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# A subfossil spirostreptid millipede from SW Libya (Diplopoda, Spirostreptida, Spirostreptidae)

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**ABSTRACT**

Two fragments of millipedes, referred to the genus *Archispirostreptus*, are reported from an archaeological site in the Tadrart Acacus region of southwestern Libya. Radiocarbon dating of the specimens shows that one of them dates to between ca. 9100 and 8800 years ago, and the other one between 6400 and 6300 years ago (calibrated dates). The site lies far from known present-day occurrences of spirostreptid millipedes, and the Libyan subfossils probably, like other isolated occurrences of *Archispirostreptus* species in the Sahara and the Middle East, represent geographical relicts of a former, continuous distribution. The millipedes were probably able to survive at the Libyan site during the early and middle Holocene periods thanks to the more humid conditions, and may descend from animals that initially colonised the area during the even more humid, and longer, last interglacial period.

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## Introduction

The palaeontological record of millipedes (Diplopoda) goes back as far as the Silurian (Wilson and Anderson 2004), and these fossil finds have been used to clarify the phylogeny of the group (e.g., Shear and Edgecombe 2010). Quaternary finds of millipedes, such as the ones we describe below, are however only very rarely reported in the literature. From the Plio-Pleistocene hominin site of Malapa in South Africa, a single find of an almost complete pill millipede (superorder Oniscomorpha) has been mentioned (Val 2014). Most of the fossil remains from this cave were found in blocks of calcified clastic sediment and it is likely that this type of setting explains the preservation of the millipede. Mauriès (1979) recorded fragments of a cylindrical millipede (order Julida, family Blaniulidae, genus *Blaniulus* [as *Typhloblaniulus*]) and a flatbacked millipede (order Polydesmida, family Polydesmidae, genus *Polydesmus*) from Pleistocene deposits in a cave in France. In his overview of the invertebrates that can be found in archaeological contexts in the north of England, Kenward (2009) mentioned that millipedes, like centipedes, are often present in archaeological deposits but that they are 'rarely reported in reports and probably of fairly limited potential'. Favourable conditions for preservation of the calcified cuticles would be anoxic waterlogging and, more often, mineral replacement. The principle of this

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mineral replacement in millipedes, centipedes and woodlice has been elaborated by Girling (1979) who also mentioned a number of sites on which she found these taxa. Millipedes in archaeological sites can be considered as penecontemporaneous intrusives or late intrusives (Gautier 1987), although one case has been mentioned in the literature of the animals being part of the human diet. This was demonstrated by the analysis of coprolites from prehistoric inhabitants of the lower Pecos area in Texas (Reinhard et al. 2003).

The two millipede fragments that are described below were retrieved during the archaeological excavations of Takarkori, a rock shelter in the Libyan desert that was inhabited by humans during the more humid part of the Holocene. The site (approximate coordinates 24°32′10″ N, 10°31′25″ E) is located in the Tadrart Acacus region of south-western Libya close to the border with Algeria (Figure 1). Nowadays the area is hyperarid, but in early and middle Holocene times it was populated by humans as demonstrated by the stratigraphic sequence at Takarkori, dated between 10,200 to 4650 years cal BP (Biagetti and di Lernia 2013; Cremaschi et al. 2014). Initially, the rock shelter was inhabited by Late Acacus hunter-gatherers from about 10,200 to 8000 cal BP. Between about 8300 and 7300 cal BP, Early Pastoral Neolithic herders visited the site. There is abundant evidence for a Middle Pastoral occupation between 7100 and 5600 cal BP, and for the seasonal occupation by Late Pastoral nomads between 5900 and 4650 cal BP. Organic remains, both of plant and animal origin, are well preserved at the site and allowed palaeoenvironmental and palaeoeconomical reconstructions (Dunne et al. 2012; Cremaschi et al. 2014; Mercuri et al. 2018; Rotunno et al. 2019). The sole major faunal report available thus far (Van Neer et al. 2020) deals mainly with the aquatic fauna (fish, crocodile, freshwater turtle) and its meaning for the palaeoenvironmental and palaeohydrographical reconstruction.

