Devonian stromatolites and exhalative mineralization, Canning Basin, Western Australia

by

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Massive limestone buildups of columnar stromatolites, intergrown with barite and iron sulfides, are known from four principal localities in the Devonian reef complexes of the Canning Basin. They outcrop in the northern Emanuel Range, southeastern Pillara Range, Minnie Pool, and Pillara Spring areas of the southeastern Lennard Shelf. The stromatolite–barite–sulfide association occurs as belts from a few hundred metres to three kilometres long, 250 m wide, and 100 m thick, within Frasnian basin facies of the upper Gogo Formation and lowermost Virgin Hills Formation.

The stromatolites, when unaltered, consist of light-coloured inclusion-rich fibrous-calcite crystals, with some interspersed sediment layers, arranged in fan-shaped aggregates displaying unidirectional growth. The well-preserved microstructure of the calcite, which includes minute single-phase fluid inclusions, indicates an original calcitic (rather than aragonitic) mineralogy.

Some stromatolites have been partly or wholly altered to inclusion-free calcite, often dark in colour, in which the original stromatolitic textures are wholly or partly destroyed. The metasomatism responsible for these changes is thought to have been linked with low-temperature fluids that were responsible for associated barite and iron-sulfide mineralization.

Barite associated with the stromatolites occurs as two forms: (a) fibrous crystals filling fractures which cross-cut the fibrous calcite, and (b) fan-shaped crystal masses intergrown with stromatolites. The intergrown barite, like the stromatolites, displays textures indicative of unidirectional growth.

Dendritic iron sulfides (marcasite and pyrite) grew into cavities between stromatolite columns during the late growth phases of the stromatolite buildups. These sulfides have been oxidized to gossanous iron oxides at the surface. The outcropping stromatolite–barite–sulfide buildups are commonly cut by fissure-filling gossans, up to several metres wide and tens of metres long, in which stromatolitic structures, of probable bacterial origin, are often well displayed. Drilling in the northern Emanuel Range and southeastern Pillara Range areas shows that the gossans have formed after marcasite and (to a lesser extent) pyrite. A few small crystals of galena have been detected within some of the iron sulfides (Wallace, M., 1999, pers. comm.). Although sphalerite has not been identified, it could occur in minor amounts, as some gossans contain anomalously high zinc values (up to 7400 ppm).

The stromatolites and associated mineralization are believed to have formed during the early and middle Frasnian as cool-water sedimentary exhalative (SEDEX) deposits, during a period of abrupt backstepping of the limestone platforms. They were formed above permeable zones where water, methane, hydrogen sulfide, and mineralizing fluids were being expelled during early compaction of organic-rich shales of the Gogo Formation. Those shales have compacted by about 70% since deposition, resulting in the expulsion of large volumes of fluids, which were channeled along permeable horizons within the Gogo Formation towards the contact with the Sadler Limestone and then along that contact towards the surface, permeating and passing through the muds (Fig. 1). Synsedimentary faults in the Gogo Formation and basal Virgin Hills Formation also acted as pathways for escaping fluids.

The stromatolites and associated mineralization form bulbous masses, believed to have been precipitated by chemosynthetic bacteria below water depths of around 200 m. The main masses of the buildups apparently developed in unconsolidated mud. Some probably extended a little above the surrounding sediment, but others clearly grew downward into the mud itself, so that photosynthesis could not have been required for their development.

A transitional relationship can be seen between limestones of the stromatolite–barite–sulfide association and Gogo nodules (cannonball concretions), which are thought to have had a similar chemosynthetic bacterial origin, growing in mud just below the sediment–water interface. Small calcite spherules, also probably of bacterial origin, are closely associated with the Gogo nodules and stromatolite buildups.

A few exploration drillholes have penetrated stromatolite–barite–sulfide buildups and their associated iron-sulfide-filled fissures. Some holes encountered minor Mississippi-Valley-type (MVT) mineralization in fractures that cut the buildups and associated fissures. This MVT mineralization is thought to have occurred during the Early Carboniferous or latest Devonian, perhaps 10 million years later than growth of the stromatolite–barite–sulfide buildups and after they were covered by more than 1000 m of sediment.

Isotope studies have been carried out on the stromatolite–barite–sulfide association by Malcolm Wallace, Nicole de Kever, and Rebecca Mason of the University of Melbourne. Carbon and oxygen isotopes from inclusion-rich stromatolites and Gogo nodules occupy similar fields, with significantly lighter carbon and oxygen values than those of Devonian seawater. These values are compatible with a bacterial origin of the stromatolites and nodules. The inclusion-free stromatolites are clustered in a distinctly different field, with even lighter carbon values, but having oxygen values comparable with that of Devonian seawater. These differences may be explained by early metasomatic alteration of the inclusion-free stromatolites.

