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Early Cretaceous terrestrial ecosystems in East Asia based on food-web and energy-flow models

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Abstract

In recent years, there has been global interest in the environments and ecosystems around the world. It is helpful to reconstruct past environments and ecosystems to help understand them in the present and the future. The present environments and ecosystems are an evolving continuum with those of the past and the future. This paper demonstrates the contribution of geology and paleontology to such continua.

Using fossils, we can make an estimation of past population density as an ecosystem index based on food-web and energy-flow models. Late Mesozoic nonmarine deposits are distributed widely on the eastern Asian continent and contain various kinds of fossils such as fishes, amphibians, reptiles, dinosaurs, mammals, bivalves, gastropods, insects, ostracodes, conchostracans, terrestrial plants, and others. These fossil organisms are useful for late Mesozoic terrestrial ecosystem reconstruction using food-web and energy-flow models. We chose Early Cretaceous fluvio-lacustrine basins in the Choyr area, southeastern Mongolia, and the Tetori area, Japan, for these analyses and as a potential model for reconstruction of other similar basins in East Asia. The food-web models are restored based on taxa that occurred in these basins. They form four or five trophic levels in an energy pyramid consisting of rich primary producers at its base and smaller biotas higher in the food web. This is the general energy pyramid of a typical ecosystem. Concerning the population densities of vertebrate taxa in 1 km^2 in these basins, some differences are recognized between Early Cretaceous and the present. For example, Cretaceous estimates suggest 2.3 to 4.8 times as many herbivores and 26.0 to 105.5 times the carnivore population. These differences are useful for the evaluation of past population densities of vertebrate taxa. Such differences may also be caused by the different metabolism of different taxa. Preservation may also be a factor, and we recognize that various problems occur in past ecosystem reconstructions.

Counts of small numbers of confirmed species and estimates of maximum numbers of species present in the basin are used for the analysis and estimation of energy flow. This approach applies the methods of modern ecosystem analysis.

Keywords: Cretaceous; East Asia; Terrestrial ecosystems; Food web; Energy flow; Population density

1. Introduction

In recent years, various modern environments and ecosystems have been studied around the world. Reconstructing past environments and ecosystems helps understand the evolving continuum from past to present and future. Using fossils, we can estimate past population densities as an ecosystem index based on food-web and energy-flow models. This is one of the best examples showing the contribution of geology and paleontology to modern society.

Because ecosystems are significantly influenced by environmental phenomena, we can use them to study environmental variation. The term "ecosystem" is used here to denote the

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biological community together with the abiotic environment in which it is set. Both are strongly linked to each other by fluxes of energy and matter (Begon et al., 1996). Thus, it is important to understand energy flow in order to understand ecosystems.

In the Early Cretaceous Epoch, the evolution of terrestrial ecosystem is thought to have been largely controlled by continental rifting and accompanying environmental change (Obata, 1993; Barrera and Johnson, 1999). At that time, continental rifting formed the framework of the present continental distribution and the angiosperms appeared, established their niche, and expanded their distribution, influencing the whole animal kingdom. Thus, terrestrial biotas and their ecosystems and environments can be understood using energy-flow models. On the basis of analyses and reconstructions of Cretaceous and other past-terrestrial ecosystems, we can perhaps better understand present and future terrestrial ecosystems. In this respect, the Cretaceous terrestrial ecosystem analyses contribute to an understanding of history of the Earth as a dynamic, ongoing process.

There have been some previous attempts to reconstruct paleoecosystems. For example, Jacobs and Murry (1980) dealt with vertebrate communities of the Upper Triassic Chinle Formation of the southwestern United States, Anderson et al. (1997) examined Upper Triassic paleoecosystems of southern Africa, Lucas et al. (1998) discussed Cretaceous terrestrial ecosystems, and Wilde and Frankenhauser (1998) touched on the Paleogene terrestrial ecosystem in Europe. These authors only considered fauna and flora interrelationships based on fossils they sampled. Bakker (1972) tried to reconstruct Late Cretaceous dinosaur communities by inferring energy flow, to prove endothermy among dinosaurs. Farlow (1976) estimated dinosaur metabolism from present endothermic and ectothermic animals and tried to reconstruct large dinosaur communities aiming at understanding the trophic dynamics of the Upper Cretaceous Oldman Formation. Foster (2003a,b) also conducted a paleoecological study of the Morrison Formation. Although there are some problems such as biases of fossil preservation, many assumptions in reconstruction processes, and lack of detailed examination of food-web models, the methods used by these authors nevertheless suggest ways of approaching the trophic dynamics of ancient vertebrate communities. Paul (1988) estimated predatory dinosaur populations based on energy flow and used it to infer evidence of endothermic dinosaurs. These methods have various problems of procedure and influence that are probably difficult to overcome entirely (Bakker, 1972; Farlow, 1976).

