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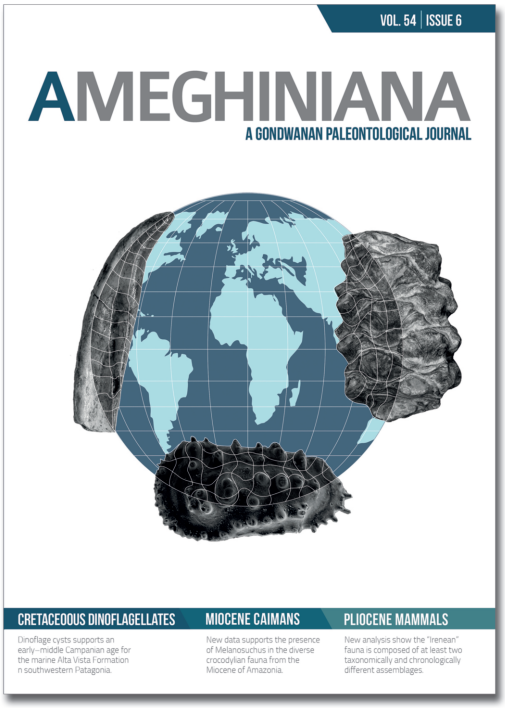

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FIRST RECORD OF FOSSIL INSECTS FROM THE MIDDLE HOLOCENE OF TIERRA DEL FUEGO, ARGENTINA

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Key words. Fossil Carabidae. *Migadops latus*. Terra Australis peat bog. Middle Holocene. Tierra del Fuego. Argentina.

Palabras clave. Carabidae fósil. *Migadops latus*. Turbera de Terra Australis. Holoceno Medio. Tierra del Fuego. Argentina.

WHILE the astonishing growth of the knowledge of Quaternary Paleoentomology during the last decades continues to accelerate, contributions related to the austral region of South America have only been made about Chilean territory. In this context, Ashworth, A.C., and Hoganson, J.W. were pioneers in the study of Quaternary fossil insect associations by studying several Late Pleistocene and Holocene insect faunas in the coastal region of central and southern Chile.

For example, in 1989, they examined the peat deposits of the archaeological site Monte Verde (Ashworth *et al.*, 1989); during 1987 (Ashworth and Hoganson, 1987), they analyzed the deposits of Río Caunahue and conducted a large-scale survey of extant insect communities in the Puyehue National Park. In the early 90's, they summarized their work with Late Pleistocene insect associations of Puerto Octay, Puerto Varas and Río Caunahue (Hoganson and Ashworth, 1992). Finally, Ashworth (2007) studied the insects from the peat deposits of Lago Rupanco and the outcrops of Dalcahue at Chiloé Island. At higher latitudes, Ashworth and Markgraf (1989) and Ashworth *et al.* (1991) studied the Late Pleistocene and Holocene faunas of Témpano Sur and Puerto Edén. Ashworth *et al.* (1997), and subsequently Ashworth and Kuschel (2003), mentioned the presence of fossil weevils (Curculionidae) in Antarctica.

On the other hand, regarding the southern regions of Argentina, an early–middle Holocene fossil insect assemblage has been reported from Islas Malvinas, Argentina (Buckland and Hammond, 1997). Studies from the Argentinean Patagonia (*e.g.*, Ariztegui *et al.*, 1997; Massaferro and Corley, 1998; Bianchi *et al.*, 1999; Massaferro *et al.*, 2004) are mainly focused on the paleolimnological implications of entomological studies and based on Chironomidae (Diptera). Quaternary fossil insects have been mentioned in some studies (*e.g.*, Pardiñas *et al.*, 1998; Petrulevičius, 1999; Voglino and Pardiñas, 2005), but only recent works have focused on them (*e.g.*, Ramírez and Alonso, 2014; Ramírez and Alonso, 2016; Ramírez and Michat, 2016; Ramírez *et al.*, 2016).

Globally, most of the Quaternary fossil insects are extracted from peat deposits (Grimaldi and Engel, 2005). That information becomes highly relevant when considering that about 95% of the area covered by peatlands in Argentina is located in Tierra del Fuego, mainly at the bottom of the southern valleys in Isla Grande (Iturraspe, 2010). With an average accumulation rate of 0.51 to 0.93 mm/yr during the Quaternary (Rabassa *et al.*, 1989), the Fuegian peatlands are a real database almost continuously recording information related with the environmental conditions and the weather in the region.

In addition to numerous palinological studies on the Island of Tierra del Fuego (*e.g.*, Heusser, 1995, 2003; Borromei and Quattrocchio, 2008; Ponce *et al.*, 2010), other bioproxies, such as ostracods (Cusminsky *et al.*, 2011), mollusks (Candel *et al.*, 2009), marine microflora (Rabassa *et al.*, 2009), calcareous macro and microfossils (Gordillo *et al.*, 2010), and diatoms (Fernández *et al.*, 2012), were used to infer the environmental conditions and weather during the Quaternary.

