Modern Foraminiferal Assemblages of the Denmark Strait

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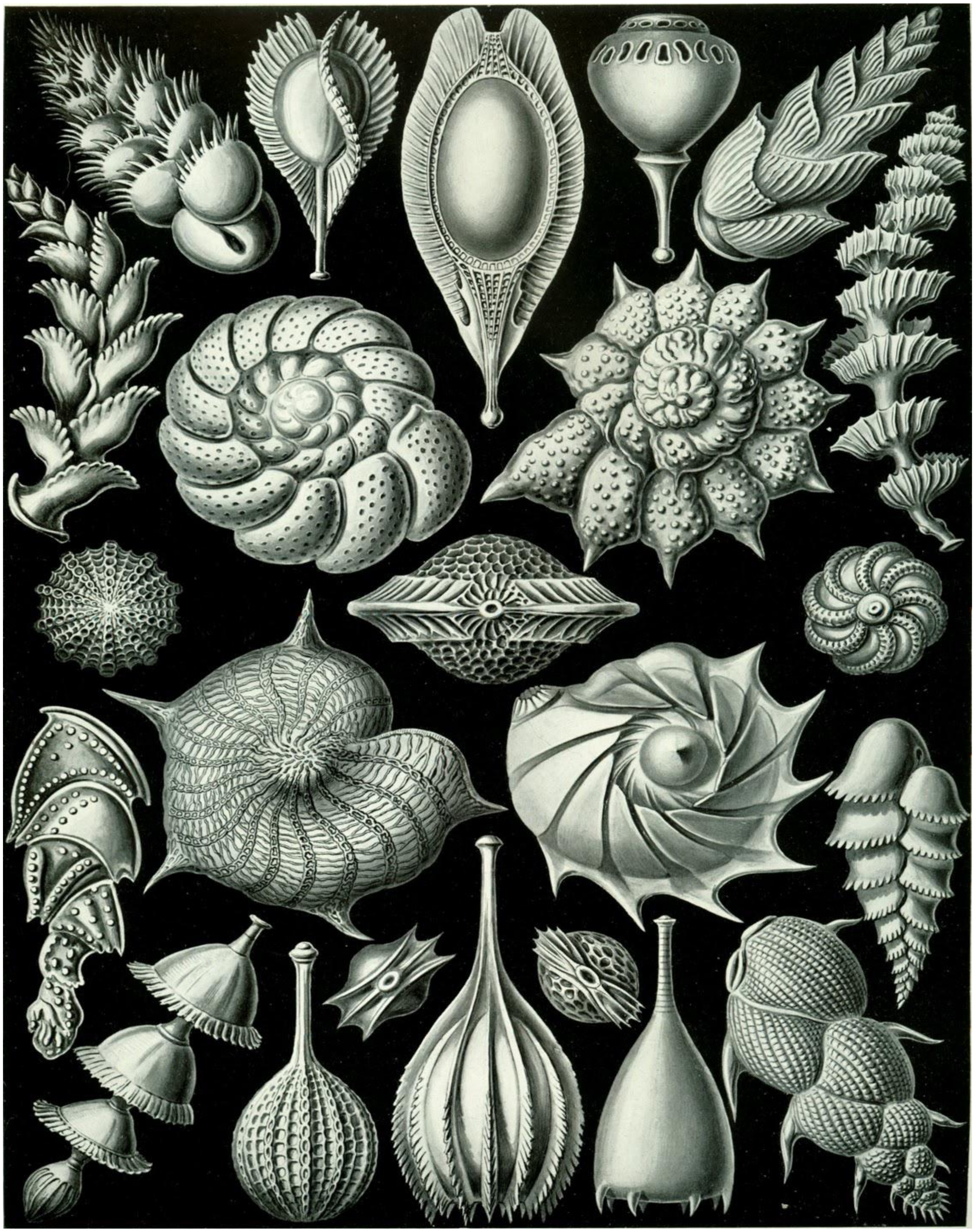

Contents

1. Abstract

Foraminifera occupy a geological range from the early Cambrian to the present day. Their well preserved shells, high relative abundance, and short response time to changing environmental conditions make foraminifera ideal proxies for environmental change. Benthic foraminifera are a valuable but poorly understood paleobiological proxy for the reconstruction of environmental conditions on continental shelves occupied by arctic and subarctic waters. This study identifies, examines, and quantifies calcareous benthic foraminiferal faunas from a sediment core taken from the Denmark Strait. Our analysis of three-thousand individuals from ten discrete samples aim to provide a better understanding of the modern patterns of foraminiferal distribution in the Denmark Strait, an important area in regulating climate. We find that the variability in foraminiferal taxa reflect changes in the environment, specifically current velocity, over the past (approximately) 600 years. The dominant genera, Cibicides, Elphidium, and Buccella, in the studied core have shown significant variability in abundance through time. The variability in these genera support a change from a warmer climate with stronger current velocities and meltwater influx (likely the Medieval Warm Period) to a cooler climate, with slower current velocities and less meltwater influx (most likely the Little Ice age), and finally a shift to our present day environment in which the climate in the region is warming due to anthropogenic impacts. Although more work needs to be done, it is clear that benthic foraminifera in the region respond to changing climate conditions and are valuable proxies for environmental change.

2. Objectives and introduction

2.1 General objectives

Our study aims to provide a better understanding of recent benthic foraminiferal assemblages in the subarctic — a region that plays a major role in the global climate system. Due to their well preserved shells, high abundance, and short response time to changing conditions, foraminifera make ideal indicators of environmental change (Alve et al., 2016; Loeblich and Tappan, 1988). More knowledge about the relationship between the responses of the benthic foraminiferal fauna to various environmental changes are needed in order to improve the application of subarctic benthic foraminifera as proxy indicators of modern and past environments. This study aims to:

i. identify and quantify 3,000 calcareous, benthic foraminifera from ten discrete samples from 0-9.5 cm of a sediment core from the Denmark Strait region.
ii. evaluate faunal abundance and variability as a tool in assessing climate fluctuations in the Denmark Strait region.
iii. improve upon our knowledge of the distribution of foraminifera in the subarctic in order to increase their value as proxy indicators for past and modern environmental change (as well as anthropogenic impacts).

Because Foraminifera occupy a large geological range, foraminifera shell chemistry is commonly used as a proxy for ocean temperature and other conditions in paleoclimate reconstructions. Benthic foraminifera are also useful indicators of ecological variability because their species composition, abundance, and distributional pattern mainly depend on environmental conditions (Lorenz, 2005). Due to their ecological sensitivity, taxa variability may be used as an indicator for distinct sediment facies or hydrographic conditions. Furthermore, foraminiferal assemblages are widely used as indicators of recent and ancient changes in water mass circulation and sea-water depth (Armstrong and Brasier, 2005). While several studies focus on the use or development of foraminifera as a bioindicator in areas of the Mediterranean, the Atlantic Coast, and southern Norway fjords, few studies focus on high latitude regions. Yet, the high latitude regions are extremely valuable in monitoring environmental change, and thus an ideal area to test the applicability of benthic foraminifera as tools in assessing environmental change.

2.2 Foraminifera

With an estimated 10,000 extant species, foraminifera represent the most diverse group of shelled microorganisms in modern oceans (Sen Gupta, 1999). Foraminifera, meaning 'hole bearers,' are amoeboid protists and classified as belonging to the kingdom Protozoa, to the phylum Sarcodina, to the class Rhizopoda, and to the order Foraminiferida (Armstrong and Brasier, 2005; Geslin, 2000). Foraminifera play an important role in ecosystem functioning and deep-sea carbon cycling, and are enormously diverse in terms of species and shell morphology (Gooday, 1992).

2.2.1 The cell

Living foraminifera are made up of a single cell, including an inner cell body, the endoplasm, and the outer layer, the ectoplasm (Figure 2.1). The endoplasm, protected by the shell (known as the test), contains a single or several nuclei, food vacuoles, and organelles such as mitochondria and ribosomes. The ectoplasm is composed of a mobile film of pseudopodia which are always changing (Armstrong and Brasier, 2005). Pseudopodia are used in feeding and locomotion.

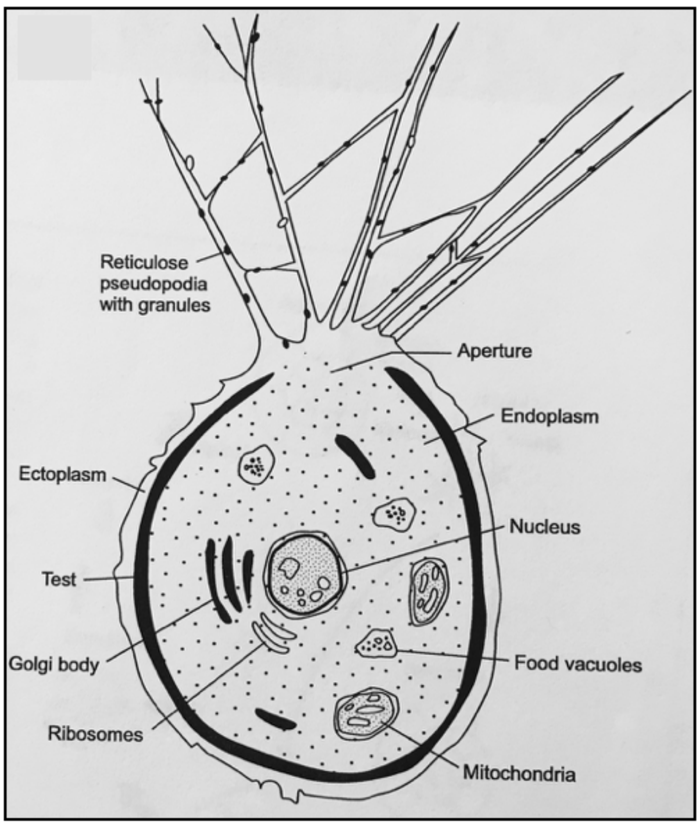

Fig. 2.1 A cross section of a living single chambered benthic foraminiferid (Armstrong and Brasier, 2005).

2.2.2 Life cycle

Few species life cycles have been studied. The individual lifespans of foraminifera vary greatly by a few weeks, up to about two years. However, their main period of growth and calcification is thought to occur primarily during the vegetation season, or times of higher food availability (Linke et al., 1995; Wollenburg and Mackensen, 1998; Bauch et al., 2004). Generally, foraminifera reproduce by an alternation between sexual (gamont generation) and asexual (agamont generation) reproduction (Armstrong and Brasier, 2005). The asexual generation begins by splitting the cytoplasm into haploid daughter cells, which contain a nucleus with half of the chromosomes found in the parent nucleus. The haploid daughter cells are released into the water column and chamber formation begins. Sexual reproduction begins with the formation of gametes, by dividing the cytoplasm mitotically. The gametes are then released into the water column where two gametes fuse to form the next agamont generation (Armstrong and Brasier, 2005).

2.2.3 Modes of life

The majority of foraminifera are benthic organisms, living on the sea floor. The remaining are planktonic and live within the water column. This study focuses on benthic genera. Benthic foraminifera may be categorized as epifaunal or infaunal. Epifaunal genera live on the surface of soft substrates such as the sea floor sediment, or hard substrate such as shells of other organisms, plants, or rocks (Murray 2006). Some epifaunal taxa may also be sessile, attached to the substrate by ways of organic glue. Sessile taxa may be either attached and mobile or attached and immobile. Alternatively, infaunal benthic foraminifera live within the sea floor sediment, the majority of which live within the top few centimeters and may be attached, free, or clinging (Murray 2006).

2.2.4 The test

The foraminiferal test is multi-purpose and serves to reduce stressors, to provide shelter, to aid in reproduction, to control buoyancy, and to assist in the growth of the cell (Murray, 2006). For example, test function may include protection from accidental ingestion by other organisms and infestation by parasites, protection from ultraviolet radiation, water turbulence, as well as salinity and toxin fluctuations (Armstrong and Brasier, 2005). Tests are generally constructed by chamber in incremental additions. The test is especially important in many classification methods and may be based upon the composition and structure, chamber shape and arrangement, aperture shape and position, surface ornamentation, as well as other morphological features (Loeblich and Tappan, 1988).

The three basic test wall compositions include organic, agglutinated, and secreted calcium carbonate (Schweizer et al., 2008). All foraminifera tests collected in this study are calcareous. Calcareous forms were chosen over agglutinated foraminifers due to the fact that the former easily disintegrate after death and thus result in variable and typically very low down core abundances of tests or test fragments (Brodniewicz, 1965; Polyak, 2002). Calcareous tests can be further divided into three main groups; microgranular, porcelaneous, and hyaline. Microgranular calcareous tests consist of tightly packed rounded grains of calcite and are confined to the Paleozoic (541 to 252.17 million years ago). Porcelaneous calcareous tests lack pores and consist of elongated high magnesium calcite crystals. The rod like crystals are randomly arranged in the interior wall and horizontally ordered on outer and inner test surfaces. Hyaline cal-

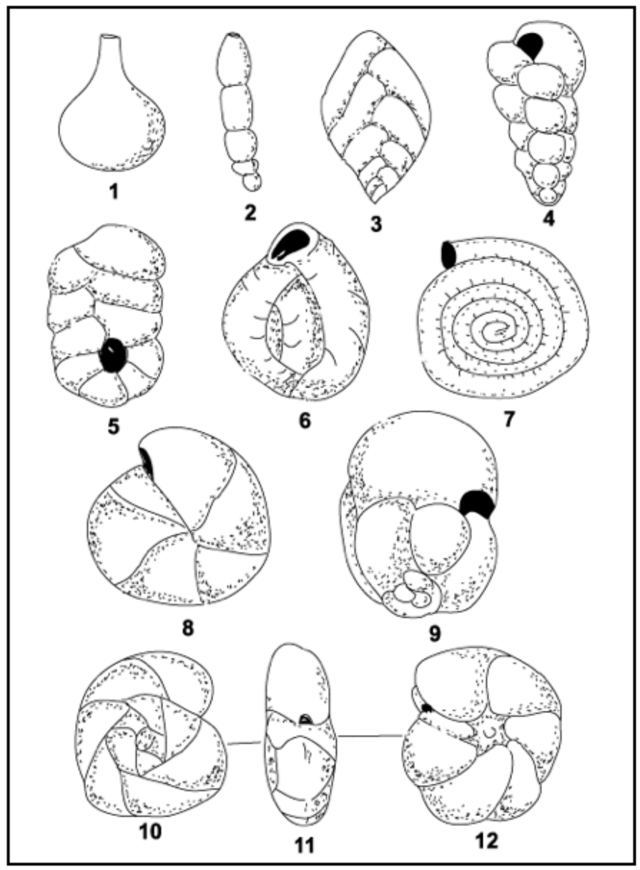

Fig. 2.2 Illustrates the common types of foraminiferal chamber arrangements. 1. unilocular, 2. uniserial, 3. biserial, 4. Triserial, 5. planispiral to biserial, 6. milioline, 7. planispiral evolute, 8. planispiral involute, 9.streptospiral, 10. trochospiral (dorsal view), 11. trochospiral (edge view), 12. trochospiral (ventral view) (Loeblich and Tappan, 1964; Ucl.ac.uk, 2016).

careous tests are perforate (with pores), appear glassy, and consist of interlocking calcium carbonate microcrystals (Hesemann, 2016). All foraminifera tests collected in this study have porcelaneous or hyaline calcium carbonate tests.

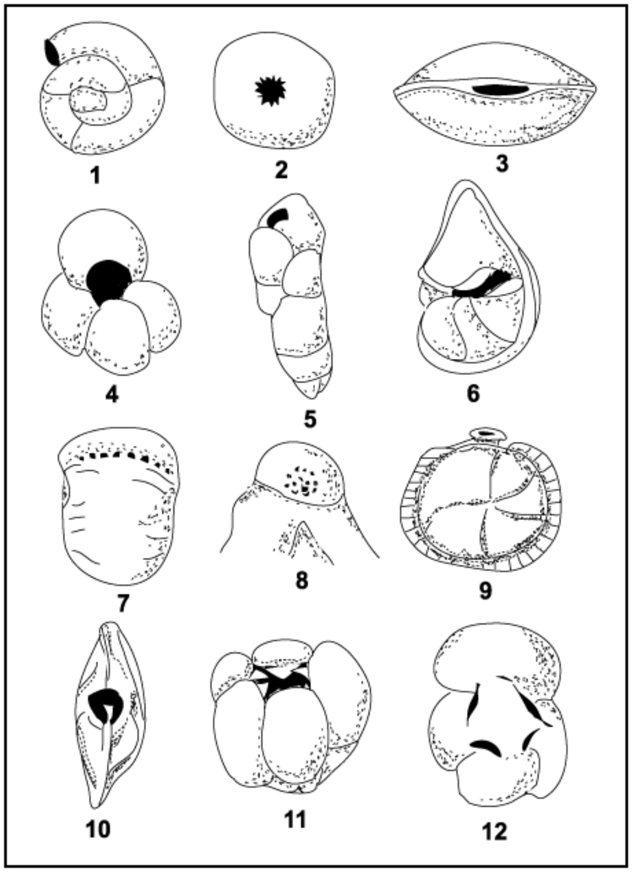

Fig. 2.3 Illustrates the common types of foraminiferal aperture types. 1. open end of tube, 2. terminal radiate, 3. terminal slit, 4. umbilical, 5. loop shaped, 6. interiomarginal, 7. interiomarginal multiple, 8. areal crbrate, 9. with phialine lip, 10. with bifid tooth, 11. with umbilical teeth, 12. with umbilical bulla (Loeblich and Tappan, 1964; Ucl.ac.uk, 2016).

Foraminifera may build tests with a single chamber (unilocular), or with multiple chambers (multilocular). The most common chamber arrangements are as follows and are illustrated in figure 2.2: (1) Unilocular, or consisting of a single chamber, (2) uniserial, consisting of chambers added in a single linear series, (3) biserial, consisting of chambers added in a double linear series, (4) triserial, consisting of chambers added in a triple linear series, (5) planispiral to biserial, where the mode of chamber addition changes during growth (6) milioline, consisting of tubular chambers, coiled like a broken spiral. (7) planispiral evolute, consisting of chambers added in a coil on a single plane (evolute refers to planispiral varieties where all chambers are visible), (8) planispiral involute, consisting of chambers added in a coil on a single plane (involute refers to planispiral varieties where only the chambers of the last coil are visible), (9) streptospiral, in which chambers are coiled in successively changing planes, and (10-12) trochospiral, consisting of chambers added in a three dimensional spiral (Loeblich and Tappan, 1964).

Additionally, foraminiferal test aperture shape and position is an important morphological feature in classification. The aperture is defined as the opening in the last chamber of the test. The function of the aperture is to connect the external pseudopodia with the internal endoplasm and acts as a passage for the cytoplasm, food, excretory outputs, and reproductive cells (Armstrong and Brasier, 2005). Foraminifera may have a single or multiple apertures which vary widely in shape and size. The most common aperture types are as follows and are illustrated in figure 2.3: (1) open end of tube, (2) terminal radiate, (3) terminal slit, (4) umbilical, (5) loop shaped, (6) interiomarginal, (7) interiomarginal multiple, (8) areal crbrate, (9) with phialine lip, (10) with bifid tooth, (11) with umbilical teeth, and (12) with umbilical bulla (Loeblich and Tappan, 1964).

2.2.5 Loeblich and Tappan classification scheme

In this work, the Loeblich and Tappan foraminiferal classification scheme is used for classification at the genera level. Loeblich and Tappan's classification scheme is primarily based on the composition and structure of the foraminiferid test wall and emphasizes features which are visible with an optical microscope. In order of significance, the scheme takes into account, (1) wall structure and composition, (2) chamber shape and arrangement, and (3) apertures and ornamentations (Armstrong and Brasier, 2005). The scheme identifies the following suborders; Allogromiina, Textulariina, Fusulinina, Involutina, Spirillinina, Carterinina, Miliolina, Silicoloculinina, Lagenina, Robertinina, Globigerinina, and Rotaliina. The genera identified in this study belong to four suborders; Miliolina, Lagenina, Robertinina, and Rotaliina, and hence is where the following descriptions will focus.

Suborder Miliolina: Foraminifera belonging to the suborder Miliolina have imperforate (lacking pores), calcareous tests. Miliolina tests are porcelaneous and milky white in appearance. The initial chamber (proloculus) is planispirally coiled. Following growth may continue in a planispiral fashion, in a uniserial fashion where the test may uncoil, or in a streptospiral fashion where the chambers are coiled in successively changing planes (like a ball of yarn) (Armstrong and Brasier, 2005; Loeblich and Tappan, 1988). Identified genera belonging to the suborder Miliolina include *Triloculina sp.* and *Quinqueloculina sp.*

Suborder Lagenina: Foraminifera belonging to the suborder Lagenina have perforate, monolamellar (wall with outer lamella only, lacking median layer and inner lamella) test walls composed of low magnesium calcite. Lagenina may be unilocular (consisting of a single chamber), uniserial, (consisting of chambers added in a single linear series), or multi chambered with serial or planispiral chamber arrangement. (Loeblich and Tappan, 1988; Sen Gupta, 1999). Identified genera belonging to the suborder Lagenina include *Fissurina sp.* and *Oolina sp.*

Suborder Robertinina: Foraminifera belonging to the suborder Robertinina have planispiral to trochospiral multi chambered tests, tests walls are hyaline, perforate, aragonite (orthorhombic crystal form of calcium carbonate) (Loeblich and Tappan, 1988; Sen Gupta, 1999). Identified genera belonging to the suborder Robertinina include *Hoeglundina sp.*

Suborder Rotaliina: Foraminifera belonging to the suborder Rotaliina have perforate, bilamellar (chamber wall formed primarily of two mineralized layers), calcareous test walls of low magnesium calcite. Tests are multilocular, and chamber arrangement is low or (rarely) high trochospiral, planispiral, or irregular (Loeblich and Tappan, 1988; Sen Gupta, 1999). Identified genera belonging to the suborder Rotaliina include *Bolivina sp., Buccella sp., Cassidulina sp., Cibicides sp., Elphidium sp., Haynesina sp., Melonis sp., Nonionellina sp., Pullenia sp.,* and *Trifarina sp.*

2.2.6 Foraminifera and environmental factors

Due to the fact that benthic foraminifera are characterized by fast turnover rates (short life cycle), large numbers, the ability to react quickly to environmental disturbances (Coccioni, 2000), as well as preference for specific environmental conditions (Boltovskoy et al., 1991), studies have shown that benthic foraminiferal assemblages may used as indicators of environmental change (Alve, 1995; Bouchet et al., 2012; Dolven et al., 2013). According to Murray (2001), benthic foraminiferal assemblages are controlled by environmental factors that have reached their critical thresholds. This theory, termed 'niche theory' states that for each species, in variable environments, different factors may limit distributions both temporally and spatially. The variability of many environmental factors including light, food, substrate, salinity, nutrients and oxygen, temperature, and water masses, control the composition of foraminiferal assemblages. Thus foraminifera may be used as indicators of specific environments or environmental change.

Light: The photic zone (zone of light penetration) is dependent upon water clarity and the sun's incident angle. Because of this, the photic zone generally decreases in depth toward high latitudes. Due to high primary production in photic zones as well as protection and the availability of substrates (sea grasses), these zones are very agreeable to foraminiferal life, especially to Miliolines such as Quinqueloculina. In addition, populations of epifaunal forms (living at the surface) who feed upon diatoms may fluctuate according to the seasonal cycle (Armstrong and Brasier, 2005).

Food availability: Foraminifera may feed on unicellular algae, diatoms, phytodetritus, bacteria, other protozoa, as well as small crustaceans such as copepods which are captured by pseudopodia (Armstrong and Brasier, 2005). In the Arctic region, Wollenburg and Mackensen (1998) found that the highest numbers of living foraminifera are associated with high productivity zones, which generally occur in areas that are seasonally ice-free, or ice-free year-round. Two of the main important food sources of benthic foraminifera, phytodetritus and bacteria are directly linked to primary production. In a study looking at benthic foraminiferal biodiversity response to a changing Arctic palaeoclimate over the past 24,000 years, Wollenburg (2007) found that species richness reflected the availability of food which depends mainly on the extent and duration of seasonal sea-ice retreat and formation. Furthermore, the 'energy-richness hypothesis' postulates that warmer, and in turn, more productive waters are more diverse (with more individuals and more species) (Currie, 1991; Wollenburg, 2007).

Substrate: Certain foraminifera prefer to live in areas where hard substrate such as rock, shell, or seagrasses are abundant. These forms usually attach themselves either temporarily or permanently to the substrate by means of a flat lower surface. One such genus that fits this mode of life is Cibicides sp. The majority of benthic forms are found on (epifaunal) or within (infaunal) the sediment down to a depth of 200 mm below the surface. Many infaunal foraminifera have elongated tests (Armstrong and Brasier, 2005).

Salinity: The highest diversity foraminiferal assemblages are usually found within water of normal salinity (35‰). Low salinity waters tend to favor agglutinated foraminifera and certain hyaline forms such as Elphidium's. Alternatively hyper saline waters favor porcelaneous forms such as Miliolina's (eg. Quinqueloculina sp.). Miliolina and hyaline forms have been shown to be useful indicators of paleosalinity (Armstrong and Brasier, 2005).

Nutrients and oxygen: In areas of low food supply (where rates of primary production are low), foraminiferal densities also tend to be lowered, however diversity may still be high in these areas. Conversely, very high rates of primary production may also yield low foraminiferal densities due to bacterial blooms, and anaerobic conditions. In these low-oxygen areas, eutrophic foraminiferal forms dominate (such as Bolivina sp.) or agglutinated forms (Armstrong and Brasier, 2005). However, temporal variability in food may result in reproductive responses and result in high abundances of opportunistic taxa (e.g. Duchemin et al., 2008; Fontanier et al., 2006; Gooday and Hughes, 2002).

Temperature: Each foraminiferal species is adapted to a specific temperature range in which successful reproduction can take place. In general temperature ranges are more narrow for low-latitude faunas than those faunas of high-latitudes (Armstrong and Brasier, 2005).

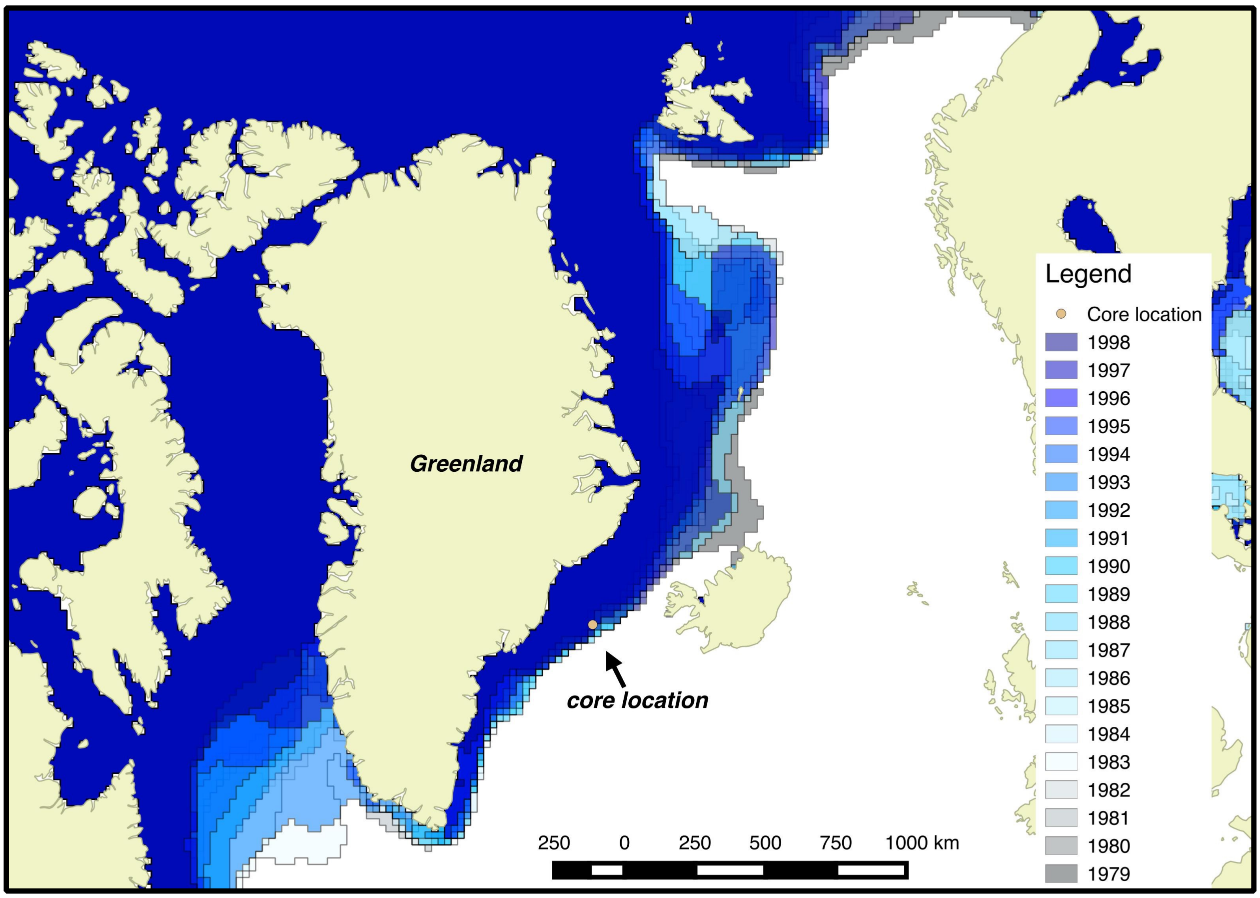

Fig. 2.4 Shows the modern maximum sea ice extent (month of March) from the beginning of the satellite record to the core extraction year (1979-1998) and the location of the studied sediment core. Data was obtained from the National Snow and Ice Data Center (NSIDC).

Water masses: It has been shown that certain benthic foraminiferal species correspond to specific water masses. Therefore, the distribution of such benthic forms can be used to reconstruct the history of a water mass in relation to climactic changes (Armstrong and Brasier, 2005).

Anthropogenic change: The response of benthic foraminifera to anthropogenic induced climate change (including a decrease in seasonal sea-ice extent, lengthening sea-ice free seasons, and increased freshwater influx due to melting glaciers) is not well understood. Benthic foraminifera are not considered to be direct proxies for sea-ice cover, however they may respond to the change in surplus of food often available at sea-ice edges (Seidenkrantz, 2013) (Note: the studied core is located on the modern seasonal sea ice edge, see figure 2.4). The composition of benthic foraminiferal faunas is widely known to be highly dependent on food supply. Therefore phytoplankton blooms observed in connection to sea-ice and especially the ice edge may have a major impact on benthic foraminiferal assemblages, with some species being especially sensitive to food supply.

3. Study area

3.1 The Denmark Strait

The area of focus of this thesis is the Denmark Strait (figure 3.1) In this study, sediment samples and accompanying benthic foraminifera from the core KN158-4-67 GC are analyzed. The Denmark Strait is a 480 km long body of water that separates Greenland and Iceland. This oceanic strait connects the Greenland Sea (an extension of the Arctic Ocean) to the Irminger Sea (part of the Atlantic Ocean).

The strait is characterized by a shallow sill with a maximum depth of 620 meters and represents the western portion of the Greenland-Scotland Ridge system (Lorenz, 2005). The Denmark Strait is very significant in global ocean circulation and the exchange of water masses, as it serves as a passageway for waters from the northern seas into the North Atlantic. Approximately 3 million cubic meters per second of dense water formed in the northern seas pass over the ridge between Greenland and Iceland and subsequently sink into the North Atlantic. This overflow of cold, dense water, termed the Denmark

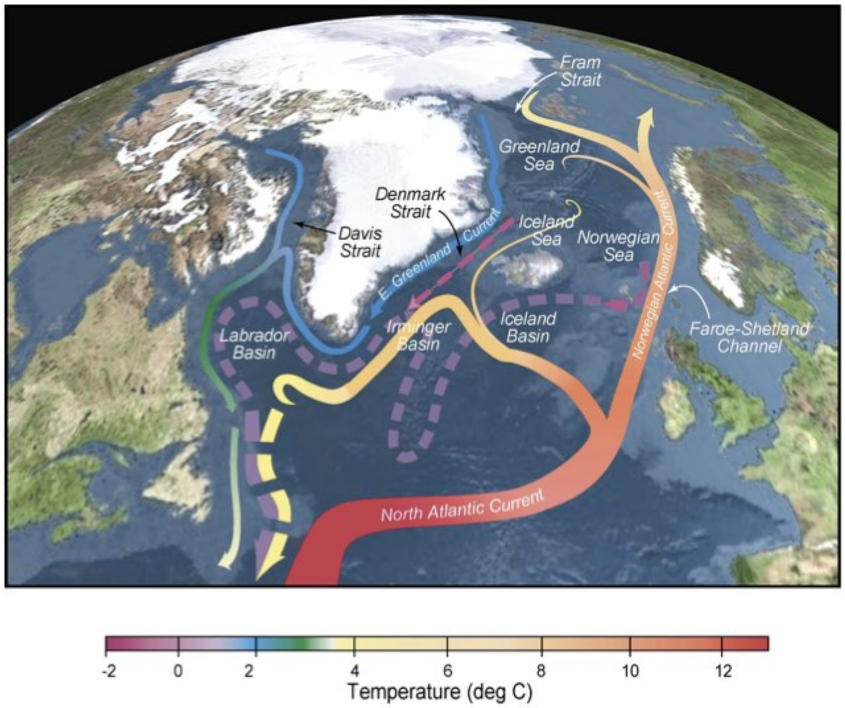

Fig. 3.2 Shows the location of the Denmark Strait and major current systems (Curry and Mauritian, 2005).

