Research Note

Littoral microfauna from Terceira Island, Azores

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Most recent revision: 3 Jan 2023 rev. 12

ABSTRACT

Six collections of shallow-water sediment distributed around the north, east, and south shores of Terceira Island, Azores, were examined for foraminifera, mollusks, and other microfauna. Surprisingly, only one of the six collections, the easternmost, contained a significant number of foraminifera. In that collection, the density of foraminifera was quite low compared to similar collections at other islands (e.g., Faial Island, Pitcairn Islands, Gambiers, Clipperton, Rocas Alijos). In two of the collections a moderate number of conical mollusks was found, but essentially no foraminifera. The distribution of microfauna (moderate populations on the east coast but no populations on the north and south coasts) is consistent with the hypothesis that high energy west winds and currents impinging on the western coastline control the growth of live fauna and the destruction of dead individuals.

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INTRODUCTION

Over the last two decades there has been extensive effort to document the marine life on the Azores Archipelago (Northeast Atlantic Ocean). Part of this effort has been to study microfauna, especially Molluska and Foraminifera, in the size range 0.1-3.0 mm. Typically the work is organized around a particular site, such as an island, along a cruise track, or as function of depth. Thus, we might find a study "Littoral gastropods of Sao Miguel Island" and other publications of similar nature.

Goals of these programs include elaborating the effects of volcanism on populations specific taxa, recolonization following catastrophic volcanic eruption, understanding the life processes of specific species in hydrodynamic and/or hydrothermal environments, comparison of species assemblages between different sites, accounting for the presence or absence of species on specific islands, relating species distributions to distant locations (e.g., Canary Islands, Madera Island, Ascension Island), and similar biogeographic issues.

A large body of work on faunal assemblages on the Azores Archipelago has been done by Sergio Avila and colleagues (1997, 1998, 2000, 2000a, 2000b, 2000c, 2003, 2004). Related work on the geologic evolution of the island shelves and seafloor by Rui Quartau and colleagues (2010, 2012, 2013), Ramalho et al. (2013), Valente (2020, and Zhao et al. (2019), among many others, are notable. Still, there is plenty of room for independent (and individual) investigators to study the marine populations and related investigations from very distant locations are potentially very valuable. Examples include the work of Di Bella and colleagues (2014, 2015) on foraminiferal assemblages in active volcanic areas (including the Azores), the investigation of repopulation following the eruptions at Mt. Pinatubo (Philippines) by Hess and colleagues (2001), and discussions of effects of eruptions on the marine environment by Colletti (___) and by Hart (2022).

In this document we describe an investigation of littoral microfauna (gastropoda and foraminifera) on Terceira Island. The raw material in this work was beach sediment collected by hand at about 1 m depth from relatively protected beaches. This report provides documentation of the methods of extracting the microfauna, preliminary statistical counts of the relative populations, and the geographic pattern of the populations that emerged from the relative populations. The geographic pattern is discussed at the end of this report.

Note: Throughout this report, references to three collections are set in red type: **Ter004**, **Ter006**, and **Ter007**. The reason for this is that these three collections contained microfauna–either foraminifera or mollusks (primarily gastropods). The other collections (**Ter001, Ter002,** and **Ter008**) contained no microfauna and are set in black.

TERCEIRA ISLAND

The nine Azores Islands are located about 1500 km due west of Portugal (they are part of Portugal). Terceira Island is one of the Central Group of the Azores islands.

Fig. 1 *(2 panels) – The Azores*

THE 2022 COLLECTIONS

On 4 Aug and 11 Aug 2022, one of the authors of this report (Joao Lima), a resident of Terceira Island, Azores, made collections of sediment at six beaches widely spaced around the island. Each collection comprised about 100 cm^3 and weighed about 200 g. The collections were air-dried and stored in Ziploc plastic bags.

In late September 2022, the other author of this report (Robert Schmieder), together with Fred Belton of Tennessee and Randy Schmieder of Switzerland, travelled to the Azores to investigate shallow-water microfauna, particularly foraminifera from the offshore Capelinhos, an area on Faial Island that had been devastated by the volcanic eruptions of 1958-59. By arrangement, the collections made by Joao Lima were sent to Eunice Santos, a resident of Faial, Island (sister-in-law of Joao Lima), and were transferred to the author on 17 Sep 2022. It is not known when, or even whether, the Terceira populations had been subjected to historical volcanic devastation.

During the stay on Faial, Schmieder made a preliminary microscopic examination of the Terceira collection. Upon return to California, Schmieder made a detailed microscopic examination of the collections. The collections were sieved, and the fractions held by the 250 µm and 125 µm sieves were examined for microfauna. Details of these examinations are summarized in this report.

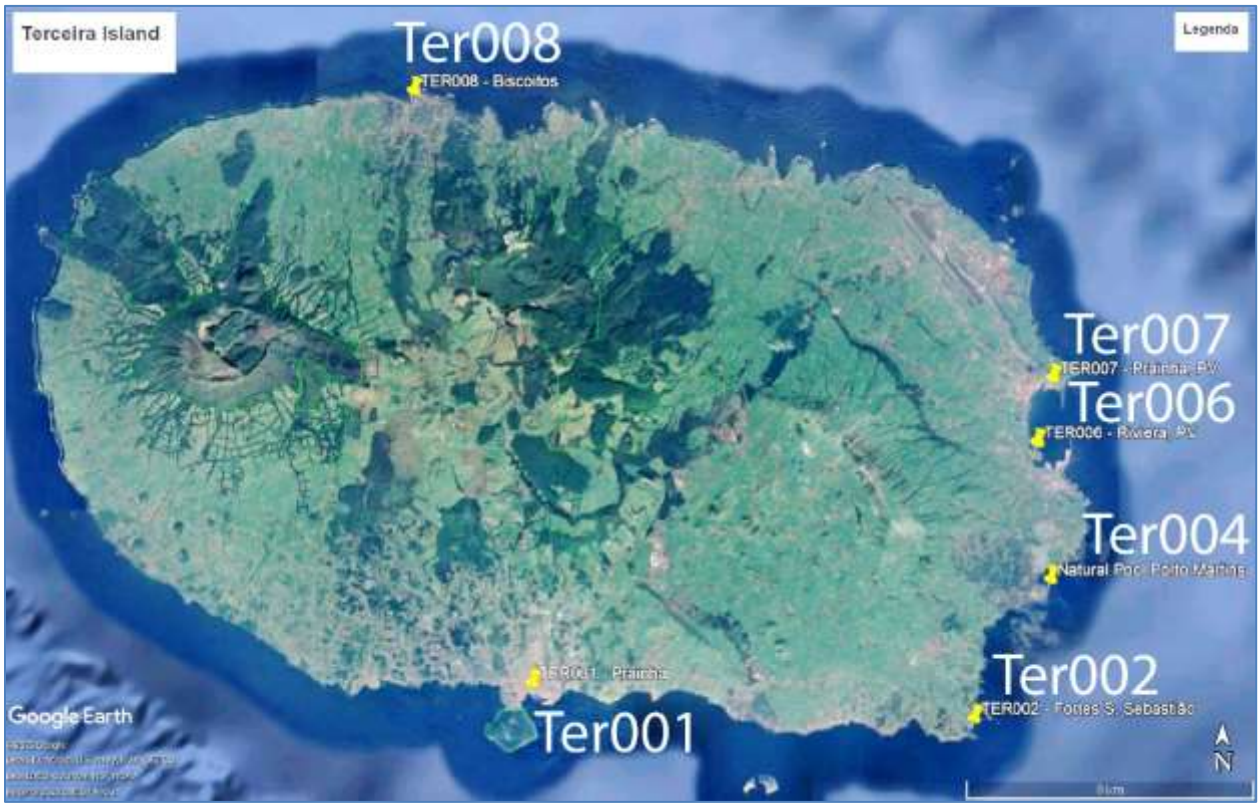

Fig. 2 *- Locations of the 2022 collections*

Table 1 was provided by Joao Lima, who made these collections by hand. The collections were air-dried, placed in Ziploc bags, and transferred to the author on Faial Island.

Table 1 – Identifications of the collections

Collection	Island	Location	Latitude	Longitude	Depth (m)	Date
Ter001	Terceira	Prainha, AH	38.653661	-27.220013	2	4-Sep-22
Ter002	Terceira	Fortes de São Sebastião***	38.645943	-27.07897	1*	4-Aug-22
Ter004	Terceira	Natural Pool Porto Martins	38.680726	-27.055106	1.5*	4-Aug-22
Ter006	Terceira	Riviera, PV	38.714731	-27.059675	2	11-Aug-22
Ter007	Terceira	Prainha, PV	38.730723	-27.054889	2	11-Aug-22
Ter008	Terceira	Biscoitos	38.800587	-27.259824	2**	4-Sep-22

* = Low Tide
**= Very little sand
***= Forte de Santa Catarina (Vila de S. Sebastiao)

Note: Two additional collections, **Ter003** and **Ter005,** were planned but not made, due to the local sediment being at too great depth to sample by hand.

