pacifica	0.00	0.00	0.00	0.00	0.00	0.76	0.00	0.21	0.67	0.00	5.33	4.67	0.37	0.58	0.63	2.20	0.48	0.53	0.62	0.74
Bolivina seminuda var. *humilis*	1.08	3.13	4.54	4.19	2.89	4.79	5.51	5.91	6.26	4.68	5.57	3.12	3.30	5.85	3.80	6.72	5.77	3.36	2.96	2.98
Bolivinita minuta	10.03	6.73	3.32	1.20	4.44	3.02	1.31	1.69	3.80	4.68	3.39	2.83	0.73	2.34	1.27	1.55	1.44	1.77	3.28	3.87
cf. *Buccella peruviana*	0.00	0.00	2.09	1.80	0.00	0.50	0.52	1.05	0.00	0.00	0.00	2.69	0.37	0.00	2.11	3.88	1.92	1.59	1.56	5.36
Buliminella tenuata	0.54	2.88	1.57	2.40	2.44	5.16	2.62	0.63	2.24	2.34	1.45	0.57	2.20	0.00	1.05	0.00	0.00	1.06	0.00	0.89
Cassidulina auka	0.00	0.00	0.00	0.00	0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.00	5.13	1.75	2.32	3.23	5.77	4.59	1.40	1.04
Cassidulina carinata	0.00	0.00	0.00	0.00	0.89	1.51	0.00	2.11	0.89	0.58	2.42	2.97	7.33	5.85	6.96	5.68	1.92	10.78	7.49	4.02
Cassidulina delicata	8.40	8.65	4.01	2.99	5.11	4.66	6.82	3.59	11.19	8.77	7.02	6.09	6.59	5.26	9.49	7.75	13.94	8.30	7.49	7.74
Epistominella afueraensis	7.05	1.20	2.09	2.40	0.00	6.30	0.79	1.48	4.25	4.09	2.91	1.42	2.20	1.17	0.63	1.03	1.44	2.47	0.16	0.45
Epistominella exigua	2.44	2.64	1.75	4.19	3.78	2.52	0.00	3.16	5.59	7.02	6.78	14.16	1.83	8.77	4.43	9.82	1.44	7.77	12.17	8.18
Epistominella obesa	0.00	1.92	3.14	6.59	6.44	6.17	7.35	6.96	18.34	7.02	12.11	8.50	12.45	14.62	10.13	10.59	10.58	8.13	2.50	9.08
Epistominella pacifica	0.27	7.21	5.76	6.59	4.89	2.77	1.57	4.64	2.91	1.17	1.21	0.85	3.30	0.00	0.00	0.13	0.00	1.24	0.47	0.00
Epistominella smithi	6.78	2.40	0.00	0.00	2.22	2.90	2.89	3.80	0.22	1.75	2.42	0.14	0.00	0.00	0.63	0.00	0.00	0.18	0.00	0.30
Fursenkoina fusiformis	0.81	1.92	0.87	1.20	2.44	2.02	2.10	1.05	1.12	1.17	5.08	3.97	0.00	0.00	0.21	0.78	0.48	0.71	0.16	0.30
Pseudoparella subperuviana	6.78	6.25	6.11	0.00	6.00	4.91	7.09	7.81	2.24	14.04	9.93	5.81	7.33	2.34	2.53	2.84	8.65	4.95	15.60	9.08
Pseudoparella sp.	0.54	2.64	4.36	0.00	5.11	1.13	4.99	4.64	8.28	7.02	0.00	7.37	0.73	17.54	5.70	1.03	4.33	4.95	4.21	9.52
Uvigerina semiornata	0.00	3.13	1.40	2.40	2.44	1.76	2.62	2.32	1.79	0.58	0.48	1.27	2.56	4.68	6.12	3.88	3.37	6.71	2.03	1.64
Virgulina cornuta	0.00	0.00	0.70	2.40	1.11	1.89	1.84	0.84	0.89	1.75	5.57	5.38	2.20	1.17	1.69	0.39	0.48	1.24	0.62	0.74
Miliolids	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.17	0.24	0.14	1.10	1.17	0.63	0.78	0.96	0.53	0.31	0.30
Other calcareous	15.99	20.43	14.66	17.37	17.33	21.41	21.00	21.52	17.23	26.32	16.71	21.39	22.71	19.30	28.48	28.16	27.88	20.85	26.83	22.92
Agglutinated species	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.37	0.00	0.00	0.13	0.00	0.00	0.00	0.15
Total number specimens	236	425	404	420	294	723	845	494	590	964	433	414	433	402	478	342	455	520	442	357
Total number species	45	48	50	41	48	53	62	67	60	77	46	60	50	53	69	67	59	63	50	51

Part 4.

