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Drifted *Nautilus* shells from the Bajuni Islands (southern Somali coast of Indian Ocean)

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ABSTRACT -Two drifted shells of *Nautilus* are described from the Bajuni Islands, that extend along the Somali coast of the Indian Ocean. The shells are the first finds in Somalia. The diverse early taphonomic signatures on the two shells are proxies of their diverse depositional history, a rapid crossing of the subtidal and intertidal environment before deposition on backshore for one and a long-stay in agitated shallow waters for the other. The conservation status of the drifted shells as well as the finding of fossil shell remains in the late Pleistocene deposits of the islands - the second find in the whole Pliocene-Pleistocene of the Indo-Pacific - could be proxies of the existence of a living community in the West Indian Ocean province since the Pleistocene.

Keywords: *Nautilus*; drifted shells; Recent; Pleistocene; Bajuni Islands; Somalia.

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1. INTRODUCTION

The occurrence of drifted *Nautilus* shells thousand kilometers outside the living area has been widely recognized (Kobayashy, 1954; Stenzel, 1964; Teichert, 1970; House, 1987); also fossil finds of nautiloids in the geological record were hypotesized as drifted dead shells (Chirat, 2000).The opportunity for shells of dead *Nautilus* to be drifted in regions far from the living area is related to the oceanic marine currents and the good buoyancy of the empty shells (Saunders and Espinosa, 1979); after the animal death and the loss of the gas-liquid system regulating the living animal buoyancy, the empty shells can become passively buoyant, trasported by the marine currents, or can rapidly sink to the sea floor (Weaver and Chamberlain, 1976; Chamberlain et al., 1981).

Finds of *Nautilus* shells along the African coast of the Indian Ocean have been considered by House (1987) as a proxy of their post-mortem drift from the living area, the tropical western Pacific Ocean. The shells might have been drifted from western Australia by the South Equatorial Current or following the continuation of the Borneo-Indonesian one. However, it was also considered the possible presence of living *Nautilus* communities in western Indian Ocean: as a proxy of the progressive expansion westwards (House, 1987), or as proxy of the existence of a disjuncted living area (Reyment, 2008). In the distribution map of Reyment (2008) are indicated two possible west Indian Ocean areas, at the eastern side of Madagascar and in front of East African coast, roughly around the Equator line. The author's hypothesis is supported by the 1967 letter from Anna Bilder (Cambridge), who wrote that she "now had evidence of living *Nautilus* from Mauritius and Zanzibar" (Reyment, 2008, pag. 3). The author further suggests that the existence of a disjuncted area in western Indian Ocean for living *Nautilus* "simplify the interpretation of post-mortem distribution of shells" in that region, even if the "biogeographical status" of the *Nautilus* shell occurrence remains "still poorly understood" (*ibidem*, p. 4).

On the other hand, the whole disposable information on the finds of *Nautilus* shells in various localities of the East and South African coasts, as precisely registered by House (1987), is devoid of pictures and is often limited to personal notices on shells occurrence observed in some shores or on sale at the markets in Mombasa. To date, the finding localities are: Malindi (about 120 Km northeast of Mombasa) and Lamu (near the Kenya-Somalia border), Shelly Bay (near Mombasa), beach of Kilify (North of Mombasa - very frequent shells), Shimoni (near the Kenya-Tanzania border - on the reef); another finding locality is Aldabra Island, where *Nautilus* shells "arrive each year" (information from R.I. Knatink and D.I. Taylor, in House, 1987). Furthemore, information received by House from R.N. Kilburn and D.H. Kennelly reports the presence of *Nautilus* shells coming from South Africa (Transkei region and False Bay, respectively) in the East London Museum; one specimen, from Western Cape, is deposited in the Natal Museum, Pietermaritzburg (according to the corrispondence received by House from R.N. Kilburn). The only available picture of western Indian Ocean nautilid shells seems to be that of *Nautilus pompilius* sketched on a Kenyan postage stamp (as *Nautilus pompileus* in the first issue, figured by House, 1987).

Goal of this paper is to provide evidence of the occurrence of shored *Nautilus* shells in the Bajuni Islands Archipelago (southern Somalia), as a contribution to the knowledge on the *Nautilus* presence in western Indian Ocean and to the significance of their early taphonomic signatures.

2. GEOLOGICAL AND ENVIRONMENTAL SETTING

The Bajuni Islands Archipelago is an alignement of more than a hundred islands and islets running parallely to the coast for more than hundred km, from south of the Kismayo town up to the Somali-Kenyan border (Fig. 1). The islands are usually narrow and more or less long, and, in most cases, exhibit a clear dune morphology (Fig. 2); the mixed bioclastic and siliciclastic cemented eolianites, usually cross-bedded, form the islands and lie on coralgal carbonates, separated by an abrasion surface, in some cases just outcropping at low tide. According to Carbone et al. (1999) the dune alignement formed during the last glacial lowstand of the sea, and is currently subjected to a strong marine erosion. An older parallel dune alignement runs on the coast (“Red Dune”), oriented in the direction of the monsoonal winds. Modern sediment is made of mixed marine carbonate bioclastic and siliciclastic grains; the sediment is supplied both by the carbonate marine skeletal production in reef environment and the terrigenous imput by winds, mainly eroding the outcropping loose or poorly cemented coastal dunes, by the river Juba, whose mouth is few km north of Kismayo and by the three small canals (Lac Badana, Lac Anole and Lac Busci Busci). The latter flow only during the rainy periods in the strait behind the Archipelago (Fig. 1). The sediment imput by the Juba river is distributed by coastal currents influenced by the monsoon winds and flowing mainly to the north but also to the south. The strait that separates the islands from the mainland has a width of 1-3 km, and a maximum depth of 10 m. The waters, which exchange with the open sea through the passes between the islands, are calm, mainly in the areas protected by the longer islands. The sediments deposited in the strait protected by the islands are muddy or fine sandy. Fringing reefs are developed on the far ends of the islands, and along the passes and in the strait, in front of the passes and where the islands are small and passes between them large. Meadows of the robust phanerogam *Thalassodendron ciliatum* are well developed manly in the more washed areas of the strait and often compete with corals for space. Outside the islands, the shallow waters facing the open sea are often rough, even during calm winds, when the monsoon changes direction (tangabili, in Somali). A long-time wave-driven sediment resuspension occurs in front of the longer islands, as observed around reefs (Orpin and Ridd, 2012). The high wave-energetics along the Somali coast is guaranteed by the continuous impulse of the winds. Where resuspended carbonate and quartz grains concentrate, water turns whitish and transparence is highly reduced. In such conditions, divers are hit by innumerable micro-collisions by the wave moved grains (personal observation). Seawards, a flat and gently sloping platform, few kilometers wide, abruptly passes to a hundred meters deep narrow strip, and then to a steep escarpment reaching depths greater than 2000 m (Fig. 3). On the outer margin of the platform, deep reefs are probably present (Carbone and Accordi, 2000).

3. MATERIAL AND METHODS

Three damaged *Nautilus* shells were collected by the author in 1985. One specimen (named “beach”) was found in the backshore of the inner sea strait, near Istanbul (Fig. 1); the shell was trapped by the bush-like vegetation developed at the margins of the coastal white dune; the shell was only partially buried into the sand. A second specimen (named “reef flat”) was found on the reef flat at the southern margin of the Ciovai Island (Fig. 1); the third specimen (named “shallow water”) was collected in the subtidal zone south of Burgao (Fig. 1), while it was floating in the shallow water (Fig. 4).