Strait Overflow (DSO), makes up a principal component and the densest fraction of the North Atlantic Deep Water (NADW), and hence is critical to Global Thermohaline Circulation (THC), or the 'Great Oceanic Conveyor Belt' (Hansen and Østerhus, 2000). The strength of the DSO depends mainly on the density gradient between water masses north and south of the Denmark Strait and the height of the dense water above the sill (Lorenz, 2005; Whitehead et al., 1974).

The Denmark Strait is characterized by three currents; the East Greenland Current (EGC), a cold, low-saline (<0 °C, <34 ‰), surface polar current which flows southward along the eastern coast of Greenland; the North Icelandic Irminger Current (NIIC), a surface, relatively warm, saline (6-10 °C, >35 ‰) northward flowing branch of the North Atlantic current (Swift, 1986); and the newly discovered North Icelandic Jet (Jonsson and Valdimarsson, 2004), a bottom cold and dense, narrow current which runs south-west through the strait at a depth of about 600 meters (Swift, 2005; Hansen and Østerhus, 2000; Våge et al., 2011) (figure 3.2). Currents north of the sill show velocities on average of about 0.10 m/s (Lorenz, 2005; Jonsson and Valdimarsson, 2004) and a mean velocity of 0.56 m/s south of the sill (but up to 1.30 m/s) (Girton and Stanford, 2003; Lorenz, 2005). The Denmark Strait Overflow is fed by the North Icelandic Jet and the

East Greenland Current (Våge et al., 2011). Because of its importance to the NADW and THC, as well as its close proximity to the Greenland Ice sheet (GIS), the Denmark Strait region is critical to Earth's climate system (Hansen et al., 2004) and can be regarded as a key region for assessing environmental and climate fluctuations (Lorenz, 2005). Dansgaard et al., 1993, describes the rapid climate oscillations of the last ice-age, seen in ice and sediment-core paleoclimate records as directly related to the 'shutoff' and 'resurgence' of deep water formation, of which a key component is the Denmark Strait Overflow. This 'shutoff' and 'resurgence' may be regulated by freshwater input to the high-latitude seas by the melt and discharge of water and ice from the Greenland Ice Sheet (GIS). In fact, a study by Rahmstorf et al., 2015 showed an exceptional slowdown in the last century of the Atlantic Meridional Overturning Circulation (AMOC), with melt from the Greenland Ice sheet as a possible contributor. Continued warming and continued slowdown of the THC triggers cooling in the North Atlantic, Europe, and North America (Vellinga and Wood, 2007). Many computer simulations have also demonstrated the impact of freshening polar and subpolar seas on deepwater formation and global climate (Dickson et al., 2002). The intensity of the DSO may also be influenced by the growth and shrinkage of land based ice-sheets of Greenland and Iceland due to isostatic uplift and rebound, sea level rise and lowering, as well as changes in bathymetry and the opening of the strait (Lorenz, 2005).

In the vicinity of our core location lies two of Greenland's major marine terminating glaciers, Kangerdlugssuaq glacier (just north of our core) and Helheim Glacier (just south of our core) (Nick et al., 2013). Present day estimates of ice discharge are 29 ± 2 km^3/yr for Kangerdlugssuaq Glacier, and 23 ± 1 km^3/yr for Helheim Glacier (Rignot et al., 2004). Therefore, it can be said that the study area is highly glacially influenced. Additionally, through high-resolution mapping of geomorphic features related to the maximum extent of the GIS during the Little Ice Age (at the end of the nineteenth century), Kjeldsen et al., 2015 estimated the total ice mass loss for the period: 1900–1983 to be 75.1 ± 29.4 gigatonnes per year. It is also important to note that this region is influenced by seasonal sea-ice coverage. Modern summer waters are sea-ice free where the minimum extent occurs in September (on average). Winter waters undergo sea-ice growth, the maximum extent occurring during the month of March (on average). During sea-ice free periods, primary production and thus benthic life increase on Arctic shelves in response to nutrients of riverine input and upwelling effects at the ice edge (Smith et al., 1987; Grebmeier et al., 1995; Wollenburg and Mackensen, 1998).

4. Materials and Methods

4.1 Sediment samples

Sediment core samples were received from Lamont Doherty Earth Observatory's Core Repository at Columbia University (see Figure A.1, appendix). Ten sediment samples were taken from core KN158-4-67 GC in discreet 1.0 cm intervals from 0.0 cm (core top) to 9.5 cm (downcore). Table A.1 (appendix) details preliminary data including the sample number and name, the given International GeoSample Number (ISGN), sample intervals (minimum and maximum depth in core), the parent core ISGN, the sample size, wet weight, and collection date. KN158-4-67 GC, a gravity core, was collected by the research vessel, Knorr, owned by the United States Navy and operated by the Woods Hole Oceanographic Institution (WHOI) on July 10th, 1998 at a depth of 447 meters. The core's location coordinates are latitude: 65.961, longitude: -30.331 (figure 4.1). The reported total core length is 72 cm and core diameter is 10 cm. The top 10 centimeters of core are described as a brown terrigenous clay consisting of abundant foraminifera.

4.2 Drying and sieving

In order to separate the foraminifera from the sediment, disaggregation and sieving techniques were used. Odd-numbered samples (sample # 1,3,5,7, and 9) were oven dried at 60 ℃ for 24 hours, disaggregated, and sieved with a warm water rinse. Sieving was

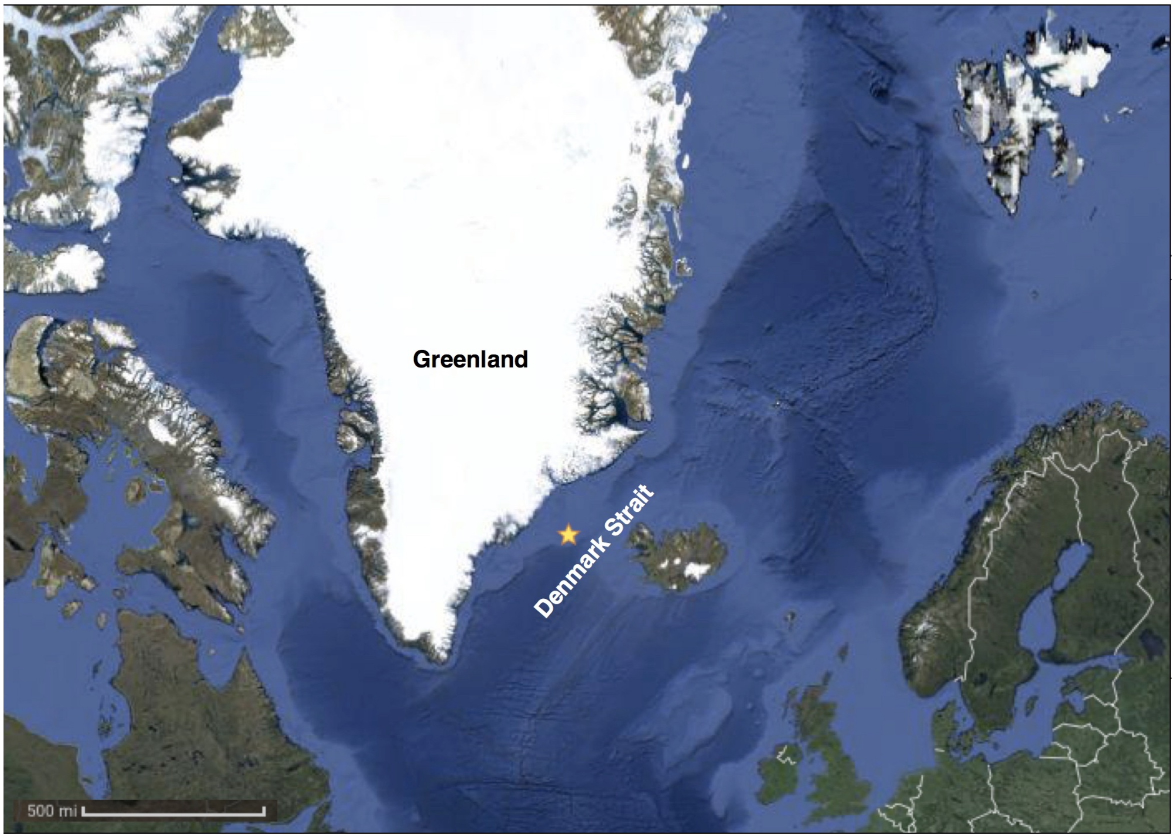

Fig. 4.1 Location of sediment core KN158-4-67 GC (yellow star). Coordinates, latitude: 65.961, longitude: -30.331(Google Earth).

performed at 63 μm (U. S. Standard Sieve No. 230) to begin, and finer remaining sediments were sieved at 125 micrometers (U. S. Standard Sieve No. 230). Even-numbered samples (sample # 2,4,6,8, and 10) were air-dried over a period of one week. The foraminifera were then manually extracted by lightly breaking up the sediment. In this study, counts are based on the > 63 μm size fraction. This size fraction was chosen in order to include smaller foraminiferal taxa. Although some studies of benthic foraminifera use the > 125 μm size fraction, it had been shown that analyses of this larger fraction under-represents smaller species, juveniles, and results in a lower diversity (Fontanier et al., 2006). Three hundred specimens from each discrete sample were collected.

5. Foraminifera collection and identification

Foraminifera specimens were collected, identified, imaged, and archived at the American Museum of Natural History's microfossil laboratory and imaging facilities. Each sample was sprinkled sparsely across a picking tray and examined under a binocular microscope. In order to determine the abundances of the genera in the assemblages, a minimum of three hundred specimens from each sediment sample (three thousand specimens in total) were counted using the wetted tip of an artist's brush, and identified down to genera level following the generic classification of Loeblich and Tappan (1988), which is most commonly used for the identification of calcareous taxa. Foraminifera specimens were then transferred to cardboard slides coated with a water-soluble glue for permanent reference. Slides were then assigned an AMNH number for permanent housing and select specimens were imaged using a Morrell microscope and Nikon's NIS imaging software.

5.1 Morphological descriptions of genera

Listed below are the morphological characteristics of each genus.

Bolivina: Test is elongate. Chambers are broad, and biserially arranged throughout. Walls are calcareous, perforate. Aperture is narrow and terminal (Loeblich and Tappan, 1988) (see Plate 9, appendix).

Buccella: Test is lenticular, trochospiral. Dorsal side with smooth surface, and with narrow, slightly curved sutures (curved back toward the periphery). Those on the umbilical side (ventral, under side) are radial and incised, and chambers are slightly inflated. Aperture is interio-marginal (basal opening at margin of final chamber, along final suture), midway between umbilicus and periphery, and may be covered by umbilical granules. Test composition is calcareous (Loeblich and Tappan, 1988). Oligocene to recent (see Plate 2, appendix).

Cassidulina: Test is lenticular, chambers are biserially arranged and planispirally enrolled. The wall is calcareous, hyaline, perforate. The surface is smooth with a polished appearance. Sutures are radial and curved. The aperture is a narrow curved or arched slit (Loeblich and Tappan 1988) (see Plate 6, appendix).

Cibicides: Test is plano-convex as it is commonly attached to a substrate. Spiral side is flat to concave, with depressed sutures. Chamber arrangement is trochospiral throughout and walls are calcareous, and thick. Spiral side is coarsely perforate, and umbilical side finely perforate. Aperture form is a slit or lip (Loeblich and Tappan, 1988). Paleocene to recent; cosmopolitan (see Plate 1, appendix).

Elphidium: Test is lenticular, chamber arrangement is planispiral, and bilaterally symmetrical (having two equal sides). Chambers are distinct, and somewhat inflated. The final chamber is often enlarged and projects beyond the general contour of the test. Sutures are distinct with bridges and depressions. Walls are calcareous, finely perforate. Aperture consists of a row of pores at the base of the septal face (Loeblich and Tappan, 1988) (see Plate 3, appendix).

Fissurina: Test is globose to ovate and single chambered. Wall material is calcareous. The aperture position is terminal and the aperture form is a slit (Loeblich and Tappan, 1988) (see Plate 6, appendix).

Haynesina: Test is broadly rounded with a perforated surface. Chamber arrangement is planispiral. Lacks sutural bridges. Considerable development of granular material on the first chamber is typical. Aperture is a basal slit (Loeblich and Tappan, 1988). Neogene to recent (see Plate 5, appendix).

Hoeglundina: Test is biconvex (lenticular), trochospiral. Chambers are triangular and straight on the umbilical side and curved on the spiral side. Wall is transparent, hyaline, calcareous, and finely perforate. Aperture position is peripheral and aperture form is a slit (Loeblich and Tappan, 1988) (see Plate 5, appendix).

Lagena: Test is calcareous perforate, and single chambered, globose to ovate. Test may be smooth or ornamented. Aperture is terminal, round. Test neck is often pronounced (Loeblich and Tappan, 1988) (see Plate 8, appendix).

Melonis: Test is planispiral involute and symmetric. Walls are calcareous, perforate and sutures are flush. Aperture is a curved basal slit (Loeblich and Tappan, 1988) (see Plate 4, appendix).

Nonionellina: Test is planispiral involute and asymmetric. Walls are calcareous, perforate. Chambers rapidly increase in height. Aperture is a basal slit (Loeblich and Tappan, 1988) (see Plate 9, appendix).

Oolina: Test is uniocular, ovate or globular. Walls are hyaline, perforate, and can be smooth or ornamented with striations.. Aperture is round to ovalular, terminal, with or without a lip (Loeblich and Tappan, 1988) (see Plate 7, appendix).

Pullenia: Test is globular, planispiral, involute. Chambers ares moderately inflated and sutures are radial and slightly depressed. Walls are calcareous and finely perforate, and the surface is smooth. Aperture is a narrow interio-marginal crescent extending across the periphery to the umbilici (Loeblich and Tappan, 1988) (see Plate 7, appendix).

Trifarina: Test is elongate and slightly tapering toward either end with an irregular uniserial arrangement. Aperture is terminal, central at the end of a tubular neck with a lip (Loeblich and Tappan, 1988) (see Plate 8, appendix).

Triloculina: Test is triloculine (the final three chambers are visible externally). The aperture is terminal, at the end of the final chamber, with a bifid tooth. The test walls are composed of imperforate, porcelaneous calcite (Loeblich and Tappan, 1988) (see Plate 8, appendix).

Quinqueloculina: Test is composed of imperforate, porcelaneous calcite. Three chambers are visible from the exterior on one side of the test and four are visible from opposite side. Aperture is terminal, rounded, with simple or bifid tooth (Loeblich and Tappan, 1988) (see Plate 9, appendix).

6. Chronology

6.1 Radioactive Isotope Analysis

Chronologies of the investigated sediment core were constructed based on ages obtained by radioactive isotope analysis (^{137}Cs and ^{210}Pb dating). Environmental radionuclides, both natural and artificial, are those radionuclides that are commonly occurring and widely distributed in the environment and are measurable (Walling 2003). Environmental radionuclides, specifically Lead-210 and Cesium-137 are a widely used to tool in geochronology to estimate sediment accumulation rates and sediment age in recent samples, deposited during the last 100-150 years. The analyses for this work was performed at the Woods Hole Oceanographic Institution's (WHOI) Café Thorium, in the Department of Marine Chemistry and Geochemistry. The core was dated on a 1.5 cm interval and five samples were tested for two radionuclides (^{137}Cs and ^{210}Pb) and analyzed. Dried and ground sediment samples were placed in calibrated counting jars on the gamma counter for 12-48 hours. Samples tested are as follows, sample #10: 0-0.5cm, sample #8: 2-2.5cm, sample #6: 4-4.5cm, sample #4: 6-6.5cm, and sample #2: 8-8.5cm.

6.1.2 Lead-210 (^{210}Pb)

^{210}Pb is a naturally occurring radionuclide that is part of the Uranium-238 decay series. In the Uranium-238 decay series, the radium isotope, Radium-226 (having a half-life of 1,622 years), decays to the inert gas Radon-222 (having a half-life of 3.83 days), which then decays through four short-lived isotopes, each with half-lives of minutes, to the ^{210}Pb radioisotope (Appleby and Oldfield 1983). Lead-210 decays exponentially with time according to its relatively short half-life of 22.2 years (Appleby and Oldfield, 1983). The total activity of ^{210}Pb must be separated into two components; unsupported activity (excess) and supported (background) activity. Young sediments will have unsupported ^{210}Pb, and it is this component that is used in geochronological estimates. The supported ^{210}Pb can be separated from the total ^{210}Pb, to find the unsupported ^{210}Pb component:

$$^{210}Pb\ Unsupported = {}^{210}Pb\ Total - {}^{210}Pb\ Supported \qquad \text{(Equation 1.)}$$

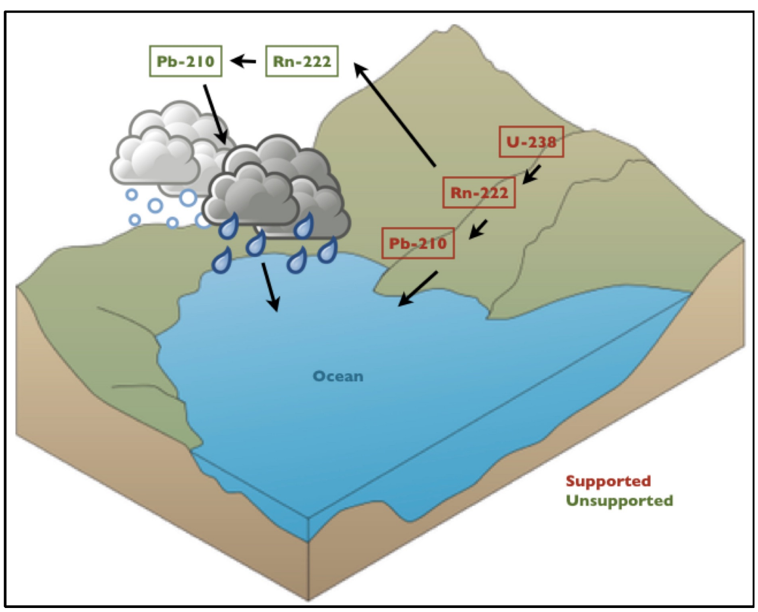

Fig. 6.1 Illustration of sources of supported (background) and unsupported (excess) ^{210}Pb.

As ^{238}U decays in continental rocks, some of the generated ^{222}Rn gas escapes into the atmosphere, where the unsupported component of ^{210}Pb is produced. Here the ^{210}Pb radioisotope attaches to atmospheric aerosols and is washed out of the atmosphere by dry fallout and precipitation, deposited, and incorporated into new sediments. The existence of ^{210}Pb in the atmosphere is short-lived, having an average residence time on the order of 5 to 10 days (Krishnaswami et al. 1978). This unsupported ^{210}Pb is not replaced as it decays. The global ^{210}Pb natural atmospheric flux is 1.3-5.8 (picocurie) pCi in^{-2} y^{-1} (Appleby and Oldfield 1983). On the contrary, supported ^{210}Pb refers to the background level of ^{210}Pb in sediment (eroded from rocks and incorporated into sediments). As this background ^{210}Pb is lost by radioactive decay, new ^{210}Pb is created by the decay of ^{226}Ra contained in the sediments (figure 6.1).

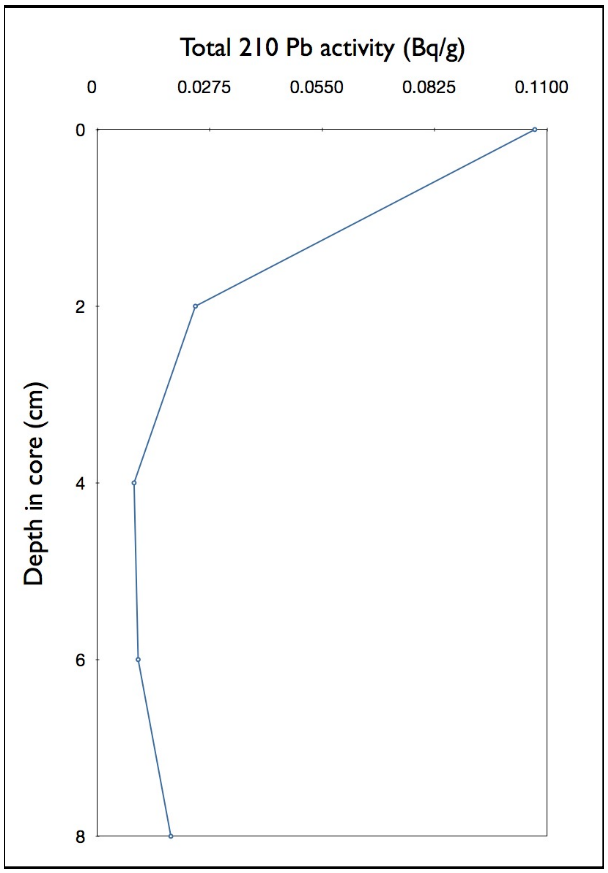

Fig. 6.2 Shows total ^{210}Pb activity from core top to down core.

The Constant Rate of Supply (CRS) model is commonly used to determine the age of a given depth from a ^{210}Pb vertical profile within a sediment column. The CRS model is the most widely accepted and relies on the following assumptions: (1) there is a constant unsupported ^{210}Pb flux to the sediment through time, (2) the initial ^{210}Pb concentration in the sediment is variable, and (3) the influx rate of sedimentation is variable (Appleby and Oldfield, 1978). According to this model, the initial concentration $C_0(t)$ of unsupported ^{210}Pb in sediment of age *t* years must satisfy the following equation:

$$C_0(t)\ r(t) = constant \quad \text{(Equation 2.)}$$

Where r(t) (grams/cm^2 yr) is the dry mass sedimentation rate at time t, and $C_0(t)$ is the unsupported ^{210}Pb in sediment of age t years. Following this, the relationship between the age of the deposit at depth x is as follows:

$$P = \sum 210Pb_{unsupported}\lambda \qquad \text{(Equation 3.)}$$

Where t is time, A_0 is the total unsupported ^{210}Pb activity in the sediment column, A_x is the total unsupported ^{210}Pb activity in the sediment column beneath depth x, and λ is the ^{210}Pb radioactive decay constant of 0.03114 y $^{-1}$. The sedimentation rate, r, can be calculated as follows:

$$t = \frac{1}{\lambda} ln(\frac{A_0}{A_x}) \qquad \text{(Equation 4.)}$$

And the net flux, P, of unsupported ^{210}Pb activity to the sediment can be calculated by:

$$r = \frac{\lambda A_x}{C} \qquad \text{(Equation 5.)}$$

6.1.3 Lead-210 (^{210}Pb) results

No excess or supported ^{210}Pb was measured from 2 cm and below. In sample #8, #6, #4, and #2, the becquerel/gram (Bq/g) values are the same within error (and therefore there is no excess or supported ^{210}Pb in these samples) (see figure 6.2, and table A.2 in the appendix). This lack of ^{210}Pb indicates that at least five half lives must have passed making these sediments greater than 100 years old. In addition, as this remains constant down the core it suggests a stable core with no mixing. Although a ^{210}Pb signal is seen in the top sample (0-0.5cm), indicating that this sample is less than 100 years old, this is not sufficient to estimate an age or sedimentation rate.

6.1.4 Cesium-137 (^{137}Cs)

^{137}Cs is an artificial radionuclide with a half-life of 30.2 years, and is used to validate ^{210}Pb geochronology with a time-dependent marker in order to produce a more effective model of age estimation (McHenry and Ritchie, 1977). ^{137}Cs is a product of nuclear testing and detectable levels begin in sediment in the year 1954 (known as the ^{137}Cs horizon). Similarly to unsupported ^{210}Pb, ^{137}Cs is released into the atmosphere, is deposited, and incorporated into the sediment. Along with the 1954 horizon, peaks of ^{137}Cs can be identified in 1958 and 1963, because of the intensification of weapons testing during these years. These peaks in the sediment record can be used to calibrate other sediment dating methods, such as the those described earlier for the radioisotope, ^{210}Pb.

6.1.5 Cesium-137 (^{137}Cs) results

As expected, samples from 2 cm and below had no detectable ^{137}Cs signal. However, the surface section (0-0.5 cm) showed measurable ^{137}Cs (see table A.3, in appendix). Additionally, because there is no mixing downcore, this suggests that (1) the 0-0.5 cm has to be younger than 1954 (the ^{137}Cs horizon) and (2) this top layer may have been deposited by some other transport process.

6.1.6 Extrapolation of dating results

Using the results obtained from the Lead-210 and Cesium-137 dating, ages were linearly extrapolated (assuming a constant sedimentation rate) (figure A.2, appendix). Using this method the following approximate age estimates are made: 0-0.5cm, 1954-1986; 1-1.5cm, 1896-1946; 2-2.5cm, 1836-1916; 3-3.5cm, 1766-1878; 4-4.5cm, 1700-1846; 5-5.5cm, 1636-1810; 6-6.5cm, 1570-1776; 7-7.5cm, 1506-1740; 8-8.5cm 1446-1706; and 9-9.5cm, 1380-1670. Following this, the approximate sedimentation rate is 0.016 - 0.033 cm/yr. Although this method provides a rough age estimate, presuming a constant rate of sediment accumulation, it is not a good assumption as rates typically vary through time, are not stable, and are influenced by decadal to century-scale variability, especially in Arctic regions (Smith, Alexander, and Jennings, 2002).

7. Results and discussion

7.1 Distinguished foraminiferal genera

A total of 16 benthic foraminiferal genera were distinguished in this study (Table 7.1). Raw data sets are shown in the appendix for identification in each sample down core (Tables A.4 - A.13).

Table 7.1 Alphabetical list of all foraminiferal taxa identified including their genera and suborder.

Genera	Suborder
Bolivina sp.	Rotaliina
Buccella sp.	Rotaliina
Cassidulina sp.	Rotaliina
Cibicides sp.	Rotaliina
Elphidium sp.	Rotaliina
Fissurina sp.	Lagenina
Haynesina sp.	Rotaliina
Hoeglundina sp.	Robertinina
Lagena sp.	Lagenina
Melonis sp.	Rotaliina
Nonionellina sp.	Rotaliina
Oolina sp.	Lagenina
Pullenia sp.	Rotaliina
Trifarina sp.	Rotaliina
Triloculina sp.	Miliolina
Quinqueloculina sp.	Miliolina

Foraminiferal abundances can be divided into three groups: genera with an occurrence of >15% are abundant, genera with an occurrence of 2-10% are common, and genera with an occurrence of <2% are rare (DeLaca, 1986). Figure A.3, appendix, details the relative abundance of the 16 genera described from the core top to the core bottom. Abundant genera include Buccella sp., Cibicides sp., and Elphidium sp. Common genera include Cassidulina sp., Fissurina sp., Haynesina sp., Hoeglundina sp., and Melonis sp. And, rare genera include Bolivina sp., Lagena sp., Nonionellina sp., Oolina sp., Pullenia sp., Trifarina sp., Triloculina sp., and Quinqueloculina sp.

7.2 Descriptions of foraminiferal assemblages

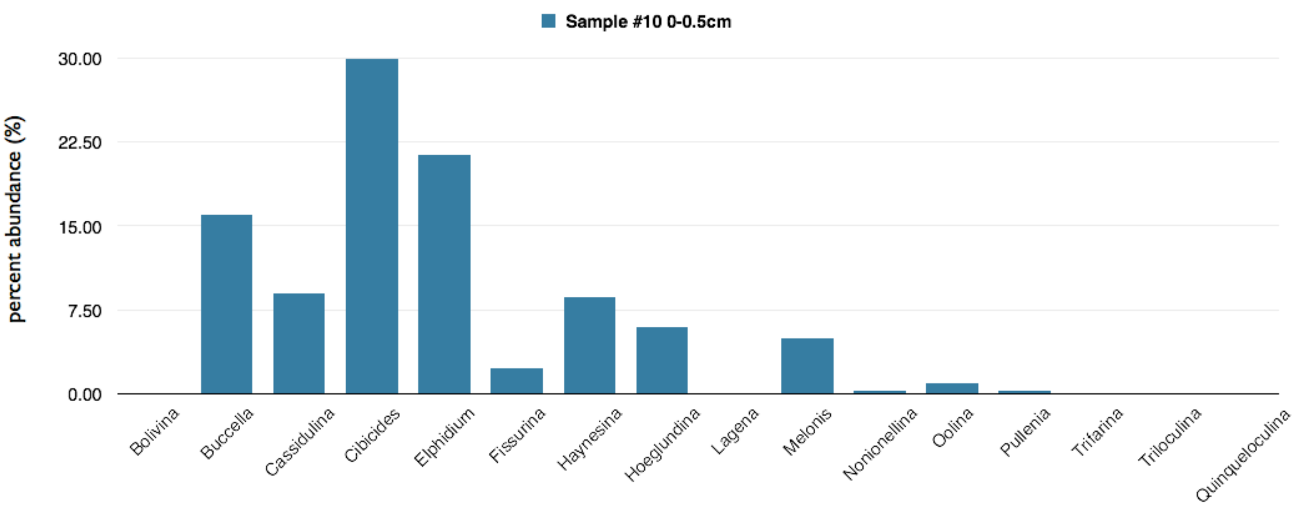

Fig. 7.1 Shows the relative abundance of each genera in the 0-0.5 cm assemblage.

0-0.5 cm assemblage: The 0-0.5 cm assemblage is the most recent (core top) and is younger than the year 1954 (the ^{137}Cs horizon), as evident by the ^{137}Cs signal (see chronology). It is characterized by a dominance of Cibicides sp. at a 30.00% relative abundance, followed by Elphidium sp. at 21.33%, Buccella sp. at 16.00%, Cassidulina sp. at 9.00%, Haynesina sp. at 8.67%, Hoeglundina sp. at 6.00%, and Melonis sp. at 5.00%. All other genera are less than 5.00% in abundance (figure 7.1).

1-1.5 cm assemblage: The 1-1.5 cm assemblage cannot be dated as it lies in between two analyzed samples, however based on extrapolation it is estimated to lie between 1896 and 1946. The 0-0.5 cm sample showed a ^{137}Cs signal and is therefore younger than

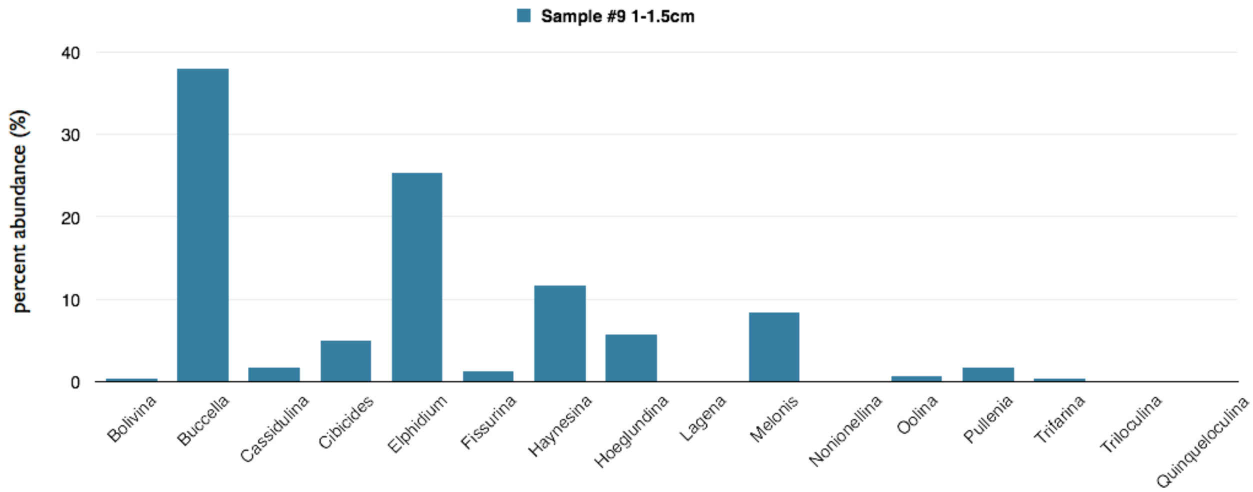

Fig. 7.2 Shows the relative abundance of each genera in the 1-1.5 cm assemblage.