Most millipedes feed on decaying vegetable matter such as leaf litter and dead wood (Crawford 1992; David 2015) and they would thus have found a suitable habitat in the rock shelter with the organic refuse left by the human inhabitants. One of the millipeds could, on the basis of the stratigraphic position, be attributed to the Late Pastoral Phase which is roughly dated to 5900 and 4650 cal BP. For the second specimen, no dating could be suggested as it was retrieved without any precise stratigraphic context, during the cleaning of a profile. We attempted a radiocarbon dating of the two individuals because of the lack of stratigraphic provenance for the last specimen, but also to ensure that the other individual, found in a Late Pastoral layer, was *in situ*. As many millipeds, especially the cylindrical one (superorder Juliformia) are burying animals (Kime and Golovatch 2000), it cannot be excluded that animals found in a particular layer are intrusive.

The outcome of the dating of the chitine fraction of the samples is given below. For each individual, we provide the provenance, the lab and sample ID (RICH = Royal Institute for Cultural Heritage (Brussels)) with the obtained radiocarbon date and the standard deviation in years before present (BP), i.e. the number of years before the arbitrary chosen reference year AD 1950. Besides this conventional date, we also calculated the calibrated radiocarbon date, expressed as cal BP with a confidence interval of 2σ.

Individual 1: TK04-II, S31, layer 7
RICH-24,628: 5578 ± 34 BP
6433–6296 cal BP (95% probability)