Table 2 was generated by the author.

Table 2 – Descriptions of the collections

Collection	Description*	Color	Mass [g]	Volume [cm^3]	Density [g/cm^3]
Ter001	Volcanic sand. Sparkly.	black	275	100	2.75
Ter002	Two distinct grain sizes	dark brown	65	45	1.44
Ter004	Speckled coarse sand. Ash?	white to tan	105	85	1.24
Ter006	Medium sand. 125 µm fractions sieved into separate bags.	dark gray	222	158	1.40
Ter007	Very fine sand. Light. Flows	reddish	122	139	0.88
Ter008	Very coarse. Wide grain size range.	gray	166	118	1.41

Generally, sand has a density around 1.4-1.6, and four of the present collections agree with this. However, Collection **Ter001** has an exceptionally high density (2.75 g/cm^3), and Collection **Ter007** has an exceptionally low density (0.88 g/cm^3). These values were checked and are not errors in measurements. While we cannot specifically explain these two exceptional values, it is possible that the combination of individual grain density and grain geometry comb7ine to produce these values. For instance, Cho, et al. (2006) describe the effects of particle properties on compactness. In a review of packing of sands, K. P. Panayiotopoulos (1989) states:

> Size distribution, sphericity, roundness and surface roughness of sand particles, all affect the packing and compressibility of sands. Size affects packing, only when particles are less than 50 µm. Maximum and minimum void ratios decrease with increasing roundness and sphericity. For narrowly graded sands, compaction is almost independent of moisture content except near air-dryness and near saturation, where it is greater.

In the light of such comments, we should not be surprised to have found two collections with exceptional mass densities (**Ter001** and **Ter007**) out of six.

PROCESSING

A preliminary examination of each of the seven collections was made using a stereo dissecting microscope. Photographs were taken of individual forams (and other objects) mounted on the slide using a stereo dissecting microscope (AmScope SM-2TZ-LED-5M). The microscope has a zoom lens, and an LED camera connected to the Win 7 computer. AmScope software (Version x64, 3.7.12924.20180915, built 16 Sep 2018) was used to view and save images. General photos showing areas of the slide and groups of objects were photographed with the microscope objective lens at various magnifications. Individual objects were photographed using the 1X objective zoomed to MAX magnification.

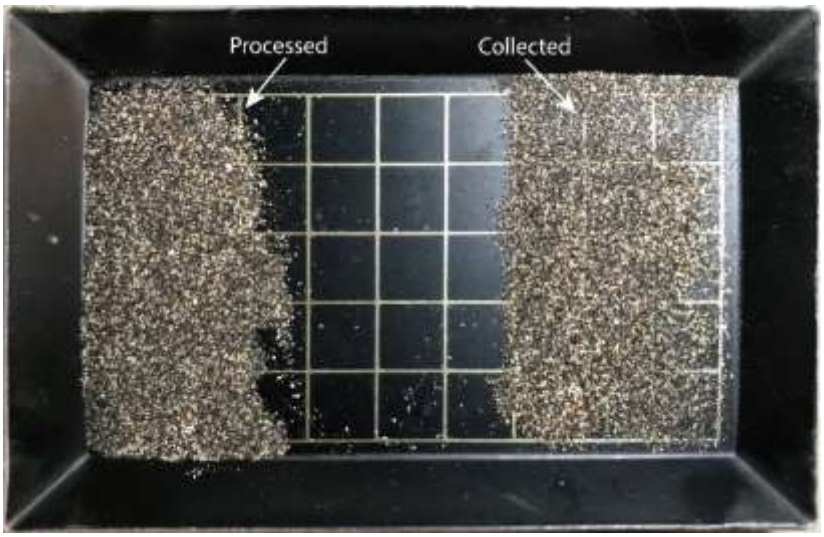

Fig. 3 *– The picking tray*

Fig. 4 *– The slide "TERCEIRA"*

The individual forams were "picked" as follows: A split of sediment (ca. 1 cm^3) was placed in the standard picking tray and positioned to the right-hand margin, spreading it out in a thin layer. With the microscope focused on the left edge of the layer, a dry /0 kolibri 8805 synthetic golden sable brush was used to move the sediment to the left, under the field of view. When a foram (or other interesting object) was seen, a separate brush wet with glue (gum traganth) was used to pick up the object and transfer it to a ruled microscope slide (32 6x6 mm^2 cells).

The preliminary examination done on Faial Island showed that there were very few microfauna in any of the Terceira collections. Only **Ter006** contained appreciable forams. Collections **Ter004** and **Ter007** contained almost no forams, but they did contain some conical gastropods. All individuals were dead. Some of the individuals show significant damage, probably due to surf erosion.

Collection Ter001

Fig. 5 *(4 panels) - Location of the* ***Ter001*** *collection*

Fig. 6 *(2 panels) – Collection* ***Ter001****. No significant microfauna were found in this collection.*

Collection Ter002

Fig. 7 *(4 panels) – Location of the* ***Ter002*** *collection*

Fig. 8 *(2 panels) – Collection* ***Ter002****. No significant microfauna were found in this collection.*

Collection Ter004

Fig. 9 *(4 panels) – Location of the* ***Ter004*** *collection*

Fig. 10 *(2 panels) – Collection* ***Ter004***


17
18
19
20
21
22
23
24


17

Fig. 11 *(4 panels) – Collection* ***Ter004****. Slide TERCEIRA, Cells 17-24 Cell size 6 mm x 6 mm.*

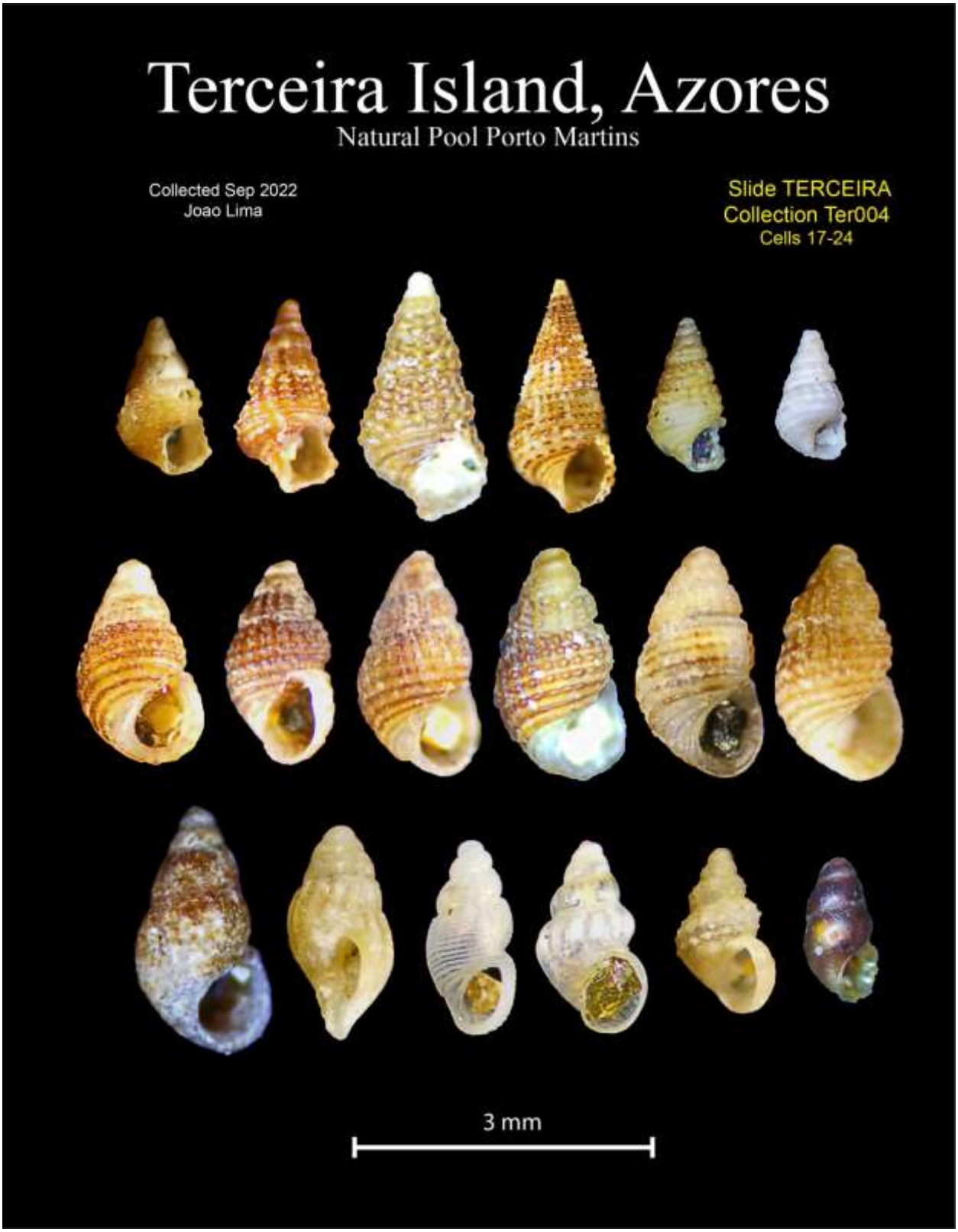

Fig 12 *- Gastropods from Collection* ***Ter004****, Slide TERCEIRA, Cells 17-24*