M77/2-47-2	BA/ACR			Heinrich Stadial-1				Last Glacial Max				
Species / Age (cal yr BP)	**13282**	**13717**	**14692**	**15388**	**16085**	**16782**	**17478**	**19568**	**20265**	**20961**	**21658**	**22354**
Bolivina costata	19.71	15.90	25.24	23.28	24.87	19.92	22.61	21.39	13.92	26.03	25.76	30.50
Bolivina seminuda var. *humilis*	5.53	3.77	0.00	1.90	2.09	1.17	3.45	3.18	1.62	1.91	2.62	0.71
Bolivinita minuta	2.88	3.35	4.11	5.94	3.14	2.73	1.53	2.60	1.94	2.50	0.87	2.13
Buccella peruviana	4.81	8.37	4.50	3.80	2.88	4.69	1.92	4.62	3.88	5.00	3.49	4.61
Cassidulina delicata	7.21	11.30	13.50	15.44	13.87	10.94	12.26	7.80	6.15	11.32	11.79	7.09
Cassidulina minuta	3.13	0.00	4.11	0.00	2.62	3.13	5.36	8.96	2.91	2.21	6.11	0.00
Epistominella obesa	9.86	14.85	3.52	2.38	11.26	14.84	15.33	15.90	15.53	9.12	6.55	7.45
Pseudoparella subperuviana	8.65	11.51	9.98	13.54	7.85	8.20	7.28	3.18	13.59	10.74	4.37	3.90
Pseudoparella sp.	9.13	5.02	4.31	6.18	8.90	7.81	4.21	11.85	10.36	6.76	5.24	13.83
Miliolids (Quinqueloculina sp.)	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other calcareous	29.09	25.94	30.72	27.55	22.51	26.56	26.05	20.52	30.10	24.41	33.19	29.79
Agglutinated species	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total number specimens	416	478	511	421	382	256	261	346	309	680	229	282
Total number species	40	37	39	36	33	34	32	33	38	45	33	37

Part 5.

M77/1-416	Last Glacial Max						
Species / Age (cal yr BP)	**20176**	**20395**	**20505**	**20615**	**21073**	**21531**	**21983**
Bolivina plicata	0.90	0.39	0.93	2.99	5.19	5.59	3.44
Bolivina seminuda var. *humilis*	3.62	6.25	6.48	12.69	1.48	13.13	22.14
Buliminella elegantissima	0.00	0.78	21.30	0.75	20.74	0.28	0.00
Cassidulina auka	38.01	16.80	21.30	14.93	6.67	5.03	1.91
Epistominella afueraensis	0.90	27.34	0.00	9.70	0.00	6.70	9.54
Epistominella exigua	6.33	2.34	0.00	0.00	0.00	0.00	0.00
Epistominella obesa	0.00	0.00	1.85	0.00	8.89	0.84	5.73
Epistominella pacifica	9.95	12.11	9.26	10.45	0.74	33.52	12.98
Gyroidina rothwelli	13.12	10.94	2.78	14.93	1.48	2.23	7.63
Nonionella auris	0.00	0.78	9.26	0.00	14.81	0.00	0.00
Planulina limbata	7.24	2.34	3.70	2.24	0.74	1.40	3.44
Pseudoparella subperuviana	0.00	0.00	4.63	0.00	17.04	0.84	2.29
Uvigerina peregrina	0.00	1.95	0.00	1.49	0.00	5.59	5.73
Uvigerina striata	0.90	0.78	0.00	0.00	0.74	2.23	5.34
Miliolids (Quinqueloculina sp.)	0.45	0.00	0.00	0.00	0.00	0.00	0.00
Other calcareous	19.00	17.19	18.52	29.85	21.48	22.63	19.85
Agglutinated species	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total number specimens	221	256	108	134	135	358	262
Total number species	26	28	21	28	22	33	26