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Original article

The decapod community from the Early Pliocene (Zanclean) of "La Serra" quarry (San Miniato, Pisa, Toscana, central Italy): sedimentology, systematics, and palaeoenvironmental implications

La communauté à décapodes du Pliocène inférieur (Zancléen) de la carrière « La Serra » (San Miniato, Pise, Toscane, Italie centrale) : sédimentologie, systématique et implications paléoenvironnementales

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Abstract

We report an unusual and rich decapod crustacean assemblage from the early Pliocene (Zanclean), recently collected during the excavations of the "La Serra" quarry, located in La Serra, near San Miniato, Pisa (Toscana, central Italy). The studied specimens have been assigned, as follows: *Axius* sp., *Callianassa chalmasii* Brocchi, 1883, and *Calliaxina* cf. *C. punica* (de Saint Laurent and Manning, 1982) (infraorder Axiidea de Saint Laurent, 1979); *Gebiacantha tuscia* Garassino, Pasini, De Angeli and Charbonnier sp. nov. (infraorder Gebiidea de Saint Laurent, 1979); *Pagurus alatus* Fabricius, 1775, and *Pagurus* sp. (infraorder

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Anomura MacLeay, 1838); *Dromia neogenica* Müller, 1978, *Dromia* sp., *Medorippe* cf. *M. ampla* Garassino, De Angeli, Gallo and Pasini, 2004, *Ilia nucleus* (Linnaeus, 1758), *Ristoria pliocaenica* (Ristori, 1891), *Pisa armata* (Latreille, 1803), *Macropodia* sp., *Maja squinado* (Herbst, 1788), *Derilambrus angulifrons* (Latreille, 1825), *Atelecyclus undecimdentatus* (Herbst, 1783), *Liocarcinus* sp., *Thalamita italica* Garassino, Pasini, De Angeli and Charbonnier sp. nov., *Pilumnus* cf. *P. hirtellus* (Linnaeus, 1761), *Eriphia cocchii* Ristori, 1886, *Goneplax rhomboides* (Linnaeus, 1758), *Goneplax sacci* Crema, 1895, (infraorder Brachyura Linnaeus, 1758). Moreover, two specimens have been assigned to callianassideans *sensu lato* and 13 specimens to indeterminate axiideans. *Calliaxina* Ngoc-Ho, 2003, *Gebiacantha* Ngoc-Ho, 1989, *Ristoria* Garassino, Pasini, De Angeli and Charbonnier gen. nov., and *Macropodia* Leach, 1814, are reported for the first time in the fossil record and the extant *Pagurus alatus*, *Ilia nucleus, Pisa armata, Derilambrus angulifrons*, and *Pilumnus* cf. *P. hirtellus*, are reported in the fossil record from the Pliocene. Everywhere "La Serra" quarry bio-community is very important, representing one of the richest and most diversified crustacean faunas from the Pliocene reported to date in the Mediterranean basin and worldwide, increasing notably the knowledge on the decapod populations and distribution during the early Pliocene. This community is indicative of a palaeoenvironment of shallow sublittoral water, with sandy-muddy and alternate hard shell bottom, partially covered or in proximity of seagrass, similar to the extant Mediterranean *Posidonia* beds, mainly inhabited by fossorial and benthonic decapods.

Keywords: Crustacea; Decapoda; Early Pliocene; Italy; Sedimentology; Palaeoenvironment

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Résumé

Nous décrivons un riche et exceptionnel assemblage de crustacés décapodes du Pliocène inférieur (Zancléen), récemment récolté durant les travaux de creusement de la carrière « La Serra » localisée à La Serra, près de San Miniato, Pise (Toscane, Italie centrale). Les spécimens étudiés ont été identifiés de la façon suivante : *Axius* sp., *Callianassa chalmasii* Brocchi, 1883, et *Calliaxina* cf. *C. punica* (de Saint Laurent et Manning, 1982) (infra-ordre Axiidea de Saint Laurent, 1979) ; *Gebiacantha tuscia* Garassino, Pasini, De Angeli et Charbonnier sp. nov. (infra-ordre Gebiidea de Saint Laurent, 1979) ; *Pagurus alatus* Fabricius, 1775, et *Pagurus* sp. (infra-ordre Anomura MacLeay, 1838) ; *Dromia neogenica* Müller, 1978, *Dromia* sp., *Medorippe* cf. *M. ampla* Garassino, De Angeli, Gallo et Pasini, 2004, *Ilia nucleus* (Linnaeus, 1758), *Ristoria pliocaenica* (Ristori, 1891), *Pisa armata* (Latreille, 1803), *Macropodia* sp., *Maja squinado* (Herbst, 1788), *Derilambrus angulifrons* (Latreille, 1825), *Atelecyclus undecimdentatus* (Herbst, 1783), *Liocarcinus* sp., *Thalamita italica* Garassino, Pasini, De Angeli et Charbonnier sp. nov., *Pilumnus* cf. *P. hirtellus* (Linnaeus, 1761), *Eriphia cocchii* Ristori, 1886, *Goneplax rhomboides* (Linnaeus, 1758), *Goneplax sacci* Crema, 1895, (infra-ordre Brachyura Linnaeus, 1758). De plus, deux spécimens ont été attribués à des callinassidés *sensu lato* et 13 spécimens à des axiidés indéterminés. *Calliaxina* Ngoc-Ho, 2003, *Gebiacantha* Ngoc-Ho, 1989, *Ristoria* Garassino, Pasini, De Angeli et Charbonnier gen. nov., et *Macropodia* Leach, 1814, sont signalés pour la première fois dans le registre fossile et les actuels *Pagurus alatus*, *Ilia nucleus, Pisa armata, Derilambrus angulifrons*, et *Pilumnus* cf. *P. hirtellus* sont signalés dans le registre fossile dès le Pliocène. La communauté de la carrière « La Serra » constitue un ensemble très important représentant l'une des faunes de crustacés les plus riches et les plus diversifiées du Pliocène du Bassin méditerranéen et même du monde. Elle augmente considérablement la connaissance des populations de décapodes et leur distribution au cours du Pliocène inférieur. Cette communauté est l'indicateur d'un paléoenvironnement sublittoral peu profond, avec un fond sablo-boueux alternant avec des coquilles dures, partiellement couvert d'un herbier ou très proche d'un herbier. Ce paléoenvironnement est très comparable aux prairies à *Posidonia* de la Méditerranée actuelle qui sont principalement habitées par des décapodes benthiques et fouisseurs.

Mots clés : Crustacea ; Decapoda ; Pliocène inférieur ; Italie ; Sédimentologie ; Paléoenvironnement

Riassunto esteso

La comunità di decapodi del Pliocene inferiore (Zancleano) della cava "La Serra" (San Miniato, Pisa, Toscana, Italia centrale): sedimentologia, sistematica e implicazioni paleo-ambientali. Viene descritta una inusuale e ricca fauna a crostacei decapodi del Pliocene inferiore (Zancleano), recentemente raccolta durante i lavori di scavo industriale della cava "La Serra", posta in località La Serra presso San Miniato, Pisa (Toscana, Italia centrale). I campioni studiati provengono da un livello di argille sabbiose di spessore limitato (0.50–0.70 m) esposto su un fronte di circa 50 m lungo la parte sommitale della cava, frammisti a una ricca malacofauna. Le analisi sedimentologiche e lo studio delle macro-microfaune hanno permesso di interpretare la complessa successione stratigrafica trasgressiva, e di ricostruire un modello articolato dell'antico ambiente costiero. In particolare le osservazioni micro-paleontologiche hanno consentito una datazione dei livelli fossiliferi al Pliocene inferiore (Zancleano). I resti dei decapodi sono generalmente conservati come modelli all'interno di concrezioni subnodulari indurite in veri noduli di piccole dimensioni o, più raramente, inglobati nel sedimento. La fauna è indicativa di un ambiente marino sublitorale poco profondo in presenza di fondali sabbioso-fangosi, con aree composte da substrato più solido derivato in prevalenza da accumuli di gusci frammentari di molluschi e, probabilmente, ricoperti da praterie algari simili alle attuali praterie a *Posidonia*, abitato in prevalenza da decapodi fossatori e bentonici. I decapodi studiati sono stati assegnati a: *Axius* sp., *Callianassa chalmasii* Brocchi, 1883 e *Calliaxina* cf. *C. punica* (de Saint Laurent & Manning, 1982) (infraordine Axiidea de Saint Laurent, 1979); *Gebiacantha tuscia* Garassino, Pasini, De Angeli & Charbonnier sp. nov. (infraordine Gebiidea de Saint Laurent, 1979); *Pagurus alatus* Fabricius, 1775 e *Pagurus* sp. (infraordine Anomura MacLeay, 1838); *Dromia neogenica* Müller, 1978, *Dromia* sp., *Medorippe* cf. *M. ampla* Garassino, De Angeli, Gallo & Pasini, 2004, *Ilia nucleus* (Linnaeus, 1758), *Ristoria pliocaenica* (Ristori, 1891), *Pisa armata* (Latreille, 1803), *Macropodia* sp., *Maja squinado* (Herbst, 1788), *Derilambrus angulifrons* (Latreille, 1825), *Atelecyclus undecimdentatus* (Herbst, 1783), *Liocarcinus* sp., *Thalamita italica* Garassino, Pasini, De Angeli & Charbonnier sp. nov., *Pilumnus* cf. *P. hirtellus* (Linnaeus, 1761), *Eriphia cocchii* Ristori, 1886, *Goneplax rhomboides* (Linnaeus, 1758) e *Goneplax sacci* Crema, 1895 (infraordine Brachyura Linnaeus, 1758). Due esemplari sono stati attribuiti a callianassidi *sensu lato* e tredici a axiidi indeterminati. Prima dello studio carcinologico de "La Serra", i crostacei decapodi della Toscana erano rappresentati da 14 famiglie, comprendenti 24 generi con 22 specie. Lo studio della ricca associazione a crostacei decapodi de "La Serra" ha permesso di incrementare le conoscenze finora acquisiste. Allo stato attuale si conoscono infatti 16 famiglie che comprendono 19 generi con 22 specie. I dati raccolti da questo studio indicano che più dell'80% dei generi e circa il 75% delle specie precedentemente conosciute nel Pliocene della Toscana sono presenti per la prima volta nello stesso paleoambiente de "La Serra", rappresentando la più abbondante e diversificata fauna carcinologica del Pliocene inferiore dell'area mediterranea. La grande quantità e la perfetta conservazione degli esemplari raccolti ha inoltre permesso d'individuare e di descrivere il nuovo genere *Ristoria* Garassino, Pasini, De Angeli & Charbonnier gen. nov. e al tempo stesso di discutere e chiarire la posizione sistematica di *Ilia pliocaenica* Ristori, 1891. Lo studio della fauna carcinologica de "La Serra" ha inoltre permesso di stabilire che *Calliaxina* Ngoc-Ho, 2003, *Gebiacantha* Ngoc-Ho, 1989, *Ristoria* Garassino, Pasini, De Angeli & Charbonnier gen. nov., e *Macropodia* Leach, 1814 sono segnalati per la prima volta nel record fossile mentre *Pagurus alatus*, *Ilia nucleus, Pisa armata, Derilambrus angulifrons* e *Pilumnus* cf. *P. hirtellus* sono riportati per la prima volta nel record fossile del Pliocene inferiore. Due specie, già note nel Miocene, *Dromia neogenica* e *Medorippe* cf. *M. ampla*, e tre specie, precedentemente segnalate nel Pleistocene, *I. nucleus*, *P. armata* e *D. angulifrons*, sono aggiunte al record fossile del Pliocene del bacino Mediterraneo. *Axius* sp., *Calliaxina* cf. *C. punica*, *P. alatus*, *D. neogenica*, *I. nucleus*, *P. armata*, *D. angulifrons*, *Atelecyclus undecimdentatus* (Herbst, 1783) e *Pilumnus* cf. *P. hirtellus*, sono segnalate per la prima volta nel Pliocene Italiano. Inoltre *Axius* sp., *Calliaxina* cf. *C. punica*, *P. alatus*, *D. neogenica*, *I. nucleus*, *P. armata*, *Maja squinado* (Herbst, 1788), *D. angulifrons*, *A. undecimdentatus* e *Pilumnus* cf. *P. hirtellus* sono segnalate per la prima volta nel Pliocene della Toscana. In conclusione, il particolare ambiente e l'eccezionale bio-diversità della fauna rinvenuta a "La Serra" è estremamente importante in quanto rappresenta una delle più ricche e differenziate associazioni di decapodi sinora note nel Pliocene del bacino Mediterraneo e del mondo, incrementando notevolmente le conoscenze sulle popolazioni e la loro distribuzione durante il Pliocene inferiore.

Parole chiave : Crustacea; Decapoda; Pliocene inferiore; Italia; Sedimentologia; Paleoambiente

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1. Introduction

The small village of La Serra is located 5 km southwest of San Miniato (Pisa, Toscana, central Italy). The "La Serra" quarry engraves a hill of continental to coastal marine deposits, belonging to the sedimentary succession of regressive-transgressive cycles cropping out in the area around San Miniato (Benvenuti and Dominici, 1992; Dominici, 1994; Benvenuti et al., 1995a,b, 2007; Dominici et al., 1995; Abbazzi et al., 2008) (Figs. 1, 2). The sedimentological features, the macropalaeontological and micropalaeontological analyses, as well as the biostratigraphic characterization allow reconstructing a transgressive sedimentary succession, and modelling an early Pliocene articulated coastal environment. At the top of the quarry, a layer of grey-blue clayey sands (0.50–0.70 m thick along a front of about 50 m) contains a rich, diversified fauna with disarticulated bivalves and gastropods. Scarce fishes and scarce small vertebrate remains (e.g.,

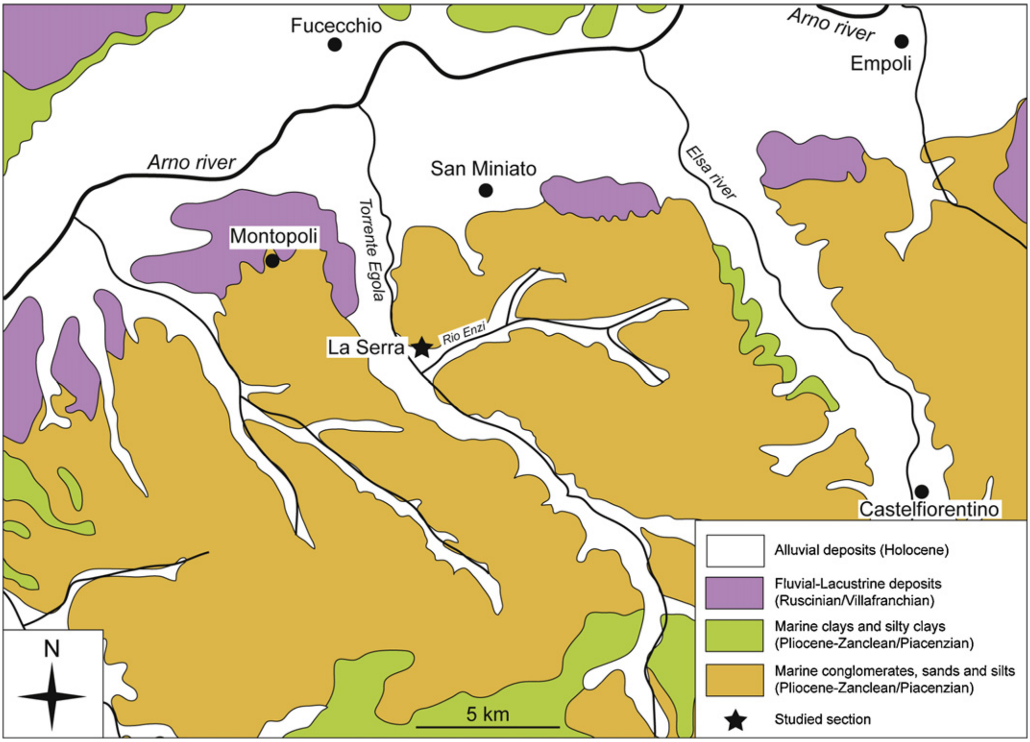

Fig. 1. Synthetic geological map and location of "La Serra" quarry.
Carte géologique synthétique et localisation de la carrière « La Serra ».

Fig. 2. Fossiliferous layers of “La Serra” quarry.
Niveaux fossilifères de la carrière « La Serra ».

cervids, turtles), regular echinoids, sponges, and vegetal remains were also recorded at different levels (Fig. 3). This bio-community also includes an unusual rich fauna of diversified thalassinid, anomuran, and brachyuran decapods, the subject of this study. Previously, the discovery of this important rich bio-community has only briefly been reported in a short preliminary poster by Pasini et al. (2010).

At present, the multifaceted data permit reconstruction of the palaeoecological context in which the decapod assemblage developed.

Since the study of “La Serra” quarry has implied geological, sedimentological, systematic, and palaeoenvironment aspects, the authors of each chapter are designated by their initials: Alessandro Garassino (A.G.), Giovanni Pasini (G.P.), Antonio De Angeli (A.D.A.), Sylvain Charbonnier (S.C.), Federico Famiani (F.F.), Angela Baldanza (A.B.) and Roberto Bizzarri (R.B.).

2. Geological setting (F.F., A.B., R.B.)

The studied section is highlighted by an historical quarry situated near the La Serra village, in the neighbourhood of San Miniato (Pisa, Toscana, central Italy) (Fig. 4). The area lies at the north-western edge of Valdelsa Basin, a 25 km wide and 60 km long NW-SE trending extensional basin filled with more than 2000 m of Neogene sediments (Ghelardoni et al., 1968; Bossio et al., 1993; Martini and Sagri, 1993; Abbazzi et al., 2008). Nevertheless, as suggested for other

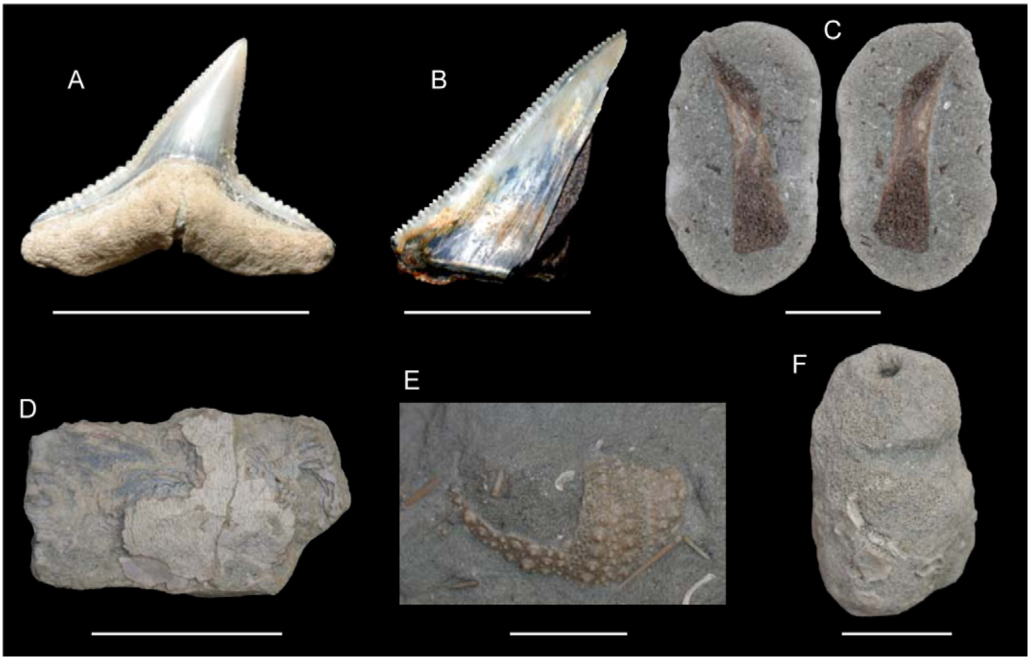

Fig. 3. Associated fauna from "La Serra" quarry. **A**. Indeterminate carcharhinid shark (GPDG 0225). **B**. *Carcharodon carcharias* (Linnaeus, 1758), anterior tooth (GPDG 0226). **C**. Indeterminate bone fragment included into a nodule (GPDG 0227). **D**. Indeterminate squid cuttlebone (GPDG 0230). **E**. Indeterminate regular echinoid (GPDG 0229). **F**. Indeterminate sponge (GPDG 0228). Scale bars: 2 cm except A: 5 mm.

*Faune associée de la carrière « La Serra ». **A**. Requin carcharhinidé indéterminé (GPDG 0225). **B**.* Carcharodon carcharias *(Linnaeus, 1758), dent antérieure (GPDG 0226). **C**. Membre osseux indéterminé inclus dans un nodule (GPDG 0227). **D**. Os interne de calmar indéterminé (GPDG 0230). **E**. Échinide régulier indéterminé (GPDG 0229). **F**. Éponge indéterminée (GPDG 0228). Barres d'échelle : 2 cm excepté A : 5 mm.*

Neogene basins of central-southern Toscana, it underwent a complex tectono-sedimentary evolution (Boccaletti et al., 1991; Bonini and Sani, 2002). Late Miocene to Pleistocene fluvio-lacustrine, fluvial, deltaic, and shallow marine deposits crop out all around San Miniato, in a wide area from Montopoli to Empoli, and they are mainly referred to the Piacenzian "Ponte a Elsa" and "San Miniato" synthems (Benvenuti and Dominici, 1992; Benvenuti et al., 1995a,b, 2007; Benvenuti and Degli Innocenti, 2001), or to the early Pliocene "Argille e Sabbie di Cerreto Guidi" Unit (Toscana Regional geological Map project: A.A.V.V., 2006). Moreover, Villafranchian mammal assemblages, belonging to both the Triversa and the Montopoli Faunal Units, are historically documented in the area (Benvenuti and Dominici, 1992; Dominici, 1994; Benvenuti et al., 1995a,b, 2007; Dominici et al., 1995; Abbazzi et al., 2008).

2.1. *Section of "La Serra" quarry*

The quarry is situated about 5 km SW of San Miniato, at "La Serra" on the southern flank of a hill along the right side of the Torrente Egola, at the confluence with the Rio Enzi. As yellowish sand and grey clay deposits irregularly alternate all around the hill, they are well exposed only on the more recent excavation fronts. Throughout the NW-SE oriented quarry

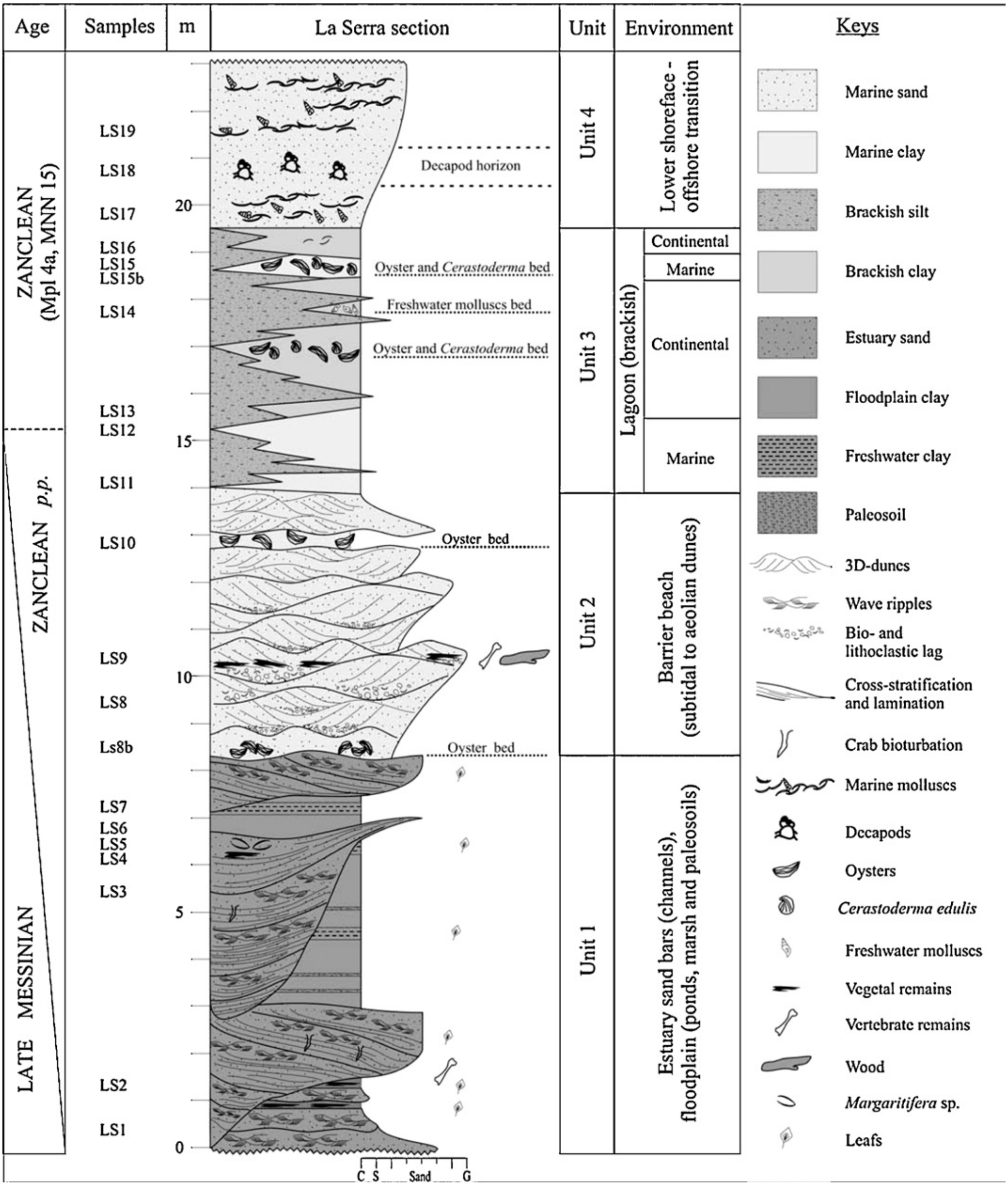

Fig. 4. Lithological log from “La Serra” quarry with fossil distribution, sedimentological structures and stratigraphic units.

