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Geological division of the rocks at southeast of Ulaanbaatar (Gachuurt-Nalaikh), central Mongolia

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Abstract

This paper describes lithology and radiolarian fossils from a chert slab in the Gachuurt-Nalaikh area, southeast of Ulaanbaatar, central Mongolia, and discusses the geological division of the rocks in this area.

The rocks in this area consist of clastic rocks with chert slab intercalations. Although the rocks of this area have been previously divided into the Gorkhi, Altan-Ovoo, and Orgioch-Uul Formations, there are no significant structural and lithological gaps across the boundaries between these formations. Therefore, there is no reason to divide the rocks of this area into the three formations, and these three formations should be regarded as a single geological unit.

A conformable succession of Devonian radiolarian chert, siliceous shale, mudstone and sandstone in ascending order, which is generally regarded as ocean plate stratigraphy (OPS), were found from this area. The repetition of chert and clastic rocks with OPS within this area might show the stacking of tectonic slices of the chert-clastic rock sequence within an accretionary complex. This suggests that the rocks of this area should be regarded as the northern extension of the Gorkhi Formation of an accretionary complex, though most of the rocks of this area have been previously assigned to Carboniferous shallow marine system.

1. Introduction

The Central Asian Orogenic Belt (CAOB) lies between the Angara craton to the North and the North China and Tarim blocks to the south, and comprises a number of tectonic zones, which includes some accretionary complexes. The age and the geological structure of these accretionary complexes are keys for understanding the forming process of the CAOB.

The Khangai-Khentei belt within the CAOB at central Mongolia is an accretionary complex with Carboniferous shallow marine system (Kurihara *et al*., 2009). Although lithology and stratigraphy of these formations have been examined, little is known about the boundary and relationship between the accretionary complex and the Carboniferous system (e.g., Kurihara *et al*., 2009; Minjin et al., 2006).

A geological mapping project between Mongolian University of Science and Technology and Nagoya University, Japan, have been carried out to reveal the detailed stratigraphy and structure of the accretionary complex and the Carboniferous system in the Ulaanbaatar area since 2009, and remarkable radiolarian chert slabs were found from the Gachuurt-Nalaikh area through the course of this project. This paper describes lithology and radiolarian fossils from one of these chert slabs, and discusses the geological division of the rocks in the Gachuurt-Nalaikh area.

2. Geological outline of the Khangai-Khentei belt

The Khangai-Khentei belt is distributed, approximately 300 km wide and 1200km long, trending NE-SW in the central part of Mongolia (Fig. 1). According to Sengör *et al*. (1993) and Sengör and Natal'in (1996), this belt consists of Neoproterozoic to Lower Cambrian ophiolites and Lower Paleozoic to Carboniferous turbidites, mafic to intermediate volcanic rocks, and minor chert.