1954, whereas the 2-2.5 sample showed no ^{137}Cs signal, and no supported or excess ^{210}Pb and is hence is greater than 100 years old. Based in the foraminiferal relative abundances, the 1-1.5 cm assemblage more closely resembles the assemblage below (2-2.5

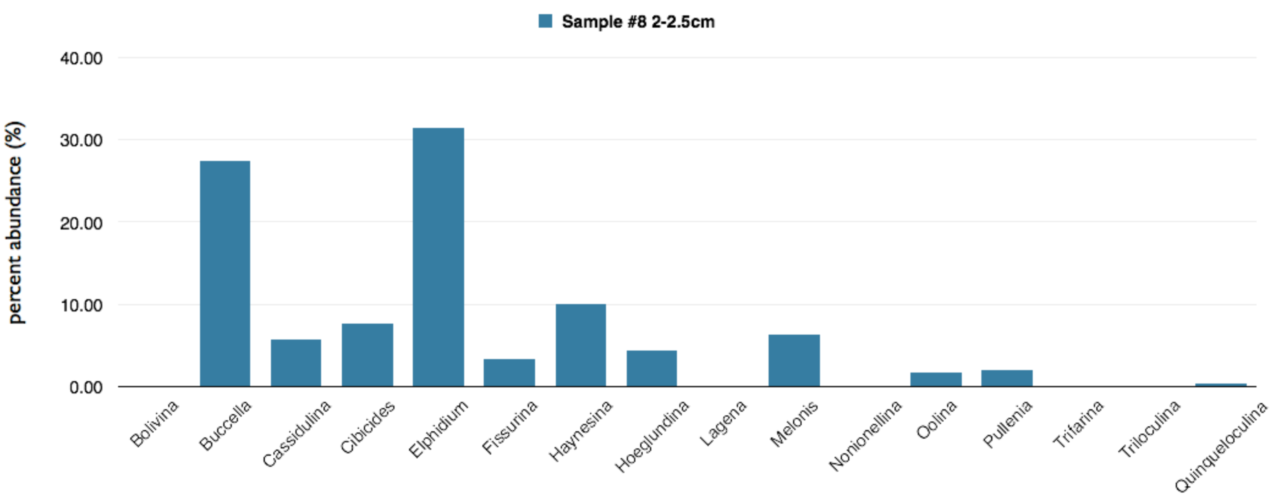

Fig. 7.3 Shows the relative abundance of each genera in the 2-2.5 cm assemblage.

cm), and therefore it is more likely that the assemblage is older than 100 years. This is especially apparent in the low relative abundance of the genera Cibicides. However, in order to make a further conclusion, this sample would have to undergo radioactive isotope analysis or another dating method. The 1-1.5 cm assemblage is characterized by a dominance of Buccella sp. at a 38.00% relative abundance, followed by Elphidium sp. at

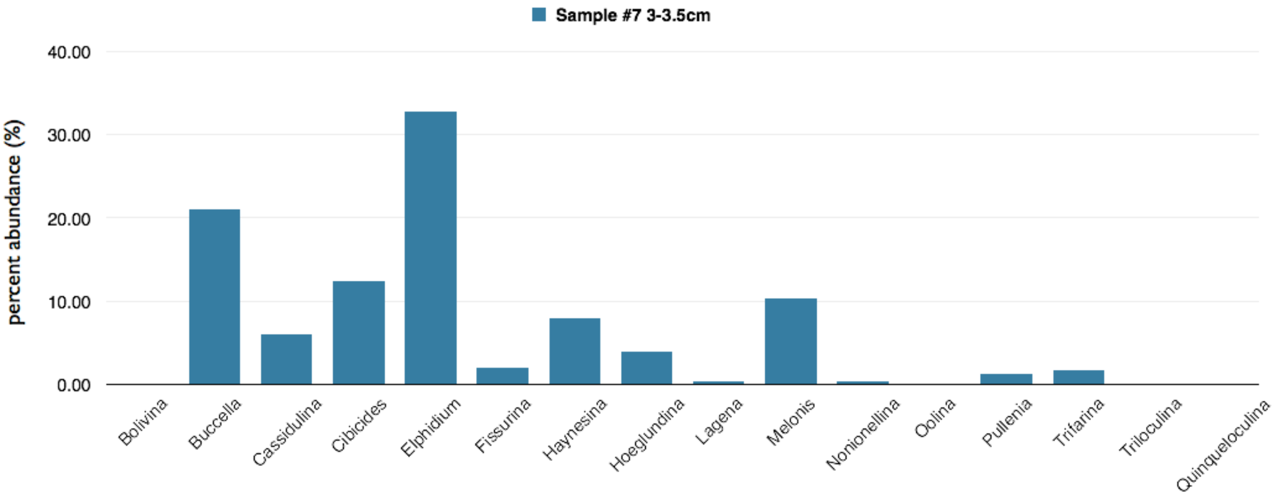

Fig. 7.4 Shows the relative abundance of each genera in the 3-3.5 cm assemblage.

25.33%, Haynesina sp. at 11.67%, Melonis sp. at 8.33%, Hoeglundina sp. at 5.67%, and Cibicides sp. at 5.00%. All other genera are less than 5.00% in abundance (figure 7.2).

2-2.5 cm assemblage: The 2-2.5 cm assemblage is greater 100 years old as evident by the lack of access or supported ^{210}Pb (see chronology). It should also be noted that all assemblages down core are also greater than 100 years old as the were deposited previous to the 2-2.5 assemblage. The 2-2.5 assemblage is characterized by a dominance of Elphidium sp. at a 31.33% relative abundance, followed by Buccella sp. at 27.33%, Haynesina sp. at 10.00%, Cibicides sp. at 7.67%, Melonis sp. at 6.33%, and Cassidulina sp. at 5.67%. All other genera are less than 5.00% in abundance (figure 7.3).

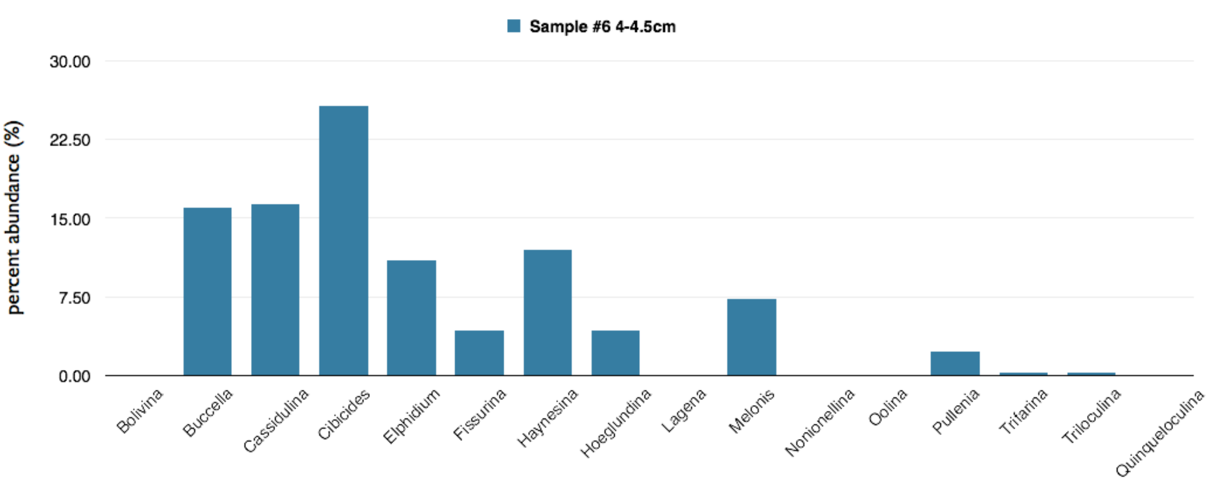

Fig. 7.5 Shows the relative abundance of each genera in the 4-4.5 cm assemblage.

3-3.5 cm assemblage: The 3-3.5 cm assemblage is greater 100 years old. The 3-3.5 as-

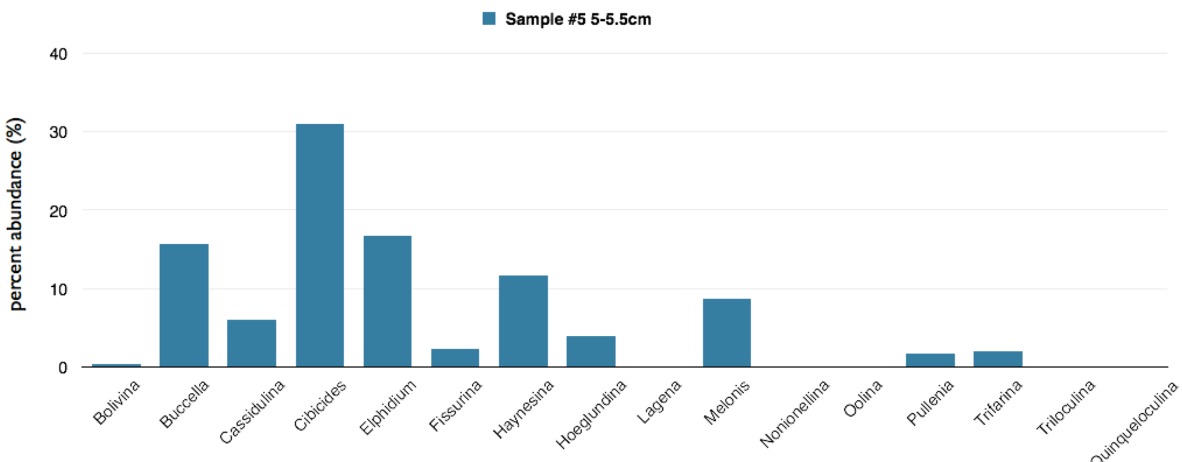

Fig. 7.6 Shows the relative abundance of each genera in the 5-5.5 cm assemblage.

semblage is characterized by a dominance of Elphidium sp. at a 32.67% relative abundance, followed by Buccella sp. at 21.00%, Cibicides sp. at 12.33%, Melonis sp. at 10.33%, Haynesina sp. at 8.00%, and Cassidulina sp. at 6.00%. All other genera are less than 5.00% in abundance (figure 7.4).

4-4.5 cm assemblage: The 4-4.5 cm assemblage is greater 100 years old. The 4-4.5 assemblage is characterized by a dominance of Cibicides sp. at a 25.67% relative abundance, followed by Cassidulina sp. at 16.33%, Buccella sp. at 16.00%, Haynesina sp. at

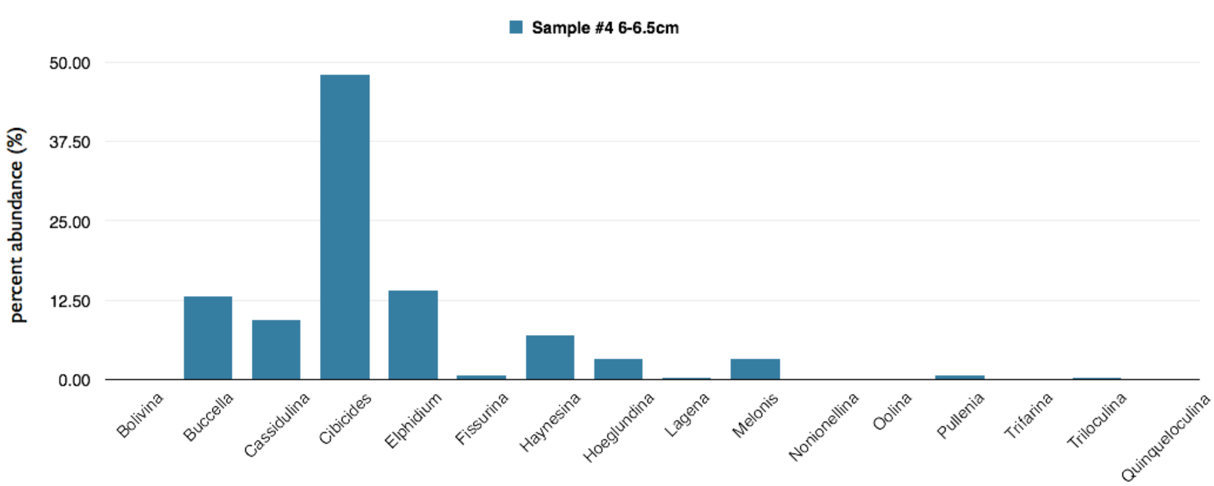

Fig. 7.7 Shows the relative abundance of each genera in the 6-6.5 cm assemblage.

12.00%, Elphidium sp. at 11.00%, and Melonis sp. at 7.33%. All other genera are less than 5.00% in abundance (figure 7.5).

5-5.5 cm assemblage: The 5-5.5 cm assemblage is greater 100 years old. The 5-5.5 assemblage is characterized by a dominance of Cibicides sp. at a 31.00% relative abundance, followed by Elphidium sp. at 16.67%, Buccella sp. at 15.67%, Haynesina sp. at 11.67%, Melonis sp. at 8.67%, and Cassidulina sp. at 6.00%. All other genera are less than 5.00% in abundance (figure 7.6).

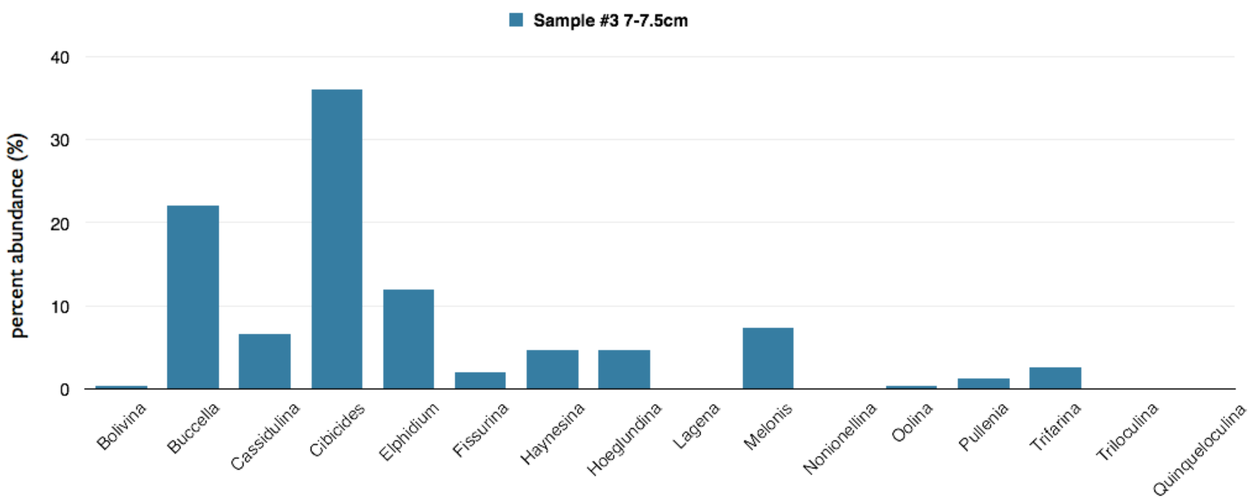

Fig. 7.8 Shows the relative abundance of each genera in the 7-7.5 cm assemblage.

6-6.5 cm assemblage: The 6-6.5 cm assemblage is greater 100 years old. The 6-6.5 assemblage is characterized by a dominance of Cibicides sp. at a 48.00% relative abundance, followed by Elphidium sp. at 14.00%, Buccella sp. at 13.00%, Cassidulina sp. at 9.33%, and Haynesina sp. at 7.00%. All other genera are less than 5.00% in abundance (figure 7.7).

7-7.5 cm assemblage: The 7-7.5 cm assemblage is greater 100 years old. The 7-7.5 assemblage is characterized by a dominance of Cibicides sp. at a 36.00% relative abun-

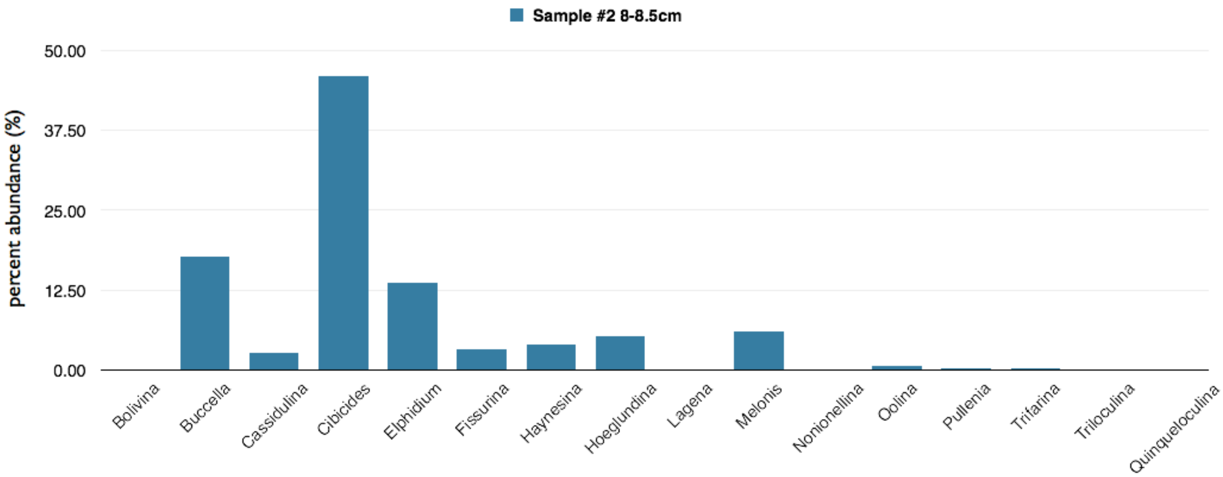

Fig. 7.9 Shows the relative abundance of each genera in the 8-8.5 cm assemblage.

dance, followed by Buccella sp. at 22.00%, Elphidium sp. at 12.00%, Melonis sp. at 7.33%, and Cassidulina sp. at 6.67%. All other genera are less than 5.00% in abundance (figure 7.8).

8-8.5 cm assemblage: The 8-8.5 cm assemblage is greater 100 years old. The 8-8.5 assemblage is characterized by a dominance of Cibicides sp. at a 46.00% relative abundance, followed by Buccella sp. at 17.67%, Elphidium sp. at 13.67%, Melonis sp. at 6.00%, and Hoeglundina sp. at 5.33%. All other genera are less than 5.00% in abundance (figure 7.9)

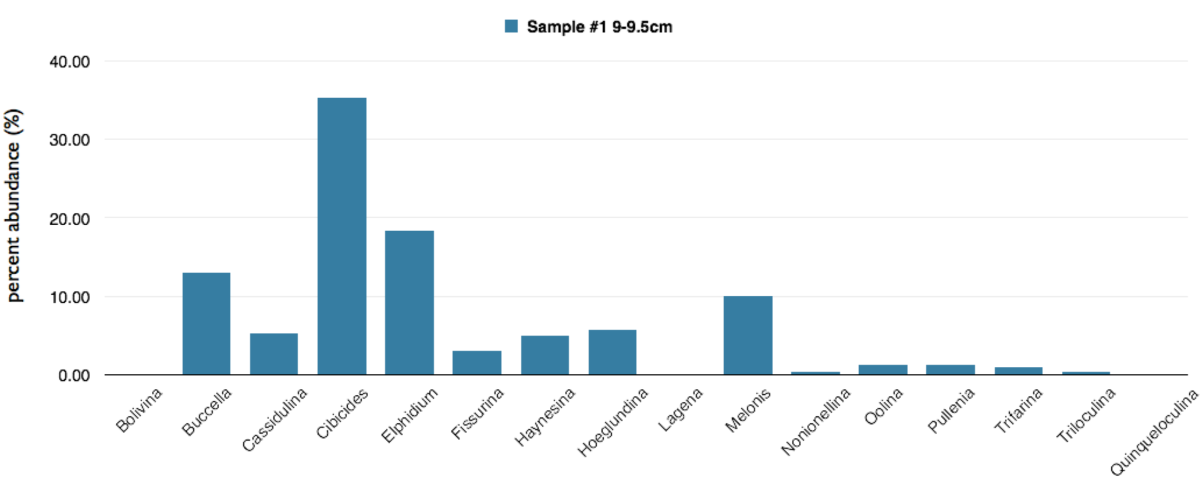

Fig. 7.10 Shows the relative abundance of each genera in the 9-9.5 cm assemblage.

9-9.5 cm assemblage: The 9-9.5 cm assemblage is greater 100 years old. The 9-9.5 assemblage is characterized by a dominance of Cibicides sp. at a 35.33% relative abundance, followed by Elphidium sp. at 18.33%, Buccella sp. at 13.00%, Melonis sp. at 10.00%, Hoeglundina sp. at 5.67%, and Cassidulina sp. at 5.33%. All other genera are less than 5.00% in abundance (figure 7.10).

7.3 Diversity Indices

Biodiversity is one of the primary interests of ecologists, and as a result, many different measures (or indices) of biodiversity have been developed. In this study we utilize three measures of diversity, the Berger-Parker dominance index (d), the Simpson index (D), and the Shannon-Wiener Diversity Index (H).

7.3.1 Berger-Parker dominance

The Berger–Parker index is the fraction of total sampled individuals that is contributed by the most abundant species (May, 1975). It is a simple measure of the numerical importance of the most abundant species. For this study, foraminifera were identified to the genera level and therefore the Berger-Parker index is modified to the fraction of total sampled individual that is contributed by the most abundant genera:

$$d = \frac{N_{max}}{N} \qquad \text{(Equation 6.)}$$

where N_{max} is the number of individuals in the most abundant genera, and N is the total number of individuals in the sample. The reciprocal of the index, 1/d may also be used, in which case an increase in the value of the index will indicate a reduction in dominance. The Berger-Parker index, d, is plotted for all 10 samples in figure 7.11. Here a general a reduction in dominance (shown by a decrease in the Berger-Parker index), d over time can be seen from the oldest samples to the most recent.

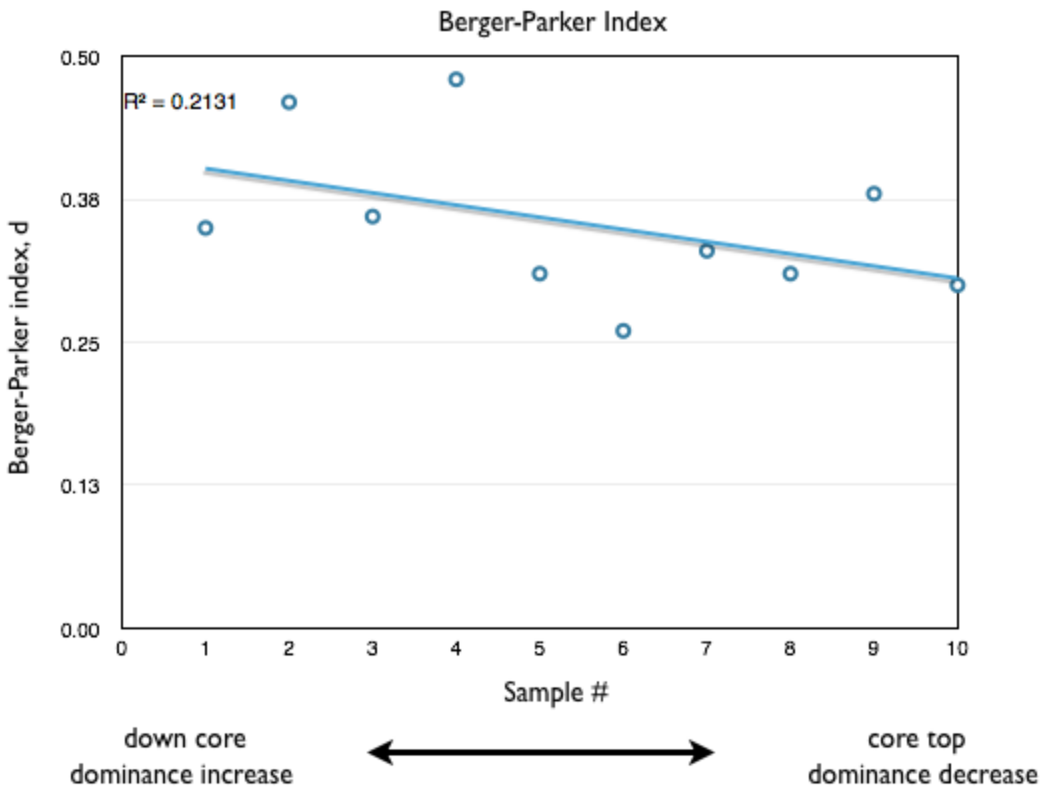

Fig. 7.11 Shows the Berger-Parker index plotted for all ten samples (down core to core top), showing a decrease in dominance through time.

7.3.2 Simpson's Index

Simpson's index (D) is a measure of diversity dependent on evenness and dominance (Simpson, 1949). Simply, it is based upon the probability that any two individuals drawn at random from an infinitely large community belong to the same species. The value D may range from 0 to 1, with zero representing infinite diversity and 1, no diversity. Therefore, larger D values denote lower diversities. D may also be subtracted from 1 to give a positive correlation where the value of D increases with increasing diversity. For our purposes, we calculate the Simpson's index based on the number of genera present, as well as the abundance of each genera within a sample:

$$D = \sum \frac{n_i(n_i - 1)}{N(N-1)} \quad \text{(Equation 7.)}$$

Where n_i is the total number of organisms of a particular genera, and N is the total number of organisms of all genera. The Simpson's index, D, is plotted for all 10 samples in figure 7.12.

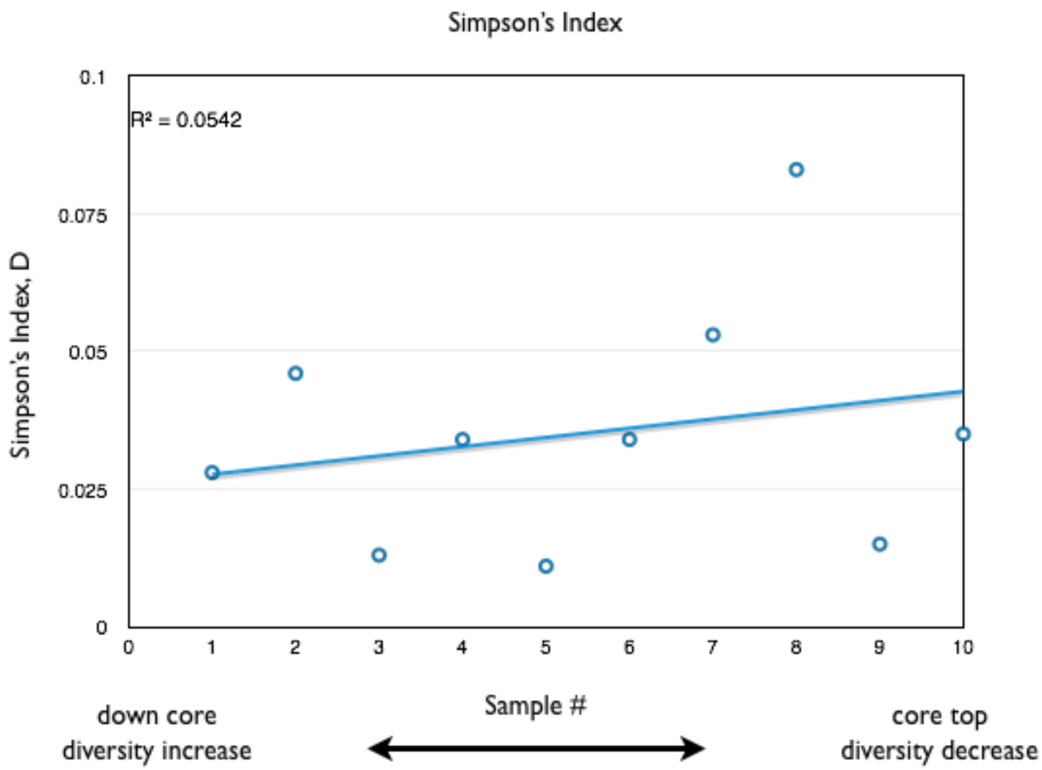

Fig. 7.12 Shows the Simpson's index plotted for all ten samples (down core to core top), showing a decrease in diversity through time.

Here a general decrease in diversity (shown by an increase in the Simpson's index, D) over time can be seen from the oldest samples to the most recent.

7.3.3 Shannon-Wiener Diversity Index

Shannon's index (H) is a measure of diversity and accounts for both abundance and evenness of the species present (Shannon, 1948). Typical H values are generally between 1.5 and 3.5 in most ecological studies (the index is rarely greater than 4). H increases as both the richness and the evenness of the community increase. For our purposes we calculate Shannon's index based on the proportion of genera i relative to the total number of genera (p_i):

$$H = -\sum p_i \ln p_i \qquad \text{(Equation 8.)}$$

Where the proportion of genera i relative to the total number of genera (p_i) is calculated, and then multiplied by the natural logarithm of this proportion ($\ln p_i$). The resulting product is summed across genera, and multiplied by -1. Shannon's index, H, is plotted for all 10 samples in figure 7.13. Here a general decrease in diversity (shown by an decrease in Shannon's index, H) over time can be seen from the oldest samples to the most recent.

The decrease in diversity over time seen in both the Simpson's and Shannon's index over time suggest that there has been an increase in environmental stress of some kind (Mur-

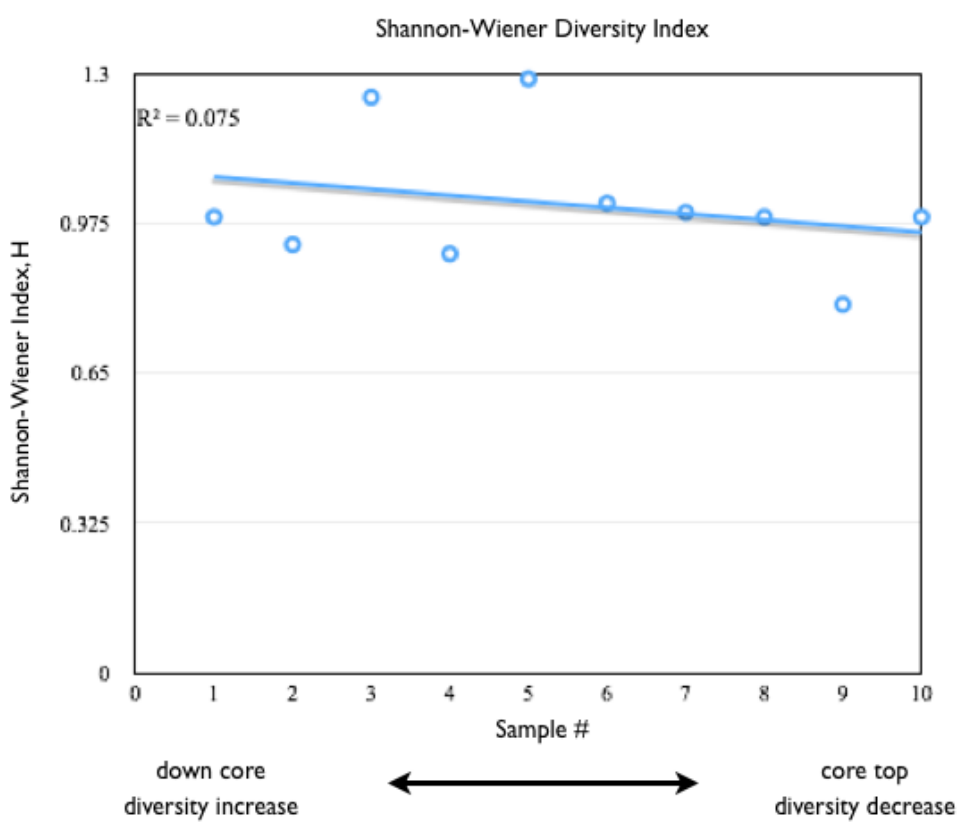

Fig. 7.13 Shows the Shannon's index plotted for all ten samples (down core to core top), showing a decrease in diversity through time.

ray, 1991). The low R^2 values also indicate that many different variables (environmental factors) effect diversity.

7.4 Ecological descriptions of genera

Ecological studies aim to uncover the relationship between living organisms and their environment. This section describes the general ecological preferences of the studied genera. Note that a more specific ecologic characterization would involve identification down to the species level.

Bolivina sp. Bolivinas are a low-oxygen tolerant infaunal foraminifer. They tend to dwell in shallow to intermediate continental shelf sediment and are indicative of high bioproductivity (Ovsepyan et al., 2013). In this study, Bolivina sp. is a rare genus with only three specimens occurring in the studied core; one specimen in the 7-7.5 cm assemblage; one specimen in the 5-5.5 cm assemblage; and one specimen in the 1-1.5 cm assemblage (Figure 7.14). Due to its rarity and failure to exhibit a trend, no conclusions can be made about its occurrence and ecological relationships.

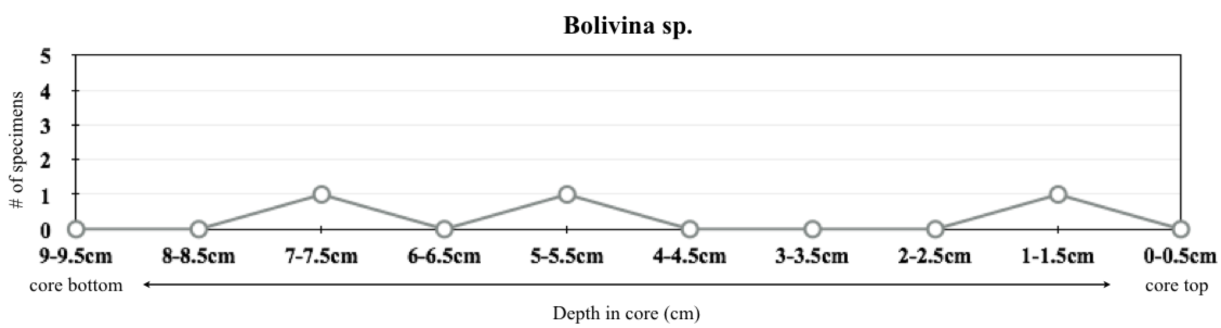

Fig. 7.14 Shows abundance (by # of specimens) of Bolivina sp. through time (from core bottom to core top).

