

## Hard bottoms

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PALMER, T.J. (1994). Hard bottoms. *Proceedings of the Shropshire Geological Society*, **10**, 19–21. Hard sea bottoms arise on the sea floor when soft sediment, the majority being of terrigenous origin, includes grains consisting of calcium carbonate which eventually lithify to form limestone. The grains are either precipitated directly from sea water or, more commonly, from organisms.

Hardgrounds may at first sight appear to be an unusual and esoteric phenomenon, but in practice their study is able to extend consideration in time and scale of large-scale climatic and chemical processes, and on evolution patterns.

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### INTRODUCTION

The subject of hard sea bottoms arises from most sea floors being covered with soft sediments, the majority being of terrigenous origin. A special case occurs when the soft sediments consisting of grains of calcium carbonate eventually lithify to form limestone. The grains are either precipitated directly from sea water or, more commonly, from organisms.

A typical modern carbonate sea bottom is shallow, extensive, and light in colour because of the pale colour of calcium carbonate. Such sediments occur in tropical or subtropical waters within the photic zone as organisms require light for photosynthesis, so they accumulate in waters up to a few tens of metres deep. Today there are hard calcareous sea bottoms in the tropics supporting a range of organisms.

Most fossils are the remains of soft-sediment organisms which originally lived in soft mud or sand which is now found as hard rock. Occasionally the fossil record shows species which are specifically associated with a hard substrate.

### HARD SUBSTRATES

Hard substrates can occur for a variety of reasons:

1. **Unconformities;** an example would be of an Ordovician quartzite overlain by Jurassic sediments containing oysters attached to what had been the sea floor, drawing the analogy with modern rocky sea floors on which barnacles, limpets etc. attach themselves. Such a hard bottom is known as rockground.

2. **Septarian nodules;** calcium carbonate can be precipitated just below the sea floor and locally cement the sediment. The process passes through a soapstone stage and then hardening, involving a volume change. If local erosion then takes place these nodules, which lie a few centimetres below the sea floor, will be exposed and form local hard substrates. An example is the coinstone in the Black Ven Marls of Dorset which are Lower Jurassic. Such concretions can then provide a hard surface for colonisation.

3. **Individual shells;** on the sea floor these form the greatest volume of hard bottoms. Most shelled organisms live in soft sediment but the shell represents islands of hard substrate which can be colonised, e.g. encrusting worms on *Gryphea* shells, also boring organisms which operate by dissolving the calcium carbonate – some bryozoa do this.

The study of boring organisms has advanced since the discovery of epoxy resins which could be used to impregnate limestone which had been bored. The limestone was then dissolved and a cast of the borings remained. Such studies range in scale from large club-shaped holes made by boring clams down to calcite prisms 10 microns across which have been bored by bacteria. At the large end of the scale the size of biotic substrates is not limited to individual organisms, as reefs are formed today by corals, since in earlier geological times they were also contributed to by other encrusting organisms.

## HARDGROUNDS

Hardgrounds arise where calcium carbonate sediment has become hardened, by chemical means, contemporaneously with sedimentation.

Most limestones accumulate as soft carbonate sediment. It used to be thought that these sediments could only be hardened by exposure to meteoritic rain. Rain is slightly acid and dissolves some limestone to reprecipitate it around grains and thus form a hardening cement. This is evident in thin section where individual grains can be seen to have a fringe of calcium carbonate crystals. This is the most usual way for limestones to form but modern research has shown that, locally, patches of soft sea floor can become hardened while still submarine. These are blocks of limestone which consist of original grains cemented by a thin rim of lime and are known as hardgrounds.

Hardgrounds can only form where there is a sufficient concentration of bicarbonate ions in the seawater. These are ultimately derived from atmospheric carbon dioxide which is dissolved in the sea. Seawater rich in bicarbonate ions circulating through the top 10-15 cm of sea floor can precipitate rims of calcium carbonate around existing grains and thereby cement them together. Because the ions are derived from sea water the process becomes progressively less effective in deeper sediments; it is most effective just below the sediment/seawater interface.