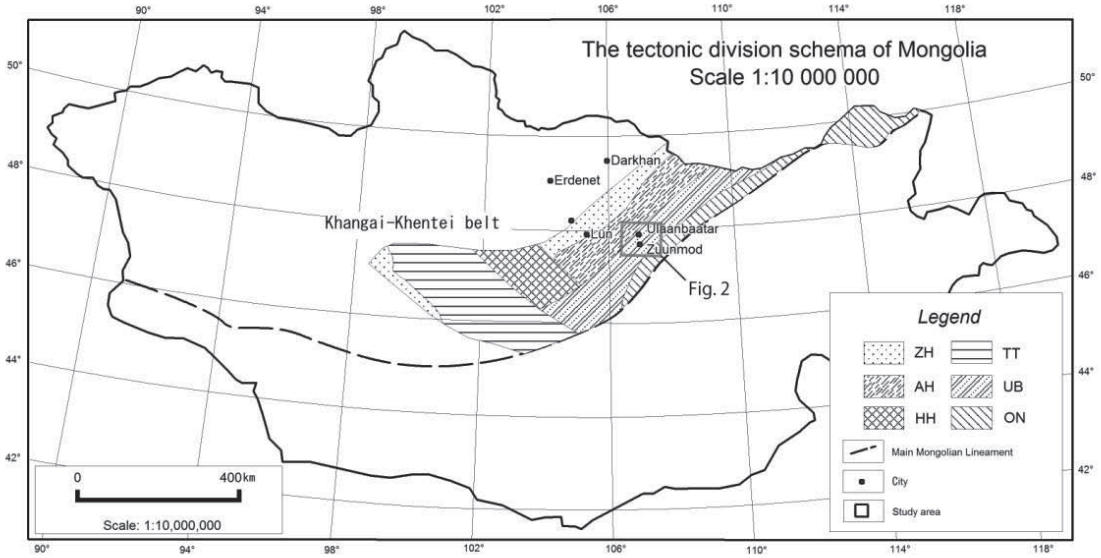

Fig. 1 The tectonic subdivision schema of Mongolia (terranes: Zag-Haraa (ZH), Asralt-Hairhan (AH), Kharhorin (HH), Tsetserleg (TT), Ulaanbaatar (UB), Onon (ON)) (modified from Tomurtogoo, 2010).

The Khangai-Khentei belt is subdivided into the Silurian Mandal Group (Tomurtogoo *et al*., 1998), the Lower Devonian Sergelen Formation, the Middle to Upper Devonian Gorkhi Formation, the Lower Carboniferous Altan-Ovoo Formation and the Lower to Upper Carboniferous Orgioch-Uul Formation (Minjin *et al*., 2006) (Fig. 2).

Tomurtogoo (2010) divided the Paleozoic rocks of the Khangai-Khentei belt into the Zag-Haraa (ZH), Asralt-hairhan (AH), Kharhorin (HH), Tsetserleg (TT), Ulaanbaatar (UB), and Onon (ON) terranes (Fig. 2).

The Devonian-Carboniferous rocks of the Ulaanbaatar terrane are subdivided into the following four lithostratigraphic units, the Sergelen, Gorkhi, Altan-Ovoo, and Orgioch-Uul Formations (Minjin *et al*., 2006), with the former two are upper Paleozoic accretionary complexes (Kurihara *et al*., 2009), and latter two are regarded as Carboniferous shallow marine system (Minjin *et al*., 2006). Takeuchi *et al*. (2013) newly divided the Paleozoic rocks around Ulaanbaatar into the Altan-Ovoo & Orgioch-Uul and Gorkhi Formations of accretionary complexes, and the Carboniferous shallow marine system.

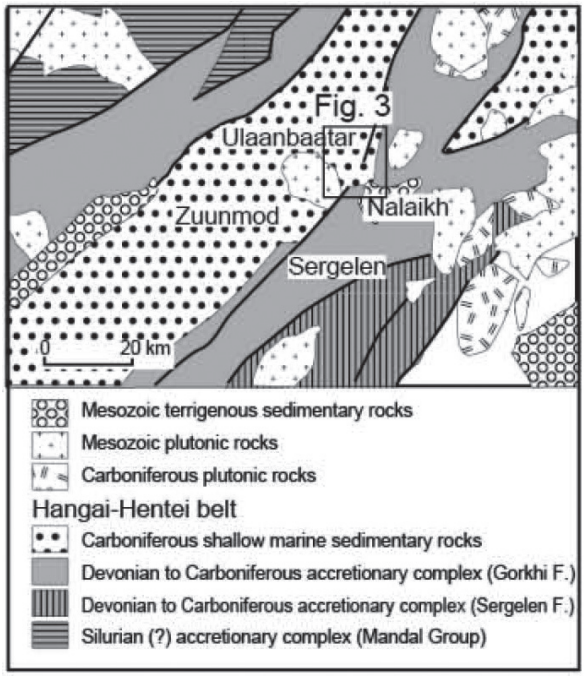

Fig. 2 Simplified geological map around Ulaanbaatar area (modified from Tomurtogoo *et al*., 1998).

The Gorkhi Formation consists of sandstone, mudstone, alternating beds of sandstone and mudstone

of turbidite affinity and chert, with small amounts of siliceous shale, basalt, limestone and clast-bearing mudstone (Kurihara *et al*., 2009). The chert of the Gorkhi Formation yields Upper Silurian to Upper Devonian radiolarians and conodonts (Kurihara *et al*., 2009). The Altan-Ovoo Formation consists of sandstone, mudstone and shale, and the Orgioch-Uul Formation consists mainly of sandstone and mudstone with conglomerate intercalations (Minjin *et al*., 2006). The Gorkhi Formation is thought to be in fault contact with the Altan-Ovoo Formation (Magic Project, 1998; Minjin *et al*., 2006).