Even for Patagonia, fossil assemblages of mammals (Tonni and Carlini, 2008), fish and penguins (Cione *et al.*, 2011), reptiles (Albino, 2011), and land birds (Tambussi, 2011) were studied with the same purpose.

Paleoclimatic data obtained from classical biomarkers has not yet led to the precise definition of climate change during the Quaternary. Insects differ from other bioproxies in the degree of detail of the environmental information they provide. Most bioproxies can only be identified at the genus or family level, while insects can often be identified to the species level.

In this work, we present the remains of *Migadops latus*, the first fossil insect extracted from the peatlands of Tierra del Fuego. The Migadopini are a small group of Carabidae that occur in southern South America, Australia, New Zealand, the circum-Antarctic islands (Jeannel, 1938) and in the north Andean region of South America (Moret, 1989). In addition, it constitutes a characteristic element of the sub-Antarctic biota and, except for some common species like *M. latus*, its specimens are usually very rare in collections. Jeannel (1938) made the only comprehensive review of the tribe; later, Straneo (1969) and Nègre (1972) added new species whereas Baher (1997) added subspecies and Moret (1989) a new genus.

The genus *Migadops* Waterhouse, 1842 is distributed throughout the southern tip of America, including Tierra del Fuego and Islas Malvinas (Reichardt, 1977); it includes only two species, both present in sub-Antarctic environments (Roig-Juñent and Dominguez, 2001). *Migadops latus* is the most abundant species on the southern fringe of Tierra del Fuego, Chile and Argentina (Niemelä, 1990). Adults are registered from December to February and show a preference for humid environments (Elgueta *et al.*, 2013). This finding is the first step in the characterization of the Quaternary paleoentomofauna of Tierra del Fuego and sets the beetles as bioproxies for paleoclimatic studies in the southernmost area of South America.

GEOLOGICAL SETTING

The archipelago of Tierra del Fuego extends from the southern coast of the Magellan Strait to Cape Horn, between nearly 52° and 56° southern latitude. This region constitutes the southernmost continental landmass in South America and offers the potential to assess the causes and effects of palaeoclimate fluctuations on terrestrial biota. It includes Isla Grande de Tierra del Fuego, the Hoste, Santa Inés, Navarino, Dawson, Clarence and Desolation islands, Staten Island and other smaller ones. The area exhibits a sub-polar oceanic climate dominated by humid and cold westerly winds. In the northern area of Isla Grande de Tierra del Fuego, an area of steppe landscape extends while the south and west are dominated by a mountainous terrain with *Nothofagus* forests and a strong oceanic influence.

The study site is located just in the transition zone, within the Terra Australis mire, placed 3.6 km south of Lago Fagnano (54° 37′ 8.19″ S; 67° 46′ 5.39″ W), in the central part of the island (Fig. 1). The sequence is 7.37 m deep and the base has been radiocarbon dated at 12,397 ± 62 yrs B.P. (Musotto *et al.*, 2013). This wetland terrain, composed of till, glaciolacustrine and glaciofluvial sediments delivered by deglaciation processes, was formed during the late Quaternary (Musotto *et al.*, 2016). The ombrogenous bog surface is formed primarily of hummocks of *Sphagnum magellanicum* accompanied by *S. fimbriatum*, Cyperaceae, Juncaginaceae, Juncaceae and lichens, and covered by *Empetrum rubrum* and *Nothofagus antarctica*. The bog is surrounded by a mixed evergreen-deciduous *Nothofagus* forest.

MATERIALS AND METHODS

Traditionally, the sampling of peat deposits was made using a Russian corer. The study of Quaternary insects is not possible by means of this methodology since a large volume of material must be analyzed. Fortunately for us, the peat bog of Terra Australis is currently under industrial exploitation and we can hence easily access vertical exposed sections.

Before sampling these sections in order to look for fossil insects, the removal of superficial material repeatedly exposed to changes in current climatic conditions is required. It is also necessary to eliminate contamination caused by modern insects that burrow into exposed banks. This procedure, therefore, helps to ensure that potential radiocarbon samples will not be altered by modern organic material. Once cleaned, peat blocks 50 cm wide and 30 cm deep are sampled in vertical increments of 10 cm and then split into 5 cm thick sub-samples. The peat blocks are wrapped in plastic bags and labeled to register the orientation of the block (top, bottom, and front) and the interval depth.

