Intricate microbial-siliceous sponge frameworks: new insights on sponge bioconstruction toward the Early Ordovician reefs

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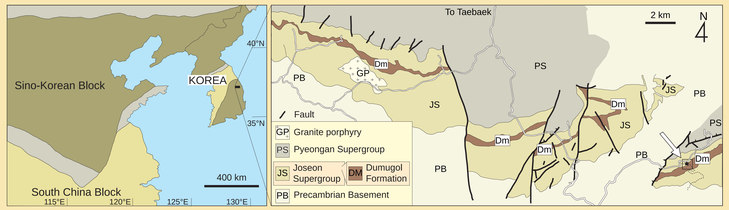
Abstract

The Early Ordovician witnessed increasing influence of skeletal organisms in microbial-dominant reef construction, which preceded Middle to Late Ordovician expansion of skeletal-dominant reefs. We provide detailed petrographic analysis of microbial-siliceous sponge reefs from the Early Ordovician Dumugol Formation, Korea with emphasis on the contributions of siliceous sponges, i.e., anthaspidellid sponge *Archaeoscyphia* and unidentified, non-anthaspidellid spiculate sponges, in the reef development. Dumugol reefs are mainly composed of microbialites, *Archaeoscyphia* with the subordinate spiculate sponges and calathids. Two types of boundstone textures were recognized: microbial-dominated and sponge-microbial boundstone. The former was mainly formed by upward and laterally stacking microbialites, whereas the latter by siliceous sponges and surrounding microbialites. The incorporation of microbialites to both types of boundstone demonstrates that microbialites were primarily responsible for the reef construction, both framework building and encrusting other components. Siliceous sponges contributed in diverse ways for construction of sponge-microbial boundstone. *Archaeoscyphia* attached to each other and formed local sub-decimeter sponge framestones creating framework, shelter, and intraskeletal cryptic spaces. Spiculate sponges played diverse roles including encrusting other constituents, dwelling in cryptic spaces, stabilizing reef-flank sediments, and rarely building framework. Overall development pattern and constituents of the Dumugol reefs are similar to coeval microbial -sponge reefs elsewhere. However, the diverse roles of siliceous sponges in construction of Early Ordovician reefs have not previously been described. Framework-building siliceous sponges reported herein represent one of the early phase of metazoan bioconstruction in addition to recently reported Early Ordovician skeletal-dominant reefs, which announce part of the prelude of changeover from microbial- to skeletal-dominated reefs afterward in the Phanerozoic.

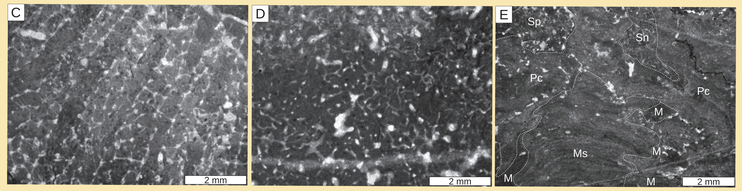
1. Purpose

Assess sedimentologic and paleoecologic aspects of Early Ordovician reef-building metazoans to further understand microbial-siliceous sponge reefs and early Paleozoic reef evolution.

2. Geologic Setting

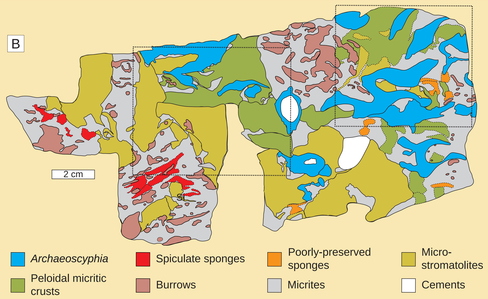


Tectonic elements of the Eastern Asia and geologic map of the study area showing distribution of the Early Ordovician Dumugol Formation. Outcrop location is marked by an arrow. Modified after Chough et al. (2000).