Similar damaged shells were observed on sale at the market in Mukdisho; sellers, questioned about the provenience, always indicated the southern coast of

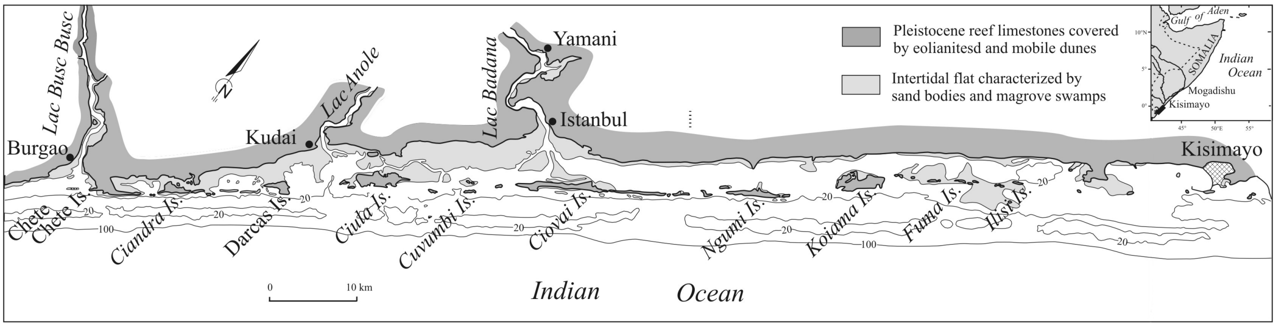


Fig. 1 - Sketch map of the Bajuni Islands Archipelago (from Carbone et al., 1999).

Fig. 2 - Southwestern ending of the Ciovai Island, exhibiting a dunar morphology. On the right the inner strait; on the left, the open sea and the fringing reef line (arrows).

Somalia, sometimes Kismayo and Bajuni, rarely Lamu (Kenya). Most of the shells were of large dimensions, all showed wide breakages, mainly on the apertural margin of the body chamber; some specimens were offered with the margins artificially rounded to simulate a not broken body chamber aperture; a few of the latter were polished to expose the pearly surface. No one complete shell on sale was observed by the author, in the time-span from 1980 and 1985. Moreover, some sections and fragments of fossil nautilid shells were observed in the cemented eolianites.

The beach shell was accidentally damaged on the ventral side of the phragmocone (Fig. 5A), during the transport. Surfaces were analyzed with a Zeiss binocular microscope; photograps were taken by a Panasonic Lumix 20x camera; a few small pieces of the wall of the phragmocone were detached and analyzed with a scanning electron microscope (SEM FEI Quanta 400) at the Department of Earth Sciences of La Sapienza, University of Roma).

The reef flat and beach specimens are stored at the MUST (Museo di Scienze della Terra), La Sapienza University. The shallow water specimen was stored at the Geological Museum of the Muqdisho University in 1985, and has to be considered lost.

4. RESULTS

4.1. Taxonomic identity of the specimens

According to Saunders (1987), only 4 out of the 11 species to date proposed for the living *Nautilus* can be recognized as valid species: *N. pompilius*, Linnaeus, 1758, the most common and widespread, *N. macromphalus* Sowerby, 1849, *N. stenomphalus* Sowerby, 1849 and *N. belauensis* Saunders, 1981; a fifth valid species, *N. scrobicolatus* (Lightfoot, 1786), has been stated as the type-species of the new genus *Allonautilus* (Ward and Saunders, 1997). Recent molecular studies confirmed the sister-taxon relationship between the two genera (Bonachum et al., 2011). Among the remaining 6 species, one, *N. repertus* Iredale, 1944, is considered questionable,

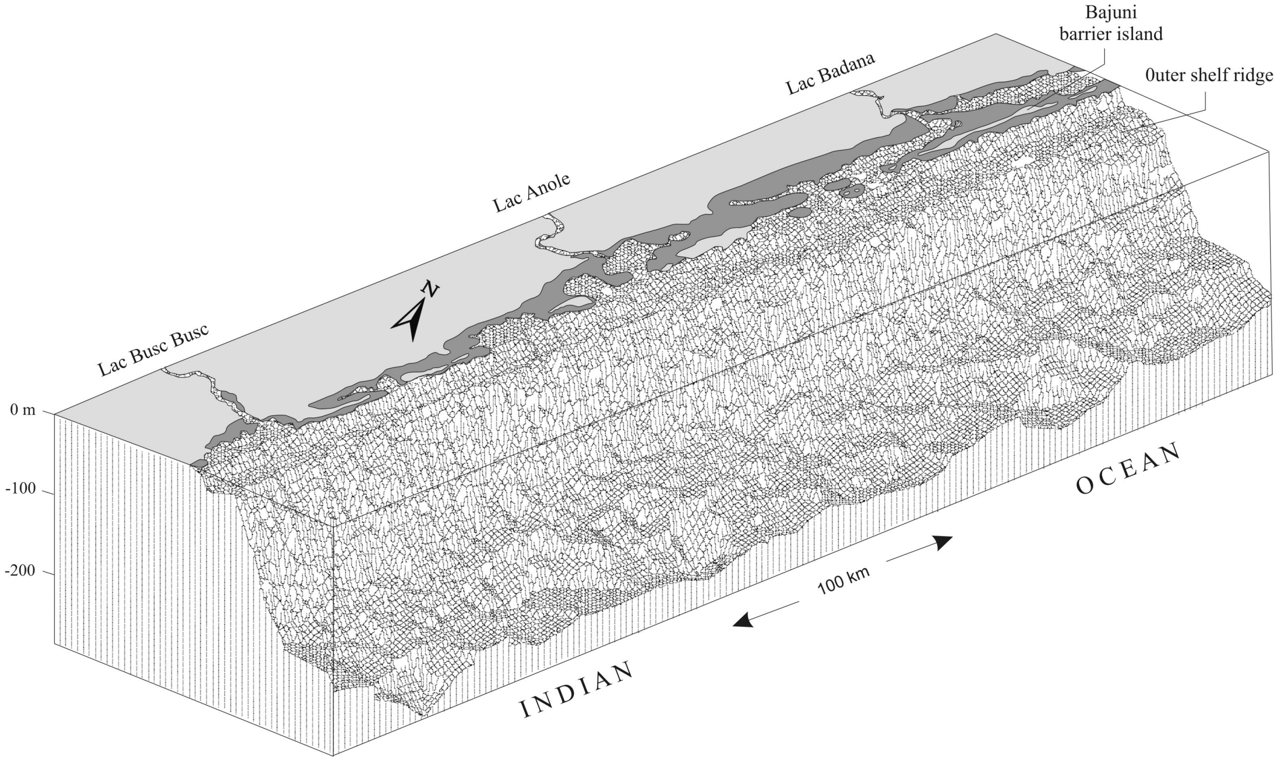


Fig. 3 - Block diagram of the southern Somali coast from Lac Badana to Lac Busci Busci (from Carbone et al., 1999).

Fig. 4 - The shallow water specimen collected in subtidal waters, south of Burgao. Note the orientation of the floating shell, with the dorsal side emerging from the water surface.

being probably a synonym of *N. pompilius*, and other three, *N. ambiguus* Sowerby, 1849, *N. alumnus* Iredale, 1944 and *N. moretoni* Willey, 1896, are considered dubious. The last three (*N. umbilicatus* Lister, 1685, *N. perforatus* Conrad, 1849 and *N. texturatus* Gould, 1857) are synonyms of *A. scrobiculatus*. On the other hand, molecular studies on populations of *N. pompilius* suggest that they could represent different cryptic species due to independent evolutive lineages (Sinclair et al., 2007, 2011; Bonacum et al., 2011;Williams et al., 2012).

The basic morphological features of both the Somali specimens are those of *N. pompilius* (closed, small umbilicus, partially covered by a callus, and irregular reddish stripes radiating from the umbilicus to the venter). However, dimensions (more than 20 cm for the complete shells, prudentially supposed for the two specimens both lacking of most of the body chamber) are at the top of the known range of the species (diameter: 100-200 mm; mean diameter in the Philippine populations: 165 mm, according Saunders,1987), and fit better to the range of the questionable species *N. repertus* (diameter:184-243 mm, mean, 220 mm), considered by Saunders (1987) and Jereb (2005) a giant form of *N. pompilius*. The weak coloration of the orange-reddish stripes (as observable at the less color-faded areas of the shells), which remain subtle also on the ventral side of the phragmocone, without merging, seems similar to that of *N. repertus*, not the extension of the stripes to the umbilicus.

