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NEW REPORT OF "*PORTUNUS*" *MONSPELIENSIS* (BRACHYURA, PORTUNIDAE) FROM THE EARLY MIOCENE OF CARNIC PREALPS (FRIULI VENEZIA GIULIA) AND THE GEOLOGIC KNOWLEDGE OF THE AREA

NUOVO RINVENIMENTO DI "*PORTUNUS*" *MONSPELIENSIS*
(BRACHYURA, PORTUNIDAE) NEL MIOCENE INFERIORE
DELLE PREALPI CARNICHE (FRIULI VENEZIA GIULIA)
E LA CONOSCENZA GEOLOGICA DELL'AREA

Abstract - Some specimens of crustacean brachyurans from the Miocene levels of the Meduna creek area (Carnic Prealps, NE Italy) dated to the Burdigalian are described. It is a lot of 36 specimens from the collections of the Museo Friulano di Storia Naturale (Udine) and all referable to "*Portunus*" *monspeliensis* (A. Milne-Edwards, 1860).

Key words: Crustacea, Brachyura, Taxonomy, Palaeogeography, Stratigraphy, Miocene, Carnic Prealps, Italy.

Riassunto breve - Vengono descritti alcuni esemplari di crostacei brachiuri provenienti dai livelli miocenici dell'area del Torrente Meduna (Prealpi Carniche) datati al Burdigaliano. Si tratta di un lotto di 36 reperti conservati nelle collezioni del Museo Friulano di Storia Naturale (Udine) e tutti riferibili a "*Portunus*" *monspeliensis* (A. Milne-Edwards, 1860).

Parole chiave: Crustacea, Brachyura, Tassonomia, Paleogeografia, Stratigrafia, Miocene, Prealpi Carniche, Italia.

Introduction

Updating of the collections' databases of the Museo Friulano di Storia Naturale (Udine), various specimens of crustacean brachyurans have been identified, most of them fragmentary, coming from Miocene levels of the western Carnic Prealps. The specimens come from two outcrops, very close to each other and belonging to the same stratigraphic level, along the Rugo (= Rio, Creek) Mizza and near the confluence of the same in the Meduna Creek (Fig. 1).

Considering the scarcity of informations available in literature about this group in relation with the Friulian Miocene, it was considered appropriate to carry out an initial cleaning operation, some detailed stratigraphic investigations and a more in-depth paleontological study.

History of Research

In Friuli, Miocene rocks emerge exclusively in the Carnic Prealps and in an isolated strip emerging from recent deposits in the area of Pozzuolo del Friuli (Udine). The terrigenous succession deposited in the

Tortonian-Aquitainian interval preserves a large amount of both marine and continental fossils that have been studied since the dawn of geological research in this region.

Sporadic citations of fossils from this area date back to the first half of the XVIII century, in the publications by Antonio VALLISNIERI (1721) and Anton Lazzaro MORO (1740); later, Antonio ZANON (1767, 1768) mentions them in his studies on peat and marl.

Tommaso Antonio CATULLO (1827, 1837, 1842) provided the first stratigraphic and structural indications, albeit rather vague and in some cases inaccurate in some of his publications on the Veneto-Friulian Prealps. Achille DE ZIGNO (1850) was the first to correctly attribute part of the conglomerates cropping out in the pre-Alps between Treviso and Friuli to the Miocene, a hypothesis that was also accepted by CATULLO (1856).

In the second half of the XIX century, Giulio Andrea PIRONA (1856, 1861, 1876) and Torquato TARAMELLI (1869, 1877, 1881, 1882) began to define in more detail the Miocene succession of Friuli; TARAMELLI (1869) also published a paleontological study on the fossil echinids of Friuli in which fossils of the Miocene succession are reported for the first time.



Fig. 1 - Map with the position of the mentioned locality (a); outcrop 1 is indicated in photo (b); on the right: view from north of the outcrop 1 (c) with a detail (d) of a fossil fragment (map ed. Tabacco, Udine; photo M. Ponton).

- La posizione geografica della località citata (a); l'affioramento 1 è indicato nella foto (b); a destra: vista da nord dell'affioramento 1 (c) con un dettaglio (d) di un frammento fossile (mappa della ed. Tabacco, Udine; foto M. Ponton).

In the early years of the XX century, Giuseppe STEFANINI (1911 a, b, 1915a, b, 1919), Egidio FERUGLIO (1924-25) and Silvia ZENARI (1927) accurately described the Miocene succession of Friuli, framing it in the geological structure of the region. STEFANINI (1916, 1919) also figured, in some monographs, part of the rich fauna preserved in this sedimentary succession (crabs are not mentioned for the Friuli area).

Studies about the Miocene of Friuli have been interrupted from the end of the '20s until the end of the '60s of the XX century, when the interest in the Miocene succession of this area is revived, with researches from the stratigraphic and the structural point of view (GELATI 1969; STEFANI 1982, 1984; MARTINIS 1979; CAVALLIN 1981; VENTURINI & TUNIS 1992, 1993; BIZZARINI et al. 2020).

From a paleontological point of view, despite the abundance and diversity of the faunas that are preserved in the Miocene succession, few systematic studies have

been made after the articles by TARAMELLI (1869) and STEFANINI (1911a, b, 1915a, b, 1916, 1919).

At the beginning of the '80s of the XX century the skull of a cetacean coming from the sandstones of the Meduna Creek near Preplans (PILLERI 1982) have been illustrated. More recently, some fossils from Friuli have been examined in more general works on Italian Miocene faunas (DE ANGELI & GARASSINO 2006; STARA et al. 2016) and in a work on vertebrate faunas of Friuli (DALLA VECCHIA 2008).

