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

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**Abstract:** Fossil body parts of the two cold-adapted ground beetle species, *Elaphrus lapponicus* and *Diacheila polita*, were found from a deposit dated in the late Last Glacial period in Hokkaido, Japan. The paleoenvironment was estimated from their modern distribution and habitat, along with the results of the paleobotanical studies at the site. The temperature was at least 6 degrees lower than modern in summer, and the area around the site was mostly covered with forest tundra, which can currently be seen in areas further north of Hokkaido.

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

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## 1. Introduction

During the Quaternary period, the warm and cold climate has alternately been repeated on the earth. Biota shifted north- and southward as a result of the drastic change in climate. The most recent period of an extremely cold climate is called the Last Glacial period, which finished about 10 thousand years ago by the climatic warming up to the present time.

The distribution of cold-adapted mammals and plants, such as the Mammoth elephants and Daurian larch have already been reported at the Last Glacial period in Hokkaido [1]. But no study has ever been conducted there from the viewpoint of paleoentomology.

In this paper, the author will report on the past distribution of two cold-adapted ground beetle species *Elaphrus lapponicus* and *Diacheila polita* at the Last Glacial period in Hokkaido. Based on the modern distribution of the two species, paleoclimate is discussed.

## 2. Abbreviation of specimen depository and the curator

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 auther).

## 3. Geological setting and sampling method

The fossils were yielded in a peaty bed in Horonobe, Hokkaido, Japan (Figure 1). The deposit is dated to the late Last Glacial about 14 to 12 thousand years BP by the $C^{14}$ radiocarbon dating [2]. Entomological sampling was conducted there by block-splitting method [3] in October 2008.

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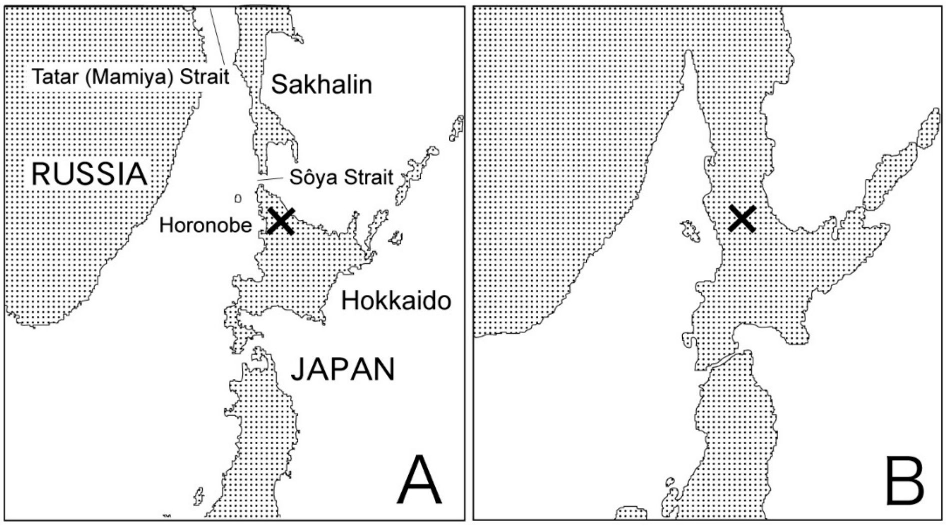


**Figure 1.** Maps of a part of the East Asia with the study site (X). A. Present coastline. B. Coastline at the Last Glacial Maximum, ca. 25,000 yrs BP.

## 3. Description

### *3.1. Elaphrus lapponicus Gyllenhal*

(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 angels and not fringed. Lateral margin fringed without depressed areas, broadly curved outwards with peaks at anterior 1/3, parallel from posterior 1/4 to the tip. Posterior margin very broadly curved outwards. Posterior angles obtusely angled. Basal fovea shallow.

Right elytron. Length 5.8 mm, width 2.1 mm. Coloration dark blueish brown. Lateral margin fringed 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; textures very fine except for the inside of the five clear spots 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 are identified with parts of *Elaphrus lapponicus* Gyllenhal by direct comparison using a microscope with determined specimens from modern populations. The diagnostic character for 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 Early Holocene in Europe, East Asia and North America [5–7].

Modern distribution. Boreal circumpolar areas mainly between 50 °and 70° in latitude [4,7,8]. Thermal range accumulated from the modern distribution is 9° to 13°C (monthly mean temperature in July) and -36° to 3°C (ditto in January) [7].

Habitat and biology. An arctic tundra insect [9]. Flyable [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].