Buccella sp. In Arctic and subarctic environments, Buccella sp. have been linked to an increased freshwater supply, a preference towards river and glacially-affected areas (Polyak, 2002; Möller et al., 2006). Buccella sp. have also been shown to prefer seasonally ice free areas and are linked to high food and nutrient supply (Möller et al., 2006). Buccella's live infaunally within the sediment (Murray, 1991). Buccella sp. is an abundant genus in the studied samples. The number of Buccellas in the core generally increase through time with the largest abundance close to the core top in the 1-1.5 cm assemblage (Figure 7.15). This increase may indicate an increase in freshwater discharge from the Greenland Ice Sheet through marine outlet glaciers and an increase in primary production due to the reduction in sea-ice extent as well as a longer ice-free summer season.

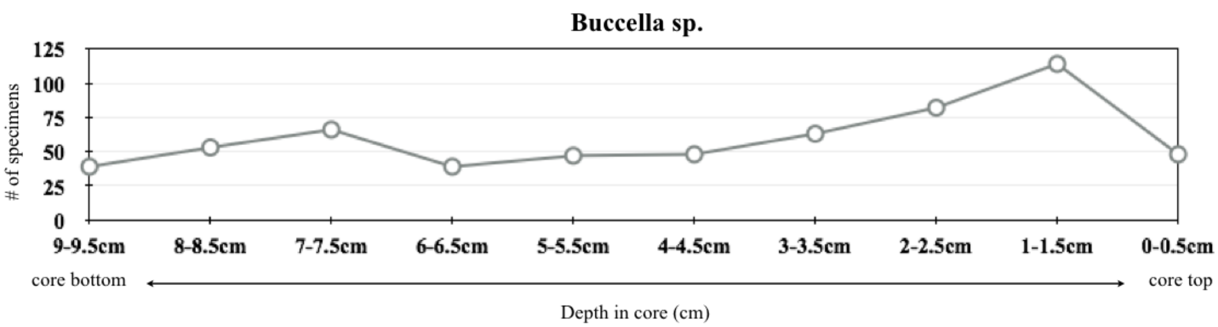

Fig. 7.15 Shows abundance (by # of specimens) of Buccella sp. through time (from core bottom to core top).

Cassidulina sp. Cassidulinas are common calcareous foraminifers on Arctic shelves, occurring from glaciated fjords to bathyal depths. Cassidulinas are epifaunal forms and suggest relatively deep waters (433-510 m). They are abundant in reduced glacially impacted environments (Korsun and Hald, 1998). Cassidulinas infer a decreased meltwater flux, and prefer higher salinity waters (Möller et al., 2006). Cassidulina reniforme has maximum abundance in intermediate zones (between river-proximal and river-distal areas). They prefer relatively cold-water areas (temperatures below 28℃) with seasonal sea-ice coverage (Polyak, 2002). The occurrence of Cassidulina sp. increases with nutrient enrichment reflected in phytoplankton abundance (Korsun and Hald, 1998). Cassidulinas are a common genus in the studied core and become abundant in the 4-4.5 cm assemblage (figure 7.16). Their low abundance in the upper core (especially in the 1-1.5

cm assemblage) may indicate a shift to glacially impacted environment, and hence an increase in meltwater flux and lower salinity waters.

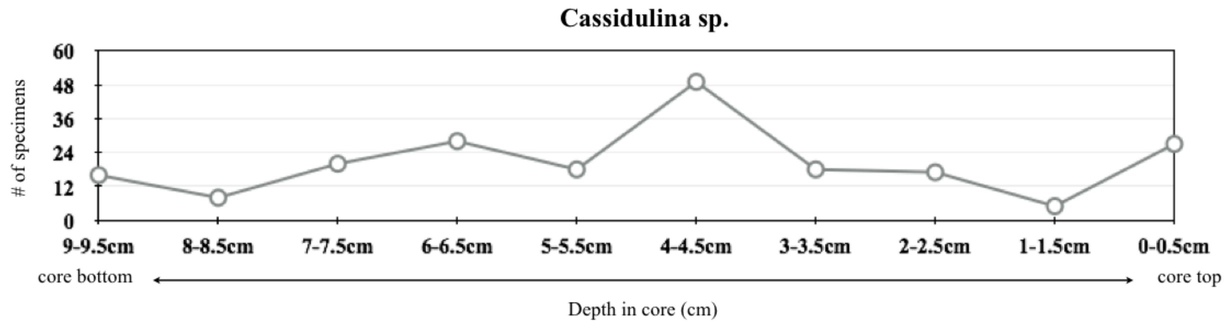

Fig. 7.16 Shows abundance (by # of specimens) of Cassidulina sp. through time (from core bottom to core top).

Cibicides sp. Cibicides, a plano-convex foraminifer, thrive in water depths $<$ 1,000 meters. Cibicides are an epifaunal, cosmopolitan species which feeds on laterally advected organic material, sometimes at an elevated position (suspension feeder) (Lutze and Thiel, 1989; Schäfer and Ritzrau, 2012). Cibicides may show a high variability of test morphology resulting from the irregularity of the substrate. Abnormal specimens of this genus thus cannot be used to indicate environmental stress (Geslin, 2000). Cibicides is well adapted to filter feeding and requires permanent lateral advective horizontal currents at the seafloor, and therefore, high velocity currents (Polyak, 2002). Furthermore, a strong inflow of Atlantic surface water indicating more oceanic heat pumping into subarctic latitudes, provide suitable conditions for Cibicides (Streeter et al., 1982; Haake and Pflaumann 1989; Struck, 1997; Schäfer and Ritzrau, 2012). Additionally, the occurrence of Cibicides was found to be extremely low during the Last Glacial Maximum (LGM) (Struck, 1995). Cibicides is an abundant genera in the lower portion of the core and subsequently begins to decrease at 6-6.5 cm to 1-1.5 cm, and then finally increase once again in the 0-0.5 assemblage (core top) (figure 7.17). The fluctuation in abundance of Cibicides throughout the core may indicate changes in the inflow of Atlantic surface waters or a change in current velocities in the vicinity of the core. It should also be noted that according to the Cesium-137 dating, it is possible that the 0-0.5 assemblage was deposited in a different manner than the rest of the core. Alternatively, another possibility is that the decrease in abundance, (from 6-6.5 to 1-1.5 cm, which have been dated to $>$ 100 years old, and estimated to be between 1570-1946) correspond to the Little Ice Age (LIA), a period of regionally cool conditions in the Northern Hemisphere between roughly AD 1300 and 1850. The coldest conditions of the LIA are estimated to lie between AD 1570 and 1730. This hypothesis corresponds to a weakening convection of the ocean during the LIA, and consequently, a reduction in northward ocean heat transport, reinforcing the expansion of the sea ice and the cooling of the Northern Hemisphere of about 0.6° C during the 15th-19th centuries (Mann, 1990; Lehner et al., 2013), as well as a reduction in the production of NADW. This timeline would also explain the peak in the above Cassidulina sp. at 4-4.5 cm which infer a decreased meltwater flux, and higher salinity waters which correspond to cooler periods. Correspondingly, the higher abundance of Cibicides at the core bottom may be explained by the previous Medieval Warm Period (MWP), a time of warm climate in the North Atlantic region from about AD 950 to 1250. The MWP is often associated with enhanced North Atlantic Ocean circulation (Dowsett et al., 1992). Therefore, the abrupt and significant change in the abundance of Cibicides may indicate a shift in climate from the MWP to the LIA. In this scenario, the core top, dating to more recent than 1954, could indicate a warming and restrengthening of ocean convection and northward ocean heat transport, and accordingly, an increase in the abundance of Cibicides. Bradley and Jonest, 1993 found that unusually warm conditions have prevailed since the 1920s, probably due to a relative absence of major explosive volcanic eruptions and higher levels of greenhouse gases.

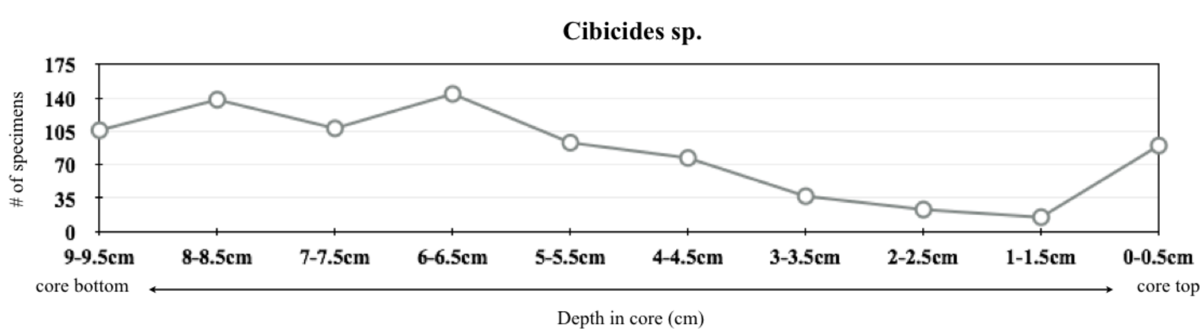

Fig. 7.17 Shows abundance (by # of specimens) of Cibicides sp. through time (from core bottom to core top).

Elphidium sp. Elphidiums are known to be widespread on the Arctic shelves and are known to live in various highly stressed environments. The ability of Elphidiums to adapt to harsh environments may be related to its high nutritional and habitat versatility (Lutze, 1965; Korsun and Hald, 2000). Elphidiums may live at the seafloor or in within the sediment, and can be termed semi-infaunal. In general Elphidiums are characteristic of polar climate, glacier-proximal (near glacier/glacier influenced), shallow water (shelf environments) (Polyak, 2002; Howe, 2010). They show a preference for low-salinity environments, and are an indicator of meltwater and freshwater influx, presumably from melting glaciers (Howe, 2010; Bauch et al., 2004). Jennings et al., 2002 postulate that the rise in Elphidiums throughout the late Holocene provides independent evidence of an overall freshening of Arctic waters. Numbers of living Elphidiums have been shown to exhibit a positive correlation with organic carbon content and phytoplankton density (Korsun and Hald, 1998). Additionally, Elphidiums are thought to be very opportunistic, which often takes advantage of environments unfavorable for most other shelf genera (Nagy, 1965). Elphidium is an abundant genera in the studied core (figure 7.18). The abundance of Elphidium remains somewhat consistent from the 9-9.5 to the 4-4.5 cm assemblage, with the 4-4.5 cm assemblage representing its lowest relative abundance at 33 specimens. Thereafter, the relative abundance jumps to its highest at 98 specimens in the 3-3.5 cm assemblage and remains high (although a general decreasing trend can be seen to the core top). This increase from the 4-4.5 cm assemblage may indicate a freshening of the water due to glacial inundation.

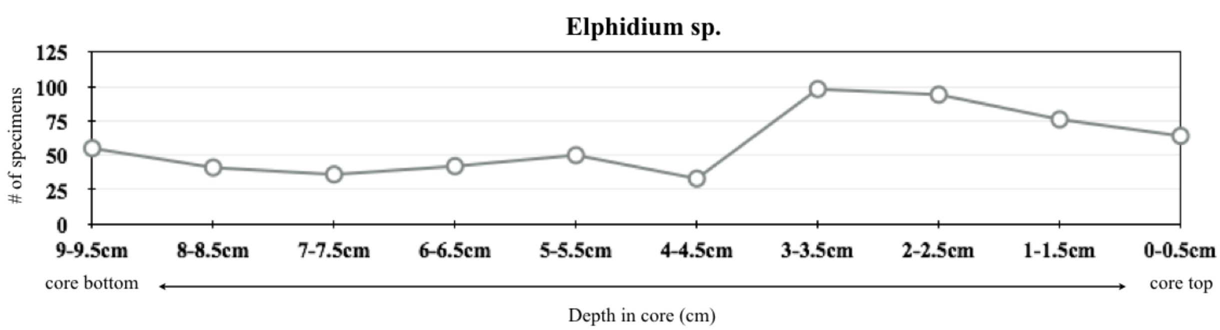

Fig. 7.18 Shows abundance (by # of specimens) of Elphidium sp. through time (from core bottom to core top).

Fissurina sp. Fissurina is typically a deep-water infaunal genus (Murray, 1991). There is limited literature on Fissurinas general ecology. Fissurina sp. is not an abundant genera in this study and no conclusions can be made about its occurrence or ecological relationships (figure 7.19).

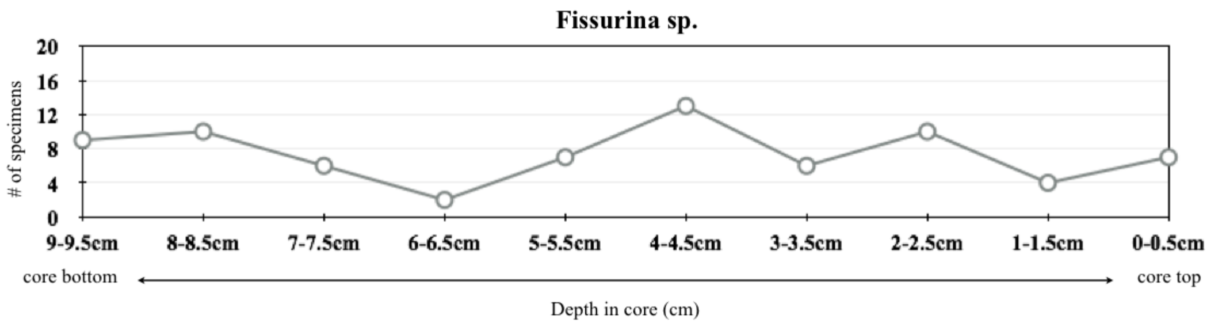

Fig. 7.19 Shows abundance (by # of specimens) of Fissurina sp. through time (from core bottom to core top).

Haynesina sp. Haynesinas tend to prefer low-salinity, shallow waters (<50 meters) and are indicative of meltwater outflow, and deglacial or end of glaciation periods (Weddle and Retelle, 2001; Korsun, 1999; Korsun and Hald, 2000; Polyak et al., 2002). Haynesina sp. are usually referred to as infaunal genus (Murray, 1991). They can be found in river-proximal environments in the Kara and Laptev Seas (Polyak et al., 2002) and are also indicators of increased depositional energy (Möller et al., 2006). Haynesina is a common genus in the studied core. A general increase in the abundance of Haynesina can be seen from core bottom to core top, indicating increased meltwater outflow and a deglacial period. These trends (especially the lower abundances in the core bottom) do not align well with the MWP and LIA timeline. However, since this genera prefers very shallow waters (of less than 50 meters) and our core has a 447 meter depth, it is possible that these specimens were deposited when already dead by bottom currents (called ghost communities). Therefore the ecological implications of this genera should be disregarded (figure 7.20).

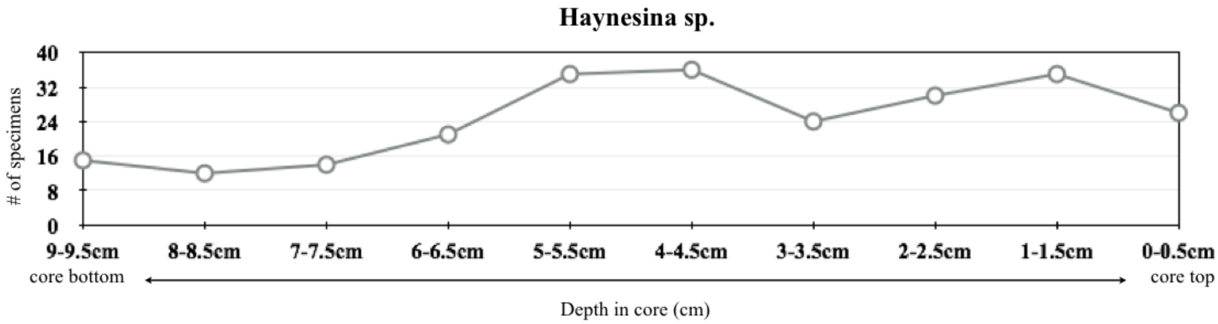

Fig. 7.20 Shows abundance (by # of specimens) of Haynesina sp. through time (from core bottom to core top).

Hoeglundina sp. Hoeglundina is a shallow infaunal foraminifer found in the highest abundances between a depth of 550 - 860 meters (Llano and Schmitt, 1967). They are an oxygen indicator and are typical of suboxic conditions (Kaiho, 1994). In addition, they show affinities to moderate (mesotrophic) to high (eutrophic) nutrient conditions (Schönfeld, 2001). Hoeglundina is a common genus found in the studied core. The abundance of Hoeglundina remains relatively consistent throughout the core, however, a notable decrease in specimen number can be seen between the 6-6.5 cm and the 2-2.5 cm assemblage (figure 7.21). This decrease in abundance may indicate low nutrient conditions, and higher dissolved oxygen content, which generally occur during cooler periods.

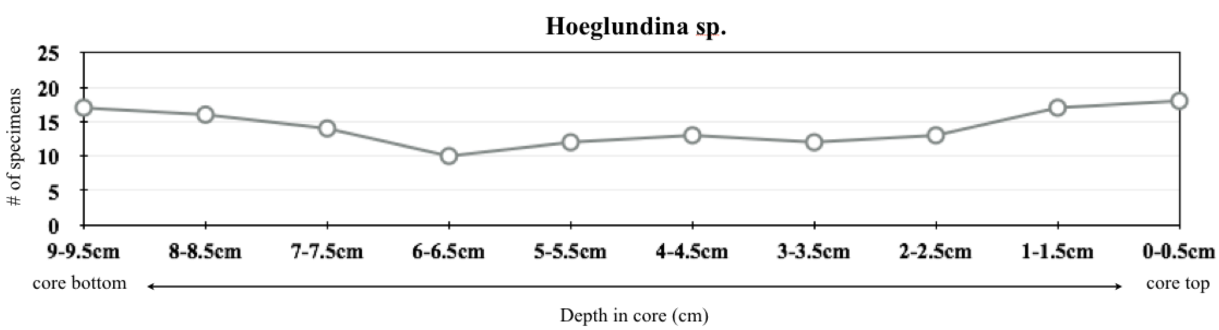

Fig. 7.21 Shows abundance (by # of specimens) of Hoeglundina sp. through time (from core bottom to core top).

Lagena sp. Lagena is an infaunal foraminifer (Murray, 1991). There is limited literature on Lagena's general ecology. Lagena sp. is not an abundant genus in this study (figure 7.22) and no conclusions can be made about its occurrence or ecological relationships.

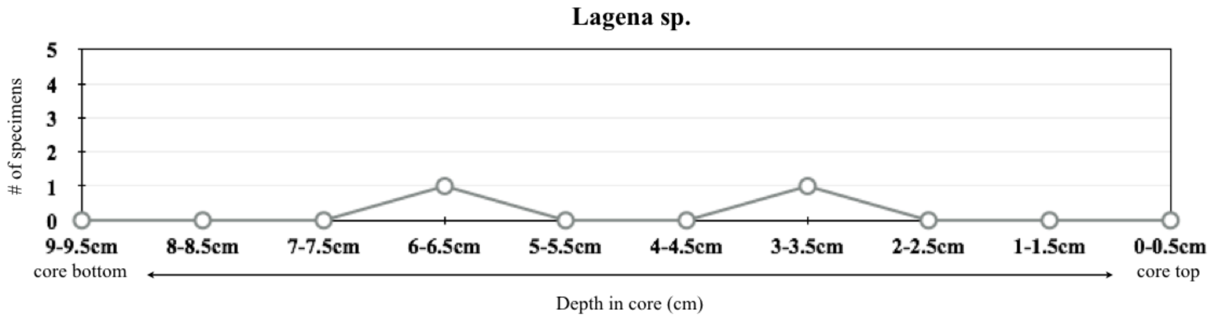

Fig. 7.22 Shows abundance (by # of specimens) of Lagena sp. through time (from core bottom to core top).

Melonis sp. The Melonis is an infaunal genus which feeds on buried organic detritus, and a typical open-sea form (Korsun and Hald, 1998). They have also been found to be common in seafloor depressions of the open Barents-Kara shelf, as well as on the continental slopes (Polyak, 2002). This genus tends to avoid areas with reduced bottom-water salinities, and are associated with normal salinity waters. Melonis are typically found in areas with absent or seasonal ice cover (Polyak, 2002). Melonis is a common genus in the studied core (figure 7.23). The highest abundances can be seen between the 5-5.5 and 3-3.5 cm assemblages. This may indicate normal salinity waters during this time (e.g.. water that are not influenced by freshwater input).

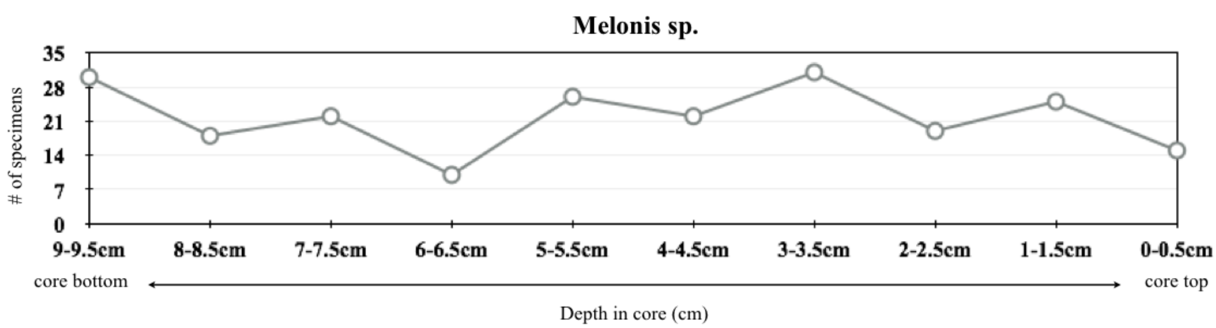

Fig. 7.23 Shows abundance (by # of specimens) of Melonis sp. through time (from core bottom to core top).

Nonionellina sp. Nonionellinas show a preference for fresh phytodetritus as a food source (Cedhagen, 1991), and live an infaunal life mode (Corliss, 1991; Corliss and Van Weering, 1993; Hunt and Corliss, 1993). This genus is best adapted to glacial-distal environments with seasonal productivity (seasonally ice free areas) (Polyak, 2002). Nonionellina is a rare genus in the studied core and only three specimens were collected. One specimen was found in each; the 9-9.5 cm, 3-3.5 cm; and 0-0.5 cm assemblage. The low abundance of this genus may be due to the preference for areas uninfluenced by glaciers. Due to the lack of specimens, no conclusions can be made about its occurrence or ecological relationships (figure 7.24).

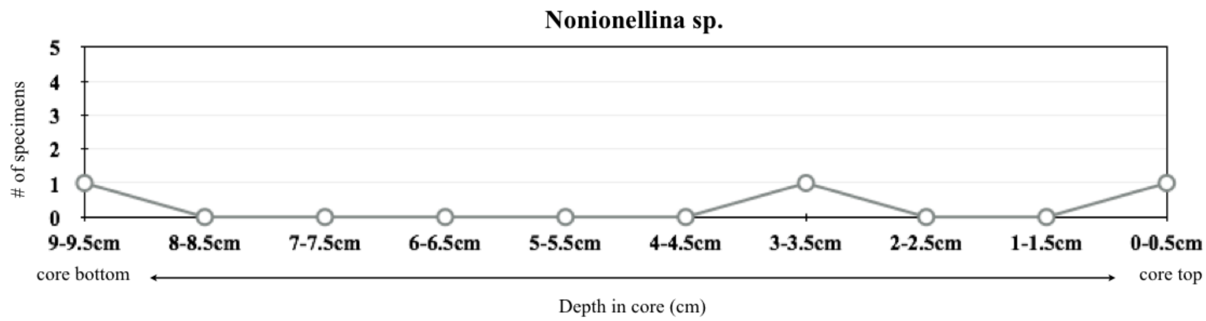

Fig. 7.24 Shows abundance (by # of specimens) of Nonionellina sp. through time (from core bottom to core top).

Oolina sp. Oolina is an infaunal foraminifer (Murray, 1991). There is limited literature on Oolina's general ecology. Oolina is a rare genus in this study. Specimens occur in the bottom and top of the core indicating that the top and bottom core environment may have been somewhat preferable to this genus and that these environments may have been similar. The genus is absent from 6-6.5 to 3-3.5 cm indicating that the environment was not congenial during this time (figure 7.25).

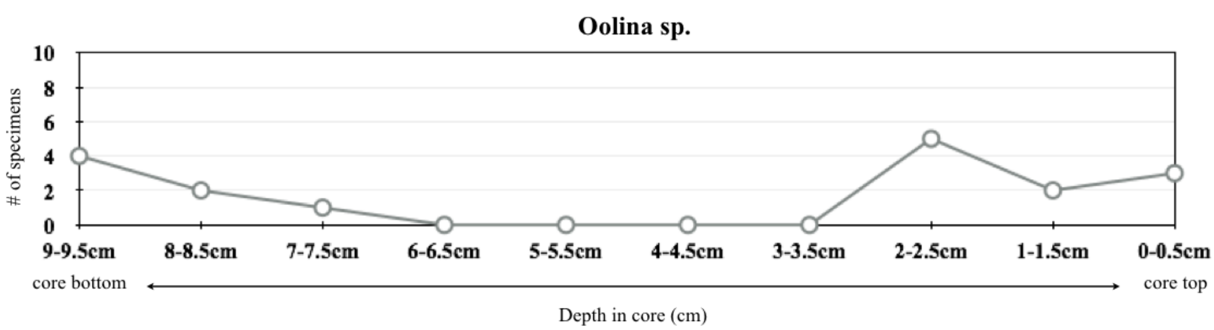

Fig. 7.25 Shows abundance (by # of specimens) of Oolina sp. through time (from core bottom to core top).

Pullenia sp. Pullenias are a shallow, infaunal taxa (Murray, 1991), and are a characteristic genus of the upper continental slope. This genus is associated with high fluxes of organic carbon and seasonally ice free areas (Mackensen et. al., 1985). The Pullenia genus is rare in the studied core. The abundance of this genus shows no clear trend and therefore no conclusions can be made about its occurrence or ecological relationships (figure 7.26).

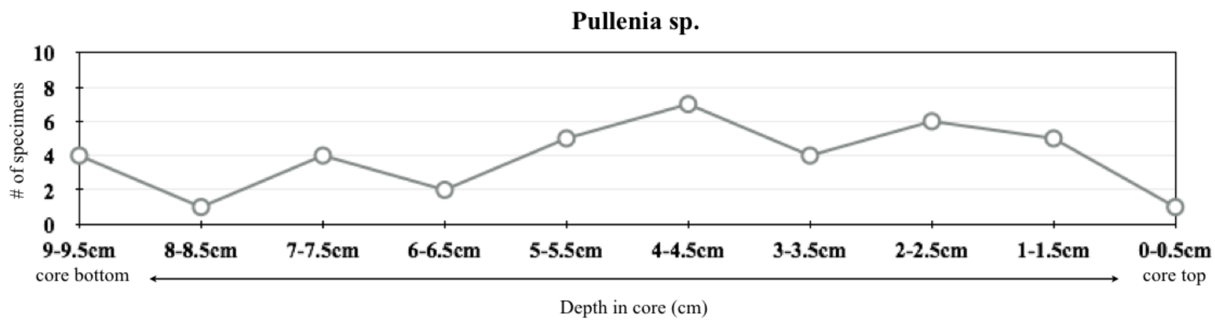

Fig. 7.26 Shows abundance (by # of specimens) of Pullenia sp. through time (from core bottom to core top).

Trifarina sp. Trifarinas prefer higher salinity waters (Möller et al., 2006). The occurrence a few specimens of Trifarina may indicate the influence of Atlantic water and is today found in the region influenced by Atlantic water off the coast of northwestern Norway (Hald and Steinsund, 1992; Möller et al., 2006). In the Barents Sea and on the Iceland shelf, this genus is abundant at relatively shallow water depths and in environments characterized by high seasonal biological productivity (Polyak, 2002). This genus is rare in the studied core. Although a general decreasing trend exists from the core bottom to core top, the lack of specimens does not allow for any conclusion regarding this genus to be made (figure 7.27).

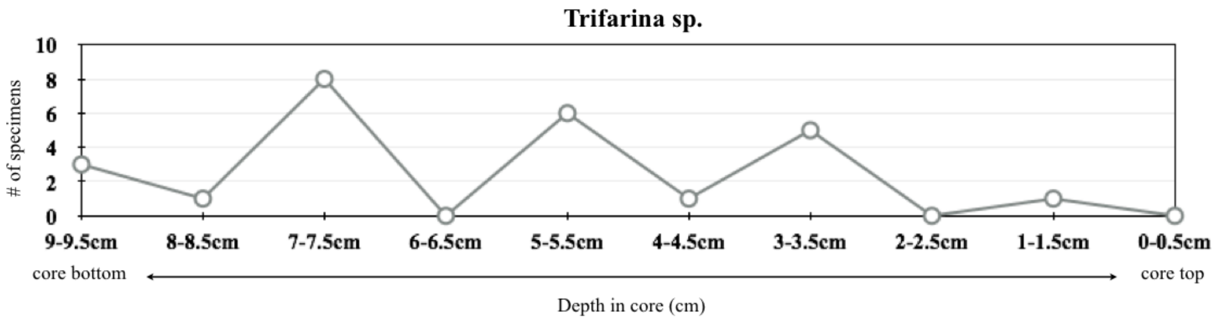

Fig. 7.27 Shows abundance (by # of specimens) of Trifarina sp. through time (from core bottom to core top).

Triloculina sp. Triloculinas are an epifaunal, deposit feeding foraminifer that are adapted to low fluxes of organic carbon (Murray, 1991). The Triloculina genus is rare in the studied core. There are a total of three specimens throughout, one in each of the following assemblages; 9-9.5 cm, 6-6.5 cm; and 4-4.5 cm. Due to the lack of specimens, no conclusion regarding this genus can be made (figure 7.28).

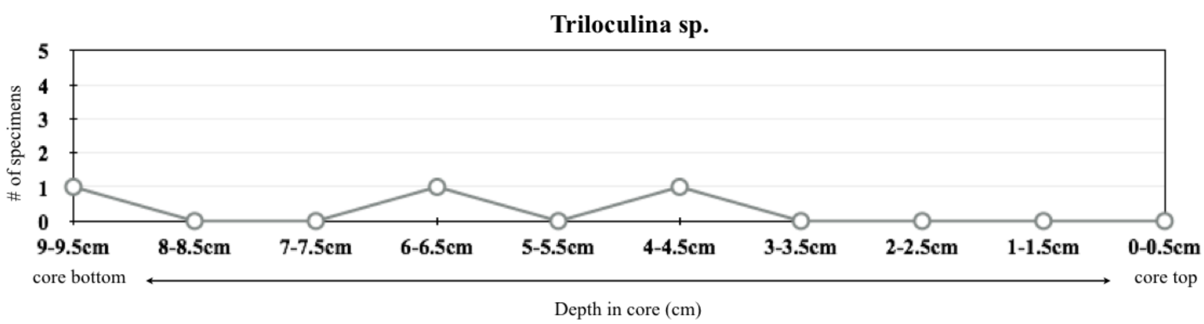

Fig. 7.28 Shows abundance (by # of specimens) of Triloculina sp. through time (from core bottom to core top).

Quinqueloculina sp. Quinqueloculina is an epifaunal genus (Murray, 1991), found in glacial marine environments (Korsun and Hald, 2000). No clear pattern can be recognized in the distribution of this genus possibly because of a combination of several individual ecological preferences; however, Quinqueloculina are typically found in shallow water (less than 50 meters) but are not excluded from a deeper habitat (Green, 1960). Quinqueloculina is the rarest genus, with only one specimen found throughout the core, occurring in the 2-2.5 assemblage. Due to the lack of specimens, no conclusion regarding this genus can be made. However, the low number of specimens is expected due to the fact that the water depth of the studied core is 447 meters (figure 7.29).

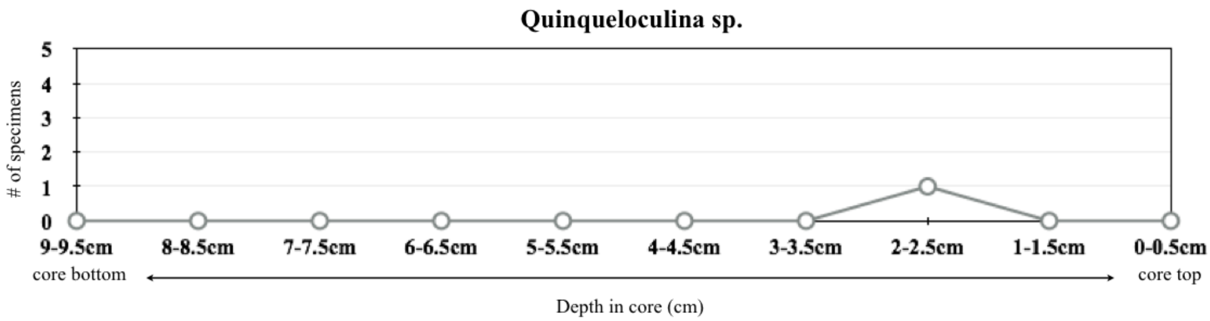

Fig. 7.29 Shows abundance (by # of specimens) of Quinqueloculina sp. through time (from core bottom to core top).

