Denys Smith

(1929-2007)

Permian geologist.

His studies, over 40 years, have resulted in our current understanding of the Permian Magnesian Limestones.

Photograph © A.H.Cooper

All You Ever Wanted to Know About

The Permian Magnesian Limestones

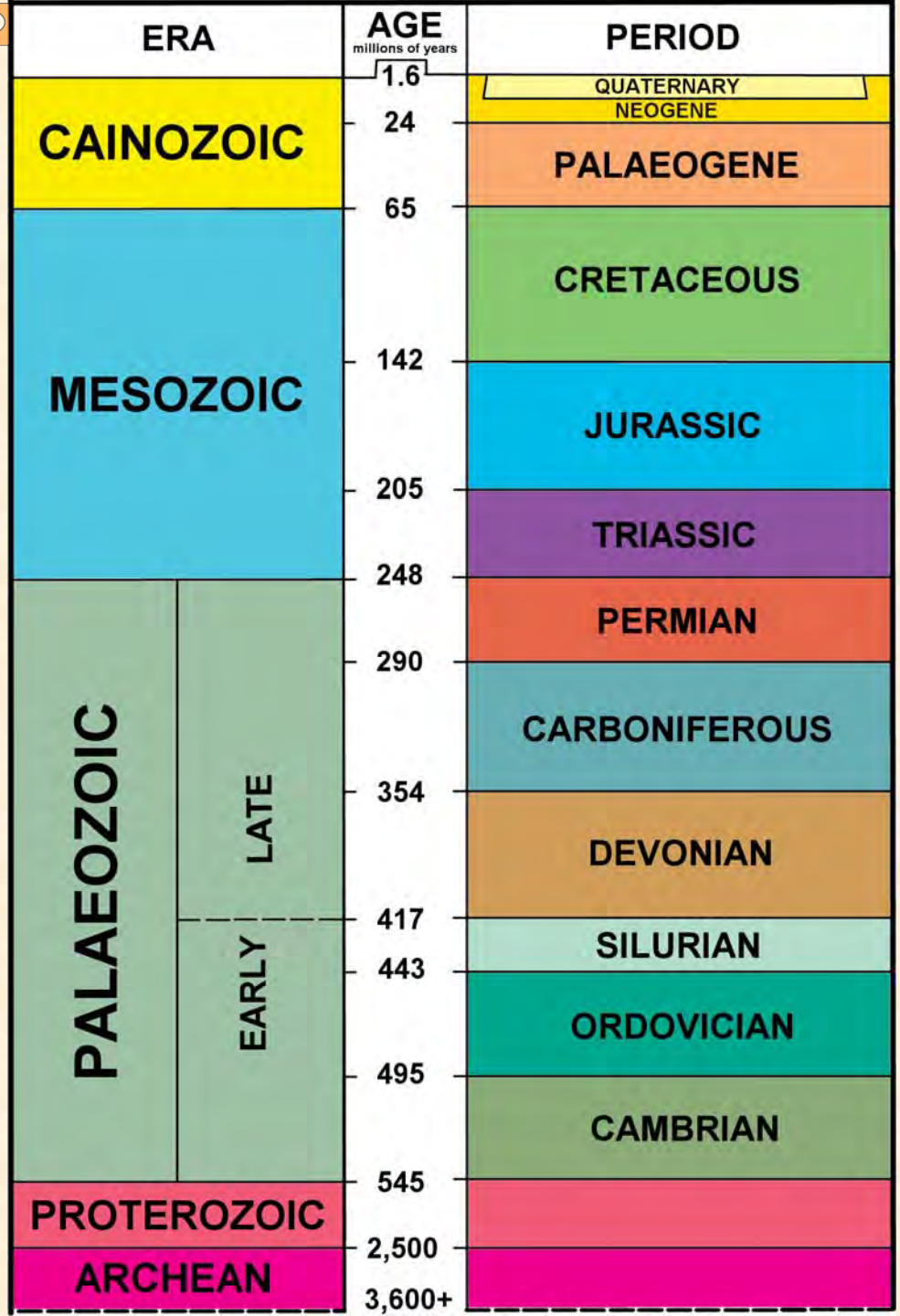
by Tim Pettigrew

How old are the Magnesian Limestones?

How Did the Limestones Form?

A "Cook's Tour" of the Deserts, Floods, Reefs, Droughts and Salts of County Durham

THE PERMIAN IN THE GEOLOGICAL TIMESCALE



Appearance of Humans

Extinction of Dinosaurs

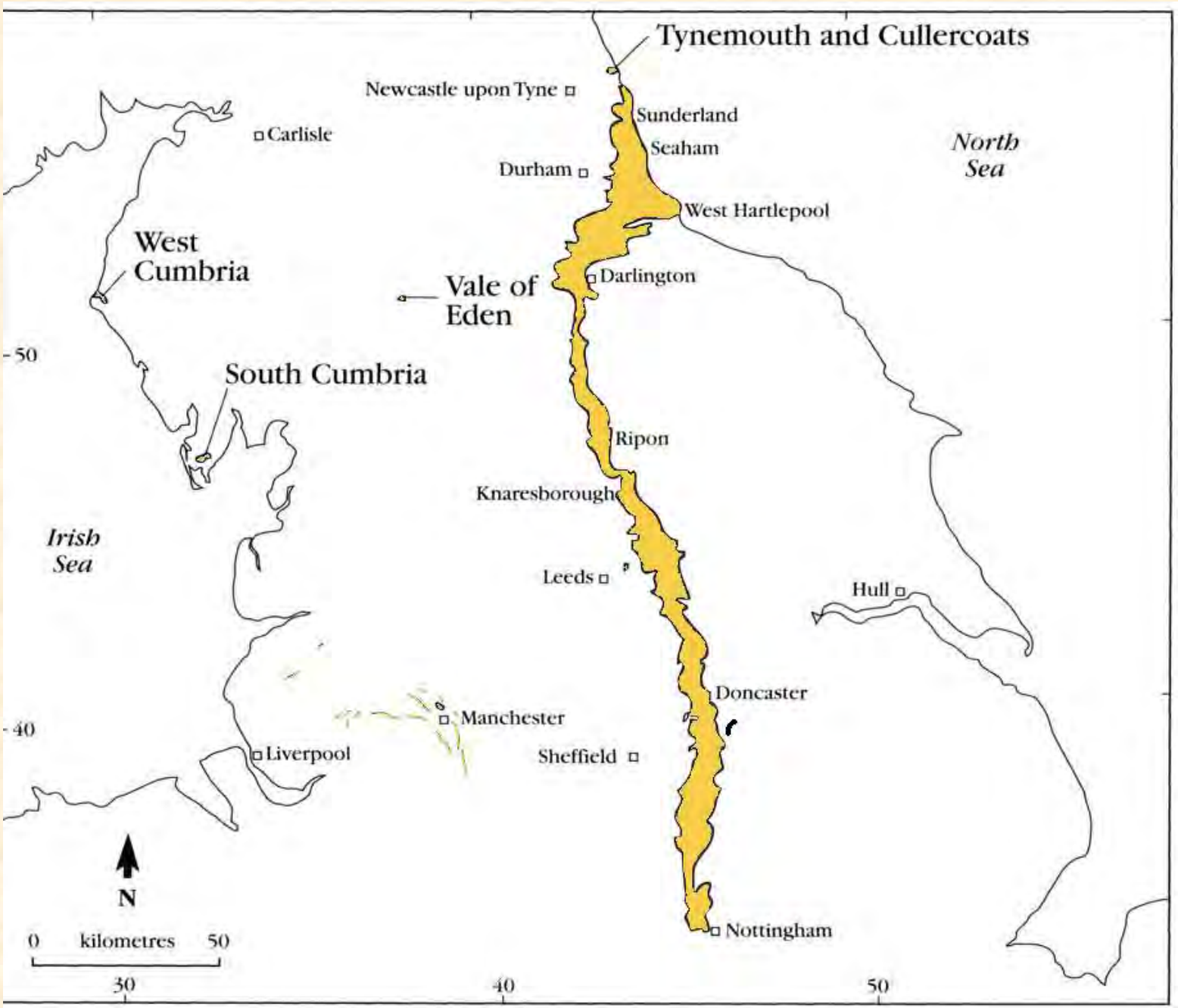
Appearance of Dinosaurs

Mass extinction of life, probably by Global Warming

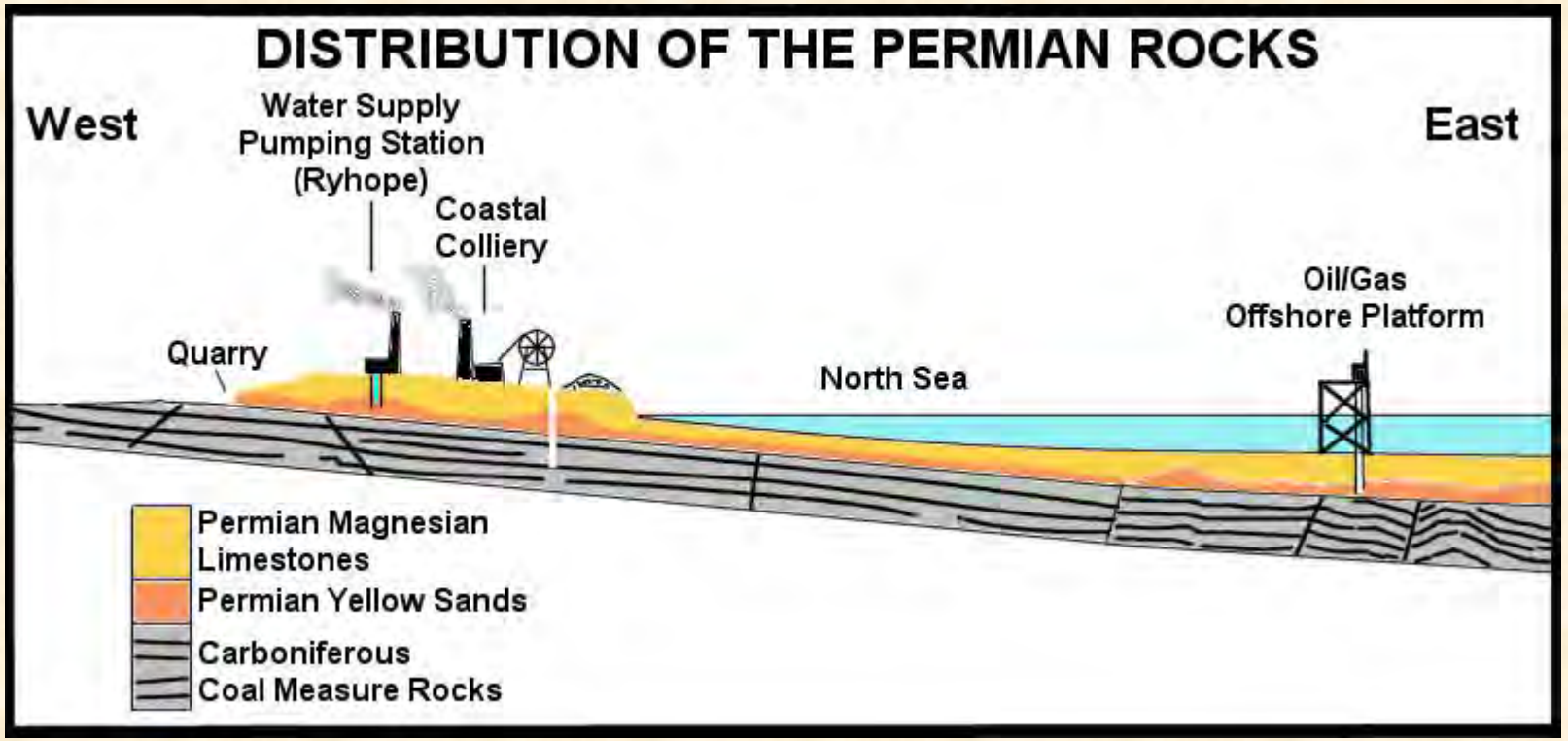
The Magnesian Limestones formed in this period.

Formation of Coal

First appearance of life in the seas



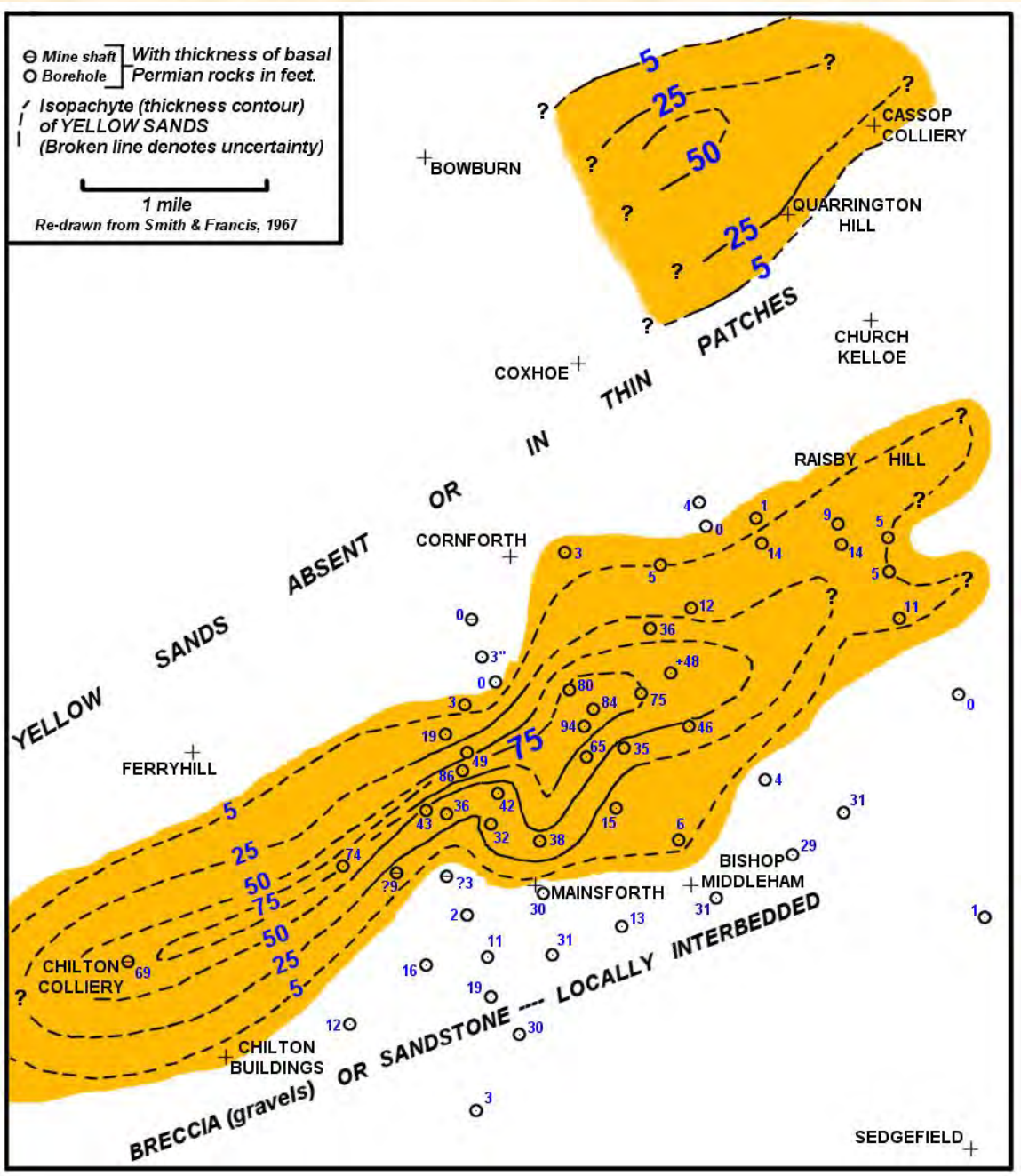
Outcrop of the marine Permian including the Magnesian Limestones



Cross-section showing the distribution of the Permian rocks in Co. Durham/Tyne & Wear

Dunal ridges of the Rhubal Khali, Arabian Peninsula. These ridges are about 1-2km wide and up to 150m high. County Durham would have looked very much like this during the Early Permian.