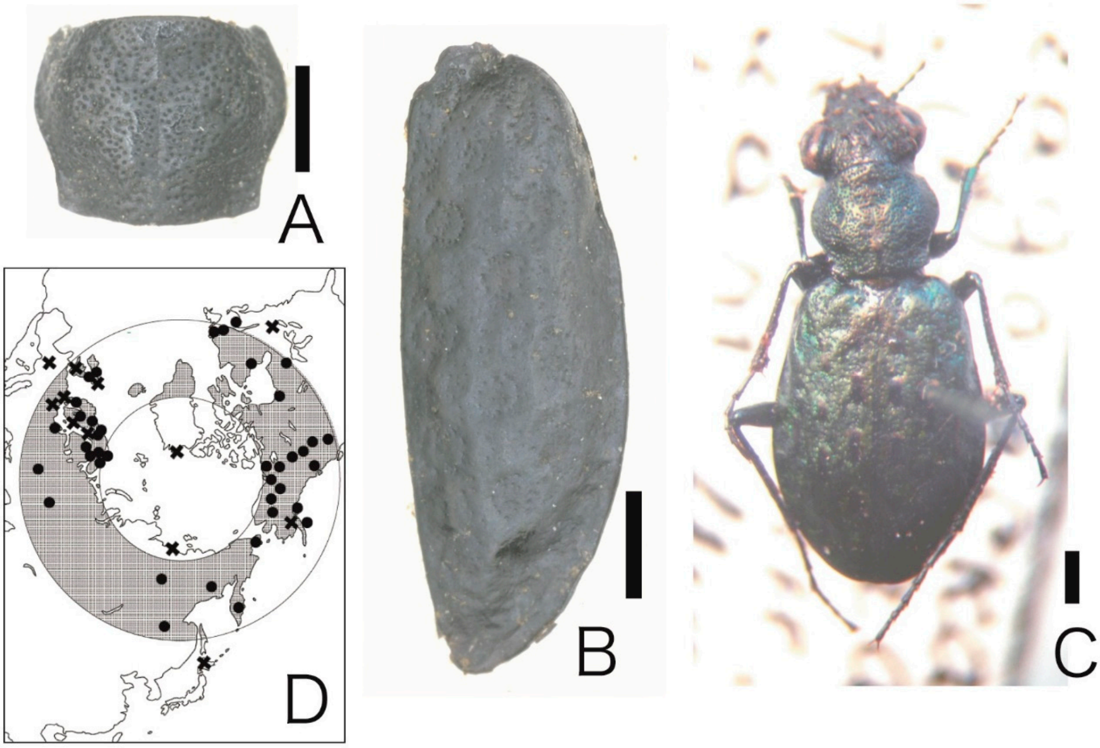


**Figure 2.** *Elaphrus lapponicus* Gyllenhal. A. Fossil pronotum. B. Fossil right elytron. C. Modern specimen from Magadan, Russia. D. Fossil (X) and modern (black circle) distribution. Scales: 1 mm.

### *3.2. Diacheila polita (Fadermann)*

(Figure 3)

Pronotum. Length 1.7 mm, width 2.2 mm. Coloration black. Punctures on surface almost regularly scattered. Anterior margin slightly emarginated at lateral 1/2 on both sides. Anterior angles acutely angulated. Lateral margins fringed with depressed areas, broadly curved outwards with peaks at anterior 1/3, constricted at posterior 1/5. Posterior margin almost straight and fringed. Basal fovea deep without lateral carinae.

Left elytron. Length 5.2 mm, width 1.6 mm. Coloration black on basal area, getting brownish posteriorly. Punctures regularly scattered on basal 1/4, forming 9 unclear elytral striae at middle area, getting shallow and disappear at posterior 1/4. Lateral margin fringed and moderately curved. Elytral apex acutely angulated and rounded at the tip.

Identification notes. The fossils are identified with parts of *Diacheila polita* by direct comparison using a microscope with determined specimens from modern populations. The absence of the carinae beside the basal fovea and the constriction of lateral margins on pronotum are diagnose to distinguish from the congener, *D. arctica* (according to [7]).

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

Modern distribution. Arctic regions from Kola Peninsula eastward in Europe. Arctic to subarctic regions of Alaska and the Yukon Territory, with isolated populations on alpine tundra in the Alaska Range in North America [13]. Thermal range accumulated from the modern distribution is 7° to 12°C (monthly mean temperature in July) and –5° to –38°C (ditto in January) [7]. Recently new localities are being found in northeastern Asia [8,14].

Habitat and biology. 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].