4.2. Status of the shells

Among the three found shells, the shallow water one was the less damaged: surface was glance and color vivid (Fig. 4); breakages concerned only the margins of the body chamber and encrustation was poor. Because the specimen is not in our hands, below, description and observaions are limited to the two other specimens.

The external surface of the reef flat shell is abraded and widely pitted; the surface of the beach shell is partially covered by a brown coating, mainly on the side which rested in the ground. On this side, traces of encrusted roots, running on the external surface of the phragmocone, parallely to a oxydized zone (Fig. 5E), and a probable root fragment adhering to the inner surface of the body chamber (Fig. 5H) are preserved. On the reef flat specimen, two black spots of hydrocharbon are present (Fig. 6 A,B). Granules from sediment are included into the brown coating of the shored shell and are trapped into the deepest parts of the phagmocone chambers corresponding to the breakage in the reef flat one (Fig. 5 A,C); only on the concave side of the innermost of the exposed septa a thin layer of sediment is preserved (Fig. 5L).

4.2.1. Damages

Both shells exhibit massive breakages in the wall of the body chamber, more than half of which has been irregularly shortened; the breakage is deeper on the ventral region than on the flanks (Figs. 5, 6). The phragmocone of the reef flat specimen exhibits a wide damage occurring on the outer edge and on one side (Fig. 6 AC), whereas that of the beach one is undamaged (Fig. 5 A-D); the small breakage observable in Fig. 5A is accidental. The broken edges of the wall are irregular and chipped in the reef flat specimen; only one chipping has been observed as fresh; two irregular holes are open in the preserved body chamber lateral wall (Fig. 6 A,B). In the beach specimen the surface of the broken edge is smooth, orthogonal to the shell one and without chippings (Fig. 5D). The wide broken area of the ventral wall of the phragmocone of the reef flat is asymmetric, and extends on the left side from the ventral median line to the umbilical region; four septa are uncovered, three of which irregularly broken, more deeply on the damaged side (Fig. 6 A,C). The siphuncular region is preserved in all the four uncovered septa. Moreover, minor breakages are aligned on the ventral line of the phragmocone, the wider on the mature side, other three, smaller, in the inner one. One of the smaller holes is rounded and could be related to a predation attack by octopids (Fig. 6I).

4.2.2. Faded color

Both the specimens exibit a marked degradation of the orange-reddish stripes of the shell, which however can be easily discerned. The original color can be observed on the dorsal side near the black zone (Figs. 5D, 6D). The beach specimen preserves a little of the glossy appearance like that of the shells of the living Nautiluses, whereas the surface of the reef flat specimen appears totally opaque and dull. This is mainly due to a chalky decay of the periostracum and the texture of the uppermost sphaerulitic layer; only in a small region on the dorsal side, near and under the black layer, partly removed, the surface appears almost perfectly glossy (Fig. 6D). The diverse preservation status of the stripes color of the stripes could be a proxy of the diverse duration of the dead shell stay in the water; the preservation of the glossy external shell surface could be a proxy of a recent dead of the animal.

4.2.3. Microtraces

The outer surface of the reef flat shell exhibits numerous and varied scratches and pits: a) straight and curved thin marks, of different length (up to 5 cm), generally asymmetric, slightly deepening in one direction and terminating more or less abruptly, both by a sharp closure and a short deviation of the direction (Fig. 6 E,G); the cross section is both rounded and V-shaped. b) short marks (1 cm max), mainly symmetrical, in cases forming sub-parallel groups (Fig. 6 F,G); c) larger marks, less deep and with flat cross section; d) sub-circular pits sparse on the whole external surface, very numerous on the ventral margin of the phragmocone, especially in its mature side. Pits, 10 to 300 microns wide, exhibit a more or less semi-spherical morphology with irregular margins; some of them are clearly the bottom of larger cavities preserved from the bioerosion of the shell; some exhibit a roughly comma morphology (Fig. 8B); others a spiral one, with septate (?) concamerations (Fig.8C). Only a few include small grains. Scratches and pits are rare on the surface of the beach specimen.

4.2.4. Epibionts

The beach specimen is mainly encrusted on the inner surface of the body chamber wall and on the umbilical outer regions. Three main kinds of encrusters are present: vermetid gastropods, membraniporid bryozoans and acervulinid foraminifers (*Gypsina plana* Carter). Vermetids (6 individuals) are encrusted on the inner side of the body chamber wall, roughly on the ventral area, and their aperture is directed towards that of the host (Fig. 5 D,I). Wall of all the individuals is brown, and, in the last part, translucid. The membranoporid colony occupies almost the whole inner surface of the right side of the body chamber, expanding outwards on part of the dark layer (Fig. 5 G,L). The gypsinid foraminifers form clusters of numerous individuals encrusted both on the inner surface of the body chamber and on the umbilical regions (Fig. 5 A,B,F,G,L). Clusters are formed by 10-30 individuals each; also in the central part of the clusters, individuals are very close to each other, sometimes in contact, rarely overlapping each other. Only on the right umbilical region, planar crusts are developed (Fig. 5 B,F). All the individuals appear white in color, except a few, which show in the central part a pinkish color (Fig. 5F) and are encircled by diatoms (Fig. 8H).

In the flat reef specimen, there is only a large valve of a spondilid bivalve encrusted on the inner side of the body chamber, developed on the rigth side, but occluding the siphuncular aperture (Fig. 5D). The bivalve shell aperture is oriented towards that of the *Nautilus* shell; its cardinal area is put in the opposite deep part of the body chamber. The outer margin of the valve exhibits the same breakage-outline of that of the encrusted body chamber; a sharp breakage limits the apical portion of the valve, whose cardinal area is lost. The conservation state of the spondilid valve is fresh, its central part preserves a pinkish-red color and no borings or encrustations are observed. On the side not occupied by the spondilid valve, a wide part of the surface is encrusted by a thin layer of a corallinacean alga (Fig.5D).