Dunal ridges of the Yellow Sands in South Durham between Bowburn and Chilton.



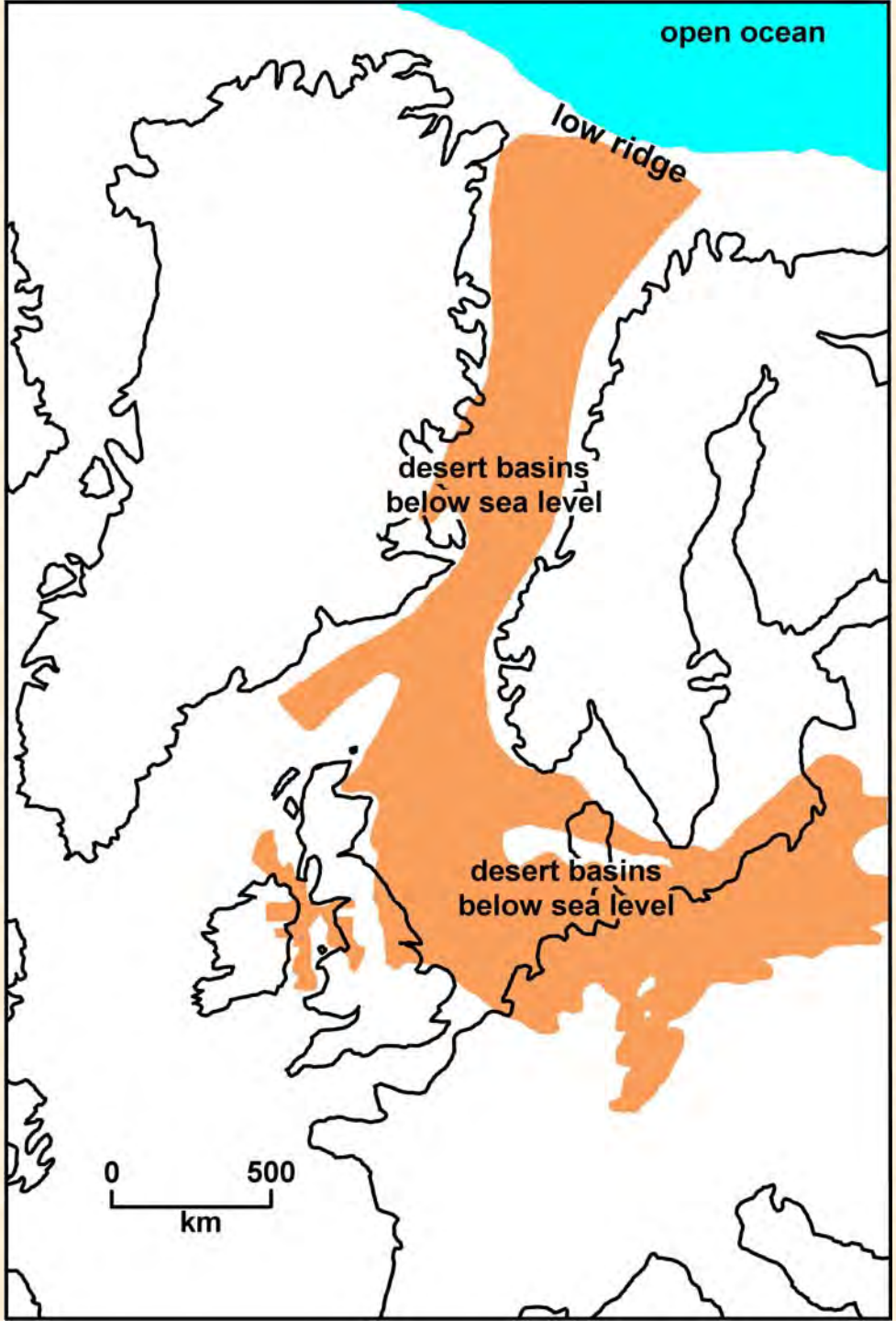
Quarry in one huge dunal ridge of Yellow Sand exposed at Field House Sand Hole near Houghton le Spring. The tractor gives some idea of the vast size of this dunal ridge

WHICH WAY DID THE WIND BLOW?

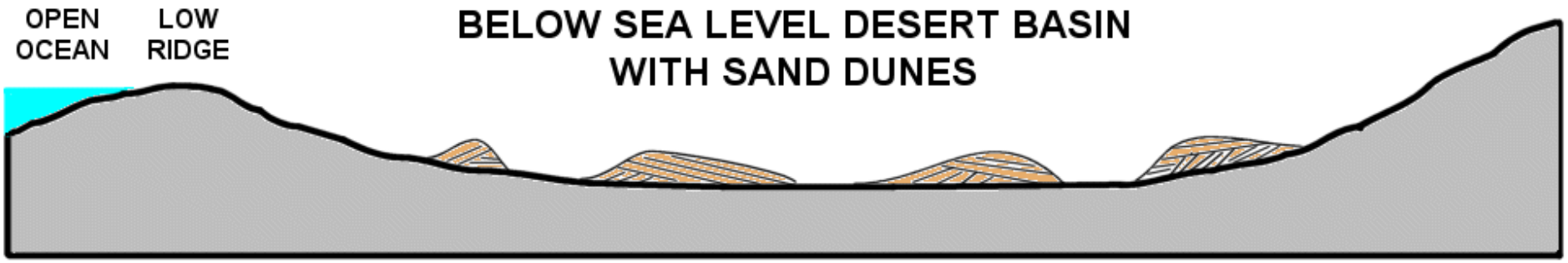
Orientation of the cross-bedding in the Yellow Sands suggests that the predominant wind direction across the Permian desert was from the east-north-east

Photo taken in Quarrington Quarry

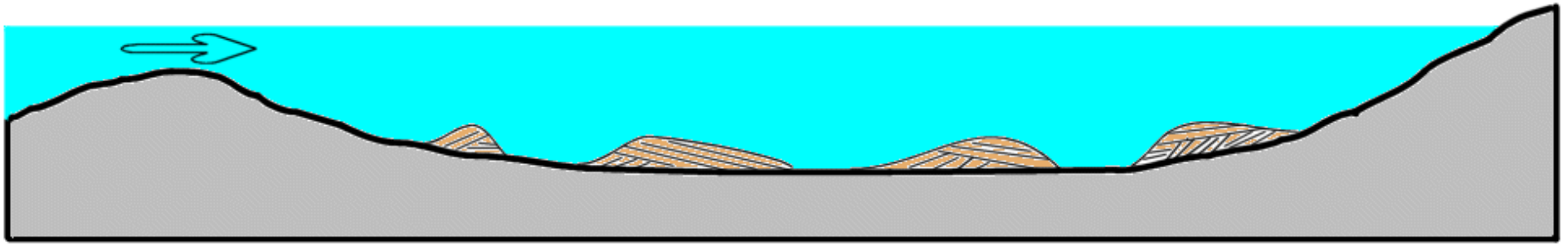
Towards the end of the Early Permian, the desert occupied a series of low-lying basins. Eastern England was situated on the western margin of this basinal area whilst somewhere between Norway and Greenland, a low land barrier separated the northernmost basin from the open sea.



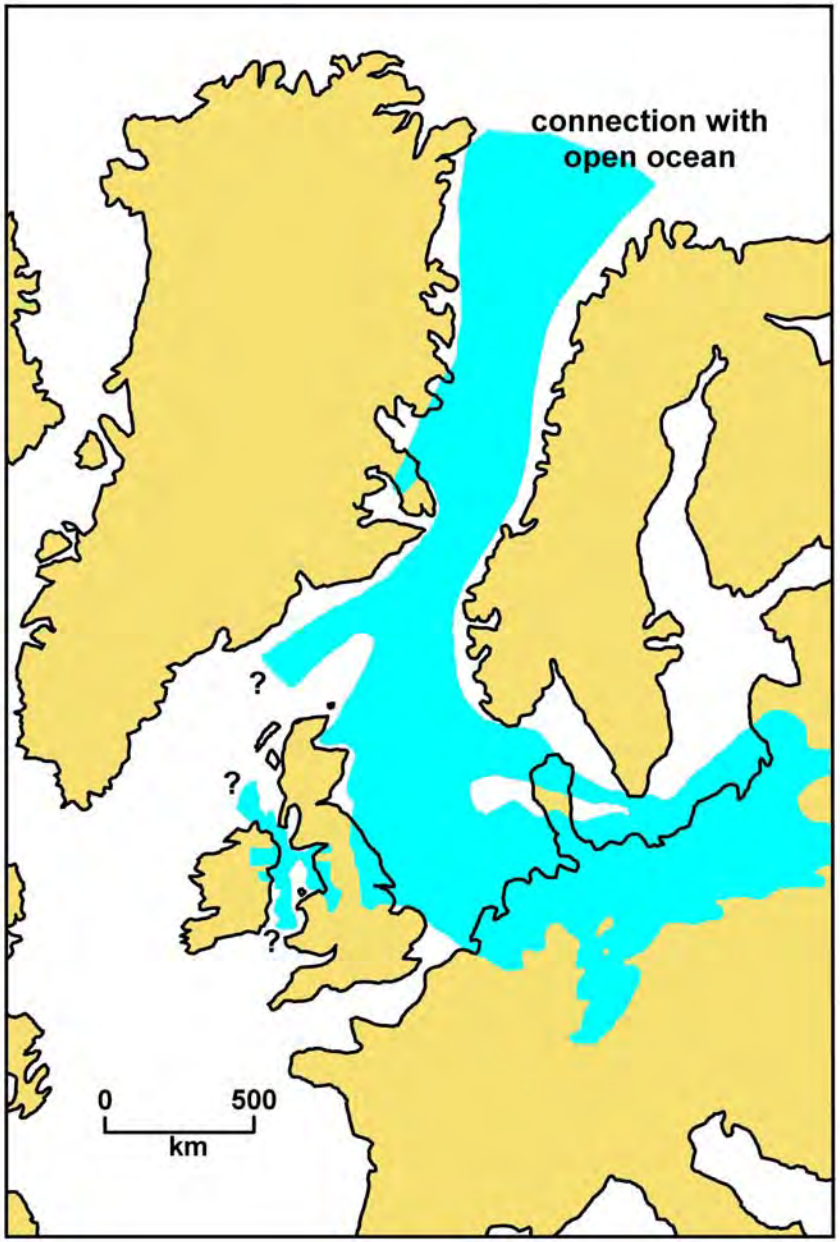
WHAT HAPPENED TO THE DESERT?

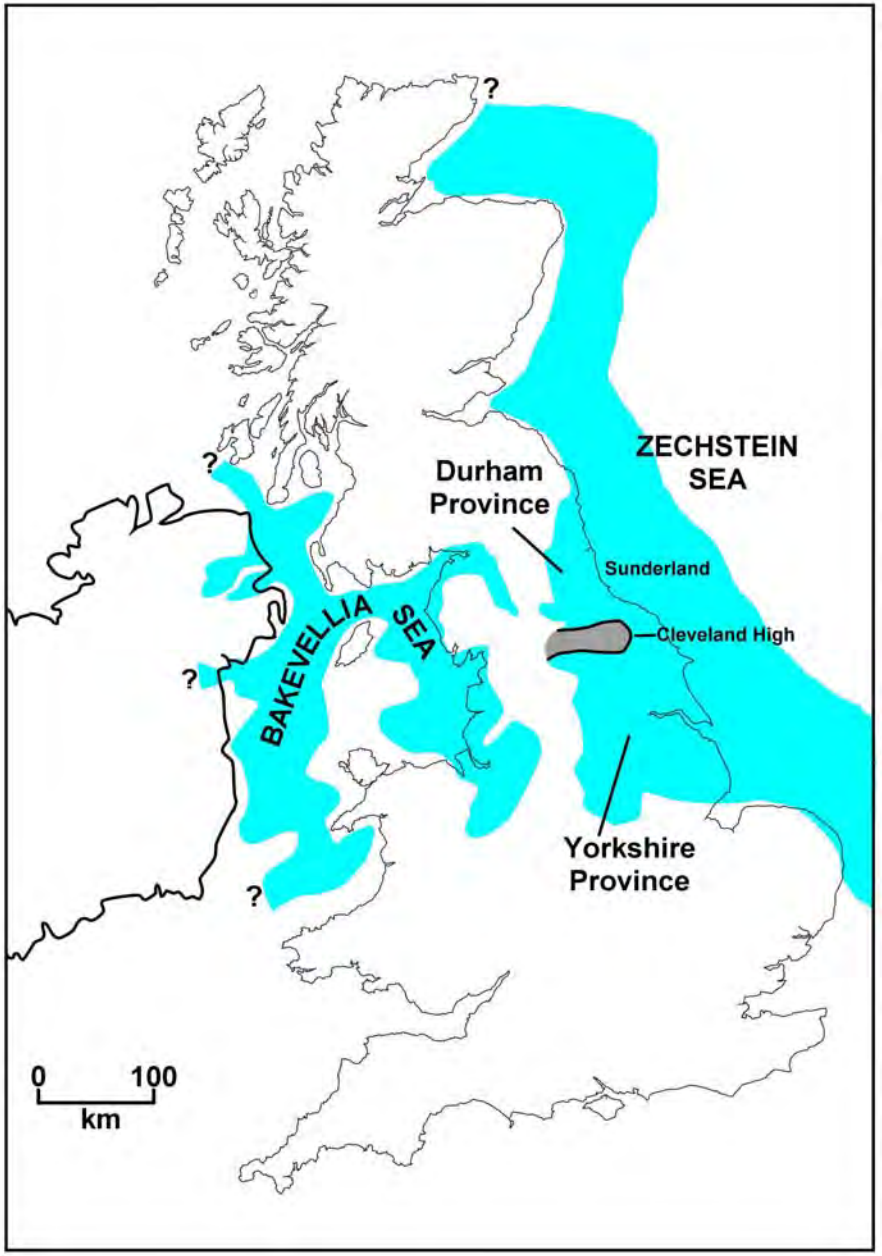


MELTING OF POLAR ICE CAPS BY GLOBAL WARMING
CAUSES SEA LEVEL RISE AND INSTANT FLOODING
OF THE DESERT TO FORM THE ZECHSTEIN SEA