The sulfur isotopes of iron sulfides in the buildups are heavier than those of Middle to Late Devonian seawater and much heavier than those of MVT sulfides from elsewhere on the Lennard Shelf. This may be explained by early bacterial sulfate reduction in muds of the Gogo Formation, which removed lighter sulfur isotopes from the interstitial fluids.

Although it seems clear that there is no direct relationship between the early SEDEX mineralization and later MVT mineralization, both are thought to have resulted from related compaction-driven processes. The SEDEX deposits formed near the sea floor from low-temperature fluids expelled during early compaction of basinal muds, whereas the MVT deposits were precipitated at depth from hotter fluids expelled during later phases of shale compaction. Whether they represent end-member products of a continuing process has yet to be resolved.

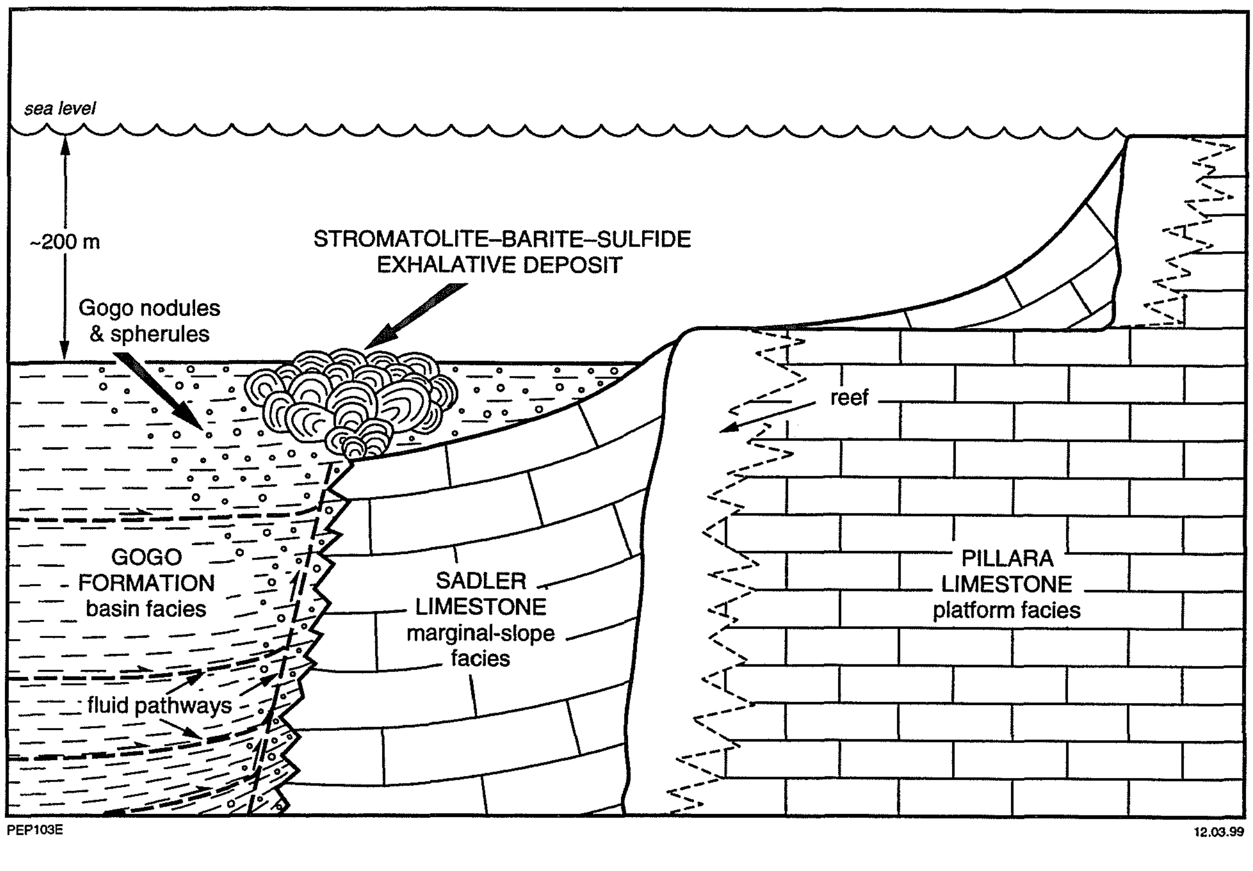

Figure 1. Diagrammatic section illustrating the origin of stromatolite–barite–sulfide exhalative (SEDEX) deposits and related nodules and spherules in the Gogo Formation