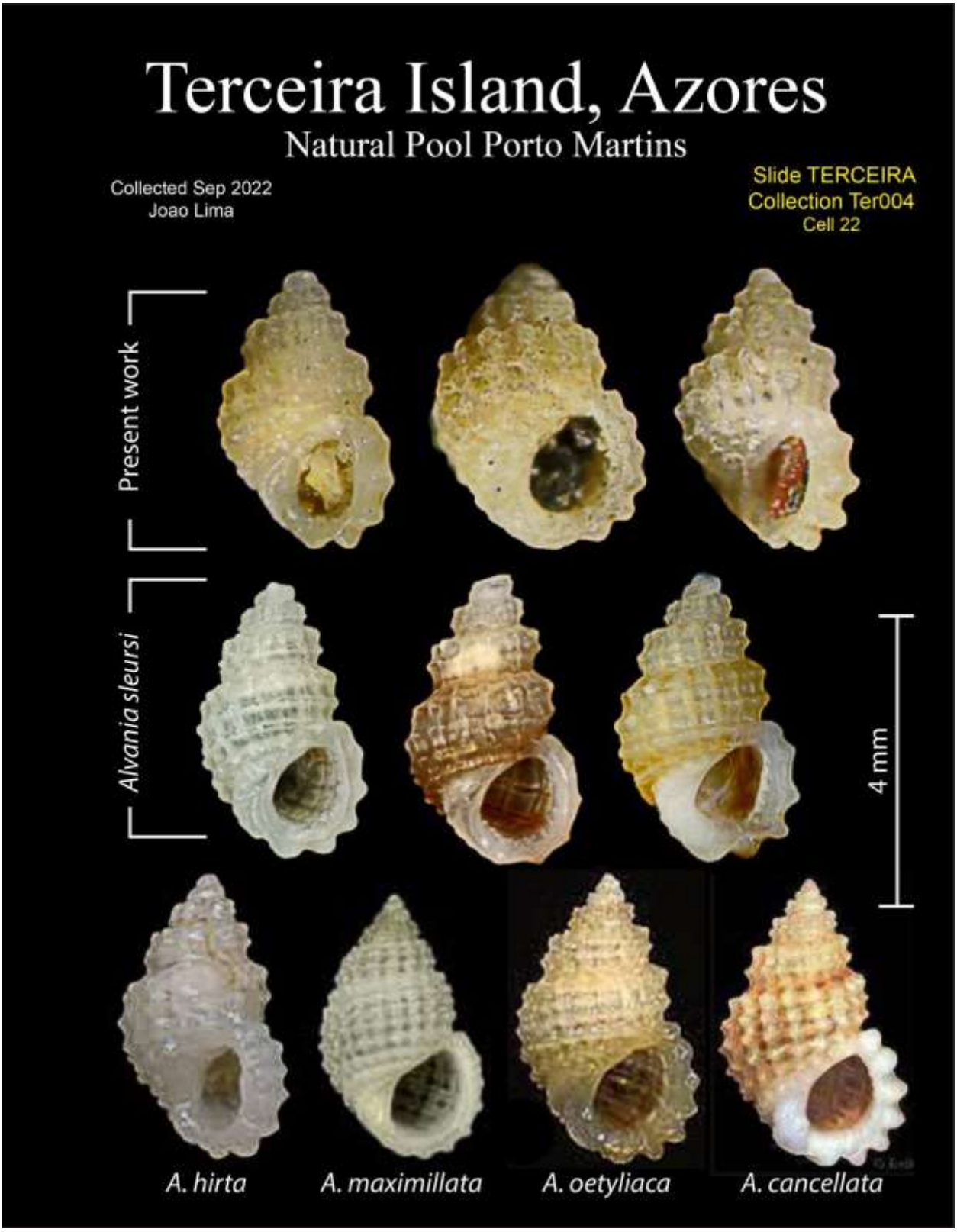

Fig. 13 *- Identification of Alvania sp. in the collection* ***Ter004****. (****Top row****) Three (different) specimens in the collection. (****Middle row****) Three (different) images of Alvania sleursi, taken from the literature. (****Bottom row****) Four different species of Alvania, taken from the literature.*

Collection Ter006

Fig. 14 *(4 panels) - Location of the* ***Ter006*** *collection*

Fig. 15 *(2 panels) - Collection* ***Ter006***


1
2
3
4


1


2

Fig. 16 *(5 panels) – Collection* ***Ter006.*** *Slide TERCEIRA, Cells 1-4. Cell size 6 mm x 6 mm.*

A moderate number of forams were found in collection **Ter006** (Slide TERCEIRA). These are shown on the following pages. The number beside each specimen is **X.Y**, where **X** is the Cell number and **Y** is the sequential number for the specimen. Generally, **Y** runs in reading order, starting at 1. Thus, in the image of Cell 1 above, the specimens are labelled {1.1, 1.2, 1.3, … 1.18}. Specimens in Cell 2 are numbered {2.1, 2.2, 2.3, … 2.9}.

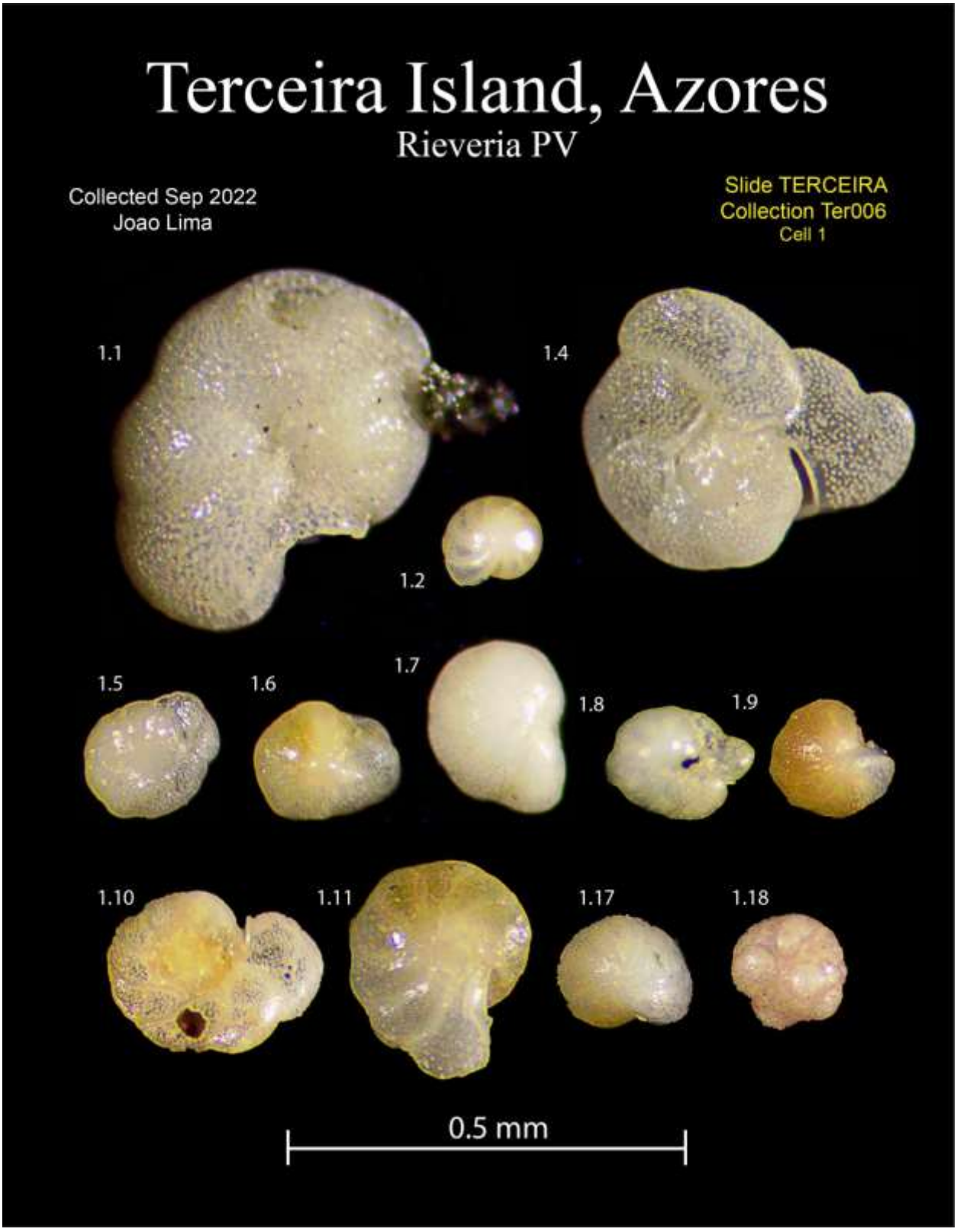

Fig. 17 *- Forams from Collection* ***Ter006****, Cell 1 Possibly all these specimens are foraminifera.*

