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A new Middle Ordovician skeletal-dominated reef association from Korea

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1 Abstract

Decimeter-scale patch reefs primarily composed of stromatoporoids and bryozoans are reported from the Duwibong Formation (Darriwilian), Taebaeksan Basin of Korea, located in eastern margin of Sino-Korean (North China) Block. The reefs are constructed by numerous centimeter-scale columns and masses made up of ragged thin laminae consisting of stromatoporoids (34%), bryozoans (16%), probable calcimicrobes and algae (4%) and siliceous sponge (<2%). Stromatoporoids (*cystostroma* sp.) are poorly preserved in general but the skeletons composed of characteristic small vesicular cyst plates are recognizable in parts. They frequently alternate with bryozoans which resulted in globular to columnar masses forming the key characteristics of the Duwibong reefs. The bryozoans, identified as a *Nicholsonella* sp., are characterized by unobvious granular walls and abundant acantho- and mesozooecia. This genus has been widely reported from Russia, North America and North China during Middle to Late Ordovician. The calcimicrobes and algae sporadically occur as tiny patches or thin encrusting laminae. Siliceous sponges encrust the surface of stromatoporoids and bryozoans as well as grow downward from the ceiling of cavities. Both stromatoporoids and bryozoans first emerged as reef building organisms during Early Ordovician from South China, associated with lithistid sponges, pelmatozoans, calcimicrobes and microbialites. The Duwibong reef built mainly by consortium of stromatoporoids and bryozoans is a new Middle Ordovician skeletal-dominated reef association not previously known, indicating the onset of widespread development of skeletal-dominated reefs afterwards.

2 Purpose & Geologic Setting

Report a new Middle Ordovician skeletal-dominated reef mainly composed of stromatoporoid and bryozoan from Korea.

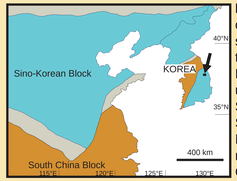
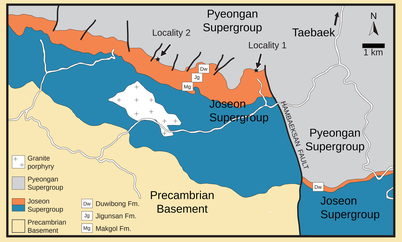


Figure 1. Tectonic elements of the Eastern Asia and simplified geologic map of the study area. Duwibong Formation is the uppermost unit of the Joseon Supergroup. Locality 1 is Sorotgol and Locality 2 is Manhangjae section, respectively (Modified after Chough *et al.*, 2000).



4 Key Constituents

Stromatoporoid (*Cystostroma*)

- Imbrication of small convex-upward cyst plates (Stearn *et al.*,1999)
- Range : M.Ordovician ~ L.Devonian (Stearn *et al.*, 1999; Dong, 2001)
- Middle Ordovician *Cystostroma*
  - Only reported from Chazy Group of North America (Galloway, 1957), Xinjiang of northwestern China (Dong, 2001) and Siberian Platform (Miagkova *et al.*, 1977)
  - This study is first example from Llanvirnian to Landeilian of Sino-Korean Platform and potentially one of the oldest *Cystostroma* to date (Dong, D.Y., personal communication).

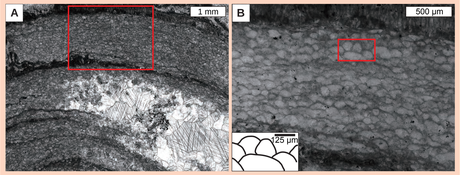


Figure 4. (A) Plane polarized light photomicrograph of stromatoporoid with both poorly- and well-preserved areas. Note most microstructures are eliminated by diagenesis in the poorly-preserved area. (B) Reflected light with "white card technique" (Zenger, 1979; Folk, 1987) view of photomicrograph. Enlargement of rectangle in A showing round, convex-upward cysts. The height and width of these cysts range from 0.03 to 0.15 mm and 0.05 to 0.3 mm. See trace of rectangle in the lower left corner.