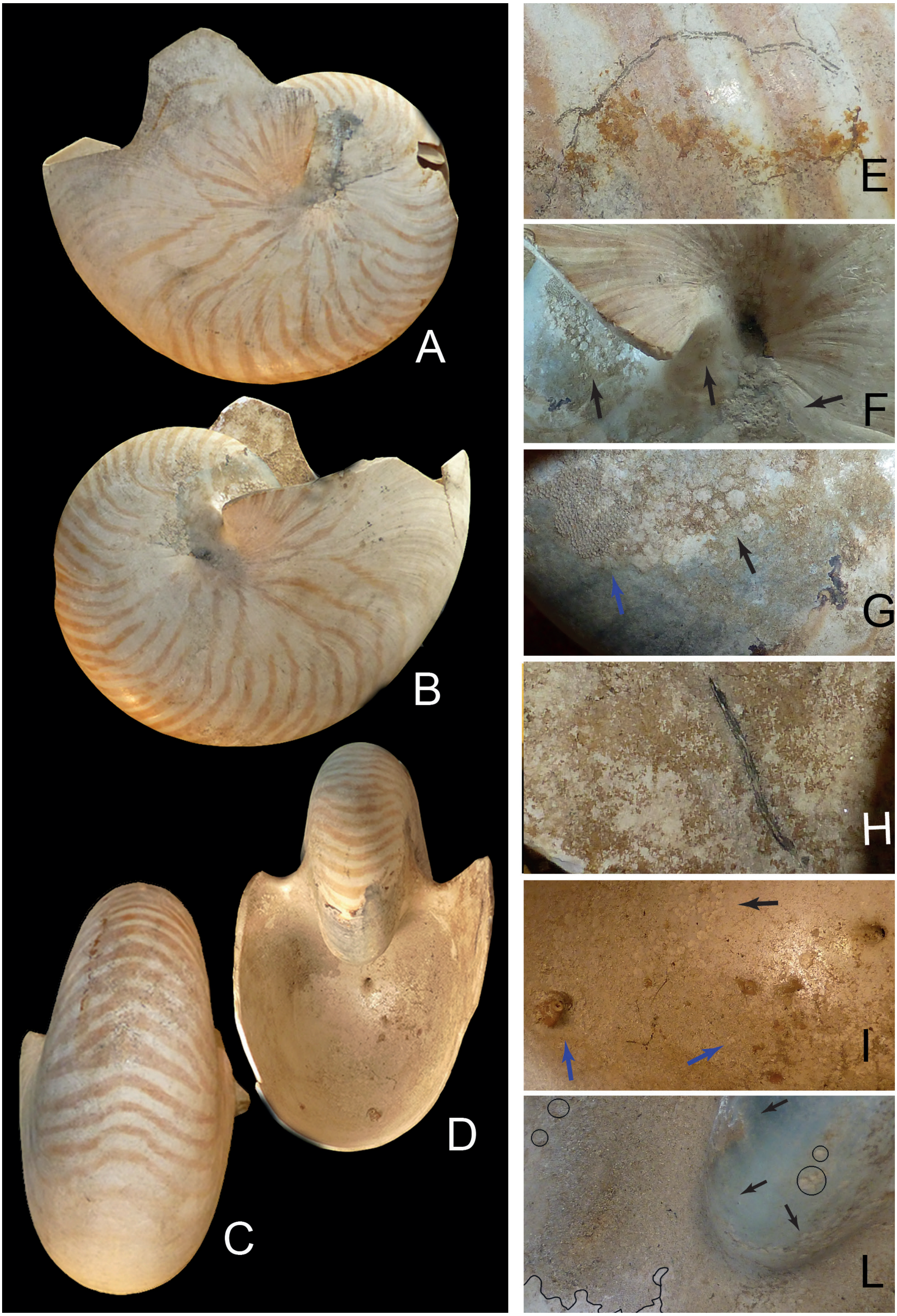
4.2.5. Endobionts

Both shells exhibit a dense net of microborings, made up of cylindrical long tunnels, with a diameter of 2-5 microns, in some cases filled by shell-derived micro-grains. Borings are developed parallel to the surface, with straight or gently curved traces, branching at various angles. The superficial net of parallel traces, bored into the outer level of the sphaerulitic layer, under the remains of the periostracum (Fig. 7 A,B), penetrates into its deeper part with perpendicular or highly inclined tunnels. The density of the traces is higher in the reef flat specimen, the wall of which assumes, in the sphaerulitic layer, a honey-comb appearance, which emerges also in the deeper eroded outer surface of the shell (Fig. 7C). Borings are both empty and filled by micro-granules; the surface of the borings exhibits a micritic lining (Fig. 7D). The tunnels, forming a net into the sphaerulitic layer, penetrate also in the prismatic one with numerous branches of various diameters (Fig. 7 E,F); a few of them are recognizable also in the underlying nacreous layer, developed both parallel to the shell surface (Fig. 7F), mainly in the topmost part of the layer, and perpendicular, reaching the inner surface of the wall (Fig. 7G). In the beach specimen, traces of penetration into the sphaerulitic layer decrease with the deepening and do not reach the inner prismatic and nacreous layers (Fig. 7H).

On the basis of various morphologic characters (2-5 microns of diameter, dichotomous branchings often associated with lobate swellings, presence of branches of various diameters), the traces are referred to the ichogenus *Ichnoreticulina* (Radtke, 1993), the producer of which is the siphonaceous green alga *Ostreobium queckettii* Bornet and Flahault (1886), a worldwide boring alga of the tropical waters (Tribollet, 2008). The boring alga is adapted to unfavorable environments as the stony corals, were the symbionts absorbe almost all the incident photosynthetically active radiation (Fork and Larkum, 1989). The dominance of long straight tunnels, with intermediate and small diameters (2.3 microns), could indicate, as observed by Radke (1993), an intermediate stage of the colonization, with prevailingly exploratory branches of the boring system. Among the well known microboring community (algae and fungi) of the tropical waters, *Ostreobium* is one of the most common component (Radtke, 1993; Tribollet, 2008).

4.2.8. Sediment content of the phragmocone

The reef flat specimen contains sediment in the deepest parts of the broken phragmocone chambers. A thin layer of sediment, with patchy texture (Fig. 8E) is present only in the concave side of the innermost of the uncovered septa (Fig. 6L).The sediment grains are made mainly by unrecognizable small bioclastic fragments and quartz grains, the latters both rounded and angular (Fig.8 E,F),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embedded in a probable automicritic deposit (Fig. 8Gd). Miliolids, ostracods, small fragments of gastropods, articles of *Halimeda*, fragments of fresh algae (Fig. 8Ga.c) and phanerogams, siliceous spicules (Fig. 8F) and small pieces of echinoid spines are relatively frequent. The sediment composition indicates a provenience from shallow waters; the abundance of small miliolids and vegetal fragments could be a proxy of a vegetated intertidal or high subtidal environment.

4.3. Occurrence of nautiloid shells in the Pleistocene cemented eolianites

As noticed by Carbone et al. (1999), rare remains of nautiloid shells were observed in the hardly cemented eolianitic sands of the islands. A transverse section of a shell and relatively numerous fragments lye at the base of the dune deposits, near the underlying erosion surface cut into the coralgal carbonates outcropping at low tide. Some remains preserved their pearly appearance and a few also traces of colored stripes. No samples have been collected; a photograph (Fig. 9) is the only available record.