The study area is southeast of Ulaanbaatar, Gachuurt-Nalaikh area. The rocks in the study area have been assigned to the Gorkhi, Altan-Ovoo, and Orgioch-Uul Formations (e.g., Magic Project, 1998; Tomurtogoo *et al*., 1998; Minjin *et al*., 2006).

3. Lithology and geological structure in the Gachuurt-Nalaikh area

The rocks of this area are composed mainly of thick massive sandstone, and minor bedded sandstone, alternating beds of sandstone and mudstone, and conglomerate with chert slabs (Fig. 3). The rocks generally strike NE to NW, steeply dip north or south, and are complexly folded in the north of the study area (Fig. 3). The axial planes of these folds strike NE and steeply dip north or south. The rocks of this area cut by several NW- and NE-trending vertical faults. In the west of the study area, the rocks are in fault contact with Mesozoic Granite.

The sandstone (Fig. 4A), greenish gray to dark gray, is commonly massive and coarse- to medium-grained, but rarely bedded and fine-grained. The sandstone is ill-sorted, with dominantly angular to very angular grains. A bed of the alternating beds of sandstone and mudstone, 10 to 30 cm thick, exhibit grading and cross lamina (Fig. 4B). The mudstone is black to gray, commonly fissile but rarely massive (Fig. 4C). The conglomerate including granules to boulders of red chert and sandstone are rarely observed at north of Nalaikh (Fig. 4D).

The chert slabs, generally several tens of meters thick, are structurally intercalated in the non-bedded massive sandstone (Fig. 4E). The chert, red and well-bedded with muddy films, includes numerous spherical radiolarian tests (Fig. 4F). A bed of the chert is generally 5 to 10 cm thick.

An eastward-facing conformable succession of chert, siliceous shale, mudstone and sandstone, in ascending order, is exposed at north of Nalaikh (Section 20100808, N47.829790°E 107.181931°; Figs. 5 and 6). The rocks in this section strike N 10° to 40°E and dip 70° to 90° to the north. The chert is in fault contact with the underlying sandstone at its western end and is conformably overlain by the siliceous shale at its eastern end (Figs. 5 and 6A-B). The chert is folded in syncline (Fig. 6C). The axial plane of the fold strikes NE and steeply dips north. Thickness of the chert is at least 10 m. The siliceous shale and the mudstone are several tens of centimeters thick each other.

4. Radiolarians from the chert lens at Section 20100808

Poorly preserved radiolarian fossils were recovered by etching in dilute hydrofluoric acid for 24 hours from a sample of red chert at Section 20100808. Individual radiolarians liberated from the matrix were washed and sieved at 63 and 108-micron fractions. Radiolarians were picked from the dried residues and identified with the aid of reflected light and scanning electron microscopes.

Although most radiolarians do not retain their surface structures and spines, we identified *Deflantrica* sp., characterized by basal spines with an irregular shell (Fig. 7). This genus has previously been reported from the Lower Devonian of Japan (e.g., Furutani, 1983; Wakamatsu *et al*., 1990; Kurihara and Sashida, 2000).