8. Implications and conclusion

8.1 Foraminiferal assemblages and environmental change

The most abundant genera (Cibicides, Elphidium, and Buccella) show considerable variability and trends over the core and therefore exhibit the greatest potential for the inference of environmental change.

Cibicides: As stated above, Cibicides rely on strong bottom currents causing the lateral advection of food supply, which make ideal living conditions for epibenthic living suspension feeders. Cibicides are also known to thrive in high stress environments and the high stress environment of this area may explain the dominance of specific genera. An increase in the level of environmental stress is generally considered to decrease species diversity, richness, and evenness. Furthermore, the Intermediate Disturbance Hypothesis suggests that maximum diversity occurs at intermediate levels of disturbance and decreases again at high levels of stress (as species are eliminated) (Lorenz, 2005). In general, Schonfeld, 2002 found that epifaunal species make up as much as 60% of assemblages at sites with high-current velocities and between 3-18% in areas with slower current velocities. The studied assemblages show a wide range of variation in percentage of epifaunal genera (Figures 8.1a and 8.1b). In general, a high percentage of epifaunal genera are seen in samples 1-4, inferring higher current velocities during this period. Subsequently the percent of epifaunal genera begins to decline, reaching the lowest point at assemblage 9, deducing weakening current velocities. Finally, from assemblage 9 to 10, the percent of epifaunal genera begins to increase, once again inferring a restrengthening in current velocity.

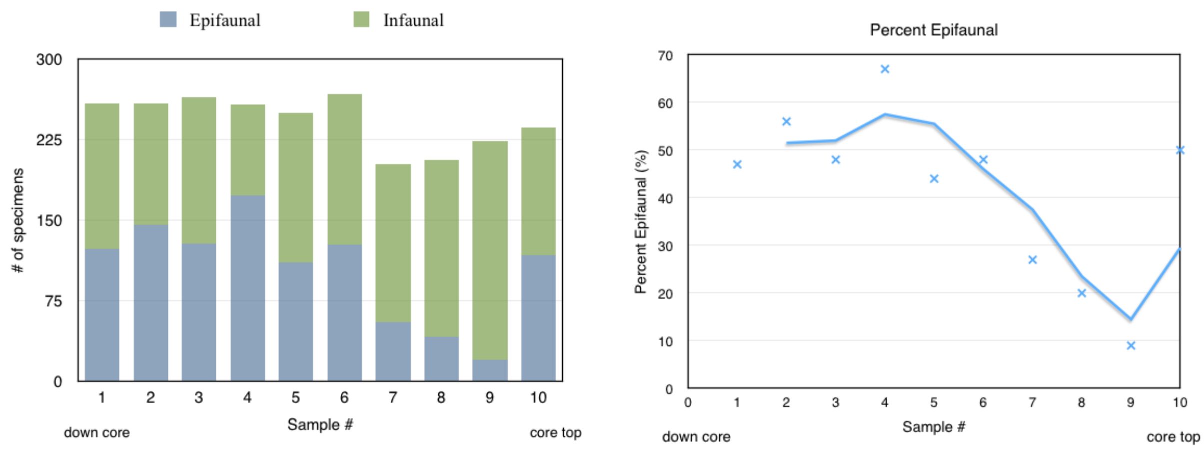

Fig 8.1a and 8.1b. Figure 8.1aa shows epifaunal and infaunal genera by # of specimens in each assemblage from down core to core top. Figure 8.1b shows the percentage of epifaunal specimens (moving average) found in each assemblage from down core to core top. Note that the semi-infaunal genera, Elphidium was not included due to its inconsistent mode of life.

During past glacials, as well as cooling periods, such as the LIA, current velocities are thought to have become weak(er) in the southern Denmark Strait. This slowdown would lead to the sedimentation of food particles rather than the lateral advection of food through higher velocity currents. Accordingly, during cooler periods, this region is more suitable for substrate than for suspension feeders (Lorenz, 2005). This trend is especially seen through the negative correlation in abundances of Cibicides and Elphidium/Buccella through the core (figure 8.2).

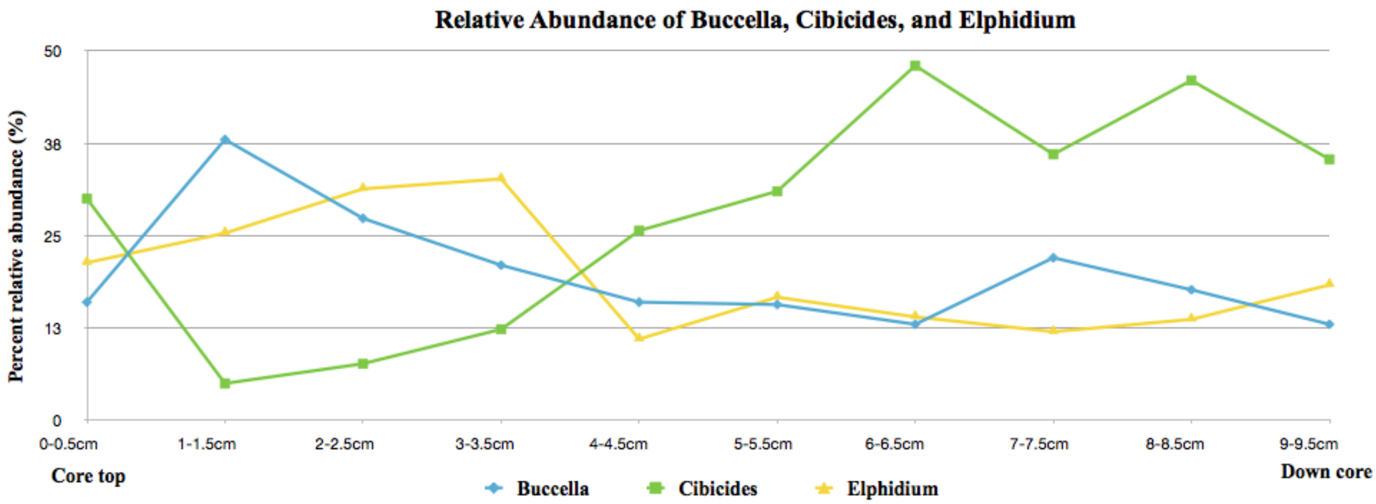

Fig. 8.2 Shows the relative abundance of the three abundant genera through time. A negative correlation in abundances of Cibicides vs. Elphidium/Buccella is seen, while a positive correlation between the abundance of Elphidium and Buccella is seen. (The correlation coefficient between Elphidium and Buccella is, r = 0.53, Buccella and Cibicides show a negative correlation of r = -0.77, and Elphidium and Cibicides show a negative correlation of r = -0.80).

The variability in the abundance of Cibicides throughout the core may indicate changes in current velocity over time, specifically the inflow of Atlantic surface waters and its impact on the formation of North Atlantic deep water. The core bottom (from 9-9.5 cm to 6-6.5 cm), where the highest abundances of Cibicides sp. are seen may indicate a period where current velocities were higher, due to increased inflow of Atlantic surface waters leading to high current velocities moving southward through the Denmark Strait. As stated above it is possible that this portion of the core coincides with the end of the Medieval Warm Period (MWP), which is associated with enhanced North Atlantic Ocean circulation. Subsequently, the abundance of Cibicides begins to decline rapidly (from 6-6.5 cm), indicating a slowing of current velocities, possibly due to meltwater influx from the MWP (as seen by the increasing abundance in Elphidium/Buccella). The low abundance assemblages from 5-5.5 cm to 1-1.5 cm indicate this area was not ideal for Cibicides during these periods. This indicates a transition into a colder period in which current velocities were low, an environment more preferable for substrate feeders. Cibicides is no longer the dominant genera during this interval and both Buccella sp.

and Elphidium sp. begin to increase in number during this interval. Both Buccella and Elphidium are infaunal substrate feeders. As stated above, it is possible that the lower abundance assemblages correspond to the the Little Ice Age (LIA) and a weakening of the convection of the ocean caused by a reduction in northward ocean heat transport. This may also explain the peak in abundance of Cassidulina sp. at 4-4.5 cm which infer a decreased meltwater flux, and higher salinity waters which correspond to cooler periods. The core top (0-0.5 cm) which is recent (estimated to be between 1954 and 1986), shows an increase in the abundance of Cibicides which can be interpreted a restrengthening of ocean convection and northward ocean heat transport in relation to the LIA.

The variability in abundance of Cibicides may also be related to the North Atlantic Oscillation (NAO) index and its impact on region. The North Atlantic Oscillation (NAO) is a recurrent pattern of atmospheric variability in the North Atlantic. Furthermore, the NAO is thought to strongly influence the deep and intermediate water formation in the North Atlantic (Dickson et al., 1996; Holfort and Albrecht, 2007). A positive NAO phase (high NAO index) indicates a larger pressure gradient and stronger wind stress over the North Atlantic, lower salinity Atlantic waters entering the Nordic seas, and therefore a decrease in subsurface salinity in the Nordic Seas (Dickson et al., 2003). Additionally, Blindheim et al., 2000 found that the inflow of Atlantic water in the Nordic Seas through the Faroe-Shetland Channel increases for positive NAO trends, yet, a suppression of strong deep water production in the Greenland Sea was also seen. Even so, a strong connection between the DSO and the NAO winter index is not obvious. Jochumsen et al., 2012 found that overflow transports above the mean sometimes coincide with positive NAO winter indices, while weaker transports always correspond to negative indices. However, a negative NAO index does not necessarily infer low overflow transports. Therefore, more data and studies are needed to verify if and how the overflow transport is linked to the NAO (Jochumsen et al., 2012).

Elphidium and Buccella: Elphidium and Buccella show similar trends throughout the core, having a correlation coefficient of $r = 0.53$. This may be due to their similar mode of life and feeding habits (semi-infaunal to infaunal substrate feeders). Both genera also thrive in river and glacier proximal environments, indicate meltwater influx, and are adapted to high variability in fluxes of food and sediment. Certain species within these genera may have supplementary apertures which are secondary openings in the test (in addition to the primary aperture) and allow for quick excretion and withdrawal of large volumes of cytoplasm for efficient capture and digestion of various food objects. The survival of these foraminifers may also be related to their increased mobility within the sediment that allows them to escape extreme freshening events by burrowing into the substrate (Brasier, 1995; Alexander and Banner, 1984; Polyak, 2002). Another important note is the increase in test size seem in Elphidium in samples 7 and 8 (assemblages 3-3.5 and 2-2.5 cm). During these periods the overall abundance of Elphidium is high further indicating that the environment was ideal for this genus. It had been shown that growth rates and test size are influenced by temperature, salinity, and food supply (Bradshaw, 1961), and may also correlate with oxygen content (Kaiho, 1994). Correspondingly, a reduced test size has been shown to occur in stressed environments (Coccioni, 2000; Geslin et al. 2000).

In order to verify the connection between foraminiferal assemblages seen in this study and inferred environmental change, another aging method (such as radiocarbon dating) must be used in order to further narrow down the time frame of the sediments. In addition, it would be beneficial to look at multiple other cores in the region to compare the trends seen in foraminiferal assemblages.

8.2 Assemblage Analysis

The analysis of foraminiferal assemblages are based on the quantitative and qualitative analysis of communities within each sample. As stated earlier, each species of foraminifer has certain environmental preferences. By summarizing the preferences of each genus, it is possible to define an ecological window for the considered characteristic. However, it is important to note that ecological preferences are inferred from empirical data on living specimens and thus this study assumes that the studied taxa preferred the same or equivalent environments in the past. Although, community change can only be established through controlled experiments, inferences may be drawn from relationships between assemblage patterns and environmental conditions. Additionally, in this study, in order to note changes in the environment, ten discrete samples were analyzed over one profile for faunal distributions to put these ecological factors in temporal context. In order to put these factors in spatial context more cores in the region would need to be analyzed. It is also important to note that a potential issue in assemblage analysis is the difficult distinction between seasonal natural variability and environmental change. Another factor that may lead to a misinterpretation of the environment is the influx and redeposition of already dead foraminifera (called ghost-communities). Even though the velocity of bottom currents are much higher in the southern portion of the Denmark Strait as compared with the northern areas, a portion of the foraminifera identified in the studied core may have been transported there passively as already dead individuals by bottom currents. However, some genera are able to resist high current velocities by attaching themselves to substrate, via burial, or by burrowing (Alve, 1999; Lorenz, 2005). Lastly, the univariate (single variable) methods used to evaluate diversity are helpful for a first approach in comparing faunal assemblages. However, they are based on particular genus identities, and therefore two samples could have the same diversity, but without having any genera in common (Lorenz, 2005). Therefore, multivariate methods of quantitative analysis may be helpful in further analysis of the faunal assemblages.

8.3 Future implications

Due to anthropogenic climate change, the arctic and subarctic regions are undergoing rapid changes. These changes include warming of the ocean and atmosphere, a decline in sea ice extent (Serreze, Holland and Stroeve, 2007), an increase in the length of the sea ice free season, and increased mass loss from the Greenland ice sheet (Arctic.noaa.gov, 2015). Furthermore, global climate models (GCMs) postulate that this region will experience the strongest temperature increases in the future due to polar amplification (IPCC, 2007). The future development of the Arctic will have significant effects both on oceanic circulation and climate (Cattle and Crossley, 1995). More studies are needed in order to better predict this future behavior, including paleoenvironmental investigations that yield improved insight into past climate variability and the evolution of the arctic climate system. Hence, more knowledge of how polar foraminiferal assemblages responded to past climate variability is of great importance in predicting future changes.

Foraminiferal assemblages may reflect the current changes in meltwater discharge from glacial and riverine input, as well as fluxes in salinity. A warming Arctic region results in more meltwater discharge and, as a result, the fauna may become 'more glacially-influenced.' This may be seen in foraminiferal assemblages as a decline in taxa preferring glacial-distal environment and an increase in taxa preferring a glacial-proximal environment. The impact on salinity is particularly strong on the shelves where large amounts of fresh water are discharged each summer from deglacial and riverine sources (Bauch et al., 2004). Applying this conclusion to present and future foraminiferal assemblages, a transition from an ice distal to an ice proximal foraminiferal assemblage may be seen, reflecting the increased meltwater production and an unstable ice front (Korson, 2000).

Low salinity surface waters exported from the Arctic Ocean, as well as freshwater influx from the GIS will also have an effect on the formation of North Atlantic Deep Water which ventilates the World Ocean (Aagard and Carmack, 1994; Polyak, 2002). Arctic riverine and glacial inputs play a critical role not only in high latitude systems, but also the climatic system through controls on sea-ice coverage and water mass exchange (Driscoll and Haug, 1998; Polyak, 2002). Recent studies have shown that the density of the DSO has diminished by about 0.02 percent over the past 40 years due to a 0.035 salinity decrease (Dickson et al. 2002). This freshening may be seen through changes in foraminiferal assemblages. Additionally, due to warming in the Arctic, the sea-ice melt season is also lengthening at both ends, with an earlier melt onset in the Spring and a later freeze-up in the Fall. The predominant phenomenon extending the melting is the later start of the freeze season. This in turn, affects the amount of solar radiation absorbed by the ocean, as well as rates of primary productivity, which has direct effects on benthic foraminiferal communities. By understanding how foraminiferal assemblages have reacted to a warming climate in the past, we may be able to better predict the future by looking at current assemblages.

8.4 Conclusion and future work

Three thousand calcareous foraminifera were identified and quantified in ten discrete samples from 0-9.5 cm of a sediment core from the Denmark Strait region. The utility of faunal abundance and variability were assessed as indicators of climate fluctuations in the region. It is clear that the abundant genera of the studied core have shown significant variability in abundance through time. The variability in Cibicides, Elphidium, and Buccella, provides evidence for a change from a warmer climate with stronger current velocities and meltwater influx (likely the Medieval Warm Periods) to a cooler climate (most likely the Little Ice age) with slower current velocities and less meltwater influx, and finally to our present day situation in which the climate is warming due to anthropogenic impacts. In order to verify the connection between the variability in foraminiferal assemblages seen in this study and inferred environmental change, the following is needed (1) another aging method (such as radiocarbon dating) must be used in order to further narrow down the time frame in which the sediments were deposited, (2) a further investigation of multiple other cores in the region to compare the foraminiferal assemblages and trends seen over a comparable time frame, and lastly, (3) foraminifera could be identified down to the species level in order to further specify ecological characterization. Although more work needs to be done, it is clear that benthic foraminifera respond to changing climate conditions and are valuable proxies for environmental change in the Denmark Strait region.

8.5 Study in context

Much has been explored on the ecology and application of benthic foraminifera. However, to our knowledge, there have been limited ecological studies of benthic foraminifera in the high latitudes. More studies are needed in order to link high latitude assemblages to specific environments and environmental change especially through the Holocene. This section will briefly summarize selected studies in an attempt to put our study in context and to highlight its potential contribution.

Lorenz (2005) looked at and compared modern faunal assemblages of living and dead benthic foraminifera north and south of the Denmark Strait between a 980 and 2,564 meter water depth. Similarly to our study, Lorenz found high abundances of calcareous foraminifera south of the sill, due to strong bottom currents and low carbonate dissolution rates. In addition, mainly agglutinated species were found north of the sill because of week bottom currents and higher carbonate dissolution rates. Again in agreement with our study, southern cores showed a large portion of epifaunal species living as suspension feeders, indicating the lateral advection of food particles. In contrast, substrate feeders dominated in the northern stations where current velocities are slower and sedimentation of food particles occurs. Therefore, it would be beneficial to further explore the role of current velocities in dictating foraminiferal assemblages and diversity in this region.

Seasonal dynamics of modern polar benthic foraminifera have also been studied. For example, Korson (2000) found that foraminiferal faunas were more diverse in winter and that the decrease in diversity during summer melting may be explained by a seasonal rise in sedimentation causing ecological stress. Correspondingly, this study also found a clear distinction between glacial proximal and glacial distal species.

In addition to modern studies, paleoclimate investigations carried out on benthic, calcareous foraminifera have also lead to interesting and significant findings. Benthic foraminifera found in sediment cores from the Nordic seas have shown glacial to interglacial contrasts in studied assemblages (Schäfer et al., 2012; Kellogg, 1977; Streeter et al., 1982), as well as the ability to reflect surface ocean productivity. Additionally, the total abundance of benthic foraminifera has been shown to be substantially reduced during glacial periods in comparison with interglacials (Struck, 1997). Furthermore, benthic foraminifera from the Arctic and subarctic regions have shown high preservation potential, which makes them optimal for paleoclimate research. Planktonic foraminifera have also been used to study changes in both the physical and chemical characteristics of the ocean.

Although many previous studies have looked at both modern and past benthic foraminifera in an attempt to link assemblages to specific environments and environmental change, more work needs to be done, as benthic foraminifera have great potential in helping to predict future change, especially in the Arctic and subarctic regions.

Acknowledgements

Many beautiful people supported and guided me during my Masters studies, thus giving me the opportunity to complete this thesis. Firstly, I would like to thank my faculty committee members including Dr. Kimberly Meehan, Dr. Marco Tedesco, and Dr. Steven Kidder. I am extremely grateful for their ongoing support. Specifically, I would like to thank Dr. Kimberly Meehan for her exceptional guidance, patience and time, as well as her constructive support, humor, and positive vibes. I would like to thank Dr. Marco Tedesco for much needed financial support during my masters studies, the opportunity to join the Cryospheric Processes Laboratory at CCNY where I grew immensely both professionally and personally, and the chance to attend professional meeting such as the annual American Geophysical Union (AGU) meeting as well as fieldwork and instrument training trips. I would like to thank Dr. Steven Kidder for his support, advice, guidance, and kindness through this study.

I would also like to express my deepest gratitude to all of my colleagues in the Cryospheric Processes Laboratory; Dr. Patrick Alexander, Dr. Erik Noble, Rajashree Datta, Jeyavinoth Jeyaratnam, Mattia Sartori, Michael Brown, Erik Orantes, and Corinne Benedict. In addition to the support, assistance, and exciting scientific discussions they have provided, I am very lucky to call them friends.

Moreover, I would like to thank the experiment.com team for their important work toward the public funding and sharing of science. Experiment.com and fifty-eight project backers, including friends, family, colleagues, and others allowed for the funding of $3,050 toward necessary laboratory analysis for this research. In particular, I would like to thank my largest backer, Joshua Wolfe and the Skypunch creative team for their support and flexibility.

I would like to thank the Lamont Doherty Core Repository at Columbia University for the sediment samples and Steven Pike at Cafe Thorium at the Woods Hole Oceanographic Institution for carrying out the radioactive isotope analysis.

I would also like to thank the American Museum of Natural History for the use of their Microscopy and Imaging facilities. In particular I would like to thank Bushra Hussaini for her kindness, guidance, and encouragement when I needed it the most.

Finally, I thank my family; Kathy, John, Brittany, and Oliver Larocca, and my partner Ben Phillips for their continuous love and support.

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Appendix

Sample #	Sample Name	Sample IGSN	Depth in Core Min (cm)	Depth in Core Max (cm)	Parent IGSN	Size (cc)	Wet Weight (grams)	Collection date
10	KN158-4-67GC_0cm	DSR000DKE	0	0.5	DSR00031B	10	14.16	2015-10-06
9	KN158-4-67GC_1cm	DSR000DKF	1	1.5	DSR00031B	10	11.66	2015-10-06
8	KN158-4-67GC_2cm	DSR000DKG	2	2.5	DSR00031B	10	16.40	2015-10-06
7	KN158-4-67GC_3cm	DSR000DKH	3	3.5	DSR00031B	10	9/01	2015-10-06
6	KN158-4-67GC_4cm	DSR000DKI	4	4.5	DSR00031B	10	11.70	2015-10-06
5	KN158-4-67GC_5cm	DSR000DKJ	5	5.5	DSR00031B	10	9.00	2015-10-06
4	KN158-4-67GC_6cm	DSR000DKK	6	6.5	DSR00031B	10	11.98	2015-10-06
3	KN158-4-67GC_7cm	DSR000DKL	7	7.5	DSR00031B	10	12.92	2015-10-06
2	KN158-4-67GC_8cm	DSR000DKM	8	8.5	DSR00031B	10	11.70	2015-10-06
1	KN158-4-67GC_9cm	DSR000DKN	9	9.5	DSR00031B	10	14.51	2015-10-06

Table A.1 Preliminary core and sample data including the sample number and name, the given International GeoSample Number (ISGN), sample intervals (minimum and maximum depth in core), the parent core ISGN, the sample size, wet weight, and collection date. Note: The IGSN or International GeoSample Number is a 9-character alphanumeric code that is assigned to samples in order to ensure their unique identification and unambiguous referencing of data generated by the study of samples.

Fig. A.1 Sediment core, KN158-4-67GC before sampling. Samples were taken in discreet 1.0 cm intervals from 0-10 cm.

		no decay		collect	
sample #	cm down core	210 Pb total (Bq/g)	+/-	210Pb^ex (Bq/g)	+/-
10	0 - 0.5	0.107	0.007	0.138	0.007
8	2 - 2.5	0.024	0.004	0.005	0.004
6	4 - 4.5	0.009	0.003	-0.014	0.003
4	6 - 6.5	0.010	0.003	-0.012	0.003
2	8 - 8.5	0.018	0.003	0.004	0.003

Table A.2 Shows laboratory results of measured ^{210}Pb. The average ^{210}Pb total is 0.015 Bq/g and the standard deviation is 0.007. Note: One becquerel is defined as the activity of a quantity of radioactive material in which one nucleus decays per second.

		Collect	
sample #	cm down core	137 Cs total (Bq/gm)	% error
10	0 - 0.5	0.0007	6.48
8	2 - 2.5	not detectable	—
6	4 - 4.5	not detectable	—
4	6 - 6.5	not detectable	—
2	8 - 8.5	not detectable	—

Table A.3 Shows laboratory results of measured ^{137}Cs.

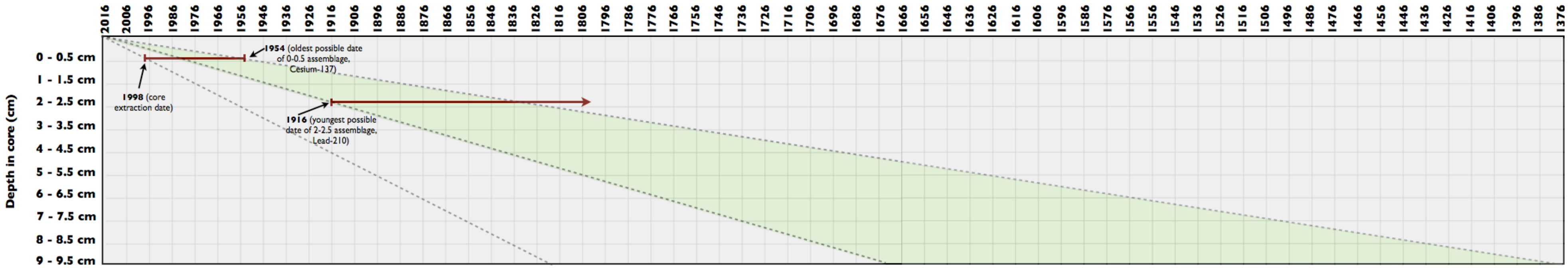


Fig. A.2 Shows linearly extrapolated ages based on Lead-210 and Cesium-137 dating.

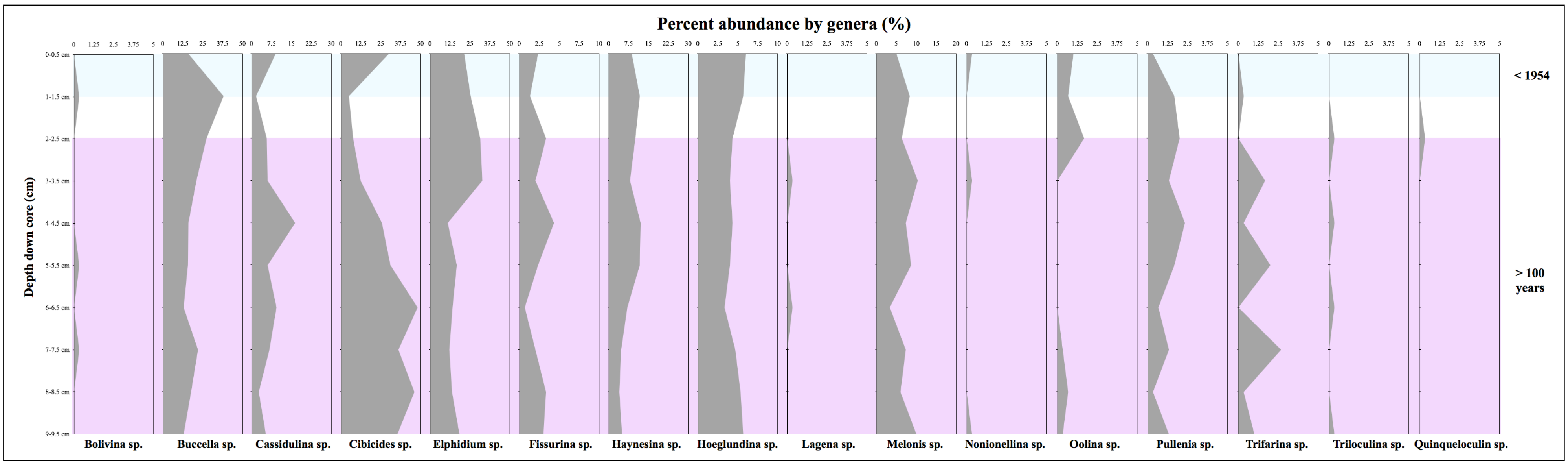


Fig. A.3 Shows the relative abundance of all 16 genera down core from 0-9.5 cm. The blue upper blue portion shows sediment that is younger than the year 1954, and the purple potion shows sediment that is greater than 100 years old. Note: The relative abundance of a genera in a sample can be defined as the percentage of the genera in relation to all the other counted specimens in the sample.

Table A.4 Sample #1: 9-9.5 cm

AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus
105626	1	Cibicides sp.	**105627**	1	Cibicides sp.	**105628**	1	Buccella sp.	**105629**	1	Melonis sp.	**105630**	1	Haynesina sp.
	2	Cibicides sp.		2	Cibicides sp.		2	Buccella sp.		2	Melonis sp.		2	Melonis sp.
	3	Cibicides sp.		3	Cibicides sp.		3	Buccella sp.		3	Melonis sp.		3	Elphidium sp.
	4	Cibicides sp.		4	Cibicides sp.		4	Buccella sp.		4	Melonis sp.		4	Haynesina sp.
	5	Cibicides sp.		5	Cibicides sp.		5	Buccella sp.		5	Melonis sp.		5	Elphidium sp.
	6	Cibicides sp.		6	Cibicides sp.		6	Buccella sp.		6	Melonis sp.		6	Elphidium sp.
	7	Cibicides sp.		7	Cibicides sp.		7	Buccella sp.		7	Melonis sp.		7	Elphidium sp.
	8	Cibicides sp.		8	Cibicides sp.		8	Buccella sp.		8	Melonis sp.		8	Elphidium sp.
	9	Cibicides sp.		9	Cibicides sp.		9	Buccella sp.		9	Melonis sp.		9	Elphidium sp.
	10	Cibicides sp.		10	Cibicides sp.		10	Buccella sp.		10	Melonis sp.		10	Haynesina sp.
	11	Cibicides sp.		11	Cibicides sp.		11	Buccella sp.		11	Melonis sp.		11	Haynesina sp.
	12	Cibicides sp.		12	Cibicides sp.		12	Buccella sp.		12	Melonis sp.		12	Elphidium sp.
	13	Cibicides sp.		13	Cibicides sp.		13	Buccella sp.		13	Melonis sp.		13	Elphidium sp.
	14	Cibicides sp.		14	Cibicides sp.		14	Buccella sp.		14	Melonis sp.		14	Elphidium sp.
	15	Cibicides sp.		15	Cibicides sp.		15	Buccella sp.		15	Melonis sp.		15	Elphidium sp.
	16	Cibicides sp.		16	Cibicides sp.		16	Buccella sp.		16	Haynesina sp.		16	Elphidium sp.
	17	Cibicides sp.		17	Cibicides sp.		17	Buccella sp.		17	Haynesina sp.		17	Elphidium sp.
	18	Cibicides sp.		18	Cibicides sp.		18	Hoeglundina sp.		18	Elphidium sp.		18	Elphidium sp.
	19	Cibicides sp.		19	Cibicides sp.		19	Hoeglundina sp.		19	Haynesina sp.		19	Elphidium sp.
	20	Cibicides sp.		20	Cibicides sp.		20	Hoeglundina sp.		20	Elphidium sp.		20	Haynesina sp.
	21	Cibicides sp.		21	Cibicides sp.		21	Hoeglundina sp.		21	Elphidium sp.		21	Elphidium sp.
	22	Cibicides sp.		22	Cibicides sp.		22	Hoeglundina sp.		22	Elphidium sp.		22	Elphidium sp.
	23	Cibicides sp.		23	Cibicides sp.		23	Hoeglundina sp.		23	Elphidium sp.		23	Triloculina sp.
	24	Cibicides sp.		24	Cibicides sp.		24	Hoeglundina sp.		24	Elphidium sp.		24	Fissurina sp.
	25	Cibicides sp.		25	Cibicides sp.		25	Hoeglundina sp.		25	Elphidium sp.		25	Fissurina sp.
	26	Cibicides sp.		26	Cibicides sp.		26	Hoeglundina sp.		26	Elphidium sp.		26	Fissurina sp.
	27	Cibicides sp.		27	Cibicides sp.		27	Hoeglundina sp.		27	Elphidium sp.		27	Fissurina sp.
	28	Cibicides sp.		28	Cibicides sp.		28	Hoeglundina sp.		28	Elphidium sp.		28	Fissurina sp.
	29	Cibicides sp.		29	Cibicides sp.		29	Hoeglundina sp.		29	Elphidium sp.		29	Fissurina sp.
	30	Cibicides sp.		30	Cibicides sp.		30	Hoeglundina sp.		30	Elphidium sp.		30	Fissurina sp.
	31	Cibicides sp.		31	Cibicides sp.		31	Hoeglundina sp.		31	Haynesina sp.		31	Fissurina sp.
	32	Cibicides sp.		32	Cibicides sp.		32	Hoeglundina sp.		32	Elphidium sp.		32	Fissurina sp.
	33	Cibicides sp.		33	Cibicides sp.		33	Hoeglundina sp.		33	Elphidium sp.		33	Pullenia sp.
	34	Cibicides sp.		34	Cibicides sp.		34	Hoeglundina sp.		34	Haynesina sp.		34	Pullenia sp.
	35	Cibicides sp.		35	Cibicides sp.		35	Cassidulina sp.		35	Elphidium sp.		35	Pullenia sp.
	36	Cibicides sp.		36	Cibicides sp.		36	Cassidulina sp.		36	Haynesina sp.		36	Pullenia sp.
	37	Cibicides sp.		37	Cibicides sp.		37	Cassidulina sp.		37	Elphidium sp.		37	Nonionellina
	38	Cibicides sp.		38	Cibicides sp.		38	Cassidulina sp.		38	Elphidium sp.		38	Trifarina sp.
	39	Cibicides sp.		39	Cibicides sp.		39	Cassidulina sp.		39	Elphidium sp.		39	Trifarina sp.
	40	Cibicides sp.		40	Cibicides sp.		40	Cassidulina sp.		40	Elphidium sp.		40	Trifarina sp.
	41	Cibicides sp.		41	Cibicides sp.		41	Cassidulina sp.		41	Elphidium sp.		41	Oolina sp.
	42	Cibicides sp.		42	Cibicides sp.		42	Cassidulina sp.		42	Elphidium sp.		42	Oolina sp.
	43	Cibicides sp.		43	Buccella sp.		43	Cassidulina sp.		43	Elphidium sp.		43	Oolina sp.
	44	Cibicides sp.		44	Buccella sp.		44	Cassidulina sp.		44	Elphidium sp.		44	Oolina sp.
	45	Cibicides sp.		45	Buccella sp.		45	Cassidulina sp.		45	Elphidium sp.			
	46	Cibicides sp.		46	Buccella sp.		46	Cassidulina sp.		46	Elphidium sp.			
	47	Cibicides sp.		47	Buccella sp.		47	Cassidulina sp.		47	Elphidium sp.			
	48	Cibicides sp.		48	Buccella sp.		48	Cassidulina sp.		48	Elphidium sp.			
	49	Cibicides sp.		49	Buccella sp.		49	Cassidulina sp.		49	Elphidium sp.			
	50	Cibicides sp.		50	Buccella sp.		50	Cassidulina sp.		50	Elphidium sp.			
	51	Cibicides sp.		51	Buccella sp.		51	Melonis sp.		51	Elphidium sp.			
	52	Cibicides sp.		52	Buccella sp.		52	Melonis sp.		52	Elphidium sp.			
	53	Cibicides sp.		53	Buccella sp.		53	Melonis sp.		53	Elphidium sp.			
	54	Cibicides sp.		54	Buccella sp.		54	Melonis sp.		54	Haynesina sp.			
	55	Cibicides sp.		55	Buccella sp.		55	Melonis sp.		55	Elphidium sp.			
	56	Cibicides sp.		56	Buccella sp.		56	Melonis sp.		56	Elphidium sp.			
	57	Cibicides sp.		57	Buccella sp.		57	Melonis sp.		57	Haynesina sp.			
	58	Cibicides sp.		58	Buccella sp.		58	Melonis sp.		58	Elphidium sp.			
	59	Cibicides sp.		59	Buccella sp.		59	Melonis sp.		59	Elphidium sp.			
	60	Cibicides sp.		60	Buccella sp.		60	Melonis sp.		60	Elphidium sp.			
	61	Cibicides sp.		61	Buccella sp.		61	Melonis sp.		61	Elphidium sp.			
	62	Cibicides sp.		62	Buccella sp.		62	Melonis sp.		62	Haynesina sp.			
	63	Cibicides sp.		63	Buccella sp.		63	Melonis sp.		63	Haynesina sp.			
	64	Cibicides sp.		64	Buccella sp.		64	Melonis sp.		64	Elphidium sp.			