Coupe lithologique de la carrière « La Serra » avec distribution des fossiles, structures sédimentologiques et unités stratigraphiques.

front, a thick section of about 25 m has been reconstructed and 21 samples (LS1 to LS19, LS8b, LS15b) have been collected. About 200 g of each sample have been processed with a H_2O_2 solution and the washed residue has been observed using a stereomicroscope. Using the standard technique of Bown and Young (1998), the smear slides for nannoplankton analysis have been prepared and analized using a polarizing-light microscope at 1000 × magnification. Four main depositional units, resulting from different palaeoenvironmental conditions, are identified on both sedimentological and palaeoecological characters (Fig. 4).

- Unit 1 (from base of the section to 8 m, samples LS1–LS7)

Mixed sand and silt. — In the lowermost section, up to 0.20 m thick medium to coarse sand beds, normally graded, with erosional base and wave ripples, alternate to climbing-ripple laminated silty sand and to thin (max.: 0.10 m) massive dark clay beds, the latter bearing leaves and other vegetal matter (Fig. 5A, F and G).

Cross-stratified sand. — Medium to fine graded sand, in 2–3 m thick channelled beds, locally amalgamated, showing large planar cross-stratification represents the main facies of Unit 1. Strata sets are made of planar cross-lamination with tangential foresets, marked by vegetal matter, in the lower part, and by wave-ripple laminations in the upper part (Fig. 5A, F, H and I). Clay chips are commonly preserved among the cross-laminations, whereas brown to reddish oxidation surfaces, due to subaerial exposure, characterize the top of wave ripples. Bioturbations referable to the ichnospecies *Psilonichnus upsilon* Frey, Curran and Pemberton, 1984 (P. Monaco, pers. comm., 2011) occur locally (Fig. 5H), as well as leaves, seeds, and other vegetal matter. In the basal portion, a fragment of indeterminate cervid antler has been recovered.

Massive clay. — The facies is dominated by structureless light grey clays, enriched in vegetal matter, locally alterning with slightly laminated clay and brown-reddish concretioned horizons (palaeosoils). Its continuity is interrupted by the aforementioned sandy channels (Fig. 5A).

Macro- and microfauna assemblages and related palaeoecology. — The basal portion of the section (samples LS1 to LS7) is very limited in macro- and microfauna content. Microfossils are represented only by the ostracods *Ilyocipris bradyi* Sars, 1868, *Ilyocipris gibba* (Ramdohr, 1808), *Candona angulata* (Müller, 1900), *Pseudocandona* sp., *Heterocypris salina* (Brady, 1868), *Cyprideis torosa* (Jones, 1850). The massive clay facies contains brackish continental shallow water species (*H. salina* and *C. angulata*) and shallow freshwater species (*I. bradyi*, *I. gibba*, *Pseudocandona* sp., and *Candona* sp.) which can tolerate oligohaline to mesohaline salinity (Ambrosetti et al., 1995; Gliozzi, 1999; Faranda et al., 2007; Faranda and Gliozzi, 2008).

The malacofauna, found in sample LS5, is mainly represented by large specimens of *Margaritifera* sp. and rare *Corbicula fluminalis* (Müller, 1774), both freshwater genera live in river and lacustrine environment with moderate energy (Esu and Girotti, 1974; Girotti et al., 2003).

- Unit 2 (from 8 m to 14 m, samples LS8b–LS10)

Large dune sand. — Dune cross-stratified medium to very coarse sand, to granules. Sands are organized in 2–3 m thick, coarsening upward beds showing large ($\lambda = 1$–2 m) three-dimensional dune cross-stratification (Fig. 5B). The internal organization is made of erosional base contacts, bio- and lithoclastic lags and high-angle bidirectional cross-laminations. The base of the interval is characterized by a cemented oyster bed, whereas a horizon bearing woody remains and also bone fragments of indeterminate turtles occur at about the level of 10 m. The woody remains are enclosed in coarse sand deposits, locally hardly cemented. In the uppermost portion, an oyster-rich, massive dark clay horizon separates the last two dune beds.

Macro- and microfauna assemblages and related palaeoecology. — The basal portion of this unit (sample LS8b) contains oligotypic oyster bed with *Neopycnodonte cochlear* (Poli, 1795) and *Ostrea edulis* (Linnaeus, 1758) (juvenile specimens), enhancing the marine control on estuarine

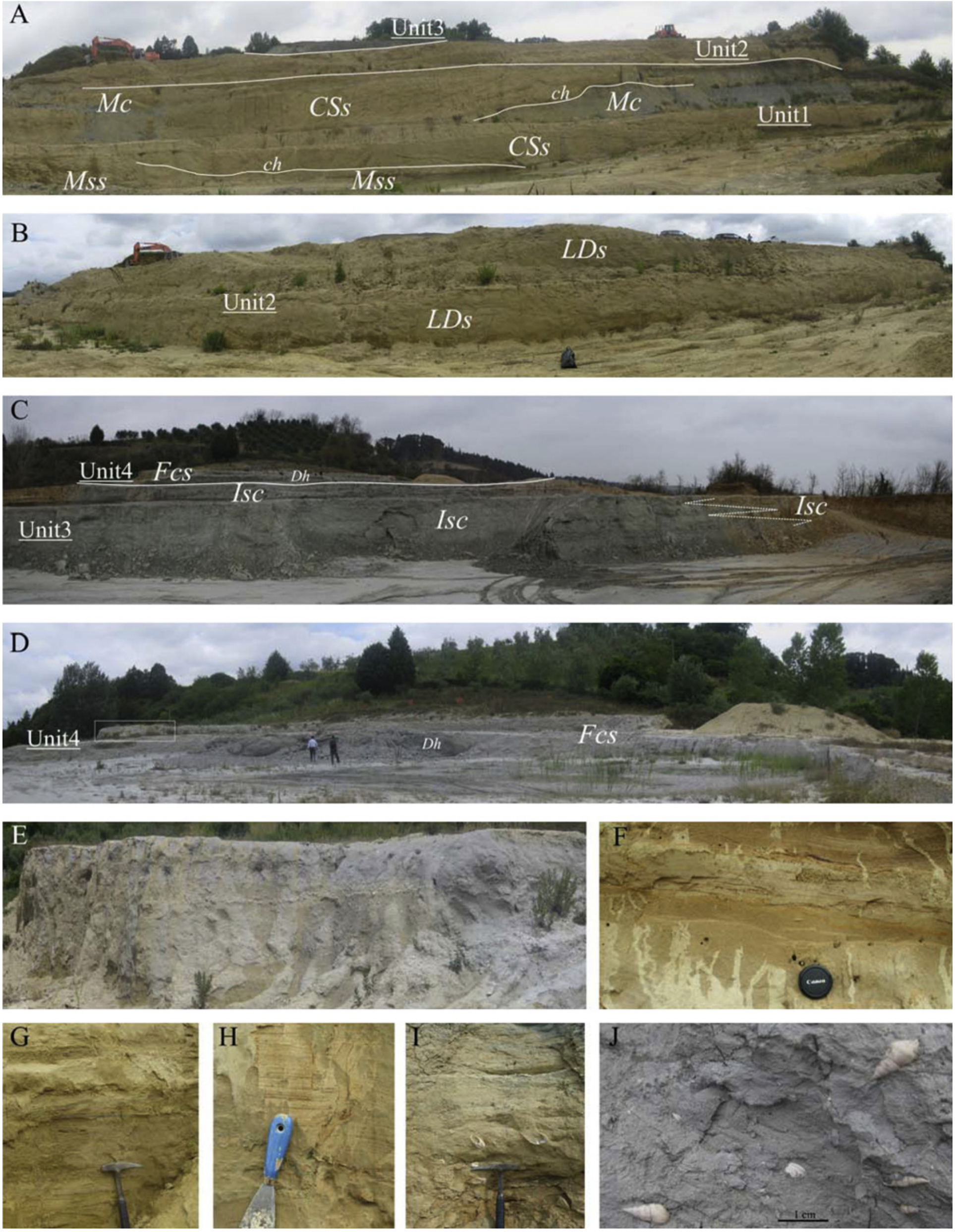

Fig. 5. Sedimentary facies observed in the "La Serra" quarry. **A–D**. Panoramic view of Units 1 to 4 and their large scale facies architecture. The main decapod horizon is well visible in D. **E**. Shell beds in the sand deposits at the top of the section (detail of D). **F**. Wave ripple-laminated sand. **G**. Alternation of climbing-ripple laminated silty sand and leaf-bearing massive dark clay. **H**. Burrow of *Psilonichnus upsilon* Frey, Curran and Pemberton, 1984, cutting the internal lamination of cross-stratified sand. **I**. Well-preserved shells of *Margaritifera* sp. in the uppermost part of cross-stratified sand. **J**. Scattered gastropods in the silty clay deposits of Unit 3. Mss = massive silt and sand; CSs = cross-stratified sand; Mc = massive clay; LDs = large sand dune; Isc = intermingled silt and clay; Fcs = fossiliferous clayey sand; ch = channel; Dh = decapod horizon.

environment. Samples LS8 and LS9 are devoid of macro- and microfauna. The first appearance of benthic foraminifera, represented by very few specimens of *Ammonia tepida* (Cushman, 1926) and *Ammonia beccarii* (Linnaeus, 1758) (shallow infaunal taxa, herbivorous, and tolerating brackish condition) occurs in sample LS10. The mesohaline ostracod *Cyprideis torosa*, first colonizer of stressed environments, that lives in estuarine and brackish waters, is the only one present in the assemblage.

The malacofauna assemblage, present at the base of this unit, is enriched for the first time by the epiphytal gastropod *Bittium reticulatum* (Da Costa, 1778), and *Cerastoderma* sp., taxa that can tolerate variable salinity conditions.

- Unit 3 (from 14 m to 19.5 m, samples LS11–LS16)

Intermingled silt and clay. — Structureless silt and silty sand, laterally grading to massive dark grey clay (Fig. 5 C and J). Organic matter (vegetal remains) is dispersed throughout the deposit, whereas the fossil content increases upward.

Macro- and microfauna assemblages and related palaeoecology. — The very poor microfauna assemblage (sample LS11), consists of rare *Ammonia beccarii, A. tepida* and *Elphidium crispum* (Linnaeus, 1758), indicates the permanence of brackish conditions.

The recover of a more diversified benthic foraminifera assemblage occurs in sample LS12: *Quinqueloculina seminula* (Linnaeus, 1758), *Triloculina bicarinata* d'Orbigny, 1826, and *A. beccarii* are very abundant and accompanied by frequent specimens of *E. crispum* and *Lobatula lobatula* (Walker and Jacob, 1798). These epifaunal taxa, with the exception of *A. beccarii*, are indicative of a sea grass vegetated floor development under oxic conditions and presence of organic matter (Murray, 1991). The ostracofauna (Fig. 6) is represented by the marine taxa *Cytheridea neapolitana* Kollmann, 1960, *Aurila convexa* (Baird, 1850), *Aurila punctata* (von Münster, 1830), *Argilloecia kissamovensis* Sissingh, 1972, *Palmoconcha turbida* (Müller, 1894), *Pontocythere turbida* (Müller, 1894), and *Tyrrhenocitere pontica* (Livental) in Agalarova, Kadyrova and Kulieva, 1961. The presence of *Prososthenia* sp. and *Bithynia leachi* Sheppard, 1823, freshwater gastropods which can tolerate mesohaline conditions, could be related to reworking phenomena or to a freshwater influx.

Sample LS13 is unproductive, whereas the microfauna of sample LS14 contains shallow freshwater ostracods (*Candona angulata*, *C. torosa*, *Ilyocipris bradyi*) which can tolerate oligohaline and occasionally mesohaline salinity, and common *Characeae oogonia*. The benthic foraminifer *Ammonia tepida* is present but very rare. Freshwater gastropods, such as *Prososthenia meneghiniana* (De Stefani, 1874), *P. etrusca* (De Stefani, 1880), *Valvata (Cincinna) piscinalis* (Müller, 1774), *Gyraulus albus* (Müller, 1774), and *Emmericia umbra* (De Stefani, 1877) provide evidence of continental brackish conditions. The bivalve *Mytilus* cf. *M. scaphoides*

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*Faciès sédimentaires observés dans la carrière « La Serra ». **A–D**. Vue panoramique des Unités 1 à 4 et leur enchaînement de faciès à grande échelle. Le principal horizon à décapodes est bien visible sur D. **E**. Bancs à coquilles dans les dépôts sableux au sommet de la coupe (détail de D). **F**. Sable laminé à rides de vagues. **G**. Alternance de sable silteux laminé et à rides entrecroisée et d'argile massive noire à feuilles. **H**. Terrier de Psilonichnus upsilon Frey, Curran and Pemberton, 1984, recoupant la lamination interne du sable à stratifications entrecroisées. **I**. Coquilles bien préservées de* Margaritifera *sp. dans la partie supérieure du sable à stratifications entrecroisées. **J**. Gastéropodes dispersés dans les dépôts argilo-silteux de l'unité 3. Mss = sable et silt massifs ; CSs = sable à stratifications entrecroisées ; Mc = argile massive ; LDs = grande dune sableuse ; Isc = argiles et silts interpénétrés ; Fcs = sable argileux fossilifère ; ch = chenal ; Dh = horizon à décapodes.*

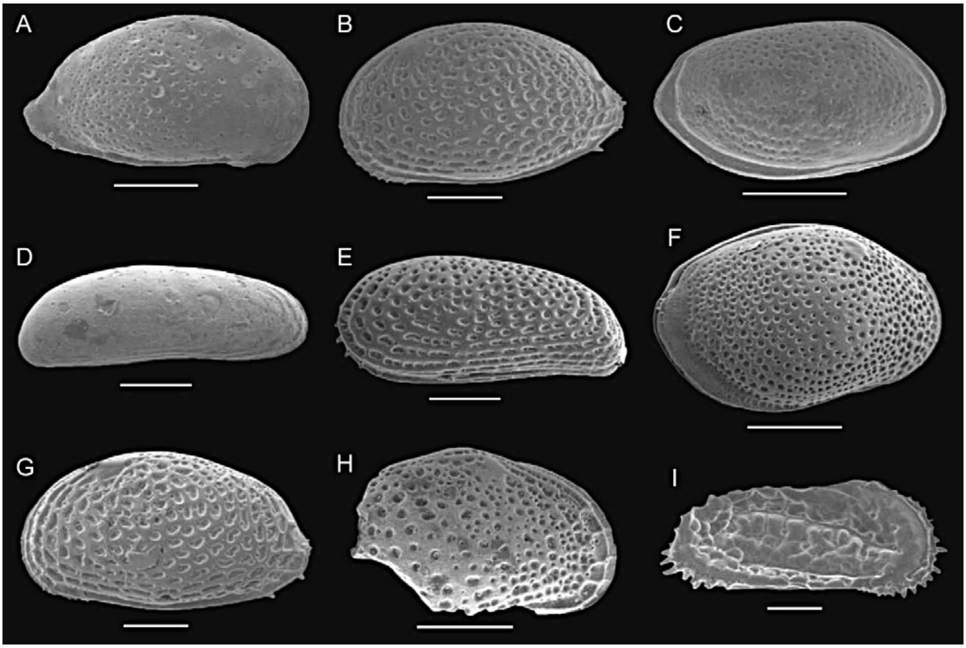

Fig. 6. Scanning electron microscope images of selected ostracods from “La Serra” quarry. **A.** *Aurila (Aurila) convexa* (Baird, 1850), RV, sample LS12. **B.** *Aurila (Aurila) punctata* (von Münster, 1830), LV, sample LS12. **C.** *Palmoconcha turbida* (Müller, 1894), RV, sample LS12. **D.** *Pontocythere turbida* (Müller, 1894), RV, sample LS12. **E.** *Cytheridea neapolitana* Kollmann, 1960, LV, sample LS12. **F.** *Loxoconcha ovulata* (Costa, 1853), RV, sample LS18. **G.** *Aurila cephalonica* Mostafawi and Matzke-Karasz, 2006, LV, sample LS18. **H.** *Tyrrhenocythere pontica* (Livental) in Agalarova, Kadyrova and Kulieva, 1961, RV, sample LS12. **I.** *Costa edwardsii* (Roemer, 1838), RV, sample LS18. RV = right valve; LV = left valve. All the specimens are in lateral external view. Scale bars: 200 µm.

Images au microscope électronique à balayage d'une sélection d'ostracodes de la carrière « La Serra ». ***A.*** Aurila *(*Aurila*)* convexa *(Baird, 1850), RV, prélèvement LS12.* ***B.*** Aurila *(*Aurila*)* punctata *(von Münster, 1830), LV, prélèvement LS12.* ***C.*** Palmoconcha turbida *(Müller, 1894), RV, prélèvement LS12.* ***D.*** Pontocythere turbida *(Müller, 1894), RV, prélèvement LS12.* ***E.*** Cytheridea neapolitana *Kollmann, 1960, LV, prélèvement LS12.* ***F.*** Loxoconcha ovulata *(Costa, 1853), RV, prélèvement LS18.* ***G.*** Aurila cephalonica *Mostafawi and Matzke-Karasz, 2006, LV, prélèvement LS18.* ***H.*** Tyrrhenocythere pontica *(Livental) in Agalarova, Kadyrova and Kulieva, 1961, RV, prélèvement LS12.* ***I.*** Costa edwardsii *(Roemer, 1838), RV, prélèvement LS18. RV : valve droite ; LV : valve gauche. Tous les spécimens sont en vue latérale externe. Barres d'échelle : 200 µm.*

(Bronn, 1831) is found with common juvenile specimens. It is tolerant of a wide range of salinity compared to other biogenic reef species and may penetrate quite far up estuaries (Santos and Mayoral, 2007). Rare *Scirpus isolepioides* May and Walther, 1988, *Nayas* sp., and *Poligonium* sp., typical riparian vegetation, which were probably waterway retransported, occur in this sample.

A gradual transition from continental brackish to marine brackish is evidenced (sample LS15b) by a gradual increase of *Ammonia tepida*, *A. beccarii*, *Quinqueloculina seminula* and *Elphidium crispum.* The presence of taxa typical of the “biocénose lagunaire euryhaline et eurytherme” (LEE biocenosis *sensu* Picard, 1965), living in brackish water lagoon such as *Cerastoderma edule* (Linnaeus, 1758), *Ostrea edulis*, *O. virleti* (Deshayes, 1832), *Neopycnodonte cochlear*, in assemblage with *Bittium reticulatum* (Da Costa, 1778), *Tellina nitida* (Poli, 1791), *Donax* sp. marks a marine water influx. The freshwater molluscs *Bithynia leachi*, *Prosothenia etrusca*, *P. meneghiniana*,? *Pisidium* sp., *Melanopsis (M.) affinis* de Férussac, 1820, are still present in the assemblage.

The restoration of the marine environment in sample LS15 is supported by the common presence of *Quinqueloculina seminula*, *Q. poeyana* d'Orbigny, 1839, *Q. carinatostriata* (Wiesner, 1923), *Triloculina bicarinata*, *Ammonia beccarii*, *Ammonia parkinsoniana* d'Orbigny, 1839, in assemblage with *Cribroelphidium decipiens* (Costa, 1856) and *Patellina corrugata* Williamson, 1858. Rare *Corbicula fluminalis* (Müller, 1774), *P. etrusca* and *Melanoides curvicosta* (Deshayes, 1832), still occur (probably as reworked specimens) in an assemblage dominated by *Bittium reticulatum*, *Cerastoderma edule*, *Tellina nitida*, *Ostrea edulis*, *Anadara diluvii* Lamarck, 1819, *Neopycnodonte cochlear*, *Natica* sp., *Donax* sp. The presence of *A. diluvii* and *Natica* sp. highlights to infralittoral marine conditions. Evidence of continental, subtropical riparian vegetation is furnished by the occurrence of megaspores attributed to *Selaginella pliocenica* Dorofeev, 1957 (Cavallo and Martinetto, 2001).

A new environmental modification is identifiable in the assemblage of sample LS16 characterized by a sharp decrease of benthic foraminifera (only few *A. tepida* and *C. decipiens* occur) and by the reappearance of brackish and freshwater ostracods as *Cyprideis torosa*, *Ilyocipris bradyi*, *Heterocypris salina.*

- Unit 4 (from 19.5 m to top of section, samples LS17–LS19)

Fossiliferous clayey sand. — The last metres of the section are characterized by marine fossil-rich, fine to medium clayey sands, lacking internal structures, except for the occurrence of thin shell-beds in the uppermost part (Fig. 5C–E). The percentage of fines (clay and silt) decreases upward, from about 70% at the base, to about 32–35% at the top. The fossil content is locally variable; at about the midpoint of the interval, the decapod horizon occurs.

Macro- and microfauna assemblages and related palaeoecology. — The basal portion of this last unit (sample LS17) contains abundant benthic foraminifera as *Quinqueloculina seminula*, indicative of a sea grass vegetated floor development under oxic conditions and presence of organic matter (Murray, 1991), and *Ammonia beccarii*, *A. tepida*, *A. parkinsoniana.* The muricid gastropods *Hexaplex trunculus* (Linnaeus, 1758), *Bolinus brandaris* (Lamarck, 1822) and *Murex* sp. dominate the assemblage whereas *Venus multilamella* and *Glans intermedia* are subordinate.

The miliolid foraminifera become abundant and diversified (*Quinqueloculina bosciana* d'Orbigny, 1839, *Q. poyeana*, *Q. carinatostriata*, *Spiroloculina angulata* Terquem, 1878, *Triloculina bicarinata*, *Pyrgo* sp.) in sample LS18, collected in the decapod-rich level; *Ammonia beccarii*, *A. tepida*, and *A. parkinsoniana* commonly occur associated with rare *Elphidium crispum* (deformed twin specimens), *E. complanatum* d'Orbigny, 1839, *Nonionella turgida* (Williamson, 1858), *Cancris auriculus* (Fitchell and Moll, 1798), *Patellina corrugata* Williamson, 1858, and *Lagena* sp. The marine ostracods (Fig. 6) *Aurila convexa*, *A. punctata*, *A. cephalonica* Mostafawi and Matzke-Karasz, 2006, *Costa edwardsii* (Roemer, 1838), *Henryhowella parthenopaea* Bonoduce, Barra and Aiello, 1999, *Cimbaurila cimbiformis* (Seguenza, 1883), and *Loxoconcha ovulata* (Costa, 1853) are present in the assemblage with a few reworked specimens of *C. angulata* and *C. torosa.* The presence of corbulid bivalves [*Corbula gibba* (Olivi, 1792)], a typical opportunistic taxon of the "peuplement hétérogène" (PE biocenosis *sensu* Picard, 1965) and of lunulithid bryozoans suggest an environment with instability. Common fish otoliths, vertebrae and scales are also present. The rich and diversified decapod assemblage is developed in a nutrient-rich sea-grass vegetated floor.

The microfossil assemblage of sample LS19 is comparable to the previous one, but the abundances increase significantly. The assemblage of marine ostracods (Fig. 6) is rich and represented by *Costa edwardsii*, *C. cimbiformis*, *Aurila punctata*, *A. cephalonica*, *Loxoconcha ovulata*, and *Cytheridea neapolitana*. The Lunulithid bryozoans are present also in this assemblage. A very rich malacofauna has been collected and is represented by muricids (*Hexaplex trunculus, Bolinus brandaris*), aporrhiids [*Aporrhais pespelacani* (Linnaeus, 1758)], calyptraeids [*Calyptrea chinensis* (Linnaeus, 1758)], conids (*Conus brocchii* Bronn, 1828, *Conus* sp.), nassariids [*Nassarius clatrathus* (Born, 1788), *Narona* sp.], turritellids (*Haustator* sp., *Turritella* sp.), naticids [*Neverita josephina* (Risso, 1826), *Natica tigrina* (Defrance, 1825), *Natica* sp.], venerids [*Sinodia brocchii* (Deshayes, 1836), *Sinodia gigas* Lamarck, 1818, *Venus multilamella* (Lamarck, 1818)], carditids [*Glans intermedia* (Brocchi, 1814), *Acanthocardia* sp.], cardiids [*Cardium* sp., *Laevicardium crassum* (Gmelin, 1791)], corbulids (*C. gibba*), nuculanids [*Nucula placentina* (Lamarck, 1819)] and fragments of pectinids and oysters. The malacological assemblage is characterized by typical infralittoral taxa with a lot of reworked shells. Indeed the tanathocenosis of this assembly is dominated by disarticulated, broken and bioeroded shells accumulated under low energy condition (Fig. 7).

2.2. Interpretations and palaeoenvironment

Both mixed sand and silt and cross-stratified sand facies from Unit 1 show evidences of alternate river current and wave deposition: thus, an estuary or deltaic environment can be postulated. Mixed sand and silt represent the mouth bars, whereas the cross-stratified sand beds are interpreted as prograding estuarine channel bars. Both facies are probably referable to a tide-dominated environment (Benvenuti and Dominici, 1992; Benvenuti et al., 2007). Nevertheless, structures such as flaser bedding are not documented in this section, and the tidal influx, still probable, can only be suspected. The estuarine conditions could also be supported by the occurrence of the ichnogenus *Psilonichnus*, associated with crabs preferring high-energy coastal environment (Nesbitt and Campbell, 2006). On the other hand, the massive clay facies documents a floodplain environment with marshes, ponds, and palaeosoils. The inferred floodplain with marshes and ponds intermingled with estuarine channels is confirmed by the presence of ostracods and bivalves.

The thick interval of Unit 2 documents a barrier island environment, where both the submarine longshore dunes and the subaerial eolian dunes are recognized. The accumulation of trunk fragments could testify to a flashflood river episode, and the consequent storm redestribution of deposits. The presence of patchy cementation, close to the woody remains, may be induced by $CaCO_3$ precipitation due to marine and freshwater mixing.

In Unit 3, continental and marine brackish conditions alternate, and a sheltered lagoon palaeoenvironment is inferred. By means of the confinement scale proposed by Guelorget and Perthuisot (1983, 1992) and Perthuisot and Guelorget (1992), the mollusc assemblages could be mainly related to the paralic zones II-III; unfortunately, collected data do not allow a more detailed characterization.