The desert was instantly flooded to form the Zechstein Sea





THE MAGNESIAN LIMESTONES

Boulby Halite & Potash Formations Named after Boulby, North Yorkshire where the potash is currently mined.	3rd EVAPORITES	CYCLE 3
Billingham Anhydrite Formation Named after Billingham, where it was formerly mined		
Seaham Formation Named after Seaham, Co. Durham	3rd MAG LIMESTONE	
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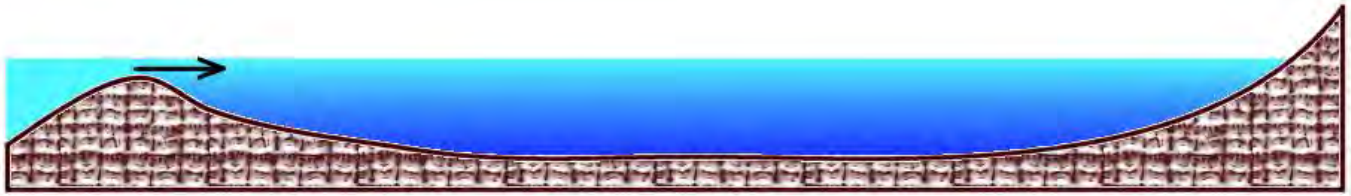
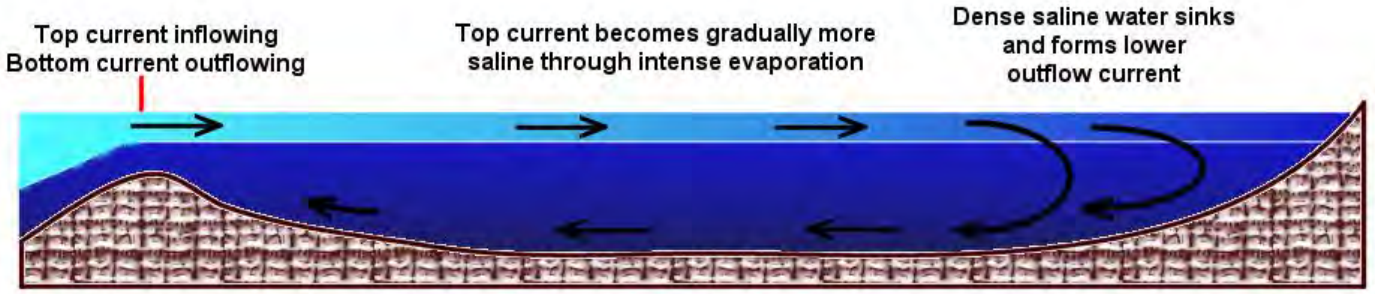
Raisby Formation Named after Raisby Quarry Coxhoe, Co Durham		
Marl Slate		

HOW DID THE MAGNESIAN LIMESTONE FORM

A further fall in external sea level can cause the basin to be isolated from the open ocean.



A small fall in sea level can restrict water flowing into the basin. Intense evaporation causes various evaporites or 'salts' to be deposited on the sea bed.



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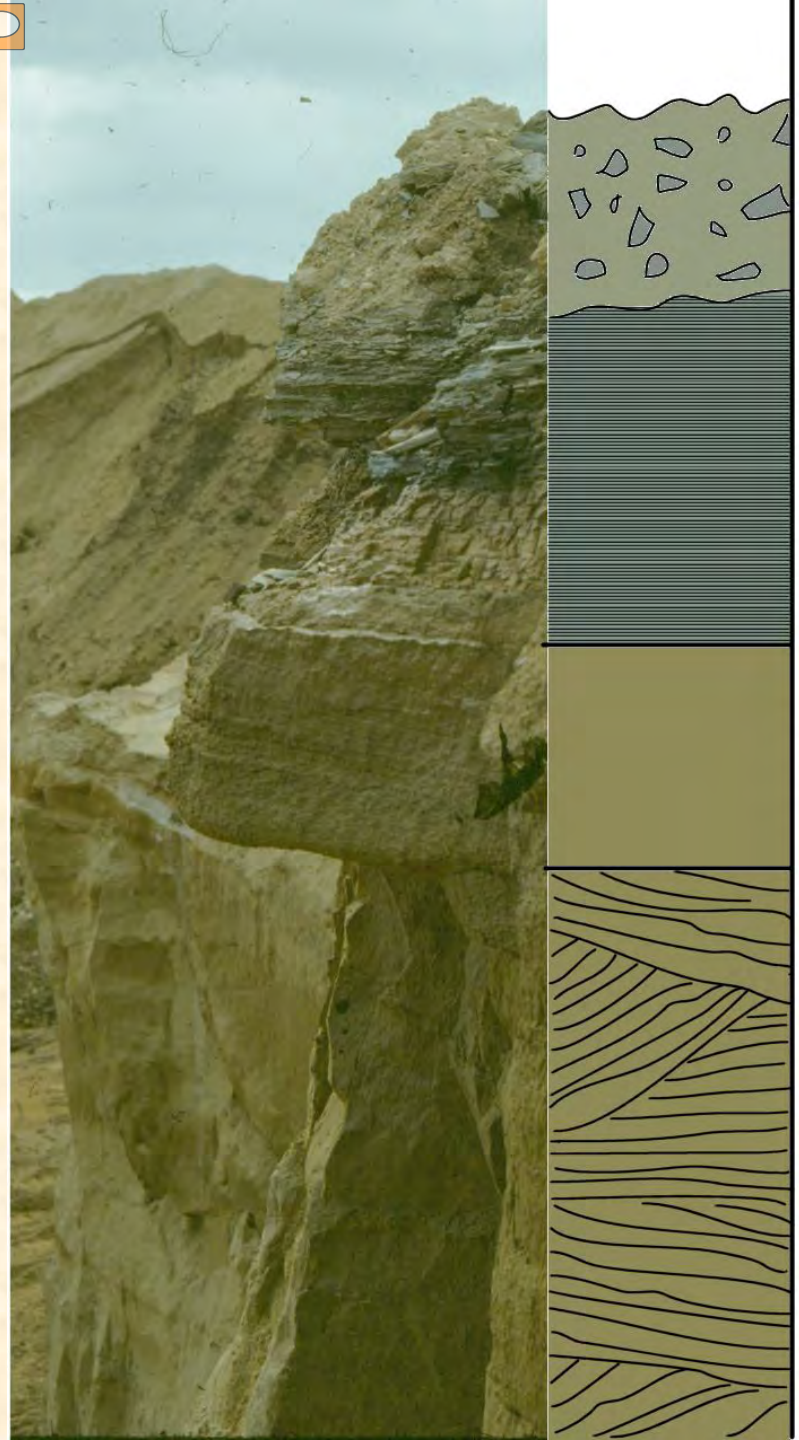


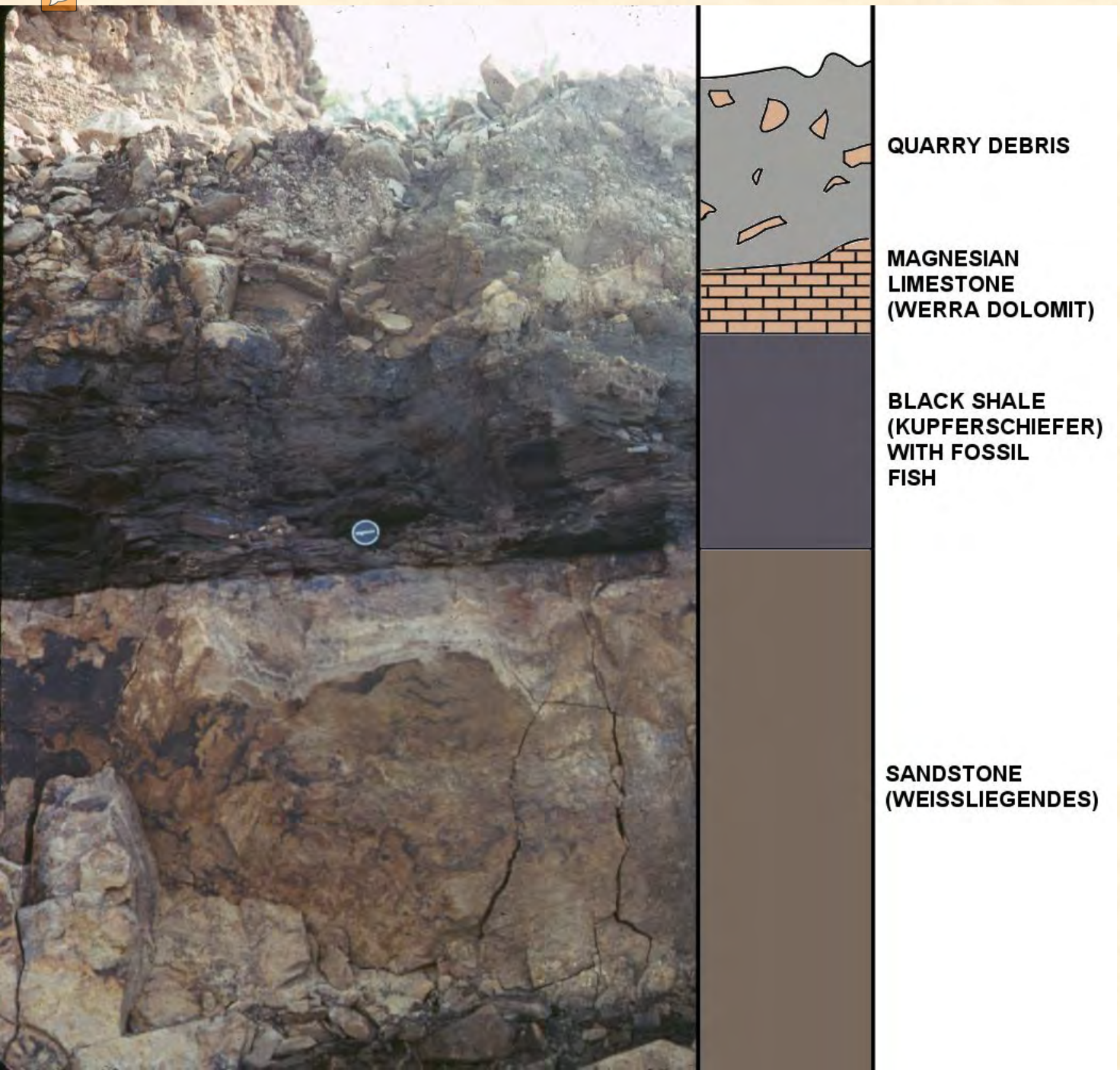
ROCK EXPOSURE AT QUARRINGTON QUARRY

This shows how quickly the flooding of the desert took place. A thin sandstone bed at the top of the sand dune contains sea shells. Then, as the sea rapidly completely submerged the dunes, black shales of the **Marl Slate** were deposited

Sandstone from the top of the dune at Quarrington with a fossil sea shell called *Lingula.* Some of the original colouration of the shell is preserved.

FRENCHMAN'S BAY, SOUTH SHIELDS

Here the crest of a dunal ridge can be clearly seen overlain by the **Marl Slate** and then the carbonates of the Magnesian Limestone



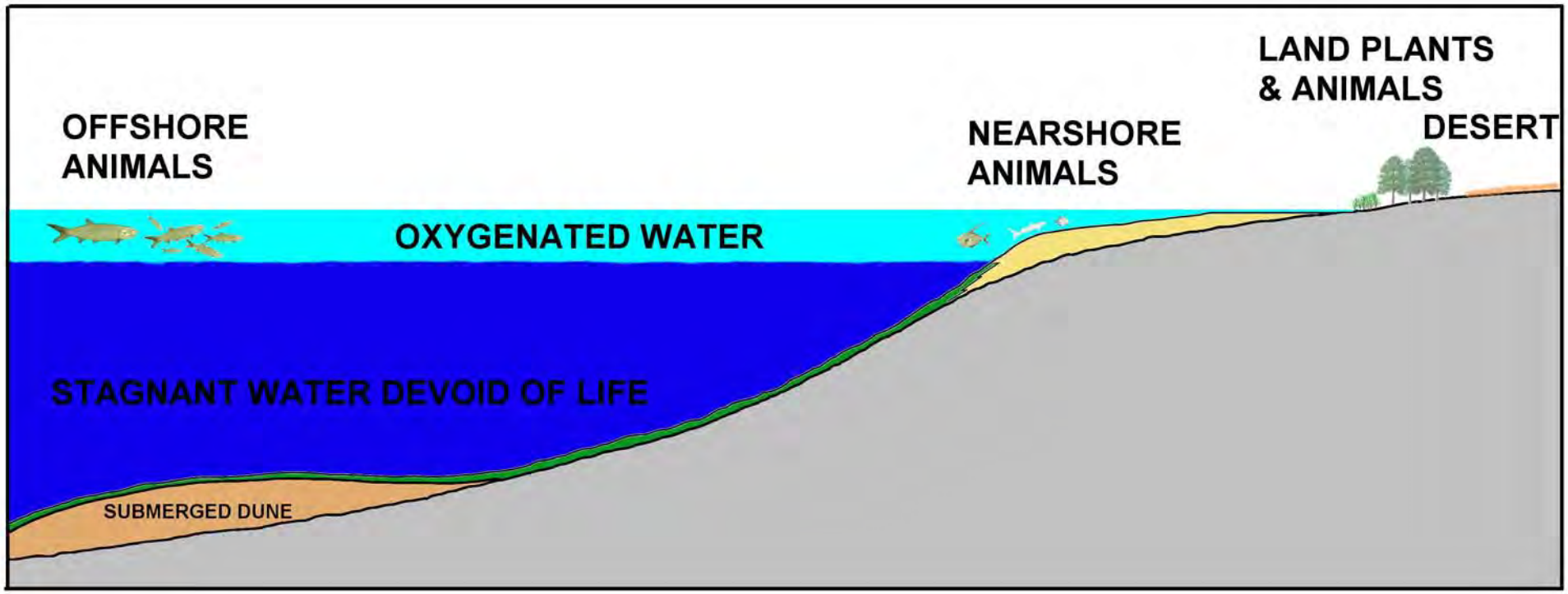
Quarry, Harz, Mountains, Germany

This location on the other (eastern) side of the Zechstein Sea shows exactly the same sequence of deposits as in Durham with desert sandstones (Weissliegendes) overlain by black shales of the Kupferschiefer (=Marl Slate), and then the Werra Dolomit (=Magnesian Limestone)

MARL SLATE AT QUARRINGTON

Even the highest dunes of the Permian desert were submerged and, in the deep water, the finely laminated shales of the **Marl Slate** formed a blanket over the top of the dunes. The layers in the **Marl Slate** are thought to have formed by seasonal algal blooms which is why the rock smells of 'petrol' when freshly broken. There is an alternation of black and pale layers each couplet representing a year. Counting these layers suggests that the **Marl Slate** formed over a time interval of 17,000 years.