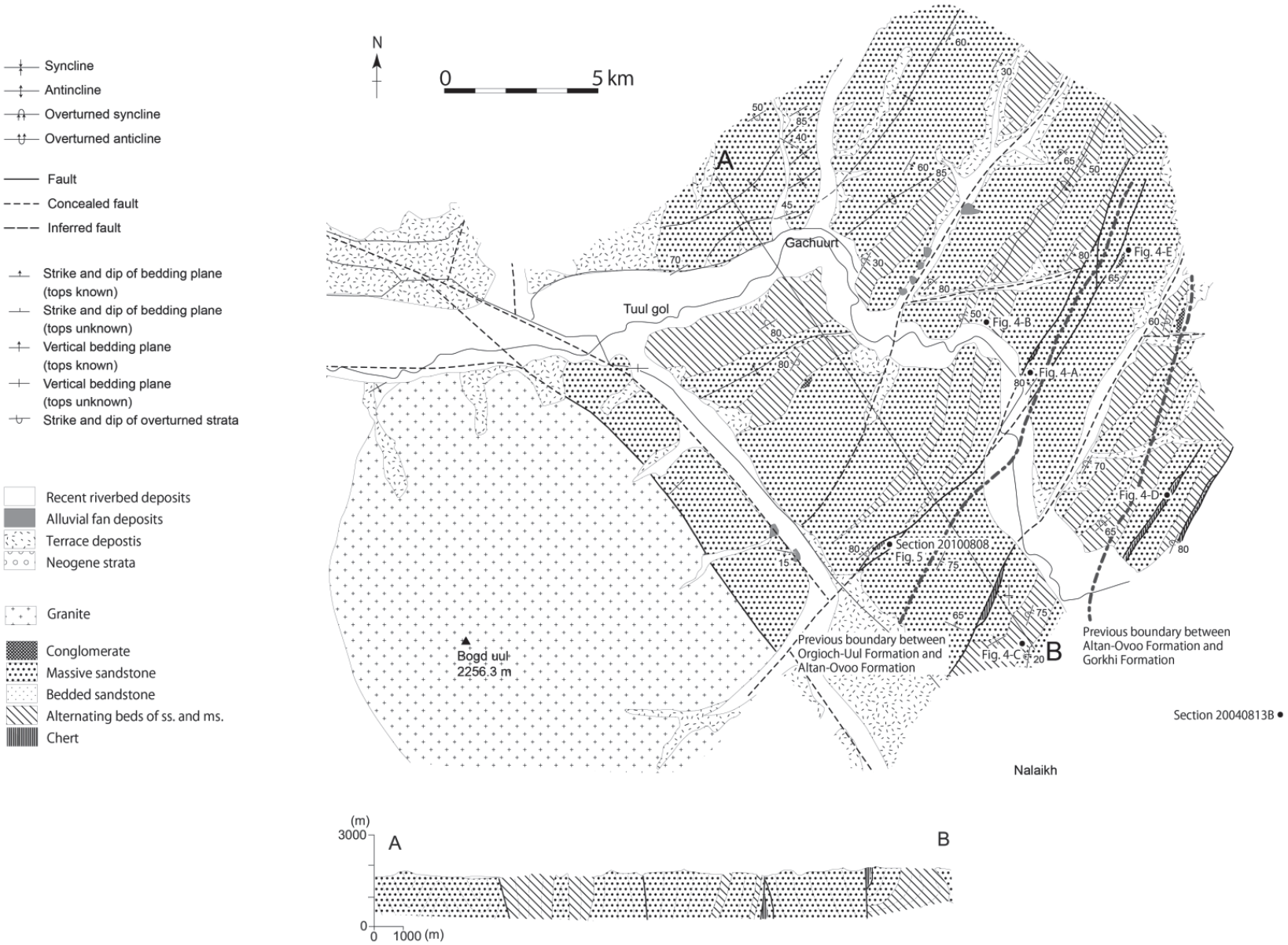

Fig. 3 Geological map in Gachuurt-Nalaikh area. See Fig. 1 for the location of the mapped area.