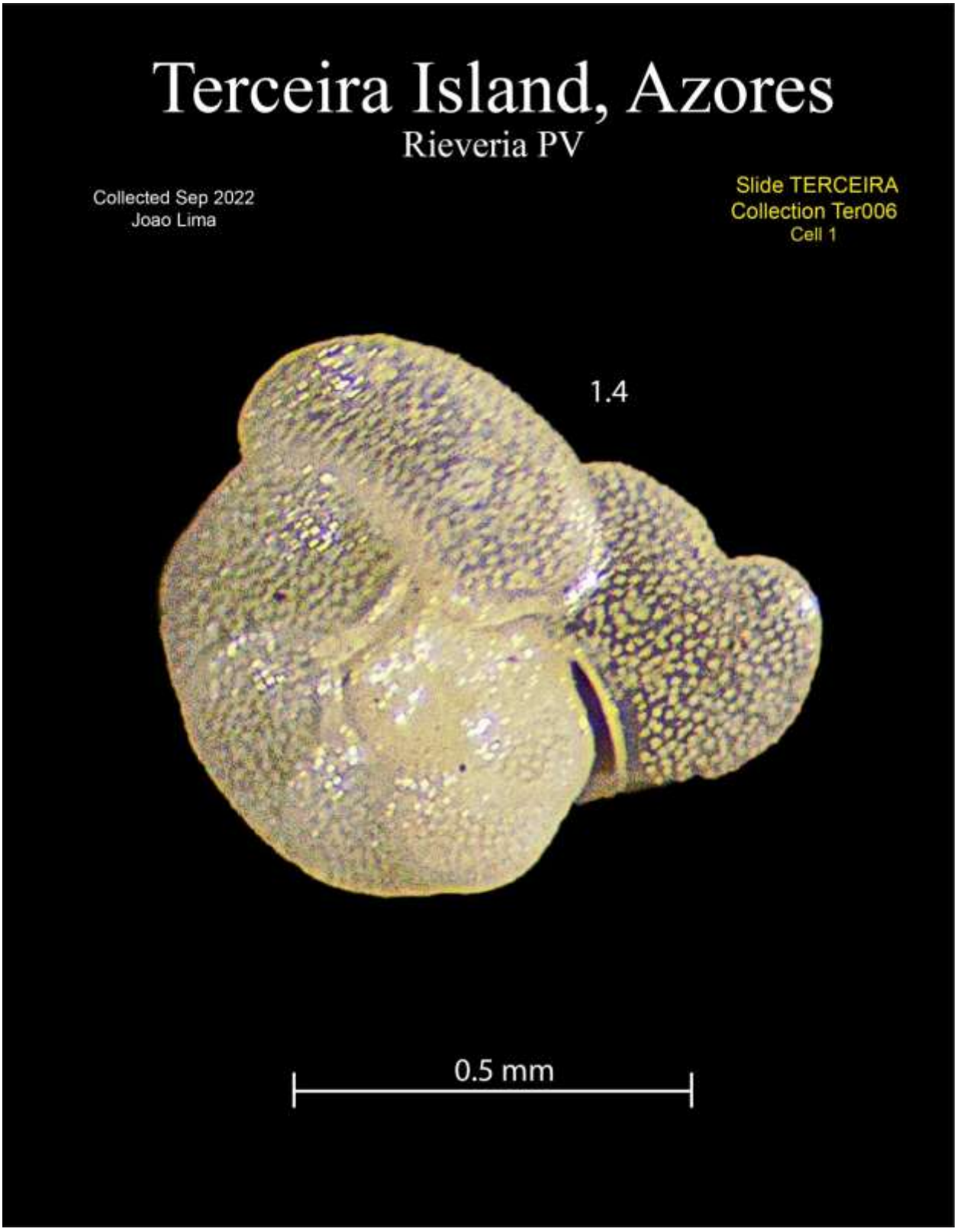

Fig. 18 *– Single foram from Collection* ***Ter006****, Cell 1*

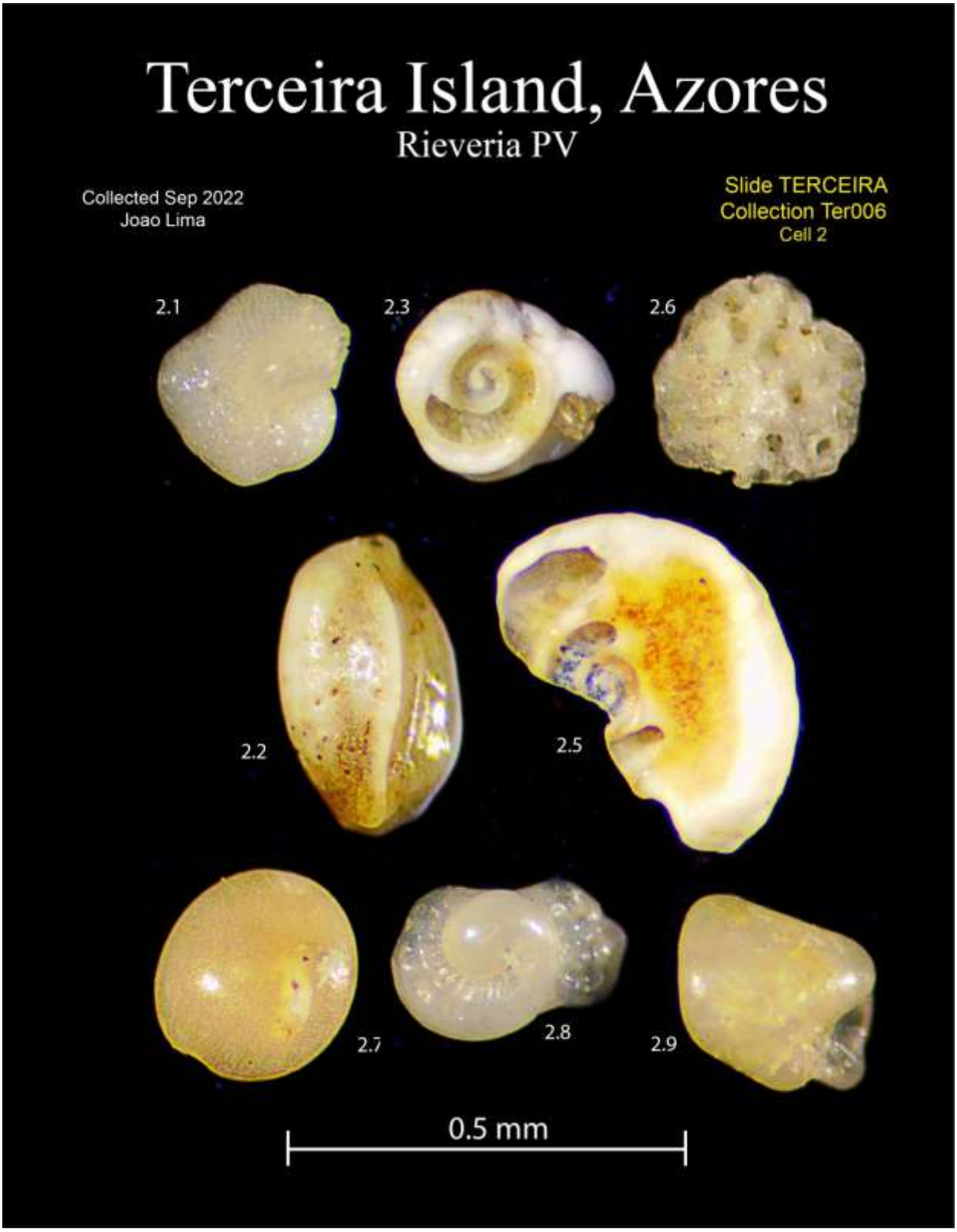

Fig. 19 *Microfauna from Collection* ***Ter006****, Cell 2. Specimens 2.1, 2.2, 2.7, 2.8 and (possibly) 2.9 are foraminifera.*