Bryozoan (*Nicholsonella*)

- Separated zooecia surrounded by diaphragms bearing abundant mesopore filled by calcareous deposit (Bassler, 1953)
- Range : Restricted to Ordovician (Nekhorosheva, 2002)
- Widely reported from Early to Late Ordovician of Russia, China and North America (Bassler, 1953; Ross, 1981; Nekhorosheva, 2002; Xia, F.S., personal communication)

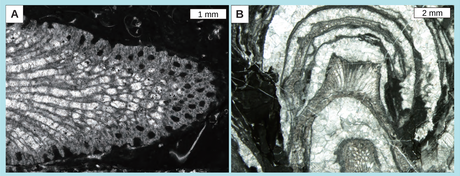


Figure 5. (A) Photomicrograph of part of ramose bryozoan. Isolated zooecia are noticeable surrounded by granular wall structure. Straight diaphragms are also visible. (B) They commonly occur as various shape of laminar and encrusting forms.

3 The Duwibong Boundstone

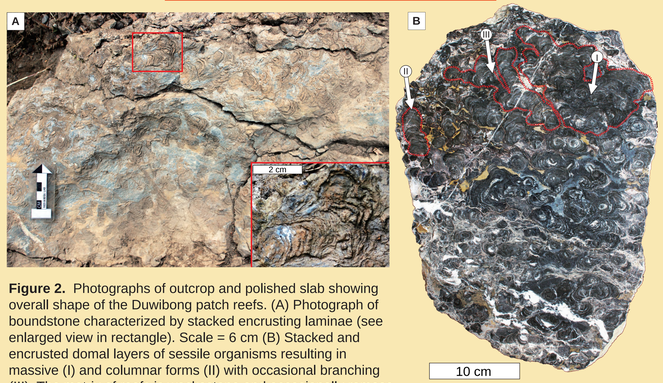


Figure 2. Photographs of outcrop and polished slab showing overall shape of the Duwibong patch reefs. (A) Photograph of boundstone characterized by stacked encrusting laminae (see enlarged view in rectangle). Scale = 6 cm (B) Stacked and encrusted domal layers of sessile organisms resulting in massive (I) and columnar forms (II) with occasional branching (III). The matrix of reefs is wackestone and occasionally ramose bryozoan packstone.

Decimeter-scale massive to columnar structures with numerous laminae

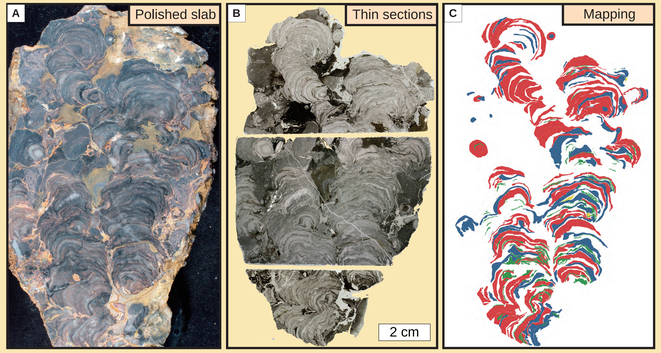


Figure 3. (A) A longitudinal cut polished slab of columnar boundstone composed of stacked domal and ragged laminae. Note that basal part of the boundstone commonly contains oncoid-like encrustation on nucleus. (B) Photograph of matched set of thin-sections with the slab shown in A. (C) Interpretive tracing of B showing frequent alternations of laminar- to domal-shaped stromatoporoids, bryozoans and others without any regular stacking order. See Table 1 for corresponding color of constituents.

Composed of laminar to domal stromatoporoids, bryozoans and others

5 Subordinate Components

Tubular organisms

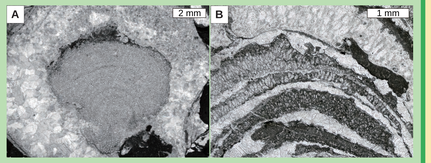


Figure 6. (A) Oblique cut view of *Solenopora*-like organism showing faint cross-sectional partition which is subsequently encrusted by poorly-preserved laminar stromatoporoid. (B) Unidentified tubular organisms with various tube dimensions repeatedly encrusting poorly-preserved stromatoporoid.