HOW THE ‘MARL SLATE’ FORMED



The bottom of the Zechstein Sea was stagnant and devoid of life. Towards the surface where there was light and oxygen, life was abundant. Animals dying and sinking to the sea-bed were perfectly preserved in the Marl Slate because of the stagnant conditions which prevented scavengers and bacteria from disturbing and decomposing the remains. This is why the Marl Slate contains exceptionally well-preserved fossils.

Three bio-communities can be recognised. **OFFSHORE ANIMALS** (mainly fish). These formed the most abundant fossils. **NEARSHORE ANIMALS** Animals living in the shallow waters of the sea (fish and various shellfish). These are rarer fossils as their remains rarely drifted out into the deeper water. **LAND PLANTS & ANIMALS** These form the rarest fossils of all in the Marl Slate as their remains were only very rarely swept out into the Zechstein Sea.

LETS LOOK AT THESE THREE GROUPS IN TURN STARTING WITH THE OFFSHORE ANIMALS

OFFSHORE ANIMALS 1

This fossil fish (***Palaeoniscum)*** is the most abundant fossil in the Marl Slate. They were probably like the modern Mackerel in habit, swimming in large shoals. Up to about 200 mm in length

OFFSHORE 2

Much rarer are large powerful fish (like this specimen of ***Pygopterus***), up to 2 metres in length and interpreted as predators chasing after the shoals of ***Palaeoniscum***! The specimen of ***Palaeonoscum*** (also shown in the previous slide) gives some idea of scale.

OFFSHORE 3

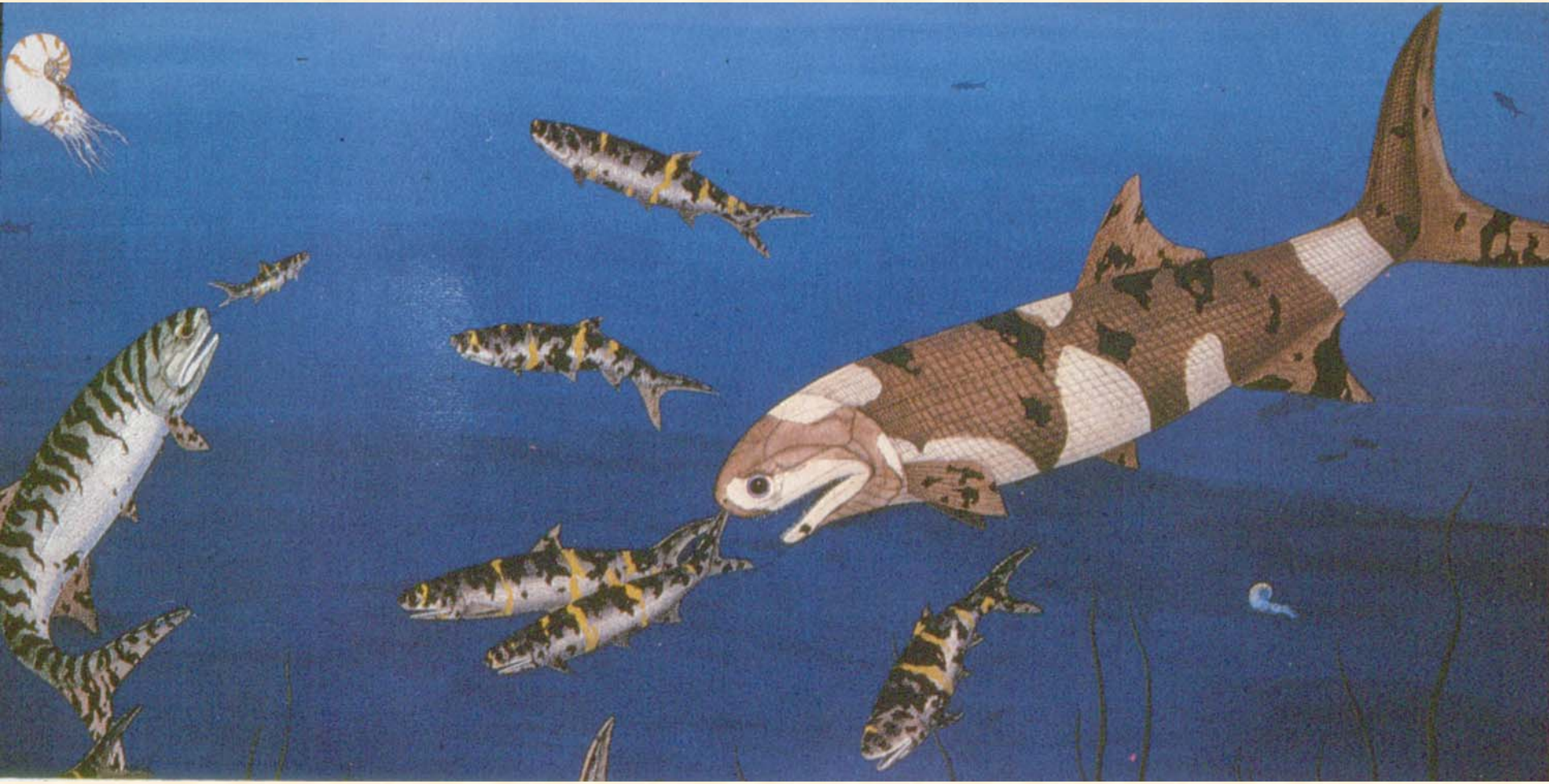
Here is a jaw of ***Pygopterus*** showing some fearsome teeth for grasping it's prey!

OFFSHORE 4

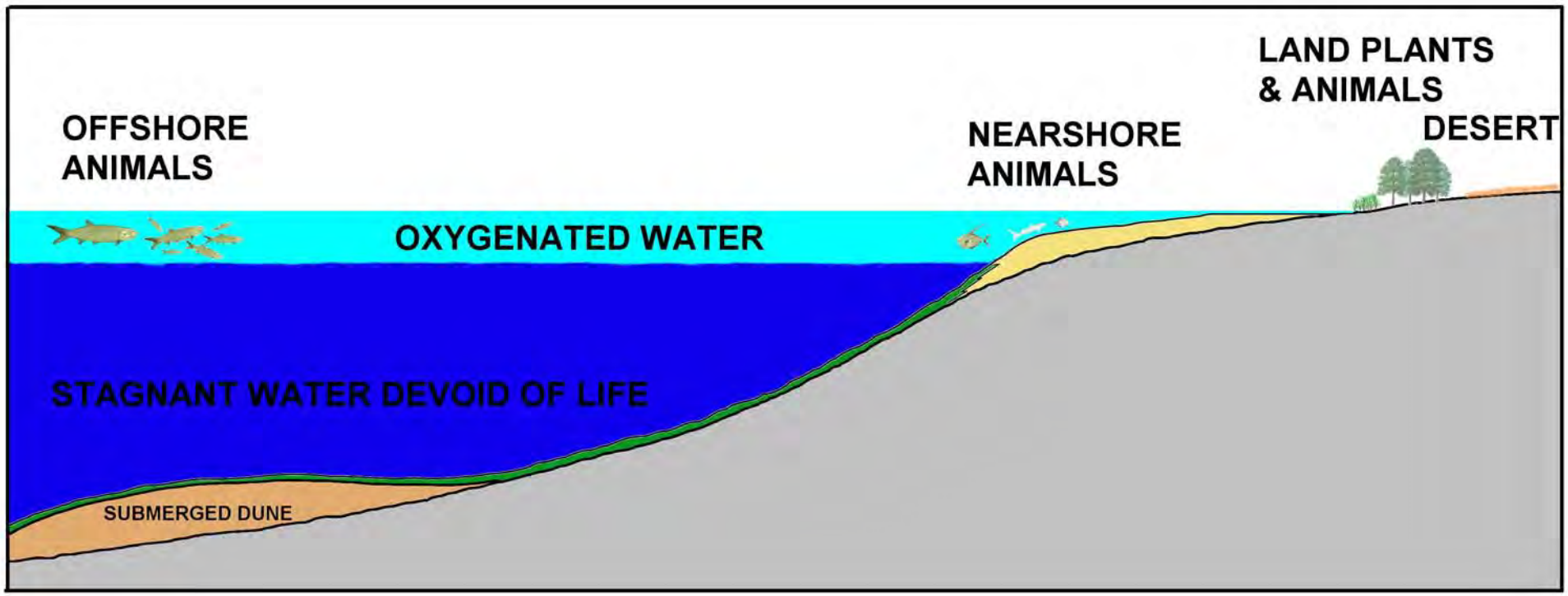
This remarkable specimen shows the body cavity of a ***Pygopterus*** containing the rear part (body and tail) of a ***Palaeoniscum*****.**

OFFSHORE 5

Here is a reconstruction of what life may have been like in the surface waters of the Zechstein Sea with shoals of ***Palaeoniscum*** being pursued by ***Pygopterus*** and other large predacious fish.

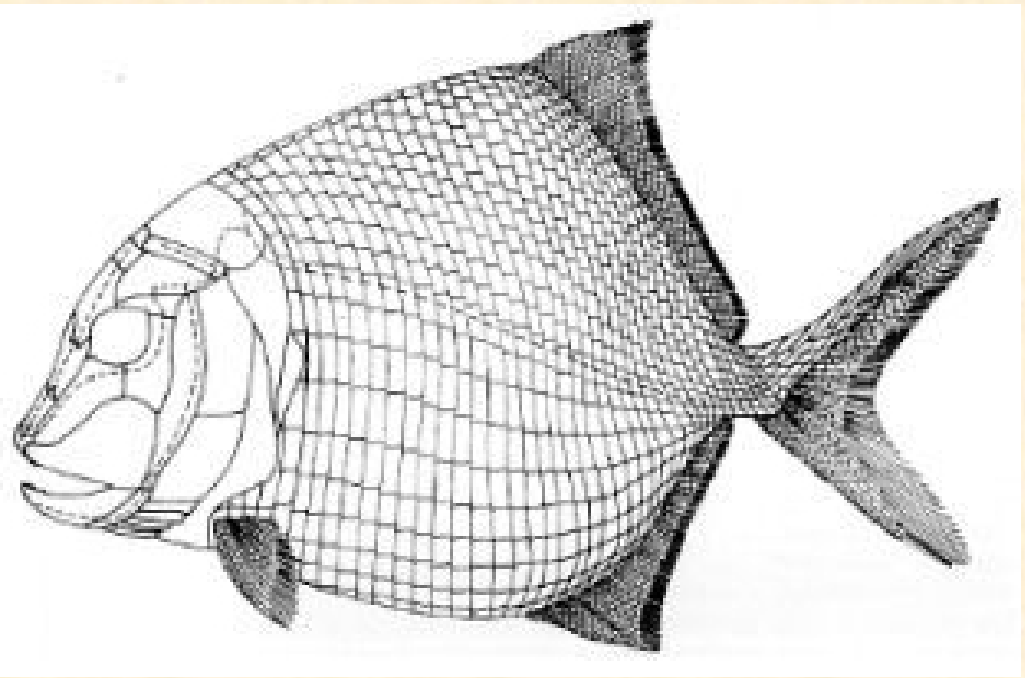


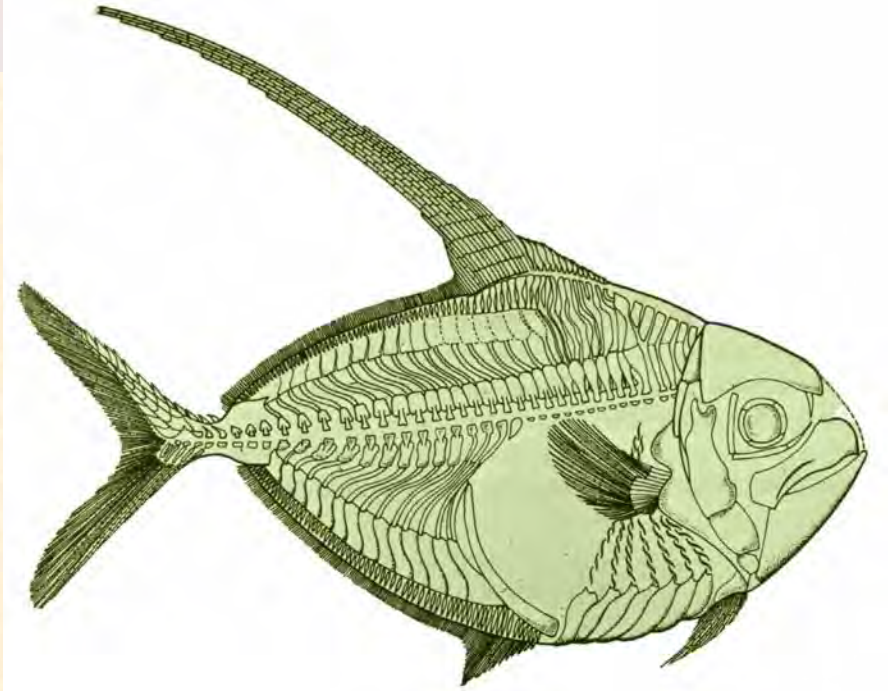
The next few slides look at the fishes living in the **NEAR-SHORE** part of the Zechstein Sea



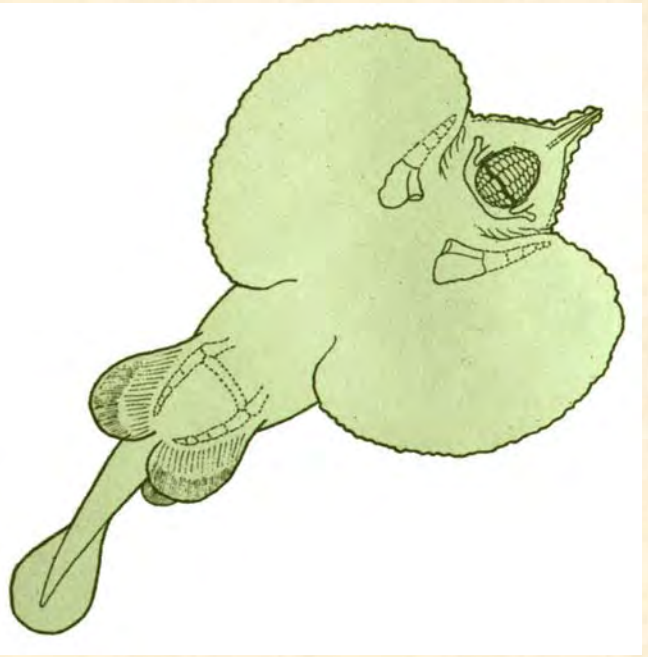
NEAR-SHORE 1

These fossil fish ***Platysomus*** (left) and ***Dorypterus*** (right) lived in the shallow marginal areas of the Zechstein Sea