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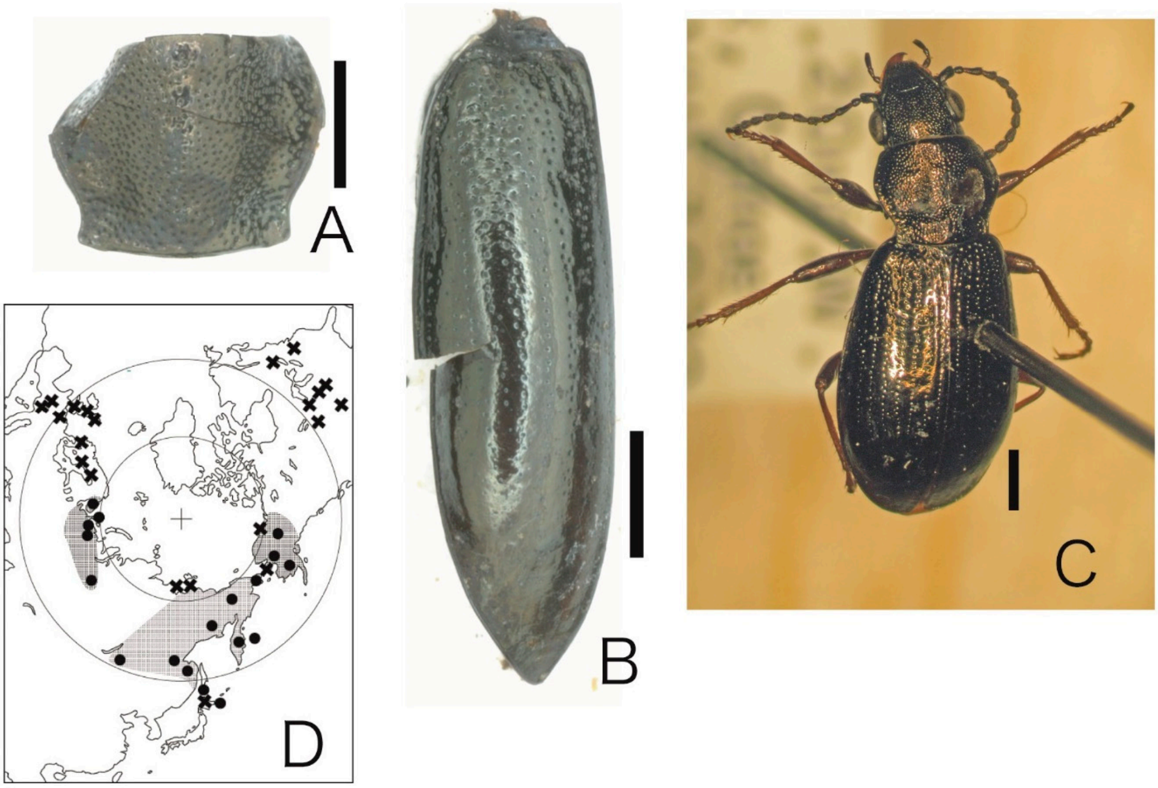


**Figure 3.** *Diacheila polita* (Faldermann). A. Fossil pronotum. B. Fossil left elytron. C. Modern specimen from Northwest Territories, Canada. D. Fossil (X) and modern (black circle) distribution. Scales: 1 mm.

## 4. Discussion

### (1) Paleoclimatic reconstruction

Both of the ground beetle species are categorized as indicators for the extremely cold climate by Quaternary entomologists in Europe and North America [13]. Buckland and Buckland [6] built up a database for paleoclimatic analysis using fossil beetle assemblages, which is based on the meteorological data and the modern beetle distribution. The database shows that the reconstructed temperature based on both beetle species ranges between 9° to 13° C in July monthly mean temperature. As the modern monthly average temperature in Horonobe is 19.5° C in the warmest month [16], the paleoclimate can be estimated to have been 6.5° to 10.5° C lower than in modern summer. Niizato et al. [2], in a study on the same deposit, also states that the summer temperature at that time was at least 6° C lower than in the present, judging from the vegetation zone inferred by the pollen analysis.

### (2) Paleoenvironmental reconstruction

Yasuda and Miyoshi [17] estimate that the lowland of northern Hokkaido was covered by forest tundra accompanied with larch and pine trees at around the Last Glacial Maximum.

Both *Elaphrus lapponicus* and *Diacheilla polita* are mainly distributed in arctic to subarctic tundra zones today. Goulet [4] described in his collecting notes that *E. lapponicus* lives near cold water in areas with moss, other short vegetation and scattered conifers. Lindroth [8] notes that *Diacheila polita* inhabits peaty soils on the open tundra, sometimes in drier places with birch trees (*Betula*). Thus, the reconstruction of the paleoenvironment from the beetle assemblage matches with the estimations from the viewpoint of the paleovegetation. However, the fact that *D. polita* can inhabit coniferous forests in eastern Siberia is revealed [14]. The characteristics as a stenothermal cold-adapted species may have needed to change. Igarashi [18] has submitted that there was no tundra zone at Last Glacial Maximum in Hokkaido, based on several palynological studies there.

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

After the ending of the warm age about 120 thousand years ago (the Last Interglacial period), the climate started to get colder, and the Last Glacial period began. Subsequently the sea level got lower, and Hokkaido Island was terrestrially connected to the Siberian continent by the land bridges through Sakhalin (Figure 1B). Cold-adapted mammal species, such as Mammoth elephants and elk, could easily colonize southward in Hokkaido under the cold climatic conditions. The two ground beetle species treated in this paper are also extremely cold-adapted species and may have the same history of colonization as these mammals.

All these cold-adapted species would have faced very difficult situations during the warming at the end of the Ice Age. The history and results following climatic warming can be categorized into three patterns with examples described below. The first category is extinction of species from the earth such as the Mammoth elephants. The second is that some species still survive in Hokkaido by evacuating to high mountains: a butterfly species *Parnassius eversmanni*, a pika species *Ochodona hyperborea* and alpine plants such as *Dryas octopetala* are examples of this senario. The third category is the extirpation from Hokkaido to boreal areas of Sakhalin Island or the Siberian continent: the elk and the Daurian larch are examples of this category. The two ground beetle species treated in this paper can be categorized into the third pattern, until the modern distribution in Hokkaido is recorded.

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