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Carbon isotope composition of Upper Cambrian to Lower Ordovician carbonate in Korea, and its bearing on the Cambrian–Ordovician boundary and Lower Ordovician paleoceanography

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ABSTRACT

This study presents an example of locating Cambrian–Ordovician boundary in the lower Paleozoic carbonate succession in Korea using carbon isotope stratigraphy. The Yeongweol Unit of the lower Paleozoic Joseon Supergroup comprises the Upper Cambrian Wagok Formation and the Lower Ordovician Mungok Formation in the Cambrian–Ordovician transition interval. Conventionally, the boundary was placed at the lithostratigraphic boundary between the two formations. This study reveals that the boundary is positioned in the basal part of the Mungok Formation based on the carbon isotope stratigraphy coupled with biostratigraphic information of conodont and trilobite faunas. The $\delta^{13}C$ curve of the Lower Ordovician Mungok Formation shows a similar trend to that of the coeval stratigraphic interval of Argentine Precordillera (Buggisch et al., 2003), suggesting that the $\delta^{13}C$ curve of the Mungok Formation reflects the Early Ordovician global carbon cycle.

1. Introduction

Stable isotopes have become the principal tool of paleoceanography and paleoclimatology. Systems in the $\delta^{13}C$ of seawater have been documented by numerous chemostratigraphic studies across a range of temporal scale (Holser, 1997; Veizer et al., 1999). The carbon isotope excursion is regarded as a change in partitioning of carbon between organic carbon and carbonate carbon sinks (Kump and Arthur, 1999). The relationship between source and sink of the geological carbon cycle is affected by volcanic activity, global sedimentation rates, primary productivity, organic carbon burial and ocean circulation (Montañez et al., 2000; Katz et al., 2005). Therefore, sharp shifts in $\delta^{13}C$ values of the carbonate are often correlated with major biological events and stratigraphic boundaries in geological history (Ripperdan et al., 1992; Veizer et al., 1999; Saltzman et al., 2000). Also, the carbon isotope pattern of one section tends to be similar to that of the different section of same age if carbon isotopic values were not influenced by local paleoceanographic conditions. For this reason, changes in carbon isotope ratios provide an excellent tool for intracratonic and global stratigraphic subdivision and correlation, in particular, for intervals that lack age-diagnostic fossil markers (Montañez et al., 2002).

An international Cambrian–Ordovician boundary is considered at the base of the *Iapetognathus* Zone and *Jujuyaspis* Zone (Acenolaza, 1992; Miller and Stitt, 1995; Miller and Taylor, 1995; Taylor and Repetski, 1995; Cooper et al., 2001). Ripperdan and Miller (1995) suggested that the drop of the $\delta^{13}C$ curve is correlated with the base of the *Iapetognathus* Zone. Also, the $\delta^{13}C$ curves across the Cambrian–Ordovician boundary section were presented by Ripperdan et al. (1992) and Buggisch et al. (2003).

The Joseon Supergroup is a lower Paleozoic sequence distributed in eastern central Korea and consists mostly of carbonate rocks with interbedded siliciclastic rocks. The Joseon Supergroup is conventionally subdivided into five units of sequences based on distinct lithologic successions and geographic distribution: namely, the Duwibong, Yeongweol, Pyeonchang, Jeongseon and Mungyeong units (Kobayashi et al., 1942) (Fig. 1A). Among the five units, the Yeongweol Unit only contains thick carbonate deposits across the Cambrian–Ordovician transition and in the Lower Ordovician succession. Conventionally, the Cambrian–Ordovician boundary has been placed at the lithostratigraphic boundary between the Upper Cambrian Wagok Formation and Lower Ordovician Mungok Formation (Kobayashi, 1966). Paleontological studies (Kobayashi, 1966; Choi, 1992; Choi et al., 1996) have suggested that the Cambrian–Ordovician boundary exists either between the Wagok and Mungok Formations, in the base of the Mungok Formation, or in the uppermost part of the Wagok Formation. Recent studies (Lee and Lee, 1999; Kim and Choi, 2000) suggested that the Cambrian–Ordovician boundary is placed in the base of the Mungok Formation because *Jujuyaspis* is observed in the base of the Mungok Formation. However, the exact