Siliceous sponges

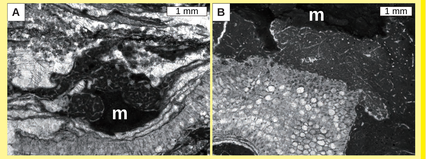


Figure 7. (A) Siliceous sponges with round outer boundary and spicule networks attached at top of ceiling of a cavity. (B) Tabular siliceous sponge encrusting the top of bryozoan. m = micrite

Growth cavities with downward growing siliceous sponges

Component	%	Number of occurrence
Stromatoporoids	34.3	109
Bryozoans	16.1	74
Tubular organisms	3.9	63
Siliceous sponges	0.1	2
Dolomite	1.7	
Micrite	1.5	
Uncertain	42.4	
Total	100.0	

Spatial abundance of constituents

Table 1. Frequency and abundance of constituents measured and counted from mapping of slab and matching set of thin sections. Note the dominance of stromatoporoid and bryozoan.

6 Discussions

Late Ordovician (ca. 458 Ma)	Hirnantian	Widespread metazoan-algal reef development
	Katian	
	Sandbian	
Middle Ordovician (ca. 470 Ma)	Darriwilian	Transitional period of reef consortia: more metazoans in reefs
	Dapingian	Microbial reefs + lithistids & calathids Incorporation of metazoans in reefs
Early Ordovician (ca. 485 Ma)	Floian	
	Tremadocian	

Table 2. Patterns of Ordovician reefs and constituents. Darriwilian is characterized by metazoan expansion such as bryozoans, stromatoporoids and corals in reefs.

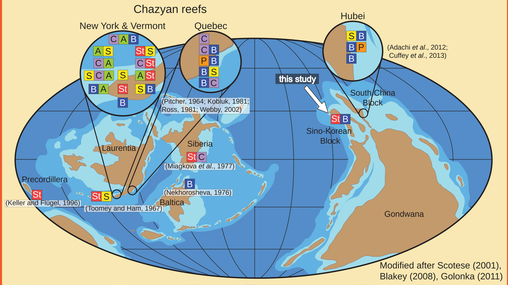
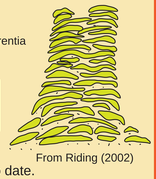


Figure 8. Global distribution of Early to Middle Ordovician skeletal-dominated reefs. Note that late Darriwilian reefs are composed of stromatoporoid, bryozoan, coral, and algae of wide range of dimensions and shapes (Webby, 2002).

Implication of the Duwibong reefs

- Tight laminar filled frame reef built by finely (< 1 cm) laminar skeletons.
  - Skeletons in close contact, laminar structure and small cavities (Riding, 2002)
- Similar Ordovician laminar filled frame reefs
  - Kobluk (1981): bryozoans and others; Chazyan of Laurentia
  - Ross (1981): stromatoporoids, corals and algae; Chazyan of Laurentia
  - Cuffey *et al.* (2013): bryozoans; Tremadocian of South China

Tight laminar filled frame reef (*sensu* Riding, 2002)



- Such skeletal-dominated reefs mainly comprised of stromatoporoid and bryozoan have not been reported to date.
  → A new type of Middle Ordovician skeletal-dominated reef
- A prelude to major Siluro-Devonian skeletal reefs built by stromatoporoids in association with tabulate corals, bryozoans and microbial crusts?

Key References

Webby, B.D., 2002, Patterns of Ordovician reef development, in Kiessling, W., Flügel, E., and Golonka, J., eds., Phanerozoic reef patterns: Tulsa, SEPM Special Publication, 72, 129-180

Riding, R., 2002, Structure and composition of organic reefs and carbonate mud mounds: concepts and categories, Earth-Science Reviews, 58, 163–231

Acknowledgments

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