

Article

Two Circumpolar Ground Beetle Species (Coleoptera: Carabidae) Were in Hokkaido, Japan, Late in the Last Glacial Period

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Abstract: Fossilized body parts of two cold-adapted ground beetle species, *Elaphrus lapponicus* and *Diacheila polita*, were identified from a deposit dated to the Late Glacial period in Hokkaido, Japan. The paleoenvironmental reconstruction presented here has been based on modern temperature ranges and environmental conditions, along with paleobotanical evidence from the site. Late Glacial temperatures were at least 6 degrees °C lower than modern temperatures in summer, and the area around the site was mostly covered with forest tundra, which exists only in areas further north than Hokkaido.

Keywords: *Diacheila polita*; *Elaphrus lapponicus*; ground beetles; forest tundra; fossil; Hokkaido; Last Glacial period; paleoenvironment

1. Introduction

The distribution of cold-adapted mammals and plants, such as the Woolly Mammoth and Daurian Lisaarch, in Hokkaido in the Late Glacial period has already been reported [1].

However, no fossil insect research has thus far been conducted on samples from this period in Japan. In this paper, I report on the discovery of two cold-adapted ground beetle species, *Elaphrus lapponicus* and *Diacheila polita*, from the Late Glacial period in Hokkaido. My paleoclimate reconstruction is based on the modern distributions of these two species.

2. Abbreviation of Specimen Depositories and Their Curators

CNCO: Canadian National Collection, Agriculture and Agri-Food Canada, Ottawa (Yves Bousquet).

IBSS: Institute of Biology and Soil Sciences, Far Eastern Branch, Russian Academy of Sciences, Vladivostok, Russia (German Lafer).

OMNH: Osaka Museum of Natural History, Osaka, Japan (Shunpei Fujie and the author).

3. Geological Setting and Sampling Method

The fossils were recovered from a peaty bed in Horonobe, Hokkaido, Japan (Figure 1). The deposit was dated to the Late Glacial interval, 14 to 12 thousand years BP by ¹⁴C radiocarbon dating [2]. Fossil insect sampling was conducted in October 2008 using the peat block-splitting method [3].



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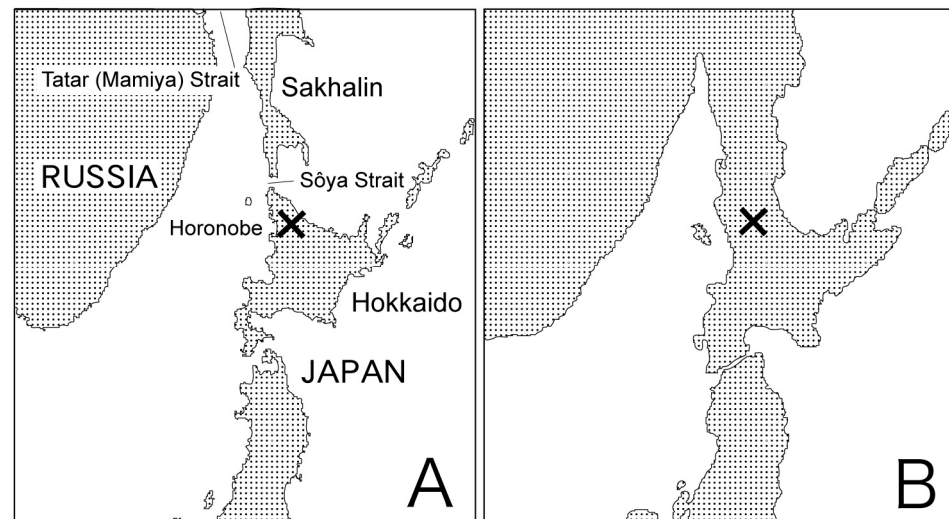


Figure 1. Maps of the part the East Asia that contains the study site (X). (A) Present coastline. (B) Coastline at the Last Glacial Maximum, ca. 25,000 yrs BP (after Ono and Igarashi, 1991).

4. Description

4.1. *Elaphrus lapponicus* Gyllenhal

Shown in Figure 2.

Pronotum. Length 1.9 mm, width 2.3 mm. Coloration dark blueish brown. Surface uneven; punctures oval to round and uniformly scattered. Anterior margin slightly emarginated near anterior angles and not edge-stitched. Lateral margin edge-stitched without depressed areas, broadly curved outwards with peaks in anterior 1/3, parallel from posterior 1/4 to the tip. Posterior margin very broadly curved outwards. Posterior angles obtuse. Basal fovea shallow.