This phenomenon is occurring today in the Persian Gulf. Four separate sedimentation events have been identified, each with a hard crust forming just below the sediment surface. Examples from the fossil record range from the Ordovician of the Mississippi region up to the Cretaceous of southern England. In the Cretaceous Chalk, these hardgrounds can be so extensive as to form useful stratigraphical markers, extending across the Channel into Normandy.

Hardgrounds can be recognised in the field by a number of indicators:

1. As persistent flat surfaces. The flatness is due to erosion after hardening. An example would be a cephalopod which had originally lain in soft limy sediment which had then become part of a hardground which had suffered contemporaneous erosion removing about a centimetre of the fossil.

2. Hardgrounds are often stained by minerals: pyrite, manganese etc. This staining shows in the cross-section of an exposure.
3. Contemporaneous boring or encrusting animals associated with the sediment indicate that it was hard at the time.

## SIGNIFICANCE OF HARDGROUNDS

This description of hardgrounds leads on to consideration of the significance of current research in this field, crossing different fields of interest. Thus while sedimentologists tend to ultimately produce palaeogeographic maps of a particular time and area, and palaeontologists tend to study individual fossil groups, the author has studied hardgrounds through geological time, i.e. he has looked at a particular environment through different ages. This is typically a tropical or subtropical shallow water area which is carbonate hosted. The frequency of occurrence of hardgrounds varies through geological time and is probably related to climate.

At present we are experiencing a cool period of the earth's history – an ice-house period. Such periods can also be recognised from the Carboniferous and Permian, and in the late Precambrian and the Cambrian. Intervening times – the middle Palaeozoic and the Mesozoic (Jurassic and Cretaceous) – experienced a significantly warmer climate and are known as greenhouse periods.

Aragonite is the more common form of calcium carbonate and provides the cement in hardgrounds. However, it is more soluble than calcite, which forms the cement in greenhouse periods. Calcite precipitates more easily, from lower temperatures and lower concentrations, than aragonite and so hardgrounds are more common in greenhouse periods. Thus the present (ice-house) period is not a good key to the past, as ocean chemistry and fauna have changed.

The occurrence of ice-house and greenhouse periods is a reflection of the buildup of carbon dioxide in the atmosphere which traps incoming solar energy and causes temperatures to rise. Geologically the current activities of Man are negligible in this respect. The main source of carbon dioxide in the atmosphere is from vulcanicity from subduction zones and mid-oceanic ridges. If the rate of movement at plate

edges is increased it will increase the emission of carbon dioxide and so cause a greenhouse period will develop, when more carbon dioxide is dissolved in sea water and hardgrounds can form.

Ordovician limestones contain many hardgrounds with encrusting bryozoa. These hardgrounds were sometimes broken up by contemporaneous storms and the resultant blocks recemented to form intraformational conglomerates which were then colonised by encrusting organisms. In Lower Palaeozoic times hardgrounds were the main source of hard substrates as only small shells were available – organisms with hard shells had yet to evolve. The existence of hardgrounds enabled a range of organisms to develop encrusting or boring habits.

The occurrence of such encrusting and boring organisms through Phanerozoic time can now be considered. Species which occur on hardgrounds (about 200) can be categorised into three categories: borers, encrusters with exoskeletons, and encrusters with endoskeletons.

During the Palaeozoic there were many encrusters which clearly survived successfully as there were relatively few predators. At this time there were not many borers or encrusters with exoskeletons. However, by the Mesozoic there is a great increase in the number of borers and encrusters with exoskeletons. This can be interpreted in terms of the populations reflecting the effect of the late Palaeozoic burst of radiation whereby marine predators such as fish, crustaceans, starfish etc., suddenly evolved causing a consequent change in morphological habit and environment within the fauna of hardgrounds.

## CONCLUSION

What appears at first sight to be an unusual and esoteric obsession with the obscure phenomenon of hard bottoms in practice is able to extend the study in time and scale of large-scale climatic and chemical processes, and on evolution patterns.

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