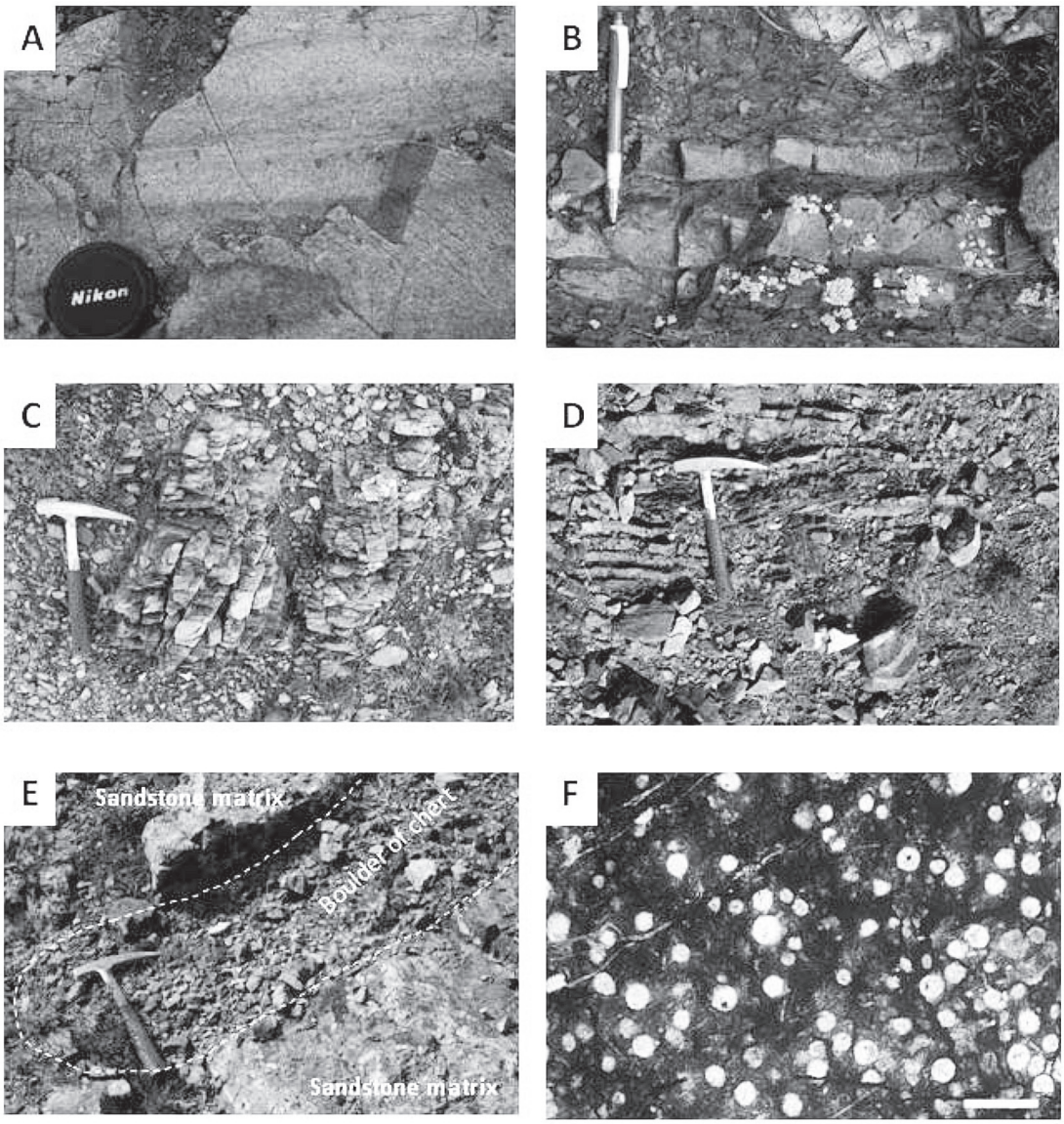

Fig. 4 Lithologies in the study area. See Fig. 2 for the location. (A) Thick sandstone. (B) Alternating beds of sandstone and mudstone with grading. Stratigraphic top is upper on the picture. (C) Mudstone. (D) Chert, red and well-bedded with muddy films. (E) Conglomerate including boulders of red chert. (F) Photomicrograph of radiolarian chert. Plane-polarized light. Scale bar = 0.5mm.

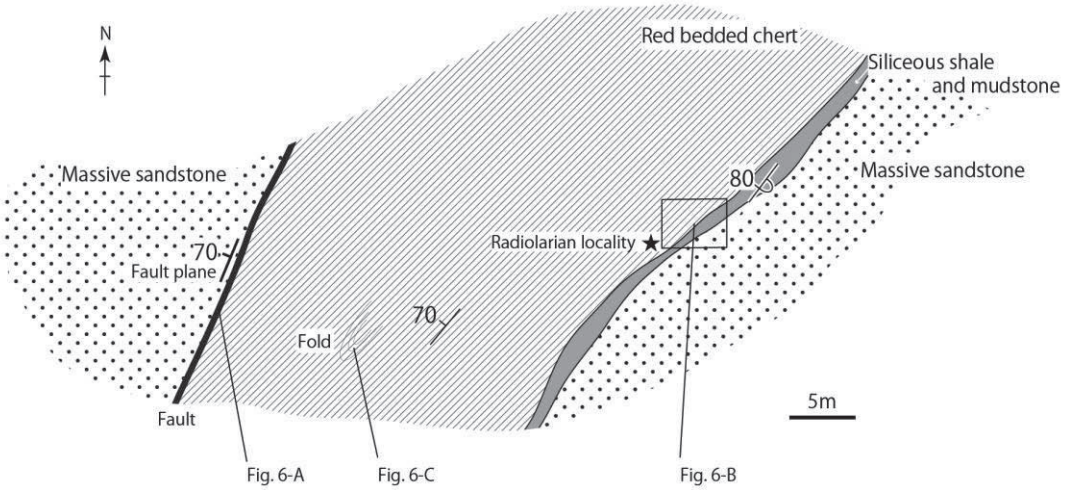

Fig. 5 Route map of section 20100808. See Fig. 2 for the location.