Right elytron. Length 5.8 mm, width 2.1 mm. Coloration dark blueish brown. Lateral margin finely serrated and broadly rounded outwards. Posterior apex rounded. Sutural margin moderately curved. Surface uneven; punctures irregularly sized and scattered, forming five clear and several unclear spots; microsculpture very fine except for five clear spots, or ‘mirrors’, which are smooth and shiny.

Sampling note. The pronotum and the elytron were found side by side on the peat surface.

Identification notes. The fossils match modern specimens of *Elaphrus lapponicus* Gyllenhal by direct comparison, using a microscope, with selected specimens from modern populations. The diagnostic feature of the subgenus *Arctelaphrus*, of which there is only one species (*E. lapponicus*), is irregularly arranged punctures on the elytra [4].

Previous fossil records: Fossils of this species are widely found from the Last Glacial period to the Early Holocene in Europe, East Asia, and North America [5–7].

Modern distribution: Boreal circumpolar areas mainly between 50° and 70° N latitude [4,7,8]. The mean July temperature (TMAX) range, based on the modern distribution of the species, is 9° to 13 °C. The corresponding mean January temperature (TMIN) ranges from −36° to 3 °C [7].

Habitat and biology. An arctic tundra insect [9]. Able to fly [6].

Modern specimens examined: 1ex., near Semchan vill. (*Larix* forest along hill slope), Magadanskaya Region, Russia, 4.vii.1965, D. Kononov leg. [IBSS]; 1ex., Southeast of Okontsanpe, Big Annachag Range, Sibit-Tyllach River, Magadanskaya Region, 19.vii.1980, S. Bychlo leg. [IBSS]; 1ex., the same locality, 11.v.1979 [IBSS].

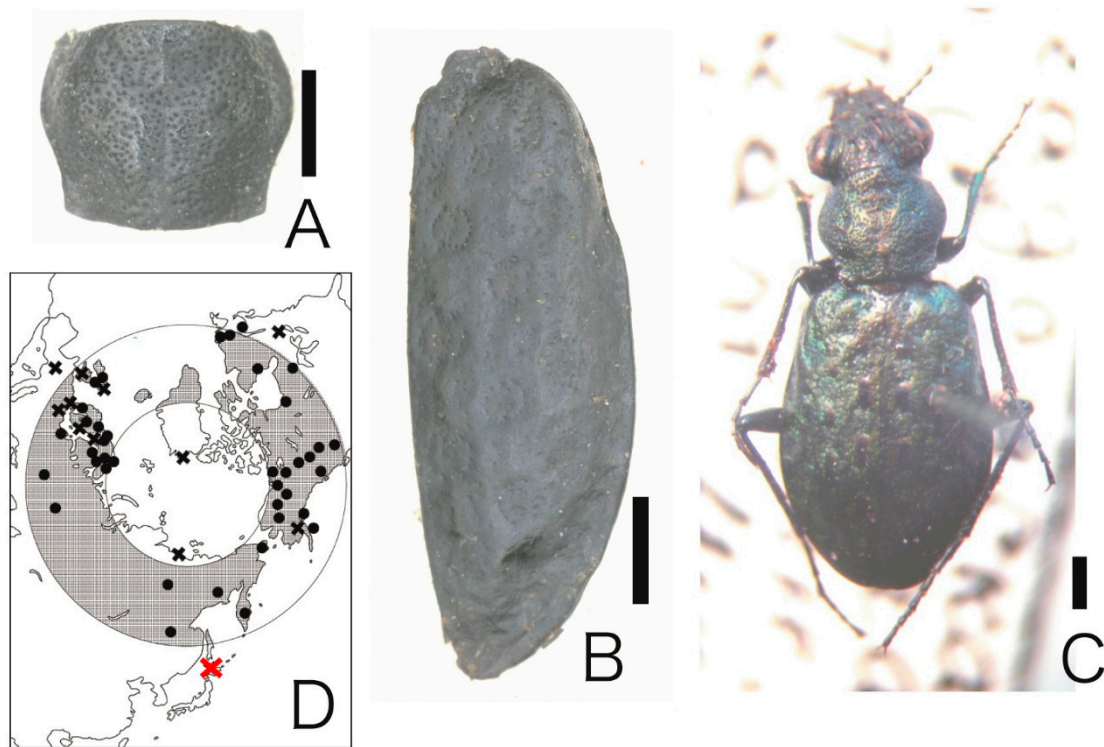


Figure 2. *Elaphrus lapponicus* Gyllenhal. (A) Fossil pronotum. (B) Fossil right elytron. (C) Modern specimen from Magadan, Russia. (D) Fossil (X) and modern (black circle) distribution. Scales: 1 mm.

