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Middle Pleistocene to Holocene mammal faunas of the Ryukyu Islands and Taiwan: An updated review incorporating results of recent research

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ABSTRACT

This paper presents an updated review on Middle Pleistocene to Holocene land mammal fossil localities and their faunas in the main part of the Ryukyu Islands (Central and Southern Ryukyus) and in Taiwan. We reconstruct the successions of land mammal faunas from the Middle Pleistocene to Holocene mainly on Okinawa Island in the Central Ryukyus, and on Miyako and Ishigaki Islands in the Southern Ryukyus, as well as in Taiwan. We also discuss the faunal relationships among the three islands and Taiwan, and paleogeographic inferences based on the results. The fauna on Okinawa Island has been of an insular type, and has shown a high degree of endemism since the Middle Pleistocene. With the exception of the wild boar (*Sus scrofa*), no mammals have immigrated onto the island since the Middle Pleistocene, indicating that the island has been isolated from other regions by the sea since at least the Middle Pleistocene. The appearance of the wild boar in the later part of the Late Pleistocene is suggestive of human introduction. On Miyako Island, the presence of the steppe mammoth (*Mammuthus trogontherii*) in the Middle Pleistocene indicates that this species immigrated from Taiwan across a temporary land bridge formed between the island and Taiwan (probably via Ishigaki Island) during a cold stage of the late Middle Pleistocene. It is probable that this land bridge did not reach Okinawa Island. The Late Pleistocene faunas of Miyako and Ishigaki Islands are also of an insular type, and non-flying forms of the two faunas are markedly different from one another, and are also different from their counterparts on Okinawa Island. These observations indicate that Miyako and Ishigaki Islands were separated from one another and from Okinawa Island in the Late Pleistocene. The Holocene faunas of Miyako and Ishigaki Islands also indicate isolated conditions. As on Okinawa Island, it is suggested that humans introduced the wild boar, probably in the later part of the Late Pleistocene. The Middle Pleistocene to Holocene mammal faunas of Taiwan are of a continental type, and differ greatly from those of the Ryukyu Islands. Thus, Taiwan has been separated from the islands since the Middle Pleistocene, with the exception of the land bridge stage.

1. Introduction

The Ryukyu Islands (Ryukyus) consist of many small islands that form an island arc between Kyushu and Taiwan with a length of ~1200 km (Fig. 1). The present land mammal faunas on the islands are of an insular type: they show low taxonomic diversities, an absence of large mammals (i.e., mammals exceeding the size of a wild boar), and the presence of highly endemic forms on some of the islands. Such faunas are considered to have formed during a history of alternating connectivity and isolation of islands, climate and vegetation changes, and human impacts in the Quaternary. The formative processes of the faunas are expected to be recorded in Quaternary mammal fossils, which are abundantly preserved on the islands. The mammal fossils have been studied by many researchers since the first systematic description of deer fossils on Okinawa Island by Matsumoto (1926) (Fig. 1). The studies of the fossils have revealed that Pleistocene faunas were considerably different from those of the present day. Overviews of the