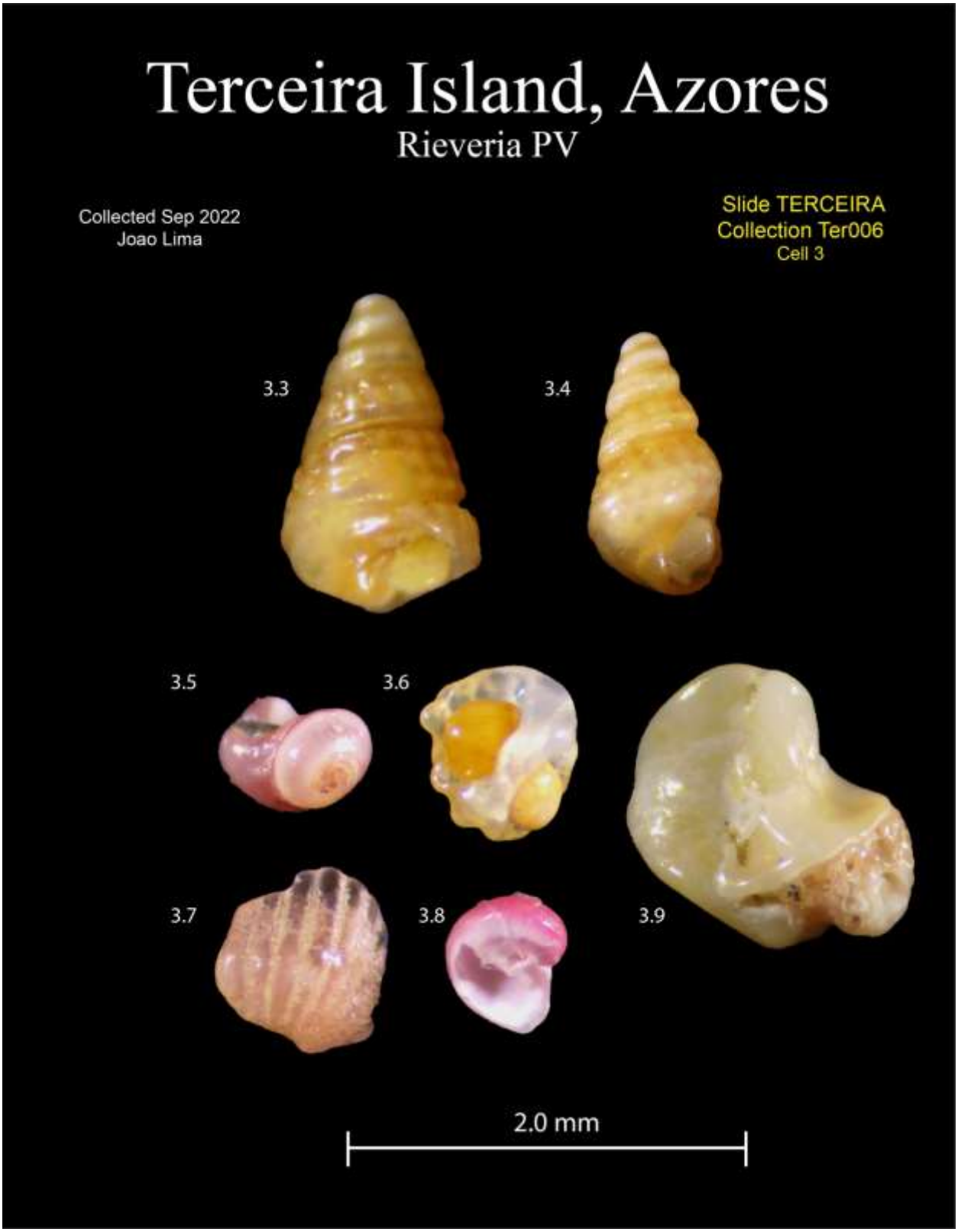

Fig. 20 *Microfauna from Collection* ***Ter006****, Cell 3. Specimens 3.3 and 3.4 are gastropods; the other specimens are unidentified.*

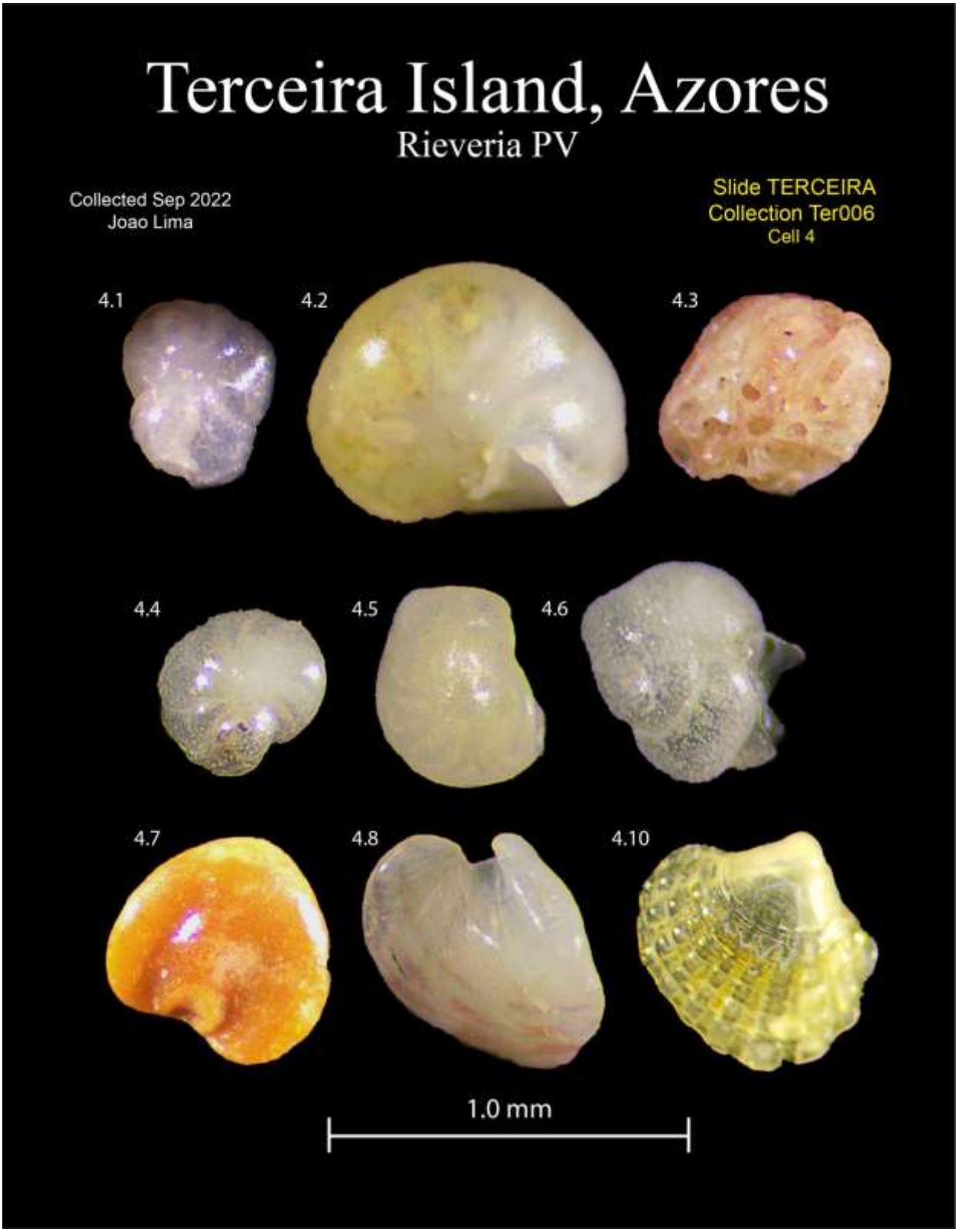

Fig. 21 *Microfauna from Collection* ***Ter006****, Cell 4. Specimens 4.1, 4.2, 4.4, 4.5, and 4.6, are foraminifera. Specimen 4.10 is a bivalve.*