The sedimentary environment of Unit 4 is referable to a low energy, marine shallow water setting, attributable to a shallowing upward offshore transition to lower shoreface.

Based upon the sedimentological and palaeoecological characters, an articulated estuary palaeoenvironment, strongly influenced by tidal processes, is inferred. The “La Serra” section documents a transgressive trend, from a coastal plain environment to a barrier island (Figs. 4 and 8). In the lowermost section (Unit 1), the depositional architecture provides evidence of the occurrence of large estuary channels and sandy mouth bars, cutting floodplain clay deposits, with

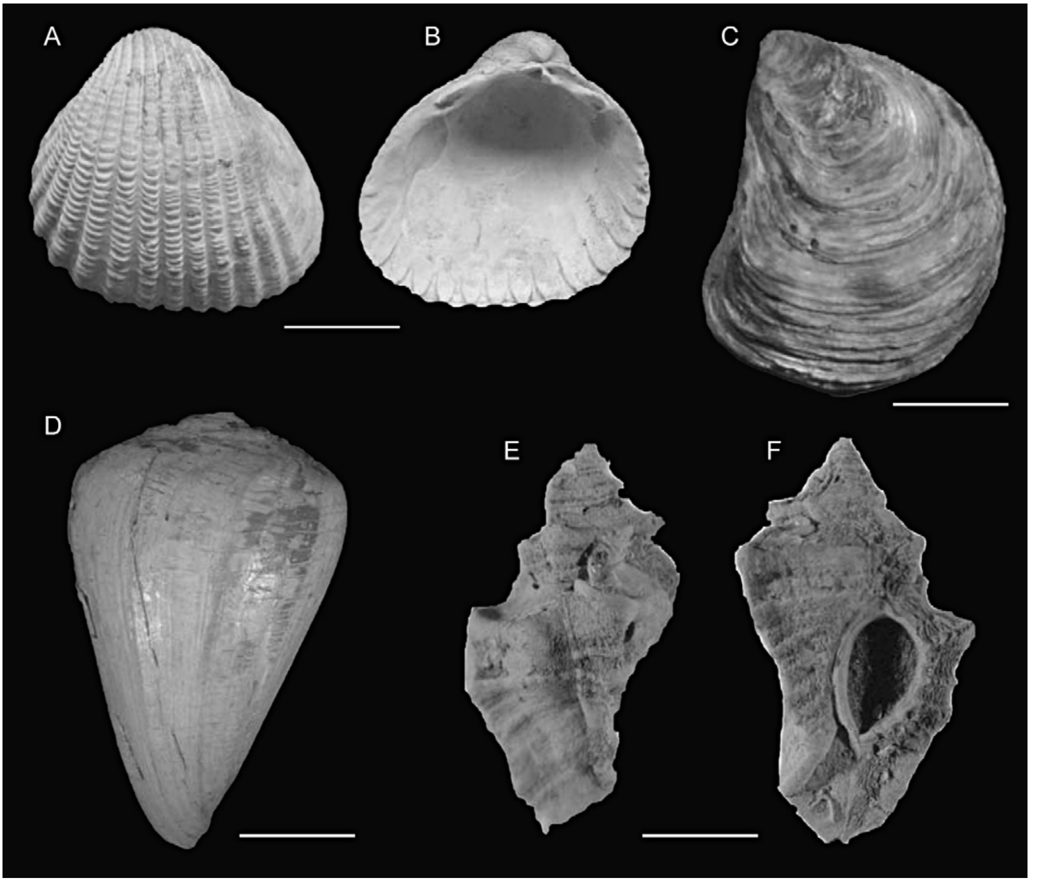

Fig. 7. Selected molluscs from the “La Serra” assemblages. **A–B**. *Cerastoderma edule* (Linnaeus, 1758). **C**. *Neopycnodonte cochlear* (Poli, 1795). **D**. *Conus betulinoides* Lamarck, 1810. **E–F**. *Ocenebra erinaceus* (Linnaeus, 1758). Scale bars: 1 cm.

*Sélection de mollusques parmi les assemblages de « La Serra ». **A–B**.* Cerastoderma edule *(Linnaeus, 1758). **C**.* Neopycnodonte cochlear *(Poli, 1795). **D**.* Conus betulinoides *Lamarck, 1810. **E–F**.* Ocenebra erinaceus *(Linnaeus, 1758). Barres d’échelle : 1 cm.*

temporary ponds and marsh, and palaeosoils. The middle section (Unit 2) documents a barrier beach environment grading from the subtidal longshore bars to the aeolian dunes, locally interrupted by tidal inlets (Fig. 8). A brackish protected lagoon, alternatively subject to continental or marine control, developed landward (Unit 3, uppermost section). Where fluvial input decreased, a lower shoreface to offshore transition environment took place (Unit 4), favourable to a large and diversified decapod community development.

2.3. Age of “La Serra” section

Units 1–3 are difficult to date because they lack high resolution markers. Several taxa have a large stratigraphic range, from Miocene onward, and are not indicative. Nevertheless following the literature (Benvenuti et al., 2007; A.A.V.V., 2006) and the geological context of the study

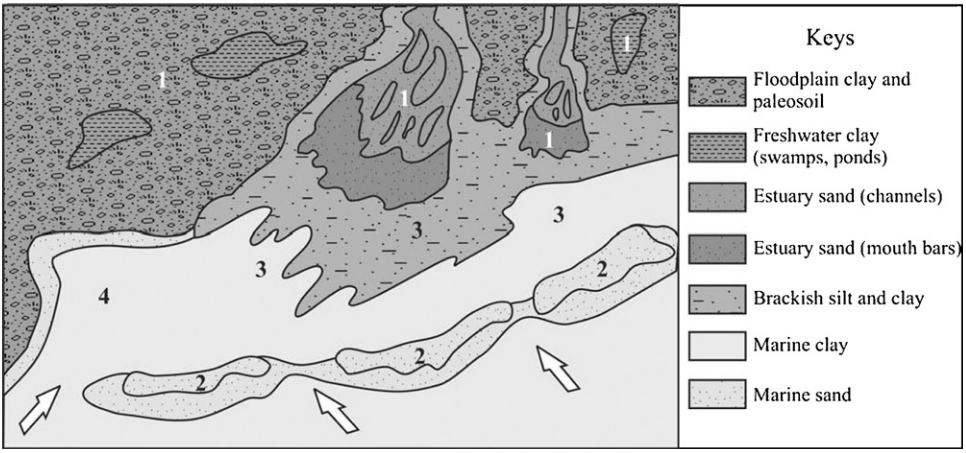

Fig. 8. Palaeoenvironmental sketch for "La Serra" quarry area (not to scale). Numbers refer to the Units 1 to 4 described in the text; arrows indicate water connections between estuary/restricted marine environment and the open sea.
Esquisse paléoenvironnementale du secteur de la carrière « La Serra » (sans échelle). Les chiffres correspondent aux inités 1 à 4 décrites dans le texte; les flèches indiquent les connections entre le milieu marin estuarien ou confiné et la mer ouverte.

area, a possible late Messinian to Zanclean *pro parte* age can be argued. The occurrence in sample LS12 of *Palmoconcha turbida* and *Pontocythere turbida* allows referring this part of the section to the early Pliocene, as these two ostracods are reported in the Mediterranean area from the Zanclean and Piacenzian respectively. The stratigraphic range of *Pontocythere turbida* is still debated (Guernet, 2005; Faranda and Gliozzi, 2008; Violanti et al., 2011).

Samples of Unit 4 allow a more detailed stratigraphic resolution, using calcareous nannoplankton and marine ostracods. The calcareous nannofossil assemblage, found in sample LS18 and characterized by the presence of *Coccolithus pelagicus* Wise, 1973, *Helicosphaera carteri* (Wallich, 1877) in Kamptner, 1954, *Helicosphaera intermedia* Martini, 1965, *Reticulofenestra minuta* Roth, 1970, *Reticulofenestra pseudoumbilicus* (Gartner, 1967) in Gartner, 1969 (medium sized specimens of 6 µm), *Reticulofenestra haqii* Backmann, 1978 (size 3.5 µm), *Calcidiscus macintyrei* (Bukry and Bramlette, 1969), is referable to the MNN 15 Nannofossil Zone (Rio et al., 1990). Thus, Unit 4 and the enclosed decapod horizon are referable to the uppermost Zanclean.

3. The decapod assemblage (A.G., G.P., A.D.A., S.C.)

3.1. Material and methods

The whole sample includes 175 decapod crustaceans, carefully selected among over 1500 specimens, and housed in the palaeontological collection of the Gruppo Paleontologico "C. De Giuli", Biblioteca Comunale Vallesiana, Castelfiorentino, Firenze (Italy), and in the palaeontological collection of the Museo di Storia Naturale di Milano, Milano (Italy). The studied specimens are three-dimensionally preserved within clayey sand sediment from the early Pliocene (Zanclean) of "La Serra" quarry, San Miniato (Pisa, Toscana, central Italy). The crustaceans are usually disarticulated and scattered in the sediments or more articulated when preserved in hardened small sub-nodular concretions or in true calcareous rounded nodules

Fig. 9. Subnodular concretion including diverse fossils. Scale bar: 2 cm.
Concrétion subnodulaire incluant des fossiles variés. Barre d'échelle : 2 cm.

(Fig. 9). They were carefully handled, prepared, and partially cleaned by mechanical engraver and micro-sandblaster, due to the hardness of the nodular concretions.

The infraorder Axiidea de Saint Laurent, 1979, includes *Axius* sp. (one specimen), *Callianassa chalmasii* Brocchi, 1883 (20 specimens) and *Calliaxina* cf. *C. punica* (de Saint Laurent and Manning, 1982) (one specimen). The infraorder Gebiidea de Saint-Laurent, 1979 includes *Gebiacantha tuscia* Garassino, Pasini, De Angeli and Charbonnier sp. nov. (36 specimens). The infraorder Anomura MacLeay, 1838, includes *Pagurus alatus* Fabricius, 1775 (two specimens), and *Pagurus* sp. (one specimen). The infraorder Brachyura Linnaeus, 1758, includes *Dromia neogenica* Müller, 1978 (one specimen), *Dromia* sp. (four specimens), *Medorippe* cf. *M. ampla* Garassino, De Angeli, Gallo and Pasini, 2004 (seven specimens), *Ilia nucleus* (Linnaeus, 1758) (eight specimens), *Ristoria pliocaenica* (Ristori, 1891) (39 specimens), *Pisa armata* (Latreille, 1803) (three specimens), *Macropodia* sp. (one specimen), *Maja squinado* (Herbst, 1788) (two specimens), *Derilambrus angulifrons* (Latreille, 1825) (five specimens), *Atelecyclus undecimdentatus* (Herbst, 1783) (nine specimens), *Liocarcinus* sp. (nine specimens), *Thalamita italica* Garassino, Pasini, De Angeli and Charbonnier sp. nov. (three specimens), *Pilumnus* cf. *P. hirtellus* (Linnaeus, 1761) (one specimen), *Eriphia cocchii* Ristori, 1886 (four specimens), *Goneplax rhomboides* (Linnaeus, 1758) (two specimens), and *Goneplax sacci* Crema, 1895 (one specimen). Moreover, two specimens have been assigned to callianassids *sensu lato*, 13 incomplete specimens have been ascribed to indeterminate axiideans.

For higher-level classification, we follow Ng et al. (2008), De Grave et al. (2009) and Schweitzer et al. (2010).

3.2. Institutional abbreviations

GPDG	Palaeontological collection from the Gruppo Paleontologico "C. De Giuli", Biblioteca Comunale Vallesiana, Castelfiorentino, Firenze;
IGF	Istituto di Geologia, Firenze;
MSNM	Museo di Storia Naturale di Milano, Milano.

3.3. Anatomical abbreviations

h	height of the palm;
ld	length of the dactylus;
li	length of the index;
lp	length of the palm (excluding index);
lt	length of the propodus (including index);
lcxp	length of carapace;
P1–P5	pereiopods 1 to 5;
s1–s6	pleonal somites 1 to 6;
wcxp	width of carapace.

4. Systematic palaeontology (A.G., G.P., A.D.A., S.C.)

Class MALACOSTRACA Latreille, 1802
Order DECAPODA Latreille, 1802
Infraorder AXIIDEA de Saint Laurent, 1979
Family Axiidae Huxley, 1879
Genus ***Axius*** Leach, 1815

Type species: *Axius stirhynchus* Leach, 1815, by monotypy.

Included fossil species: See Schweitzer et al. (2010).

Axius sp.

Fig. 10A B

Geological age: Early Pliocene (Zanclean).

Material and measurements: One incomplete chela (GPDG 0216: lp = 8 mm; h = 6 mm; lt = 13 mm; li = 5 mm).

Description: Left subrectangular flat palm. Elongate, pointed index, strongly directed upward distally; occlusal margin bearing a row of eight triangular teeth decreasing in size anteriorly; occlusal margin smooth distally. Short row of lateral spinules along the proximal part of the index and along the upper lateral articular margin. Some alternate hair pits present along the occlusal margin of the index and on the lower margin of the palm. Dactylus not preserved.

Discussion: The studied specimen shows some affinities with the chela of the extant *Axius stirhyncus* (Ngoc-Ho, pers. comm., 2011). *Axius stirhyncus* is widespread from the Eastern Atlantic coast to the Mediterranean Sea, from intertidal to about 34 m deep in burrows in coarse muddy sand bottom with the entrance often hidden under large rock (d'Udekem d'Acoz, 1999). *Axius* is reported for the first time from the Pliocene of Italy.

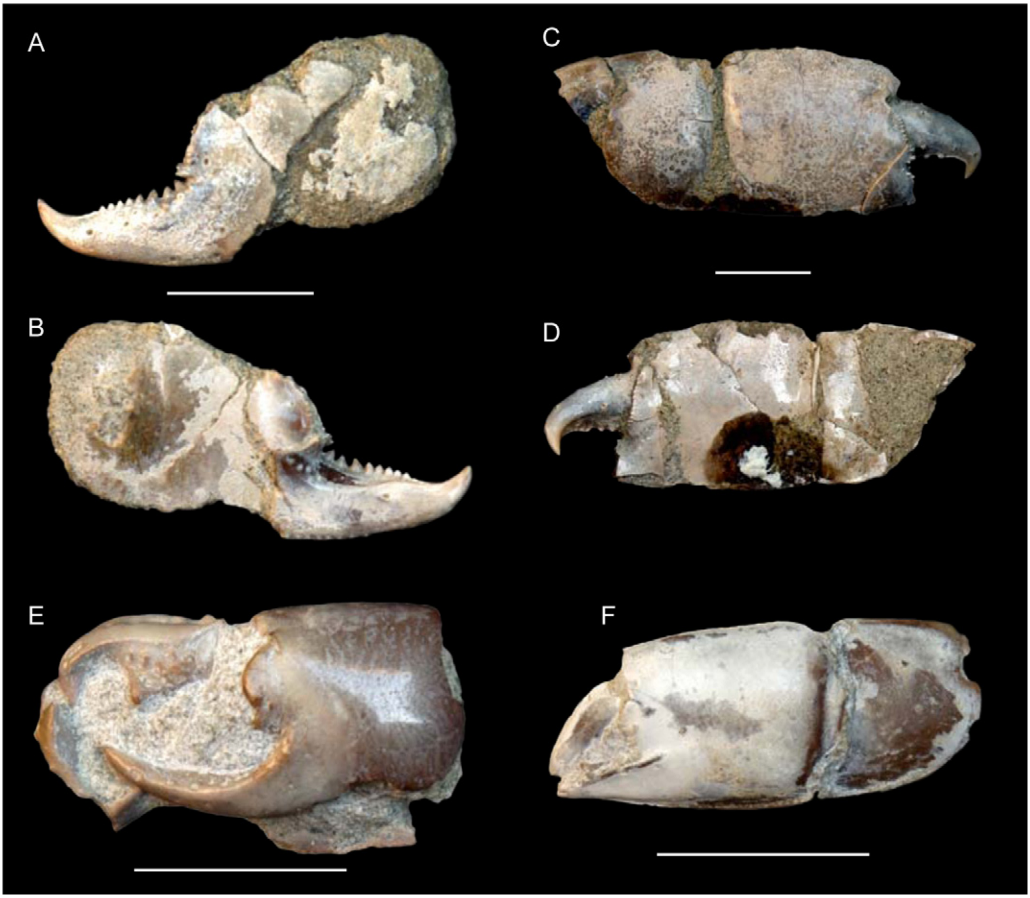

Fig. 10. Axiid crustaceans from “La Serra” quarry. **A–B**. *Axius* sp. (GPDG 0216), left chela in outer (A) and inner (B) views. **C–D**. Callianassidae *sensu lato* species 1 (GPDG 0217), right propodus in outer (C) and inner (D) views. **E**. Callianassidae *sensu lato* species 2 (GPDG 0218), left palm in outer view. **F**. *Calliaxina* cf. *C. punica* (de Saint Laurent and Manning, 1982) (GPDG 0215), left palm in outer view. Scale bars: 5 mm.

*Crustacés axiidés de la carrière « La Serra ». **A–B**.* Axius *sp. (GPDG 0216), pince gauche en vues externe (A) et interne (B). **C–D**. Callianassidae* sensu lato *species 1 (GPDG 0217), propodus droit en vues externe (C) et interne (D). **E**. Callianassidae* sensu lato *species 2 (GPDG 0218), paume gauche en vue externe. **F**.* Calliaxina *cf.* C. punica *(de Saint Laurent and Manning, 1982) (GPDG 0215), paume gauche en vue externe. Barres d’échelle : 5 mm.*

Family Callianassidae Dana, 1852

Subfamily Callianassinae Dana, 1852

Genus ***Callianassa*** Leach, 1814

Type species: *Cancer* (*Astacus*) *subterraneus* Montagu, 1808, by original designation.

Included fossil species: See Schweitzer et al. (2010).

Callianassa chalmasii Brocchi, 1883

Callianassa chalmasii Brocchi, 1883: 6, 7, pl. 5, figs. 7, 8.

Callianassa espichelensis Veiga Ferriera, 1961: 478, pl. 1, figs. 1–11.

Callianassa chalmasii–Lőrenthey, 1898: 93, 105, 114. — Lőrenthey and Beurlen, 1929: 33, 65, pl. 2, fig. 15a, b. — Müller, 1979: 274, pl. 1, fig. 5. — Müller, 1984: 50, pl. 2, figs. 3–7. — De Angeli et al., 2009: 168, fig. 2c, d. — Schweitzer et al., 2010: 34.

Geological age: Early Pliocene (Zanclean).

Material and measurements:20 specimens including five almost complete chelipeds (GPDG 0144), one incomplete specimen with left and right propodi (GPDG 0145), nine left propodi (GPDG 0146a–i) and five right propodi (GPDG 0147l–p). — GPDG 0146a: lp = 10 mm; h = 9 mm; lt = 14 mm; li = 4 mm. — GPDG 0146b: lp = 6 mm; h = 6 mm; lt = 9 mm; li = 3 mm. — GPDG 0147l: lp = 11 mm; h = 9 mm; lt = 13 mm; li = 2 mm. — GPDG 0147 m: lp = 7 mm; h = 6 mm; lt = 9 mm; li = 2 mm.

Description: Short carpus, raised on outer surface and with lower margin strongly convex. Subsquare palm, as long as high. Upper margin slightly convex, straight lower margin, ridged externally. Convex, smooth outer surface. Small granulations are located in the median part of palm, close to the index. Inner surface almost flat. Nine oval pits present in the upper part, some orifices present in the lower part, along the margin. Index poorly developed with one tooth on occlusal margin.

Discussion: The studied propodi show morphological affinities with *Callianassa chalmasii* Brocchi, 1883, described from the Miocene (middle Badenian) of Hungary and recorded also from the Miocene (Tortonian) of Portugal (Veiga Ferriera, 1961; Müller, 1984). Peculiar characters are the presence of one short index with one tooth on the occlusal margin and aligned pits located on the upper part of the inner surface of the palm. De Angeli et al. (2009) have already reported this species from the early Pliocene (Piacentian) of Terre Rosse (Siena, Italy). The extant Mediterranean species of *Callianassa* are active burrowers in muddy sands at two to three meters in depth (Ngoc-Ho, 2003), or in sub-littoral fine or coarse sandy bottoms where they are locally abundant. Chelipeds of *C. chalmasii* are very abundant in “La Serra” quarry.

Callianassidae *sensu lato* **species 1**

Fig. 10 C D

Geological age: Early Pliocene (Zanclean).

Material and measurements: One incomplete chela (GPDG 0217: lp = 10 mm; h = 8 mm; ld = 6 mm).

Description: Right propodus compressed with slightly concave dorsal margins. Subrectangular carpus, higher than long, with strongly convex lower posterolateral margin. Subrectangular propodus, higher than long, with straight lower posterior margin, lanceolate in transverse section. Palm nearly as long as high, bearing a row of small spinules directed anteriorly along the upper articular margin with the dactylus and on the proximal margin of the index. Strong, short, uncinate dactylus with pointed tip, strongly directed downward; denticulate occlusal margin. Some hair pits along the occlusal margin and on the proximal dorsal part of the dactylus.

Discussion: The chela shows some morphological affinities with the Callinassidae *sensu lato*. Callianassids are actually subdivised into several genera, but for a specific assignment other important characters of the chelipeds are needed. Moreover not all the authors agree with the new arrangement (Ngoc-Ho pers. comm., 2011); so, due their incompleteness, we propose only a family systematic assignment for the studied specimen.

Callianassidae *sensu lato* **species 2**

Fig. 10E

Geological age: Early Pliocene (Zanclean).

Material and measurements: One incomplete chela (GPDG 0218: lp = 4 mm; h = 4 mm; lt = 9 mm; li = 5 mm; ld = 4 mm).

Description: Left palm with smooth, moderately convex lateral margins; sinuous, smooth articular anterior margin. Strong dactylus weakly uncinate and pointed distally, bearing a single proximal squared occlusal tooth. Slender, elongate index, pointed distally, with edentate occlusal margin. Deep lined pits along the occlusal margins of both the fingers.

Discussion: This chela shows some morphological affinities with the Callinassidae *sensu lato*. Moreover, based upon the characters described, it can confidently be assigned to a different indeterminate form than "species 1". So, for the same reasons previously reported and due to their incompleteness, we propose only a family systematic assignment for the studied specimen.

Subfamily Eucalliacinae Manning and Felder, 1991

Genus ***Calliaxina*** Ngoc-Ho, 2003

Type species: *Calliax punica* de Saint Laurent and Manning, 1982, by original designation.

Included fossil species: *Calliaxina* cf. *C. Punica* (this work).

Calliaxina cf. ***C. punica*** (de Saint Laurent and Manning, 1982)

Fig. 10F

Geological age: Early Pliocene (Zanclean).

Material and measurements: One isolated right P1 (GPDG 0215: lp = 7 mm; h = 7 mm; lt = 11 mm; li = 4 mm; ld = 5 mm).

Description: Carpus slightly higher than long, probably lanceolate in transverse section; dorsal margin nearly convex; strongly convex lower proximal margin. Carpus-propodus articulation inclined. Propodus with subrectangular palm, longer than high; smooth outer surface with ridged lower margin. Short, triangular index, with one ridge on outer margin; straight occlusal margin with one median small tooth; some hair pits along the occlusal margin. Strong dactylus, gently curved downward; spooned distally, bearing a single, directed forward, lateral tooth near the tip.

Discussion: The studied specimen shows morphological characters with the extant representatives of *Calliaxina punica* (de Saint Laurent and Manning, 1982), particularly for the presence of one small median tooth on the occlusal margin of the index and one ridge on the outer margin of the index. However the specimen, laking the main characters of the body, does not allow a specific assignment. The extant *C. punica* lives in the Mediterranean Sea, between 0.25 m and 1 m deep in sand or muddly sand bottoms with or without seagrass and between 2 m and 21 m deep in mud or silty-mud bottoms (de Saint Laurent and Manning, 1982; Ngoc-Ho, 2003).

Indeterminate axiideans

Material: 13 small incomplete specimens (GPDG 0178) including one incomplete chela, one right merus, and eleven loose, poorly preserved fingers.

Discussion: All the studied specimens belong to as many as three different indeterminate species that show close morphological affinities with the representatives of *Callianassa* Leach, 1814. Unfortunately, the incompleteness of the specimens does not allow any specific assignment.

Infraorder GEBIIDEA de Saint Laurent, 1979

Family Upogebiidae Borradaille, 1903

Genus ***Gebiacantha*** Ngoc-Ho, 1989

Type species: *Upogebia talismani* Bouvier, 1915, by original designation.

Included fossil species: *Gebiacantha tuscia* sp. nov. (this work).

Gebiacantha tuscia Garassino, Pasini, De Angeli and Charbonnier sp. nov.

Fig. 11

Etymology: The trivial name alludes to Tuscia, ancient italic name of Toscana, where the species has been discovered.

Type material: Holotype GPDG 0179; paratypes GPDG 0185, 0186, 0187, 0188, 0189.