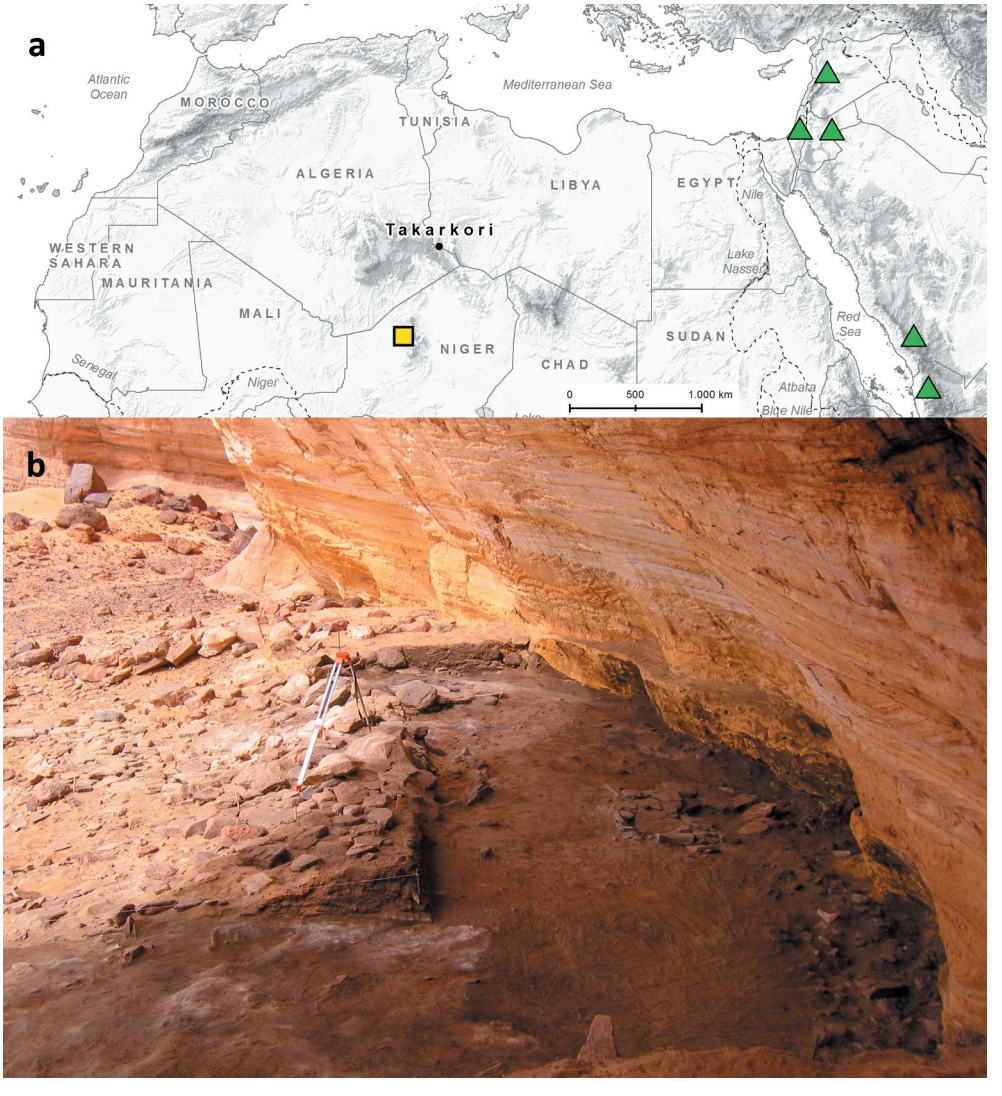


**Figure 1.** (a) Map of northern Africa with location of the site as well as occurrences of *Archispirostreptus syriacus* in the Middle East (green triangles), and *A. lugubris villiersi* in the Aïr Mountains, Niger (yellow square). (b) General view of Takarkori rock shelter (© The Archaeological Mission in the Sahara, Sapienza University of Rome).

Individual 2: TK04-II, RIP sezione N-S
RICH-24,627: 8096 ± 38 BP
9134–8794 cal BP (95% probability)

The date of Individual 1, roughly between 6400 and 6300 cal BP, places this specimen in the Middle Pastoral Phase which is older than the age that was suggested by the stratigraphic position. Post-depositional phenomena, like digging of pits and other soil movements, must be responsible for the discrepancy. The other specimen dates between ca. 9100 and 8800 cal BP. This means there is evidence for the presence of millipeds in the

beginning of the Holocene when climatic conditions were relatively humid, and also about 2600 years later in the Middle Holocene.

## Description of the finds

The millipedes could no doubt survive in the deposits of the Takarkori rock shelter thanks to the arid conditions that prevailed until the present day. Remarkable about their preservation is also that the sclerotised body rings are still in articulation over considerable parts of the animals' bodies which fortunately also retained some diagnostic characters allowing an identification beyond the level of the class of the Diplopoda.

The fragment corresponding to Individual 1 consists of seven complete, connected body rings and a complete telson (pre-anal ring, anal valves and subanal plate), and small pieces of an additional body ring, presumably the one preceding the connected ones (Figure 2a-d). The total length of the fragment is 13.7 mm, its maximal vertical diameter is 9.0 mm, and it is somewhat tapering towards the hind end. All seven body rings have sockets for two pairs of legs. The dorsal profile of the pre-anal ring is concave; the anal valves have moderately thick, marginal lips; the subanal scale is broadly bell-shaped. Although we are aware that taphonomic processes may have altered the colours of the Holocene specimens, we nevertheless include them in the further description below. The anterior part of each body ring (prozonite) is pale yellowish and has a number of parallel striae encircling the body. No sigilla ('Gelbe Punkte', cf. Krabbe 1982, p. 13–14; Enghoff and Larsson 2018: Figure 2) are visible on the small pieces of the additional body ring which can be examined from the inside. The posterior part of the body rings (metazonite) is blackish but with many irregular yellowish blotches; the metazonites have no obvious sculpture, and no hyaline limbus is seen at the posterior margins of the metazonites. Small openings of defence glands (ozopores) can be seen on the anteriormost rings of the fragment.