The Miocene macrofuna from the Mizza-Meduna Creeks area is mainly made up of bivalves, gastropods, echinoids and more rare corals, barnacles and bryozoans. Among the vertebrate remains, fragments of fish have been reported, mainly teeth, and more rare bone remains of cetaceans.

The fossil crabs from Meduna Creek area near Preplans (Frisanco, Pordenone) have been preliminarily described by DE ANGELI & GARASSINO (2006).

Geological setting of the area

The Cenozoic section of the Meduna Creek is located in correspondence to its flow into the upper Friulian Plain near Meduno (Pordenone). This section is reported in the scientific literature dealing with the stratigraphy of the Molasse successions of the eastern Southern Alps because it is a reference for the Friulian sector with respect to those of more western sectors (STEFANINI 1911a, b, 1915a, b, 1919; ZENARI 1927; GELATI 1969; STEFANI 1982, 1984, 1987, MASSARI et al. 1986; MELLERE et al. 2000; GRANDESSO & STEFANI 2008). The section occurs in the most external deformation belt of the Carnic Prealps where the Cenozoic lithostratigraphic units are deformed by antiform and sinform folds, often with verticalized or upside down bedding.

The fossil faunas object of this paper come mostly from (Fig. 1) a level in the right bank of the creek streaming from the "Pichiàs" spring (close and parallel to the Mizza Creek), a few meters from the confluence of the creek with the Meduna Creek (outcrop 1) near Preplans village. Some of them come from the same level outcropping in the high course of the Mizza Creek (outcrop 2). They have been found into a few-meters-thick horizon composed of fine and gray-greenish sandstone. This sandstone is well-sorted, quartz and micas-rich, faintly glauconitic and scarcely cemented (carbonate cement).

At the base of the outcrop, a several-meters-thick succession of prevailing yellowish and compact ibrid arenite alternated with siltstone in the lower portion is present; it crops out just upstream of the Mizza Creek, from which it got the name of "arenaria del Rugo Mizza" (Mizza Creek sandstone; STEFANI 1982). In the first papers, it included also the horizon that is the subject of this study; therefore, the "arenaria del Rugo Mizza" corresponds pro parte to the "arenaria di San Gregorio" by MASSARI et al. (1986).

At its top, the fine sandstone containing the fossils that are the subject of this paper, is overlain in sequence by green glauconitic sandstone about one meter thick 1 m, micaceous siltstone, silty marl and dark marl rich in small bivalves. This sequence is overall about 14 m-thick, but it is crossed by some faults disturbing it. The following sequence starts with a few-meters-thick horizon (the exact thickness cannot be measured because of tectonic disturb) of dark green arenite with centimetric chert and quartz pebbles and variously sized bioclasts; the arenite contains quartz, glauconite, abundant dark clasts made of chert and opaque minerals and fragments of non-carbonate rocks. In a few meters we pass to yellowish ibrid arenites, then to light yellowish calcisiltstones with small glassy fragments scattered inside, and finally to calcarenites; the latter make the raised ridge that from

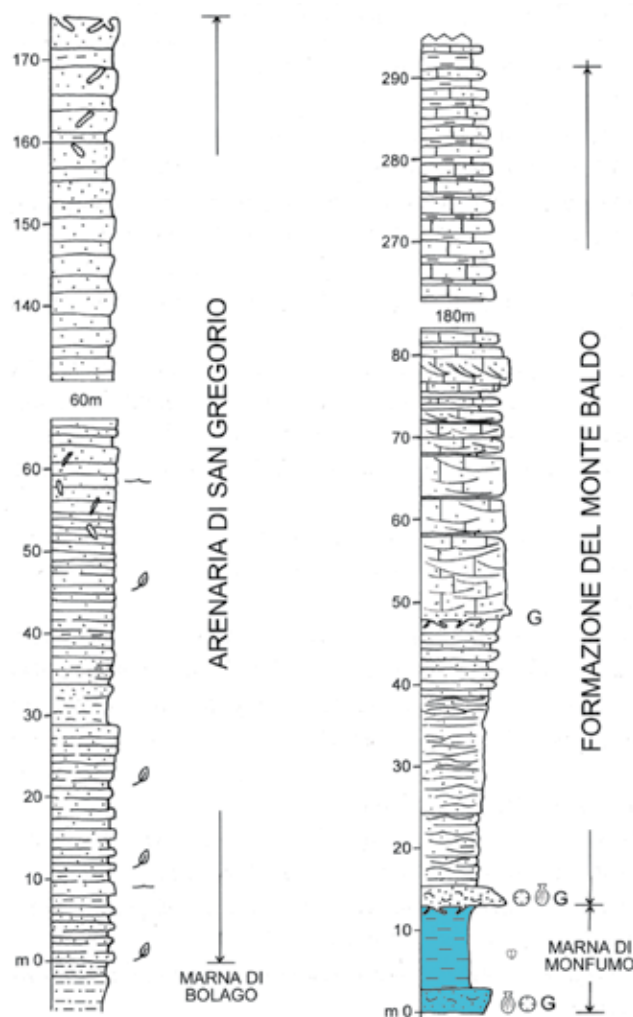


Fig. 2 - Stratigraphic section of the Burdigalian-Langhian units of the Meduna Creek area (from GRANDESSO & STEFANI 2008). The levels from which the described specimens come from are in color.

- Sezione stratigrafica delle unità burdigaliane-langhiane dell'area del Torrente Meduna (da GRANDESSO & STEFANI 2008). In colore i livelli dai quali provengono gli esemplari descritti.

the town of Fanna reaches Meduno downtown and the San Martino church (from which the unit takes its name of "calcarenite di San Martino") crossing the Meduna Creek.