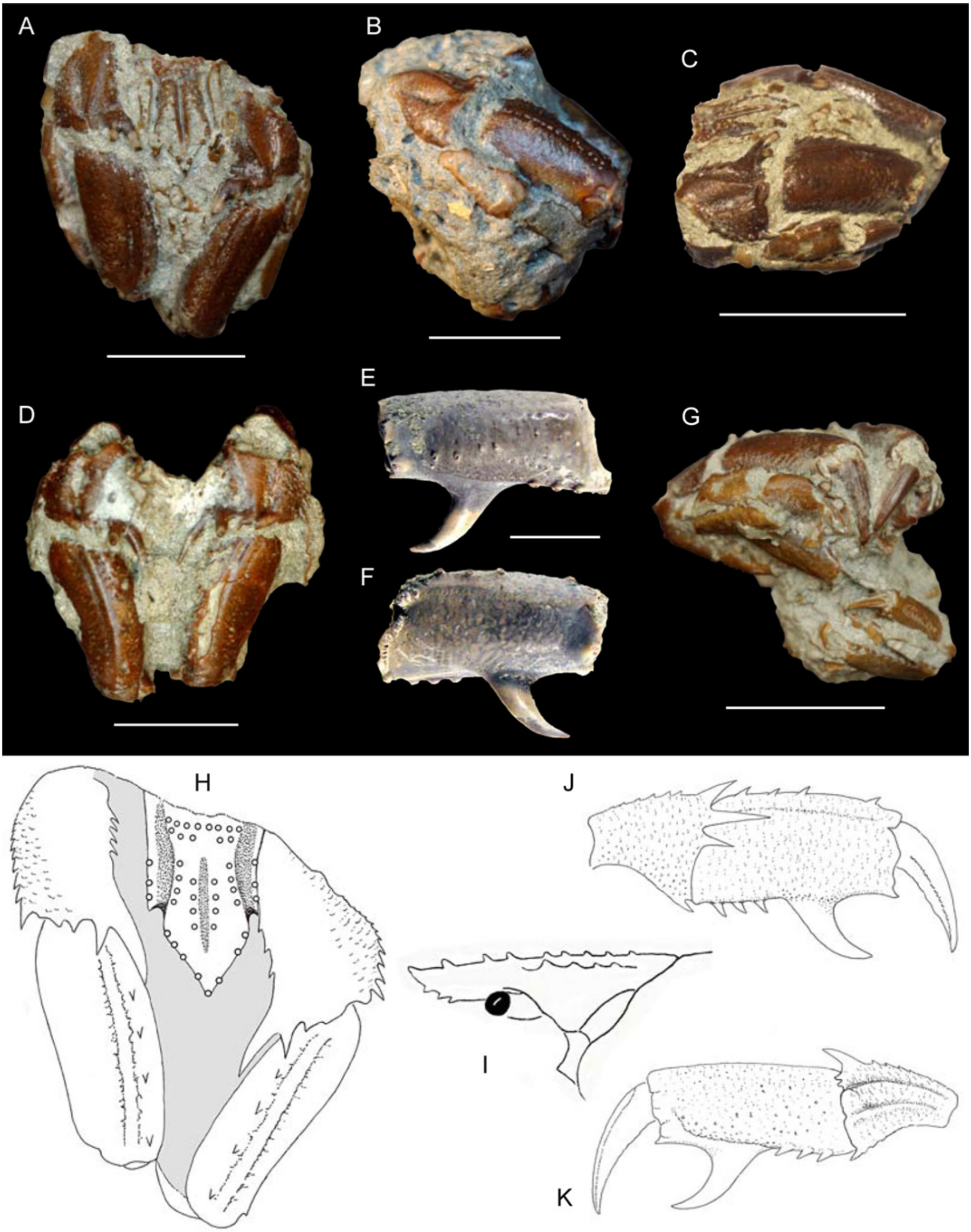

Fig. 11. *Gebiacantha tuscia* Garassino, Pasini, De Angeli and Charbonnier sp. nov. **A**. Holotype GPDG 0179, detail of rostrum and P1. **B**. Specimen GPDG 0219, detail of infrarostral spines. **C**. Holotype GPDG 0179, detail of P1 carpus. **D**. Specimen MSNM i27651, detail of the strong spines of P1 carpus. **E–F.** Paratype GPDG 0189, detail of the strong spine in the lower margin of P1 propodus. **G.** Holotype GPDG 0179, P1-P3 pereiopods. **H–K**. Partial reconstruction based on some morphological characters of the cephalothorax and pereiopods. Line drawings: A.D.A. Scale bars: 5 mm.

Type locality: “La Serra” quarry, San Miniato (Pisa, Toscana, central Italy).

Geological age: Early Pliocene (Zanclean).

Examined material: Thirty-six specimens three-dimensionally preserved in small irregular nodular concretions including eight incomplete carapaces with articulate pereiopods (GPDG 0179, GPDG 0180a–f, GPDG 0185, GPDG 0186, GPDG 0187, GPDG 0188, MSNM i27648, i27650); seven associated left and right P1 (GPDG 0181a-f; MSNM i27651); two articulated P1 (GPDG 0182a,b); 10 loose right and left disarticulate propodi (GPDG 0189, GPDG 0183a–i); five articulate P2 (GPDG 0184a–e); one with articulated P1-P3 (MSNM i27649); two with infrarostral spines (GPDG 0219, MSNM i27647); one with isolated pleonal somite (GPDG 0220).

Diagnosis: Elongate front; short, pointed lanceolate rostrum, wider than long, with 6 to 7 small spines directed forward on lateral margins and at least three very small infrarostral spines; rostrum with deep smooth median groove and slightly curved downward; P1 subchelate; propodus, ovoid in cross section, equal in size and shape, moderately elongate with spines on upper and lower margins and elongate groove running parallel to upper margin; P1 propodus with a single elongate curved lower pointed spine, directed forward; wide, subtriangular P1 carpus; distal margin of P1 carpus with one well-developed inner bifurcate spine and two median spines smaller than the first one; upper and lower margins of carpus with spines increasing in size distally; elongate dactylus, with one strong lower spine proximally; index very reduced.

Description:

Cephalothorax.— only the frontal preserved; short, pointed lanceolate rostrum, wider than long, depressed medially, slightly curved downward at the tip; rostrum with a row of 6 to 7 small spines directed forward on lateral margins and at least three very small infrarostral spines; rostrum with a deep, smooth median groove.

Pleon.— not preserved; only a single disarticulate subrectangular somite has been recognized as probably belonging to this species (GPDG 0220).

Thoracic appendages.— stout P1 equal in size and shape; P1 propodus ovoid in cross section, with smooth inner margin with sparse tubercles and outer margin with small pits uniformly arranged and an elongate deep groove extending parallel to the upper margin; upper margin of P1 propodus with a row of 7/8 strong spines equal in size and protruded forward; lower margin of P1 propodus with one elongate, strong spine curved forward; subtriangular, stout P1 carpus; distal margin of P1 carpus with one inner bifurcate spine and two median spines smaller than the first one; bifurcate spine of P1 carpus with the first spine elongate and narrow, directed forward, the second one shorter and stronger, directed slightly upward; upper and lower margins of P1 carpus with a row of spines, increasing in size forward; outer margin of P1 carpus with two lateral, parallel rows of spines, increasing in size forward; elongate P1 dactylus slightly curved downward distally, with one lower strong spine located proximally; P1 index strongly reduced; slender P2, incomplete distally; upper margin of P2 merus with a row of strong spines increasing in size distally and directed upward; slender, triangular P2 carpus; P2 propodus, ovoid in cross section, with an elongate groove parallel to the upper margin; P3 smaller and shorter than P2.

Gebiacantha tuscia *Garassino, Pasini, De Angeli and Charbonnier sp. nov.* ***A.*** *Holotype GPDG 0179, détail du rostre et de P1.* ***B.*** *Spécimen GPDG 0219, détail des épines infrarostrales.* ***C.*** *Holotype GPDG 0179, détail du carpus de P1.* ***D.*** *Spécimen MSNM i27651, détail des grosses épines du carpus de P1.* ***E–F.*** *Paratype GPDG 0189, détail de la grosse épine sur la marge inférieure du propodus de P1.* ***G.*** *Holotype GPDG 0179, péréiopodes P1-P3.* ***H–K.*** *Reconstitution partielle basée sur certains caractères morphologiques du céphalothorax et des péréiopodes. Dessins au trait: A.D.A. Barres d'échelle : 5 mm.*

Ornamentation.— surface of all articles of pereiopods with weak imbricate striae.

Discussion: The above-mentioned morphological characters allow assigning the studied specimens to Upogebiidae Borradaille, 1903. Only two species are known to date from the Pliocene. Ristori (1891b) reported *Upogebia* cf. *U. stellata* (Montagu, 1808), from the Farnesina, Roma (Lazio, central Italy), while Gemmellaro (1914) reported some specimens of the same species from Ficarazzi (Palermo, Sicilia, southern Italy). Feldmann et al. (2008) reported *U. kowai* Feldmann, Schweitzer, Maxwell and Kelley, 2008, from New Zealand. This species differs notably from the studied specimens, above all in the shape and in the form of the spinate propodus. Moreover, the other fossil species of *Upogebia* from the Cenozoic do not show characters closely related to the studied specimens. Instead, among the extant Mediterranean upobebiids, the studied specimens show some morphological characters, such as the short lanceolate rostrum, with infrarostral spines, the rows of spines on propodus, carpus, and merus of pereiopods, the P1 propodus with one strong median ventral spine, more closely related to *Gebiacantha* Ngoc-Ho, 1989, than to *Upogebia*, Leach, 1814 (Ngoc-Ho, 1989). Further Ngoc-Ho (2001), based upon the recently collected specimens, proposed the rediagnosis of the most important distinctive characters of the genus, as follows: "*...presence of infraorbital spines, rostrum approximately ovoid bordered by teeth or spines, pereiopod 1 subcheliform, carpus and propodus with numerous spines lower border of pereiopod 1 propodus with two long spines (often one large and one small) posterior to the fixed finger...*". We do not report the other characters not useful in this discussion because they are not preserved in the studied specimens. Moreover, Ngoc-Ho (2001), reported also *Austinogebia* Ngoc-Ho, 2001, closely related to *Gebiacantha*, but differing in lacking the strong, elongate ventral spines of P1 propodus, character present in the studied specimens. *Gebiacantha* includes eleven extant small sized species (Ngoc-Ho, 1989): the largest is *G. plantae* (Sakai, 1982), from Madagascar measuring 39 mm in total length; seven are from Indonesia and southwestern Pacific area; three from the Indian Ocean; the type species *G. talismani* (Bouvier, 1915), from northern Atlantic and northern Mediterranean Sea (for complete list see Ngoc-Ho, 1989). *Gebiacantha tuscia* sp. nov. differs distinctly from all the Indo-Pacific species in the shape of the lanceolate pointed rostrum, with deep median groove, and in the ornamentation and arrangement of spines of P1 carpus and P1 propodus. The new species differs particularly from the group including *G. lagonensis* Ngoc-Ho, 1989, *G. richeri* Ngoc-Ho, 1989, and *G. laurentae* Ngoc-Ho, 1989, all lacking the strong elongate spines on the ventral margin of the propodus. Moreover, the new species also differs from the only extant Mediterranean species *G. talismani*, further rediscussed by Ngoc-Ho (2001), in having at least three short smaller infrarostral spines, triangular rostrum shorter and wide, with deep elongate frontal median groove; elongate outer dorsal groove extending parallel to the margin of P1 propodus; a single elongate ventral spine directed forward posterior to the index; and a different shape of the upper bifurcate distal spine on the coarse, tuberculate, short, and wide carpus with a longitudinal smooth groove crossing at the midheight of the outer side. Finally the studied specimens are notably larger than *G. talismani* and generally larger than any other living species (see measurements in Ngoc-Ho, 1989, 2003), excluding *G. plantae*, as extrapolated from the length of the P1 propodus (between 8 and 12 mm). *Gebiacantha tuscia* sp. nov. is the most common thalassinid present in the studied assemblage with specimens of different size or growth stage (or sexual dimorphism?). Unfortunately they are mainly loose and poorly preserved in hardened irregular concretions, often including two or more incomplete specimens, excluding pleons, representing about 50% of the total decapod faunal assemblage. The similar and related species, *G. talismani*, occurs in the Mediterranean Sea among rocks, shells, or muddy sand bottoms between 20 m and 150 m deep (Ngoc-Ho, 2003).

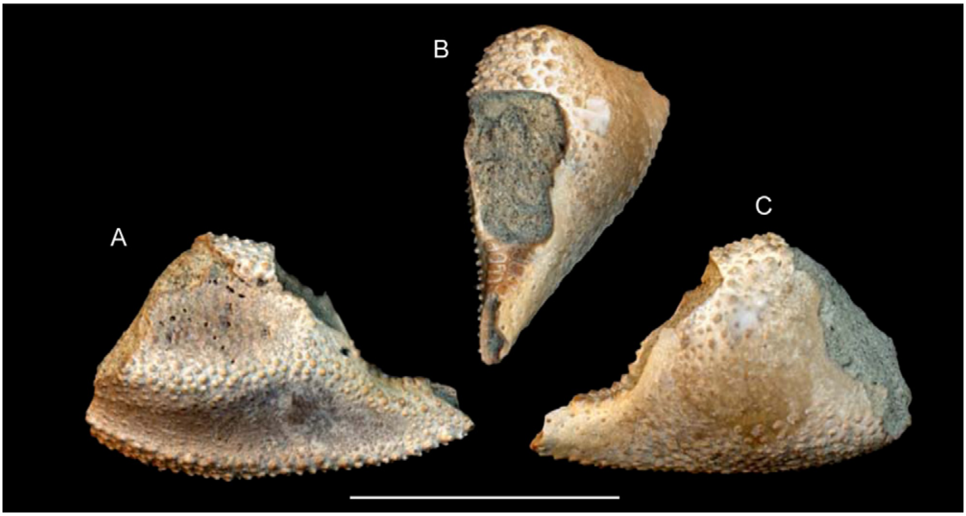

Fig. 12. *Pagurus alatus* Fabricius, 1775 (GPDG 0176a), right chela in outer (**A**), occlusal (**B**), and inner (**C**) views. Scale bar: 10 mm.
Pagurus alatus *Fabricius, 1775 (GPDG 0176a), pince droite en vues externe (**A**), occlusale (**B**), et interne (**C**). Barre d'échelle: 10 mm.*

Infraorder ANOMURA MacLeay, 1838

Superfamily Paguroidea Latreille, 1802

Family Paguridae Latreille, 1802

Genus ***Pagurus*** Fabricius, 1775

Type species: *Cancer bernhardus* Linnaeus, 1758, subsequent designation by Latreille (1810).

Included fossil species: See Schweitzer et al. (2010).

Pagurus alatus Fabricius, 1775

Fig. 12

Pagurus alatus Fabricius, 1775: 411.

Pagurus alatus–Zariquiey Álvarez, 1968: 247, figs. 89–91. — Ingle, 1985: 762, figs. 3, 9, 13, 19, 47, 58, 64. — Falciai and Minervini, 1992: 163. — Ingle, 1993: 136, figs. 109–112. — Ingle and Christiansen, 2004: 212–216, figs. 185, 186, 200.

Pagurus variabilis–A. Milne Edwards and Bouvier, 1892: 217. — Zariquiey Álvarez, 1968: 248, figs. 89 g, 90c.

Eupagurus variabilis–Selbie, 1921: 36, pl. 4, figs. 4, 5, pl. 5, figs. 1–3. — Bouvier, 1940: 134, fig. 91. — Allen, 1967: 61, 93. — Christiansen, 1972: 48, fig. 60. — Moyse and Smaldon, 1990: 525, figs. 10, 15.

Eupagurus tricarinatus–Sars, 1885: 11, pl. 1, figs. 8–10.

Eupagurus excavatus–Pocock, 1889: 428.

Geological age: Early Pliocene (Zanclean).

Material and measurements: Two nearly complete right chelae, lacking the dactyli. — GPDG 0176a: lp = 8.5 mm; h = 8.5 mm. — GPDG 0176b: lp = 6 mm; h = 5.5 mm.

Description: Subsquare palm, longer than wide, with short, granulate upper margin and lower margin curved with spiny tubercles; convex, slightly granulate inner surface; median outer surface of palm with a longitudinal, raised, granulate ridge; one depression almost smooth located under the median ridge, extending also onto index; moderately long, curved index, with granulate outer surface and posterior occlusal margin with five pairs of flat combined teeth; distal part of index incomplete; dactylus slightly curved.

Discussion: The above mentioned characters allow assignment of the studied specimens to *Pagurus alatus* Fabricius, 1775, widespread in the Mediterranean Sea, but also present along the Atlantic coast to the Great Britain and western Norway where it lives in sandy, muddy settings and more rarely rocky environments between 104 m to 2500 m deep (Falciai and Minervini, 1992; Ingle and Christiansen, 2004). *Pagurus alatus* is reported for the first time in the fossil record.

Pagurus sp.

Geological age: Early Pliocene (Zanclean).

Material and measurements: One fragmentary right index poorly preserved (GPDG 0177: li = 10 mm).

Discussion: One single incomplete specimen showing some morphological affinity with *Pagurus*. It consists of a distal right index, slightly curved toward the inner side, covered by coarse tubercles and by small spines directed forward on the outer side and along the lower margin. Occlusal margin bearing two rows of molariform teeth, joining toward the distal tip, where the teeth become smaller and aligned on a single row. A row of alternate hair (setae) pits extends along the occlusal margin.

Infraorder BRACHYURA Linnaeus, 1758
Section PODOTREMATA Guinot, 1977
Superfamily Dromioidea De Haan, 1833
Family Dromiidae De Haan, 1833
Subfamily Dromiinae De Haan, 1833
Genus ***Dromia*** Weber, 1795

Type species: *Cancer personatus* Linnaeus, 1758, subsequent designation by I.C.Z.N. (1964: Opinion 688).

Included fossil species: See Schweitzer et al. (2010).

Dromia neogenica Müller, 1978

Fig. 13A

Dromia neogenica Müller, 1978: 274, 278, pl. 8, fig. 1.

Dromia neogenica–Müller, 1984: 63, pl. 29, figs. 1–6. — Fraaije et al., 2007: tab. 1. — van Bakel et al., 2009: 56. — Schweitzer et al., 2010: 64. — Gatt and De Angeli, 2010: 1328, pl. 2, fig. 10. — Fraaije et al., 2011: 234, figs. 2–3.

Geological age: Early Pliocene (Zanclean).

Material and measurements: One complete carapace (GPDG 0159: lcxp = 14 mm; wcxp = 16 mm).

Discussion: The three-dimensionally preserved specimen permitted the identification of *Dromia neogenica* based upon the following morphological characters: globular carapace strongly convex in both directions; smooth dorsal surface; front with three short spines, the median one located in a lower level and directed downward, the lateral ones directed upward; well-developed suborbital spine; weak supraorbital spine; well-developed extraorbital spine located on an upper level than the anterolateral spines; four anterolateral spines, decreasing posteriorly; weak cervical

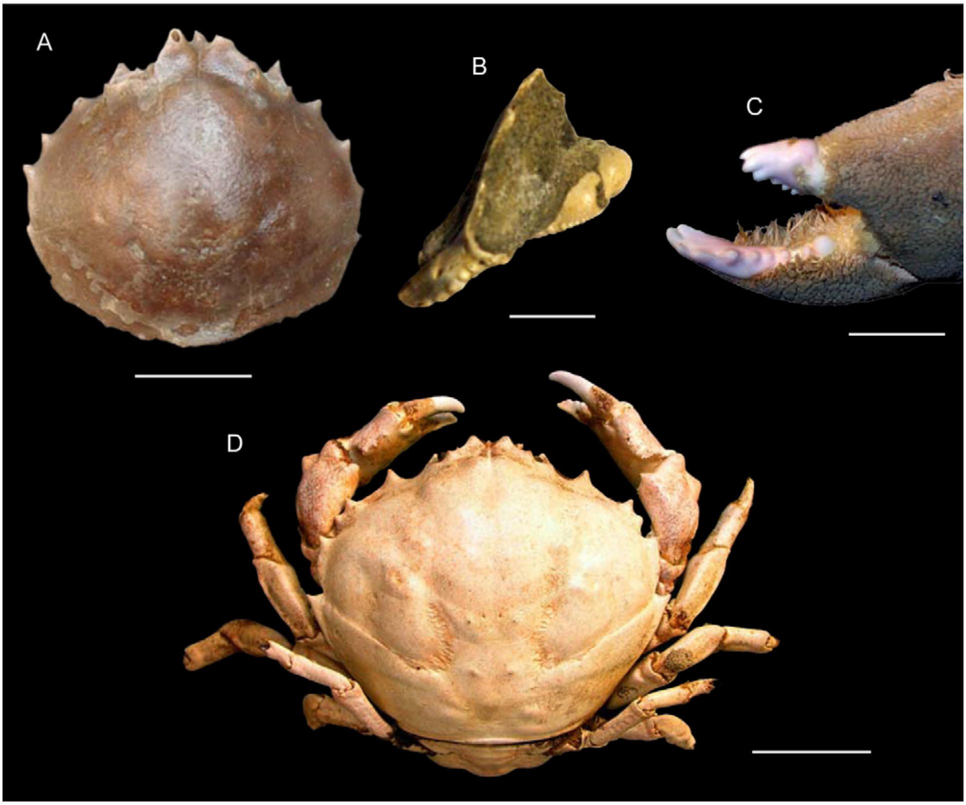

Fig. 13. Dromiids from "La Serra" quarry. **A**. *Dromia neogenica* Müller, 1978 (GPDG 0159), carapace in dorsal view. **B**. *Dromia* sp. (GPDG 0191), detail of the occlusal margin. **C–D**. *Dromia personata* (Linnaeus, 1759), extant specimen (MSNM 2427), detail of the chela (C) and general view (D), Mediterranean Sea. Scale bars: 5 mm except D: 2 cm.
*Dromiidés de la carrière «La Serra». **A**.* Dromia neogenica *Müller, 1978 (GPDG 0159), carapace en vue dorsale. **B**.* Dromia *sp. (GPDG 0191), détail de la marge occlusale. **C–D**.* Dromia personata *(Linnaeus, 1759), spécimen actuel (MSNM 2427), détail de la pince (C) et vue générale (D), Mer Méditerranée. Barres d'échelle: 5 mm excepté D : 2 cm.*

groove. This species is known from the Badenian to the Messinian (middle-late Miocene) of Hungary (Müller, 1978, 1984) and Malta (Gatt and De Angeli, 2010), and the Neogene (late Miocene-early Pliocene) of The Netherlands (Fraaije et al., 2011). Moreover, Varola (1981) reported *Dromia personata* (Linnaeus, 1758) from the middle Pliocene of Leuca (Lecce, Puglie, southern Italy), representing the only record for the species from the Italian Pliocene. The extant *Dromia* lives, in the Mediterranean Sea, on rocky or stony infralittoral substrates, ranging from the lower shore to 90 m deep.

Dromia sp.
Fig. 13B
Geological age: Early Pliocene (Zanclean).
Material and measurements: Four loose fragmentary distal fingers (GPDG 0190, 0191: from 4 to 10 mm long).

Discussion: Although incomplete, these specimens are assigned to *Dromia* based upon the spoon shaped form of the distal occlusal side, bordered by alternating teeth directed upward, and on the presence of two deep setal pits along the outer margin of the fingers, similar to those of the extant *D. personata* (Fig. 13 C, D), widespread in Mediterranean Sea.

Section EUBRACHYURA de Saint Laurent, 1980
Superfamily Dorippoidea MacLeay, 1838
Family Dorippidae MacLeay, 1838
Genus ***Medorippe*** Manning and Holthuis, 1981

Type species: *Cancer lanatus* Linnaeus, 1767, by monotypy.

Included fossil species: See Schweitzer et al. (2010).

Medorippe cf. ***M. ampla*** Garassino, De Angeli, Gallo and Pasini, 2004

Medorippe ampla Garassino, De Angeli, Gallo and Pasini 2004: 260, figs. 5, 6 a, b.

Medorippe ampla–De Angeli and Garassino, 2006: 40. — De Angeli et al., 2009: 174, fig. 6. — Schweitzer et al., 2010: 79.

Geological age: Early Pliocene (Zanclean).

Material: Seven specimens including five incomplete carapaces (GPDG 0166) and two nearly complete carapaces (GPDG 0212, 0172).

Discussion: *Medorippe ampla* was described based upon two specimens from the Messinian (late Miocene) of Cocconato (Asti, Piemonte, northern Italy) (Garassino et al., 2004) and reported also by De Angeli et al. (2009) from the Messinian (late Miocene) of Rio Popogna (Livorno, Toscana, central Italy). Although the studied specimens are incomplete, they show some morphological characters of this species, as follows: subhexagonal carapace, weakly convex, wider than long; divergent anterolateral margins with an epibranchial spine; elongate postero-lateral margins; well-marked regions with granulations; deep cervical and cardiac grooves; narrow cardiac region with Y-shaped granulate ridge anteriorly; hepatic and branchial regions with granulate ridges. The extant *Medorippe lanata* (Linnaeus, 1767) lives in the Mediterranean Sea, especially in infralittoral sandy-muddy bottoms, but also occurs in intertidal coral reefs and oyster banks. The genus is uncommon at "La Serra" quarry, documented only by scarce, fragmentary, poorly preserved carapace remains. This is the first record of the genus from the Pliocene of Italy.

Superfamily Leucosioidea Samouelle, 1819
Family Leucosiidae Samouelle, 1819
Subfamily Ebaliinae Stimpson, 1871
Genus ***Ilia*** Leach, 1817

Type species: *Cancer nucleus* Linnaeus, 1758, by monotypy.

Included fossil species: See Schweitzer et al. (2010).

Ilia nucleus (Linnaeus, 1758)
Fig. 14

Cancer nucleus Linnaeus, 1758: 627.

Ilia levigata Risso, 1827: 20.

Ilia rugulosa Risso, 1827: 20.

Cancer nucleus–Herbst 1783: 87, pl. 11, fig. 14.

Ilia rugulosa–Carus, 1885: 501.

