A Symbiotic World:
The Significance of Symbiosis in the Fossil Record

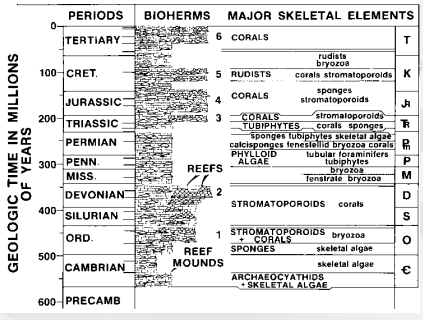
Reefs: Rainforests of the Marine Realm

A reef, rising above the sea floor, is an entity of its own making - a sedimentary system within itself. The numerous, large calcium carbonate secreting organisms stand upon the remains of their ancestors and are surrounded and often buried by the skeletal remains of the many small organisms that once lived on, beneath, and between them.

- Noel James

Reefs Through Time

Note: The dominant reef-builders and reef-dwellers have changed through time as a result of extinction and evolution



Probably all powered by photosynthesis

Advantages of Algal Symbiosis

Some corals grow up to 25 cm per year !

Such intense production of calcium carbonate is only possible with the help of certain algae (known as Zooxanthellae).

These algae live in the soft tissues of the coral (Fig. 6).

Due to their photosynthetic lifestyle they produce carbohydrates which are, to a large part, used by the coral animal.

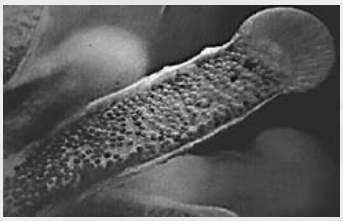
Significance of Phosphates

On the other hand, the algae gain protection and can use phosphates and carbon dioxide produced by the coral.

Phosphates inhibit the growth of calcareous coral skeletons but are a must for algal growth, although they are very rare in the nutrient deserts of the tropical seas.

Only by this interdependent relation are reef corals able to grow rapidly despite the overall lack of nutrients.

Zooxanthellae control saturation of calcium carbonate in coral

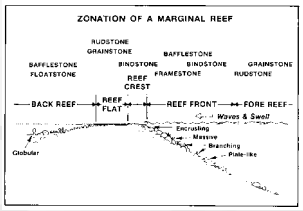


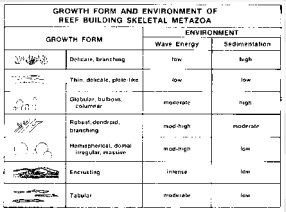
Zooxanthellae in tentacle of coral

$$CaCO_3 + CO_2 + H_2O = HCO_3^- + Ca^{2+}$$

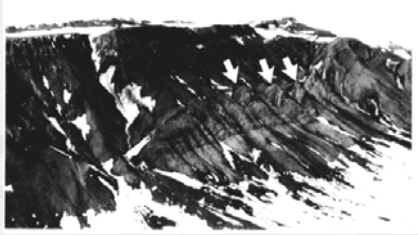
Decrease CO_2 in coral tissues,
drive reaction to left, in favour of carbonate production

Reef Zonation





Form of reef builders dependent on physical agitation, light availability and sedimentation rate



Massive reef limestone (right) of the Nansen Formation (Permo-Pennsylvanian) extending downward and basin ward into dark, argillaceous limestones of the Hare Fjord Formation (left). Arrows point out small reef mounds developed on the seaward slopes of the reef front, western side of Blind Fjord, Ellesmere Island, N.W.T.