The techniques used for the extraction and concentration of the fossil insects are summarized in Elias (1994). However, we opted for an already tested alternative to the kerosene flotation, proposed by Ramírez and Michat (2016). Before treating the sediments, we checked the peat blocks looking for conspicuous pieces of insects. Once disaggregated, we skipped the sieving process until all the material was checked under the microscope. This method enables the recovery of fragments of heavy non-floating insects and prevents the damage of the material during the sieving and detergent washing. Moreover, the recovered samples are still suitable for radiocarbon dating. The evidence is stored in small vials with ethanol 70% and measurements were taken using a filar micrometer as follows: pronotal length, straight from anterior to posterior margin along midline; pronotal width, across the widest point; elytral length, straight from anterior to posterior margin along midline; elytral width, across the widest point. The fossil specimen was identified by comparison with modern specimens from the author's personal collection and using published identification keys (Roig-Juñent, 2004). The specimen is deposited in Museo del Fin del Mundo's (**MFM**) collection as MFM 3135.

SYSTEMATIC PALEONTOLOGY

Order Coleoptera Linnaeus, 1758
Suborder Adephaga Schellenberg, 1806
Family Carabidae Latreille, 1802

Genus ***Migadops*** Waterhouse, 1842

Type species. *Migadops virescens* Waterhouse, 1842.

Migadops latus (Guérin-Méneville, 1841)
Figure 2

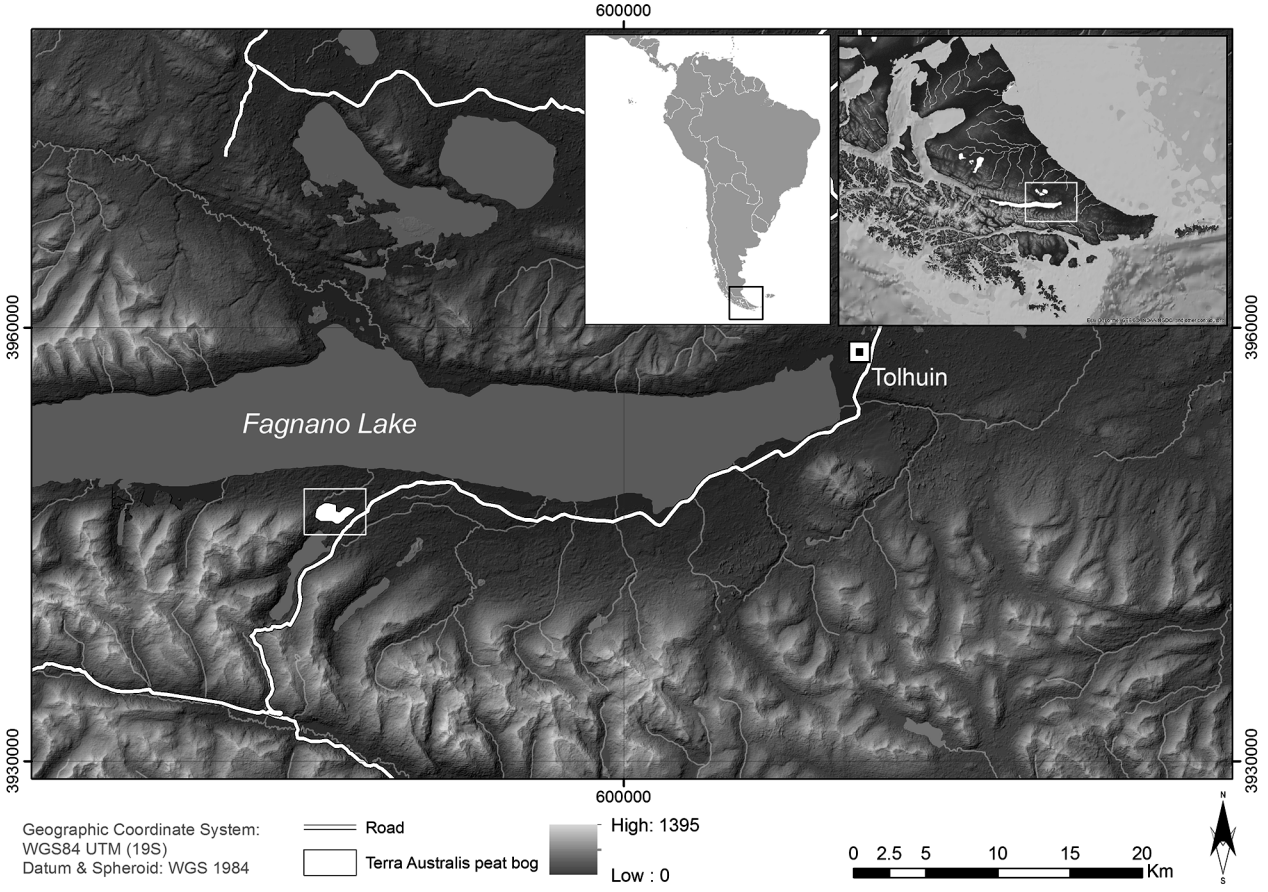

Figure 1. Location of the Terra Australis peat bog.