NEAR-SHORE 2



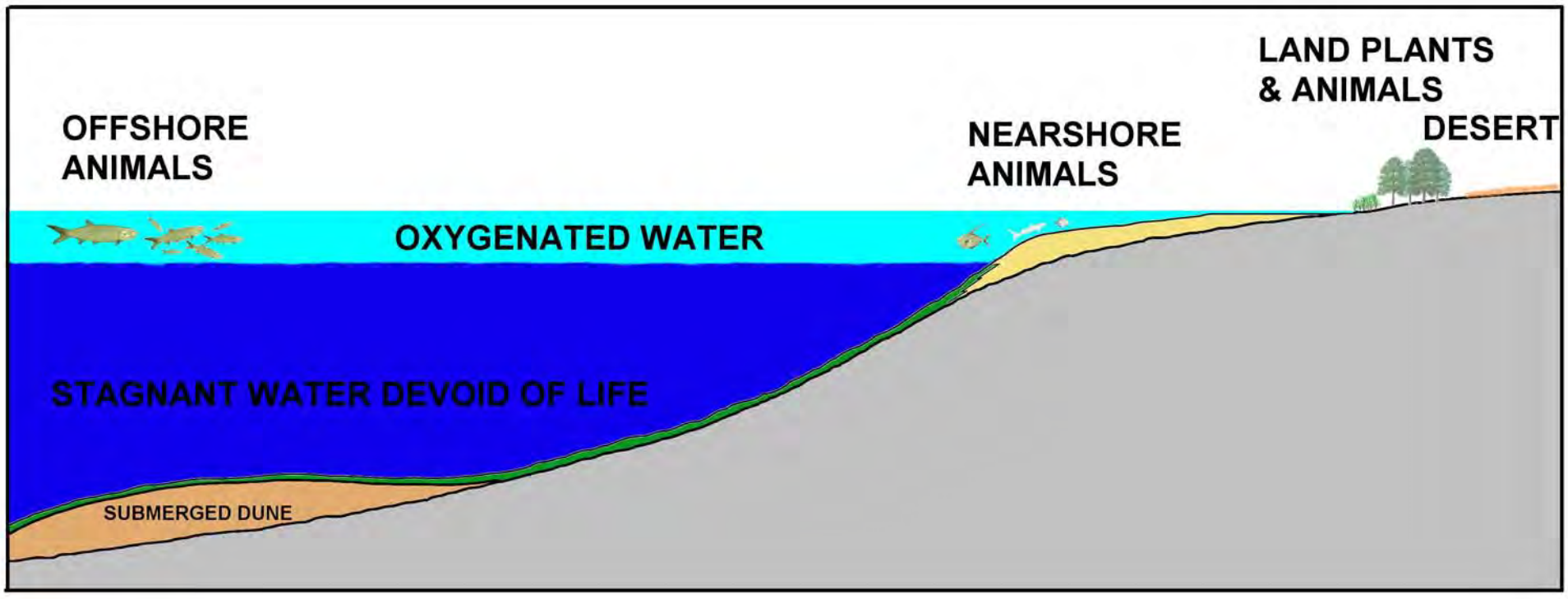
JANASSA BITUMINOSA

A ray-like fish from the Marl Slate which fed on shellfish in the shallow marginal areas of the Zechstein Sea. After death their remains occasionally drifted out before sinking in the deep offshore parts of the Zechstein sea. They are therefore rarer fossils.

NEAR- SHORE 3. Upper and lower jaws with teeth, of ***Janassa bituminosa*** adapted for crushing the shells of invertebrate animals on which this fish fed.

A coprolite (fossilised dung) containing dark scales & bones. Made by one of the fishes living in the Zechstein Sea

The next few slides look at the rarest fossils in the Marl Slate. Those of **LAND PLANTS & ANIMALS** the dead remains of which were only rarely swept into the sea to sink & become fossilised in the Marl Slate.



These terrestrial plants and animals are thought to have lived in a narrow zone between the Zechstein Sea and arid desert.

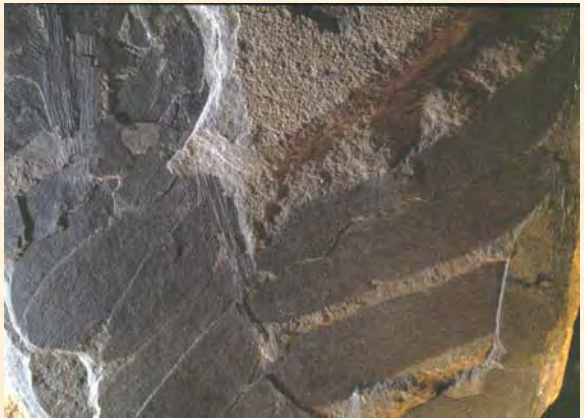
Conifer (*Ullmannia*)

Ginko (*Sphenobaiera*)

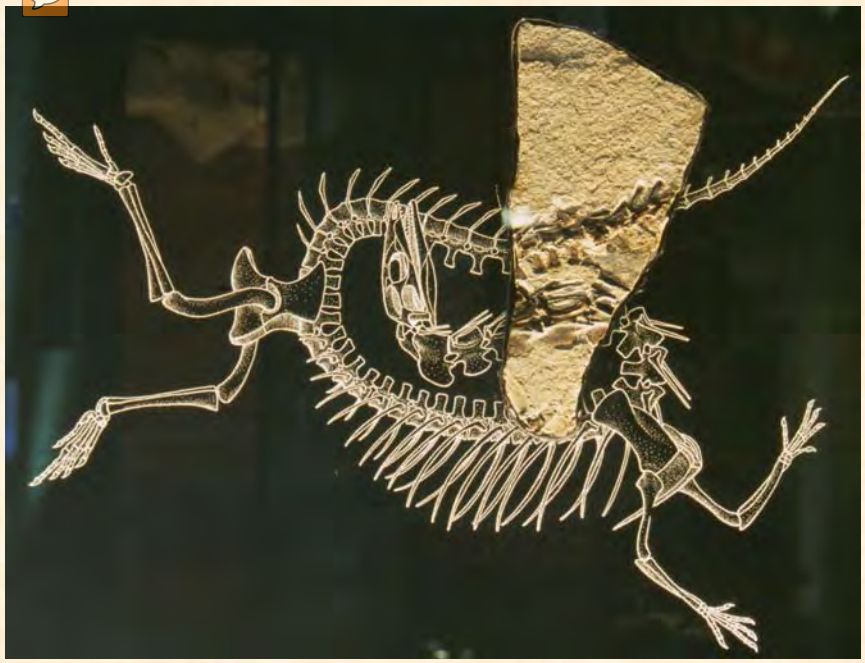
Horse Tail *(Calamites)*

Fern (*Taeniopteris*)

A selection of fossil plants from the Marl Slate. Conifers were the most abundant plants and the thick cuticles on the leaves suggest harsh semi-arid conditions.



Conifer *(Durhamia)*



Protorosaurus a small lizard-like reptile which probably lived amongst the vegetation adjacent to the shoreline of the Zechstein Sea. Known from very rare specimens in the Marl Slate (above) and the German equivalent (Kupferschiefer) rocks.

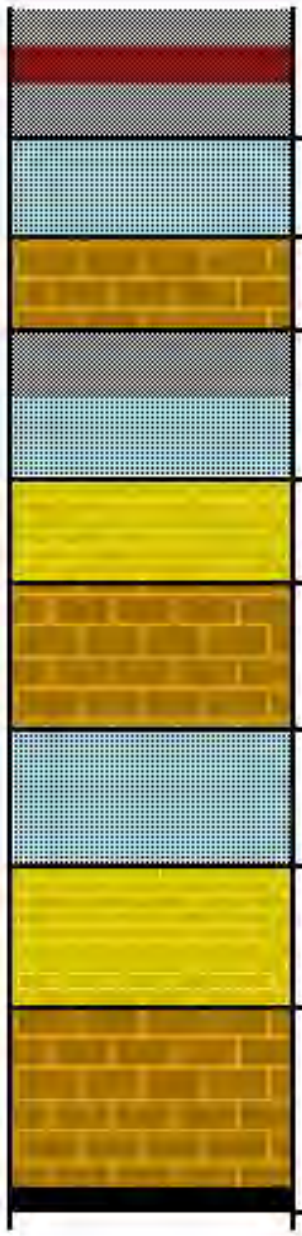
Sunderland Museum specimen, the only one known from the UK.

German Kupferschiefer specimen

Coelurosauravus

The oldest known reptile capable of gliding flight. Discovered in the Marl Slate at Hetton-le-Hole (Sunderland). Also known from fossils in Germany & Madagascar.

THE MAGNESIAN LIMESTONES



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Marl Slate		

MAGNESIAN LIMESTONE EXPOSED AT RAISBY HILL QUARRY

The Marl Slate is overlain by a thick sequence of limestones. Pictured are limestones of the **Raisby Formation** exposed at the type locality of **Raisby Hill Quarry**. The underlying Marl Slate and top of the Yellow Sands are exposed in a cutting on the quarry floor towards the bottom of the photograph.

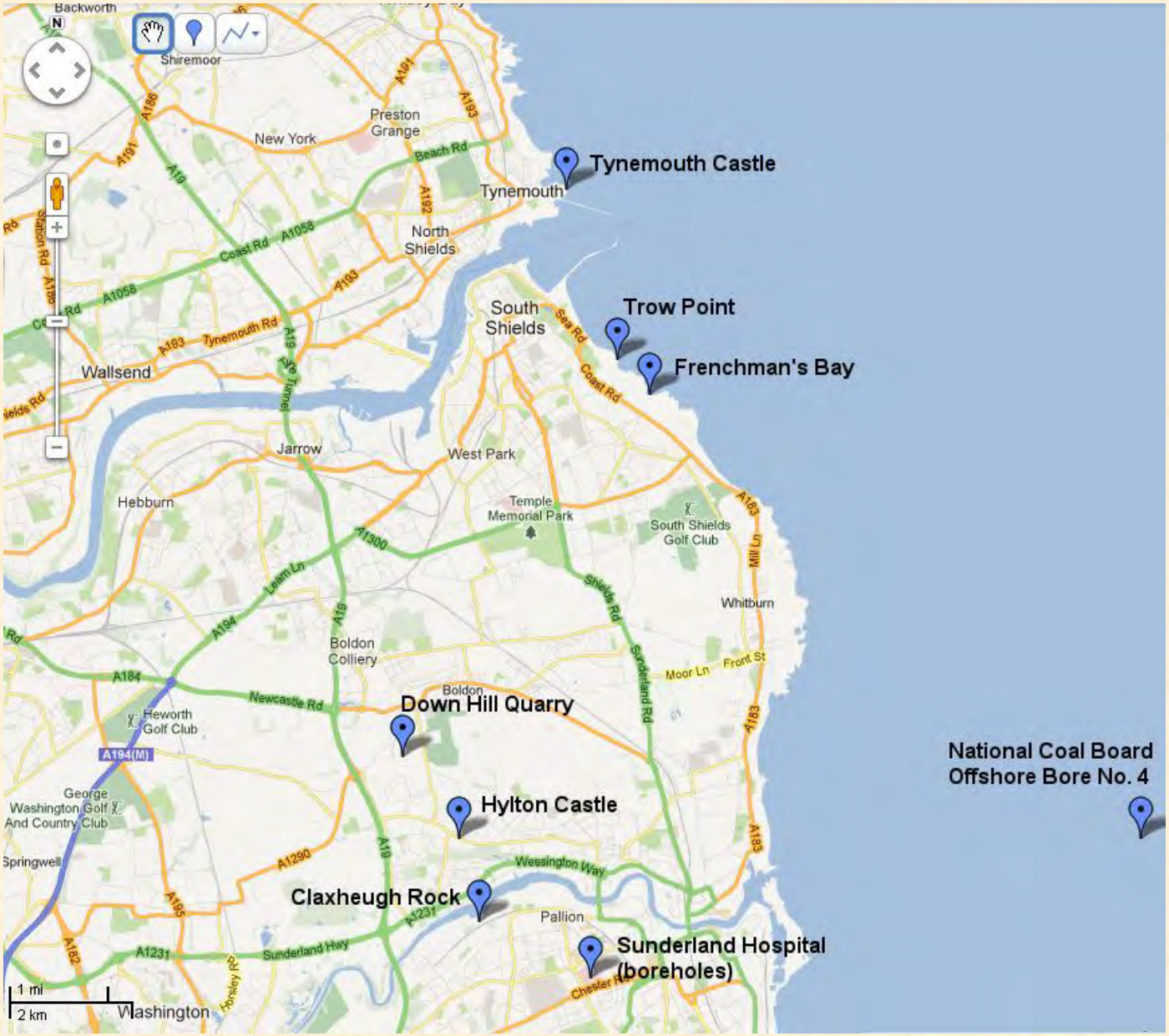
Coastal Cliff Section at Trow Point, South Shields

Later limestones deposited on the sea floor after the 'avalanche'.