The morphological features of the area are due to the different lithologies and to the stratigraphic structure that is upside down, NW dipping with inclination at about 60° along the flank of a broad anticline fold. This fold is crossed by a system of faults and fractures that are both parallel and oblique to the bedding and become more frequent at the passage between variably competent lithologies as it is the case here.

The fossil-bearing outcrop is located slightly aside respect to the sections that have been studied in the past. Keeping in consideration the local tectonical disturbs, this outcrop can be referred to the upper part of the "molasse a Pecten lisci e coralli semplici" of STEFANINI (1915), to the "livello e" of ZENARI (1929)

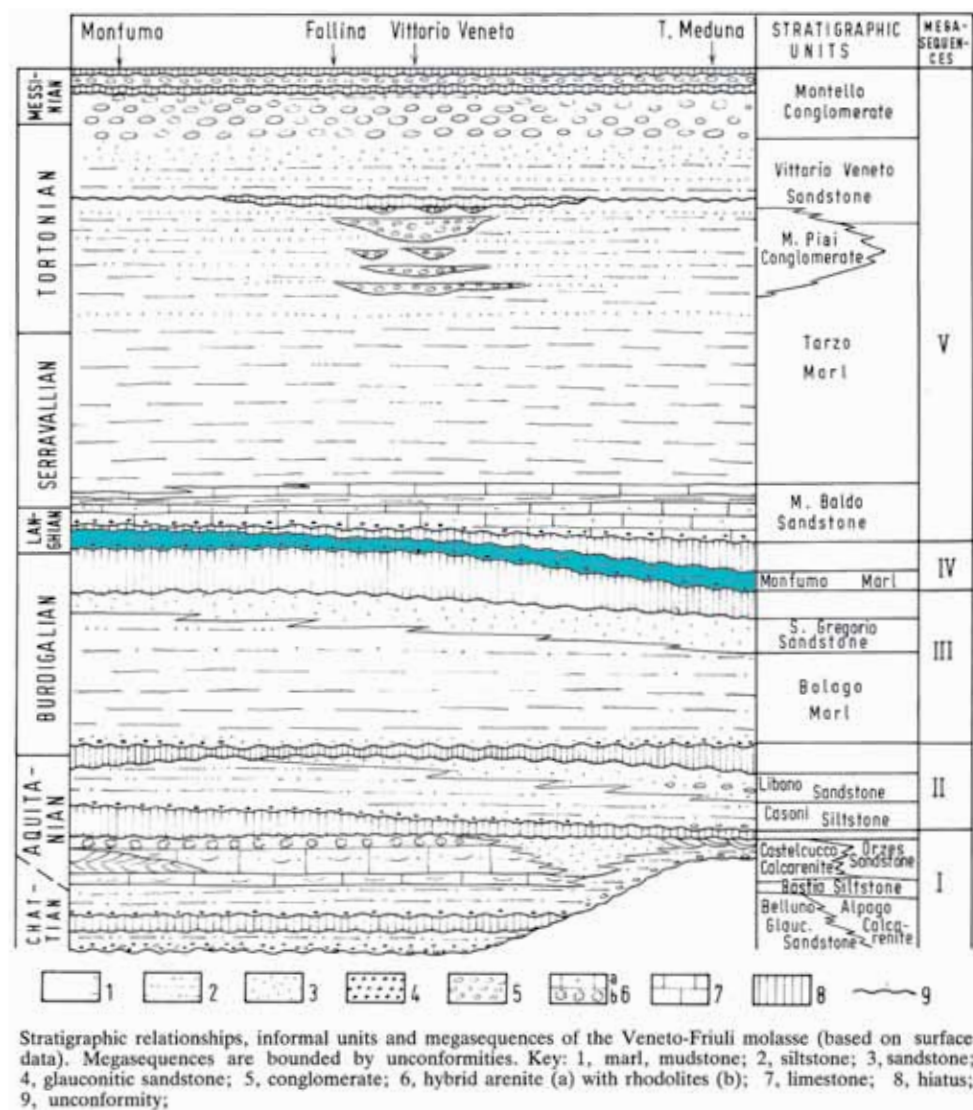


Fig. 3 - Scheme of the stratigraphic relationships between units of the Veneto-Friuli Molasse (from MASSARI et al. 1986). The Formation from which the described specimens come from is in color.

- Schema dei rapporti stratigrafici fra unità delle Molasse veneto-friulane (da MASSARI et al. 1986). In colore la Formazione dalla quale provengono gli esemplari descritti.

and to the lower part of the “litozona 3” by GELATI (1969). Finally, as already said above, it corresponds to the uppermost part of the “arenaria del Rugo Mizza” just below to its boundary with the “calcarene di San Martino” (STEFANI 1982), a unit which corresponds pro parte to the “arenaria del Monte Baldo” (MASSARI 1988) or to the “formazione del M. Baldo” (GRANDESSO & STEFANI 2008).

STEFANI (1982) describes these levels as rich in brachiopods, bryozoans, corals, echinids and pectinid bivalves and stratigraphically significant planktonic forams such as *Globigerina bollii*, *G. officinalis*, *Globigerinoides bisphericus*, *G. ruber ruber*, *G. sacculifer*, *G. trilobus immaturus*, *G. trilobus trilobus*, *Globoquadrina dehiscens*, *G. langhiana*, *Globovalia obesa*, and *G. scitula praescitula*. These forams are indicative of the upper part of the Burdigalian.