The fragment corresponding to Individual 2 consists of 11 connected body rings and telson (pre-anal ring, subanal scale); the anal valves are missing (Figure 2e). The total length of the fragment is 16.4 mm, its maximal vertical diameter is 8.3 mm, and it is somewhat tapering towards the hind end. All eleven body rings have sockets for two pairs of legs, and a single article (coxa) of one leg is still attached to the second body ring counted from the front. The dorsal profile of the pre-anal ring is straight. The colour is better preserved than in Individual 1: prozonites are yellowish, metazonites uniformly brownish. Ozopores are clearly seen on the first 10 body rings. In all other characters, it resembles Individual 1, and the observed differences can be explained by individual variation (dorsal profile of pre-anal ring) or taphonomic factors (colouration).

The fragments can be referred to the family Spirostreptidae based on the structure of the body rings which are divided into a pro- and a metazonite and have the prozonites covered by parallel, encircling furrows (Krabbe 1982). The lack of dorsal denticles on the anal valves excludes the related, endemic Afrotropical family Odontopygidae (Kraus 1966).

The Spirostreptidae is basically a Neotropical-Afrotropical family with a few outliers in southern N America, in NW Africa (Morocco), the Arabian peninsula and the Middle East from Israel to Syria (Krabbe 1982; Mwabvu et al. 2010). Based on the only moderately developed anal valve lips, and the large body diameter, the fragments do not belong to