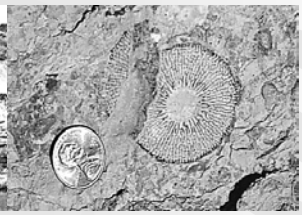
Precambrian (Archaean to Proterozoic)
Dominant Reef Builders: Cyanobacteria

Stromatolite mound of Proterozoic age Kuuik Formation, Kilohigok Basin, Northwest Territories

Cambrian

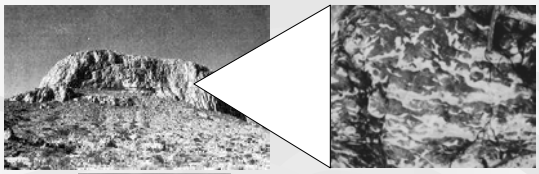
Dominant Reef Builders:
Archaeocyathans (sponges) and skeletal algae

Reef in Newfoundland



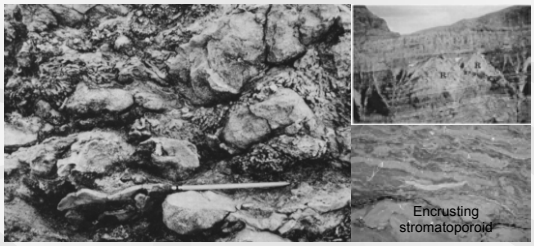
Cross section of Archaeocyathan sponge

Ordovician-Silurian:
Mostly mudmounds (dominated by algae, bryozoa and microbes)



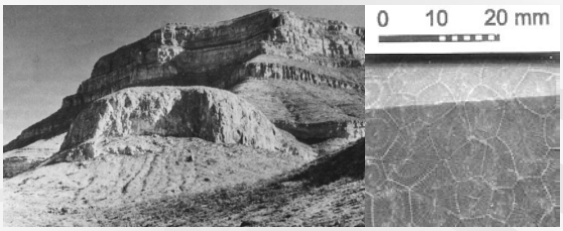
Stromatactis, sub-horizontal layers of calcite spar illustrating irregular digitate tops and smooth bottoms, from Gros Morne, reefmound facies, Silurian West Point reef complex, Gaspé, Quebec. Possibly due to cyanobacterial decay

Devonian:
Dominated by stromatoporoids (sponges) and corals



The diversification stage of an Upper Devonian reef, comprising domal stromatoporoids, and domal to branching tabulate corals, Blue Fjord Formation, south side of Eids Fjord, Ellesmere Island, N.W.T.

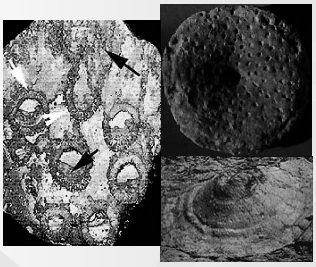
Carboniferous-Permian
Dominated by algae, bryozoa (many mudmounds)



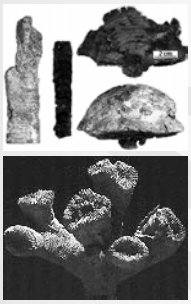
Muleshoe bioherm, a 60 m high reef mound of Late Mississippian age exposed along the western escarpment of the Scaremento Mountains, New Mexico.

A well-developed Permian reef:
El Capitan in Guadalupe Mountains, New Mexico/Texas

Triassic-Jurassic
Dominated by stromatoporoids, other sponges and few corals

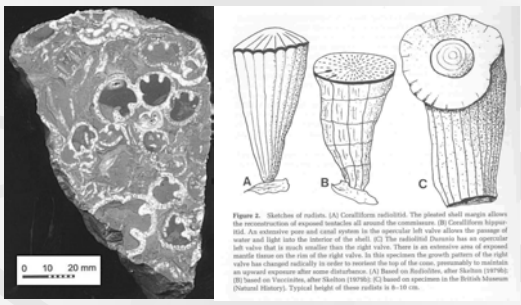


sponges



corals

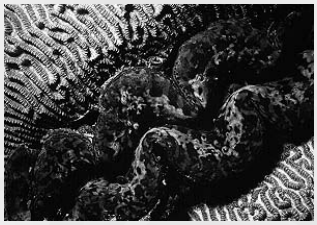
Cretaceous
Dominated by rudists and corals



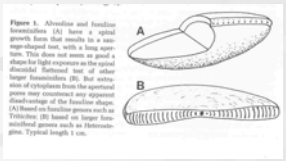
Rudists: bizarre reef-building clams !