Figure 2. MFM 3135 ***Migadops latus*** (Guérin-Méneville, 1841). **1,** dorsal view of the pronotum; **2,** dorsal view of the elytra. Scale bar= 1mm.

Description. The fossil consists of a pronotum and both the left and right elytra (Fig. 2). The pronotum is 1.58 mm long and 1.86 mm wide, and the elytra are 5.13 mm long and 1.85 mm wide. Pronotal and elytral surfaces shiny black. Elytral striae smooth.

Label. "*Migadops latus* MFM 3135/ Col. Ramírez, L.C. 2015".

Current distribution. *Migadops* is distributed in the southern tip of South America, including Tierra del Fuego and the Islas Malvinas (Reichardt, 1977). Fairmaire (1885) reported *Migadops latus* from Puerto de Hambre, Navarino Island (Bahia Orange, Choungougon), Hermite Island, Cape Horn and Hoste Island. Blackwelder (1947) added Staten Island and Madre de Dios Island to its distribution. Lanfranco (1983) reported the species from Deceit Island and indicated that it occurs in low abundance in forest and peat bog environments.

DISCUSSION

Musotto *et al.* (2013) defined 3 palynological zones, from bottom to top, in the sequence of Terra Australis. Insect remains were recovered from the TA-3 zone, which ranges from 520 to 0 cm in depth and is dated ca. 6,500-0 cal. yr B.P.

The pollen record of the TA-3 zone suggests that a *Nothofagus* closed-canopy forest established after 6,500 cal. BP at Terra Australis under cold and more humid conditions. The identified plant communities resemble the current mixed Magellanic forest of *Nothofagus betuloides*. and *N. pumilio* in southern Tierra del Fuego, where annual rainfall ranges from 500 to 800 mm and the average annual temperature is 7°C (Pisano, 1977; Heusser, 1998).

The development of an ombrotrophic *Sphagnum* bog at the site is thought to be a strong evidence of an increase in humidity. *Sphagnum* ombrotrophic peat bogs are nowadays found leeward of the Andes as well as throughout the deciduous and evergreen cool-temperate ecoregions of Tierra del Fuego (Loisel and Yu, 2013), where precipitations exceed 600 mm per year (Tuhkanen, 1992). Furthermore, high quantities of the reproductive bodies of fungi indicate that an even more closed forest developed, likely reflecting higher humidity conditions (Musotto *et al.*, 2016).

The species herein reported is a subantarctic element (*sensu* Morrone, 2000). *M. latus* has been cited as the most abundant species on the southern fringe of Tierra del Fuego, showing a preference for humid environments and being especially abundant in the surroundings of Ushuaia (Niemelä, 1990). This is the most abundant species of the Migadopini, as reflected in the entomological collections nowadays often found in domestic environments in the city of Ushuaia (pers. obs.). While the absence of other taxa cannot be considered as evidence, the good preservation and abundance of the remains of a single species at the studied level enable inferring a certain dominance of the taxon.

The most restrictive parameter in the distribution of *M. latus* appears to be the humidity. Considering this aspect,

the presence of the species supports the environmental interpretations that propose the increase of humidity and the advance of closed *Nothofagus* forests around 3,000 years BP.

Notably, the adults of these species lack the hind wing and instead have just an alar stump. This feature prevents them from flying, restricting their movement and, consequently, their chances of dispersion. Quaternary beetle records mostly consist of disarticulated exoskeletons, mainly heads, pronota, and elytra. The observable characters on the mentioned structures are often enough to identify them at the species level, mainly in sites where diversity is relatively low. Diversity decreases towards higher latitudes and does not differ between marine and terrestrial groups, active and passive dispersers or ectothermic and endothermic taxa (Hillebrand, 2004). In addition to facilitating the study of Fuegian fossil beetles, this feature increases the relevance of the paleoclimatic inferences made on their basis. The accuracy of the taxonomic identifications allows us to adjust environmental interpretations of the past.

The most accurate paleoenvironmental reconstructions of a given site are never based on the isolated study of a single bioproxy. On the contrary, they are the result of the interdisciplinary study of a broad spectrum of fossils, including not just insects but also pollen, plant macrofossils, diatoms, ostracodes, mollusks, and vertebrates, among other markers. The integration of different paleoclimatic proxies with different temporal and spatial resolutions is a powerful tool for understanding the processes involved in global climate change.

This study constitutes the first approach to the Quaternary paleoentomology of Tierra del Fuego and highlights the potential of paleoentomological information when evaluated in combination with previous knowledge of global climate conditions after the last glacial maximum. Future studies of the many peat bogs in the area will allow us to adjust the paleoclimatic interpretations made until today.

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