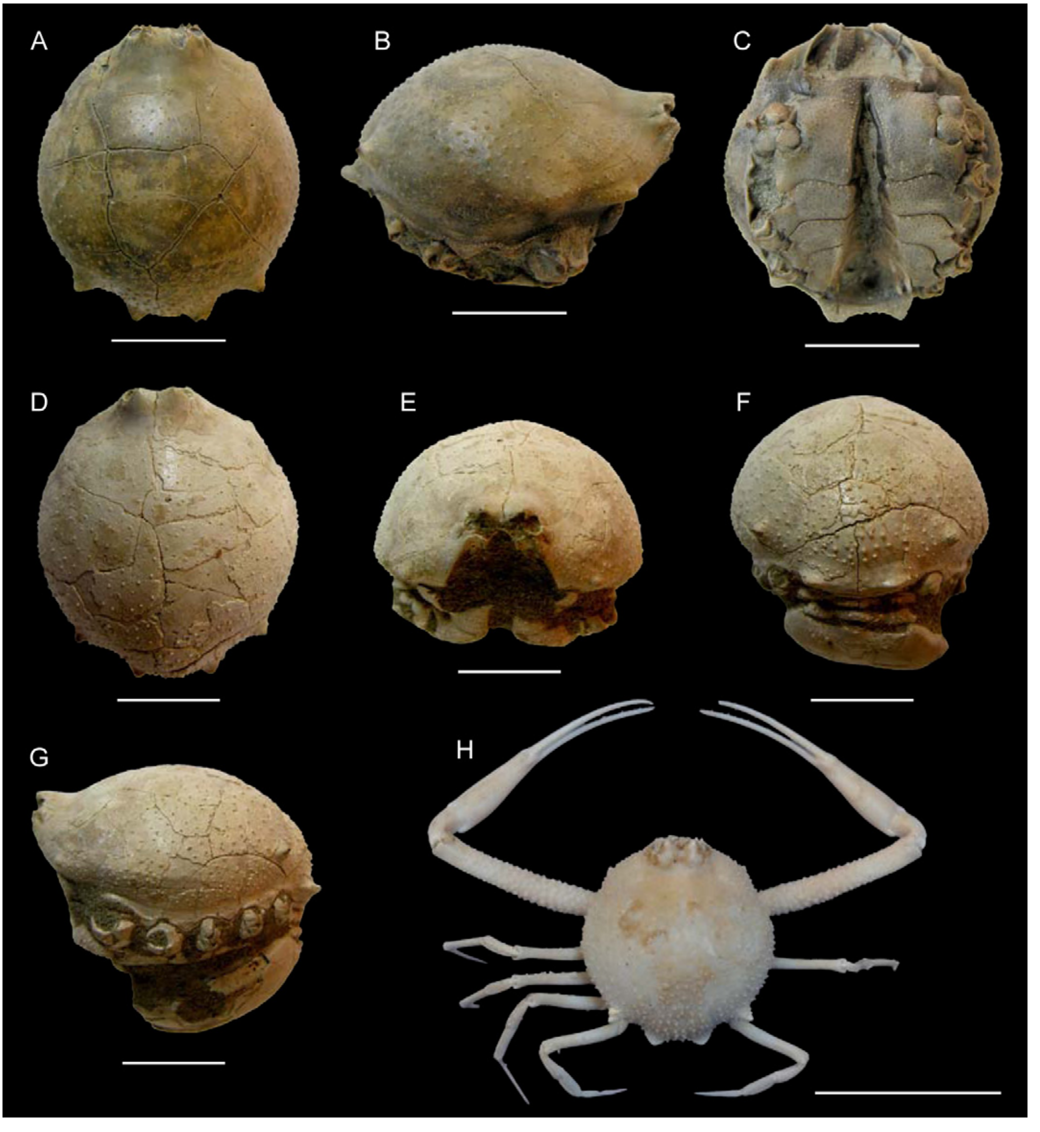

Fig. 14. *Ilia nucleus* (Linnaeus, 1758). **A–C**. Male specimen (GPDG 0149), carapace in dorsal (A), lateral (B) and ventral (C) views, note the pleonal sternites. **D–G**. Female specimen (GPDG 0150), carapace in dorsal (D), frontal (E), posterior (F) and left lateral (G) views. **H**. Extant specimen (MSNM 2428), Mediterranean Sea. Scale bars: 1 cm.

Ilia nucleus *(Linnaeus, 1758). **A–C**. Spécimen mâle (GPDG 0149), carapace en vues dorsale (A), latérale (B) et ventrale (C), noter les sternites abdominaux. **D–G**. Spécimen femelle (GPDG 0150), carapace en vues dorsale (D), frontale (E), postérieure (F) et latérale gauche (G). **H**. Spécimen actuel (MSNM 2428), Mer Méditerranée. Barres d'échelle : 1 cm.*

Ilia nucleus–Leach 1817: 24. — Heller, 1863: 122, pl. 4, figs. 1, 2. — Carus, 1885: 101. — Pesta, 1918: 293, fig. 90. — de Miranda and Ribera 1933: 35. — Bouvier, 1940: 214, fig. 143; pl. 8, fig. 4. — Zariquiey Álvarez, 1946: 147, pl. 10, fig. f. — Monod, 1956: 139. — Holthuis and Gottlieb, 1958: 82. — Holthuis, 1961: 44. — Forest, 1965: 371. — Zariquiey Álvarez, 1968: 322, figs. 11c, 94f. — Falciai and Minervini, 1992: 183, pl. 13.

Ilia cf. *nucleus*–Ristori, 1891b: 23. — Schweitzer et al., 2010: 88.

Ilia pliocaenica-Ristori, 1891a: pl. 1, fig. 14. — Glaessner, 1929: 225. — Delle Cave, 1981: 45. —Garassino and De Angeli, 2004b: 40, fig. 4 (5). — Garassino et al., 2004: 266, fig. 8a. — De Angeli and Garassino, 2006: 46. — De Angeli et al., 2009: 181, 182, fig. 12 a, b. — Schweitzer et al., 2010: 88.

Geological age: Early Pliocene (Zanclean).

Material and measurements: Eight specimens including five complete carapaces [GPDG 0148, 0149 (see Fig. 14A–C), 0151, 0152, 0153]; one complete female with pleonal shield (GPDG 0150, see Fig. 14D–G); one isolated merus (GPDG 0154); one isolated female pleonal shield (GPDG 0211).

GPDG 0149: lcxp = 23 mm; wcxp = 21 mm. — GPDG 0151: lcxp = 32 mm; wcxp = 30 mm. —GPDG 0153: lcxp = 12 mm; wcxp = 10 mm.

Description:

Cephalothorax. — Subspherical carapace, slightly longer than wide, narrowed anteriorly; front subacutely bidentate, elevated, pterygostomial gutters (respiratory canals) not extended beyond orbits; posterior margin with two small, well-developed and rounded central lobes and one spine turned upward distally, on either side; one tubercle at middle of lateral margin, another on hepatic region; hepatic region slightly swollen; cervical suture partly defined at hepatic region; cardiac and intestinal regions defined by faint grooves on either side; dorsal surface of carapace with very small, uniformly arranged granules; posterior margin with two well-developed, rounded lobes; one strong spine directed upward on either lateral margin.

Thoracic appendages. — Elongate merus of cheliped, ovoid in section, with granulose ornamentation.

Male pleon and sternites. — Sternal plastron with small granules; sterno-pleonal cavity deeply excavated, triangular, elongate until anterior part of sternum; s3–6 fused; subtriangular telson.

Female pleon. — s4–s6 fused in a notably wide, convex shield, subovoid in outline, slightly restricted distally; subtriangular, narrow telson.

Discussion: Zariquiey Álvarez (1968) pointed out the main diagnostic characters of *Ilia nucleus* (Fig. 14H), as follows: typical globular carapace, slightly longer than wide; very narrow front subacutely bidentate; posterior margin with well-developed, rounded two median lobes, and one strong spine directed upward on either lateral margin; elongate merus of cheliped, with ovoid section and granulose ornamentation. We assign the studied specimens to the extant *I. nucleus* based upon the following morphological characters: typical globular carapace, slightly longer than wide, very narrow front subacutely bidentate, posterior margin with well-developed, rounded two median lobes, and one strong spine directed upward on either lateral margins, and elongate merus, ovoid in section, with granulose ornamentation. According to Schweitzer et al. (2010) *Ilia* is known in the fossil record of Italy with *I. pliocaenica* Ristori, 1891. However, we justify the assignment of the studied specimen to *I. nucleus* because the fossil *I. pliocaenica* Ristori, 1891, described by some incomplete, disarticulated fragments (two carapaces, one pleon, and some meri of chelipeds), was assigned by the author to *Ilia*. Indeed, the pleon and the meri, figured by Ristori (1891a: pl. 1 figs. 8, 9, 11, 12) and the carapaces, figured by Ristori (1892: fig. 1a) do not show the diagnostic characters of *Ilia*, having a subpentagonal and globose carapace, moderately produced, upcurved, bilobate, front with short, triangular, distally rounded rostrum, anterolateral, posterolateral, and posterior margins granulate, and P1 trigonal merus, bearing perliform tubercles on anterior and posterior margins. Based upon these data Ristori's specimens show the diagnostic characters of *Ristoria* gen. nov. to which they are assigned (see following species in the text).

Only the elongate merus figured by Ristori (1891a: pl. 1 fig. 14) belongs to *I. nucleus* with its typical granulose ornamentation and ovoid section.

Following these results, the assignment of *I. pliocaenica* of other samples from the Pliocene of Italy, made by Garassino and De Angeli (2004b), Garassino et al. (2004), and De Angeli et al. (2009) must be reviewed. Garassino and De Angeli [2004b: 40, fig. 4 (5)] assigned to this species five meri from the Pliocene of Arda river (Castell'Arquato, Emilia Romagna, northern Italy). However, these meri show the ovoid section and the granulose ornamentation typical of *I. nucleus*. Subsequently, Garassino et al. (2004: 266, fig. 8) assigned one merus to this species from the Pliocene of Masserano (Biella, Piemonte, northern Italy). Indeed, this merus also has the characteristic granulose ornamentation and ovoid section of *I. nucleus*. Finally, De Angeli et al. (2009: 181, fig. 12) described four fragmentary dactylus and index, having the morphological characters of *I. nucleus*.

In conclusion, we can state that all specimens previously ascribed to Ristori's species from the Pliocene of Italy must be assigned to *I. nucleus*, recently also reported from the early Pleistocene (Emilian) of Pomezia (Lazio, Roma, central Italy) by Garassino and Pasini (2012).

Subfamily Leucosiinae Samouelle, 1819

Ristoria Garassino, Pasini, De Angeli and Charbonnier gen. nov.

Etymology: The name alludes to Giuseppe Ristori who first reported these specimens from the Pliocene of Toscana.

Type species: *Ilia pliocaenica* Ristori, 1891

Diagnosis: Globose, subpentagonal carapace, slightly longer than wide, with indistinct regions; moderately produced, upcurved frontal region, with short rostrum rounded distally and slightly turned downward; triangular, depressed infraorbital sinus; small, rounded orbits; anterolateral margin weakly convex along the hepatic region; lateral angle of carapace slightly sinuous not overhanging thoracic sinus, margin smooth; weak, poorly tormentose thoracic sinus, anteriorly not defined by overhanging margin of pterygostomian region; granulate anterolateral, posterolateral, and posterior margins; deflexed and tuberculate posterolateral margins, concave medially; deflexed, beaded posterior margin; five beaded granules above basis of P1 propodus; subequal, robust lanceolate chelipeds, inflated basally, carinate dorsally; granulations on lower inner side; fingers slightly shorter than propodus; index sinuous distally; globular P1 carpus; trigonal P1 merus, bearing perliform tubercles on anterior and posterior margins; upper surface bearing two margino-lateral rows of perliform tubercles decreasing distally, the posterior row is longer bearing almost 10 tubercles; between the lateral tuberculate rows two median, longitudinal shorter ridges divergent distally bearing four tubercles; lower surface of P1 merus granulate proximally, bearing a row of tubercles smaller than the dorsal ones; male s3–s5 fused, subtrapezoidal s6 with median denticle; triangular telson; rounded female s3–s6 fused, shield like shaped.

Description: As for the type species.

Ristoria pliocaenica (Ristori, 1891)

Fig. 15

Ilia pliocaenica Ristori, 1891a: 10–11, pl. 1, figs. 8, 9, 11, 12 (not fig. 14).

Ilia pliocaenica–Ristori, 1892: 86, figs. 1, 1a.

Type locality: Spicchio (Empoli, Toscana, central Italy).

Type material: Syntypes IGF 938E (two meri; one figured by Ristori (1891a: pl. 1 figs. 11, 12, same specimen in outer and inner views).

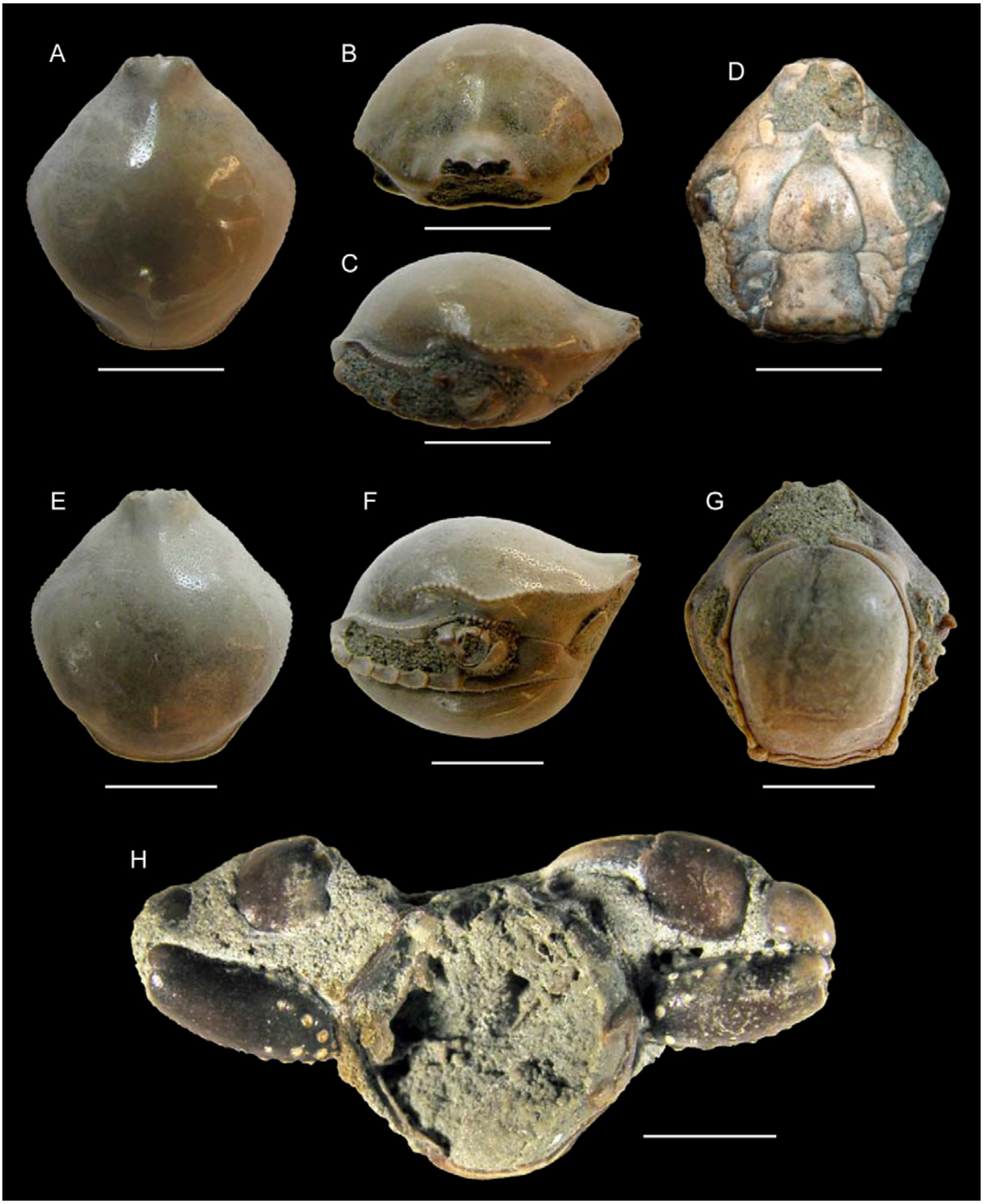

Fig. 15. *Ristoria pliocaenica* (Ristori, 1891). **A–C**. Male specimen (GPDG 0200), carapace in dorsal (A), frontal (B) and right lateral (C) views. **D**. Male specimen (GPDG 0209), carapace in ventral view, note the pleonal somites. **E–G**. Female specimen (GPDG 0208), carapace in dorsal (E), right lateral (F) and ventral (G) views, note the rounded pleon. **H**. Specimen GPDG 0201, detail of P1 chelipeds with ornamentation of merus. Scale bars: 5 mm.

Ristoria pliocaenica *(Ristori, 1891).* ***A–C****. Spécimen mâle (GPDG 0200), carapace en vues dorsale (A), frontale (B) et latérale gauche (C).* ***D****. Spécimen mâle (GPDG 0209), carapace en vue ventrale, noter les somites abdominaux.* ***E–G****. Spécimen femelle (GPDG 0208), carapace en vues dorsale (E), latérale droite (F) et ventrale (G), noter le pleon arrondi.* ***H****. Spécimen GPDG 0201, détail des chélipèdes P1 et de l'ornementation du mérus. Barres d'échelle : 5 mm.*

Comments: The original syntypes of *Ilia pliocaenica*, as reported by Ristori himself, consist of one pleon and four incomplete meri (not all figured by the author), while the juvenile carapace figured by Ristori (1892: figs. 1, 1a) and assigned to the same species is lost; we can state, by the present review of Ristori's syntypes, that the pleon and the merus figured by Ristori (1891a: pl. 1 figs. 8, 9, 14) must be assigned to *Ilia nucleus* (see the discussion of *I. nucleus* in the text), while the merus figured by Ristori (1891a: pl. 1 figs. 11, 12) must be assigned to *Ristoria pliocaenica* comb. nov.

Geological age: Pliocene–early Pliocene (Zanclean).

Note: Pliocene *sensu lato* is referred to Spicchio, lacking sedimentological and stratigraphical data, while early Pliocene (Zanclean) is referred to "La Serra" quarry.

Material and measurements: 39 specimens including eight carapaces with chelipeds (GPDG 0201, 0202, 0203, 0204a-c; MSNM i27652, i27653); 13 isolated carapaces without pleonal somites (GPDG 0173, 0174, 0199, 0200, 0205a–f); eight isolated carapaces with evidences of predation (GPDG 0174, 0175a–g, 0198); one isolated cheliped (GPDG 0206); one female with pleonal shield (GPDG 0208); two males with pleonal somites (GPDG 0209, 0210); six fragmentary male and female pleonal somites (GPDG 0207a–f).

GPDG 0173: lcxp = 13 mm; wcxp = 12 mm. — GPDG 0198: lcxp = 11 mm; wcxp = 10 mm. — GPDG 0199: lcxp = 13.5 mm; wcxp = 12.5 mm.

Description:

Cephalothorax. — Globose, subpentagonal carapace, slightly longer than wide, with indistinct regions; smooth to sparsely punctate dorsal surface; frontal region moderately produced, upcurved; front concave laterally, with lateral fossae ventrally; anterior frontal margin with short rostrum rounded distally and slightly turned downward; triangular infraorbital sinus medially depressed; small, rounded orbits; outer margin unisutured laterally; anterolateral margin weakly convex along the hepatic region; lateral angle of carapace slightly sinuous not overhanging thoracic sinus, smooth margin; weak, poorly tormentose thoracic sinus, anteriorly not defined by overhanging margin of pterygostomian region; prominent anterolateral margins finely tuberculate proximally, smooth distally; deflexed posterolateral margins finely tuberculate, slightly concave and inflated medially; deflexed posterior margin sinous in male, but wider and more rounded in female, tuberculate along the margin; beaded outer margin, sinous in male. Thoracic sinuous with granulate ventral margin, followed by a row of five to six perliform granules above basis of P1 propodus.

Thoracic appendages. — Subequal, robust chelipeds, lanceolate in transverse section, smooth on both surfaces; carinate upper margin; rounded lower margin granulate in the lower inner side; dactylus and index a little shorter than propodus, serrate inner margins, index slightly sinuous distally; globular, inflated, smooth carpus; merus trigonal in transverse section, bearing perliform tubercles on anterior and posterior margins; upper surface bearing two marginolateral rows of perliform tubercles decreasing distally; the anterior row bears about nine tubercles; the posterior bears 10/12 tubercles, all decreasing distally; between the lateral tuberculate rows, two median, longitudinal, shorter ridges diverge distally bearing four perliform tubercles, the first proximal two larger than the second ones; lower surface of merus granulate proximally, bearing a row of about eight tubercles decreasing distally, smaller than the dorsal ones; inner surface granulate proximally.

Male pleon. — Smooth thoracic sternites; s1 narrow, transverse; s2 minute, bulb-shaped; s3–s5 fused, forming an elongate subtrapezoidal shield, with lateral margins converging distally; surface with three small tubercles equally spaced and parallel to lateral margin; subtrapezoidal s6, rounded distally, bearing a prominent tubercle medially and separated from s5 by a transverse continuous suture; triangular telson.

Female pleon. — s3–s6 fused in a notably convex shield-like, subrectangular in outline, rounded distally and slightly sinuous proximally; triangular telson.

Discussion: Among Leucosiidae, *Leucosia* Weber, 1795, "was longer considered a well defined and homogeneous genus" (Galil, 2003a). Instead, Galil (2003a) redescribed the definition of the genus, ascribing to new genera some species previously ascribed to *Leucosia sensu lato* (Galil, 2003b, 2005a,b, 2006a,b; Galil and Ng, 2010). Unfortunately, the first male pleopod, a diagnostic character used in the systematics of the extant specimens, is not useful in the fossil specimens because it is usually not preserved. So, the systematics of the fossil specimens uses other, preserved generic characters, such as the outline and ornamentation of the carapace and pleon, shape of the frontal region, shape of fused male pleonal somites, shape of chelipeds, palms, and dactyli.

The Cenozoic fossil species previously reported from the Indo-Pacific area range from the Miocene of Ceylon (e.g., *Leucosia unidentata lankae* Deraniyagala, 1969), the Mio-Pleistocene of Borneo (e.g., *Leucosia calcarata* Collins, Lee and Noad, 2003) (Collins et al., 2003), the Neogene of Brunei, Sabah, and Sarawak (e.g., *Leucosia longiangulata* Morris and Collins, 1991, *L. serenei* Morris and Collins, 1991, and *L. tutongensis* Morris and Collins, 1991) (Morris and Collins, 1991) to the middle and late Pleistocene of Japan (e.g., *Urnalana parahaemastotica* Galil, 2005a,b; *Leucosia* sp.) (Obata and Hayashi, 2001; Kobayashi et al., 2008).

Vega et al. (2010) reported *Leucosia persica* Vega, Gholamanian and Bahrami, 2010, from the middle Miocene of Iran, this was the first fossil record for the genus out of the Indo-Pacific area. This species differs in general morphology and shape from the carapace of *Ristoria pliocaenica*. The fragmentary species from Ceylon and Japan, are not comparable, and they need perhaps more careful review of their generic assignment following the new systematics proposed by Galil (2003a,b; 2005a,b; 2006 a,b) and Galil and Ng (2010).

Galil (2003a,b; 2005a,b; 2006 a,b) and Galil and Ng (2010) have described several genera of Leucosiinae, *Leucosia*, *Euclosia*, *Urnalana*, *Seulocia*, *Coleusia*, and *Soceulia*. *Ristoria* gen. nov. shows some morphological affinities with *Soceulia*, *Leucosia*, *Euclosia*, and *Urnalana*, having similar subpentagonal carapace with rounded lateral angles, fingers nearly as long as propodus, similar arrangement of tubercles on merus, s3–s5 fused in the male (in *Seulocia* and *Coleusia* s3–s6 are fused), and s6 with median tubercle. However, we justify the erection of the new genus *Ristoria* because it differs essentially from all extant genera by exhibiting a slightly sinuous lateral angle of carapace not overhanging the weak thoracic sinus, weakly tormentose, and anteriorly not defined by the overhanging margin of pterygostomian region. Indeed in all extant genera the thoracic sinus is deep, bearing ovate granules, and anteriorly defined by overhanging margin of pterygostomial region.

Based upon these data, we ascribe the studied specimens to *Ristoria* gen. nov. Moreover, we add the Pliocene species described by Ristori (1891a) as *Ilia pliocaenica*, represented by one female pleon (Ristori, 1891a: pl. 1, figs. 8, 9), one isolated merus (Ristori, 1891a: pl. 1, figs. 11, 12), and one complete carapace (Ristori, 1892: figs. 1, 1a) (see the discussion of *Ilia nucleus* in this study). Indeed, the general shape of the carapace, pleon, and merus shows the same characters of the studied specimens from "La Serra" and so Ristori's specimens must be assigned to *Ristoria* gen. nov. Finally, *Ristoria pliocaenica* (Ristori, 1891) represents the most common brachyuran decapod present in "La Serra" quarry, with hundreds of carapaces of both sexes at different stages of growth. The males are only about 10 percent of the individuals.

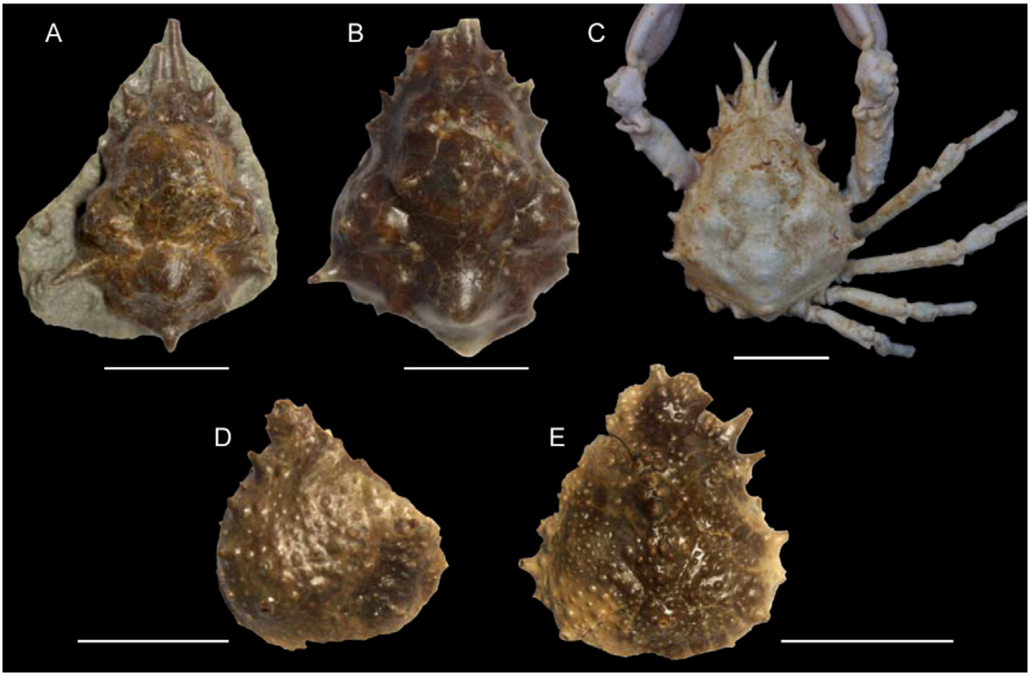

Fig. 16. Majoids from "La Serra" quarry. **A**. *Pisa armata* (Latreille, 1803), carapace (GPDG 0155) in dorsal view. **B**. *Pisa armata* (Latreille, 1803), carapace (GPDG 0156) in dorsal view. C. *Pisa* sp., extant specimen (MSNM 2429), Mediterranean Sea. **D**. *Macropodia* sp. (GPDG 0195), carapace in dorsal view. **E**. *Maja squinado* (Herbst, 1788), carapace (GPDG 0143) in dorsal view. Scale bars: 2 cm (A, C, E) and 1 cm (B, D).