Table A.5 Sample #2: 8-8.5 cm

AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus
105631	1	Cibicides sp.	**105632**	1	Cibicides sp.	**105633**	1	Cibicides sp.	**105634**	1	Cassidulina sp.	**105635**	1	Elphidium sp.
	2	Cibicides sp.		2	Cibicides sp.		2	Cibicides sp.		2	Cassidulina sp.		2	Elphidium sp.
	3	Cibicides sp.		3	Cibicides sp.		3	Cibicides sp.		3	Cassidulina sp.		3	Elphidium sp.
	4	Cibicides sp.		4	Cibicides sp.		4	Cibicides sp.		4	Cassidulina sp.		4	Elphidium sp.
	5	Cibicides sp.		5	Cibicides sp.		5	Buccella sp.		5	Cassidulina sp.		5	Elphidium sp.
	6	Cibicides sp.		6	Cibicides sp.		6	Buccella sp.		6	Cassidulina sp.		6	Elphidium sp.
	7	Cibicides sp.		7	Cibicides sp.		7	Buccella sp.		7	Melonis sp.		7	Elphidium sp.
	8	Cibicides sp.		8	Cibicides sp.		8	Buccella sp.		8	Melonis sp.		8	Elphidium sp.
	9	Cibicides sp.		9	Cibicides sp.		9	Buccella sp.		9	Melonis sp.		9	Elphidium sp.
	10	Cibicides sp.		10	Cibicides sp.		10	Buccella sp.		10	Melonis sp.		10	Fissurina sp.
	11	Cibicides sp.		11	Cibicides sp.		11	Buccella sp.		11	Melonis sp.		11	Fissurina sp.
	12	Cibicides sp.		12	Cibicides sp.		12	Buccella sp.		12	Melonis sp.		12	Fissurina sp.
	13	Cibicides sp.		13	Cibicides sp.		13	Buccella sp.		13	Melonis sp.		13	Fissurina sp.
	14	Cibicides sp.		14	Cibicides sp.		14	Buccella sp.		14	Melonis sp.		14	Fissurina sp.
	15	Cibicides sp.		15	Cibicides sp.		15	Buccella sp.		15	Melonis sp.		15	Fissurina sp.
	16	Cibicides sp.		16	Cibicides sp.		16	Buccella sp.		16	Melonis sp.		16	Fissurina sp.
	17	Cibicides sp.		17	Cibicides sp.		17	Buccella sp.		17	Melonis sp.		17	Fissurina sp.
	18	Cibicides sp.		18	Cibicides sp.		18	Buccella sp.		18	Melonis sp.		18	Fissurina sp.
	19	Cibicides sp.		19	Cibicides sp.		19	Buccella sp.		19	Melonis sp.		19	Fissurina sp.
	20	Cibicides sp.		20	Cibicides sp.		20	Buccella sp.		20	Melonis sp.		20	Pullenia sp.
	21	Cibicides sp.		21	Cibicides sp.		21	Buccella sp.		21	Melonis sp.		21	Oolina sp.
	22	Cibicides sp.		22	Cibicides sp.		22	Buccella sp.		22	Haynesina sp.		22	Trifarina sp.
	23	Cibicides sp.		23	Cibicides sp.		23	Buccella sp.		23	Haynesina sp.		23	Melonis sp.
	24	Cibicides sp.		24	Cibicides sp.		24	Buccella sp.		24	Haynesina sp.		24	Melonis sp.
	25	Cibicides sp.		25	Cibicides sp.		25	Buccella sp.		25	Haynesina sp.		25	Buccella sp.
	26	Cibicides sp.		26	Cibicides sp.		26	Buccella sp.		26	Haynesina sp.		26	Buccella sp.
	27	Cibicides sp.		27	Cibicides sp.		27	Buccella sp.		27	Haynesina sp.		27	Buccella sp.
	28	Cibicides sp.		28	Cibicides sp.		28	Buccella sp.		28	Haynesina sp.		28	Buccella sp.
	29	Cibicides sp.		29	Cibicides sp.		29	Buccella sp.		29	Haynesina sp.		29	Buccella sp.
	30	Cibicides sp.		30	Cibicides sp.		30	Buccella sp.		30	Haynesina sp.		30	Hoeglundina sp.
	31	Cibicides sp.		31	Cibicides sp.		31	Buccella sp.		31	Haynesina sp.		31	Hoeglundina sp.
	32	Cibicides sp.		32	Cibicides sp.		32	Buccella sp.		32	Haynesina sp.		32	Cibicides sp.
	33	Cibicides sp.		33	Cibicides sp.		33	Buccella sp.		33	Haynesina sp.		33	Cibicides sp.
	34	Cibicides sp.		34	Cibicides sp.		34	Buccella sp.		34	Elphidium sp.		34	Cibicides sp.
	35	Cibicides sp.		35	Cibicides sp.		35	Buccella sp.		35	Elphidium sp.		35	Melonis sp.
	36	Cibicides sp.		36	Cibicides sp.		36	Buccella sp.		36	Elphidium sp.		36	Cassidulina sp.
	37	Cibicides sp.		37	Cibicides sp.		37	Buccella sp.		37	Elphidium sp.		37	Cassidulina sp.
	38	Cibicides sp.		38	Cibicides sp.		38	Buccella sp.		38	Elphidium sp.		38	Hoeglundina sp.
	39	Cibicides sp.		39	Cibicides sp.		39	Buccella sp.		39	Elphidium sp.		39	Hoeglundina sp.
	40	Cibicides sp.		40	Cibicides sp.		40	Buccella sp.		40	Elphidium sp.		40	Elphidium sp.
	41	Cibicides sp.		41	Cibicides sp.		41	Buccella sp.		41	Elphidium sp.		41	Cibicides sp.
	42	Cibicides sp.		42	Cibicides sp.		42	Buccella sp.		42	Elphidium sp.		42	Cibicides sp.
	43	Cibicides sp.		43	Cibicides sp.		43	Buccella sp.		43	Elphidium sp.		43	Oolina sp.
	44	Cibicides sp.		44	Cibicides sp.		44	Buccella sp.		44	Elphidium sp.		44	Cibicides sp.
	45	Cibicides sp.		45	Cibicides sp.		45	Buccella sp.		45	Elphidium sp.			
	46	Cibicides sp.		46	Cibicides sp.		46	Buccella sp.		46	Elphidium sp.			
	47	Cibicides sp.		47	Cibicides sp.		47	Buccella sp.		47	Elphidium sp.			
	48	Cibicides sp.		48	Cibicides sp.		48	Buccella sp.		48	Elphidium sp.			
	49	Cibicides sp.		49	Cibicides sp.		49	Buccella sp.		49	Elphidium sp.			
	50	Cibicides sp.		50	Cibicides sp.		50	Buccella sp.		50	Elphidium sp.			
	51	Cibicides sp.		51	Cibicides sp.		51	Buccella sp.		51	Elphidium sp.			
	52	Cibicides sp.		52	Cibicides sp.		52	Buccella sp.		52	Elphidium sp.			
	53	Cibicides sp.		53	Cibicides sp.		53	Hoeglundina sp.		53	Elphidium sp.			
	54	Cibicides sp.		54	Cibicides sp.		54	Hoeglundina sp.		54	Elphidium sp.			
	55	Cibicides sp.		55	Cibicides sp.		55	Hoeglundina sp.		55	Elphidium sp.			
	56	Cibicides sp.		56	Cibicides sp.		56	Hoeglundina sp.		56	Elphidium sp.			
	57	Cibicides sp.		57	Cibicides sp.		57	Hoeglundina sp.		57	Elphidium sp.			
	58	Cibicides sp.		58	Cibicides sp.		58	Hoeglundina sp.		58	Elphidium sp.			
	59	Cibicides sp.		59	Cibicides sp.		59	Hoeglundina sp.		59	Elphidium sp.			
	60	Cibicides sp.		60	Cibicides sp.		60	Hoeglundina sp.		60	Elphidium sp.			
	61	Cibicides sp.		61	Cibicides sp.		61	Cibicides sp.		61	Elphidium sp.			
	62	Cibicides sp.		62	Cibicides sp.		62	Cibicides sp.		62	Elphidium sp.			
	63	Cibicides sp.		63	Cibicides sp.		63	Cibicides sp.		63	Elphidium sp.			
	64	Cibicides sp.		64	Cibicides sp.		64	Cibicides sp.		64	Elphidium sp.			

Table A.6 Sample #3 7-7.5 cm

AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus
105636	1	Cibicides sp.	**105637**	1	Cibicides sp.	**105638**	1	Buccella sp.	**105639**	1	Cassidulina sp.	**105640**	1	Elphidium sp.
	2	Cibicides sp.		2	Cibicides sp.		2	Buccella sp.		2	Cassidulina sp.		2	Elphidium sp.
	3	Cibicides sp.		3	Cibicides sp.		3	Buccella sp.		3	Cassidulina sp.		3	Elphidium sp.
	4	Cibicides sp.		4	Cibicides sp.		4	Buccella sp.		4	Cassidulina sp.		4	Elphidium sp.
	5	Cibicides sp.		5	Cibicides sp.		5	Buccella sp.		5	Cassidulina sp.		5	Elphidium sp.
	6	Cibicides sp.		6	Cibicides sp.		6	Buccella sp.		6	Cassidulina sp.		6	Elphidium sp.
	7	Cibicides sp.		7	Cibicides sp.		7	Buccella sp.		7	Cassidulina sp.		7	Elphidium sp.
	8	Cibicides sp.		8	Cibicides sp.		8	Buccella sp.		8	Cassidulina sp.		8	Elphidium sp.
	9	Cibicides sp.		9	Cibicides sp.		9	Buccella sp.		9	Cassidulina sp.		9	Elphidium sp.
	10	Cibicides sp.		10	Cibicides sp.		10	Buccella sp.		10	Cassidulina sp.		10	Elphidium sp.
	11	Cibicides sp.		11	Cibicides sp.		11	Buccella sp.		11	Cassidulina sp.		11	Elphidium sp.
	12	Cibicides sp.		12	Cibicides sp.		12	Buccella sp.		12	Cassidulina sp.		12	Elphidium sp.
	13	Cibicides sp.		13	Cibicides sp.		13	Buccella sp.		13	Cassidulina sp.		13	Elphidium sp.
	14	Cibicides sp.		14	Cibicides sp.		14	Buccella sp.		14	Melonis sp.		14	Elphidium sp.
	15	Cibicides sp.		15	Cibicides sp.		15	Buccella sp.		15	Melonis sp.		15	Elphidium sp.
	16	Cibicides sp.		16	Cibicides sp.		16	Buccella sp.		16	Melonis sp.		16	Elphidium sp.
	17	Cibicides sp.		17	Cibicides sp.		17	Buccella sp.		17	Melonis sp.		17	Melonis sp.
	18	Cibicides sp.		18	Cibicides sp.		18	Buccella sp.		18	Melonis sp.		18	Melonis sp.
	19	Cibicides sp.		19	Cibicides sp.		19	Buccella sp.		19	Melonis sp.		19	Melonis sp.
	20	Cibicides sp.		20	Cibicides sp.		20	Buccella sp.		20	Melonis sp.		20	Melonis sp.
	21	Cibicides sp.		21	Cibicides sp.		21	Buccella sp.		21	Melonis sp.		21	Melonis sp.
	22	Cibicides sp.		22	Cibicides sp.		22	Buccella sp.		22	Melonis sp.		22	Melonis sp.
	23	Cibicides sp.		23	Cibicides sp.		23	Buccella sp.		23	Melonis sp.		23	Melonis sp.
	24	Cibicides sp.		24	Cibicides sp.		24	Buccella sp.		24	Melonis sp.		24	Melonis sp.
	25	Cibicides sp.		25	Cibicides sp.		25	Buccella sp.		25	Melonis sp.		25	Melonis sp.
	26	Cibicides sp.		26	Cibicides sp.		26	Buccella sp.		26	Melonis sp.		26	Cassidulina sp.
	27	Cibicides sp.		27	Cibicides sp.		27	Buccella sp.		27	Haynesina sp.		27	Cassidulina sp.
	28	Cibicides sp.		28	Cibicides sp.		28	Buccella sp.		28	Haynesina sp.		28	Cassidulina sp.
	29	Cibicides sp.		29	Cibicides sp.		29	Buccella sp.		29	Haynesina sp.		29	Cassidulina sp.
	30	Cibicides sp.		30	Cibicides sp.		30	Buccella sp.		30	Haynesina sp.		30	Cassidulina sp.
	31	Cibicides sp.		31	Cibicides sp.		31	Buccella sp.		31	Haynesina sp.		31	Cassidulina sp.
	32	Cibicides sp.		32	Cibicides sp.		32	Buccella sp.		32	Haynesina sp.		32	Cassidulina sp.
	33	Cibicides sp.		33	Cibicides sp.		33	Buccella sp.		33	Haynesina sp.		33	Cibicides sp.
	34	Cibicides sp.		34	Cibicides sp.		34	Buccella sp.		34	Haynesina sp.		34	Cibicides sp.
	35	Cibicides sp.		35	Cibicides sp.		35	Buccella sp.		35	Haynesina sp.		35	Cibicides sp.
	36	Cibicides sp.		36	Cibicides sp.		36	Buccella sp.		36	Haynesina sp.		36	Cibicides sp.
	37	Cibicides sp.		37	Cibicides sp.		37	Buccella sp.		37	Haynesina sp.		37	Cibicides sp.
	38	Cibicides sp.		38	Cibicides sp.		38	Buccella sp.		38	Haynesina sp.		38	Cibicides sp.
	39	Cibicides sp.		39	Cibicides sp.		39	Buccella sp.		39	Haynesina sp.		39	Cibicides sp.
	40	Cibicides sp.		40	Cibicides sp.		40	Buccella sp.		40	Haynesina sp.		40	Cibicides sp.
	41	Cibicides sp.		41	Buccella sp.		41	Buccella sp.		41	Elphidium sp.		41	Bolivina sp.
	42	Cibicides sp.		42	Buccella sp.		42	Buccella sp.		42	Elphidium sp.		42	Oolina sp.
	43	Cibicides sp.		43	Buccella sp.		43	Buccella sp.		43	Elphidium sp.		43	Trifarina sp.
	44	Cibicides sp.		44	Buccella sp.		44	Buccella sp.		44	Elphidium sp.		44	Trifarina sp.
	45	Cibicides sp.		45	Buccella sp.		45	Buccella sp.		45	Elphidium sp.		45	Trifarina sp.
	46	Cibicides sp.		46	Buccella sp.		46	Buccella sp.		46	Elphidium sp.		46	Trifarina sp.
	47	Cibicides sp.		47	Buccella sp.		47	Hoeglundina sp.		47	Elphidium sp.		47	Trifarina sp.
	48	Cibicides sp.		48	Buccella sp.		48	Hoeglundina sp.		48	Elphidium sp.		48	Trifarina sp.
	49	Cibicides sp.		49	Buccella sp.		49	Hoeglundina sp.		49	Elphidium sp.		49	Trifarina sp.
	50	Cibicides sp.		50	Buccella sp.		50	Hoeglundina sp.		50	Elphidium sp.		50	Trifarina sp.
	51	Cibicides sp.		51	Buccella sp.		51	Hoeglundina sp.		51	Elphidium sp.		51	Pullenia sp.
	52	Cibicides sp.		52	Buccella sp.		52	Hoeglundina sp.		52	Elphidium sp.		52	Pullenia sp.
	53	Cibicides sp.		53	Buccella sp.		53	Hoeglundina sp.		53	Elphidium sp.		53	Pullenia sp.
	54	Cibicides sp.		54	Buccella sp.		54	Hoeglundina sp.		54	Elphidium sp.		54	Pullenia sp.
	55	Cibicides sp.		55	Buccella sp.		55	Hoeglundina sp.		55	Elphidium sp.		55	Fissurina sp.
	56	Cibicides sp.		56	Buccella sp.		56	Hoeglundina sp.		56	Elphidium sp.		56	Fissurina sp.
	57	Cibicides sp.		57	Buccella sp.		57	Hoeglundina sp.		57	Elphidium sp.		57	Fissurina sp.
	58	Cibicides sp.		58	Buccella sp.		58	Hoeglundina sp.		58	Elphidium sp.		58	Fissurina sp.
	59	Cibicides sp.		59	Buccella sp.		59	Hoeglundina sp.		59	Elphidium sp.		59	Fissurina sp.
	60	Cibicides sp.		60	Buccella sp.		60	Hoeglundina sp.		60	Elphidium sp.		60	Fissurina sp.

Table A.7 Sample #4 6-6.5 cm

AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus
105641	1	Cibicides sp.	**105642**	1	Cibicides sp.	**105643**	1	Buccella sp.	**105644**	1	Haynesina sp.	**105645**	1	Cibicides sp.
	2	Cibicides sp.		2	Cibicides sp.		2	Buccella sp.		2	Haynesina sp.		2	Cibicides sp.
	3	Cibicides sp.		3	Cibicides sp.		3	Buccella sp.		3	Haynesina sp.		3	Cibicides sp.
	4	Cibicides sp.		4	Cibicides sp.		4	Buccella sp.		4	Haynesina sp.		4	Cibicides sp.
	5	Cibicides sp.		5	Cibicides sp.		5	Buccella sp.		5	Haynesina sp.		5	Cibicides sp.
	6	Cibicides sp.		6	Cibicides sp.		6	Buccella sp.		6	Haynesina sp.		6	Cibicides sp.
	7	Cibicides sp.		7	Cibicides sp.		7	Buccella sp.		7	Haynesina sp.		7	Cibicides sp.
	8	Cibicides sp.		8	Cibicides sp.		8	Buccella sp.		8	Haynesina sp.		8	Cibicides sp.
	9	Cibicides sp.		9	Cibicides sp.		9	Buccella sp.		9	Haynesina sp.		9	Cibicides sp.
	10	Cibicides sp.		10	Cibicides sp.		10	Buccella sp.		10	Elphidium sp.		10	Cibicides sp.
	11	Cibicides sp.		11	Cibicides sp.		11	Buccella sp.		11	Elphidium sp.		11	Cibicides sp.
	12	Cibicides sp.		12	Cibicides sp.		12	Buccella sp.		12	Elphidium sp.		12	Cibicides sp.
	13	Cibicides sp.		13	Cibicides sp.		13	Buccella sp.		13	Elphidium sp.		13	Cibicides sp.
	14	Cibicides sp.		14	Cibicides sp.		14	Buccella sp.		14	Elphidium sp.		14	Cibicides sp.
	15	Cibicides sp.		15	Cibicides sp.		15	Buccella sp.		15	Elphidium sp.		15	Cibicides sp.
	16	Cibicides sp.		16	Cibicides sp.		16	Buccella sp.		16	Elphidium sp.		16	Cibicides sp.
	17	Cibicides sp.		17	Cibicides sp.		17	Buccella sp.		17	Elphidium sp.		17	Cibicides sp.
	18	Cibicides sp.		18	Cibicides sp.		18	Buccella sp.		18	Elphidium sp.		18	Cibicides sp.
	19	Cibicides sp.		19	Cibicides sp.		19	Buccella sp.		19	Elphidium sp.		19	Cibicides sp.
	20	Cibicides sp.		20	Cibicides sp.		20	Buccella sp.		20	Elphidium sp.		20	Cibicides sp.
	21	Cibicides sp.		21	Cibicides sp.		21	Hoeglundina sp.		21	Elphidium sp.		21	Buccella sp.
	22	Cibicides sp.		22	Cibicides sp.		22	Hoeglundina sp.		22	Elphidium sp.		22	Buccella sp.
	23	Cibicides sp.		23	Cibicides sp.		23	Hoeglundina sp.		23	Elphidium sp.		23	Buccella sp.
	24	Cibicides sp.		24	Cibicides sp.		24	Hoeglundina sp.		24	Elphidium sp.		24	Buccella sp.
	25	Cibicides sp.		25	Cibicides sp.		25	Hoeglundina sp.		25	Elphidium sp.		25	Buccella sp.
	26	Cibicides sp.		26	Cibicides sp.		26	Hoeglundina sp.		26	Elphidium sp.		26	Buccella sp.
	27	Cibicides sp.		27	Cibicides sp.		27	Hoeglundina sp.		27	Elphidium sp.		27	Cassidulina sp.
	28	Cibicides sp.		28	Cibicides sp.		28	Hoeglundina sp.		28	Elphidium sp.		28	Cassidulina sp.
	29	Cibicides sp.		29	Cibicides sp.		29	Hoeglundina sp.		29	Elphidium sp.		29	Cassidulina sp.
	30	Cibicides sp.		30	Cibicides sp.		30	Hoeglundina sp.		30	Elphidium sp.		30	Cassidulina sp.
	31	Cibicides sp.		31	Cibicides sp.		31	Cassidulina sp.		31	Elphidium sp.		31	Cassidulina sp.
	32	Cibicides sp.		32	Cibicides sp.		32	Cassidulina sp.		32	Elphidium sp.		32	Cassidulina sp.
	33	Cibicides sp.		33	Cibicides sp.		33	Cassidulina sp.		33	Elphidium sp.		33	Cassidulina sp.
	34	Cibicides sp.		34	Cibicides sp.		34	Cassidulina sp.		34	Elphidium sp.		34	Melonis sp.
	35	Cibicides sp.		35	Cibicides sp.		35	Cassidulina sp.		35	Elphidium sp.		35	Haynesina sp.
	36	Cibicides sp.		36	Cibicides sp.		36	Cassidulina sp.		36	Elphidium sp.		36	Haynesina sp.
	37	Cibicides sp.		37	Cibicides sp.		37	Cassidulina sp.		37	Elphidium sp.		37	Pullenia sp.
	38	Cibicides sp.		38	Cibicides sp.		38	Cassidulina sp.		38	Elphidium sp.		38	Pullenia sp.
	39	Cibicides sp.		39	Cibicides sp.		39	Cassidulina sp.		39	Elphidium sp.		39	Fissurina sp.
	40	Cibicides sp.		40	Cibicides sp.		40	Cassidulina sp.		40	Elphidium sp.		40	Fissurina sp.
	41	Cibicides sp.		41	Cibicides sp.		41	Cassidulina sp.		41	Elphidium sp.		41	Lagena sp.
	42	Cibicides sp.		42	Cibicides sp.		42	Cassidulina sp.		42	Elphidium sp.		42	Triloculina sp.
	43	Cibicides sp.		43	Cibicides sp.		43	Cassidulina sp.		43	Elphidium sp.		43	Cibicides sp.
	44	Cibicides sp.		44	Cibicides sp.		44	Cassidulina sp.		44	Elphidium sp.		44	Cibicides sp.
	45	Cibicides sp.		45	Cibicides sp.		45	Cassidulina sp.		45	Elphidium sp.		45	Cibicides sp.
	46	Cibicides sp.		46	Cibicides sp.		46	Cassidulina sp.		46	Elphidium sp.		46	Cibicides sp.
	47	Cibicides sp.		47	Cibicides sp.		47	Cassidulina sp.		47	Melonis sp.		47	Cibicides sp.
	48	Cibicides sp.		48	Cibicides sp.		48	Melonis sp.		48	Melonis sp.		48	Buccella sp.
	49	Cibicides sp.		49	Cibicides sp.		49	Melonis sp.		49	Melonis sp.		49	Buccella sp.
	50	Cibicides sp.		50	Cibicides sp.		50	Melonis sp.		50	Cassidulina sp.		50	Buccella sp.
	51	Cibicides sp.		51	Cibicides sp.		51	Melonis sp.		51	Cassidulina sp.		51	Buccella sp.
	52	Cibicides sp.		52	Cibicides sp.		52	Melonis sp.		52	Cassidulina sp.		52	Buccella sp.
	53	Cibicides sp.		53	Buccella sp.		53	Melonis sp.		53	Cassidulina sp.		53	Elphidium sp.
	54	Cibicides sp.		54	Buccella sp.		54	Haynesina sp.		54	Cibicides sp.		54	Elphidium sp.
	55	Cibicides sp.		55	Buccella sp.		55	Haynesina sp.		55	Cibicides sp.		55	Elphidium sp.
	56	Cibicides sp.		56	Buccella sp.		56	Haynesina sp.		56	Cibicides sp.		56	Elphidium sp.
	57	Cibicides sp.		57	Buccella sp.		57	Haynesina sp.		57	Cibicides sp.		57	Elphidium sp.
	58	Cibicides sp.		58	Buccella sp.		58	Haynesina sp.		58	Cibicides sp.		58	Haynesina sp.
	59	Cibicides sp.		59	Buccella sp.		59	Haynesina sp.		59	Cibicides sp.		59	Haynesina sp.
	60	Cibicides sp.		60	Buccella sp.		60	Haynesina sp.		60	Cibicides sp.		60	Haynesina sp.

Table A.8 Sample #5 5-5.5 cm

AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus
105646	1	Cibicides sp.	**105647**	1	Cibicides sp.	**105648**	1	Buccella sp.	**108505**	1	Melonis sp.	**108506**	1	Elphidium sp.
	2	Cibicides sp.		2	Cibicides sp.		2	Buccella sp.		2	Melonis sp.		2	Elphidium sp.
	3	Cibicides sp.		3	Cibicides sp.		3	Buccella sp.		3	Melonis sp.		3	Elphidium sp.
	4	Cibicides sp.		4	Cibicides sp.		4	Buccella sp.		4	Melonis sp.		4	Elphidium sp.
	5	Cibicides sp.		5	Cibicides sp.		5	Buccella sp.		5	Melonis sp.		5	Elphidium sp.
	6	Cibicides sp.		6	Cibicides sp.		6	Buccella sp.		6	Melonis sp.		6	Elphidium sp.
	7	Cibicides sp.		7	Cibicides sp.		7	Buccella sp.		7	Melonis sp.		7	Elphidium sp.
	8	Cibicides sp.		8	Cibicides sp.		8	Buccella sp.		8	Melonis sp.		8	Elphidium sp.
	9	Cibicides sp.		9	Cibicides sp.		9	Buccella sp.		9	Melonis sp.		9	Elphidium sp.
	10	Cibicides sp.		10	Cibicides sp.		10	Buccella sp.		10	Melonis sp.		10	Elphidium sp.
	11	Cibicides sp.		11	Cibicides sp.		11	Buccella sp.		11	Melonis sp.		11	Elphidium sp.
	12	Cibicides sp.		12	Cibicides sp.		12	Buccella sp.		12	Melonis sp.		12	Elphidium sp.
	13	Cibicides sp.		13	Cibicides sp.		13	Buccella sp.		13	Melonis sp.		13	Elphidium sp.
	14	Cibicides sp.		14	Cibicides sp.		14	Buccella sp.		14	Haynesina sp.		14	Elphidium sp.
	15	Cibicides sp.		15	Cibicides sp.		15	Buccella sp.		15	Haynesina sp.		15	Elphidium sp.
	16	Cibicides sp.		16	Cibicides sp.		16	Buccella sp.		16	Haynesina sp.		16	Elphidium sp.
	17	Cibicides sp.		17	Cibicides sp.		17	Buccella sp.		17	Haynesina sp.		17	Elphidium sp.
	18	Cibicides sp.		18	Cibicides sp.		18	Buccella sp.		18	Haynesina sp.		18	Elphidium sp.
	19	Cibicides sp.		19	Cibicides sp.		19	Buccella sp.		19	Haynesina sp.		19	Elphidium sp.
	20	Cibicides sp.		20	Cibicides sp.		20	Buccella sp.		20	Haynesina sp.		20	Fissurina sp.
	21	Cibicides sp.		21	Cibicides sp.		21	Hoeglundina sp.		21	Haynesina sp.		21	Fissurina sp.
	22	Cibicides sp.		22	Cibicides sp.		22	Hoeglundina sp.		22	Haynesina sp.		22	Fissurina sp.
	23	Cibicides sp.		23	Cibicides sp.		23	Hoeglundina sp.		23	Haynesina sp.		23	Fissurina sp.
	24	Cibicides sp.		24	Cibicides sp.		24	Hoeglundina sp.		24	Haynesina sp.		24	Fissurina sp.
	25	Cibicides sp.		25	Cibicides sp.		25	Hoeglundina sp.		25	Haynesina sp.		25	Fissurina sp.
	26	Cibicides sp.		26	Cibicides sp.		26	Hoeglundina sp.		26	Haynesina sp.		26	Fissurina sp.
	27	Cibicides sp.		27	Cibicides sp.		27	Hoeglundina sp.		27	Haynesina sp.		27	Pullenia sp.
	28	Cibicides sp.		28	Cibicides sp.		28	Hoeglundina sp.		28	Haynesina sp.		28	Pullenia sp.
	29	Cibicides sp.		29	Cibicides sp.		29	Hoeglundina sp.		29	Haynesina sp.		29	Pullenia sp.
	30	Cibicides sp.		30	Cibicides sp.		30	Hoeglundina sp.		30	Haynesina sp.		30	Pullenia sp.
	31	Cibicides sp.		31	Cibicides sp.		31	Hoeglundina sp.		31	Haynesina sp.		31	Pullenia sp.
	32	Cibicides sp.		32	Cibicides sp.		32	Hoeglundina sp.		32	Haynesina sp.		32	Trifarina sp.
	33	Cibicides sp.		33	Cibicides sp.		33	Cassidulina sp.		33	Haynesina sp.		33	Trifarina sp.
	34	Cibicides sp.		34	Buccella sp.		34	Cassidulina sp.		34	Haynesina sp.		34	Trifarina sp.
	35	Cibicides sp.		35	Buccella sp.		35	Cassidulina sp.		35	Haynesina sp.		35	Trifarina sp.
	36	Cibicides sp.		36	Buccella sp.		36	Cassidulina sp.		36	Haynesina sp.		36	Trifarina sp.
	37	Cibicides sp.		37	Buccella sp.		37	Cassidulina sp.		37	Elphidium sp.		37	Trifarina sp.
	38	Cibicides sp.		38	Buccella sp.		38	Cassidulina sp.		38	Elphidium sp.		38	Bolivina sp.
	39	Cibicides sp.		39	Buccella sp.		39	Cassidulina sp.		39	Elphidium sp.		39	Elphidium sp.
	40	Cibicides sp.		40	Buccella sp.		40	Cassidulina sp.		40	Elphidium sp.		40	Elphidium sp.
	41	Cibicides sp.		41	Buccella sp.		41	Cassidulina sp.		41	Elphidium sp.		41	Elphidium sp.
	42	Cibicides sp.		42	Buccella sp.		42	Cassidulina sp.		42	Elphidium sp.		42	Elphidium sp.
	43	Cibicides sp.		43	Buccella sp.		43	Cassidulina sp.		43	Elphidium sp.		43	Elphidium sp.
	44	Cibicides sp.		44	Buccella sp.		44	Cassidulina sp.		44	Elphidium sp.		44	Elphidium sp.
	45	Cibicides sp.		45	Buccella sp.		45	Cassidulina sp.		45	Elphidium sp.		45	Elphidium sp.
	46	Cibicides sp.		46	Buccella sp.		46	Cassidulina sp.		46	Elphidium sp.		46	Haynesina sp.
	47	Cibicides sp.		47	Buccella sp.		47	Cassidulina sp.		47	Elphidium sp.		47	Haynesina sp.
	48	Cibicides sp.		48	Buccella sp.		48	Cassidulina sp.		48	Elphidium sp.		48	Haynesina sp.
	49	Cibicides sp.		49	Buccella sp.		49	Cassidulina sp.		49	Elphidium sp.		49	Haynesina sp.
	50	Cibicides sp.		50	Buccella sp.		50	Cassidulina sp.		50	Elphidium sp.		50	Haynesina sp.
	51	Cibicides sp.		51	Buccella sp.		51	Melonis sp.		51	Elphidium sp.		51	Haynesina sp.
	52	Cibicides sp.		52	Buccella sp.		52	Melonis sp.		52	Elphidium sp.		52	Haynesina sp.
	53	Cibicides sp.		53	Buccella sp.		53	Melonis sp.		53	Elphidium sp.		53	Haynesina sp.
	54	Cibicides sp.		54	Buccella sp.		54	Melonis sp.		54	Elphidium sp.		54	Haynesina sp.
	55	Cibicides sp.		55	Buccella sp.		55	Melonis sp.		55	Elphidium sp.		55	Haynesina sp.
	56	Cibicides sp.		56	Buccella sp.		56	Melonis sp.		56	Elphidium sp.		56	Haynesina sp.
	57	Cibicides sp.		57	Buccella sp.		57	Melonis sp.		57	Elphidium sp.		57	Haynesina sp.
	58	Cibicides sp.		58	Buccella sp.		58	Melonis sp.		58	Elphidium sp.		58	Melonis sp.
	59	Cibicides sp.		59	Buccella sp.		59	Melonis sp.		59	Elphidium sp.		59	Melonis sp.
	60	Cibicides sp.		60	Buccella sp.		60	Melonis sp.		60	Elphidium sp.		60	Melonis sp.