5. DISCUSSION

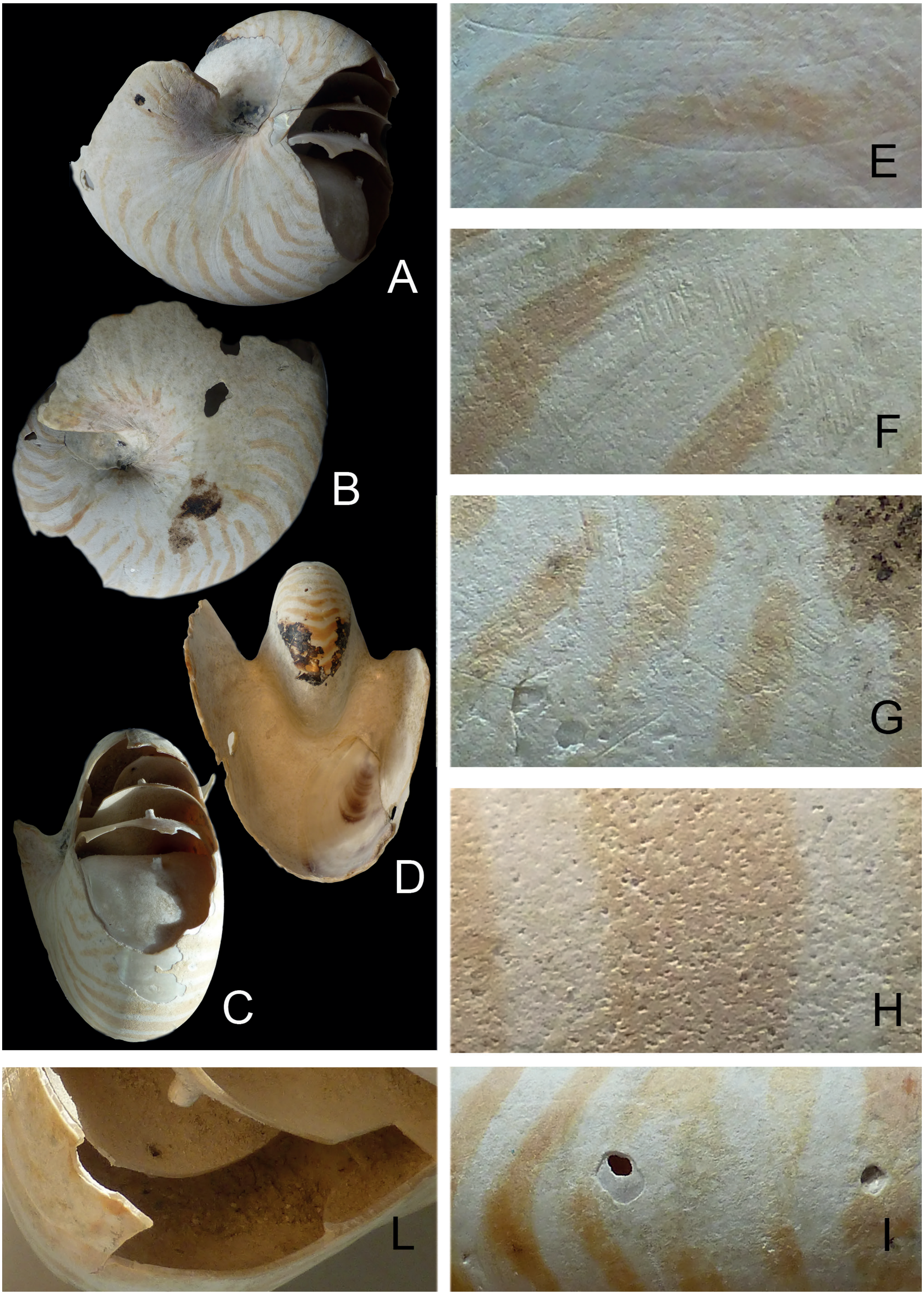
5.1. Early taphonomy

Bioerosion and encrustation of living and dead Nautiluses and the meaning of signatures on the shells have been deeply studied recently (Landman et al., 1987; Wani, 2004; Wani et al., 2005; Mapes et al., 2010a; Mapes et al., 2010b; Hembree et al., 2014; Seuss et al., 2015a; Seuss et al., 2015b). The early taphonomic signatures are diverse in backshore and deep-marine deposited shells and are useful for reconstructing the depositional processes of the collected specimens.

Signatures on the Somali specimens give us some information on their last floating and depositional processes. Deep breakage of the body chamber wall is a proxy of hard impacts of both the shells on reef. The multi-breakage zones of the reef flat specimen probably indicates a more numerous impact episodes; moreover, the broken encrusted spondilid valve and the marks on the external surface of the reef flat specimen are a proxy of a stay of the shell in reef environment. The more than 8 cm long encrusted specimen of *Spondylus* - an ubiquitous bivalve of the reef environment, needing of firm, creviced substrate on which encrusts (Logan, 1984) - has been growing for many years to reach a semi-adult stage, before breaking due to a violent impact. Marks and most of pits were produced by impacts of granules moving in the turbulent shallow water, mainly during storms. The penetration of grains was probably favoured by the weakening of the outer wall of the shell, infested by microboring organisms, as occurs in marine ooids (Gaffeys, 1983). The deepening downstream and the more or less abrupt termination of the marks depend on the impact angle, similarly to some sole marks (prod and bounce marks) in storm event beds (Beuckes, 1996; Bhattacharya et al., 2004). Differently to the sole marks - that reflect instantaneous near bottom flows - direction and morphology of marks on the *Nautilus* shell - mainly those asymmetrical - do not indicate the flow direction (Duke, 1990), depending also on the instantaneous passive movements of the floating shell during the impacts. Rounded and v shaped cross sections of marks mainly depend on the morphology of the impacting quartz grains - rounded or angular - both present in the sediment. Most of the pits were made by perpendicular impacting grains, some of which were trapped into the shell wall. Larger pits are empty; only in a few cases translucent small quartz grains were observed. Comma morphology of the pit (Fig. 8 A,B) indicates that the granule was throw out immediately after the impact; most of the grains has probably abandoned their cavities later, favored by the subsequent bioerosion of the shell surface and, also, their possible enlarging movement into the cavities, induced by water flow and passive but often violent movements of the shell. The concentration of pits along the median line of the terminal part of the phragmocone and the basal part of the body chamber could indicate a vertical floating orientation of the shell, with passages near the bottom. However, the dimensions of some large pits are compatible with the cavities produced by small boring foraminifers, the presence of which in shells of living *Nautilus* has been evidenced by Suess et al. (2015b).The morphology of some of the cavities - which exhibit a spiral septate outline (Fig. 8C), and small channels radiating from the edges - could be a proxy of the work of boring foraminifers, whose tests were detached by the deepening of the superficial erosion by microborers. Also the patchy concentration of the pits could be interpreted as a proxy of an infestation. The wide dimensional spectre of the pits and their presence in all the external surfaces of the shell and near the umbilica could indicate their double origin.

Traces of micro-impacts on the outer surface of the same specimen is another proxy of a long stay in a wave or storm induced turbulent environment, with high

Fig. 5 - “Beach” specimen. A,B,C,D) Left lateral, right lateral, ventral and dorsal views; x 0,5. E) Root trace and red ferruginous oxidations on the ventral - right side; x 2,5. F) *Gypsina plana* encrusted on the umbilical region of the left side; x1,0. G) *Gypsina plana* and membraniform bryozoan encrusted on the umbilical region, right side; x 2,6. H) Root fragment adhering on the left lateral inner wall of the body chamber; note the brown color of the surface, due to fine organic material; x 2.0. I) Inner wall of the body chamber: encrusted vermetids (blue arrow) and gypsinids (black arrow); note the brown color of the surface on its left side; x 0,9. L) Extension on the deep body chamber and the dorsal inner whorl surfaces of the membraniform bryozoan (outline and arrows) and gypsinid encrustations (encircled); x 1,0.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suspended grains concentration, perhaps with various scraping passages against the bottom sediment or the *Thalassodendron ciliatum* spiny leafs (sub-parallel bounce-like marks).

The absence of impact traces on the beach specimen can be considered a proxy for a less long-lasting stay of the shell in turbulent waters and, perhaps, of a faster crossing of the subtidal zone towards the calm waters of the inner strait. Also the encrusting assemblage, made up of vermetid gastropods, gypsinid foraminifers and membraniporiform bryozoans, has to be considered a proxy of a not long stay of the floating shell in shallow-waters; in fact, these encrusting taxa are considered as the pioneering forms of the encrusting assemblages (Gherardi and Bosence, 1999). Even if colonization can occur on external shells of living Nautiluse*s*, as shown by Landman and al. (1987) on living *Nautilus* from Papua New Guinea, with prevalence (36% of the encrusted surface area) of encrusting foraminifera, most of the observed encrusters took place on the dead specimen, occupying also the inside of the body chamber. A not climax stage of the encrusting assemblage is indicated also by the little overgrowth between encrusters and the wide disposability of spaces between them. The absence of encrusting corallinaceans (which, instead, encrusts the inner surface of the body chamber of the reef flat specimen) is another proxy of an encrusting phase occurred in relatively deep waters, where competition with crustose algae, that are rapid encrusters, is reduced by the scarce light (Rasser and Piller, 1997). Thus, the permanence in the shallower waters must have been rather short. The persistence of color in the vermetids and in a few of the encrusted gypsinids could indicate that the pass across the shallow waters and the deposition on the beach was - when sampled - quite recent.