Majidés de la carrière « La Serra ». ***A***. Pisa armata *(Latreille, 1803), carapace (GPDG 0155) en vue dorsale.* ***B***. Pisa armata *(Latreille, 1803), carapace (GPDG 0156) en vue dorsale.* C. Pisa *sp., spécimen actuel (MSNM 2429), Mer Méditerranée.* ***D***. Macropodia *sp. (GPDG 0195), carapace en vue dorsale.* ***E***. Maja squinado *(Herbst, 1788), carapace (GPDG 0143) en vue dorsale. Barres d'échelles : 2 cm (****A****,* ***C****, E) et 1 cm (****B****,* ***D****).*

The only extant correlated species reported from the Mediterranean Sea is *Coleusia signata* (Paulson, 1875) an exotic Lessepsian species introduced through the Suez Channel and established in the eastern Mediterranean and western Marmara Seas in subtidal to 25 m deep waters with muddy and sandy gravel bottoms (Artüz, 2007). Perhaps the species is occasionally also present in southern Italy, along the coast of the Linosa Island (Agrigento, Sicily, southern Italy). *Leucosia sensu lato* Weber, 1759, are from the Indo-Pacific Ocean to the Red Sea, inhabiting various environments at different depths from shallow subtidal estuarine bottoms, to sub-littoral sandy mud bottoms with rocks and weed, and from intertidal pools to coral reefs.

Superfamily Majoidea Samouelle, 1819
Family Epialtidae MacLeay, 1838
Subfamily Pisinae Dana, 1851
Genus ***Pisa*** Leach, 1814
Type species: *Cancer biaculeatus* Montagu, 1813, by monotypy.
Included fossil species: See Schweitzer et al. (2010).
Pisa armata (Latreille, 1803)
Fig. 16A-C

Maia armata Latreille, 1803: 98.

Pisa gibbsii Leach, 1815: pl. 19, figs. 1–4.

Pisa armata–Pesta, 1918: 344, figs. 110, 111. — Nobre, 1931: 155, figs. 91–94. — Holthuis and Gottlieb, 1958: 119. — Zariquiey Álvarez, 1968: 454, figs. 151d, 152e, 154d. — Falciai and Minervini, 1992: 251, pl. 17. — Schweitzer et al., 2010: 93.

Pisa gibbsi–Bouvier, 1940: 331, fig. 202, pl. 13, fig. 5. — Zariquiey Álvarez, 1946: 170, pl. 23, fig. d. — Zariquiey Álvarez, 1950: 109, pl. 5, fig. 2. — Monod, 1956: 486, fig. 654. — Nunes-Ruivo, 1961: 31.

Geological age: Early Pliocene (Zanclean).

Material and measurements: Three complete carapaces. GPDG 0155: lcxp = 26 mm; wcxp = 19 mm. — GPDG 0156: lcxp = 22 mm; wcxp = 16 mm. — GPDG 0214: lcxp = 18 mm; wcxp = 13 mm.

Discussion: The three-dimensionally preserved specimens permitted assignment to the extant *Pisa armata* based upon the morphological characters, as follows: pyriform carapace, much longer than wide; bifid rostrum with two very elongate, narrow spines, diverging distally; one strong post-orbital spine; anterolateral margins with one acute hepatic spine directed outward; posterolateral margins with one strong branchial spine directed outward; well-developed inflated regions; gastric region with two small tubercles; cardiac region with one small median tubercle; intestinal region with one strong median spine directed upward. This species was already known in the fossil record of Italy from the late Pleistocene of Monte Pellegrino (Palermo, Sicilia, southern Italy) (Gemmellaro, 1914). In the Mediterranean Sea, *P. armata* usually occupies rocky hard grounds between the tides or sandy mud rich in weeds, ranging in depth from 1 m to 500 m, but commonly between 50–160 m (Falciai and Minervini, 1992). The similar *Pisa nodipes* (Leach, 1815) instead is a common species living among the *Posidonia* leaves. Although *P. armata* is rare at "La Serra" quarry, this report enlarges its presence in the Mediterranean basin to the early Pliocene.

Family Inachidae MacLeay, 1838

Genus ***Macropodia*** Leach, 1814

Type species: *Cancer longirostris* Fabricius, 1775, by monotypy.

Included fossil species: *Macropodia* sp. (this work).

***Macropodia* sp.**

Fig. 16D

Geological age: Early Pliocene (Zanclean).

Material: one incomplete carapace (GPDG 0195).

Description: rounded posterior part of carapace, with well-developed regions, weakly marked by grooves; granulate surface; one hepatic spine; four branchial spines; one cardiac spine.

Discussion: the branchial region, with convex margins having some spines, allows assigning the studied specimen to *Macropodia* Leach, 1814, reported for the first time in the fossil record. The studied specimen shows some affinities with the extant *M. rostrata* (Linnaeus, 1761) having three branchial spines and with the extant *M. longipes* (A. Milne Edwards and Bouvier, 1899) having two branchial spines. However, the studied specimen has four branchial spines and a granulate dorsal surface. *Macropodia* lives in the Mediterranean Sea with five species, ranging between 80–400 m on sandy, muddy bottoms (Falciai and Minervini, 1992). This genus is very rare at "La Serra" quarry.

Family Majidae Samouelle, 1819
Subfamily Majinae Samouelle, 1819
Genus ***Maja*** Lamarck, 1801

Type species: *Cancer squinado* Herbst, 1788, subsequent designation by I.C.Z.N. (1958: Opinion 511).

Included fossil species: See Schweitzer et al. (2010).

Maja squinado (Herbst, 1788)
Fig. 16E

Cancer squinado Herbst, 1788: 214, pl. 14, figs. 84, 85.

Maja squinado–Leach 1817: 1817, pl. 18, figs. 1–6. — Meneghini, 1857: 557. — Heller, 1863: 49, pl. 1, figs. 17–24. — Gemmellaro, 1914: 81, pl. 1, figs. 11, 12. — Pesta, 1918: 361, fig. 116. — Nobre, 1931: 142, fig. 82. — Bouvier, 1940: 321, fig. 95. — Zariquiey Álvarez, 1946: 169, fig. 171. — Capart, 1951: 98, fig. 32. — Monod, 1956: 474, figs. 638–643. — Zariquiey Álvarez, 1968: 446, figs. 149a, 150 g, h. — Ingle, 1980: 23, 45, 141. — Varola, 1981: 13, pl. 3, fig. 1. — Falciai and Minervini, 1992: 247, pl. 17, fig. 2. — Garassino and De Angeli, 2004b: 40, fig. 7. — Pasini and Garassino, 2009: 16, figs. 3, 4. — Schweitzer et al., 2010: 95.

Geological age: Early Pliocene (Zanclean).

Material and measurements: Two specimens including one complete carapace (GPDG 0143: lcxp = 31 mm; wcxp = 28 mm) and one deformed carapace (GPDG 0196: lcxp = 22 mm; wcxp = 24 mm).

Discussion: Although the studied specimen lacks the frontal region, chelipeds and all pereiopods, it shows many affinities with the morphology of *Maja* Lamarck, 1801, and the peculiar characters of the extant *M. squinado*, as follows: pyriform outline and size; form, arrangement and general distribution of the smooth spines and granulate tubercles of the carapace that are enlarged anteriorly and posteriorly but not distinctly humped; the lateral and the five axial spines are smaller and are facing in different ways than in the other fossil and extant species. Therefore, on the basis of the above-mentioned characters, the studied specimen is considered to be to a juvenile individual of *M. squinado*. This species is known to date in Italy from the Pliocene of Monte Mario (Roma), Rocca Vecchia (Penisola Salentina, Puglia, Italy), Capo San Marco (Sardegna), Arda River (Emilia Romagna) and Masserano (Piemonte) (Meneghini, 1857; Ristori, 1891a,b; Varola, 1981; Garassino and De Angeli, 2004b; Pasini and Garassino, 2009) and from the Pleistocene of Monte Pellegrino (Sicilia) (Gemmellaro, 1914). The specimens reported from Monte Mario (Roma), from the "yellow sands" (Ristori, 1891b), without precise stratigraphy, are most probably referables to the Santernian (early Pleistocene) on the basis of the more recent studies on litho-bio-chronostratigraphy of the Monte Mario successions (for instance see Cosentino et al., 2009). In the Mediterranean Sea this species ranges from the subtidal depths of about 90–100 m in rocky vegetated bottoms alternating with sandy areas. Juveniles, especially, inhabit shallow water (up to 15 m) with mixed rocky and sandy bottoms. The species is uncommon at "La Serra" quarry and represented only by incomplete juvenile individuals. This is the first record of the species from the Pliocene of Toscana.

Superfamily Parthenopoidea MacLeay, 1838
Family Parthenopidae MacLeay, 1838
Subfamily Parthenopinae MacLeay, 1838
Genus ***Derilambrus*** Tan and Ng, 2007

Type species: *Parthenope angulifrons* Latreille, 1825, by original designation.

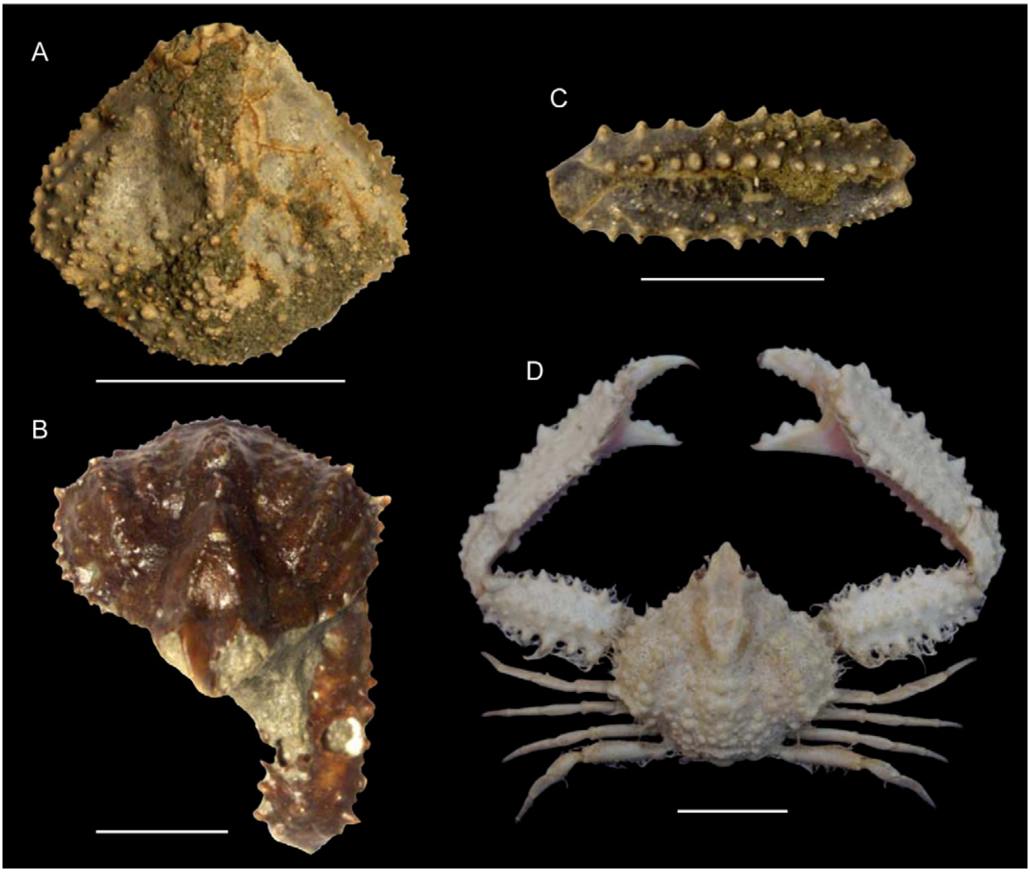

Fig. 17. *Derilambrus angulifrons* (Latreille, 1825). **A**. Carapace (GPDG 0133) in dorsal view. **B**. carapace (GPDG 0132) with left merus, frontal dorsal view. **C**. disarticulated merus (GPDG 0136). **D**. Extant specimen (MSNM 2430), Mediterranean Sea. Scale bars: 1 cm.

Derilambrus angulifrons *(Latreille, 1825). **A**. Carapace (GPDG 0133) en vue dorsale. **B**. Carapace (GPDG 0132) avec mérus gauche, vue dorsale frontale. **C**. Mérus désarticulé (GPDG 0136). **D**. Spécimen actuel (MSNM 2430), Mer Méditerranée. Barres d'échelle : 1 cm.*

Included fossil species: See Schweitzer et al. (2010).

Derilambrus angulifrons (Latreille, 1825)

Fig. 17

Parthenope angulifrons Latreille, 1825; 46.

Parthenope angulifrons–Zariquiey Álvarez, 1968: 439, fig. 148b. — Falciai and Minervini, 1992: 242. — Garassino and De Angeli, 2004a: 22, figs. 2, 4a, b.

Lambrus angulifrons–Heller, 1863: 57, pl. 2. — Pesta, 1918: 371, fig. 119. — Nobre, 1931: 140, figs. 80, 81. — Bouvier, 1940: 310, fig. 191, pl. 2, fig. 1. — Zariquiey Cenarro, 1941: 351, 365, figs. 36–44a–c. — Zariquiey Álvarez, 1946: 167, pl. 20.

Derilambrus angulifrons–Tan and Ng, 2007: 102, fig. 4. — Schweitzer et al., 2010: 97.

Geological age: Early Pliocene (Zanclean).

Material and measurements: Five specimens including two complete carapaces (GPDG 0132: lcxp = 22 mm; wcxp = 24 mm. — GPDG 0133: lcxp = 21 mm; wcxp = 23 mm) and three isolated meri (GPDG 0134, 0135, 0136).

Description: The studied specimens exhibit a subtriangular carapace, slightly longer than wide; triangular frontal margin; subcircular orbits; raised supraorbital margins with narrow and long fissure; triangular extraorbital tooth; convex and tuberculate lateral margins; tubercles well developed along branchial regions with small dorsal granulations; anterior dorsal part of dorsal surface with two granulate longitudinal ridges joining on metagastric regions to make a "V"; frontal region depressed in the median part; well-developed and convex gastric, branchial, and cardiac regions, all with granulations; branchial regions with two oblique rows of tubercles; elongate merus, trigonal in transverse section, with strong spines along all the lateral margins.

Discussion: The studied specimens show the typical characters of the extant *Derilambrus angulifrons* (Fig. 17D), reported in the fossil record of Italy from the Sicilian (early Pleistocene) of Favignana Island (Sicilia, southern Italy) (Garassino and De Angeli, 2004a). This species lives at depths between 2 and 80 m in the Mediterranean Sea and southwestern Spain, inhabiting sandy mud bottoms or along submarine seamounts and knolls in deeper waters. The species is not rare at "La Serra" quarry, enlarging its stratigraphic range from the Pliocene.

Superfamily Cancroidea Latreille, 1802
Family Atelecyclidae Ortmann, 1893
Genus ***Atelecyclus*** Leach, 1814

Type species: *Cancer* (*Hippa*) *septemdentatus* Montagu, 1813, by monotypy.

Included fossil species: See Schweitzer et al. (2010).

Atelecyclus undecimdentatus (Herbst, 1783)
Fig. 18A–C

Geological age: Early Pliocene (Zanclean).

Material and measurements: Nine specimens including six complete carapaces (GPDG 0161–0165, 0213); one incomplete carapace with chelipeds (GPDG 0192); two loose chelipeds (GPDG 0193). GPDG 0162: lcxp = 23 mm; wcxp = 25 mm. — GPDG 0163: lcxp = 15 mm; wcxp = 18 mm.

Description: Subelliptic carapace, wider than long, covered by small granulations dorsally. Frontal margin tridentate. Rounded frontolateral margin bearing 9–11 pointed triangular sharped teeth directed anteriorly. Concave posterolateral margin, with short, straight posterior margin. Palm of chelipeds slightly convex, trapezoidal in outline, with three distinct longitudinal, tuberculate ridges, and index directed downward.

Discussion: The studied specimens are assigned to the extant *Atelecyclus undecimdentatus* (Fig. 18 C), having a broad elliptic granulate carapace wider than long, frontolateral margins typically spinose and elliptic granulate carapace larger than long, palm of chelipeds slightly convex, with three distinct longitudinal tuberculate ridges, and index directed downward. *Atelecyclus undecimdentatus* lives in the eastern Atlantic and, less commonly, in the Mediterranean Sea from 1 m to 60 m deep on sandy or gravel bottoms. *Atelecyclus undecimdentatus* is represented in "La Serra" quarry by specimens at different stages of growth. This is the first record for the species from the Pliocene of Italy.

Superfamily Portunoidea Rafinesque, 1815
Family Portunidae Rafinesque, 1815
Subfamily Polybiinae Ortmann, 1893

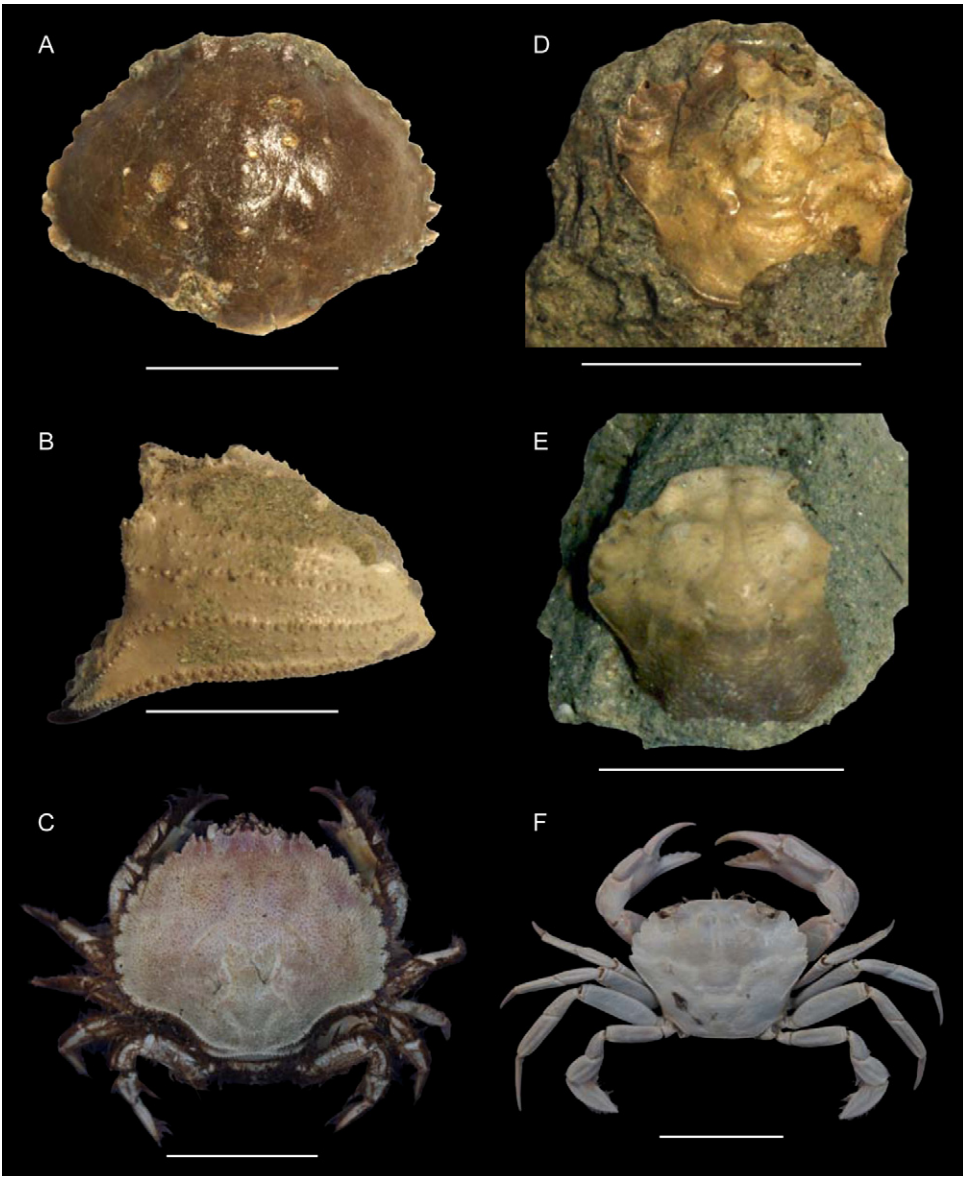

Fig. 18. Atelecyclids and portunids from “La Serra” quarry. **A–C**. *Atelecyclus undecimdentatus* (Herbst, 1783): **A**. Carapace (GPDG 0192) in dorsal view; **B**. Left chela (GPDG 0193) in outer view; **C**. Extant specimen (MSNM 2431), Mediterranean Sea. **D**. *Liocarcinus* sp. (GPDG 0169), carapace in dorsal view. **E**. *Liocarcinus* sp. (GPDG 0171), carapace in dorsal view. **F**. *Liocarcinus navigator* (Herbst, 1794), extant specimen (MSNM 2432), Mediterranean Sea. Scale bars: 1 cm except C: 2 cm.

Atelecyclidés et portunidés de la carrière « La Serra ». Atelecyclus undecimdentatus *(Herbst, 1783): **A**. Carapace (GPDG 0192) en vue dorsale; **B**. Pince gauche (GPDG 0193) en vue externe; **C**. Spécimen actuel (MSNM 2431), Mer Méditerranée. **D**.* Liocarcinus *sp. (GPDG 0169), carapace en vue dorsale. **E**.* Liocarcinus *sp. (GPDG 0171), carapace en vue dorsale. **F**.* Liocarcinus navigator *(Herbst, 1794), spécimen actuel (MSNM 2432), Mer Méditerranée. Barres d’échelle : 1 cm excepté C: 2 cm.*

Genus ***Liocarcinus*** Stimpson, 1871

Type species: *Portunus holsatus* Fabricius, 1798, by original designation.

Included fossil species: See Schweitzer et al. (2010).

Liocarcinus sp.

Fig. 18D-F

Geological age: Early Pliocene (Zanclean).

Material and measurements: Nine complete carapaces (GPDG 0167–0171). GPDG 0169: lcxp = 10 mm; wcxp = 13 mm. — GPDG 0170–lcxp = 12 mm; wcxp = 15 mm.

Description: Wide orbits; supra-orbital margin with two fissures; four subtriangular anterolateral spines, slightly curved forward (excluding posterolateral spine); fourth anterolateral spine smaller; shallow cervical groove; oval epigastric lobes well raised; subpentagonal mesogastric region; long anterior mesogastric process, narrow between protagastric regions; wide metagastric region poorly developed in length, forming one convex protuberance; trilobate cardiac region; dorsal surface with short, granulate lines.

Discussion: The studied specimens are too incomplete to allow a certain systematic assignment. However they show affinities with *Liocarcinus oroszyi* (Bachmayer, 1953) from the Miocene of Hungary (Müller, 1984) and with the extant *Liocarcinus depurator* (Linnaeus, 1758), widespread in the Atlantic and the Mediterranean Sea, living in sandy bottoms from a few meters to 300 m. *Liocarcinus* sp. is represented at “La Serra” quarry by small specimens of subequal size, surely juvenile stages.

Subfamily Thalamitinae Paul’son, 1875

Genus ***Thalamita*** Latreille, 1829

Type species: *Cancer admete* Herbst, 1803, by monotypy.

Included fossil species: See Schweitzer et al. (2010).

Thalamita italica Garassino, Pasini, De Angeli and Charbonnier sp. nov.

Fig. 19

Etymology: The trivial name alludes to Italy, the state in which the studied specimens were discovered.

Type material: Holotype (GPDG 0157) and paratype (GPDG 0158).

Type locality: “La Serra” quarry, San Miniato (Pisa, Toscana, central Italy).

Geological age: Early Pliocene (Zanclean).

Measurements: Three specimens including two complete carapaces lacking right cheliped and ambulatory legs (GPDG 0157: lcxp = 21 mm; wcxp = 35 mm. — GPDG 0158: lcxp = 14 mm; wcxp = 19 mm) and one right dactylus and index (GPDG 0197).

Diagnosis: Carapace clearly wider than long; frontal, protogastric, mesogastric, metagastric, and epibranchial ridges present and granular; one pair of granular short cardiac ridges; one pair of short granular mesobranchial ridges, located lateral to cardiac ones; front (excluding inner supra-orbital lobe) about same width as posterior margin of carapace; front cut into six lobes: regularly rounded median lobes, widest, rounded submedian lobes, narrowest, triangular lateral lobes; five sharp main anterolateral spines equal in size; chelipeds with imbricate granular costae on merus, carpus, and propodus.