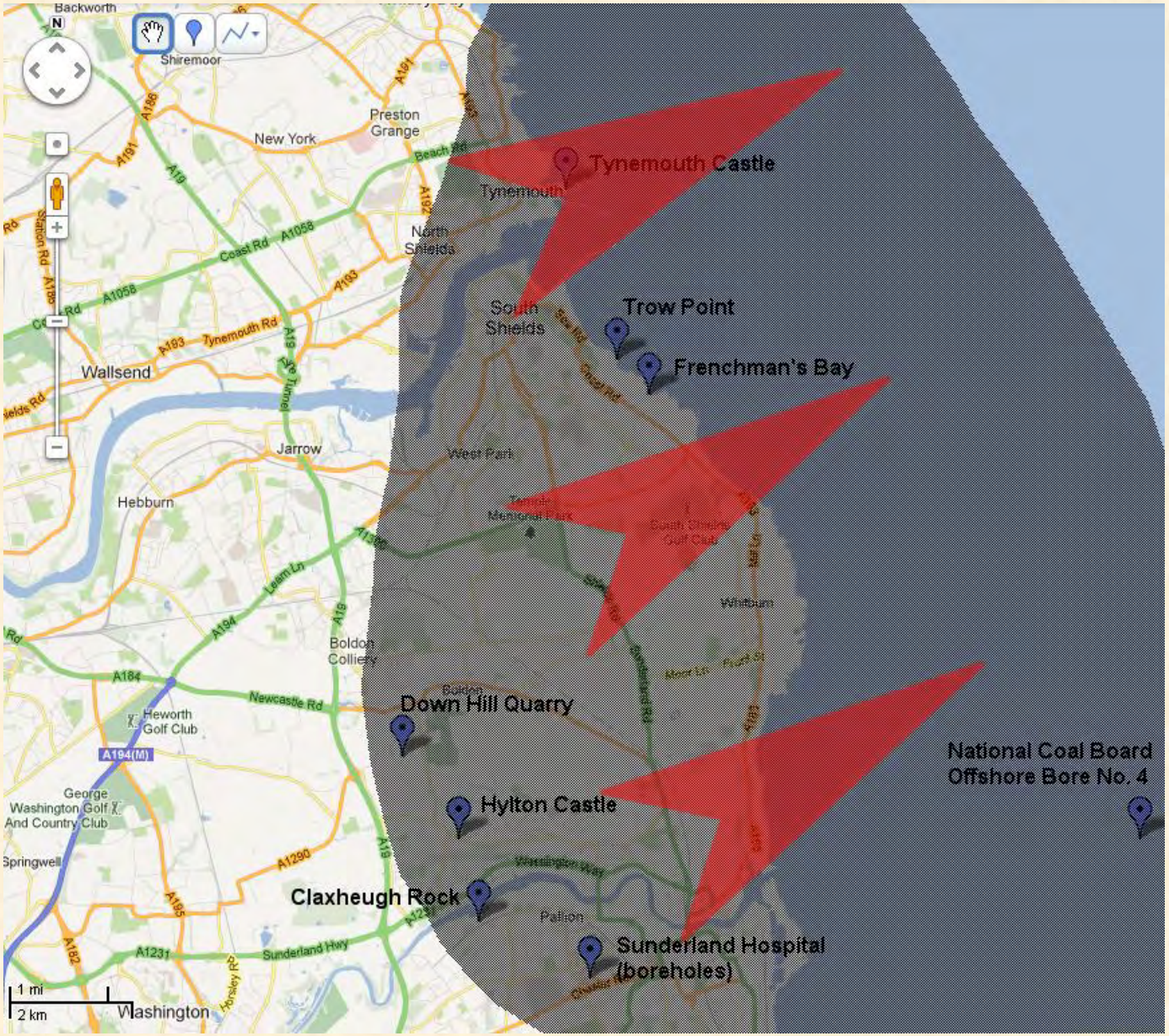
Contorted broken (slumped) blocks of Raisby Formation limestones deposited from a colossal submarine avalanche.

Normally stratified Raisby Formation limestones extending down beneath the sand.

Locations exposing the “Down Hill” Slide



Inferred minimum extent of the ‘Down Hill’ Slide



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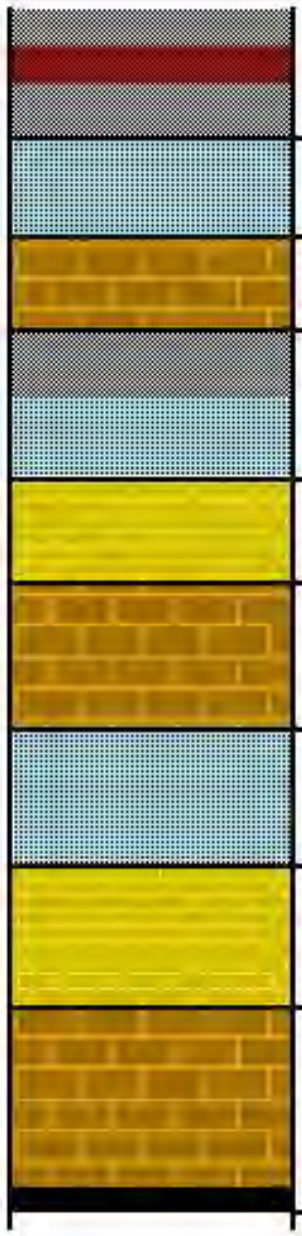

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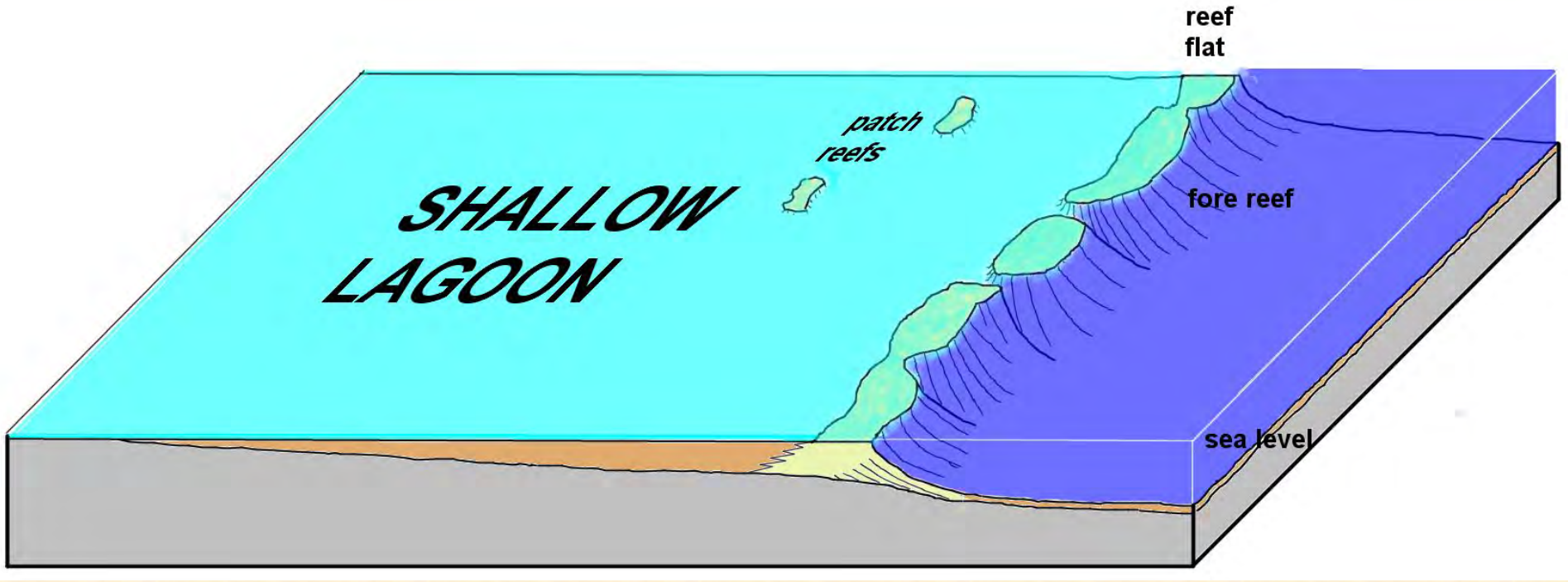
STRUCTURE OF A BARRIER REEF

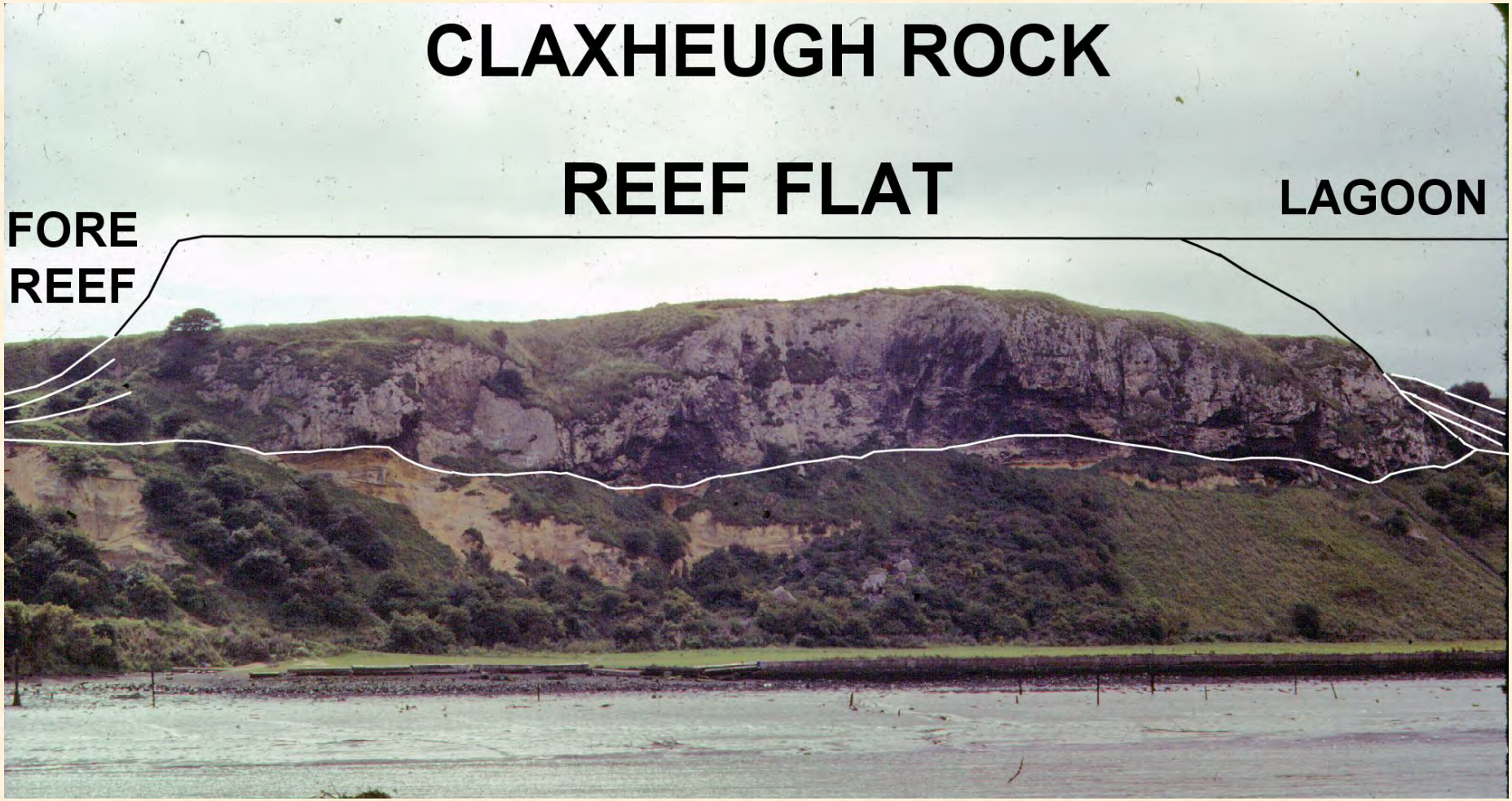
Perhaps one of the best known features of the Durham Magnesian Limestone are the spectacular exposures of a barrier reef which can be traced from Down Hill in the north as far south as Hartlepool.



Here is an idealised cross section of the reef which formed a barrier between the deeper waters of the Zechstein Sea to the east (now beneath the North Sea), and a shallow lagoon which probably extended westwards as far as the Pennines.

THE PERMIAN BARRIER REEF IN DURHAM

An artists impression of what the Zechstein Barrier Reef of Durham may have looked like. The turquoise colours represent the areas of the reef flat and patch reefs whilst to the east, submarine cliffs fall steeply away into the deeper mauve coloured waters of the Zechstein Sea. To the west, shallow water lagoons are represented by pale blue colouration.



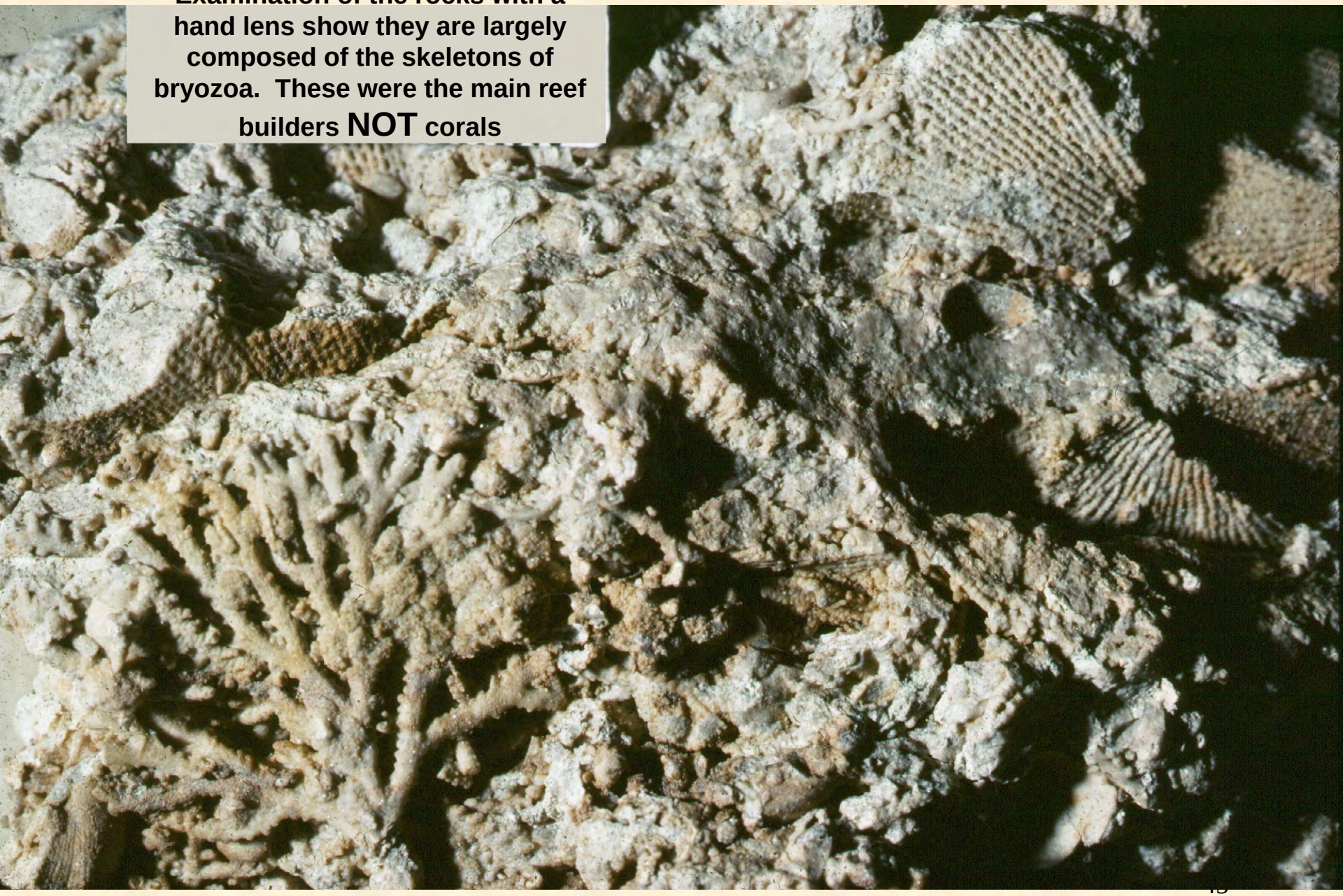
The spectacular exposures at Claxheugh Rock (on the River Wear), show an almost complete east-west cross section through the Magnesian Limestone Barrier Reef.