STEFANI (1984) distinguished a sequence (E) in this succession (fine sandstone at the base, siltstone and marl) that is rapidly transgressive in an outer platform environment with scarce sedimentation, followed by a correspondingly rapid regression (the following

glauconitic sandstone); this stand-alone sequence is distinct from the underlying sandstone deposited in a prodelta or delta front environment and from the overlying calcarenites deposited in an outer platform with high sedimentation rates. Furthermore, according to STEFANI (1984), this sequence is basal in a megasequence showing a clear change in the sediment composition from prevailing silicoclastic to carbonate, which occurred from the Langhian on.

In a broader analysis, MASSARI et al. (1986) referred the lower two-thirds of the “arenaria del Rugo Mizza” to the Burdigalian “arenaria di San Gregorio” (San Gregorio sandstone), which is at the top of the “third megasequence”. The fourth megasequence has a very reduced thickness. In the entire Veneto-Friulian Basin, it begins with a horizon of glauconitic sandstone with fossils followed by outer platform marl containing abundant and diversified microfossil associations composed of up to 70% of planktonic forams. This is the “marna di Monfumo” (Monfumo Marl). These facies are truncated by a further glauconitic horizon, which marks the beginning of the fifth megasequence.



Fig. 4 - MFSN 53747, nearly complete specimen in dorsal view.
- MFSN 53747, esemplare quasi completo in norma dorsale.

Therefore, the “marna di Monfumo” is the upper part of the “arenaria del Rugo Mizza” (STEFANI 1982).

Noteworthy, the “marna di Monfumo” is clearly diachronous, being younger in the Veneto Region (Langhian) and older in Friuli (spanning from the upper Burdigalian at the base of the sequence to the lower Langhian at its top) and it is marked by disconformities at its base and top.

The crab-bearing level under discussion may be referred to the upper Burdigalian because it occurs at the base of this unit (Figs 2, 3).

Palaeontological aspects

Previous records of “Portunus” monspeliensis

The swimming crab “*Portunus*” *monspeliensis* (A. MILNE-EDWARDS, 1860) was widespread from the early to middle Miocene (Burdigalian-early Serravallian) sediments from Mediterranean, Atlantic and Paratethys Seas coastal waters. This species is well known in the fossil record of Austria, Bosnia-Herzegovina, France, Hungary, Italy, Malta, Portugal, Slovenia, Spain, and Egypt (A. MILNE-EDWARDS 1860; BLANCKENHORN 1901; GLAESSNER 1928, 1933; LÖRENTHEY & BEURLIN 1929; VIA 1932; VEIGA FERREIRA 1954; MÜLLER 1979, 1984, 1993; MIKUŽ 2003; GATT 2006; GAŠPARIČ & OSSÓ

2016; DIAZ-MEDINA et al. 2018; GAŠPARIČ et al. 2019; HYŽNÝ & DULAI 2021). The fossil record from Italy includes several Miocene localities from Sardinia (Monte San Michele, Tresnuraghes, Flussio, to name just a few), Puglia (Lecce), Emilia-Romagna (Bologna), and Friuli Venezia Giulia (Pordenone) (RISTORI 1888; LÖRENTHEY 1909; COMASCHI CARIA 1956; MARRAS & VENTURA 1991; DE ANGELI & GARASSINO 2006; MARANGON & DE ANGELI 2009). ALLASINAZ (1987) reported some specimens from the Oligocene of Piedmont (Acqui, Alessandria), but DE ANGELI & GARASSINO (2006) raised some doubts about the belonging of these specimens to “*P.*” *monspeliensis*, suggesting that they could belong to a subspecies similar to this species.

The new report from the area of Mizza Creek, nearly 2.5 km NW of the previously reported Meduno (Pordenone) locality, and considered as upper Burdigalian (lower Miocene), result to be the second occurrence and the oldest from the Friuli Venezia Giulia, enlarging the knowledge on the geological range and geographic distribution of the species in the North Eastern Mediterranean.

Material

The collected sample includes 36 incomplete and complete specimens and isolated chelipeds, collected from the area of Mizza Creek (Carnic Prealps, Porde-



Fig. 5 - MFSN 53742, carapace in dorsal view.
- MFSN 53742, carapace in norma dorsale.



Fig. 6 - MFSN 53741, carapace male in dorsal view.
- MFSN 53741, carapace maschile in norma dorsale.



Fig. 7 - MFSN 53741, male in ventral view.
- MFSN 53741, esemplare maschile in norma ventrale.

none). We selected nine specimens, as follows: one nearly complete specimen with chelipeds, in dorsal view (MFSN 53747), five poorly preserved carapaces in dorsal and ventral views (MFSN 51696, 53413, 53741, 53742, 53744a-b; the last one not figured), one isolated incomplete carapace and left chela (MFSN 53477), and one complete right chela (MFSN 53412). The undescribed and studied specimens are housed in the Museo Friulano di Storia Naturale, Udine (MFSN).

Abbreviations: lcxp: carapace length; wcxp: carapace width; lc: chela length (including dactylus).

Systematic palaeontology

Section	Eubrachyura DE SAINT LAURENT, 1980
Subsection	Heterotremata GUINOT, 1977
Superfamily	Portunoidea RAFINESQUE, 1815
Family	Portunidae RAFINESQUE, 1815
Subfamily	Portuninae RAFINESQUE, 1815
Genus	<i>Portunus</i> WEBER, 1795

Type species: *Cancer pelagicus* LINNAEUS, 1758, subsequent designation by RATHBUN (1926: 75).

“Portunus” monspeliensis (A. MILNE-EDWARDS, 1860)
Figs 4-10.