Table A.9 Sample #6 4-4.5 cm

AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus
108507	1	Cibicides sp.	**108508**	1	Buccella sp.	**108509**	1	Cassidulina sp.	**108510**	1	Elphidium sp.	**108511**	1	Elphidium sp.
	2	Cibicides sp.		2	Buccella sp.		2	Cassidulina sp.		2	Elphidium sp.		2	Melonis sp.
	3	Cibicides sp.		3	Buccella sp.		3	Cassidulina sp.		3	Elphidium sp.		3	Melonis sp.
	4	Cibicides sp.		4	Buccella sp.		4	Cassidulina sp.		4	Elphidium sp.		4	Melonis sp.
	5	Cibicides sp.		5	Buccella sp.		5	Cassidulina sp.		5	Elphidium sp.		5	Haynesina sp.
	6	Cibicides sp.		6	Buccella sp.		6	Cassidulina sp.		6	Elphidium sp.		6	Elphidium sp.
	7	Cibicides sp.		7	Buccella sp.		7	Cassidulina sp.		7	Elphidium sp.		7	Elphidium sp.
	8	Cibicides sp.		8	Buccella sp.		8	Cassidulina sp.		8	Elphidium sp.		8	Haynesina sp.
	9	Cibicides sp.		9	Buccella sp.		9	Cassidulina sp.		9	Elphidium sp.		9	Buccella sp.
	10	Cibicides sp.		10	Buccella sp.		10	Cassidulina sp.		10	Elphidium sp.		10	Buccella sp.
	11	Cibicides sp.		11	Buccella sp.		11	Cassidulina sp.		11	Elphidium sp.		11	Cibicides sp.
	12	Cibicides sp.		12	Buccella sp.		12	Cassidulina sp.		12	Elphidium sp.		12	Cibicides sp.
	13	Cibicides sp.		13	Buccella sp.		13	Cassidulina sp.		13	Elphidium sp.		13	Haynesina sp.
	14	Cibicides sp.		14	Buccella sp.		14	Cassidulina sp.		14	Elphidium sp.		14	Haynesina sp.
	15	Cibicides sp.		15	Buccella sp.		15	Cassidulina sp.		15	Elphidium sp.		15	Cibicides sp.
	16	Cibicides sp.		16	Buccella sp.		16	Cassidulina sp.		16	Elphidium sp.		16	Cibicides sp.
	17	Cibicides sp.		17	Buccella sp.		17	Cassidulina sp.		17	Elphidium sp.		17	Haynesina sp.
	18	Cibicides sp.		18	Buccella sp.		18	Cassidulina sp.		18	Elphidium sp.		18	Cibicides sp.
	19	Cibicides sp.		19	Buccella sp.		19	Cassidulina sp.		19	Elphidium sp.		19	Melonis sp.
	20	Cibicides sp.		20	Buccella sp.		20	Cassidulina sp.		20	Elphidium sp.		20	Melonis sp.
	21	Cibicides sp.		21	Buccella sp.		21	Cassidulina sp.		21	Elphidium sp.		21	Elphidium sp.
	22	Cibicides sp.		22	Buccella sp.		22	Cassidulina sp.		22	Elphidium sp.		22	Elphidium sp.
	23	Cibicides sp.		23	Buccella sp.		23	Cassidulina sp.		23	Fissurina sp.		23	Elphidium sp.
	24	Cibicides sp.		24	Buccella sp.		24	Cassidulina sp.		24	Fissurina sp.		24	Cibicides sp.
	25	Cibicides sp.		25	Buccella sp.		25	Cassidulina sp.		25	Fissurina sp.		25	Buccella sp.
	26	Cibicides sp.		26	Buccella sp.		26	Cassidulina sp.		26	Fissurina sp.		26	Buccella sp.
	27	Cibicides sp.		27	Buccella sp.		27	Cassidulina sp.		27	Fissurina sp.		27	Melonis sp.
	28	Cibicides sp.		28	Buccella sp.		28	Cassidulina sp.		28	Fissurina sp.		28	Haynesina sp.
	29	Cibicides sp.		29	Buccella sp.		29	Cassidulina sp.		29	Fissurina sp.		29	Haynesina sp.
	30	Cibicides sp.		30	Buccella sp.		30	Cassidulina sp.		30	Fissurina sp.		30	Haynesina sp.
	31	Cibicides sp.		31	Buccella sp.		31	Cassidulina sp.		31	Fissurina sp.		31	Elphidium sp.
	32	Cibicides sp.		32	Buccella sp.		32	Cassidulina sp.		32	Fissurina sp.		32	Haynesina sp.
	33	Cibicides sp.		33	Buccella sp.		33	Cassidulina sp.		33	Fissurina sp.		33	Cibicides sp.
	34	Cibicides sp.		34	Buccella sp.		34	Melonis sp.		34	Pullenia sp.		34	Cibicides sp.
	35	Cibicides sp.		35	Buccella sp.		35	Melonis sp.		35	Pullenia sp.		35	Haynesina sp.
	36	Cibicides sp.		36	Buccella sp.		36	Melonis sp.		36	Pullenia sp.		36	Cibicides sp.
	37	Cibicides sp.		37	Hoeglundina sp.		37	Melonis sp.		37	Pullenia sp.		37	Cibicides sp.
	38	Cibicides sp.		38	Hoeglundina sp.		38	Melonis sp.		38	Pullenia sp.		38	Buccella sp.
	39	Cibicides sp.		39	Hoeglundina sp.		39	Melonis sp.		39	Pullenia sp.		39	Cibicides sp.
	40	Cibicides sp.		40	Hoeglundina sp.		40	Melonis sp.		40	Trifarina sp.		40	Cibicides sp.
	41	Cibicides sp.		41	Hoeglundina sp.		41	Melonis sp.		41	Triloculina sp.		41	Haynesina sp.
	42	Cibicides sp.		42	Hoeglundina sp.		42	Melonis sp.		42	Fissurina sp.		42	Haynesina sp.
	43	Cibicides sp.		43	Hoeglundina sp.		43	Melonis sp.		43	Buccella sp.		43	Haynesina sp.
	44	Cibicides sp.		44	Hoeglundina sp.		44	Melonis sp.		44	Cibicides sp.		44	Haynesina sp.
	45	Cibicides sp.		45	Hoeglundina sp.		45	Melonis sp.		45	Cibicides sp.		45	Haynesina sp.
	46	Cibicides sp.		46	Hoeglundina sp.		46	Melonis sp.		46	Cibicides sp.		46	Hoeglundina sp.
	47	Cibicides sp.		47	Cassidulina sp.		47	Haynesina sp.		47	Cibicides sp.		47	Haynesina sp.
	48	Cibicides sp.		48	Cassidulina sp.		48	Haynesina sp.		48	Cibicides sp.		48	Haynesina sp.
	49	Cibicides sp.		49	Cassidulina sp.		49	Haynesina sp.		49	Elphidium sp.		49	Cibicides sp.
	50	Cibicides sp.		50	Cassidulina sp.		50	Haynesina sp.		50	Haynesina sp.		50	Buccella sp.
	51	Cibicides sp.		51	Cassidulina sp.		51	Haynesina sp.		51	Haynesina sp.		51	Cibicides sp.
	52	Cibicides sp.		52	Cassidulina sp.		52	Haynesina sp.		52	Haynesina sp.		52	Haynesina sp.
	53	Cibicides sp.		53	Cassidulina sp.		53	Haynesina sp.		53	Melonis sp.		53	Cassidulina sp.
	54	Cibicides sp.		54	Cassidulina sp.		54	Haynesina sp.		54	Cibicides sp.		54	Cassidulina sp.
	55	Cibicides sp.		55	Cassidulina sp.		55	Haynesina sp.		55	Elphidium sp.		55	Cibicides sp.
	56	Buccella sp.		56	Cassidulina sp.		56	Haynesina sp.		56	Cibicides sp.		56	Fissurina sp.
	57	Buccella sp.		57	Cassidulina sp.		57	Haynesina sp.		57	Elphidium sp.		57	Melonis sp.
	58	Buccella sp.		58	Cassidulina sp.		58	Haynesina sp.		58	Melonis sp.		58	Hoeglundina sp.
	59	Buccella sp.		59	Cassidulina sp.		59	Haynesina sp.		59	Elphidium sp.		59	Hoeglundina sp.
	60	Buccella sp.		60	Cassidulina sp.		60	Haynesina sp.		60	Pullenia sp.		60	Haynesina sp.

Table A.10 Sample #7 3-3.5 cm

AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus
108512	1	Cibicides sp.	**108513**	1	Buccella sp.	**108514**	1	Melonis sp.	**108515**	1	Elphidium sp.	**108516**	1	Fissurina sp.
	2	Cibicides sp.		2	Buccella sp.		2	Melonis sp.		2	Elphidium sp.		2	Fissurina sp.
	3	Cibicides sp.		3	Buccella sp.		3	Melonis sp.		3	Elphidium sp.		3	Fissurina sp.
	4	Cibicides sp.		4	Buccella sp.		4	Melonis sp.		4	Elphidium sp.		4	Fissurina sp.
	5	Cibicides sp.		5	Buccella sp.		5	Melonis sp.		5	Elphidium sp.		5	Fissurina sp.
	6	Cibicides sp.		6	Buccella sp.		6	Melonis sp.		6	Elphidium sp.		6	Fissurina sp.
	7	Cibicides sp.		7	Buccella sp.		7	Melonis sp.		7	Elphidium sp.		7	Nonionellina sp.
	8	Cibicides sp.		8	Buccella sp.		8	Melonis sp.		8	Elphidium sp.		8	Trifarina sp.
	9	Cibicides sp.		9	Buccella sp.		9	Melonis sp.		9	Elphidium sp.		9	Trifarina sp.
	10	Cibicides sp.		10	Buccella sp.		10	Melonis sp.		10	Elphidium sp.		10	Trifarina sp.
	11	Cibicides sp.		11	Buccella sp.		11	Melonis sp.		11	Elphidium sp.		11	Trifarina sp.
	12	Cibicides sp.		12	Buccella sp.		12	Melonis sp.		12	Elphidium sp.		12	Trifarina sp.
	13	Cibicides sp.		13	Buccella sp.		13	Melonis sp.		13	Elphidium sp.		13	Lagena sp.
	14	Cibicides sp.		14	Buccella sp.		14	Melonis sp.		14	Elphidium sp.		14	Pullenia sp.
	15	Cibicides sp.		15	Buccella sp.		15	Melonis sp.		15	Elphidium sp.		15	Pullenia sp.
	16	Cibicides sp.		16	Buccella sp.		16	Melonis sp.		16	Elphidium sp.		16	Pullenia sp.
	17	Cibicides sp.		17	Buccella sp.		17	Melonis sp.		17	Elphidium sp.		17	Pullenia sp.
	18	Cibicides sp.		18	Buccella sp.		18	Melonis sp.		18	Elphidium sp.		18	Buccella sp.
	19	Cibicides sp.		19	Buccella sp.		19	Haynesina sp.		19	Elphidium sp.		19	Buccella sp.
	20	Cibicides sp.		20	Buccella sp.		20	Haynesina sp.		20	Elphidium sp.		20	Buccella sp.
	21	Cibicides sp.		21	Buccella sp.		21	Haynesina sp.		21	Elphidium sp.		21	Buccella sp.
	22	Cibicides sp.		22	Buccella sp.		22	Haynesina sp.		22	Elphidium sp.		22	Buccella sp.
	23	Cibicides sp.		23	Hoeglundina sp.		23	Haynesina sp.		23	Elphidium sp.		23	Cibicides sp.
	24	Cibicides sp.		24	Hoeglundina sp.		24	Haynesina sp.		24	Elphidium sp.		24	Cibicides sp.
	25	Buccella sp.		25	Hoeglundina sp.		25	Haynesina sp.		25	Elphidium sp.		25	Cibicides sp.
	26	Buccella sp.		26	Hoeglundina sp.		26	Haynesina sp.		26	Elphidium sp.		26	Cibicides sp.
	27	Buccella sp.		27	Hoeglundina sp.		27	Haynesina sp.		27	Elphidium sp.		27	Cibicides sp.
	28	Buccella sp.		28	Hoeglundina sp.		28	Haynesina sp.		28	Elphidium sp.		28	Cibicides sp.
	29	Buccella sp.		29	Hoeglundina sp.		29	Haynesina sp.		29	Elphidium sp.		29	Cibicides sp.
	30	Buccella sp.		30	Hoeglundina sp.		30	Haynesina sp.		30	Elphidium sp.		30	Cibicides sp.
	31	Buccella sp.		31	Hoeglundina sp.		31	Haynesina sp.		31	Elphidium sp.		31	Cibicides sp.
	32	Buccella sp.		32	Hoeglundina sp.		32	Haynesina sp.		32	Elphidium sp.		32	Cibicides sp.
	33	Buccella sp.		33	Hoeglundina sp.		33	Haynesina sp.		33	Elphidium sp.		33	Cibicides sp.
	34	Buccella sp.		34	Cassidulina sp.		34	Haynesina sp.		34	Elphidium sp.		34	Cibicides sp.
	35	Buccella sp.		35	Cassidulina sp.		35	Haynesina sp.		35	Elphidium sp.		35	Melonis sp.
	36	Buccella sp.		36	Cassidulina sp.		36	Haynesina sp.		36	Elphidium sp.		36	Melonis sp.
	37	Buccella sp.		37	Cassidulina sp.		37	Haynesina sp.		37	Elphidium sp.		37	Elphidium sp.
	38	Buccella sp.		38	Cassidulina sp.		38	Haynesina sp.		38	Elphidium sp.		38	Elphidium sp.
	39	Buccella sp.		39	Cassidulina sp.		39	Haynesina sp.		39	Elphidium sp.		39	Elphidium sp.
	40	Buccella sp.		40	Cassidulina sp.		40	Elphidium sp.		40	Elphidium sp.		40	Elphidium sp.
	41	Buccella sp.		41	Cassidulina sp.		41	Elphidium sp.		41	Elphidium sp.		41	Elphidium sp.
	42	Buccella sp.		42	Cassidulina sp.		42	Elphidium sp.		42	Elphidium sp.		42	Elphidium sp.
	43	Buccella sp.		43	Cassidulina sp.		43	Elphidium sp.		43	Elphidium sp.		43	Elphidium sp.
	44	Buccella sp.		44	Cassidulina sp.		44	Elphidium sp.		44	Elphidium sp.		44	Elphidium sp.
	45	Buccella sp.		45	Cassidulina sp.		45	Elphidium sp.		45	Elphidium sp.		45	Elphidium sp.
	46	Buccella sp.		46	Cassidulina sp.		46	Elphidium sp.		46	Elphidium sp.		46	Elphidium sp.
	47	Buccella sp.		47	Cassidulina sp.		47	Elphidium sp.		47	Elphidium sp.		47	Elphidium sp.
	48	Buccella sp.		48	Cassidulina sp.		48	Elphidium sp.		48	Elphidium sp.		48	Elphidium sp.
	49	Buccella sp.		49	Cassidulina sp.		49	Elphidium sp.		49	Elphidium sp.		49	Elphidium sp.
	50	Buccella sp.		50	Melonis sp.		50	Elphidium sp.		50	Elphidium sp.		50	Elphidium sp.
	51	Buccella sp.		51	Melonis sp.		51	Elphidium sp.		51	Elphidium sp.		51	Elphidium sp.
	52	Buccella sp.		52	Melonis sp.		52	Elphidium sp.		52	Elphidium sp.		52	Elphidium sp.
	53	Buccella sp.		53	Melonis sp.		53	Elphidium sp.		53	Elphidium sp.		53	Elphidium sp.
	54	Buccella sp.		54	Melonis sp.		54	Elphidium sp.		54	Elphidium sp.		54	Hoeglundina sp.
	55	Buccella sp.		55	Melonis sp.		55	Elphidium sp.		55	Elphidium sp.		55	Haynesina sp.
	56	Buccella sp.		56	Melonis sp.		56	Elphidium sp.		56	Elphidium sp.		56	Cassidulina sp.
	57	Buccella sp.		57	Melonis sp.		57	Elphidium sp.		57	Elphidium sp.		57	Cassidulina sp.
	58	Buccella sp.		58	Melonis sp.		58	Elphidium sp.		58	Elphidium sp.		58	Cibicides sp.
	59	Buccella sp.		59	Melonis sp.		59	Elphidium sp.		59	Elphidium sp.		59	Haynesina sp.
	60	Buccella sp.		60	Melonis sp.		60	Elphidium sp.		60	Elphidium sp.		60	Haynesina sp.

Table A.11 Sample #8 2-2.5 cm

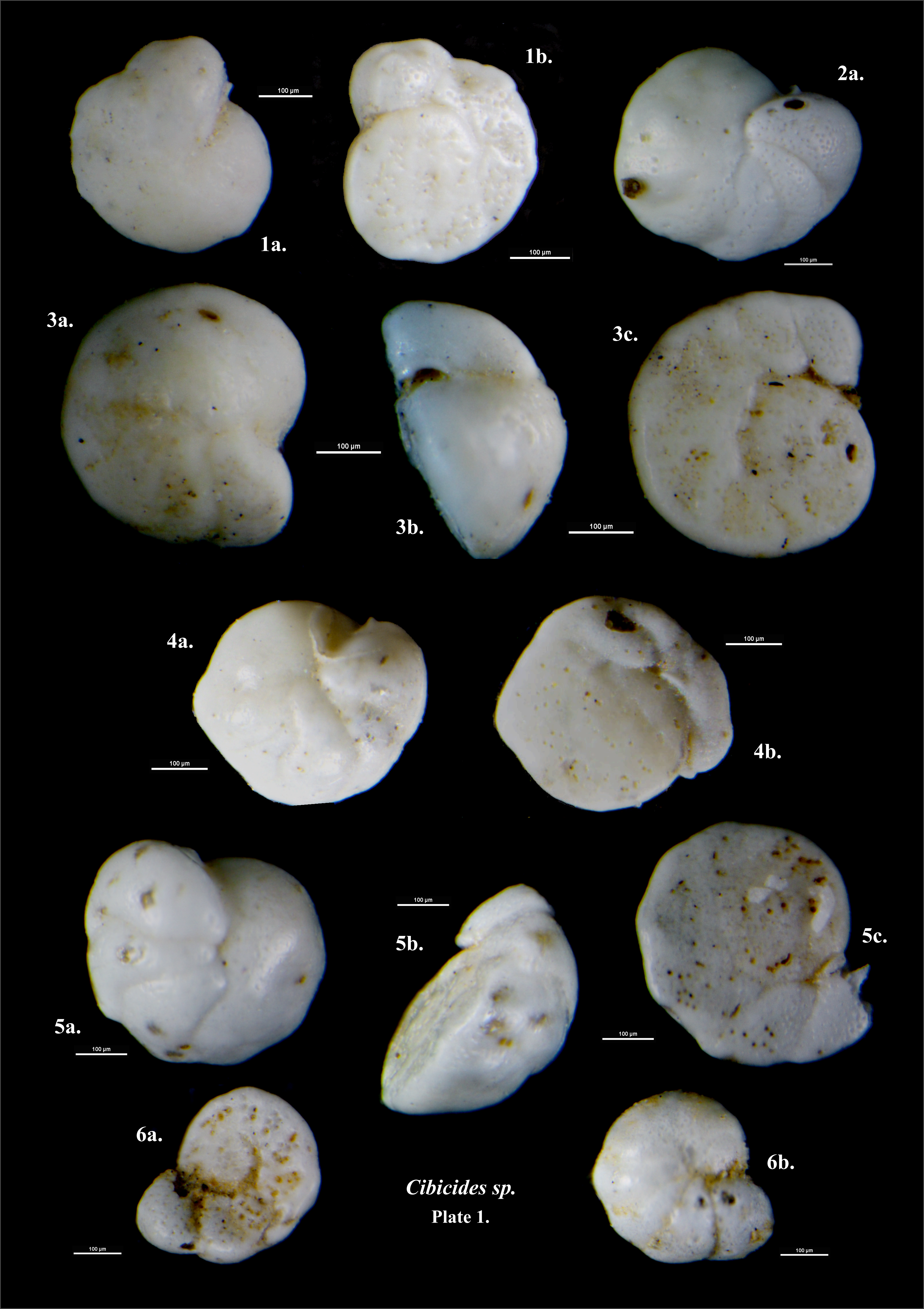
AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus
108517	1	Cibicides sp.	**108518**	1	Buccella sp.	**108519**	1	Haynesina sp.	**108520**	1	Elphidium sp.	**108521**	1	Cibicides sp.
	2	Cibicides sp.		2	Buccella sp.		2	Haynesina sp.		2	Elphidium sp.		2	Haynesina sp.
	3	Cibicides sp.		3	Buccella sp.		3	Haynesina sp.		3	Elphidium sp.		3	Haynesina sp.
	4	Cibicides sp.		4	Buccella sp.		4	Elphidium sp.		4	Elphidium sp.		4	Elphidium sp.
	5	Cibicides sp.		5	Buccella sp.		5	Elphidium sp.		5	Elphidium sp.		5	Cassidulina sp.
	6	Cibicides sp.		6	Buccella sp.		6	Elphidium sp.		6	Elphidium sp.		6	Elphidium sp.
	7	Cibicides sp.		7	Buccella sp.		7	Elphidium sp.		7	Elphidium sp.		7	Buccella sp.
	8	Cibicides sp.		8	Buccella sp.		8	Elphidium sp.		8	Elphidium sp.		8	Melonis sp.
	9	Cibicides sp.		9	Buccella sp.		9	Elphidium sp.		9	Elphidium sp.		9	Elphidium sp.
	10	Cibicides sp.		10	Buccella sp.		10	Elphidium sp.		10	Elphidium sp.		10	Cibicides sp.
	11	Cibicides sp.		11	Buccella sp.		11	Elphidium sp.		11	Elphidium sp.		11	Buccella sp.
	12	Buccella sp.		12	Buccella sp.		12	Elphidium sp.		12	Elphidium sp.		12	Buccella sp.
	13	Buccella sp.		13	Buccella sp.		13	Elphidium sp.		13	Fissurina sp.		13	Buccella sp.
	14	Buccella sp.		14	Buccella sp.		14	Elphidium sp.		14	Fissurina sp.		14	Oolina sp.
	15	Buccella sp.		15	Buccella sp.		15	Elphidium sp.		15	Fissurina sp.		15	Oolina sp.
	16	Buccella sp.		16	Buccella sp.		16	Elphidium sp.		16	Fissurina sp.		16	Elphidium sp.
	17	Buccella sp.		17	Buccella sp.		17	Elphidium sp.		17	Fissurina sp.		17	Cibicides sp.
	18	Buccella sp.		18	Buccella sp.		18	Elphidium sp.		18	Fissurina sp.		18	Buccella sp.
	19	Buccella sp.		19	Hoeglundina sp.		19	Elphidium sp.		19	Fissurina sp.		19	Haynesina sp.
	20	Buccella sp.		20	Hoeglundina sp.		20	Elphidium sp.		20	Fissurina sp.		20	Cassidulina sp.
	21	Buccella sp.		21	Hoeglundina sp.		21	Elphidium sp.		21	Pullenia sp.		21	Haynesina sp.
	22	Buccella sp.		22	Hoeglundina sp.		22	Elphidium sp.		22	Pullenia sp.		22	Elphidium sp.
	23	Buccella sp.		23	Hoeglundina sp.		23	Elphidium sp.		23	Pullenia sp.		23	Melonis sp.
	24	Buccella sp.		24	Hoeglundina sp.		24	Elphidium sp.		24	Pullenia sp.		24	Haynesina sp.
	25	Buccella sp.		25	Hoeglundina sp.		25	Elphidium sp.		25	Pullenia sp.		25	Cassidulina sp.
	26	Buccella sp.		26	Cassidulina sp.		26	Elphidium sp.		26	Buccella sp.		26	Buccella sp.
	27	Buccella sp.		27	Cassidulina sp.		27	Elphidium sp.		27	Hoeglundina sp.		27	Cassidulina sp.
	28	Buccella sp.		28	Cassidulina sp.		28	Elphidium sp.		28	Hoeglundina sp.		28	Haynesina sp.
	29	Buccella sp.		29	Cassidulina sp.		29	Elphidium sp.		29	Cassidulina sp.		29	Fissurina sp.
	30	Buccella sp.		30	Cassidulina sp.		30	Elphidium sp.		30	Cibicides sp.		30	Oolina sp.
	31	Buccella sp.		31	Cassidulina sp.		31	Elphidium sp.		31	Melonis sp.		31	Cibicides sp.
	32	Buccella sp.		32	Cassidulina sp.		32	Elphidium sp.		32	Oolina sp.		32	Hoeglundina sp.
	33	Buccella sp.		33	Cassidulina sp.		33	Elphidium sp.		33	Elphidium sp.		33	Haynesina sp.
	34	Buccella sp.		34	Cassidulina sp.		34	Elphidium sp.		34	Haynesina sp.		34	Quinqueloculina sp.
	35	Buccella sp.		35	Cassidulina sp.		35	Elphidium sp.		35	Elphidium sp.		35	Elphidium sp.
	36	Buccella sp.		36	Melonis sp.		36	Elphidium sp.		36	Buccella sp.		36	Cibicides sp.
	37	Buccella sp.		37	Melonis sp.		37	Elphidium sp.		37	Cibicides sp.		37	Cassidulina sp.
	38	Buccella sp.		38	Melonis sp.		38	Elphidium sp.		38	Melonis sp.		38	Cassidulina sp.
	39	Buccella sp.		39	Melonis sp.		39	Elphidium sp.		39	Cibicides sp.		39	Buccella sp.
	40	Buccella sp.		40	Melonis sp.		40	Elphidium sp.		40	Buccella sp.		40	Elphidium sp.
	41	Buccella sp.		41	Melonis sp.		41	Elphidium sp.		41	Buccella sp.		41	Elphidium sp.
	42	Buccella sp.		42	Melonis sp.		42	Elphidium sp.		42	Buccella sp.		42	Elphidium sp.
	43	Buccella sp.		43	Melonis sp.		43	Elphidium sp.		43	Buccella sp.		43	Elphidium sp.
	44	Buccella sp.		44	Melonis sp.		44	Elphidium sp.		44	Cibicides sp.		44	Elphidium sp.
	45	Buccella sp.		45	Melonis sp.		45	Elphidium sp.		45	Hoeglundina sp.		45	Elphidium sp.
	46	Buccella sp.		46	Melonis sp.		46	Elphidium sp.		46	Buccella sp.		46	Melonis sp.
	47	Buccella sp.		47	Melonis sp.		47	Elphidium sp.		47	Oolina sp.		47	Pullenia sp.
	48	Buccella sp.		48	Haynesina sp.		48	Elphidium sp.		48	Haynesina sp.		48	Haynesina sp.
	49	Buccella sp.		49	Haynesina sp.		49	Elphidium sp.		49	Buccella sp.		49	Elphidium sp.
	50	Buccella sp.		50	Haynesina sp.		50	Elphidium sp.		50	Fissurina sp.		50	Elphidium sp.
	51	Buccella sp.		51	Haynesina sp.		51	Elphidium sp.		51	Hoeglundina sp.		51	Cibicides sp.
	52	Buccella sp.		52	Haynesina sp.		52	Elphidium sp.		52	Haynesina sp.		52	Elphidium sp.
	53	Buccella sp.		53	Haynesina sp.		53	Elphidium sp.		53	Haynesina sp.		53	Cibicides sp.
	54	Buccella sp.		54	Haynesina sp.		54	Elphidium sp.		54	Cibicides sp.		54	Elphidium sp.
	55	Buccella sp.		55	Haynesina sp.		55	Elphidium sp.		55	Elphidium sp.		55	Haynesina sp.
	56	Buccella sp.		56	Haynesina sp.		56	Elphidium sp.		56	Elphidium sp.		56	Elphidium sp.
	57	Buccella sp.		57	Haynesina sp.		57	Elphidium sp.		57	Hoeglundina sp.		57	Elphidium sp.
	58	Buccella sp.		58	Haynesina sp.		58	Elphidium sp.		58	Elphidium sp.		58	Melonis sp.
	59	Buccella sp.		59	Haynesina sp.		59	Elphidium sp.		59	Haynesina sp.		59	Elphidium sp.
	60	Buccella sp.		60	Haynesina sp.		60	Elphidium sp.		60	Melonis sp.		60	Elphidium sp.