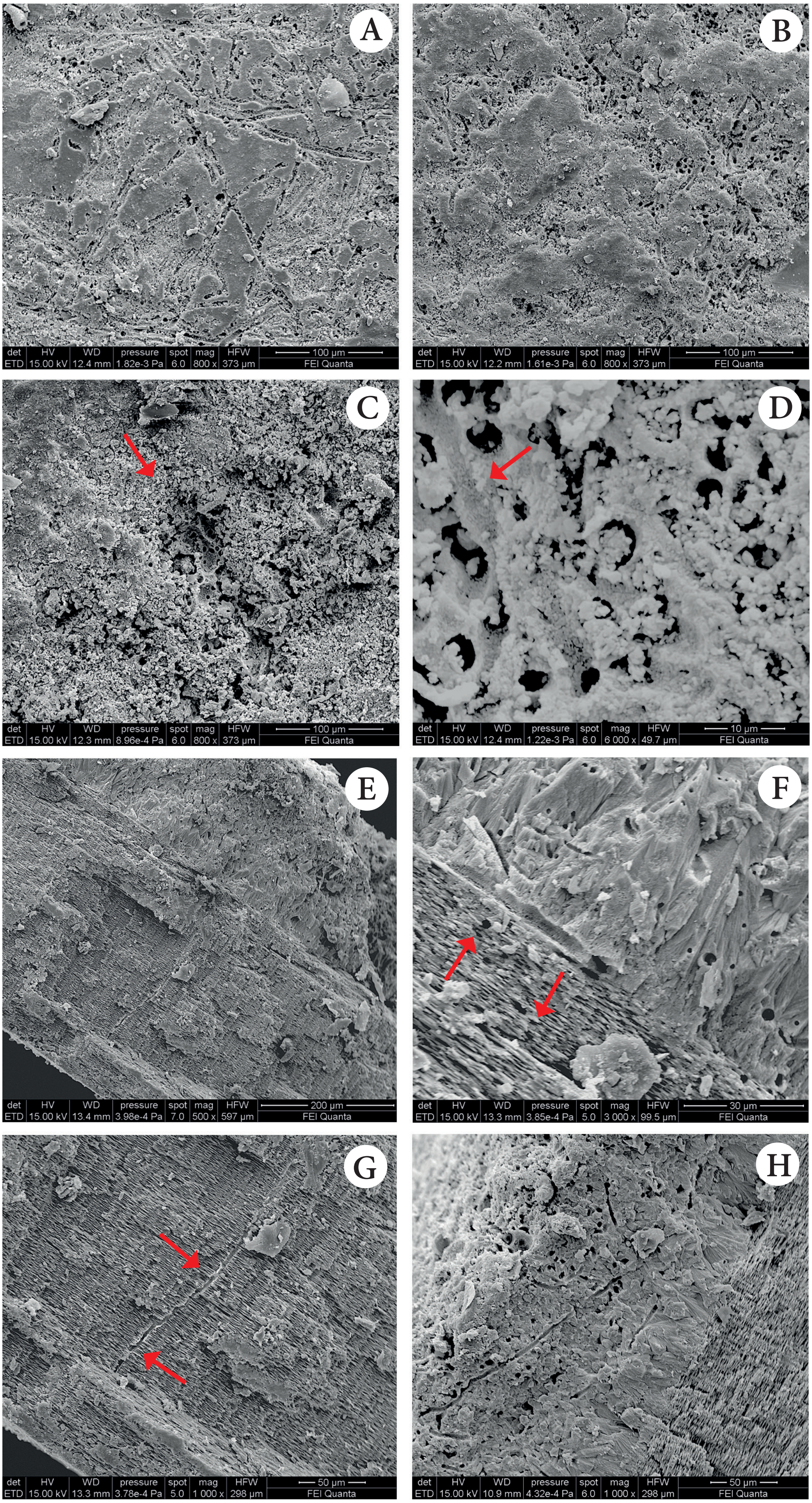
In conclusion, the early taphonomic signatures on the two shells are different, as a proxy of a different terminal drifting and depositional history, even if both crossed the same shallow water environment. Both shells exhibit microborings, which probably began to be excavated in the deep euphotic zone; but, only in the reef flat specimen they invaded the inner prismatic and nacreous layers. So, we can suppose that the beach specimen crossed the shallow waters towards the coast rapidly, even if through violent impacts, whereas the reef flat specimen had a long stay in turbulent waters, repeatedly impacting against the reef and the sandy bottom and trapping loose sediment in the phragmocone through its large breakage.

5.2. Biogeography

The living *Nautilus* habitat substantially coincides with the “Coral Triangle”, or “Indian-Malaysian Triangle” (Fig.10), the well known world’s richest marine biodiversity hot-spot (Hoeksema, 2007; Renema et al., 2008; Carpenter et al., 2011; Veron et al., 2011; Carpenter et al., 2011; Tornabene et al., 2015). Such an exceptional concentration of biodiversity has been an exciting goal, which produced many hypotheses: the Triangle as a centre of elevated rate of speciation (Eckman, 1953; Briggs, 1999) and endemisms (Veron, 1995); as a centre of accumulation of species elsewhere originated (Ladd, 1969) and of overlap of taxa favoured by its boundary position between Indian and Pacific Oceans (Woodland, 1983; Veron, 1995); or, also, as the result of the contribute by all the above hypothesized processes (Mironov, 2006; Bowen et al., 2013) and others, as the geological history ogf the Indo-Pacific region (Renema et al., 2008; Veron et al., 2011). Finally, it has been hypothesized that the Triangle could have acted as a refuge during the Quaternary glacial cycles (Bellwood and Hughes, 2001; Pellissier et al., 2014) and that, currently, is acting as a centre of increasing diversity and species dispersion (Briggs and Bowen, 2013). For *Nautilus*, Bonacum et al. (2011) suggest that the living lineage, originated around New Guinea potentially two million years ago, is moving both eastward to the archipelagos of New Caledonia, Fiji and Samoa, and north- and southward to the Philippines, the South China Sea and Australia. The derived fragmented distribution produced significant genetic divergence, abundantly demonstrated by recent data on genetics of some isolated populations of *N. pompilius*. The distinction of three geographic clades (western Australian/Indonesian, western Pacific and eastern Australia/Papua-New Guinea populations) postulated by Wray et al. (1995), has been confirmed by recent works (Bonachum et al., 2011; Sinclair et al., 2011;Williams et al., 2012). The finding of dubious living specimens at Cocos and Chagos Archipelagos, made House (1987) to consider a possible westward expansion of modern *Nautilus*.

Effectively, the low rate of metabolism helps the living *Nautilus* to be passively drifted for long distances; so, the supposed living areas in the west and southern Australian shelves of the problematic species *N. repertus* (House 1987; Reyment, 2008), based on the findings of live specimens (Stenzel, 1964), has been considered an area of southward dispersion of shells from northern Australia by the Leeuwin warm coastal current (McGowran et al.,

Fig. 6 - “Reef flat” specimen. A,B,C,D) Left lateral, right lateral, ventral and dorsal views; x 0,4. E) Prod-like marks on the external surface of the body chamber (left side); note their asymmetry and the irregular endings; x 2,0. F) Parallel bounce-like marks on the external surface of the phragmocone; note the numerous various sized pits; x 3,0. G) Outer surface of the left side of the body chamber, near the broken margin, with a set of minor breakages, prod-like and bounce-like marks variously oriented; note the oil-spot on the upper right corner; x 3,0. H) Ventral side of the shell, at the passage from the phragmocone and the body chamber; note the density of pits and their various dimensions; x 4,2. I) Dorsal view of the phragmocone exhibiting two more or less rounded breakages or borings; x 2,8. L) View of the breakage area of the phragmocone, showing the thin layer of the sediment deposited on the innermost septum; x 2,5.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C
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D
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E
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F
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G
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det HV WD pressure spot mag HFW 50 µm
ETD 15.00 kV 10.9 mm 4.32e-4 Pa 6.0 1 000 x 298 µm FEI Quanta

1997). However, the migration attitude and the dispersal potential of the nekton-benthic *Nautilus*, which lives moving on steep coral reef drop-offs, are poor and can be assimilated to that of the benthic shallow water fauna, even if expansion pathways seem probably active (Nabhithabhata and Wongkamhaeng, 2012); indeed, *Nautilus* is a deep fore-reef scavenger, vertically mobile near the bottom and reef-slope; mid-waters movements seem limited to short periods, mainly at the depths between 300 to 500 m. Predatory attacks by fish are the main constraints against expansion in both deep and shallow waters (Saunders, 1987). The scarce dispersal potential in shallow waters of the not open sea swimmer *Nautilus* is increased by its temperature limits (not exceeding 25°C, according to Saunders and Ward, 1987) and by the absence of the larval stage.