Description:

Cephalothorax. — Carapace clearly wider than long, with maximum width between fifth anterolateral spines. The following granular carapace ridges present: frontal ridges as a group of few granules; conspicuous protogastric ridges, rather long, nearly straight; mesogastric ridges slightly inclined upward, interrupted in the midline; epibranchial ridges curving gradually

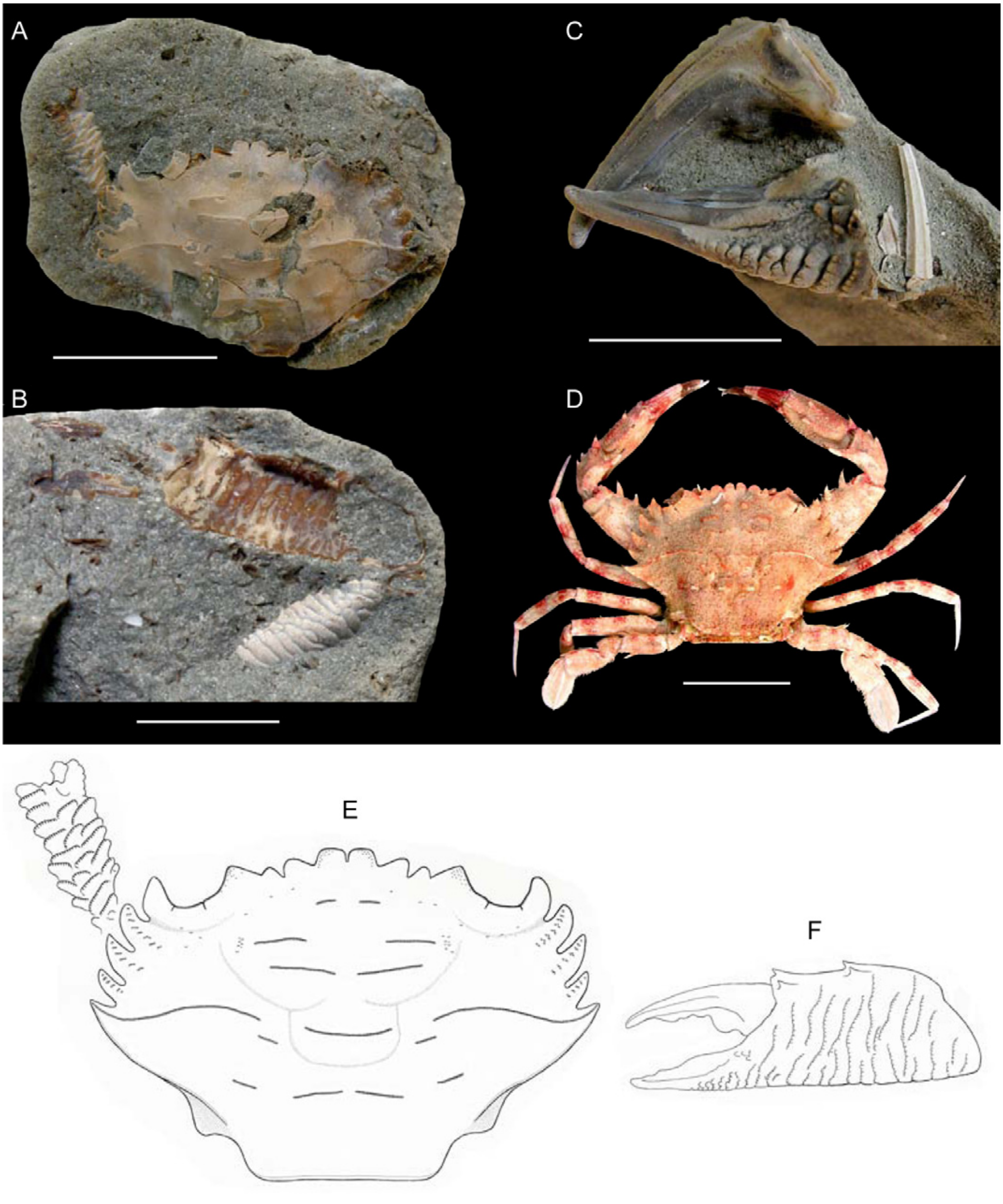

Fig. 19. Portunids from “La Serra” quarry. **A–C**. *Thalamita italica* Garassino, Pasini, De Angeli and Charbonnier sp. nov.: **A–B**. Holotype GPDG 0157, carapace in dorsal view (A) and left cheliped in ventral view (B). **C**. Specimen GPDG 0197, dactylus with embricate ornamentation. **D**. *Thalamita macrospinifera* Rathbun, 1911 (MSNM 2433), extant specimen. **E–F**. Recontruction of *Thalamita italica* Garassino, Pasini, De Angeli and Charbonnier sp. nov. Line drawings: A.D.A. Scale bars: 1 cm.

*Portunidés de la carrière « La Serra ». **A–C**.* Thalamita italica *Garassino, Pasini, De Angeli and Charbonnier sp. nov.: **A–B**. Holotype GPDG 0157, carapace en vue dorsale (A) et chélipède gauche en vue ventrale (B). **C**. Spécimen GPDG 0197, dactylus avec ornementation imbriquée. **D**.* Thalamita macrospinifera *Rathbun, 1911 (MSNM 2433), spécimen actuel. **E–F**. Reconstitution de* Thalamita italica *Garassino, Pasini, De Angeli and Charbonnier sp. nov. Dessins: A.D.A. Barres d’échelle : 1 cm.*

forward from last anterolateral spine to level of penultimate one and then backward separated from metagastric by cervical groove; metagastric ridge slightly concave; a pair of short, nearly straight cardiac ridges; slightly concave mesobranchial ridge, located laterally to cardiac ones. Front (excluding outer supra-orbital lobe) about same width as posterior margin of carapace, cut into six lobes: median lobe regularly rounded, separated by distinct incision in midline, lying in lower plane than others; widest, rounded submedian lobes; narrowest, triangular lateral lobes. Spiny inner supra-orbital lobe. Orbital margin with one median fissure. Five main anterolateral spines, sharp, equal in size, curved, anteriorly directed. Surface of second and third spines granular. Dorsal surface of carapace smooth.

Thoracic appendages. — Left chelipeds with imbricate granular costae on merus, carpus, and propodus. Elongate curved dactylus with three deep longitudinal grooves and strong molariform posterior tooth; index with denticulate cutting margin and imbricate lower margin.

Discussion: The study of the three-dimensionally preserved specimens permits the identification with the extant *Thalamita* based upon the following morphological characters: carapace clearly wider than long, front (excluding inner supra-orbital lobe) about the same width as the posterior margin of carapace, front not protruding, cut into six lobes, and five anterolateral spines.

This genus, represented by more 60 mainly Indo-Pacific species (De Grave et al., 2009: 154), is known in the fossil record by only four species: *T. fragilis* Müller, 1978 (Miocene, Hungary), *T. pleistocenica* Hu and Tao, 1979, *T. truncatata* Hu and Tao, 1996, and *T. fani* Hu and Tao, 1996 (Miocene, Pliocene, Pleistocene, Taiwan) (Müller, 1978; Hu and Tao, 1979, 1996). Müller's species preserves only a portion of the carapace (Müller, 1978: pl. 17) not enough to make a comparison with *T. italica* sp. nov. and, at the same time, it is not likely that the new species has morphological affinities with the Taiwan species based upon temporal and geographical differences. At present, two exotic Indo-Pacific species are established in the Mediterranean Sea, *T. indistincta* Apel and Spridonof, 1996, that differs from the new species in having unequal chelipeds with three longitudinal granulate costae, and *T. poissonii* (Audouin, 1826) that differs from the new species in having only two wide frontal lobes. Although *T. italica* sp. nov. has the front divided into six lobes, like other extant species, the peculiar imbricate granular costae on the merus, carpus, and propodus of the cheliped are not comparable with any extant species usually having smooth or slightly granular surfaces. The extant *T. poissoni*, widespread in the Aegean Levantine Sea (Zenetos et al., 2010), lives behind 0–80 m under stones or rocky areas in sandy-mud bottoms with sea grounds of *Posidonia* and *Caulerpa*; instead *T. indistincta*, of probably Lessepsian origin, is present along Lebanese and Syrian coasts at shallow depths (1–5 m). A third alien species, *T. doriensis* Crossier, 1962, only recently introduced by marine traffic, was occasionally reported from the Mediterranean Sea, near Genova harbour (Liguria, northern Italy) and southern of Sardegna (Italy) (Rellini Orsi and Mori, 1979), inhabiting intertidal coral sands and sea weeds. The new species is rare at "La Serra" quarry.

Superfamily Pilumnoidea Samouelle, 1819
Family Pilumnidae Samouelle, 1819
Subfamily Pilumninae Samouelle, 1819
Genus ***Pilumnus*** Leach, 1815
Type species: *Cancer hirtellus* Linnaeus, 1761, by monotypy.
Included fossil species: See Schweitzer et al. (2010).
Pilumnus cf. ***P. hirtellus*** (Linnaeus, 1761)
Fig. 20A B
Geological age: Early Pliocene (Zanclean).

Fig. 20. Pilumnids and goneplacids from "La Serra" quarry. **A**. *Pilumnus* cf. *P. hirtellus* (Linnaeus, 1761), GPDG 0160, carapace in dorsal view. **B**. *Pilumnus hirtellus* (Linnaeus, 1761), extant specimen (MSNM 2434), Mediterranean Sea. **C**. *Goneplax rhomboides* (Linnaeus, 1758), carapace (GPDG 0138) in dorsal view. **D**. *Goneplax rhomboides* (Linnaeus, 1758), extant specimen (MSNM 2435), Mediterranean Sea. **E**. *Goneplax sacci* Crema, 1895, carapace (GPDG 0194) in dorsal view. Scale bars: 1 cm.

*Pilumnidés et goneplacidés de la carrière « La Serra ». **A**.* Pilumnus cf. P. hirtellus *(Linnaeus, 1761), GPDG 0160, carapace en vue dorsale. **B**.* Pilumnus hirtellus *(Linnaeus, 1761), specimen actuel (MSNM 2434), Mer Méditerranée. **C**.* Goneplax rhomboides *(Linnaeus, 1758), carapace (GPDG 0138) en vue dorsale. **D**.* Goneplax rhomboides *(Linnaeus, 1758), spécimen actuel (MSNM 2435), Mer Méditerranée. **E**.* Goneplax sacci *Crema, 1895, carapace (GPDG 0194) en vue dorsale. Barres d'échelle : 1 cm.*

Material and measurements: One complete carapace (GPDG 0160: lcxp = 15 mm; wcxp = 20 mm).

Description: Suboval carapace, wider than long (lcxp/wcxp = 0.75) slightly convex longitudinally and transversely; bilobate front, engraved medially; frontal margin with some spiny tubercles and one spine on both outer angles; wide orbits; supraorbital margin with two fissures and one raised preorbital tooth well distinct from front by a groove; convex anterolateral margins, with four spines (excluding postorbital spine); first spine small in size, very close to postorbital spine; other three spines strong and equal in size; posterolateral margin longer than the previous one, converging to posterior margin; posterior margin slightly convex, with a granulate ridge; dorsal regions marked by very weak grooves; wide frontal region, marked by a median groove; well-raised oval epigastric lobes; meso and metagastric regions in subpentagonal relief; anterior part of mesogastric region extending in a narrow and elongate process between protogastric regions; protogastric region wide, slightly raised, marked along margins by very weak hepatic grooves; very large oval cardiac region, almost flat, not marked along margins by branchiocardiac grooves; subtriangular hepatic regions not marked by cervical groove; wide branchial regions, with a weak granulate epibranchial relief located posterior to cervical groove; anterior dorsal surface with granules arranged randomly; posterior dorsal surface with small pits on cardiac and posterior branchial regions.

Discussion: The studied specimen shows some morphological affinities with the extant *Pilumnus hirtellus* (Linnaeus, 1761) (Fig. 20B), having anterolateral margins with four spines (excluding postorbital spine). However, *P. hirtellus* has a carapace that is almost as long as wide, less developed orbits, narrower cardiac region, and smooth dorsal surface with many pits. The studied specimen also shows morphological affinities with the Miocene species from Europe. However, *Pilumnus olivellai* Müller, 1993, from the Miocene (Langhian) of Olérdola (Spain) differs in having a deflected front with two elongated lobes, short anterolateral margins with three subequal teeth, and a smooth dorsal surface (Müller, 1993); *Pilumnus scaber* Gatt and De Angeli, 2010, from the Miocene (Messinian) of Malta differs in having anterolateral margins with four spines, an indistinct cardiac region, and a dorsal surface with spiny tubercles; *Pilumnus mediterraneus* (Lőrenthey, 1898) from the middle Miocene (Badenian) of Austria, Hungary, Poland (Müller, 1984, 1996, 1998) differs in having a narrower carapace, anterolateral margins adorned with a lobe-like, flat first tooth, and three outer teeth, a narrower cardiac region, and a dorsal surface with small granules. Moreover, De Angeli et al. (2009) reported *Pilumnus ristorii* (new replacement name for *Pilumnus spinosus* Ristori, 1886) from the Pliocene of Pianosa Island (Livorno) and Terre Rosse (Siena, Toscana). *Pilumnus spinosus* was originally described by Ristori (1886), from the Pliocene of San Venanzio, Modena (Emilia Romagna, northern Italy). This species, known only by one carpus and two propodi, does not allow comparison with the studied specimen.

The specimen from "La Serra" quarry can be considered as a Pliocene intermediate form between the Miocene and the extant species. Although the main morphological affinities are with *P. hirtellus*, the studied specimen has poorly preserved frontal and anterolateral margins and systematic assignment is not certain.

Pilumnus is known in the Mediterranean Sea with *P. aestuarii* Nardo, 1869, *P. hirtellus* (Linnaeus, 1761), *P. inermis* A. Milne Edwards and Bouvier, 1894, *P. spinifer* H. Milne Edwards, 1836, and *P. villosissimus* (Rafinesque, 1814). These species live in shallow water in various substrates including muddy, sandy, rocky bottoms, and under stones and even among the holdfasts of seaweeds. *Pilumnus* cf. *P. hirtellus* is not rare at "La Serra" quarry but mainly represented by incomplete chelipeds.

Superfamily Eriphioidea MacLeay, 1838

Family Eriphiidae MacLeay, 1838

Genus ***Eriphia*** Latreille, 1817

Type species: *Cancer spinifrons* Herbst, 1785, subsequent designation by H. Milne Edwards (1842) in H. Milne Edwards (1836–1844).

Included fossil species: See Schweitzer et al. (2010).

Eriphia cocchii Ristori, 1886

Eriphia cocchii Ristori, 1886: 105, pl. 2, figs 3, 4, 11, 13; pl. 3, figs 1, 2.

Eriphia punctulata Ristori, 1886: 109, pl. 2, figs 2, 15, 16.

Eriphia cocchii–Ristori, 1891a: 9. — Fucini, 1910: 3, figs 1 a, c, 2. — Glaessner, 1929: 149. — Delle Cave, 1981: 46. — De Angeli and Garassino, 2006: 67. — De Angeli et al., 2009: 186. — Schweitzer et al., 2010: 131.

Eriphia punctulata-Delle Cave, 1981: 47.

Geological age: Early Pliocene (Zanclean).

Material and measurements: Four specimens including one complete cheliped, lacking the distal part of the dactylus (GPDG 0139: lp = 28 mm; h = 22 mm; li = 17 mm); one carpus (GPDG 0140) and two incomplete index (GPDG 0141, 0142).

Discussion: Although the studied specimens are poorly preserved, some characters, such as the carpus and the propodus with strong spines and the index with a strong rounded proximal molariform tooth, allowed assigning them to *Eriphia cocchii*. Ristori (1886) recorded for the first time this species from the Pliocene of Montrappoli (Firenze, Toscana, central Italy) and Montebicchieri (Pisa, Toscana, central Italy). Later Fucini (1910) reported one specimen of this species from the Pliocene of Spicchio (Empoli, Toscana, central Italy). Moreover, Fucini (1910) considered *Eriphia punctulata* Ristori, 1886, from the Pliocene of Montrappoli to be synonymous with *E. cocchii*. Recently, De Angeli et al. (2009) reported this species from the early Pliocene (Zanclean-Piacentian) of Balconevisi (Pisa, Toscana, central Italy) and Pietrafitta and Terre Rosse (Siena, Toscana, central Italy). This species is known from Toscana, although Garassino et al. (2004) ascribed to *Eriphia* sp. three specimens from the Pliocene of Piemonte, pointing out some morphological affinities with the Toscana species, and Pasini and Garassino (2011) reported *Eriphia* cf. *E. cocchi* from the Pliocene of Lombardia (northern Italy). The Mediterranean species *E. verrucosa* (Forskäl, 1775) lives among rocks and seaweeds in shallow water among the rocky meso-intertidal Italian coastlines up to a depth of 15 m. This common species from the Pliocene of Toscana, is present at "La Serra" quarry only as fragmentary specimens at different stages of growth, with evidences of transport.

Superfamily Goneplacoidea MacLeay, 1838

Family Goneplacidae MacLeay, 1838

Subfamily Goneplacinae MacLeay, 1838

Genus ***Goneplax*** Leach, 1814

Type species: *Ocypoda bispinosa* Lamarck, 1801, by original designation.

Included fossil species: See Schweitzer et al. (2010).

Goneplax rhomboides (Linnaeus, 1758)

Fig. 20 C D

Cancer rhomboides Linnaeus, 1758: 626.

Goneplax angulata Leach, 1814: 430.

Goneplax impressa Desmarest, 1817: 504, 505.

Goneplax rhomboides–A. Milne Edwards, 1861: 88. — Heller, 1863: 104, pl. 3, figs. 3, 4. — Holthuis and Gottlieb, 1958: 99. — Zariquiey Álvarez, 1959: 5. — Holthuis, 1961: 57. — Zariquiey Álvarez, 1968: 414, fig. 138a, b. — Falciai and Minervini, 1992: 238, pl. 17, fig. 1. — Garassino and De Angeli, 2004b: 44, figs. 12–15. — De Angeli et al., 2009: 188. — Schweitzer et al., 2010: 135.

Goneplax cf. *rhomboides*–Gemmellaro, 1914: 90, pl. 1, fig. 26.

Goneplax angulata–Heller, 1863: 103. — Nobre 1936: 57; pl. 21, fig. 40. — Bouvier, 1940: 278, fig. 176; pl. 9, fig. 2. — Zariquiey Álvarez, 1946: 162, pl. 18, figs. a, b.

Gonoplax [sic] *impressa*–Desmarest, 1822: 102–104, pl. 8, figs. 13, 14.

Gonoplax [sic] *bispinosa*–Ristori, 1891b: 20.

Geological age: Early Pliocene (Zanclean).

Material and measurements: Two complete specimens. GPDG 0137: lcxp = 20 mm; wcxp = 21 mm. — GPDG 0138: lcxp = 16 mm; wcxp = 22 mm.

Description: Subrectangular carapace, convex longitudinally; straight front extended beyond the orbits; well-developed orbits; sinuous and elongate supraorbital margin; well-developed extraorbital spine; lateral margins slightly concave up to the small antero-lateral spine and convergent to the posterior margin; dorsal regions not marked; smooth dorsal surface; branchiocardiac grooves not marked; branchial regions with a weak transverse depression; very elongate chelipeds in the male individuals; elongate and dentate index and dactylus; elongate ambulatory legs.

Discussion: The morphological characters mentioned above are those of the extant *Goneplax rhomboides* (Linnaeus, 1758), widespread in the eastern Atlantic, northern Africa, and Mediterranean Sea (Fig. 20D). The carapace of this species is extremely variable and it has been incorrectly interpreted by some authors. Desmarest (1817) described *Goneplax impressa* from the Pliocene of Monte Mario (Roma, Lazio, central Italy) and illustrated it later (Desmarest, 1822). Subsequently, Ristori (1891b) reported an incomplete carapace from the same locality, ascribing it to *Goneplax bispinosa*, now synonym with *G. rhomboides*. These specimens, coming from the "yellow sands" from Monte Mario (Ristori, 1891b), are most probably referable to the Santernian (early Pleistocene) by the most recent studies on litho-bio-chronostratigraphy of the Monte Mario successions (Cosentino et al., 2009). A. Milne-Edwards (1861) reported *G. rhomboides* from the Pleistocene of Palermo (Sicilia, southern Italy). Later Gemmellaro (1914) reported the same species from the Pleistocene of Ficarazzi (Palermo, Sicilia, southern Italy). As reported by Müller (1993), the two species *Goneplax formosa* Ristori, 1886 and *Goneplax meneghinii* Ristori, 1886, from the Pliocene of Rapolano (Siena, Toscana, central Italy) probably could be ascribed to *G. rhomboides*. Recently De Angeli et al. (2009) recorded *Goneplax sacci* Crema, 1895 (= *Goneplax gulderi* Bachmayer, 1953; see discussion below) from the late Miocene (Messinian) of Rio Popogna (Livorno, Toscana, central Italy) and from the Pliocene of Monterotondo Marittimo (Grosseto, Toscana, central Italy). As reported by Müller (1993), *G. sacci* (= *Goneplax gulderi* Bachmayer, 1953) differs from *G. rhomboides* by the presence of the two well-marked transverse ridges on the carapace and by the anterior margin where every orbit is as wide as the front; in *G. rhomboides* the orbits are indeed wider than the width of the front. The studied specimens confirm the observations made by Müller (1993) and therefore they are ascribed to *G. rhomboides*, known to date in Italy from the Miocene to the Pleistocene of Piemonte, Emilia Romagna, Toscana, Lazio, and Sicilia (Ristori, 1891a; Gemmellaro, 1914; Garassino and De Angeli, 2004b; Garassino et al., 2004). *Goneplax rhomboides* (Linnaeus, 1758) (Fig. 20D) burrows in sublittoral shallow muddy and sandy bottoms from a few to about 100 m deep. Extant "multi species burrow complex", including different burrowers genera are very common in some localities (Rice and Chapman, 1971). The species is aboundant at "La Serra" quarry with specimens at different stages of growth, as testified by the incomplete or fragmentary specimens observed in the selected original sample, and not reported in this study.

Goneplax sacci Crema, 1895

Fig. 20E

Goneplax sacci Crema, 1895: 674, fig. 15.

Goneplax gulderi Bachmayer, 1953: 143, pl. 9, figs. 1–3. **syn. nov.**

Goneplax cf. *sacci*-Lőrenthey 1907: 94, pl. 3, figs. 4a–c, 6, 7; pl. 4, fig. 6. — Lőrenthey, 1909: 249, pl. 1, figs. 4 a–c, 6–7, pl. 2, fig. 6.

Goneplax cf. *saccoi*–Vía, 1948: 146, pl. 1, fig. 6. — Solé and Vía Boada 1988: 34.

Goneplax saccoi–Glaessner, 1929: 199. — Schweitzer et al., 2010: 135.

Goneplax gulderi-Müller, 1984: 96, pl. 93, figs. 2–3. — Müller, 1993: 23, fig. 11 K. — Mayoral et al., 1998: 508, fig. 2 (5). — Müller, 1998: 38. — Garassino and De Angeli, 2004b: 45. — De Angeli and Garassino, 2006: 65.

Geological age: Early Pliocene (Zanclean).

Material: One single complete carapace three-dimensionally preserved (GPDG 0194).

Description: Subrectangular carapace, wider than long, nearly smooth dorsally with two smooth continuous transverse ridges slightly convex anteriorly; regions undefined; carapace weakly convex longitudinally, notably inflated in transverse section; frontal margin straight, bilobate with deep median longitudinal groove; wide, sinuous supraorbital margin; small, rounded postorbital tooth, directed forward; anterolateral margin wide, convex, smooth, with very small reduced marginal spine at the end of two transverse rounded ridges on dorsal surface of carapace; smooth, rounded posterolateral margin; appendages not preserved.

Discussion: Although the specimen is not well preserved, it differs from *Goneplax rhomboides* (Linnaeus, 1758) in having more convex anterolateral margins, slightly expanded laterally, with short anterolateral spines. The frontal margin is wider than that of *G. rhomboides* and more similar to that of *G. sacci* Crema, 1895 (= *G. gulderi* Bachmayer, 1953), reported from the Piacentian (late Pliocene) of Monte Capriolo (Bra, Piemonte) and from the Messinian (late Miocene) and Pliocene of Rio Popogna (Livorno, Toscana) and Monterotondo Marittimo (Grosseto, Toscana) (De Angeli et al., 2009).

Müller (1993), comparing the main characters of the holotypes of *G. sacci* and *G. gulderi* from the Miocene of Austria and Hungary, has considered *G. sacci* to be a synonym of *G. gulderi*. However following the rules of the International Code of Zoological Nomenclature, *G. gulderi* is a junior synonym of *G. sacci*.

5. Palaeoenvironmental and palaeoecological comments (A.G., P.G., A.D.A., S.C., F.F., A.B., R.B.)

The peculiar, varied and rich taphocoenosis from “La Serra” quarry allows a possible reconstruction of the palaeoenvironment, based on lithostratigraphic and biostratigraphic data and comparison with the habitat and behaviour of the correlated extant decapods. The sedimentological composition of the layers preserving the crustacean remains, indicates a depositional environment with low energy on the bottom, favoring specimen preservation in absence of important burial events. A lower shoreface to offshore transition marine environment, with only limited fluvial supply, lateral to a brackish protected lagoon, can be reconstructed (Fig. 8). This environment developed during a transgressive trend, in an estuarine coastal context.

The malacological assemblage includes mainly gastropods and bivalves and scarce scaphopods (Table 1). The study of the richer fauna collected during the excavations in the quarry on Unit 4 is still in progress enlarging the number of species presents in the taphocoenosis. The preliminary note (Forli, pers. comm., 2011) listed in particular the presence of various species or subspecies (Table 2: *Rissoa variabilis, Alvania sculpta, Jujubinus striatus, Tricolia pullus, Hexaplex trun-*

Table 1
Invertebrate assemblage of "La Serra" quarry (without decapod crustaceans).
Assemblage des invertébrés de la carrière « La Serra » (sans les crustacés décapodes).