Collection Ter007

Fig. 22 *(4 panels) - Location of the* ***Ter007*** *collection*

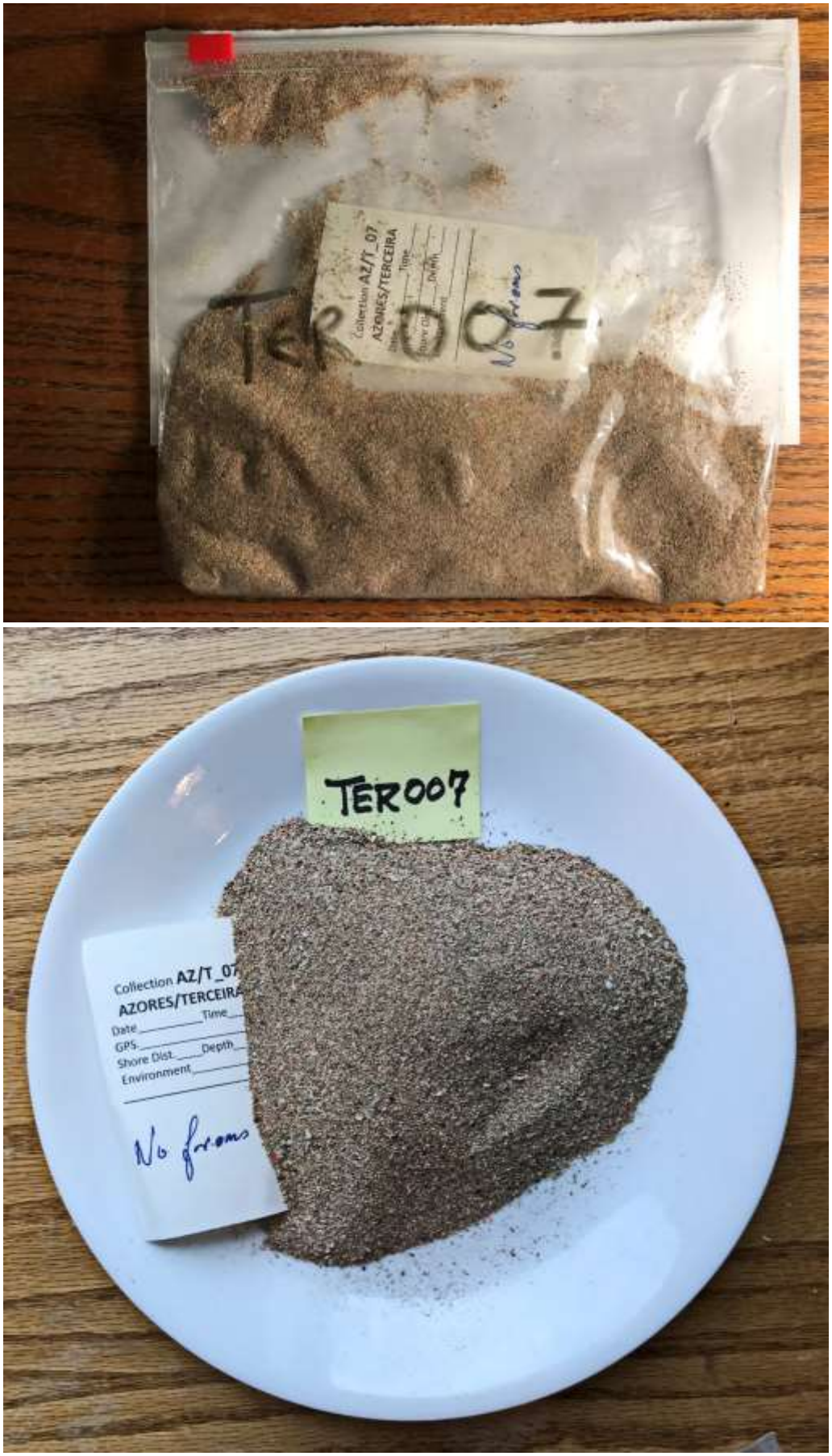

Fig. 23 *(2 panels) - Collection* ***Ter007***

Fig. 24 *(4 panels) –Collection* ***Ter007****. Slide TERCEIRA, Cells 9-12. Cell size 6 mm x 6 mm. (****Upper****) Cells 9-11. (****Lower****) Enlargements of the cells. Cell 9 contains 7 gastropods; Cell 10 contains 6 gastropods; Cell 11 contains 5 gastropods and one unidentified; Cell 12 contains 2 gastropods and on (likely bivalve).*