Neptunus monspeliensis

A. MILNE-EDWARDS, 1860: 232-6, pl. 4, fig. 1, pl. 5, fig. 1.

Portunus monspeliensis

DE ANGELI & GARASSINO 2006: 59, 60 (see this reference for previous synonymies).

ARTAL & GILLES 2007: 8, pl. 1, fig. C.

MARANGON & DE ANGELI 2007: 70-2, pl. 1, figs A-H.

MARANGON & DE ANGELI 2009: 5, 6, 10, figs 2-4.

GAŠPARIČ & OSSÓ 2016: 58-60, pl. 1, figs A-G, pl. 2, figs A-G.

DÍAZ-MEDINA et al. 2018: 133-5, fig. 3A-E.

GAŠPARIČ et al. 2019: 6, 7, figs 3.1, 3.2.

“Portunus” monspeliensis

SPIRIDONOV (2020): 158.

Locality: Along the Mizza Creek (=Rugo or Rio Mizza) (outcrop 2) and close to the confluence of this creek with the Meduna Creek (outcrop 1), between Frisanco and Cavasso Nuovo, Carnic Prealps (Pordenone, Friuli Venezia Giulia, NE Italy; Fig. 1).

Occurrence and measurements: Nine specimens in dorsal and ventral views and one complete right chela. Measurements in mm, ? = uncertain measurements.

MFSN 51696 - lcxp: 36; wcxp: 40.

MFSN 53412 - lcxp: 24 (?); wcxp: 33; lc: 41.

MFSN 53413 - lcxp: 36; wcxp: 44; lc: 43.
 MFSN 53477 - wcxp: 62; lc: 55.
 MFSN 53741 - lcxp: 35; wcxp: 36.
 MFSN 53742 - lcxp: 52; wcxp: 30(?).
 MFSN 53744a - lcxp: 36; wcxp: 47.
 MFSN 53744b - lcxp: 35; wcxp: 42.
 MFSN 53747 - lcxp: 33; wcxp: 60; lc: 40.

Discussion: SPIRIDONOV (2020) revised the extant Portunoidea, pointing out that *Portunus* (*sensu lato*) should be splitted within other genera, making, however, more problematic to assign the fossil species of this genus to other ones. Indeed, as attested by SPIRIDONOV himself (2020: 158) “numerous fossil examples of *Portunus* (*sensu lato*) which may belong to other genera such as *Portunus* (*sensu stricto*), *Achelous*, *Monomia* and others. Distinguishing between them is not an easy task because many important characters are not available for study”. Concerning “*Portunus*” *monspeliensis*, it “could be referred either to *Achelous* and *Monomia* on account of the single visible spine on the cheliped manus and well-developed sculpture of the carapace, although the shape of the front and orbits and the relative size of the 1st anterolateral tooth support assignment of this species to *Achelous*”. Although HYŽNÝ & DULAI (2021) proposed the new combination, *Achelous monspeliensis*, based on SPIRIDONOV’s reappraisal of extant Portunoidea, we do not concur, thinking that it is a premature assumption which still needs a careful and more accurate review of all fossil available specimens assigned to *monspeliensis* in order to establish its precise generic assignment. Indeed, some morphological details of the studied specimens, such as the less-developed sculpture of the carapace, the lack of a strong spine on the cheliped manus, and the undifferentiated first anterolateral spine, raise some doubts about their possible assignment to *Achelous*.

Based upon SCHWEITZER et al. (2021: 28), the above mentioned characters should fit better those of *Portunus* in having “carapace much wider than long; regions moderately developed; frontal margin with six spines, including inner-orbital spines; orbits with two closed fissures; anterolateral margin with nine spines including outer-orbital spine; chelae with well developed keels”.

Therefore, based upon the above-mentioned characters, we prefer to keep the studied specimens within *Portunus*. However, until additional best-preserved specimens won’t be collected in order to solve definitively their systematic assignment, we propose to use “*Portunus*” (*sensu lato*) by SPIRIDONOV (2020) and non *Portunus* (*sensu stricto*) by SCHWEITZER et al. (2021).

GAŠPARIČ & OSSÓ (2016) reported the main morphological characters of *P. monspeliensis*, such as hexagonal carapace, wider than long; front protruding and slightly downturned, with two forward directed short spines on either side, followed by a distinctive sharp, outward



Fig. 8 - MFSN 51696, male in ventral view.
 - MFSN 51696, esemplare maschile in norma ventrale.



Fig. 9 - MFSN 53412, right complete chela.
 - MFSN 53412, chela destra completa.



Fig. 10 - MFSN 53477, left complete chela.
 - MFSN 53477, chela sinistra completa.

pointing, inner orbital spine; orbits wider than front, forward directed; supraorbital margin sinuous, incised by two closed fissures; anterolateral margin long and slightly convex with nine anterolateral subtriangular spines, the ninth prominent, the longer, and laterally directed; posterolateral margin straight; protogastric region semi-circular lobes with transverse ridge; trapezoid-shaped mesogastric and metagastric regions; cardiac region well defined, pentagonal; intestinal region faint and circular; hepatic region flat and triangular; epibranchial region wide; cervical groove distinct; branchiocardiac groove well marked, along sides of cardiac region; P1 subequal with elongate merus, short carpus, and rectangular, elongate palm, with three longitudinal ridges on outer surface; triangular, elongate index, as long as palm; and occlusal margin of chelae heterodontic with a clear knob stick molariform tooth in the right chela, followed by a series of tuberculous teeth.

The studied specimens share the main diagnostic characters of this species, such as the hexagonal carapace, wider than long; six frontal spines (Figs 4, 5); wide orbits with two supraorbital fissures (Figs 4, 5); nine anterolateral subtriangular spines (the ninth prominent, the longer and laterally directed (Fig. 6); keeled elongate chelae with long dactyli having serrated occlusal margins (Figs 9, 10), and male pleon typically triangular with petaloid sternites (Figs 7, 8).