Early Cretaceous nonmarine deposits are distributed widely on the eastern Asian continent and contain various kinds of fossils such as fishes, amphibians, reptiles, dinosaurs, mammals, bivalves, gastropods, insects, ostracodes, conchostracans, terrestrial plants, and trace fossils. In this area, we can fill in data for the Early Cretaceous terrestrial biota that has been lacking in other regions. In this paper, we analyze the Early Cretaceous fluvio-lacustrine systems in the Choyr basin, southeastern Mongolia, and the Tetori basin, Japan. These analyses may help reconstructions in similar basins in East Asia.

2. Characteristics of Cretaceous terrestrial basins in East Asia

Cretaceous strata are distributed across East Asia in several belts from the Asian continent to the Japanese Islands with a northeast-southwest trend (Fig. 1). From west to east, the strata are characterized principally by nonmarine, alternating nonmarine and marine, and marine deposits, which are interpreted to have accumulated in fluvio-lacustrine through shallow marine shelf to trench environments. Additionally, these Lower Cretaceous strata show an asymmetric array of sedimentary facies and represent deposition in continental, back-arc, fore-arc, and trench settings. This setting can be compared with present sedimentary basins in similar tectonic settings (Haggart et al., 2006). Cretaceous terrestrial deposits are distributed in continental, back-arc and fore-arc basins. These settings correspond to the Cretaceous stratigraphic units in the Choyr Basin succession (southeastern Mongolia), the Yanji and Jixi Groups (eastern China), the Tetori Group (Japan), and the Gyeongsang Group (Korea) and the Sanchu Cretaceous (Japan), respectively (Matsukawa, 1983; Matsukawa et al., 1993, 1997a,b, 1998, 2003b).

2.1. *Choyr Basin (southeastern Mongolia)*

The Choyr Basin consists of fluvial-lacustrine delta-lake systems that are middle to late Albian in age (Nichols et al., 2006). Rich dinosaur, crocodilian, turtle, small lizard, pterosaurs, fish, bivalve, insect, terrestrial plant and pollen biotas are reported from these deposits (Novodvorskaya, 1974; Shuvalov, 1974; Barsbold and Perle, 1984; Matsukawa et al., 1997b; Hicks et al., 1999; Nichols et al., 2002, 2006; Ichinnorov, 2003; Kobayashi and Barsbold, 2003; Ito and Matsukawa, 2003; Ito et al., 2006). Based on studies of the stratigraphy and paleoenvironments of the basin, these rich zoo- and phyto-assemblages occur from deposits of topsets of lacustrine deltas, fluvial channels and river-mouth bars (Matsukawa et al., 1997b; Ito et al., 2006). Vegetation at the waterside and in the hinterland plateau is reconstructed based on taphonomic analysis of megafossil plant remains and scatted pollen and spores (Okubo, 1998; Saiki and Okubo, 2006). Various well-preserved vertebrate fossils occur in topset deposits of lacustrine deltas. Thus, food-web and energy-flow models can be made from analysis of faunal species composition, diversity censuses and inferred feeding habits.

2.2. *Tetori Basin (inner zone of southwest Japan)*

The basin of the Tetori Group consists of fluvial-lacustrine delta-lake system deposits (Matsukawa et al., 2003a,b; Ito et al., 2006). Various kinds of fossils such as fishes, amphibians, reptiles, dinosaurs, mammal-like reptiles, mammals, bivalves, gastropods, insects, and terrestrial plants occur in the Tetori Group (Kimura et al., 1978; Manabe et al., 1989;