On the other side, the ancestry of modern *Nautilus*, its geological history and paleobiogeography are puzzling. The tertiary record of Nautiloids is discontinuous and relatively scarce. Whereas during Paleocene and Eocene their paleobiogeographic distribution has been extremely wide, from North America (Squires, 1988) and England (Hewitt,1989) to the Antartic Peninsula (Dzik and Gaździcki, 2001) and New Zealand (Fleming, 1945; Stilwell and Grebneff, 1996), to India (D'Archiac et Haime, 1854; Halder, 2012) and Northern Somalia (Haas and Miller, 1952) and Mozambique (Gliozzi and Malatesta, 1983), the evidence of their later occurrence is rarer, except an expanding pulse in middle Miocene, mainly with the aturid lineages. (Dzik and Gaździcki, 2001). The climatic control of the Tertiary paleobiogeographic distribution of the Nautiloids, marked by expansion pulses towards high latitudes in correspondence of warming and transgressive episodes (Dzik and Gaździcki, 2001), mainly occurred in Paleocene, Eocene and middle Miocene (Miller, 1947), supports the hypothesis that Equatorial seas acted through times the role of centre of refuge and dispersion of these organisms. According to Dzik and Gaździcki (2001), the range of temperature of fossil nautiloids has been probably limited as that of the living *Nautilus* (25-28 °C at upward daily excursions from the optimum of 9-21 °C at the usual habitat, 100-300 m deep, according to Saunders and Ward, 1987). Moreover, mainly on the geological distribution of larger Foraminifera and considering the role of climatic and tectonic factors, Renema et al. (2008) locate the biodiversity hot-spot in the West-Tethyan region during the Eocene and in the paleo-Arabian and indo-Malaysian domains during the middle Miocene; only the last continued to date.

The attempts to reconstruct the ancestry of recent *Nautilus*, as that of a relationship with the Eocene equatorial lineage of the compressed conch forms of *Euciphoceras* of Fayum by Dzik and Gaździcki (2001), the Miocene australian *Eutrephoceras* by Ward (1984) and the Cretaceous *Nautilus* by Ward and Saunders (1987) are made uncertain by the almost total Plio-Pleistocene gap of the nautiloid fossil record. The supposed direct ancestor of the modern *Nautilus*, *N. praepompilius* Shimansky (1957) from the early Oligocene from Kazakhstan (Saunders et al., 1996) is followed by a vacuum of findings of about 30 million years (Teichert and Matsumoto, 1987).

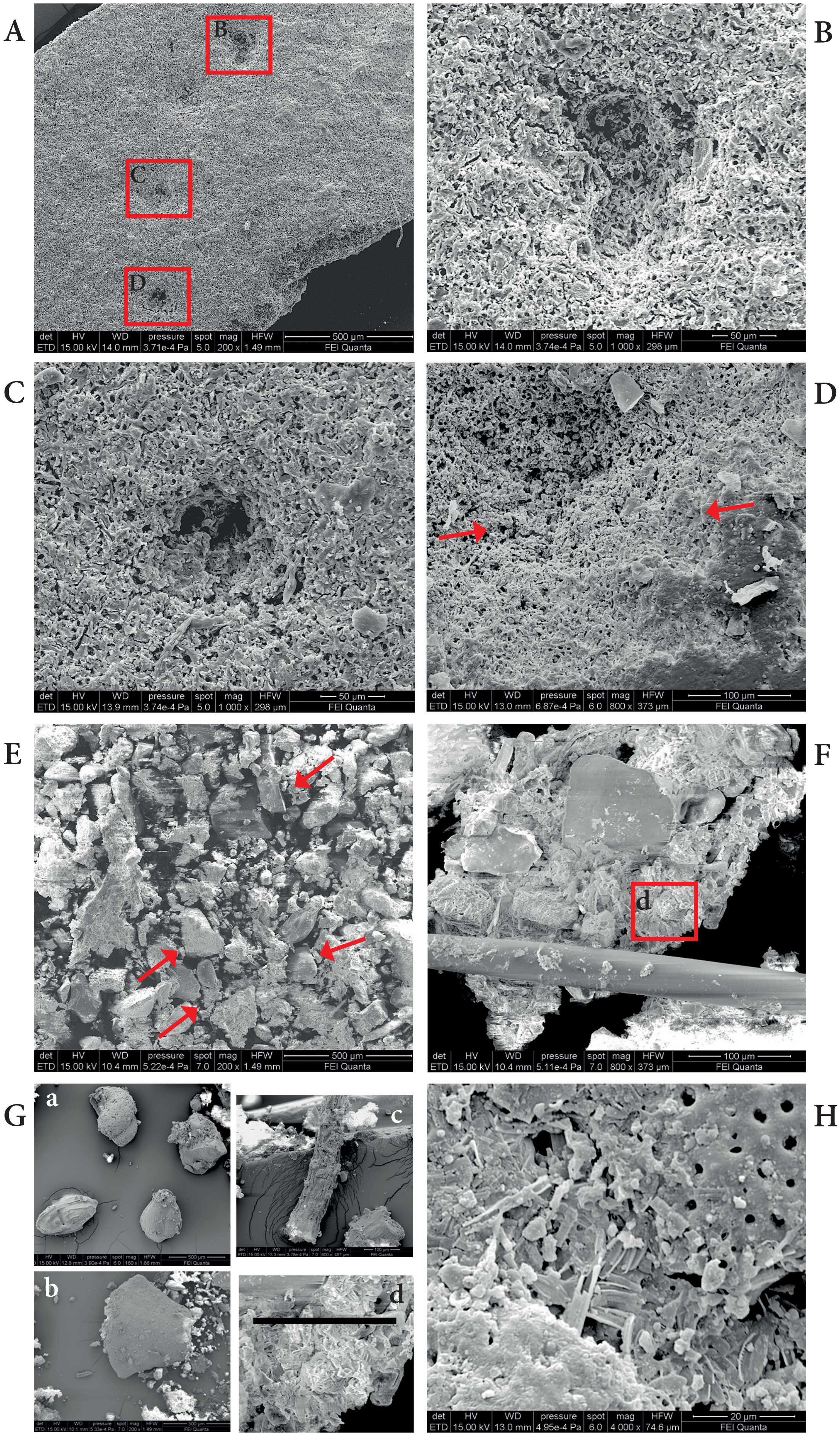
The find of nautilid remains in the late Pleistocene of Bajuni Islands, the second Pleistocene nautilid record after that of early Pleistocene in northwest Philippines by Wani et al. (2008), could support the hypothesis of the presence of living *Nautilus* in the western Indian Ocean in Plio-Pleistocene times, besides that in the Indian-Malaysian area. The Bajuni Islands fossil nautilid remains could be a proxy of the belonging of *Nautilus* to the Plio-Pleistocene WIO (Western Indian Ocean) shelf fauna, perhaps derived from the Miocene Arabian hot-spot of biodiversity recognized by Renema et al. (2008), rather than from a westwards expansion from the Indian-Malaysian one. Of course, new finds are needed, in a region whose recent and fossil biodiversity is under-explored.

Moreover, the hypothesis that the modern distribution of shallow water fauna has been influenced by the Quaternary sea-level variations (Pellissier et al., 2014) is supported by the discontinuous geographic distribution of some benthic taxa during the Quaternary. For example, Accordi et al. (2012) recognized in Pleistocene deposits of Kenyan coast *Tridacna gigas*, which is also present in the late Pleistocene of Somalia (personal observation), whereas its current living area is restricted to the southeastern Asian shallow seas (Syukri bin Othman et al., 2010).