In conclusion, they are assigned to “*Portunus*” *monspeliensis* based upon the above-mentioned characters.

Palaeoecology and environmental notes

“*Portunus*” *monspeliensis* results to be the most common brachyuran crab recovered “from typical Miocene siliciclastic and carbonate sediments” (GAŠPARIČ & OSSÓ 2016: 61; DÍAZ-MEDINA et al. 2018: 130; GAŠPARIČ et al. 2019: 2; HYŽNÝ & DULAI 2021). Moreover, according to GAŠPARIČ & OSSÓ (2016: 61), this species is “almost exclusively collected from sandstone and sandy limestone that is interbedded with marl”, a datum in agreement with the sedimentology of the studied locality. According to GAŠPARIČ & OSSÓ (2016) and MARANGON & DE ANGELI (2009), this lithology usually represents a variety of sublittoral facies comprising from inshore to offshore waters, or from estuarine and even lagoon or brackish environments with a sandy, muddy, or sea grass bottom (NICHOLS 2009).

In conclusion “*Portunus*” *monspeliensis* may be mostly considered a euryhalin species due to the high salinity fluctuation existent in the different observed ecosystems in which it lived (MÜLLER 1993), an adaptation also shared with many extant portunids. Although the supposed oldest record of “*Portunus*” *monspeliensis* was reported by ALLASINAZ (1987) from the Oligocene (Rupelian) of the Ligure-Piemontese Basin (NE Italy), this record was considered dubious by the author him-

self. Therefore the only unambiguous record known to date is from the Burdigalian of SE France (ARTAL & GILLES 2007).

The new report from the upper Burdigalian of Friuli (NE Italy) represents the oldest record of “*Portunus*” *monspeliensis* from Northern Italy, supported by relevant sedimentological data.

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References

- ALLASINAZ, A. 1987. Brachyura decapoda oligocenici (Rupeliano) del Bacino Ligure Piemontese. *Boll. Mus. reg. Sc. nat. Torino* 5 (2): 509-66.
- ARTAL, P., & A. GILLES. 2007. New Miocene crabs from Pignon (southeast France). In *3rd Symposium on Mesozoic and Cenozoic Decapod Crustaceans*, cur. A. GARASSINO, R.M. FELDMANN & G. TERUZZI, 8-11. Mem. Soc. it. Sc. nat. e Mus. civ. di St. nat. Milano, 35 (2).
- BIZZARINI, F., P. MADDALeni, G. MUSCIO, M. PONTON, L. SIMONETTO & S. VENTURINI. 2020. La geologia dell'area di Pozzuolo del Friuli e gli affioramenti miocenici: storia della ricerche e prospettive. *Gortania. Geol., Paleont., Paleont.* 41: 13-42
- BLANCKENHORN, M. 1901. Neues zur Geologie und Paläontologie Aegyptens. III. Das Miozän. *Zeitsch. der Deut. Gesell. für Geowissen.* 53: 52-132.
- CATULLO, T.A. 1827. *Saggio di Zoologia fossile ovvero Osservazioni sopra li petrefatti delle Provincie Austro-Venete con la descrizione dei monti entro i quali si trovano*. Padova: Tip. Seminario.
- CATULLO, T.A. 1837. Memoria geologico-chimica sopra le puddinghe alluviali e sopra il terreno di trasporto delle Provincie Venete. *Biblioteca Italiana* 87: 276, 417.
- CATULLO, T.A. 1842. *Catalogo delle specie organiche fossili raccolte nelle Alpi Venete e donate al Gabinetto di Storia Naturale dell'Università di Padova*. Padova: Tip. A. Sicca.
- CATULLO, T.A. 1856. *Dei Terreni di sedimento superiore delle Venezie e dei fossili bryozoari, antozoari e spongiari ai quali danno ricetto*. Padova: Tip. A. Sicca.
- CAVALLIN, A. 1981. Fogli 24 Maniago e 39 Pordenone. In *Carta tettonica delle Alpi Meridionali alla scala 1: 200.000*, cur. A. CASTELLARIN, 46-50. CNR.
- COMASCHI CARIA, I. 1956. I Crostacei miocenici della Sardegna. *Boll. Serv. Geol. It.* 78 (1-2): 283-90.
- DALLA VECCHIA, F.M. 2008. *Vertebrati fossili del Friuli. 450 milioni di anni di evoluzione*. Udine: Mus. Friul. St. Nat., pubbl. 50
- DE ANGELI, A., & A. GARASSINO. 2006. New reports of decapod crustaceans from the Mesozoic and Cenozoic of Friuli