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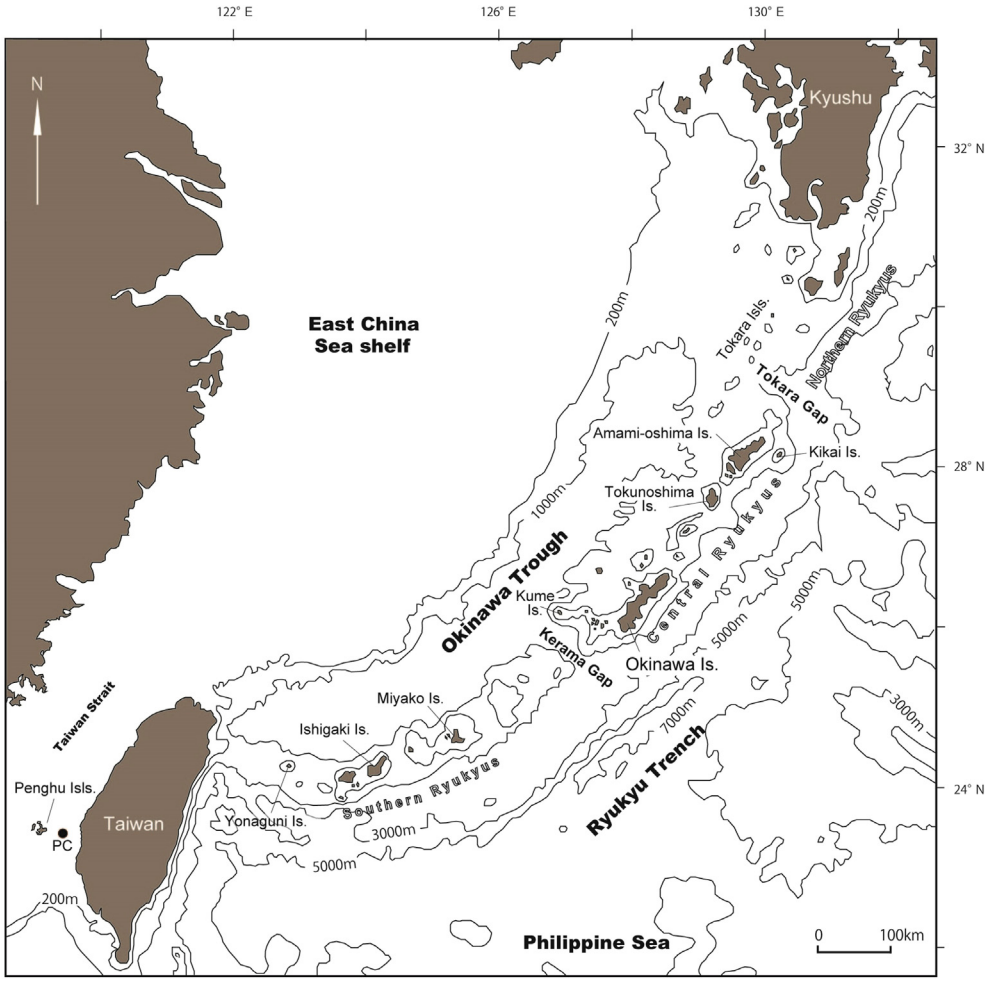

Fig. 1. Geographic setting of the Ryukyu Islands and Taiwan. Bathymetric contours show the submarine topography. PC = Penghu Channel, where numerous fossils of land mammals have been dredged.

Quaternary mammal faunas of the islands have been provided by Hasegawa (1980), Kawamura (1991), Oshiro (2001), Otsuka (2002), Kawamura (2010), Van der Geer et al. (2010), and others, based mainly on data from the fossil record.

In addition to the data used for these overviews, recent research has provided several new and important pieces of information on Middle Pleistocene to Holocene mammal fossils and fossil-bearing sediments from the islands. In this paper, we therefore present an updated review that describes and discusses the succession of Middle Pleistocene to Holocene mammal faunas on the islands, and which include the new information as well as previous data.

This paper also presents an updated review of the Middle Pleistocene to Holocene mammal faunas of Taiwan, including new data from our recent research in this area. The faunas of Taiwan are expected to provide important data clarifying the evolution of mammal faunas in the Ryukyu Islands, as Taiwan is geographically close to the Ryukyu Islands which presently belong to the same biogeographic region except for the northern part adjoining Kyushu (Northern Ryukyus; Fig. 1). We also discuss the Middle Pleistocene to Holocene faunal succession in Taiwan.

The comparison of Middle Pleistocene to Holocene faunas of the Ryukyu Islands with those of Taiwan allows for discussions of faunal relationships, of the immigration of non-flying mammals to the islands, and of paleogeographic processes. The present review, which includes the comparison, represents a new phase of Quaternary mammalian paleontology of the Ryukyu Islands and Taiwan, as previous authors have discussed the results of research in each region separately.

2. Geographical, geological, and faunal settings

The Ryukyu Islands are separated from the continental shelf of East Asia (East China Sea shelf) by the Okinawa Trough, a deep and narrow submarine basin that extends to depths of more than 1000 m and runs along the northwestern side of the islands. The southeastern side of the Ryukyu Islands is bounded by the Ryukyu Trench, which extends to depths of more than 5000 m. Two unusually deep straits through the Ryukyu Islands, the Tokara and Kerama Gaps, divide the Ryukyu Islands into three island groups, known as the Northern, Central, and Southern Ryukyus (Fig. 1). The Central and Southern Ryukyus, which constitute the main part of the Ryukyu Islands, are considered in this paper; but the Northern Ryukyus are omitted from the ensuing discussion because of the poor Quaternary record of mammal fossils in this area, and for biogeographic reasons that are mentioned below.

The surficial geology of the Ryukyu Islands is characterized by a wide distribution of the Pleistocene Ryukyu Group consisting mainly of reef-building limestone, generally referred to as the Ryukyu Limestone. The Ryukyu Group overlies the Late Miocene to Early Pleistocene Shimajiri Group, which consists mainly of marine mudstone and sandstone (in contrast to the limestone of the

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