TUNSTALL HILL

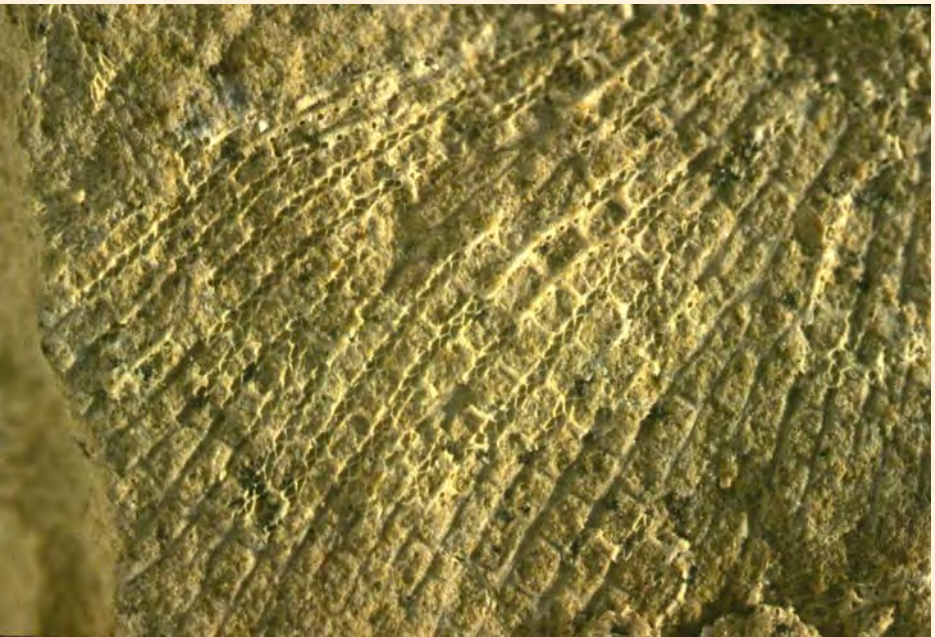
The reef rocks tend to form conspicuous hillocks as here at Tunstall Hill in Sunderland.

The reef rocks are typically unstratified and irregular in form as on this picture on the right.

Examination of the rocks with a hand lens show they are largely composed of the skeletons of bryozoa. These were the main reef builders **NOT** corals



Various Permian bryozoa.

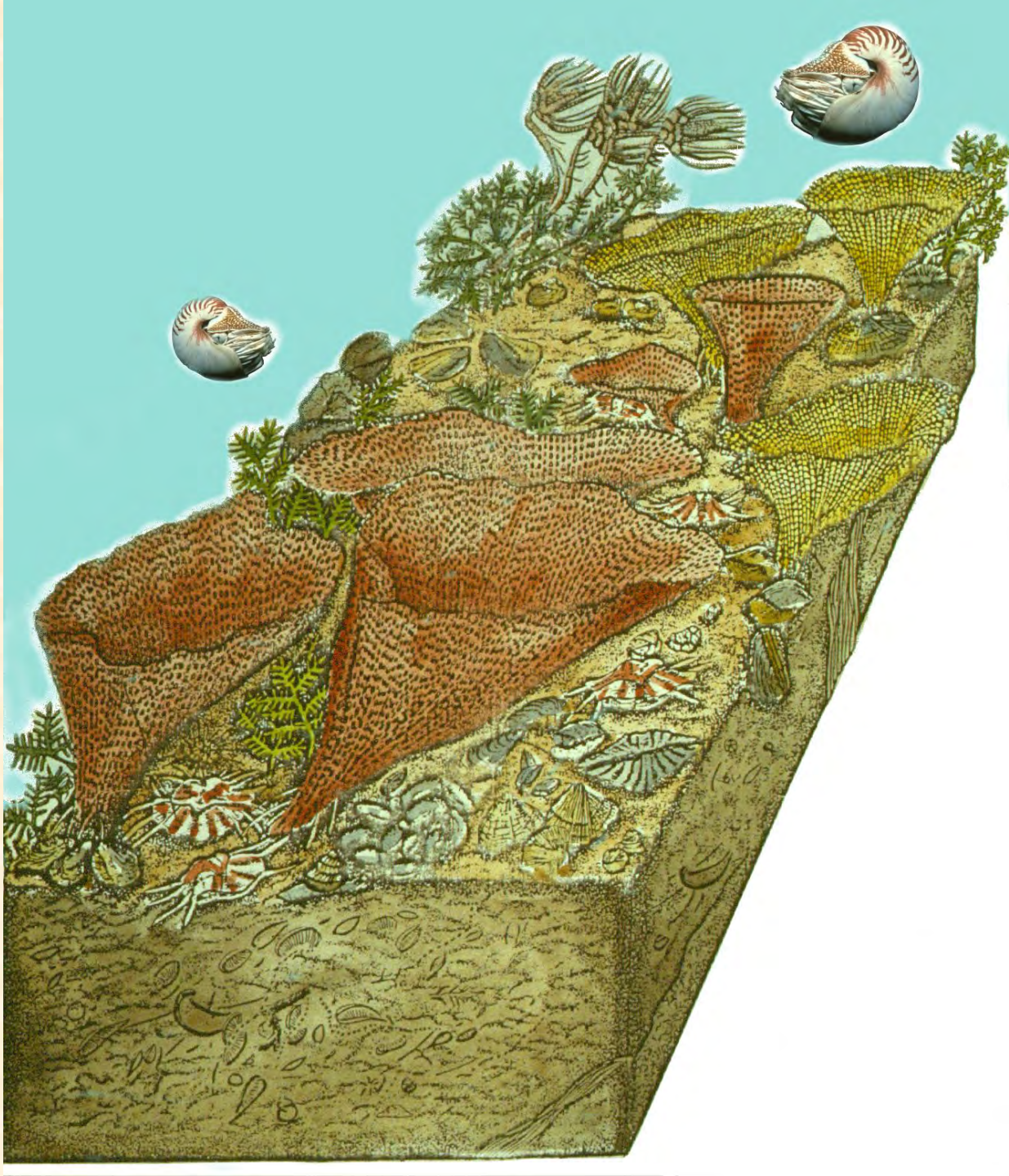


More reef fossils including snail with zig-zag colour banded shell (top right) & sea urchins (bottom photos)

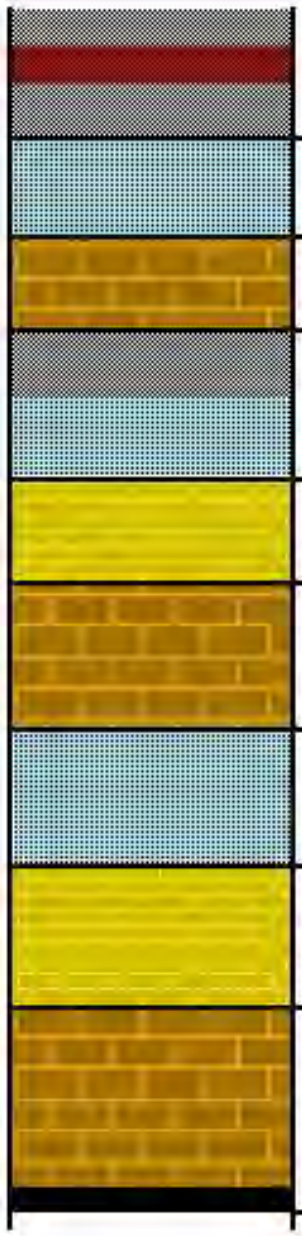
More reef fossils; brachiopods & mussels

More reef fossils. *Peripetoceras*; a fossil nautilus (top left and middle top), a modern nautilus for comparison (top right), and *Permonautilus* (bottom left) a very rare form known from only two specimens in the UK in Sunderland Museum. Complete specimen of *Permonautilus* (bottom right).

Restoration showing what a fore reef community may have looked like on the Durham Magnesian Limestone Barrier Reef



THE MAGNESIAN LIMESTONES



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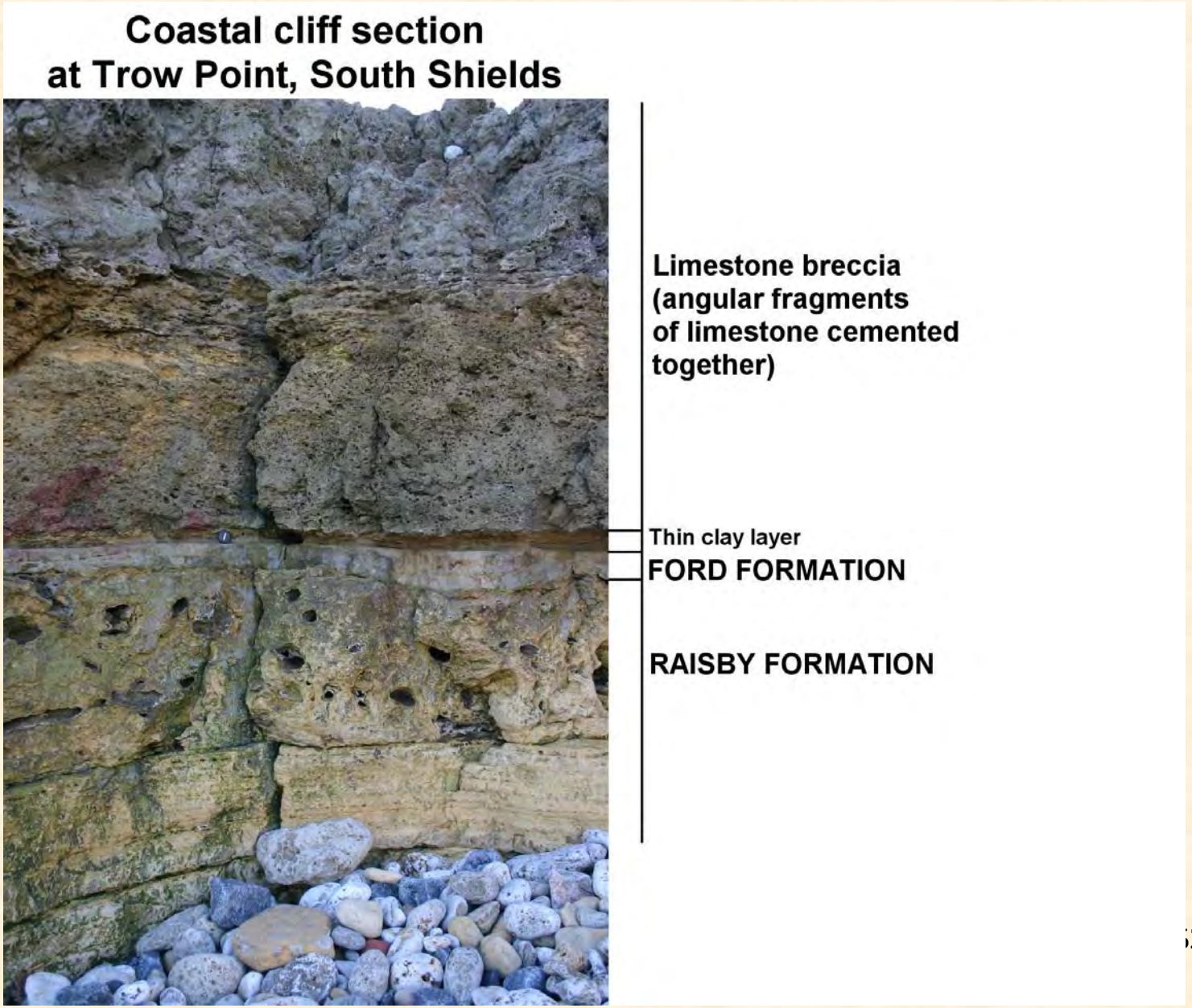
Roker Dolomite Formation Named after Roker, Sunderland.	2nd MAG LIMESTONES	
Concretionary Limestone Formation Well exposed on the coast at South Shields and at Fulwell Quarries, Sunderland		
Hartlepool Anhydrite Formation Named after Hartlepool where it was formerly mined.	1st EVAPORITES	CYCLE 1
Ford Formation Named after Ford Quarry Sunderland, Tyne & Wear	1st MAG LIMESTONES	
Raisby Formation Named after Raisby Quarry Coxhoe, Co Durham		
Marl Slate		

‘SOLUTION’ OF A MYSTERY!

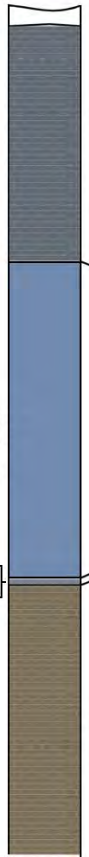


‘SOLUTION’ OF A MYSTERY!