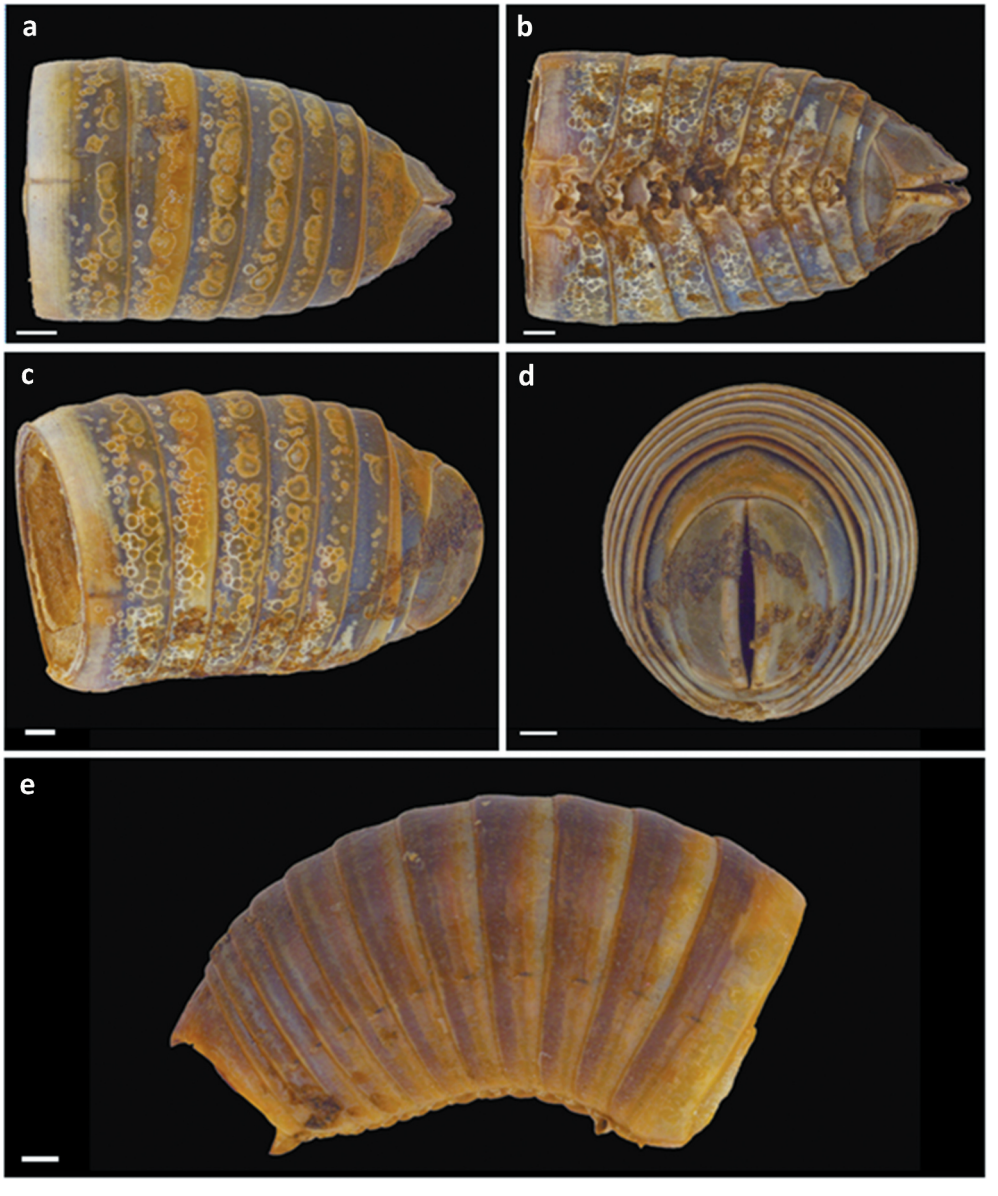


**Figure 2.** The millipede fragments found at Takarkori. a–d. Individual 1 (TK04-II, S31, layer 7). (a) Dorsal view. (b) Ventral view. (c) Lateral View. (d) Posterior view. (e) Individual 2 (TK04-II, RIP sezione N-S), lateral view. Scale bars = 1 mm.

the genus represented in Morocco (*Odontostreptus*). They are, however, consistent with the genus *Archispirostreptus* which occurs in the Middle East and also has several species in E Africa as far north as Eritrea (Mwabvu et al. 2010) (Figure 1). There is another genus of relatively large spirostreptids, *Tibiozus* with one species in Sudan, but the Takarkori specimens do not resemble this species, *T. robustus* Attems, 1950, as much as they resemble *Archispirostreptus* spp., e.g., in the shape of the telson. The two fragments are therefore, with reservation, identified as representing a species of *Archispirostreptus*. The

tentative identification is based on comparison with recent specimens of relevant species, including *Archispirostreptus* spp., *Odontostreptus* spp., and *Tibiozus robustus* from the collection of the Natural History Museum of Denmark.

## Discussion and conclusions

Millipedes in general are poor colonisers (Enghoff 2015), and isolated occurrences like the probable *Archispirostreptus* subfossils are most likely relicts from formerly more continuous distributions. During the last interglacial, conditions were even more humid in the Sahara than during the early and middle Holocene wet periods, and it has been hypothesised that rivers flowing across the Sahara created north-south corridors allowing humans to migrate over long distances (Coulthard et al. 2013). Such routes could also have been taken by millipeds and may have allowed them to colonise wider regions.

The oldest indication at Takarkori for the presence of *Archispirostreptus* is between ca. 9100 and 8800 cal BP whereas the other specimen is about 2600 years younger with a date between 6400 and 6300 cal BP. During these time periods, when conditions were more humid than today, there was the so-called 8.2-kiloyear event characterised by increased aridity (Figure 3). As millipede finds are so rare at the site, it is unclear if they survived this arid spell and if they were hence continuously present. However, other, more frequently represented faunal elements demonstrate that conditions at Takarkori were probably not very unfavourable. The aquatic fauna, consisting of fish, crocodiles and freshwater turtles survived throughout the whole period of human occupation of the rock shelter, i.e. between about 10,200 to 4650 years cal BP (Van Neer et al. 2020).