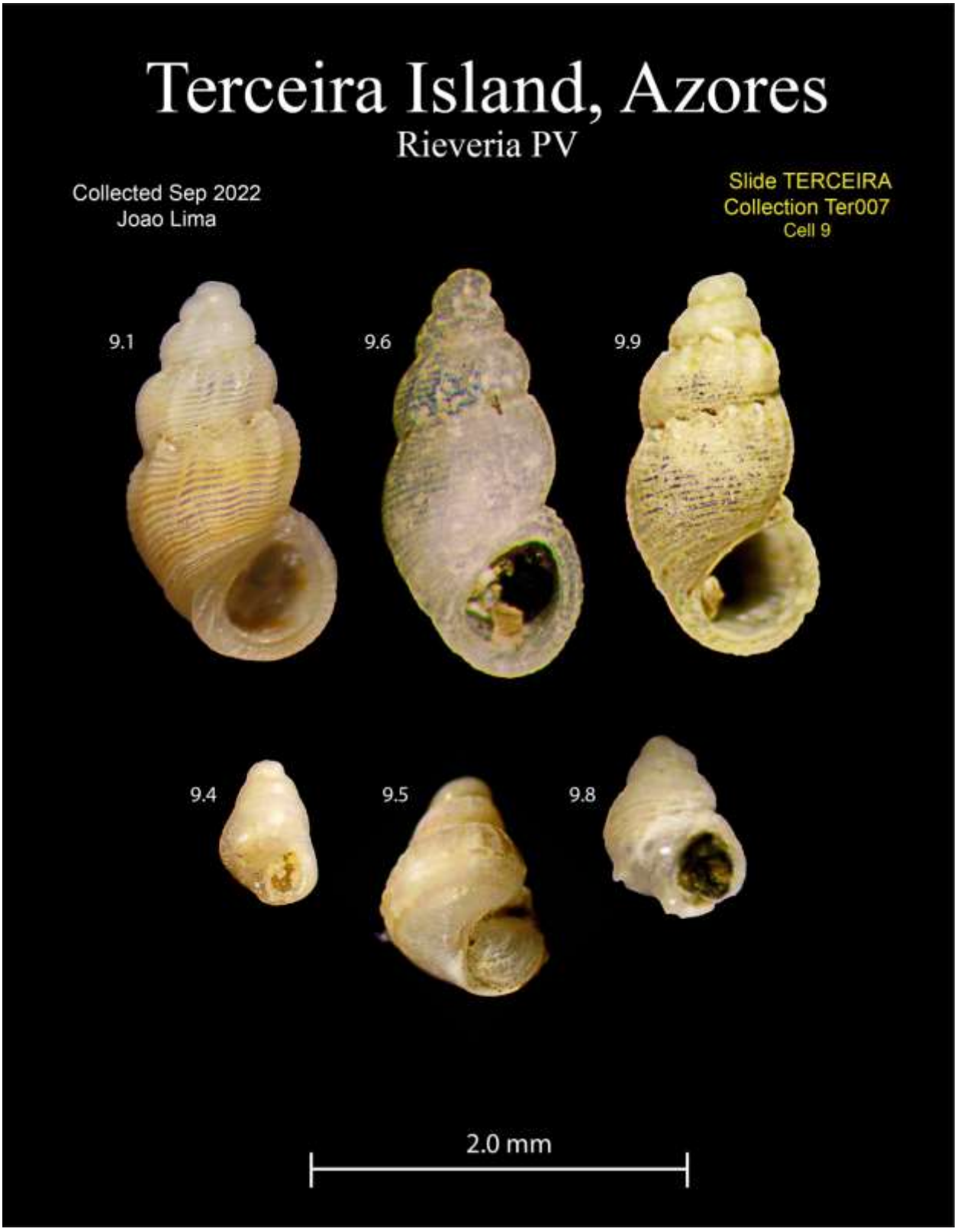

Fig. 25 *Gastropods from Collection* ***Ter007****, Cell 4*

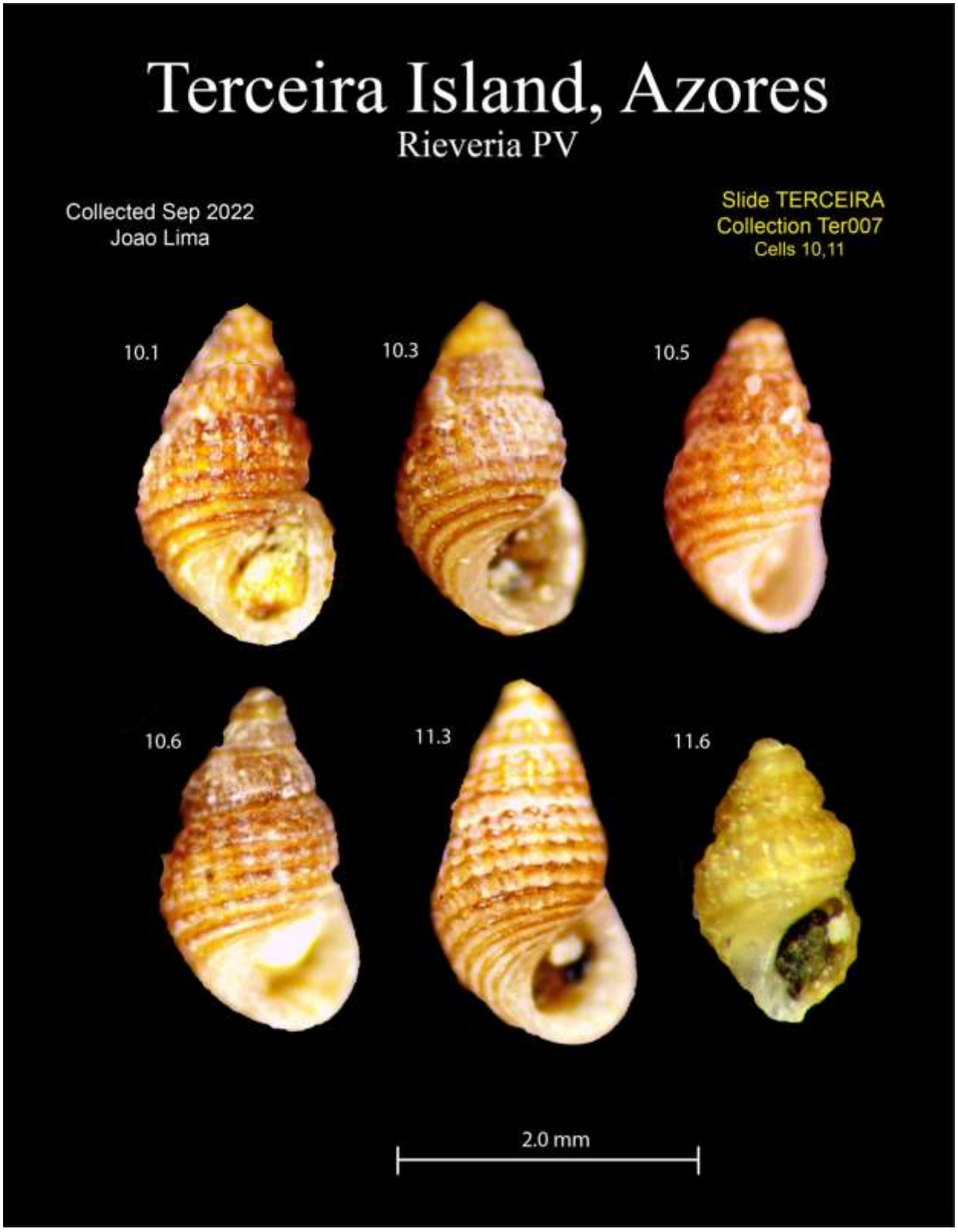

Fig. 26 *Gastropods from Collection* ***Ter007****, Cell 4*

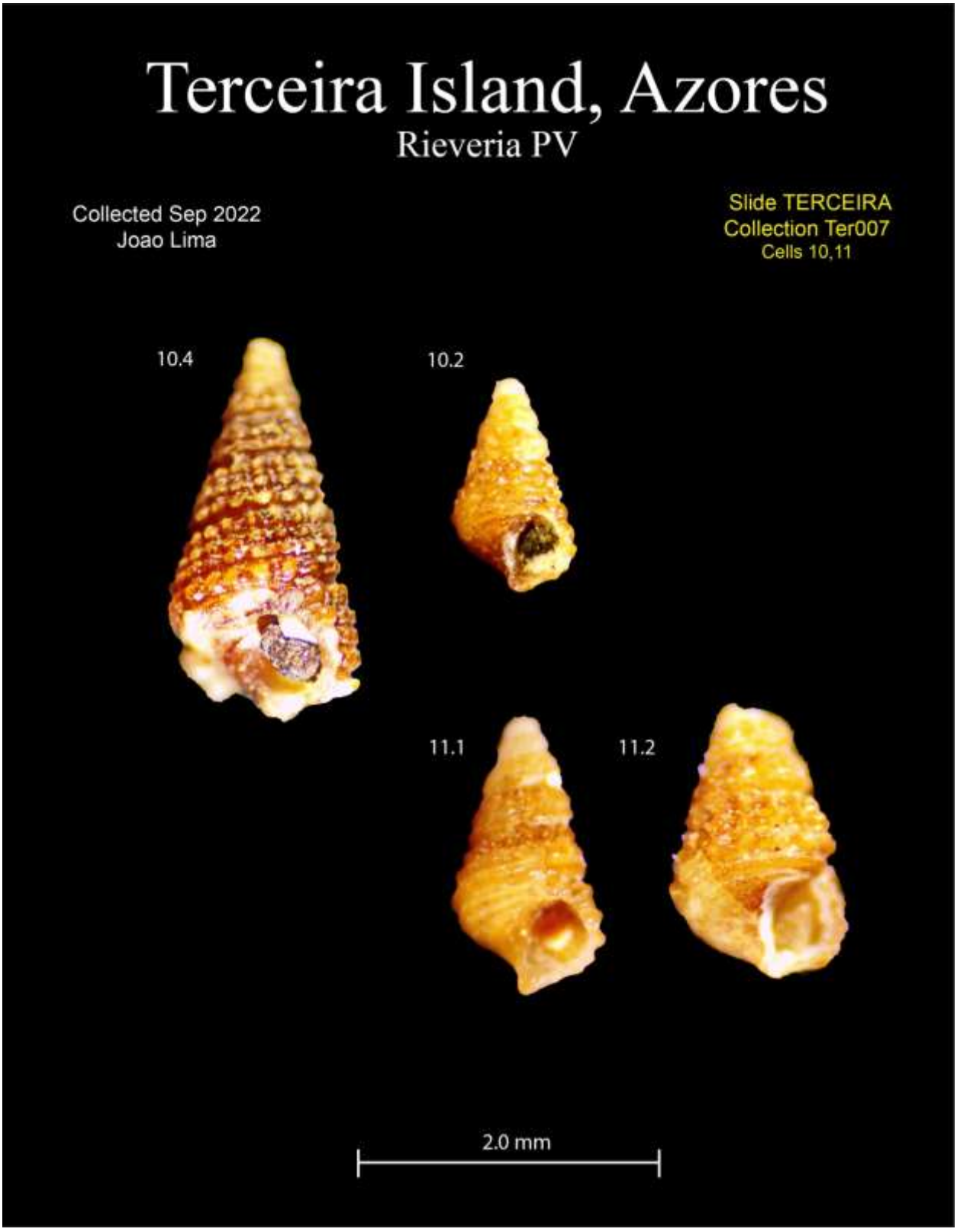

Fig. 27 *Gastropods from Collection* ***Ter007****, Cell 4*

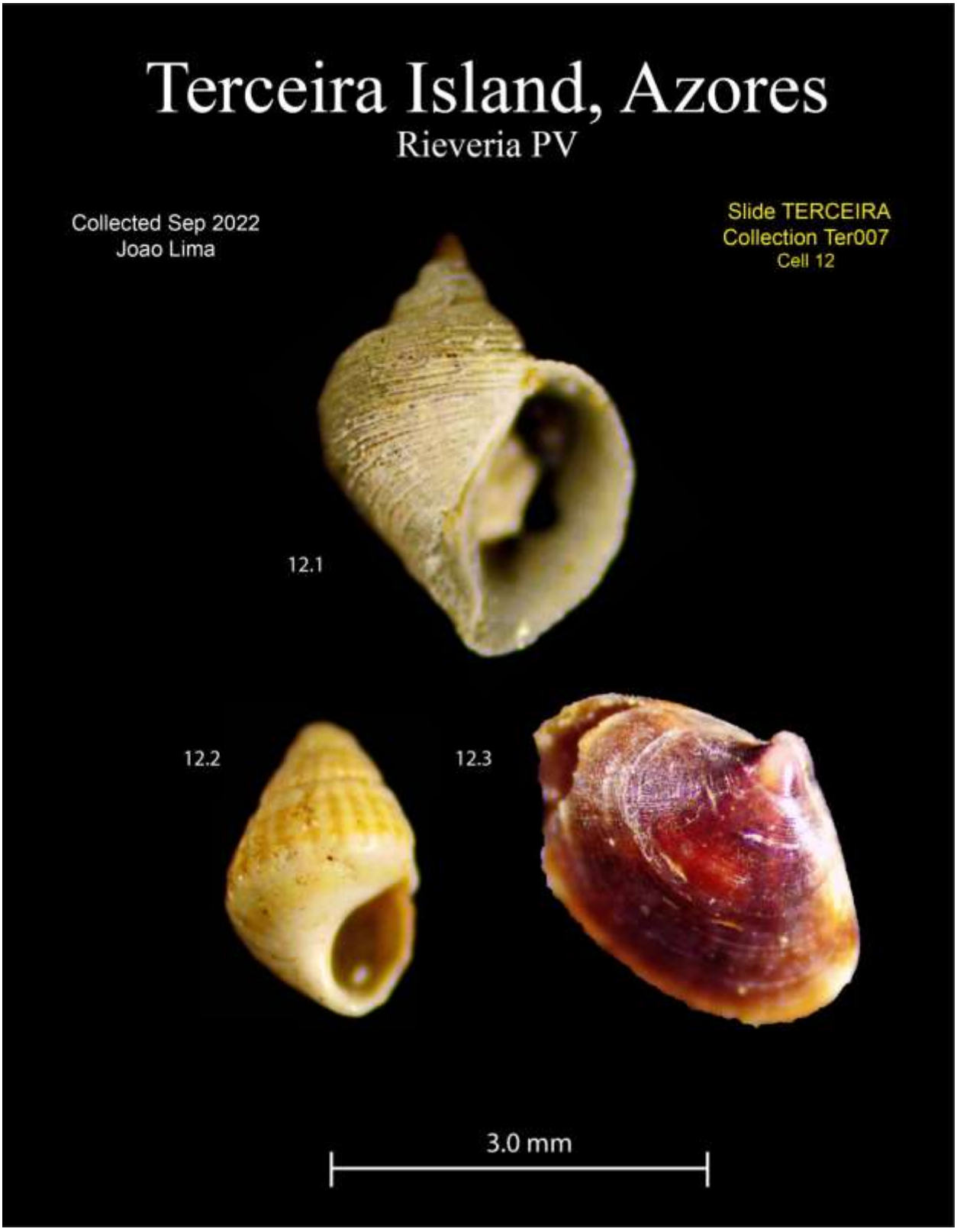

Fig. 28 *Microfauna from Collection* ***Ter007****, Cell 4. Specimens 12.1 and 12.2 are gastropods. Specimen 12.3 appears to be a bivalve.*

Collection Ter008

Fig. 29 *(4 panels) - Location of the* ***Ter008*** *collection*

Fig. 30 *(2 panels) - Collection* ***Ter008.*** *No significant microfauna were found in this collection.*

DISCUSSION

The microfauna described in this report were obtained by picking the 125 µm sieve splits from each of six collection locations. **Table 3** lists the numbers of microfauna picked in approximately 1 cm^3 of these collections.