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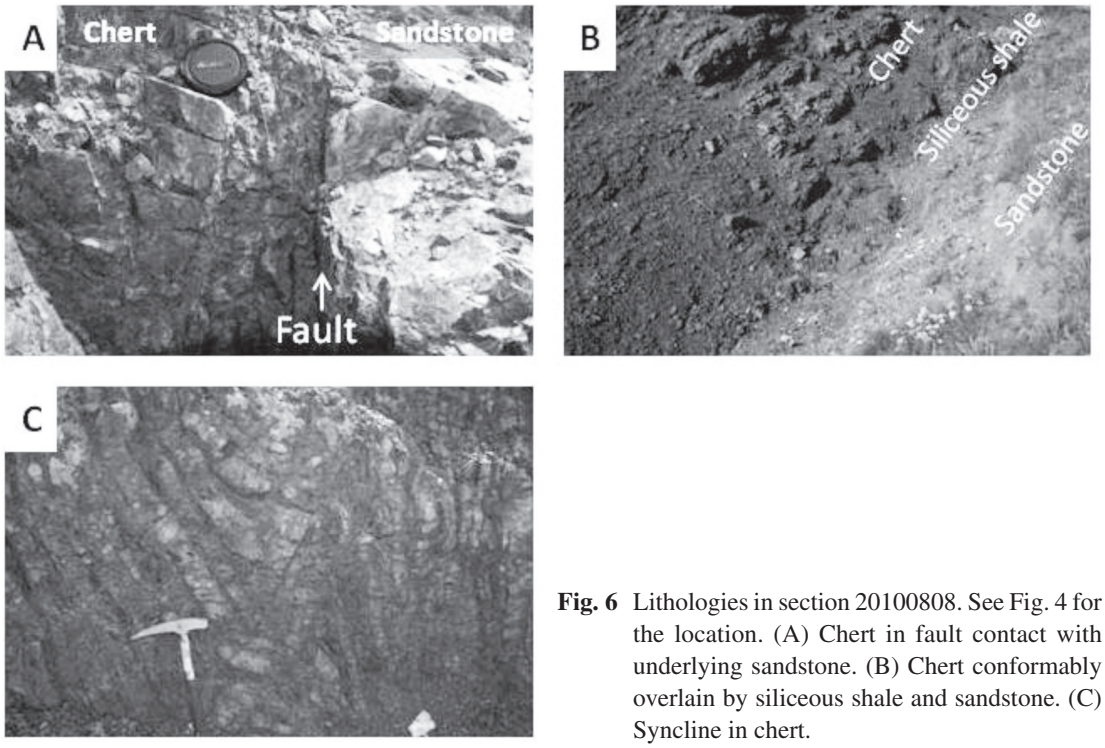

Fig. 6 Lithologies in section 20100808. See Fig. 4 for the location. (A) Chert in fault contact with underlying sandstone. (B) Chert conformably overlain by siliceous shale and sandstone. (C) Syncline in chert.