It is unlikely that *Archispirostreptus* millipedes have survived to the present day in southwest Libya, considering that such large, conspicuous invertebrates would probably not be overlooked. In his faunal reconnaissance of southwest Libya, Scortecci (1937, p. 218) found that Myriapoda are poorly represented in the Fezzan and the oasis of Ghat. Among the Chilopoda, he reported *Scolopendra canidens puncticornis* Brolemann (now considered

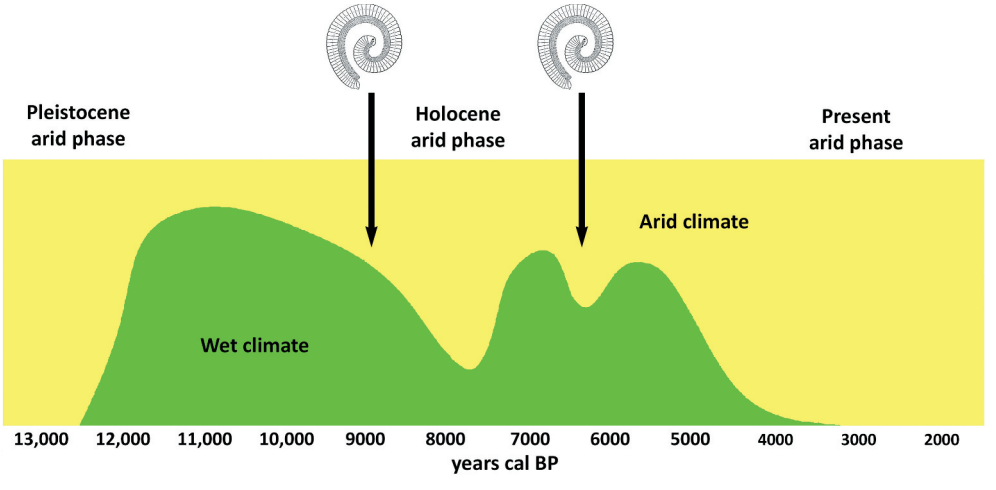


**Figure 3.** Curve showing the climatic changes in SW Libya with indication of the dates of the millipedes (modified after Anag et al. 2007, p. 42).

synonymous with *S. canidens* Newport, 1844) from a locality near Ghat and *Asanada brevicornis* Meinert, 1886, >300 km north-east of the Acacus, between Brak and Sebha. According to Akkari et al. (2008) *S. canidens* is the only myriapod in Tunisia found in pure sandy deserts. In his survey of the woodlice and myriapods of the Sahara, Lewis (1984) concluded that the knowledge of the distribution of these groups is unsatisfactory due to the limited efforts to collect specimens and also to difficulties determining the exact location of place names. The sole millipede taxa he mentioned for the Sahara are *Polyxenus lagurus* (L. 1758), found in the Hoggar, and *Archispirostreptus lugubris villiersi* (Schubart, 1951), from the Aïr region. From the latter locality also an unidentified odontopygid was reported. Both the *Polyxenus* and the *Archispirostreptus* come from high altitude localities (2810 and 1200–1300 m a.s.l.) which may explain why they survived here. The region of Takarkori is also in a rather mountainous environment, ca. 900–1000 m a.s.l.

The ecology of desert millipedes was considered by Crawford (1979) and Golovatch (2009). Among adaptations to the desert climate mentioned by these authors are prolonged dormancy periods (for example, some millipedes from dry environments seek shelter inside termites' nest), an increased ability to resist water loss, and an ability to take up water against a vapour-pressure gradient. The habitat use of the Middle East species of *Archispirostreptus*, viz., *A. syriacus*, was studied by Crawford et al. (1987). This species is able to maintain populations in rather arid environments, including a site heavily disturbed by human activities where the soil is subject to 'considerable burrowing activity by large numbers of millipedes'. Perhaps this situation is comparable to the one that prevailed at Takarkori several thousand years ago?

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## Disclosure statement

No potential conflict of interest was reported by the authors.

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