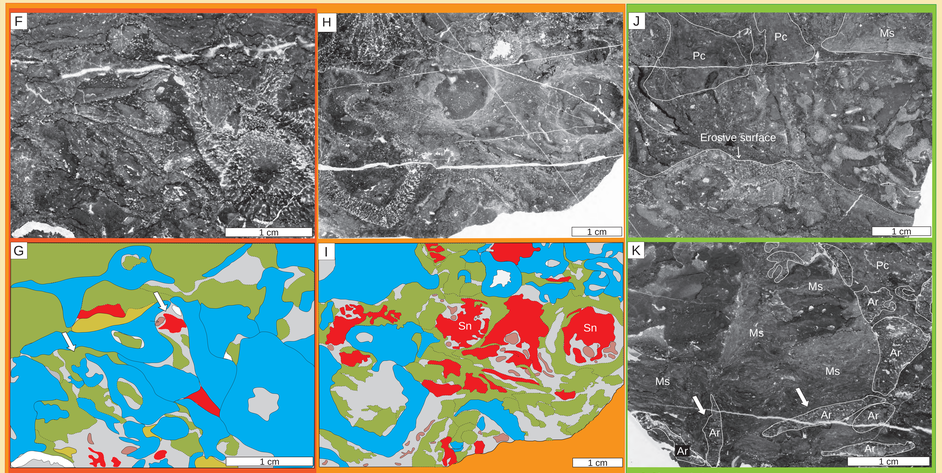


Photomicrographs of principal reef constituents of the Dumugol patch reefs. (C) *Archaeoscyphia* with characteristic well-organized lattice-like arrangement of spicules. (D) Unidentified, non-anthaspidellid spiculate sponges with reticulate arranged, straight to weakly curved spicules. (E) Micro-stromatolites and poorly- to non-laminated peloidal micritic crusts. Ms = micro-stromatolite; Pc = peloidal micritic crust; Sn = spiculate sponge; Sp = poorly-preserved siliceous sponge; M = micrite.

3. Dumugol Patch Reefs



(A) Photograph of meter-scale Dumugol patch reefs overlying bioturbated mudstone to wackestone and overlain by thin-bedded lime mudstone. (B) Interpretive sketch of a longitudinal cut slab of the reef showing heterogeneous distribution of siliceous sponge-microbial (right rectangle) and microbial-dominant boundstones (left rectangle).



Archaeoscyphia framestone (3 % of the reefs)

Sponge-microbial boundstone (34 % of the reefs)

Microbial-dominant boundstone (18 % of the reefs)

(F-G) Photograph and interpretive tracing of siliceous sponge-dominant boundstone. Closely attached *Archaeoscyphia* forming framework with primary cavities (white arrows), where these cavities are housed cryptic spiculate sponges and peloidal micritic crusts. (H-I) Photograph and Interpretive tracing of transverse cut view of siliceous sponge-microbial boundstone with spiculate sponges. *Archaeoscyphia* mostly encrusted by peloidal micritic crusts as well as some spiculate sponges. Note upright growing spiculate sponges (Sn) encrusted by peloidal micritic crusts. (J) Photograph of erosive surface and abraded boundstone within a reef. The surface is covered by micritic sediments followed by laminated peloidal micritic crusts (Pc) and micro-stromatolites (Ms). (K) Photograph of micro-stromatolitic frameworks. Note the binding of several *Archaeoscyphia* (Ar) by micro-stromatolites (white arrows).

4. Reef-forming Processes

Microbialites	Constructor	Mutually amalgamate to form frameworks	**Microbial-dominant boundstone**
	Encruster & binder	Encrust and enclose siliceous sponges	
	Sediment stabilizer	Encrust on top of micritic substrates	
Archaeoscyphia	Constructor	Provide sites for microbial encrustation	*Archaeoscyphia* framestone
		Form primary cavities	
		Construct limited frameworks	
Spiculate sponges	Encruster	Encrust microbialites and *Archaeoscyphia*	**Sponge-microbial boundstone**
	Cryptic dweller	Occur in crypts	
	Limited constructor	Rarely encrusted by peloidal micritic crusts	

5. Discussion

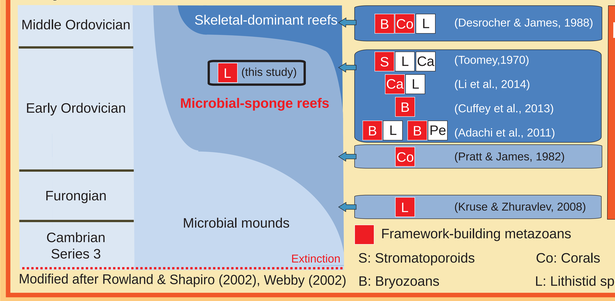
Early Ordovician microbial-sponge reefs

Previous understanding	Microbial binding dominant frameworks	Cryptic system?
The Dumugol reef system	Limited sponge framestone	Cavity system by sponge

Microbial-dominant + ***localized skeletal frameworks***

Early Paleozoic reef evolution

Skeletal frameworks



Part of the prelude of transition from microbial- to metazoan-dominant reefs

Framework-building metazoans | Metazoan participants

S: Stromatoporoids | Co: Corals | Ca: Calathids

B: Bryozoans | L: Lithistid sponges | P: Pelmatozoans

Modified after Rowland & Shapiro (2002), Webby (2002)

Key references

Webby, B.D., 2002, Patterns of Ordovician reef development. In: Kiessling, W., Flügel, E., Golonka, J. (Eds.), Phanerozoic reef patterns: SEPM No 72, pp. 129-180.

Acknowledgments

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