6. CONCLUSIONS

The *Nautilus* specimens from Bajuni Islands are the first found in the southern Somali coast backshore and the first figured from the East African coasts.Their conservation status mainly depends from their time of stay in the shallow waters, and probably repeated crackling collisions. The traces on one ("reef flat") of the two specimens are a proxy of a series of micro-impacts

Fig. 7 - Microborings. A) Outer surface of the beach specimen with a parallel dense net of cylindrical tunnels. B) Outer surface of the reef flat specimen; deeper superficial erosion evidence the deep-wards orientation of the borings. C) Highly eroded external surface of the reef flat specimen with a probable prod-like mark, abruptly terminating in a rounded pit (arrow). D) Detail of the surface densely bored; some tunnels, often filled by carbonate particles, show an internal lining (arrow). E) Transverse section of the wall of the reef flat specimen, showing the sphaerulitic, prismatic and nacreous layers. F) Detail of E) showing the prismatic layer densely bored; note the tunnels of small and large diameter. Also the top level of the nacreous layer exhibits numerous borings of small diameter, parallel to the surface (arrows). G) detail of E), showing a boring crossing the nacreous layer directed to the inner surface; note a few branchings (arrows). H) Transverse section of the wall of the shored specimen: only the sphaerulitic layer exhibits borings.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B
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D
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E
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ETD 15.00 kV 10.4 mm 5.22e-4 Pa 7.0 200 x 1.49 mm FEI Quanta
F
d
det HV WD pressure spot mag HFW 100 µm
ETD 15.00 kV 10.4 mm 5.11e-4 Pa 7.0 800 x 373 µm FEI Quanta
G
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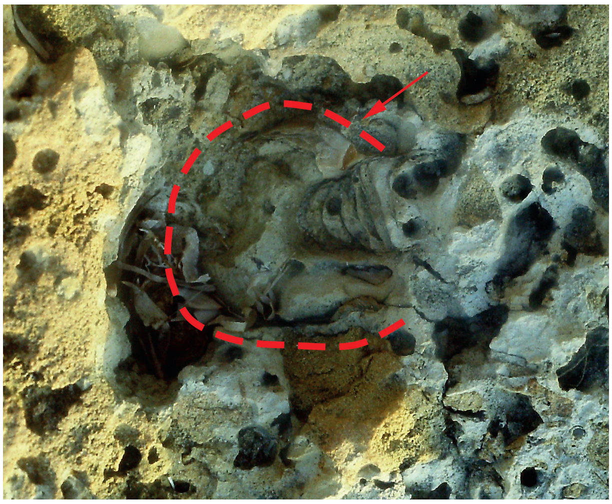

Fig. 9 - Natural transverse section of a nautilid shell at the surface of the cemented eolianite outcropping in the intertidal of the Ciovai Island; the body chamber section is outlined by a dashed line; note the preserved piece of wall (arrow).

in turbulent waters, rich in suspended quartz grains. The low alteration of the shell surface of the second specimen ("beach") and the preservation of a more fresh appearance can be considered as proxies of a less long persistence in shallow waters and, perhaps, of a recent dead.

The Bajuni specimens do not contribute definitely to the question of the location of the living area of provenience, even if the presence of nautilid shell remains in the late Pleistocene rocks and the preservation status of the beach specimen could be a proxy of the existence of a *Nautilus* living area in the WIO province. On the other side, there are some morphological similarities of the Somali specimens with those pertaining to the questionable species *N. repertus*, known only along the southwestern coast of Australia, where doubtfully lives, probably drifted by the Leeuwin current; moreover, the travel from the coast of Australia to that of Africa could have been brief, less than a year, as the travel made by

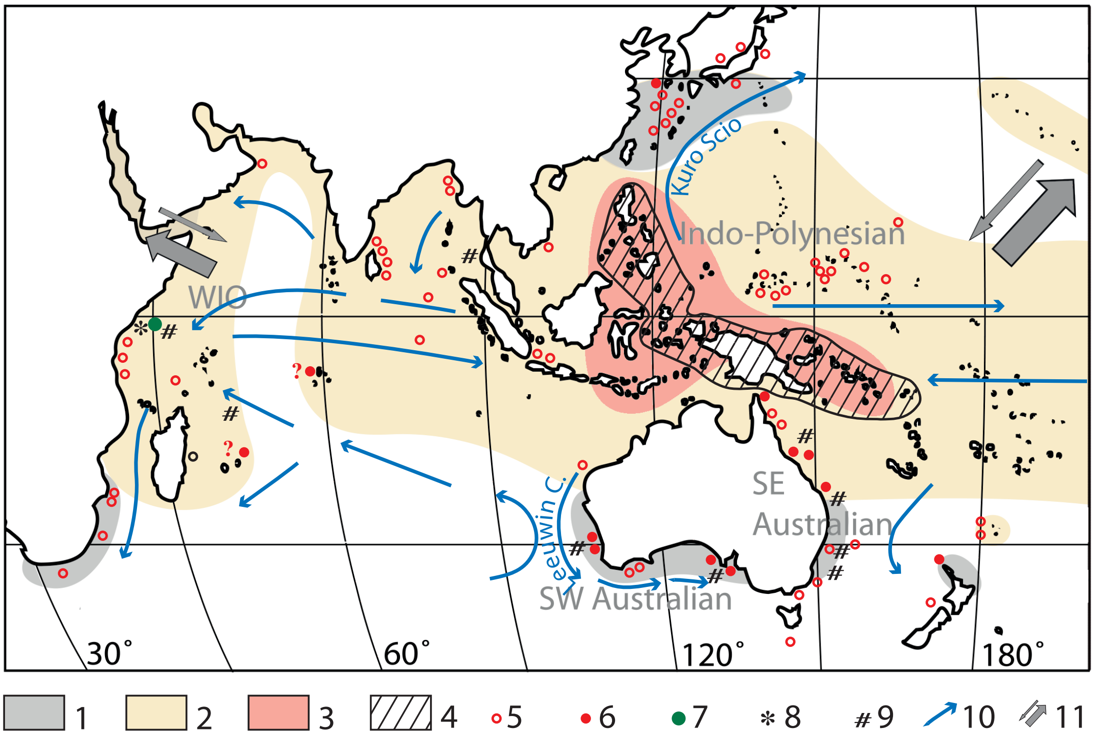

Fig. 10 - Distribution of *Nautilus* in the Indo-Pacific Ocean. Data from maps of Briggs and Bowen, 2013; House, 1987; Reyment, 2008; Fries, 2010). 1- warm-temperate provinces; 2- tropical provinces; 3- the Coral Triangle; 4- the living area of *Nautilus*; 5- reports of drifted *Nautilus* shells outside the living area; 6- reports of living *Nautilus* shells outside the living area; 7- the Bajuni Islands drifted *Nautilus* shells; 8- the Pleistocene *Nautilus* remains; 9- presumed living areas of *Nautilus*; 10- major oceanic currents of presumend significance for dispersion of *Nautilus* shells; 11- primary and secondary flows of species towards and from the peripheral provinces. WIO = Western Indian Ocean.

Fig. 8 - Reef flat (A-G) and beach (H) specimens. A) Eroded surface of the sphaerulitic layer with pits. B and C) details of a comma shaped pit (B) and a spirally septate one (C). D) Detail of the furrowed wall (arrows) of a deep pit, from the surface of a colored stripe (right bottom corner) to the bottom of the pit (left upper corner). E) Sediment from the phragmocone; note the rounded and angular quartz grains (arrows) among the carbonate ones. F) Grains are embedded in a microdetritic and automicritic sediment; in the centre, two quartz grains; in foreground a siliceous spicula. Ga-c) Some common shallow water bioclasts: a) gastropod and mollusk fragments, miliolid, ostracod; b) Halimeda; c) vegetal fragment. G, d) particular of F), showing a subsphaerical peloid. H) Detail of a cluster of diatoms partly trapped in the outer chambers of a gypsinid foraminifer.

the bottle mentioned by House (1987). Finally, despite the relative frequency of the shell findings, validated also by the choice to represent a *Nautilus* shell on a postage stamp of Kenya, no living specimens have been observed until now (except the witness of A. Bilder, reported in Reyment, 2008). Also is at least strange that the specimen of the postage stamp of Kenya, figured by House (1987), seems an incomplete shell, devoid of much of the body chamber, whose margins were evidently smoothed artificially.

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