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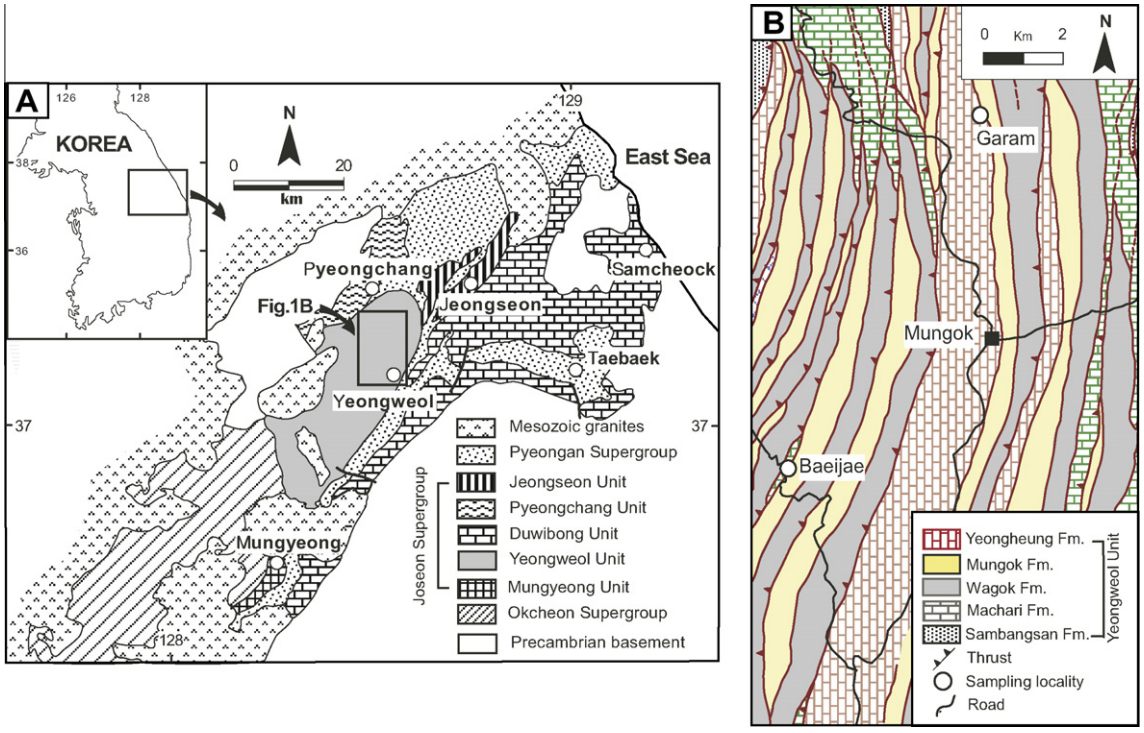

Fig. 1. (A) Index map showing simplified geology and distribution of the Early Palezoic Joseon Supergroup (modified after GICTR (1962)). (B) Geological map of the Yeongweol Unit of the Joseon Supergroup and the localities of the studied sections (modified after Lee, 1995).

stratigraphic position of the Cambrian–Ordovician boundary has not been set due to the lack of definitive evidence in the Mungok Formation. Thus, integrated approach using carbon isotope stratigraphy and currently available biostratigraphic information may provide an example to define the Cambrian–Ordovician boundary.

For the Ordovician, the existing database is relatively sparse and covers mostly the Late Ordovician. For the Early Ordovician rather coarse resolution carbon isotope values were reported (Qing and Veizer, 1994). In a recent study, Buggisch et al. (2003) presented for the first time a high resolution carbon isotope curve for the Early to early Middle Ordovician with a prominent 2‰ sharp positive $\delta^{13}C$ exclusion in the *Rossodus manitouensis* Zone. However, global significance of the observed trend is yet certain. In this study, we present a biostratigraphically well-constrained high resolution $\delta^{13}C$ curve for the Lower Ordovician strata in Korea. The carbon isotope curve of Argentina (Buggisch et al., 2003) can be compared with that of the Lower Ordovician Mungok Formation in this study. If the two carbon isotope curves match across paleogeographically widely separated regions, the results can be used to present the high resolution global carbon isotope curve for the Early Ordovician.

The present study discusses and attempts to locate the Cambrian–Ordovician boundary in the Yeongweol Unit through an analysis of carbon isotope stratigraphy. Also, by providing a high resolution carbon isotope stratigraphy for the Lower Ordovician strata, the aims of this paper are to contribute the global carbon isotope curve for the Early Ordovician and to present relationship between the sequence stratigraphy and the carbon isotope stratigraphy.

2. Geological setting

The Yeongweol Unit rests unconformably on Precambrian rocks and is disconformably overlain by the Upper Paleozoic Pyeongan Supergroup. The Yeongweol Unit consists mostly of carbonate rocks with some interbedded siliciclastic rocks, and comprises five lithostratigraphic units, namely, the Sambangsan, Machari, Wagok, Mungok, and Yeongheung Formations with decrease age (Lee and Lee, 1986; Fig. 2). The Sambangsan, Machari and Wagok Formations are assigned to the Cambrian, while the Mungok and Yeongheung Formations to the Ordovician.

The Upper Cambrian Wagok Formation is about 200–400 m thick and comprises exclusively light gray to gray, massive dolostone with vuggy porosities. Because of pervasive dolomitization,

Geological age		**Yeongweol Unit** *(Lee and Lee, 1986)*
Ordovician	Himantian	
	Katian	Yeongheung Formation
	Sandbian	
	Darriwilian	
	Dapingian	
	Floian	Mungok Formation
	Tremadocian	
Cambrian	Late	Wagok Formation
		Machari Formation
	Middle	Sambangsan Formation
	Early	

Fig. 2. Stratigraphic subdivision of the Yeongweol Unit of the Joseon Supergroup.