4.2. *Diacheila polita* (Fadermann)

Shown in Figure 3.

Pronotum. Length 1.7 mm, width 2.2 mm. Coloration black. Punctures on surface almost regularly scattered. Anterior margin slightly emarginated in lateral 1/2 on both sides. Anterior angles acute. Lateral margins finely serrated with depressed areas, broadly curved outwards with peaks in anterior 1/3, constricted in posterior 1/5. Posterior margin almost straight and finely serrated. Basal fovea deep, lacking latero-basal carinae.

Left elytron. Length 5.2 mm, width 1.6 mm. Coloration black on basal area, becoming brownish posteriorly. Punctures regularly scattered on basal 1/4, forming 9 unclear elytral striae in the central area and becoming shallow and disappearing in the posterior 1/4. Lateral margin finely serrated and moderately curved. Elytral apex acute and rounded at the tip.

Identification notes. The fossils were identified as *Diacheila polita* by direct comparison, using a microscope, with selected specimens from modern populations. The absence of the latero-basal carinae and the constriction of lateral pronotal margins separate *D. polita* from the congener *D. arctica* (according to [7]).

Previous fossil record. Widely found from the Last Glacial period to the Early Holocene in Europe, East Asia, and North America [5,6,9–12].

Modern distribution. Arctic regions from the Kola Peninsula eastward in Asia. Arctic to subarctic regions of Alaska and the Yukon Territory, with isolated populations on alpine tundra in the Alaska Range, Alaska, USA, in North America [13]. TMAX range of the modern species is 7° to 12 °C and its TMIN is −5° to −38 °C [7]. Recently, new localities containing the species have been found in northeastern Asia [8,14].

Habitat and biology. This species inhabits mesic to moist tundra in cold regions. Some are found today in bogs within the boreal zone [15]. Flightless [7].

Modern specimens examined: 3exs., Canoe Lake, 20 miles west of Aklavik, Northwest Territories, Canada, vi–viii. 1972, Norma Peterson leg. [CNCO].