Table 3 –Number of microfauna in the collections

Collection	# Forams	# Gastropods	# Microfauna
Ter001	0	0	0
Ter002	0	0	0
Ter004	0	35	35
Ter006	40	5	45
Ter007	0	20	20
Ter008	0	0	0

The most surprising aspect of these collections is how few microfauna they contain. Similar collections from other locations (e.g., Foraminifera from Porto Pim Beach, Faial Island), typically contained one to two orders of magnitude higher densities. Collections were not made on the western coast of Terceira because there are no protected beaches there. It is assumed that the high energy coarse rocky cliff environment both prevents the development of populations and rapidly destroys the tests of dead individuals.

FIG. 31 shows a plot of the distribution given in **Table 3**. For this plot, we have arbitrarily added six locations (12 total) to the coastline of Terceira, and arbitrarily added 0.5 individuals to each location for the purpose of emphasizing the asymmetry of the distribution.

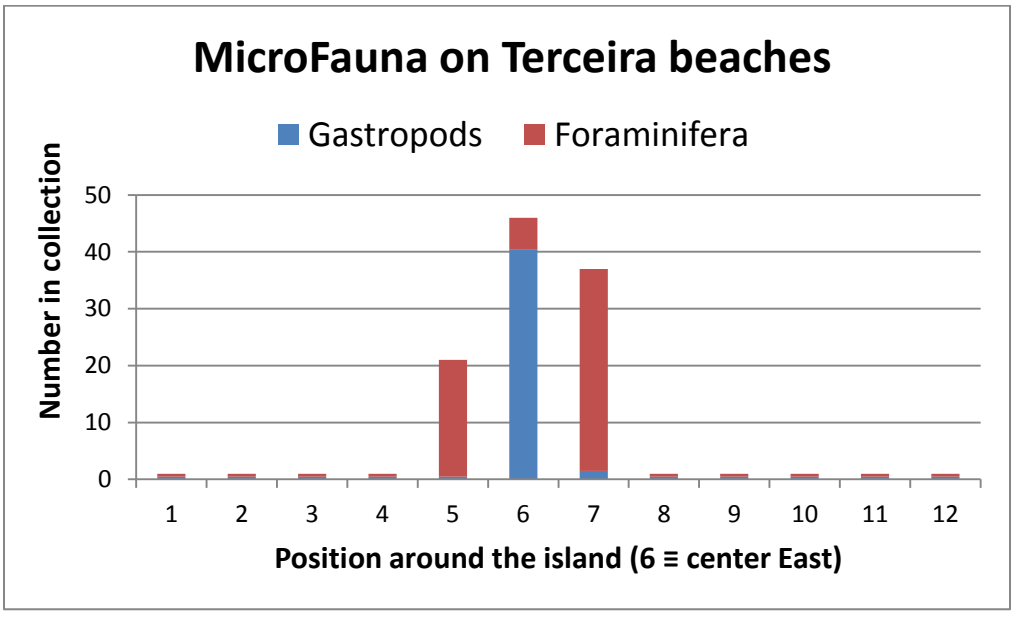

FIG. 31 – Relative populations of microfauna on Terceira Island beaches

According to Wikipedia, the Azores Current is a generally eastward-to-southeastward-flowing ocean current in the North Atlantic Ocean." From the (admittedly sparse) data, it appears that significant populations of microfauna are present on the east coast of Terceira, and extremely low (or zero) elsewhere around the island. This circumstance is consistent with the idea that the currents strike the island roughly directly on the west coast, obliquely on the north and south coasts, and very weakly (or not at all) on the east coast. Thus, it appears that the beach sediments experience kinetic stress in the geographical order: **West > North,South > East**.

FIG. 32 illustrates the hypothesis of current-controlled microfaunal populations. It is worth noting that foraminifera were found only in collection **Ter006**, the most protected stretch of coastline among the six collections.

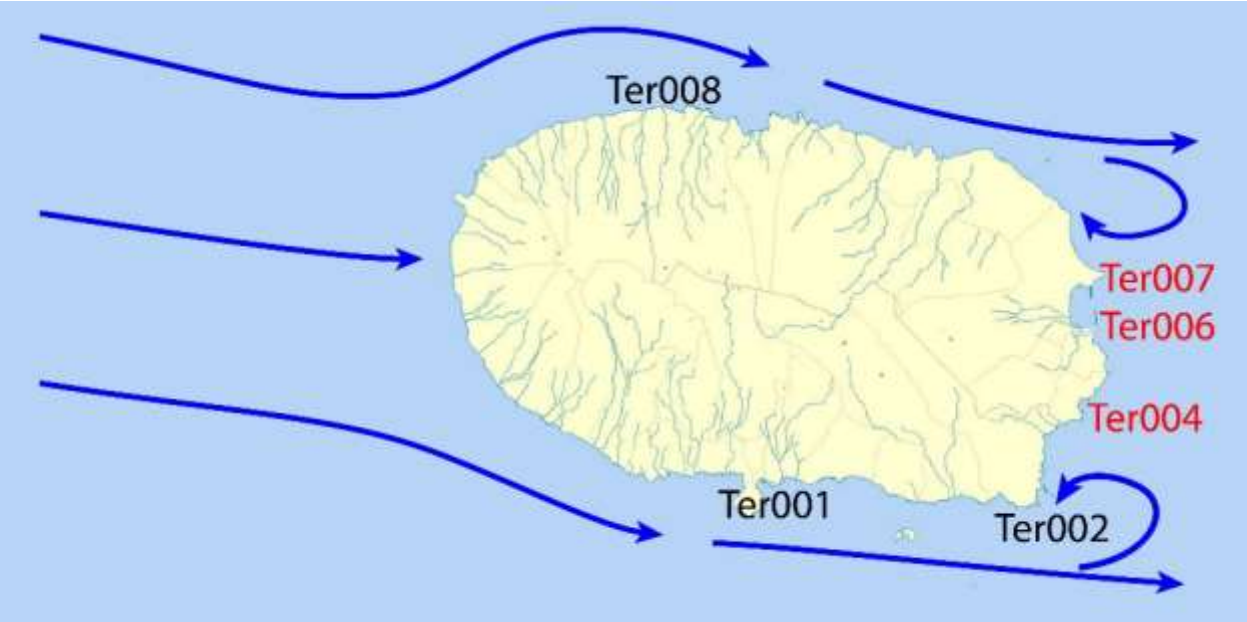

***Fig. 32** – Proposed dynamic environment control of microfauna on the shelf of Terceira Island*

It is emphasized that the descriptions of these collections are preliminary–they do not represent a full examination and statistical analysis of the collections. We have lumped all species together into three taxa Foraminifera, Gastropoda, and Other. In addition, all the individuals examined in this study were dead, so we do not have any data on the growth of live populations. In spite of its preliminary nature, the data are consistent with the hypothesis that the dynamic environment (currents and winds) control the populations of microfauna on the coasts of Terceira, strongly favoring the low energy of the lee (east) coast for both population growth and for preservation of dead tests.

The present work also ignores the possibility that increased energy could *enhance* the production of populations. The idea is that performance (including population growth) will be optimal at a stress level intermediate between very low and very high is common to many disciplines, including human performance (the Yerkes-Dodson Law). In population dynamics, this idea is known as the Intermediate Disturbance Hypothesis (IDH) of biological diversity. According to this theory, at intermediate levels of disturbance, diversity is maximized because species that thrive at both early and late successional stages can coexist. Clearly, more observations of relative microfaunal populations on Terceira will be needed if this hypothesis is to be rigorously tested.

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General

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Intermediate Disturbance Hypothesis. Wikipedia article.

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ACKNOWLEDGEMENTS

Mr. Joao Lima (Radio callsign CU3AA), a resident of Terceira Island, selected the sites on that island, made the collections, and transferred them to the author via his sister-in-law, Eunice Santos, a resident of Faial, Island. Robert Schmieder processed and picked these collections, recognized the geographic pattern, and wrote this report.

During September, 2022, Robert Schmieder, Fred Belton, and Randy Schmieder made collections of sediment on several of the Azores Islands: Faial, Pico, and Corvo. Analysis of these collections is ongoing.

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