BIVALVIA
Acanthocardia sp.
Anadara diluvii (Lamarck, 1819)
Cardium sp.
Cerastoderma edule (Linnaeus, 1758)
Corbicula fluminalis (Müller, 1774)
Corbula gibba (Olivi, 1792)
Donax sp.
Glans intermedia (Brocchi 1814)
Laevicardium crassum (Gmelin, 1791)
Margaritifera sp.
Mytilus cf. *scaphoides* (Bronn, 1831)
Neopycnodonte cochlear (Poli 1795)
Nucula placentina (Lamarck, 1819)
Ostrea edulis (Linnaeus, 1758)
Ostrea lamellosa Brocchi, 1814
Ostrea virleti (Deshayes 1832)
Sinodia brocchii (Deshayes, 1836)
Sinodia gigas (Lamarck, 1818)
Tellina nitida (Poli 1791)
Venus multilamella (Lamarck, 1818)

SCAPHOPODA
Dentalium sexangulum (Gmelin, 1790)

GASTEROPODA
Aporrhais pespelecani (Linnaeus, 1758)
Bithynia leachi Sheppard, 1823
Bittium reticulatum (Da Costa, 1778)
Bolinus brandaris (Lamarck, 1822)
Bolinus brandaris turolarinus (Lamarck, 1822)
Calyptrea chinensis (Linnaeus, 1758)
Conus brocchii Bronn, 1828
Conus betulinoides Lamarck, 1810
Conus sp.
Emmericia umbra (De Stefani, 1877)
Gyraulus albus (Müller, 1774)
Haustator sp.
Hexaplex (Trunculariopsis) trunculus (Linnaeus, 1758)
Jujubinus striatus Linnaeus, 1758
Melanoides curvicosta (Deshayes, 1832)
Melanopsis (M.) affinis de Férussac, 1820
Narona sp.
Nassarius clathratus (Born, 1788)
Nassarius mutabilis (Brocchi, 1814)
Natica tigrina (Defrance, 1825)
Natica sp.

OSTRACODA
Argilloecia kissamovensis Sissingh, 1972
Aurila cephalonica Mostafawi & Matzke-Karasz, 2006
Aurila convexa (Baird, 1850)
Aurila punctata (von Münster, 1830)
Aurila sp.
Candona angulata (Müller, 1900)
Candona sp.
Cimbaurila cimbaeformis (Seguenza, 1883)
Costa edwardsii (Roemer, 1838)
Cyprideis torosa (Jones, 1850)
Cytheridea neapolitana Kollmann, 1960
Henryhowella parthenopaea Bonaduce, Barra & Aiello, 1999
Heterocypris salina (Brady, 1868)
Ilyocipris bradyi Sars, 1868
Ilyocipris gibba (Ramdohr, 1808)
Loxoconcha ovulata (Costa, 1853)
Palmoconcha turbida (Müller, 1894)
Pontocythere turbida (Müller, 1894)
Pseudocandona sp.
Tyrrhenocitere pontica (Livental) in Agalarova, Kadyrova & Kulieva, 1961

NANNOFOSSILS
Calcidiscus macintyrei (Bukry & Bramlette, 1969)
Coccolithus pliopelagicus Wise, 1973
Helicosphaera carteri (Wallich, 1877) *in* Kamptner, 1954
Helicosphaera intermedia Martini, 1965
Reticulofenestra haqii Backmann, 1978
Reticulofenestra minuta Roth, 1970
Reticulofenestra pseudoumbilicus (Gartner, 1967) *in* Gartner, 1969

CARPOFLORA
Najas sp.
Polygonum sp.
Selaginella pliocenica Dorofeev, 1957
Scirpus isolepioides Mai & Walther, 1988

FORAMINIFERA
Ammonia beccarii (Linnaeus, 1758)
Ammonia parkinsoniana d'Orbigny, 1839
Ammonia tepida (Cushman, 1926)
Cancris auriculus (Fitchell & Moll, 1798)
Cribroelphidium decipiens (Costa, 1856)
Elphidium complanatum d'Orbigny, 1839
Elphidium crispum (Linnaeus, 1758)

Table 1 (*Continued*)

Neverita josephina (Risso, 1826)
Prososthenia meneghiniana (De Stefani, 1874)
Prososthenia etrusca (De Stefani, 1880)
Purpurellus veranyi (Paolucci, 1866)
Rissoa variabilis (von Mühfeldt, 1824)
Tectonatica astensis (Sacco, 1890)
Tricolia pullus Linnaeus, 1758
Turritella sp.
Valvata (Cincinna) piscinalis (Müller, 1774)

Lagena sp.
Lobatula lobatula (Walker & Jacob, 1798)
Nonionella turgida (Williamson, 1858)
Patellina corrugata Williamson, 1858
Pyrgo sp.
Quinqueloculina bosciana d'Orbigny, 1839
Quinqueloculina carinatostriata (Wiesner, 1923)
Quinqueloculina poeyana d'Orbigny, 1839
Quinqueloculina seminula (Linnaeus, 1758)
Spiroloculina angulata Terquem, 1878
Triloculina bicarinata d'Orbigny, 1826

culus, Bolinus brandaris turolarius, Bittium reticulatum, Conus sp.*, Tectonatica astensis, Venus multilamella, Anadara diluvii*), indicative of the presence of a possible *Posidonia* bed environment, but remarking the small size of the specimens and the absence of other taxa such as *Gibbula* Risso, 1826.

Moreover, some remains of vertebrates are preserved in hardened concretions (Fig. 3 C), especially indeterminate teleostean fishes, whereas teeths of selacians are rare and small (Fig. 3A, B). Carbonized and poorly preserved vegetal remains are also presents into some concretions. Finally some remains of marine invertebrates (Fig. 3D–F), such as sponge, regular echinoids, and probable squid cuttlebone are isolated or preserved in some concretions.

Among the crustaceans the rich burrower-community is documented by *Axius, Callianassa, Calliaxina, Goneplax* and especially by *Gebiacantha*, the most common and abundant thalassinid present in the taphocoenosis. The specimens belonging to *Gebiacantha* lack the poorly mineralized pleon and are preserved in hardened irregular small concretions, including two or more specimens, preserving some pereiopods and the front part of the carapace more or less articulated in living position, testifying to the absence of transport and rapid fossilization at the time of origin of the nodules. This kind of preservation was probably due to the fact that the specimens are mainly moulds that fossilized quickly in the burrows, similar to *Thalassina anomala* (Herbst, 1804) found *in situ* in the coastal mangrove-environment from the Pleistocene around Darwin Bay in northern Australia (Bishop and Williams, 2005). *Axius, Callianassa*, *Calliaxina*, *Gebiacantha*, and *Goneplax* are active burrowers and indicate an environment with a high concentration "burrower-community" in deep water with muddy-sandy and shelly bottom. Two other forms of callianassids and some axiidean remains were also recognized, but their specific identification was impossible due to the poor preservation. The large number of taxa and specimens, the quality of preservation, and the richness of individuals of both sexes at different stages of grow indicate that a large part of this burrower community was autochthonous, preserved *in situ*, and not linked to accumulation by transport. No evidence of the original burrower activity or bioturbation is preserved or actually observable in the layers of Unit 4. Probably these structures were destroyed by subsequent community replacement as indicated by the environmental and faunal change in the upper part of Unit 4, or collapsed due to diagenetic processes. Nevertheless, the burrower activity is sparcely documented only at the base of the section, were the ichnogenus *Psilonichnus* is found. The anomurans are rare and poorly documented, recorded only by some fragmentary chelae ascribed to *Pagurus alatus* and *Pagurus* sp. On the contrary their predatory behaviour is documented by the presence of numerous gastropod shells typically damaged by putative pagurids, as also reported in other Pliocene assemblages from Italy (Pasini and Garassino, 2006).

Table 2
Decapod crustaceans from the Pliocene of Toscana: updated and revised list of the decapod crustaceans reported from the Pliocene of the Toscana Basin, central Italy (after Garassino and De Angeli, 2004b; De Angeli and Garassino, 2006; De Angeli et al., 2009). The geological age is reported in square bracklets only for the species having precise chronostratigraphic data.
Crustacés décapodes du Pliocène de Toscane : liste révisée et mise à jour des crustacés décapodes du Pliocène du bassin de Toscane, Italie centrale (d'après Garassino and De Angeli, 2004b ; De Angeli and Garassino, 2006 ; De Angeli et al., 2009). L'âge géologique est indiqué entre crochets uniquement pour les espèces ayant des données chronostratigraphiques précises.

AXIIDEA de Saint Laurent, 1979
Pleocyemata Burkenroad, 1963
Axiidae Huxley, 1879
Axius Leach, 1816
Axius sp. – "La Serra" quarry, San Miniato (Pisa) [Zanclean]
Callianassidae Dana, 1852
Callianassinae Dana, 1852
Callianassa Leach, 1814
Callianassa chalmasii Brocchi, 1883 – "La Serra" quarry, San Miniato (Pisa) [Zanclean], Terre Rosse (Siena)
Callianassidae *sensu lato* species 1 – "La Serra" quarry, San Miniato (Pisa) [Zanclean]
Callianassidae *sensu lato* species 2 – "La Serra" quarry, San Miniato (Pisa) [Zanclean]
Eucalliacinae Manning and Felder, 1991
Calliaxina Ngoc-Ho, 2003
Calliaxina cf. *punica* (de Saint Laurent & Manning, 1982) – "La Serra" quarry, San Miniato (Pisa) [Zanclean]

GEBIIDEA de Saint Laurent, 1979
Laomediidae Borradail, 1903b
Jaxea Nardo, 1847
Jaxea cf. *J. nocturna* Nardo, 1847 – Castelfiorentino (Firenze)
Thalassinidae Latreille, 1831
Thalassina Latreille, 1806
Thalassina sp. – Spicchio, Empoli (Firenze)
Upogebiidae Borradaille, 1903
Gebiacantha Ngoc-Ho, 1989
Gebiacantha tuscia Garassino, Pasini, De Angeli & Charbonnier sp. nov. – "La Serra" quarry, San Miniato (Pisa) [Zanclean]

ANOMURA MacLeay, 1838
Paguroidea Latreille, 1802
Diogenidae Ortmann, 1892
Dardanus Paulson, 1875
Dardanus substriatus (A. Milne Edwards, 1861) – Terre Rosse (Siena), Balconevisi, San Miniato (Pisa), Volterra (Pisa)
Paguridae Latreille, 1802
Pagurus Fabricius, 1775
Pagurus alatus Fabricius, 1775 – "La Serra" quarry, San Miniato (Pisa) [Zanclean]
Pagurus squamosus Ristori, 1886 – Sarteano (Siena)
Pagurus sp. – "La Serra" quarry, San Miniato (Pisa) [Zanclean]

BRACHYURA Linnaeus, 1758
Podotremata Guinot, 1977
Dromioidea De Haan, 1833
Dromiidae De Haan, 1833
Dromiinae De Haan, 1833
Dromia Weber, 1795
Dromia neogenica Müller, 1984 – "La Serra" quarry, San Miniato (Pisa) [Zanclean]
Dromia sp. – "La Serra" quarry, San Miniato (Pisa) [Zanclean]

Table 2 (*Continued*)

Raninoidea De Haan, 1839
Raninidae De Haan, 1839
Lyreidinae Guinot, 1993
Lysirude Goeke, 1985
  Lysirude paronae (Crema, 1895) – "I Sodi" quarry, Castelnuovo Berardenga-Scalo (Siena)
Tribolocephalus Ristori, 1886
  Tribolocephalus laevis Ristori, 1886 – Orciano (Pisa)
Raninoidinae Lőrenthey *in* Lőrenthey & Beurlen, 1929
Raninoides H. Milne Edwards, 1837
  Raninoides pliocenicus De Angeli, Garassino & Pasini, 2009 – Monterotondo Marittimo (Grosseto)
Eubrachyura de Saint Laurent, 1980
Heterotremata Guinot, 1977
Dorippoidea MacLeay, 1838
Dorippidae MacLeay, 1838
Medorippe Manning & Holthuis, 1981
  Medorippe cf. *M. ampla* Garassino, De Angeli, Gallo & Pasini, 2004 – "La Serra" quarry, San Miniato (Pisa) [Zanclean]
Calappoidea De Haan, 1833
Calappidae De Haan, 1833
Calappa Weber, 1795
  Calappa granulata (Linnaeus 1758) – Presciano, Terre Rosse (Siena)
  Calappa sp. – Orciano (Pisa)
Leucosioidea Samouelle, 1819
Leucosiidae Samouelle, 1819
Ebaliinae Stimpson, 1871
Ebalia Leach, 1819
Ebalia cranchii Leach, 1817 – Parrana San Giusto (Livorno) [Plio-Pleistocene]
  Ebalia cf. E. deshayesi Lucas, 1846 – Poggio alla Staffa (Siena)
  Ebalia fucinii Ristori, 1892 – Spicchio, Empoli (Firenze); Parrana San Giusto (Livorno) [Plio-Pleistocene]
Ilia Leach, 1817
  Ilia nucleus (Linnaeus, 1758) – "La Serra" quarry, San Miniato (Pisa) [Zanclean]; Spicchio, Empoli (Firenze); Ciuciano, Pietrafitta (Siena)
Palaeomyra A. Milne Edwards, 1861
  Palaeomyra bispinosa A. Milne Edwards, 1861 – La Strolla (Siena)
Leucosiinae Samouelle, 1819
Ristoria Garassino, Pasini, De Angeli & Charbonnier gen. nov.
  Ristoria pliocaenica (Ristori, 1891) – Spicchio, Empoli (Firenze); "La Serra" quarry, San Miniato (Pisa) [Zanclean]
Majoidea Samouelle, 1819
Epialtidae MacLeay, 1838
Pisinae Dana, 1851
Pisa Leach, 1814 (*in* Leach, 1813–1815)
  Pisa armata (Latreille, 1803) – "La Serra" quarry, San Miniato (Pisa) [Zanclean]
Inachidae Mac Leay, 1838
Macropodia Leach, 1814
  Macropodia sp. – "La Serra" quarry, San Miniato (Pisa) [Zanclean]
Majidae Samouelle, 1819
Maja Lamarck, 1801
  Maja squinado (Herbst, 1788) – "La Serra" quarry, San Miniato (Pisa) [Zanclean]
Parthenopoidea MacLeay, 1838
Parthenopidae MacLeay, 1838
Parthenopinae MacLeay, 1838

Table 2 (*Continued*)

- *Derilambrus* S. H. Tan & Ng, 2007
  - *Derilambrus angulifrons* (Latreille, 1825) – “La Serra” quarry, San Miniato (Pisa) [Zanclean]
- Cancroidea Latreille, 1802
- Atelecyclidae Ortmann, 1893
- *Atelecyclus* Leach, 1814
  - *Atelecyclus undecimdentatus* (Herbst, 1783) – “La Serra” quarry, San Miniato (Pisa) [Zanclean]
- Portunoidea, Rafinesque, 1815
- Portunidae Rafinesque, 1815
- Polybiinae Ortmann, 1893
- *Liocarcinus* Stimpson, 1871
  - *Liocarcinus* sp. – “La Serra” quarry, San Miniato (Pisa) [Zanclean]
  - *Liocarcinus* sp. – Pietrafitta (Siena)
- Portuninae Rafinesque, 1815
- *Portunus* Weber, 1795
  - *Portunus edwardsi* Sismonda 1846 – Spicchio, Empoli (Firenze)
  - *Portunus* sp. – Isola di Pianosa (Livorno)
- Thalamitinae Paulson, 1875
- *Thalamita* Latreille, 1829
  - *Thalamita italica* Garassino, Pasini, De Angeli & Charbonnier sp. nov. – “La Serra” quarry, San Miniato (Pisa) [Zanclean]
- Carpilioidea Ortmann, 1893
- Tumidocarcinidae Schweitzer, 2005
- *Titanocarcinus* A. Milne Edwards, 1863
  - *Titanocarcinus subovalis* Ristori,1896 – Monteroni d’Arbia (Siena)
  - *Titanocarcinus edwardsi* (E. Sismonda, 1846) – Orciano (Pisa)
- Pilumnoidea Samouelle, 1819
- Pilumnidae Samouelle, 1819
- Pilumninae Samouelle, 1819
- *Pilumnus* Leach, 1816
  - *Pilumnus* cf. *P. hirtellus* (Linnaeus, 1761) – “La Serra” quarry, San Miniato (Pisa) [Zanclean]
  - *Pilumnus ristorii* new replacement name for *P. spinosus* Ristori, 1886 – Terre Rosse (Siena), Isola di Pianosa (Livorno)
- *Galenopsis* A. Milne Edwards, 1865
- *Galenopsis* sp. – Orciano (Pisa)
- Eriphioidea MacLeay, 1838
- Eriphiidae MacLeay, 1838
- *Eriphia* Latreille, 1817
  - *Eriphia cocchii* Ristori, 1886 – “La Serra” quarry, San Miniato [Zanclean]; Balconevisi, San Miniato; Montebicchieri; Val d’Era (Pisa); Val d’Elsa, Montrappoli, Spicchio, Poggio all’Olio; Empoli (Firenze). Pietrafitta; Terre Rosse; Torrita Val di Chiana (Siena)
- Xanthoidea MacLeay, 1838
- Xantidae MacLeay, 1838
- Euxanthinae Alcock, 1818
- *Monodaeus* Guinot, 1967
  - *Monodaeus bortolotti* Delle Cave, 1988 – Botro dell’Alpino, Volterra (Pisa); Monterotondo Marittimo (Grosseto)
- Goneplacoidea MacLeay, 1838
- Euryplacidae Stimpson, 1871
- Goneplacinae MacLeay, 1838
- *Chlinocephalus*, Ristori, 1886
  - *Chlinocephalus dimissifrons*, Ristori, 1886 – Mucigliani (Siena)
- *Simonellia* Vinassa de Regny, 1897
  - *Simonellia quiricensis* Vinassa de Regny, 1897 – San Quirico d’Orcia (Siena)
- Goneplacidae MacLeay, 1838

Table 2 (*Continued*)

Goneplax Leach, 1814
  Goneplax rhomboides (Linnaeus, 1858) – Rapolano; “I Sodi” quarry (Siena); “La Serra” quarry, San Miniato (Pisa) [Zanclean]
  Goneplax sacci Crema, 1895 – “La Serra” quarry, San Miniato (Pisa) [Zanclean]; Monterotondo Marittimo (Grosseto)
Thoracotremata, Guinot 1977
Ocypodoidea Rafinesque, 1815
Ocypodidae Rafinesque, 1815
Ocypodinae Rafinesque, 1815
Ocypode Webwer, 1795
Ocypode italica Garassino, De Angeli, Pasini & Tangocci, 2010 – Poggibonsi (Siena) [Piacentian]
Grapsoidea MacLeay, 1838
Varunidae H. Milne Edwards, 1858
Asthenognathus Stimpson, 1858
  Asthenognathus sp. – Monterotondo Marittimo (Grosseto)

Four common specimens of gastropods are here figured as examples of this indirect predatory activity (Fig. 21). Probably this limited, yet thickly inhabited environment, was only temporarily frequented by individuals hunting for food, coming from deeper waters; alternatively, the damaged shells were transported post-mortem. Among the brachyurans are four genera having fossorial behaviour, living embedded in soft sandy or muddy sediments, *Ilia*, *Atelecyclus*, *Liocarcinus* and the very common *Ristoria* gen. nov. Other less common brachyurans, such as *Dromia, Pisa*, *Maja*, *Macropodia*, *Thalamita*, *Pilumnus*, and *Eriphia* lived under stones or in rocky environments and in

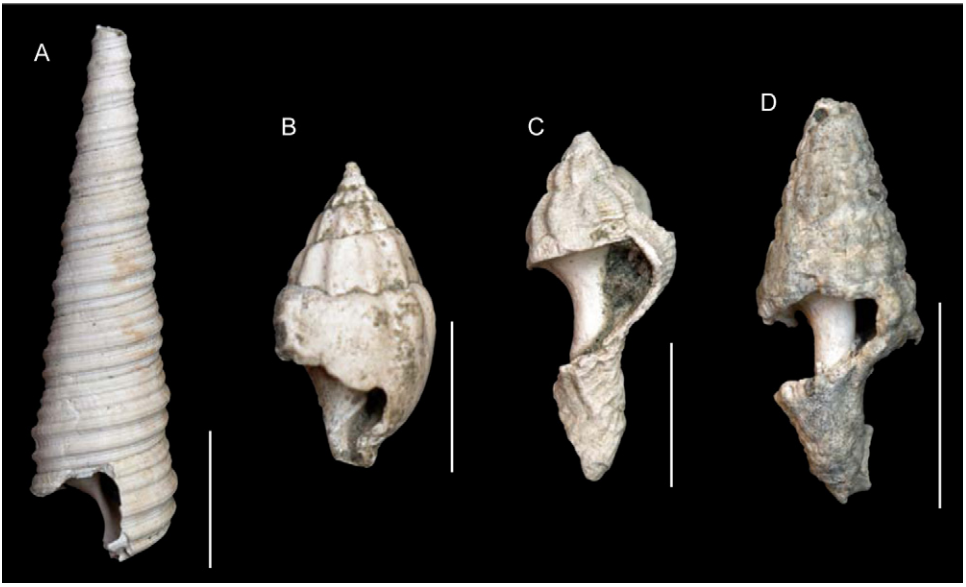

Fig. 21. Gastropod shells preyed by putative pagurids. **A**. *Turritella* sp. (GPDG 0223). **B**. Nassarid *sensu lato* (GPDG 0224). **C**. *Ocinebrina* sp. (GPDG 0222). **D**. *Clavatula* sp. (GPDG 0221). Scale bars: 1 cm (A, D) and 5 mm (B, C).
Coquilles de gastéropodes probablement endommagées par des paguridés. ***A***. Turritella *sp. (GPDG 0223).* ***B***. Nassarid sensu lato *(GPDG 0224).* ***C***. Ocinebrina *sp. (GPDG 0222).* ***D***. Clavatula *sp. (GPDG 0221). Barres d’échelle : 1 cm (**A**, **D**) et 5 mm (**B**, **C**).*

the presence of sea grass. The presence of *Ristoria pliocaenica* is remarkable because it is the first record for a Leucosiinae from the Cenozoic of the Mediterranean Basin. Moreover, *Gebiachanta* is reported for the first time in the fossil record.

The decapod assemblage of "La Serra" quarry seems to indicate a restricted exclusive environment, favourable to different groups of decapods, mainly having fossorial behaviour, in shallow oxygenated and calm waters with low energy, situated along a coastal margin, with a sandy-muddy and shelly bottoms or near possible seaweed beds. Beside, some decapod remains and malacological allochthonous incomplete specimens were probably transported and mixed into the original biocoenosis under lower energy condition. This environment is reminiscent of the extant *Posidonia oceanica* (Linnaeus) Delile, 1813, or similar sea-grass bottoms and the related bio-community, still present along the coastlines in nearly all the Mediterranean Sea. For instance, the extant *Posidonia* beds occupy an endemic benthonic infralittoral zone in the Mediterranean Sea, in oxygenated waters with a 35 g/L salinity, ranging from a few centimetres to 30–40 m deep, on hard or soft bottoms. This important ecosystem is inhabited by many different invertebrate organisms, including taxa that live on or among plant leaves, or at the base of the grass between the rhizomes and intermingled roots. The typical malacofauna includes gastropods and bivalves; most of them were small sized specimens. The typical decapod fauna includes several species of galatheids, majids, portunids and xanthids and some anomuran paguroids. The crustacean endofauna is characterized by some species of burrowing thalassinids [e.g., *Gourretia denticulata* (Lutze, 1937), *Upogebia mediterranea* Noël, 1992] that are typical of the "matte" structures.

Based upon these data, the studied fossil assemblage may be indicative of transport from a nearby *Posidonia* bed, or of the presence of an organic bottom composed of remains of *Posidonia* leaves and part of their epibiont fauna.

6. Conclusions (A.G., G.P., A.D.A., S.C., F.F., A.B., R.B.)

De Angeli et al. (2009) reported an updated list of the Pliocene *sensu lato* decapod crustaceans from different localities of Toscana; a total of 14 families, 23 genera, and 21 species. Later, Garassino et al. (2010) added another family to this list, with a single genus and species. The studied sample from the early Pliocene of "La Serra" quarry includes 16 families with 19 genera represented by a total of 22 species. These data indicate that more than 80% of the genera and about 75% of the species previously known from the Pliocene of the Toscana are present in the same restricted "La Serra" palaeoenvironment. Consequently, the decapod crustaceans from "La Serra" quarry constitute the most abundant and diversified community of the whole Mediterranean Pliocene. Therefore, a reviewed and updated list of the decapod fauna from the Pliocene of Toscana is proposed herein (Table 2).

The study of this unsuspected rich community allows describing the new thalassinid *Gebiachanta tuscia* sp. nov. and the new portunid *Thalamita italica* sp. nov. *Calliaxina*, *Gebiacantha*, *Ristoria* gen. nov. and *Macropodia* are reported for the first time in the fossil record. The extant *Pagurus alatus*, *Ilia nucleus*, and *Derilambrus angulifrons* are reported for the first time from the Pliocene. Two fossil species, already known only from the Miocene, as *Dromia neogenica* and *Medorippe* cf. *M. ampla*, and three species previously reported only from the Pleistocene, as *Ilia nucleus*, *Pisa armata* and *Derilambrus angulifrons*, are added to the Mediterranean Pliocene record. Moreover, *Axius* sp., *Calliaxina* cf. *C. punica*, *Pagurus alatus*, *Dromia neogenica*, *I. nucleus*, *P. armata*, *D. angulifrons*, *Atelecyclus undecimdentatus*, and *Pilumnus* cf. *P. hirtellus*, are reported for the first time from the Pliocene of Italy. Besides these species, *Maja squinado* is also reported for the first time from the Pliocene of Toscana. Finally, two specimens have been assigned to Callianassidae *sensu lato* and 13 specimens to indeterminate axiideans. *Ristoria pliocaenica* is thus the oldest and sole record of Leucosiinae, having a probable Indo-Pacific origin, testifing to a possible first introduction in the Mediterranean area through the possible reopening of eastern marine corridors during the early Pliocene. Finally, the composition of the bio-community and the palaeontological and sedimentological data indicate a near-shore, sub-littoral local environment, favourable to different groups of various decapods, mainly having a burrowing or fossorial behaviour, in calm and very shallow, near shore oxygenated waters, with soft and, in part, hard or shell bottoms and seaweeds (e.g. *Posidonia* beds).

This discovery enlarges notably our knowledge of the distributional area, the diversity, and the environmental behaviour of some decapod species that are at the origin of the extant crustacean populations of the Mediterranean Sea, approximating the restoration of normal marine conditions after the Messinian salinity crisis. In conclusion the "La Serra" assemblage is relatively modern but represents only a sporadic episode in the general context of the Pliocene which cannot be taken as an absolute result.

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