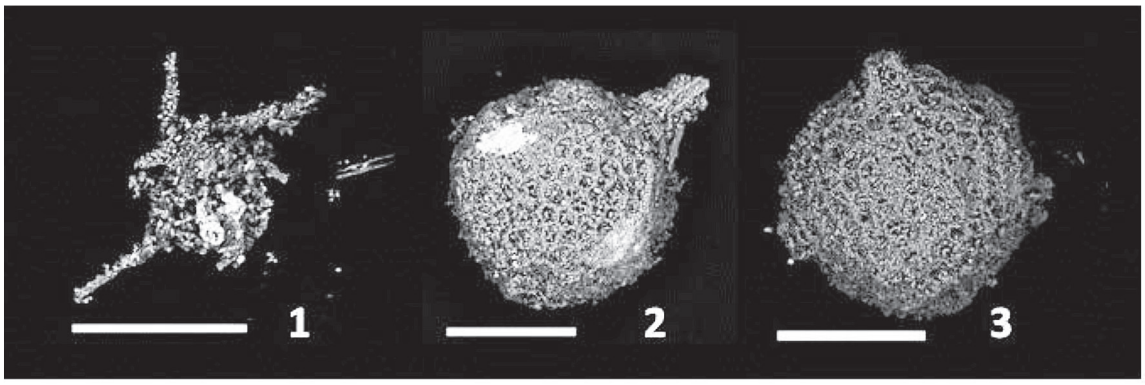

Fig. 7 Early Devonian radiolarians from section 20100808. All scale bars represent 100 μm. (1) Deflantrica sp. (2, 3) spherical radiolarians.

Discussion

Geological division of the rocks at the Gachuurt-Nalaikh area

Although the rocks of this area have been previously divided into the Gorkhi, Altan-Ovoo, and Orgioch-Uul Formations from south to north (e.g., Magic Project, 1998; Tomurtogoo *et al*., 1998; Minjin *et al*., 2006; Fig. 3), there are no significant structural and lithological gaps across the boundaries between these formations. In addition, the sandstones of the Gorkhi, Altan-Ovoo, and Orgioch-Uul Formations in this area are mostly similar and cannot be distinguished each other in their texture and grain composition (Suzuki *et al*., 2013). Therefore, there is no reason to divide the rocks of this area into the three formations, and they should be regarded as a single geological unit.

Several slabs of bedded radiolarian chert, ca. 1 to 3 km in length, are intercalated in the massive sandstone in this area. Although actual boundary between the chert and the surrounding sandstone cannot be observed due to poor exposure, the sandstone around the slabs never includes clasts or fragments of chert, and does not show sedimentary structures such as bedding and slumping. These observations suggest that the chert slabs were not olistostromally settled as sedimentary blocks in the sandstone.

Furthermore, a conformable succession of chert, siliceous shale, mudstone and sandstone in ascending order is exposed at Section 20100808. This litho-stratigraphical set has generally been described as a part of ocean plate stratigraphy (OPS) at stacked tectonic slices of accretionary complexes through the Phanerozoic (e.g., Kamiaso Unit of the Mino belt, Southeast Japan; see Kimura and Hori, 1993, Nakae, 2000). Therefore the repetition of chert and clastic rocks with OPS within this area might show the stacking of tectonic slices of the chert-clastic rock sequence within an accretionary complex.

The rocks in and around Ulaanbaatar have been previously divided into the Gorkhi Formation that consists mainly of stacking sheets of a chert-clastic rock sequence within an accretionary complex (Kurihara *et al*., 2009), and the Carboniferous shallow marine system (Orgioch-Uul and Altan-Ovoo Formations) that consists largely of sandstone, mudstone and conglomerate (Minjin *et al*., 2006). Takeuchi *et al*. (2013) newly divided the Paleozoic rocks around Ulaanbaatar into the Altan-Ovoo & Orgioch-Uul and Gorkhi Formations of accretionary complexes, and the Carboniferous shallow marine system. Although most of the rocks in the study area have been previously assigned to the Carboniferous shallow marine system (e.g., Magic Project, 1998; Tomurtogoo *et al*., 1998; Minjin *et al*., 2006), they are the stacking of tectonic slices within an accretionary complex as mentioned above. Moreover, the rocks in this area are lithologically and stratigraphically similar to those not of the Altan-Ovoo & Orgioch-Uul Formation but of the Gorkhi Formation.

Kurihara *et al*. (2009) reported Upper Silurian to Upper Devonian radiolarians and conodonts from a slab of red radiolarian chert of the Gorkhi Formation at Section 20040813B (Fig. 3), about 5 km southeast of this area. The radiolarian fossils presented here possibly suggest that the chert of this area can be correlated with that in the Gorkhi Formation in their age.

These lithological, stratigraphical, and chronological facts suggest that the rocks of this area should be assigned to the Gorkhi Formation. Consequently, it is appropriate that the rocks of this area are not of the Carboniferous system but regarded as the northern extension of the Gorkhi Formation.

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