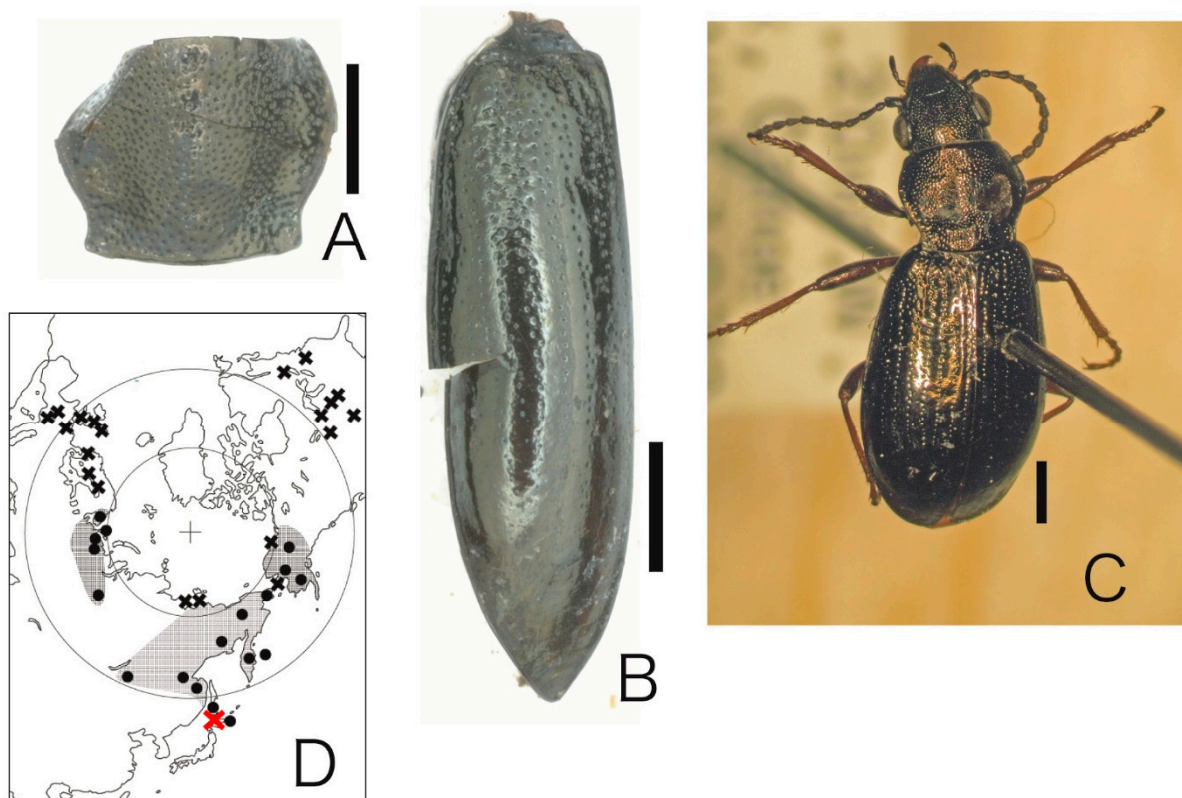


Figure 3. *Diacheila polita* (Faldernmann). (A) Fossil pronotum. (B) Fossil left elytron. (C) Modern specimen from Northwest Territories, Canada. (D) Fossil (X) and modern (black circle) distribution. Scales: 1 mm.

5. Discussion

(1) Paleoclimatic reconstruction

Both of these ground beetle species are categorized as indicators of an extremely cold climate by Quaternary entomologists in Europe and North America [13,16]. Buckland and Buckland [6] built up a database for paleoclimatic analysis using fossil beetle assemblages which is based on meteorological data associated with modern beetle distributions. Their database shows that the mutual climatic range of the species yields a TMAX of 9° to 13° C. Based on a modern TMAX value of 19.5 °C at the fossil site [15], the TMAX during the Late Glacial interval would have been 6.5° to 10.5 °C colder than the modern one.

(2) Paleoenvironmental reconstruction

Yasuda and Miyoshi [17] estimate that the lowlands of northern Hokkaido were covered by forest tundra and larch and pine trees during the Last Glacial Maximum. Both *Elaphrus lapponicus* and *Diacheila polita* are mainly found in arctic to subarctic tundra zones today. In his collecting notes, Goulet [4] stated that *E. lapponicus* lives near cold water in areas with moss, other short vegetation, and scattered conifers.

Lindroth [8] notes that *Diacheila polita* usually inhabits peaty soils on the open tundra, but sometimes inhabits in drier places with birch trees (*Betula*). Thus, the reconstruction of the paleoenvironment from the beetle assemblage matches paleobotanical reconstructions. However, we must consider that *D. polita* has also been found in the coniferous forests of eastern Siberia [18]. Its characterization as a stenothermal cold-adapted species may need revision. Igarashi [19] argued that there was no tundra zone in Hokkaido during the Last Glacial Maximum based on several palynological studies there.

(3) Estimation of the distributional history of the Ice Age species

At the end of the Last Interglacial period, 120 thousand years ago, the climate cooled, leading to the Last Glacial period. Subsequently, the sea level fell, and what is now

Hokkaido Island was a peninsula connected to the Asian continent by a land bridge through what is now Sakhalin Island (Figure 1B) [1]. Cold-adapted mammal species, such as mammoths and elk, easily colonized the Hokkaido region under glacial conditions. The two ground beetle species examined in this paper are also species that have adapted to extreme cold and may have had similar colonization patterns to those of these mammals.

All these cold-adapted species likely faced very difficult situations during the warming at the end of the last glaciation. The pattern of biotic responses to regional climatic warming falls into three patterns, with examples described below. The first scenario is species extinction, such as with mammoths. The second is the relocation of some species to high mountains. These species still survive at high elevations on Hokkaido, including the butterfly *Parnassius eversmanni* [20], the pika species *Ochodona hyperborea* [1], and alpine plants such as *Dryas octopetala* [21]. The third scenario is expatriation from Hokkaido. Some expatriated species remain in the boreal regions of Sakhalin Island or in Siberia: elk (*Cervus elaphus*) and Daurian larch (*Larix gmelinii*) are examples of this scenario. The two ground beetle species examined in this paper fall into the third pattern, unless modern species can be found on Hokkaido.

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