Table A.12 Sample #9 1-1.5 cm

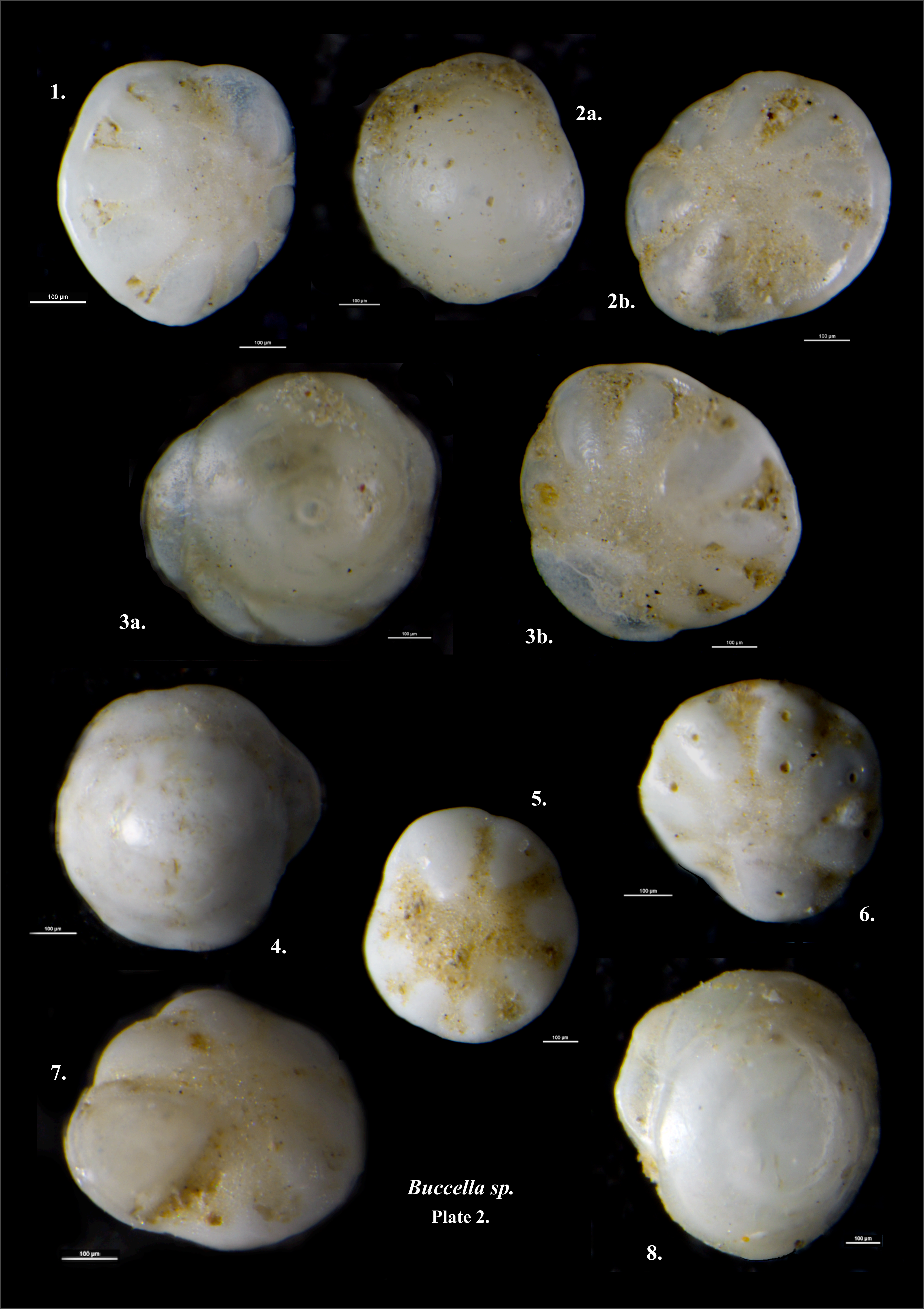
AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus
108522	1	Cibicides sp.	**108523**	1	Buccella sp.	**108524**	1	Buccella sp.	**108525**	1	Haynesina sp.	**108526**	1	Elphidium sp.
	2	Cibicides sp.		2	Buccella sp.		2	Hoeglundina sp.		2	Haynesina sp.		2	Elphidium sp.
	3	Cibicides sp.		3	Buccella sp.		3	Hoeglundina sp.		3	Haynesina sp.		3	Elphidium sp.
	4	Cibicides sp.		4	Buccella sp.		4	Hoeglundina sp.		4	Haynesina sp.		4	Elphidium sp.
	5	Cibicides sp.		5	Buccella sp.		5	Hoeglundina sp.		5	Haynesina sp.		5	Elphidium sp.
	6	Cibicides sp.		6	Buccella sp.		6	Hoeglundina sp.		6	Haynesina sp.		6	Elphidium sp.
	7	Cibicides sp.		7	Buccella sp.		7	Hoeglundina sp.		7	Haynesina sp.		7	Elphidium sp.
	8	Cibicides sp.		8	Buccella sp.		8	Hoeglundina sp.		8	Fissurina sp.		8	Elphidium sp.
	9	Cibicides sp.		9	Buccella sp.		9	Hoeglundina sp.		9	Fissurina sp.		9	Elphidium sp.
	10	Cibicides sp.		10	Buccella sp.		10	Hoeglundina sp.		10	Fissurina sp.		10	Elphidium sp.
	11	Cibicides sp.		11	Buccella sp.		11	Hoeglundina sp.		11	Fissurina sp.		11	Elphidium sp.
	12	Cibicides sp.		12	Buccella sp.		12	Hoeglundina sp.		12	Pullenia sp.		12	Elphidium sp.
	13	Cibicides sp.		13	Buccella sp.		13	Hoeglundina sp.		13	Pullenia sp.		13	Elphidium sp.
	14	Cibicides sp.		14	Buccella sp.		14	Hoeglundina sp.		14	Pullenia sp.		14	Elphidium sp.
	15	Cibicides sp.		15	Buccella sp.		15	Hoeglundina sp.		15	Pullenia sp.		15	Elphidium sp.
	16	Buccella sp.		16	Buccella sp.		16	Hoeglundina sp.		16	Pullenia sp.		16	Elphidium sp.
	17	Buccella sp.		17	Buccella sp.		17	Hoeglundina sp.		17	Oolina sp.		17	Elphidium sp.
	18	Buccella sp.		18	Buccella sp.		18	Hoeglundina sp.		18	Oolina sp.		18	Elphidium sp.
	19	Buccella sp.		19	Buccella sp.		19	Cassidulina sp.		19	Trifarina sp.		19	Elphidium sp.
	20	Buccella sp.		20	Buccella sp.		20	Cassidulina sp.		20	Elphidium sp.		20	Elphidium sp.
	21	Buccella sp.		21	Buccella sp.		21	Cassidulina sp.		21	Elphidium sp.		21	Elphidium sp.
	22	Buccella sp.		22	Buccella sp.		22	Melonis sp.		22	Elphidium sp.		22	Elphidium sp.
	23	Buccella sp.		23	Buccella sp.		23	Melonis sp.		23	Elphidium sp.		23	Elphidium sp.
	24	Buccella sp.		24	Buccella sp.		24	Melonis sp.		24	Elphidium sp.		24	Elphidium sp.
	25	Buccella sp.		25	Buccella sp.		25	Melonis sp.		25	Elphidium sp.		25	Elphidium sp.
	26	Buccella sp.		26	Buccella sp.		26	Melonis sp.		26	Elphidium sp.		26	Elphidium sp.
	27	Buccella sp.		27	Buccella sp.		27	Melonis sp.		27	Elphidium sp.		27	Elphidium sp.
	28	Buccella sp.		28	Buccella sp.		28	Melonis sp.		28	Elphidium sp.		28	Elphidium sp.
	29	Buccella sp.		29	Buccella sp.		29	Melonis sp.		29	Elphidium sp.		29	Elphidium sp.
	30	Buccella sp.		30	Buccella sp.		30	Melonis sp.		30	Elphidium sp.		30	Elphidium sp.
	31	Buccella sp.		31	Buccella sp.		31	Melonis sp.		31	Elphidium sp.		31	Elphidium sp.
	32	Buccella sp.		32	Buccella sp.		32	Melonis sp.		32	Elphidium sp.		32	Elphidium sp.
	33	Buccella sp.		33	Buccella sp.		33	Melonis sp.		33	Elphidium sp.		33	Elphidium sp.
	34	Buccella sp.		34	Buccella sp.		34	Melonis sp.		34	Elphidium sp.		34	Elphidium sp.
	35	Buccella sp.		35	Buccella sp.		35	Melonis sp.		35	Elphidium sp.		35	Elphidium sp.
	36	Buccella sp.		36	Buccella sp.		36	Melonis sp.		36	Elphidium sp.		36	Haynesina sp.
	37	Buccella sp.		37	Buccella sp.		37	Melonis sp.		37	Elphidium sp.		37	Haynesina sp.
	38	Buccella sp.		38	Buccella sp.		38	Melonis sp.		38	Elphidium sp.		38	Haynesina sp.
	39	Buccella sp.		39	Buccella sp.		39	Melonis sp.		39	Elphidium sp.		39	Haynesina sp.
	40	Buccella sp.		40	Buccella sp.		40	Melonis sp.		40	Elphidium sp.		40	Cassidulina sp.
	41	Buccella sp.		41	Buccella sp.		41	Melonis sp.		41	Elphidium sp.		41	Cassidulina sp.
	42	Buccella sp.		42	Buccella sp.		42	Melonis sp.		42	Elphidium sp.		42	Bolivina sp.
	43	Buccella sp.		43	Buccella sp.		43	Melonis sp.		43	Elphidium sp.		43	Haynesina sp.
	44	Buccella sp.		44	Buccella sp.		44	Haynesina sp.		44	Elphidium sp.		44	Haynesina sp.
	45	Buccella sp.		45	Buccella sp.		45	Haynesina sp.		45	Elphidium sp.		45	Haynesina sp.
	46	Buccella sp.		46	Buccella sp.		46	Haynesina sp.		46	Elphidium sp.		46	Haynesina sp.
	47	Buccella sp.		47	Buccella sp.		47	Haynesina sp.		47	Elphidium sp.		47	Melonis sp.
	48	Buccella sp.		48	Buccella sp.		48	Haynesina sp.		48	Elphidium sp.		48	Melonis sp.
	49	Buccella sp.		49	Buccella sp.		49	Haynesina sp.		49	Elphidium sp.		49	Melonis sp.
	50	Buccella sp.		50	Buccella sp.		50	Haynesina sp.		50	Elphidium sp.		50	Haynesina sp.
	51	Buccella sp.		51	Buccella sp.		51	Haynesina sp.		51	Elphidium sp.		51	Haynesina sp.
	52	Buccella sp.		52	Buccella sp.		52	Haynesina sp.		52	Elphidium sp.		52	Haynesina sp.
	53	Buccella sp.		53	Buccella sp.		53	Haynesina sp.		53	Elphidium sp.		53	Buccella sp.
	54	Buccella sp.		54	Buccella sp.		54	Haynesina sp.		54	Elphidium sp.		54	Buccella sp.
	55	Buccella sp.		55	Buccella sp.		55	Haynesina sp.		55	Elphidium sp.		55	Buccella sp.
	56	Buccella sp.		56	Buccella sp.		56	Haynesina sp.		56	Elphidium sp.		56	Buccella sp.
	57	Buccella sp.		57	Buccella sp.		57	Haynesina sp.		57	Elphidium sp.		57	Buccella sp.
	58	Buccella sp.		58	Buccella sp.		58	Haynesina sp.		58	Elphidium sp.		58	Buccella sp.
	59	Buccella sp.		59	Buccella sp.		59	Haynesina sp.		59	Elphidium sp.		59	Buccella sp.
	60	Buccella sp.		60	Buccella sp.		60	Haynesina sp.		60	Elphidium sp.		60	Buccella sp.

Table A.13 Sample #10 0-0.5 cm

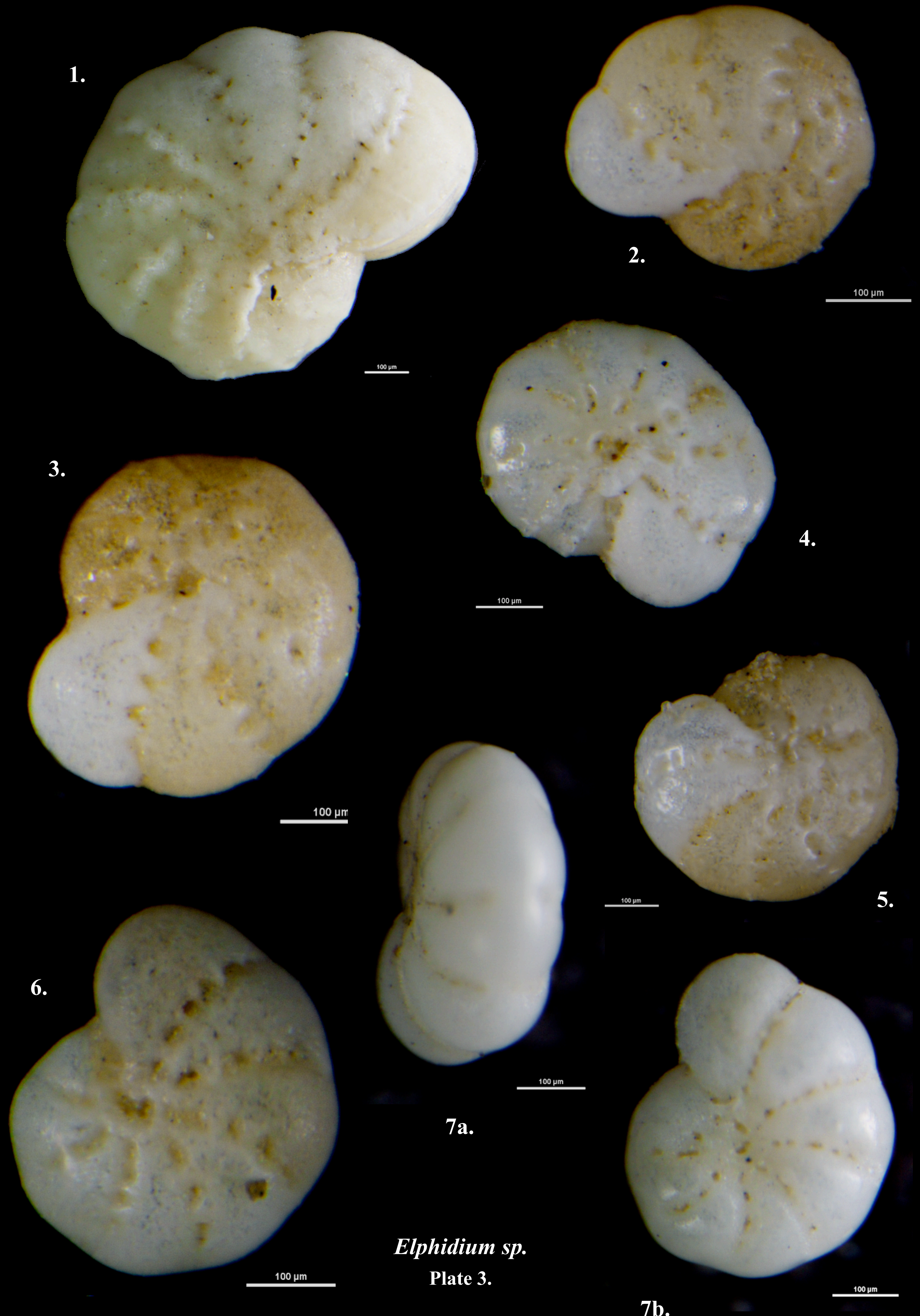
AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus	AMNH #	Sample #	Genus
108527	1	Cibicides sp.	**108528**	1	Cibicides sp.	**108529**	1	Cassidulina sp.	**108530**	1	Elphidium sp.	**108531**	1	Elphidium sp.
	2	Cibicides sp.		2	Buccella sp.		2	Cassidulina sp.		2	Elphidium sp.		2	Cibicides sp.
	3	Cibicides sp.		3	Buccella sp.		3	Cassidulina sp.		3	Elphidium sp.		3	Elphidium sp.
	4	Cibicides sp.		4	Buccella sp.		4	Cassidulina sp.		4	Elphidium sp.		4	Cassidulina sp.
	5	Cibicides sp.		5	Buccella sp.		5	Cassidulina sp.		5	Elphidium sp.		5	Cibicides sp.
	6	Cibicides sp.		6	Buccella sp.		6	Cassidulina sp.		6	Elphidium sp.		6	Oolina sp.
	7	Cibicides sp.		7	Buccella sp.		7	Cassidulina sp.		7	Elphidium sp.		7	Cibicides sp.
	8	Cibicides sp.		8	Buccella sp.		8	Cassidulina sp.		8	Elphidium sp.		8	Elphidium sp.
	9	Cibicides sp.		9	Buccella sp.		9	Cassidulina sp.		9	Elphidium sp.		9	Cibicides sp.
	10	Cibicides sp.		10	Buccella sp.		10	Cassidulina sp.		10	Elphidium sp.		10	Haynesina sp.
	11	Cibicides sp.		11	Buccella sp.		11	Cassidulina sp.		11	Buccella sp.		11	Haynesina sp.
	12	Cibicides sp.		12	Buccella sp.		12	Cassidulina sp.		12	Buccella sp.		12	Fissurina sp.
	13	Cibicides sp.		13	Buccella sp.		13	Cassidulina sp.		13	Cibicides sp.		13	Melonis sp.
	14	Cibicides sp.		14	Buccella sp.		14	Cassidulina sp.		14	Buccella sp.		14	Fissurina sp.
	15	Cibicides sp.		15	Buccella sp.		15	Cassidulina sp.		15	Cibicides sp.		15	Elphidium sp.
	16	Cibicides sp.		16	Buccella sp.		16	Melonis sp.		16	Elphidium sp.		16	Elphidium sp.
	17	Cibicides sp.		17	Buccella sp.		17	Melonis sp.		17	Cibicides sp.		17	Elphidium sp.
	18	Cibicides sp.		18	Buccella sp.		18	Melonis sp.		18	Elphidium sp.		18	Elphidium sp.
	19	Cibicides sp.		19	Buccella sp.		19	Melonis sp.		19	Cibicides sp.		19	Oolina sp.
	20	Cibicides sp.		20	Buccella sp.		20	Melonis sp.		20	Cibicides sp.		20	Cibicides sp.
	21	Cibicides sp.		21	Buccella sp.		21	Melonis sp.		21	Elphidium sp.		21	Buccella sp.
	22	Cibicides sp.		22	Buccella sp.		22	Melonis sp.		22	Elphidium sp.		22	Elphidium sp.
	23	Cibicides sp.		23	Buccella sp.		23	Haynesina sp.		23	Melonis sp.		23	Fissurina sp.
	24	Cibicides sp.		24	Buccella sp.		24	Haynesina sp.		24	Fissurina sp.		24	Haynesina sp.
	25	Cibicides sp.		25	Buccella sp.		25	Haynesina sp.		25	Elphidium sp.		25	Hoeglundina sp.
	26	Cibicides sp.		26	Buccella sp.		26	Haynesina sp.		26	Cibicides sp.		26	Cibicides sp.
	27	Cibicides sp.		27	Buccella sp.		27	Haynesina sp.		27	Elphidium sp.		27	Cassidulina sp.
	28	Cibicides sp.		28	Buccella sp.		28	Haynesina sp.		28	Cassidulina sp.		28	Elphidium sp.
	29	Cibicides sp.		29	Buccella sp.		29	Haynesina sp.		29	Elphidium sp.		29	Hoeglundina sp.
	30	Cibicides sp.		30	Buccella sp.		30	Haynesina sp.		30	Fissurina sp.		30	Fissurina sp.
	31	Cibicides sp.		31	Buccella sp.		31	Haynesina sp.		31	Nonionellina sp.		31	Melonis sp.
	32	Cibicides sp.		32	Buccella sp.		32	Haynesina sp.		32	Hoeglundina sp.		32	Elphidium sp.
	33	Cibicides sp.		33	Buccella sp.		33	Haynesina sp.		33	Elphidium sp.		33	Oolina sp.
	34	Cibicides sp.		34	Buccella sp.		34	Haynesina sp.		34	Cibicides sp.		34	Haynesina sp.
	35	Cibicides sp.		35	Buccella sp.		35	Haynesina sp.		35	Melonis sp.		35	Cassidulina sp.
	36	Cibicides sp.		36	Buccella sp.		36	Haynesina sp.		36	Pullenia sp.		36	Elphidium sp.
	37	Cibicides sp.		37	Buccella sp.		37	Haynesina sp.		37	Haynesina sp.		37	Elphidium sp.
	38	Cibicides sp.		38	Buccella sp.		38	Haynesina sp.		38	Cassidulina sp.		38	Cassidulina sp.
	39	Cibicides sp.		39	Buccella sp.		39	Haynesina sp.		39	Elphidium sp.		39	Cibicides sp.
	40	Cibicides sp.		40	Buccella sp.		40	Haynesina sp.		40	Elphidium sp.		40	Buccella sp.
	41	Cibicides sp.		41	Hoeglundina sp.		41	Haynesina sp.		41	Buccella sp.		41	Elphidium sp.
	42	Cibicides sp.		42	Hoeglundina sp.		42	Elphidium sp.		42	Melonis sp.		42	Cassidulina sp.
	43	Cibicides sp.		43	Hoeglundina sp.		43	Elphidium sp.		43	Elphidium sp.		43	Elphidium sp.
	44	Cibicides sp.		44	Hoeglundina sp.		44	Elphidium sp.		44	Elphidium sp.		44	Fissurina sp.
	45	Cibicides sp.		45	Hoeglundina sp.		45	Elphidium sp.		45	Cibicides sp.		45	Elphidium sp.
	46	Cibicides sp.		46	Hoeglundina sp.		46	Elphidium sp.		46	Melonis sp.		46	Elphidium sp.
	47	Cibicides sp.		47	Hoeglundina sp.		47	Elphidium sp.		47	Elphidium sp.		47	Buccella sp.
	48	Cibicides sp.		48	Hoeglundina sp.		48	Elphidium sp.		48	Elphidium sp.		48	Buccella sp.
	49	Cibicides sp.		49	Hoeglundina sp.		49	Elphidium sp.		49	Elphidium sp.		49	Cibicides sp.
	50	Cibicides sp.		50	Hoeglundina sp.		50	Elphidium sp.		50	Elphidium sp.		50	Elphidium sp.
	51	Cibicides sp.		51	Hoeglundina sp.		51	Elphidium sp.		51	Elphidium sp.		51	Elphidium sp.
	52	Cibicides sp.		52	Hoeglundina sp.		52	Elphidium sp.		52	Haynesina sp.		52	Haynesina sp.
	53	Cibicides sp.		53	Hoeglundina sp.		53	Elphidium sp.		53	Cibicides sp.		53	Buccella sp.
	54	Cibicides sp.		54	Hoeglundina sp.		54	Elphidium sp.		54	Cibicides sp.		54	Cibicides sp.
	55	Cibicides sp.		55	Hoeglundina sp.		55	Elphidium sp.		55	Melonis sp.		55	Cibicides sp.
	56	Cibicides sp.		56	Cassidulina sp.		56	Elphidium sp.		56	Cibicides sp.		56	Cibicides sp.
	57	Cibicides sp.		57	Cassidulina sp.		57	Elphidium sp.		57	Melonis sp.		57	Cibicides sp.
	58	Cibicides sp.		58	Cassidulina sp.		58	Elphidium sp.		58	Cibicides sp.		58	Cibicides sp.
	59	Cibicides sp.		59	Cassidulina sp.		59	Elphidium sp.		59	Cibicides sp.		59	Cibicides sp.
	60	Cibicides sp.		60	Cassidulina sp.		60	Elphidium sp.		60	Cibicides sp.		60	Cibicides sp.



Cibicides sp.
Plate 1.



Buccella sp.
Plate 2.

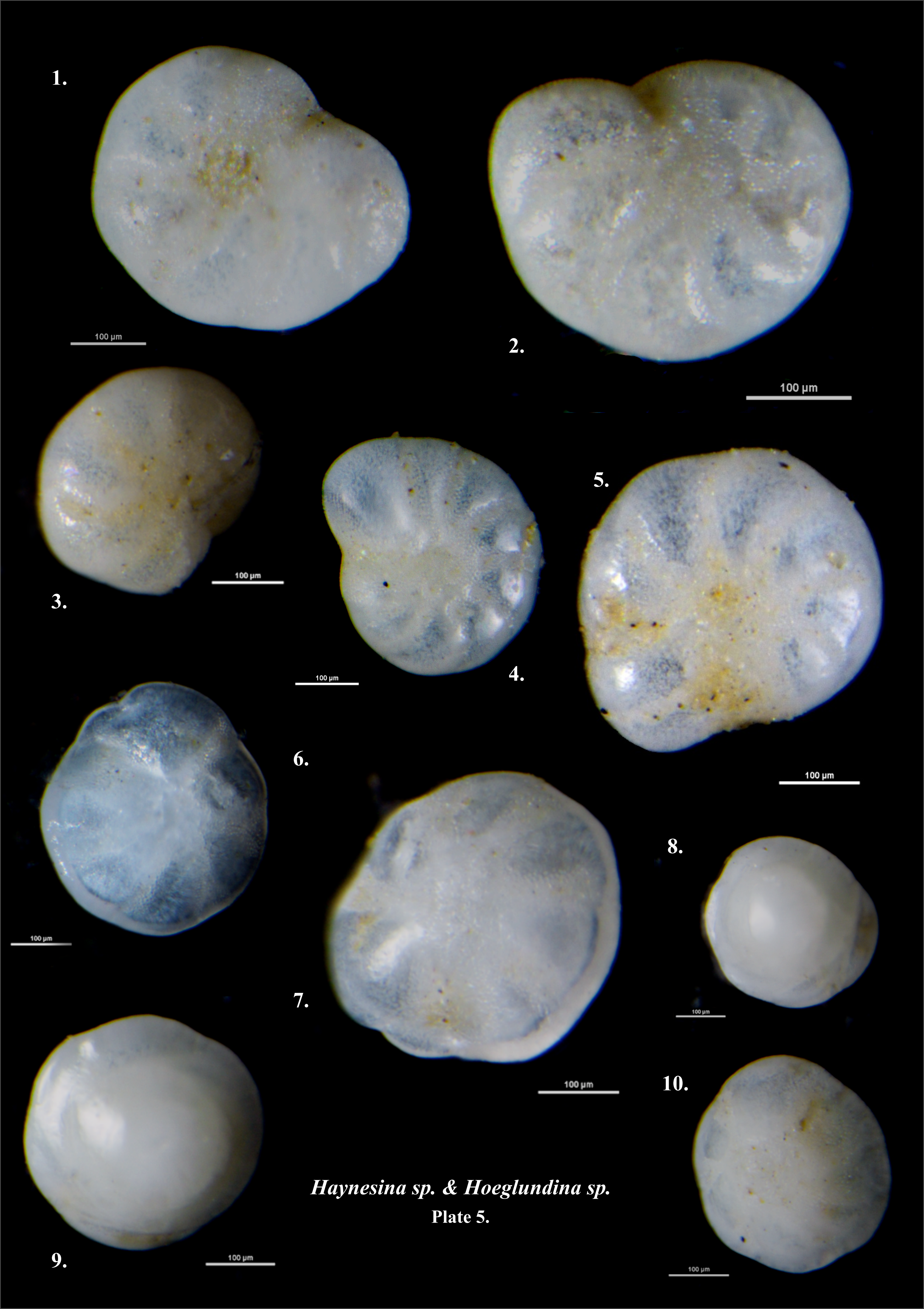


Elphidium sp.

Plate 3.

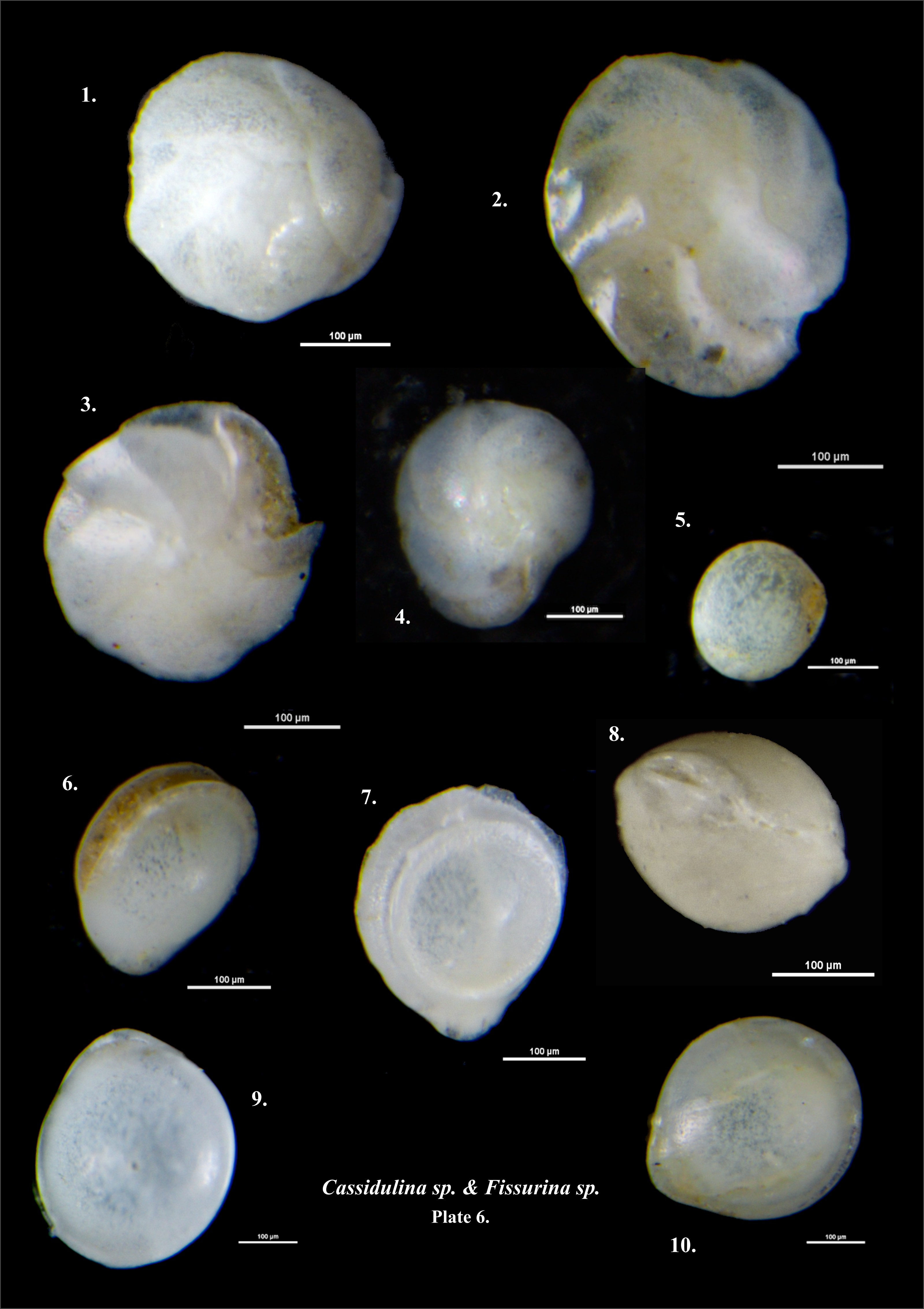
Melonis sp.

Plate 4.



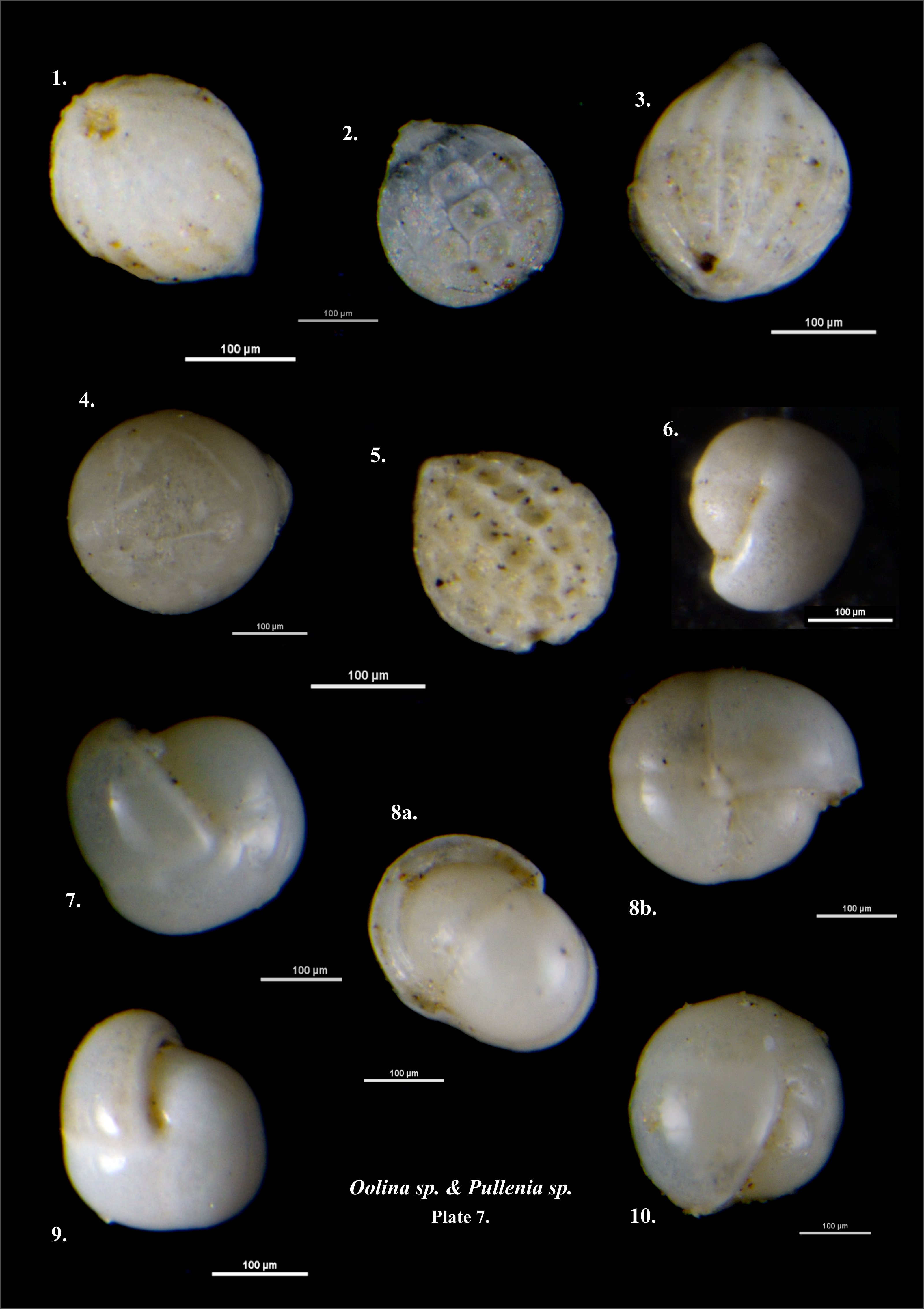
Haynesina sp. & Hoeglundina sp.

Plate 5.



Cassidulina sp. & Fissurina sp.

Plate 6.



Oolina sp. & Pullenia sp.

Plate 7.

Lagena sp., Trifarina sp, & Triloculina sp.

Plate 8.

Nonionellina sp, Bolivina sp., & Quinqueloculina sp.

Plate 9.