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Middle Cambrian microbial-metazoan reef, Zhangxia Formation, Shandong Province, North China

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Middle and Upper Cambrian reefs were constructed mostly by stromatolite and thrombolite because the previously flourished archaeocyaths went extinct at the end of the Early Cambrian, and new reefal metazoans did not evolve until the Ordovician. Although some sponges were reported from middle Cambrian reefs, their diversity was very low (mostly single taxon) and their role in the reef was limited. Here, we report relatively diverse reefal metazoan community from the Middle Cambrian Zhangxia Formation (Changhian Stage) and discuss their paleoenvironmental implications. The Zhangxia Formation in central Shandong Province consists mainly of oolite, bioturbated wackestone and microbial carbonates of thrombolite, dendrolite and stromatolites. Microbial bioherms in the lowermost part of the formation (*Crepicephalina* Zone) are characterized by metazoan community of sponges and octagonal cone-shaped organisms (OCOs, uncertain affinity). The reefs were built by stacks of several layers (about 20 cm in thickness) of microbial and metazoan buildups. Most of the layers formed by lateral train of small thrombolite and stromatolite bioherms containing calcimicrobes such as *Epiphyton*, *Renalcis*, *Angulocelluria* and *Girvanella*. Metazoan- rich bioherms usually occur along certain layers. The base of the metazoan-rich bioherm consists of coalescent small bioherms of thrombolite containing few sponges or OCOs. Large tube-shaped anthaspidellid sponges usually started growing on the top of the stabilized surface of this thrombolite aggregates. Attachment of smaller sponges and OCOs on the large sponges resulted in framework of reef body. OCOs usually showed pendent-style growth mode attaching to the lower surface or side wall of the large sponges. Large masses of *Epiphyton*, most likely, developed on the thrombolitic surface, coexisting with other metazoans. *Epiphyton* masses usually formed finger-like body with layered texture by arrayed short branches. Theses metazoan and *Epiphyton* masses have downward tufts of thrombolite and stromatolite. Stromatolite commonly encrusted large body of metazoan and microbial complex. Metazoans in this reef were members of the constructors and made a loose framework of the bioherm with solitary or rarely branching body, which was strengthened by microbial binders. The resulting framework with bush-like *Epiphyton* acted as a baffler to trap fine- and coarse-grained sediments. The reef abutted on bioturbated wackestone and intervening oolitic, oncolitic and skeletal packstone to grainstone in the southern end. Inter- filling sediment in the northern end is characterized by oolitic and oncolitic packstone to grainstone. The whole reef is overlain by oncolitic bioturbated wackestone. Common skeletal grains are articulate brachiopods and polymeroid trilobites which are frequently encrusted by microbial masses. These sedimentary facies around the reef suggest that it was located in the lagoonal environments which had enhanced energy regime around the reef. The reef community of Middle Cambrian Zhangxia Formation is relatively diverse compared to their time- equivalent reef communities. This is the earliest metazoan reef of the North China Platform and may represent an ecological stepping-stone between archaeocyath-rich Early Cambrian reef and sponge-rich Early Ordovician reef.