- Venezia Giulia (NE Italy). *Atti Soc. it. Sc. nat. e Mus. civ. St. nat. Milano* 147 (2): 267-94.
- DE ZIGNO, A. 1850. On the Stratified Formations of the Venetian Alps. *Quart. Jour. Geol. Soc.* 6: 422-32.
- DÍAZ-MEDINA, G., Á. OSSÓ & M. HYŽNÝ. 2018. A middle Miocene decapod faunule from Granada (Spain), with remarks on distribution pattern of the crab *Portunus monspeliensis*. *N. Jahr. für Geol. und Paläont., Abhand.* 288 (2): 129-41.
- FERUGLIO, E. 1924-25. Le Prealpi tra l'Isonzo e l'Arzino. *Bollettino della Associazione Agraria Friulana* s. 7, 39: 1-96 e 40: 97-302.
- GAŠPARIČ, R., M. HYŽNÝ, G. JOVANOVIĆ, S. ČORIĆ, & S. VRABAC. 2019. Middle Miocene decapod crustacean assemblage from the Tuzla Basin (Tušani, Bosnia and Herzegovina), with a description of two new species and comparison with coeval faunas from Slovenia. *Palaeontologia Electronica*: 22.1.9A 1-21. doi: 10.26879/894.
- GAŠPARIČ, R., & Á. OSSÓ. 2016. New reports of decapod *Portunus monspeliensis* A. Milne Edwards, 1860 from Miocene beds of eastern Slovenia with notes on palaeoecology and palaeobiogeography. *Geologija*, 59 (1): 55-66.
- GATT, M. 2006. Il-Geologija u l-Paleontologija tal-Gzejjer Maltin. *Pubblikazzjonijiet Indipendenza*, Malta.
- GELATI, R. 1969. Nuove osservazioni sulla successione stratigrafica di età miocenica affiorante sul torrente Meduna in provincia di Pordenone. *Riv. It. Paleont. Strat.* 75 (1): 165-182.
- GLAESSNER, M.F. 1928. Die Dekapodenfauna des Österreichischen Jungtertiars. *Jahrb. Geolog. Bundesan.* 78: 161-219.
- GLAESSNER, M.F. 1933. New Tertiary crabs in the collection of the British Museum. *Annals Mag. Nat. Hist.* 10 (12): 1-28.
- GRANDESSO, P., & C. STEFANI. 2008. La successione miocenica. In *Carta Geologica d'Italia alla scala 1:50.000 - Foglio Maniago. Note illustrative*. Tavaganacco: APAT - Servizio Geologico d'Italia, Regione Autonoma Friuli Venezia Giulia - Servizio Geologico.
- HYŽNÝ, M., & A. DULAI. 2021. *Badenian decapods of Hungary*. Szeged: GeoLitera.
- LŐRÉNTHEY, E. 1909. Beiträge zur tertiären Dekapodenfauna Sardiniens. *Mathem. Naturwissensch. Ber. Ungarn* 24: 202-59.
- LŐRÉNTHEY, E., & K. BEURLIN. 1929. Die fossilen Dekapoden der Länder der ungarischen Krone. *Geologica Hungarica*, Series. Palaeont. 3: 1-420.
- MARANGON, S., & A. DE ANGELI. 2007. Preservation of some specimens of *Portunus monspeliensis* (Milne Edwards, 1860) from the Miocene of Sardinia (Italy). In *3rd Symposium on Mesozoic and Cenozoic Decapod Crustaceans*, cur. A. GARASSINO, R.M. FELDMANN & G. TERUZZI, 70-2. *Mem. Soc. it. Sc. nat. e Mus. civ. di St. nat. Milano*, 35 (2).
- MARANGON, S., & A. DE ANGELI. 2009. Exceptionally preserved specimens of *Portunus monspeliensis* (A. Milne-Edwards, 1860) (Brachyura, Portunidae) from the Miocene of Sardinia (Italy). *Atti Soc. it. Sc. nat. e Mus. civ. St. nat. Milano* 150 (1): 3-12.
- MARRAS, G., & G. VENTURA. 1991. Crostacei decapodi del Miocene di Sassari (Sardegna nord occidentale). *Boll. Soc. Sarda Sc. Nat.* 28: 105-19.
- MARTINIS, B. 1955. L'Oligocene friulano. In *Atti 1° Conv. Friul. Sc. Nat., Udine sett.* 1955, 336-95.
- MARTINIS, B., 1979. La struttura del M. Jof: un nuovo elemento sovrascorso delle Prealpi Carniche. *Accademia Nazionale dei Lincei* s. 8, 65: 313-8.
- MASSARI, F., P. GRANDESSO, C. STEFANI & P.G. JOBSTRAIBIZER. 1986. A small polyhistory foreland basin evolving in a context of oblique convergence: the Venetian basin (Chattian to Recent, Southern Alps, Italy). In *Foreland basins*, cur. P.A. ALLEN & P. HOMEWOOD, 141-68. *Intern. Ass. Sed., Spec. Publ.* 8.
- MELLERE, D., C. STEFANI & C. ANGEVINE. 2000. Polyphase tectonics through subsidence analysis: the Oligo-Miocene Venetian and Friuli Basin, north-east Italy. *Basin Research* 12: 159-82.
- MIKUŽ, V. 2003. Miocenske rakovice iz okolice Šentilja v Slovenskih Goricah (The Miocene crabs from vicinity Šentilj in Slovenske Gorice, Slovenia). *Razprave IV. Razreda SAZU* 44: 187-99.
- MILNE-EDWARDS, A. 1860. Histoire des Crustacés podophthalmiques fossiles et Monographie des Décapodes Macroures de la famille des Thalassinens. *Ann. Sc. Natur.* 4^e série, 14: 129-357.
- MORO, A.L. 1740. *De' Crostacei e degli altri marini corpi che si trovano sui monti*. Venezia: Tipografia Stefano Monti.
- MÜLLER, P. 1979. The Indo-West-Pacific character of the Badenian Decapod Crustaceans of the Paratethys. *Ann. Géol. Pays Hellén.* 2: 865-9.
- MÜLLER, P. 1984. Decapod Crustacea of the Badenian. *Geologica Hungarica*, Series Palaeontologica, 42: 3-317.
- MÜLLER, P. 1993. Neogene Decapod Crustaceans from Catalonia. *Scr. Mus. Geol. Sem. Barcin.* 225: 1-39.
- NICHOLS, G. 2009. *Sedimentology and Stratigraphy*. London: Blackwell Science Ltd.
- PILLERI, G. 1982. Record of *Schizodelphis sulcatus* (Cetacea, Odontoceti) from the Miocene of Preplans, Friuli (Carnian Pre-Alps). *Gortania, Atti Mus. Fr. St. Nat.* 7: 75-86.
- PIRONA, G.A. 1856. Lettere geologiche del Friuli. *Annotatore Friulano* 4.
- PIRONA, G.A. 1861. Cenni geognostici sul Friuli. *Ann. Assoc. Agraria friulana* 1861: 3-45.
- PIRONA, G.A. 1876. La Provincia di Udine sotto l'aspetto storico naturale. cenni. *Cron. R. Liceo Stellini per l'anno 1875-76*: 3-45.
- RATHBUN, M.J. 1926. The fossil stalk-eyed Crustacea of the Pacific slope of North America. *Un. States Nat. Museum Bull.*, 138: 1-155.
- RISTORI, G. 1888. Alcuni Crostacei del Miocene medio italiano. *Atti Soc. Tosc. Sc. Nat.* 9: 212-9.
- SCHWEITZER, C.E., R.M. FELDMANN & H. KARASAWA. 2021. Part R, Revised, Volume 1, Chapter 8T15: Systematic descriptions: Superfamily Portunoidea. *Treatise Online* 151: 1-40.
- SPIRIDONOV, V.A. 2020. An update of phylogenetic reconstructions, classification and morphological characters of extant Portunoidea Rafinesque, 1815 (Decapoda, Brachyura, Heterotremata), with a discussion of their relevance to fossil material. *Geologija* 63 (1): 133-66.
- STARA, P., E. BORGHI & A. KROH. 2016. Revision of the genus *Mariania* (Echinoidea) with the description of two new species from the Miocene of Italy. *Bull. Geosc.* 91 (1): 65-88.
- STEFANI, C. 1982. Geologia dei dintorni di Fanna e Cavasso Nuovo (Prealpi Carniche). *Mem. Sc. Geol.* 35: 203-12.
- STEFANI, C. 1984. Sedimentologia della molassa delle Prealpi Carniche occidentali. *Mem. Sc. Geol.* 36: 427-42.