Cenozoic (both Paleocene and Neogene)
Dominated by corals

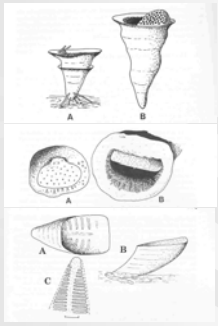
Some other photosymbiotic critters



The giant clam *Tridacna*. This is a species which lets itself become partially overgrown by a coral. The colors are largely due to the chlorophyll of the photosymbiontic algae living in the soft tissue ('mantle') of the clam.

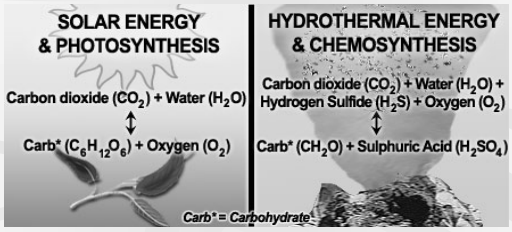


Giant foraminifera



Reef-dwelling brachiopods
(Permian)

Chemosymbiosis



Just as photosynthesis provides nutrition for hosts of endosymbiotic algae, so too can chemosythesis for hosts of endosymbiotic sulphide-oxidiving bacteria.

Chemosynthesis is the basis for deep sea communities that live around hydrothermal vents at midocean ridges.

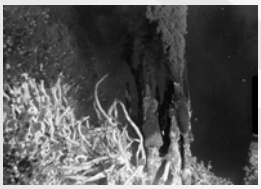
Vent Faunas

Many species of organisms are uniquely adapted to conditions associated with hydrothermal vents.

The Giant Tubeworm is one of the most common vent dweller (ranging up to 2 metres in length).

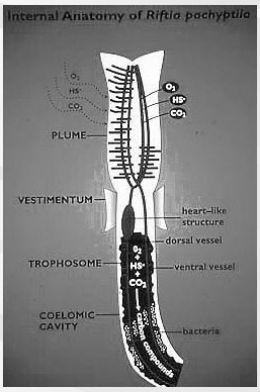
The red “plume” of the tubeworm act as a gill to exchange water, dissolved gases, and waste.

But the actual “work” is done by bacteria housed in the trunk of the animal.



Endosymbiotic bacteria oxidize sulphide in this way (forming sugars).

$4H_2S + CO_2 + O_2 \rightarrow CH_2O + 4S + 3H_2O$



Sugars that are not used by the bacteria are transferred to the tubeworms.

Incredibly, these worms have no gut or anus !

The bacteria supply all the nutritional needs of the tubeworm.

In return for supplying the tubeworms with food, the tubeworms function as a supplier of sulphide and carbon dioxide.

Both parties are happy.

Some clams, also housing chemosymbiotic bacteria work in a similar way to that of the tubeworms. The clam ***Calyptogena magnifica*** grows to extremely large sizes, sometimes exceeding 20 cm in length.

Crustaceans, such as crabs and shrimps have become specialized to sweep bacteria into their mouths.

In turn, crustaceans, and fishes feed on dead animals and the various inhabitants of the vent community (including tubeworms)

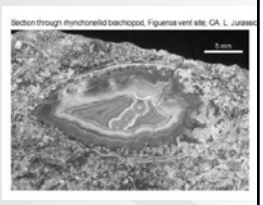
So vent communities are very ecologically complex.

An increasing number of fossil hydrothermal vent communities have been found in terrestrial massive sulphide deposits from around the World (currently at least 20).

The oldest of these communities (Silurian) is approximately 430 million years old. All of the fossil vent assemblages contain worm tubes (analogues to modern vent tubewormd). , some of which have been identified as polychaete and vestimentiferan tubes.

Some assemblages also contain a small diversity of brachiopods and molluscs.

Expect to hear more about fossil vent communities in future scientific literature !



Fossil brachiopod in ancient hydrothermal vent deposit.

While we often think that endosymbiosis is strange in a biological sense, it is more widespread than one might think !

END OF LECTURE