- STEFANI, C. 1987. Composition and provenance of arenites from the Chattian to Messinian clastic wedges of the Venetian foreland basin (Southern Alps, Italy). *Giorn. Geol.* 49 (1): 155-66.
- STEFANINI, G. 1911a. *Sulla stratigrafia e sulla tettonica dei terreni miocenici del Friuli*. Venezia: Pubbl. Uff. Idrogr. R. Mag. Acque, 31.
- STEFANINI, G. 1911b. Osservazioni sul Miocene del Friuli. *Atti R. Ist. Ven. Sc. Ll. Aa.* 70 (2): 751-5.
- STEFANINI, G. 1915a. Il Neogene del Veneto. *Mem. Ist. Geol. Univ. Padova* 3: 337-624.
- STEFANINI, G. 1915b. Specie nuove dal Miocene Veneto. *Atti. Acc. Sc. Ven. Trent. Istr.* 3 (8): 151-62.
- STEFANINI, G. 1916. Fossili del Neogene Veneto. *Mem. Ist. Geol. Univ. Padova* 4: 1-198.
- STEFANINI, G. 1919. Fossili del Neogene Veneto. Parte II: Brachiopoda, Echinodermata. *Palaeontog. Italica. Mem. di Paleont.* 25: 127-71.
- TARAMELLI, T. 1869. Sopra alcuni echinidi cretaci e terziari del Friuli. *Atti R. Ist. Veneto Sc. Ll. e Aa. s. III*, 14: 1-40.
- TARAMELLI, T. 1877. Catalogo ragionato delle rocce del Friuli. *Mem. R. Accad. Lincei s. 3*, 1: 511-609.
- TARAMELLI, T. 1881. *Spiegazione della Carta Geologica del Friuli (provincia di Udine)*. Pavia: Tip. Fusi.
- TARAMELLI, T. 1882. Geologia delle Province Venete. *Mem. R. Accad. Lincei s. 3*, 13: 305-536.
- VALLISNERI, A. 1721. *De' corpi marini, che su' monti si trovano, della loro origine, e dello stato del Mondo avanti il Diluvio, nel diluvio, e dopo il diluvio*. Venezia: Tipografia D. Lovisa.
- VEIGA FERREIRA, O. 1954. Malacostraceos do Miocénico Marinho de Portugal. *Comm. Serv. Geol. Portugal* 35: 5-23.
- VENTURINI, S., & G. TUNIS. 1992. Segnalazione di depositi miocenici nella Val Tremugna e presso Osoppo (Friuli). *Atti Tic. Sc. Terra* 34: 39-42.
- VENTURINI, S., & G. TUNIS. 1993. La composizione dei conglomerati cenozoici del Friuli: dati preliminari. *St. Geol. Camerti* vol. spec., 1992/2 (CROP 1-1A): 285-95.
- VIA, L. 1932. Els crancs fòssils del Terciari de Catalunya. *Butlletí Inst. Cat. Hist. Nat.* 32 (4): 131-46.
- ZANON, A. 1767. *Della formazione della torba ed altri fossili combustibili*. Venezia: Modesto Fenzo.
- ZANON, A. 1768. *Della marna ed altri fossili atti a rendere fertili le terre*. Venezia: Modesto Fenzo.
- ZENARI, S. 1929. *Note illustrative della Carta geologica delle Tre Venezie, Foglio Maniago*. Venezia: Ufficio Idrografico del R. Magistrato alle Acque.

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