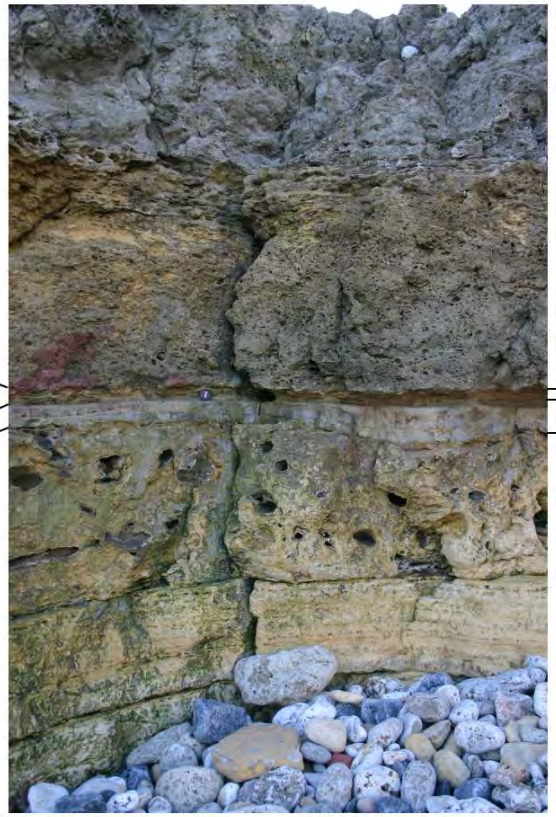
NCB drilling rig "Mr Cap" active in the North Sea a few miles east of the Durham coast in the 1960's

The 'Missing Rock'

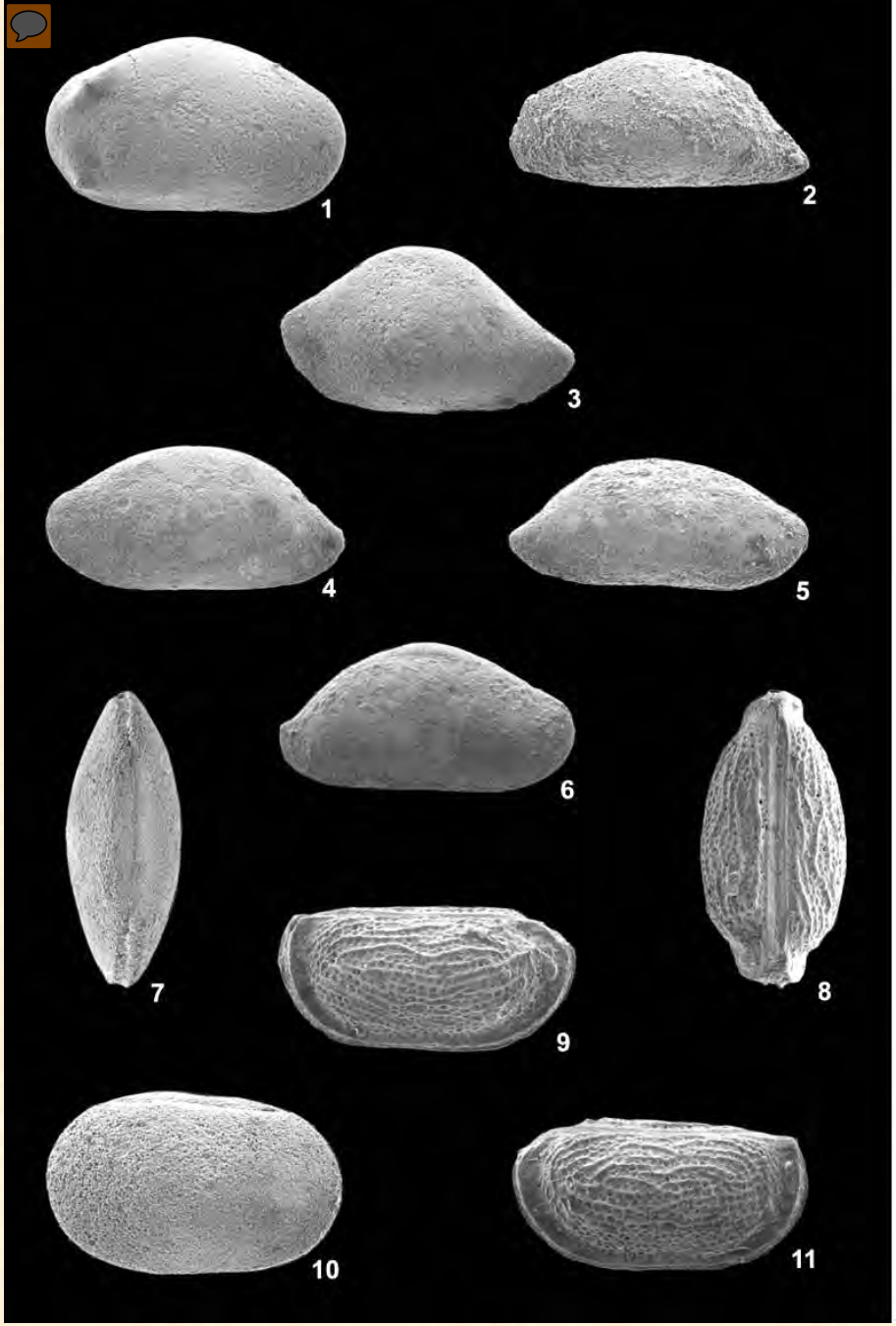
Borehole core of HARTLEPOOL ANHYDRITE made by the drilling rig

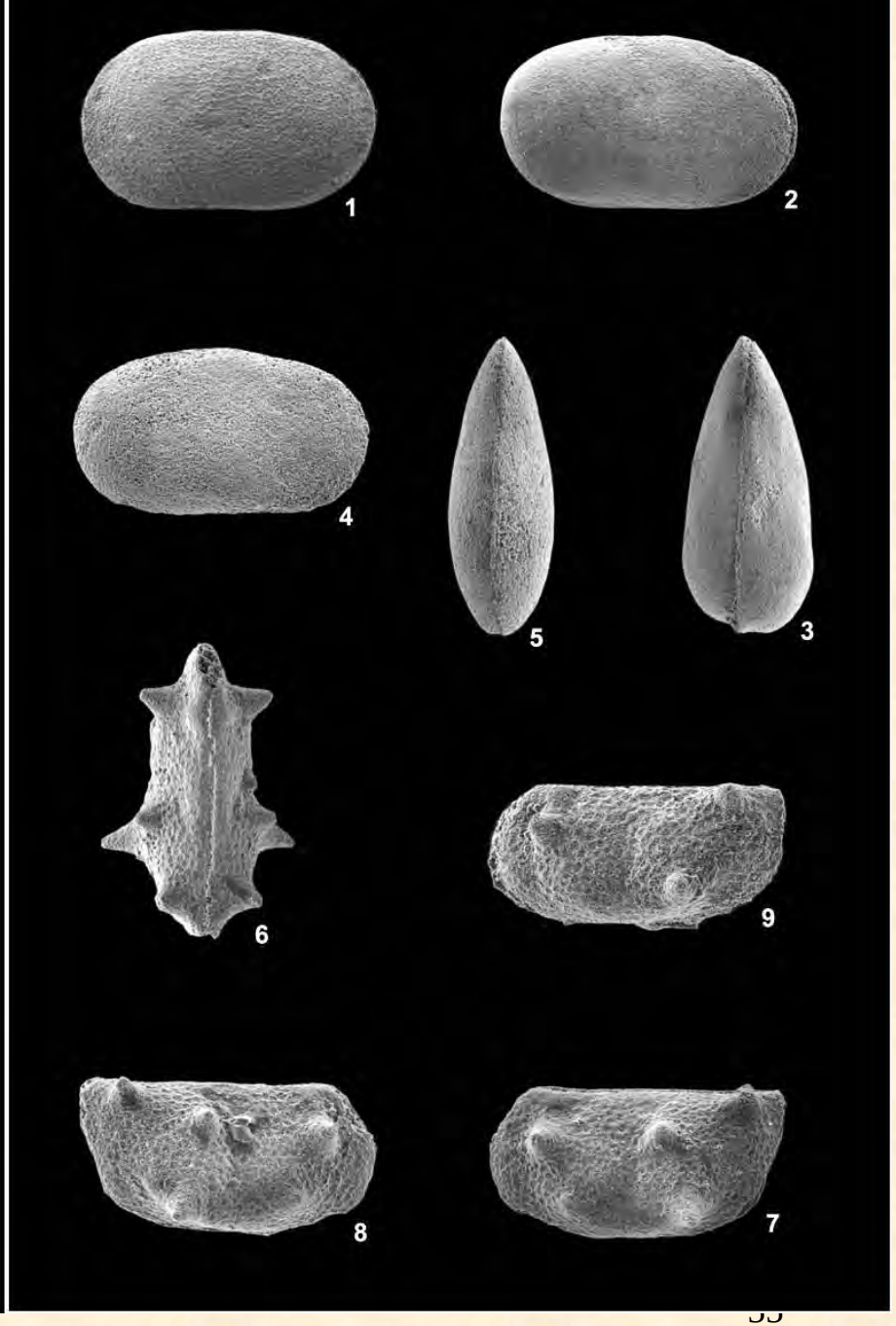


Coastal cliff section at Trow Point, South Shields



The Concretionary Limestone forms the superb coastal scenery between South Shields & Sunderland

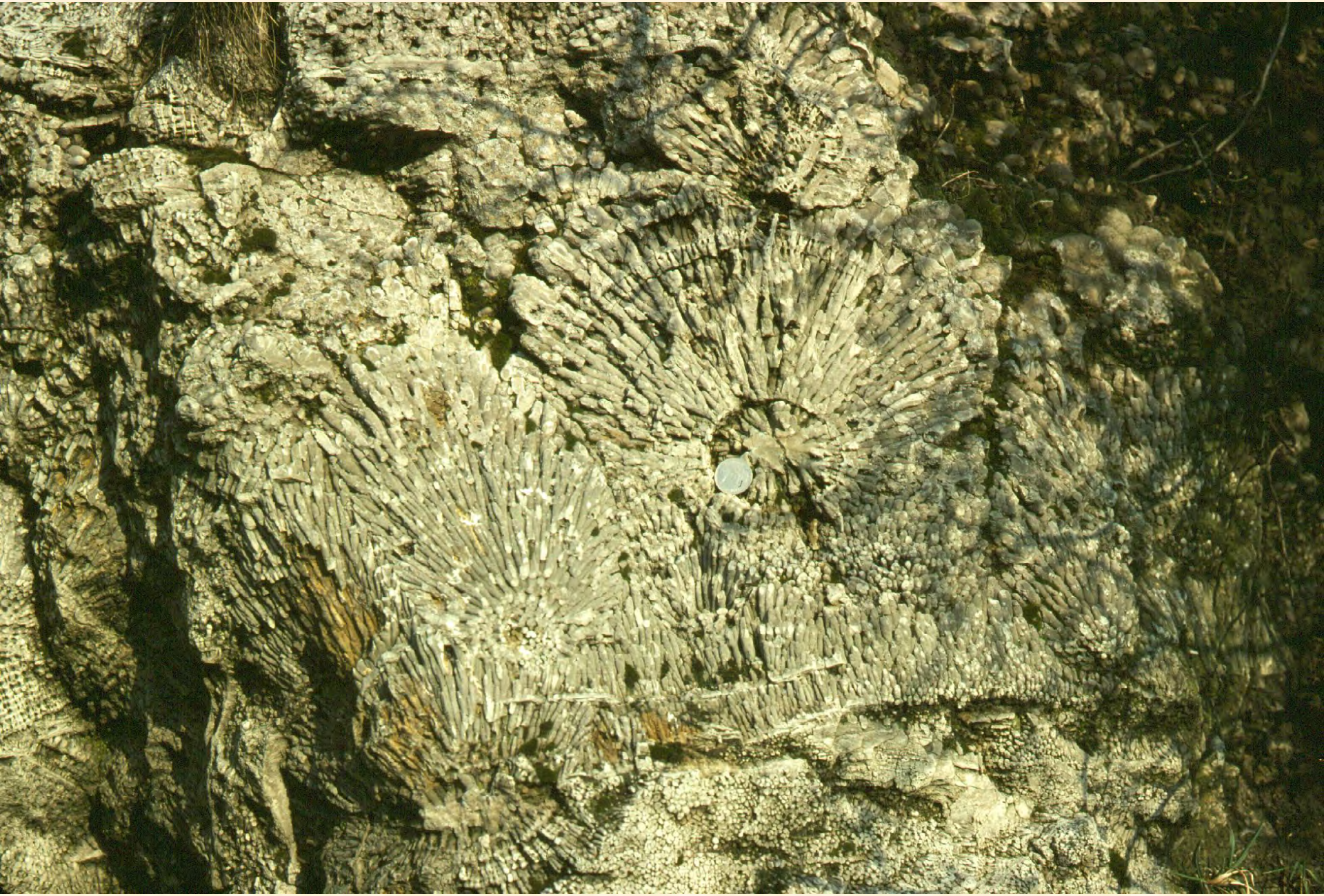




Ostracods; microscopic marine shellfish from the Concretionary Limestone

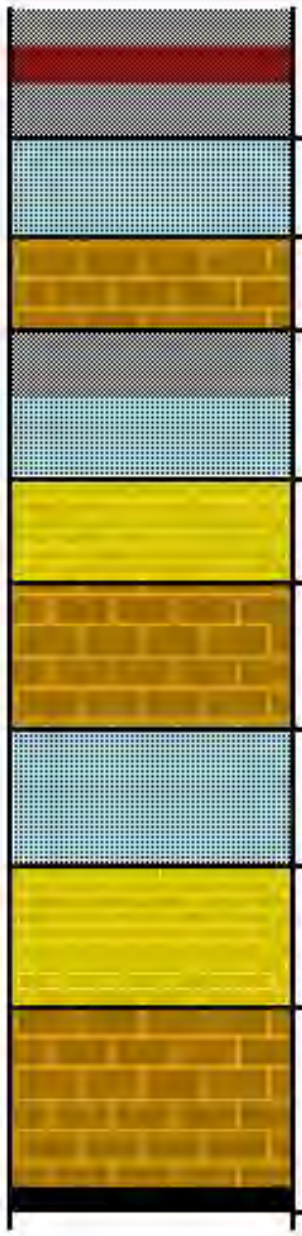
Detail of fossil fish *Acrolepis* from the Concretionary Limestone

This & following pictures show exposures of the Concretionary Limestone at the old complex of quarries at Fulwell & Carley Hill, Sunderland

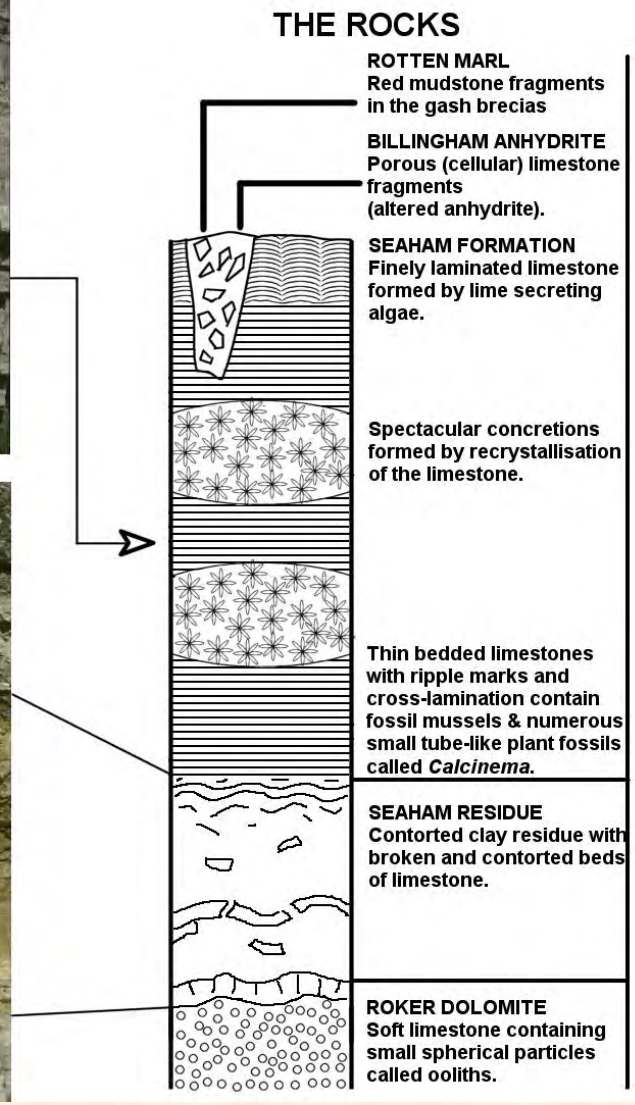



minolta

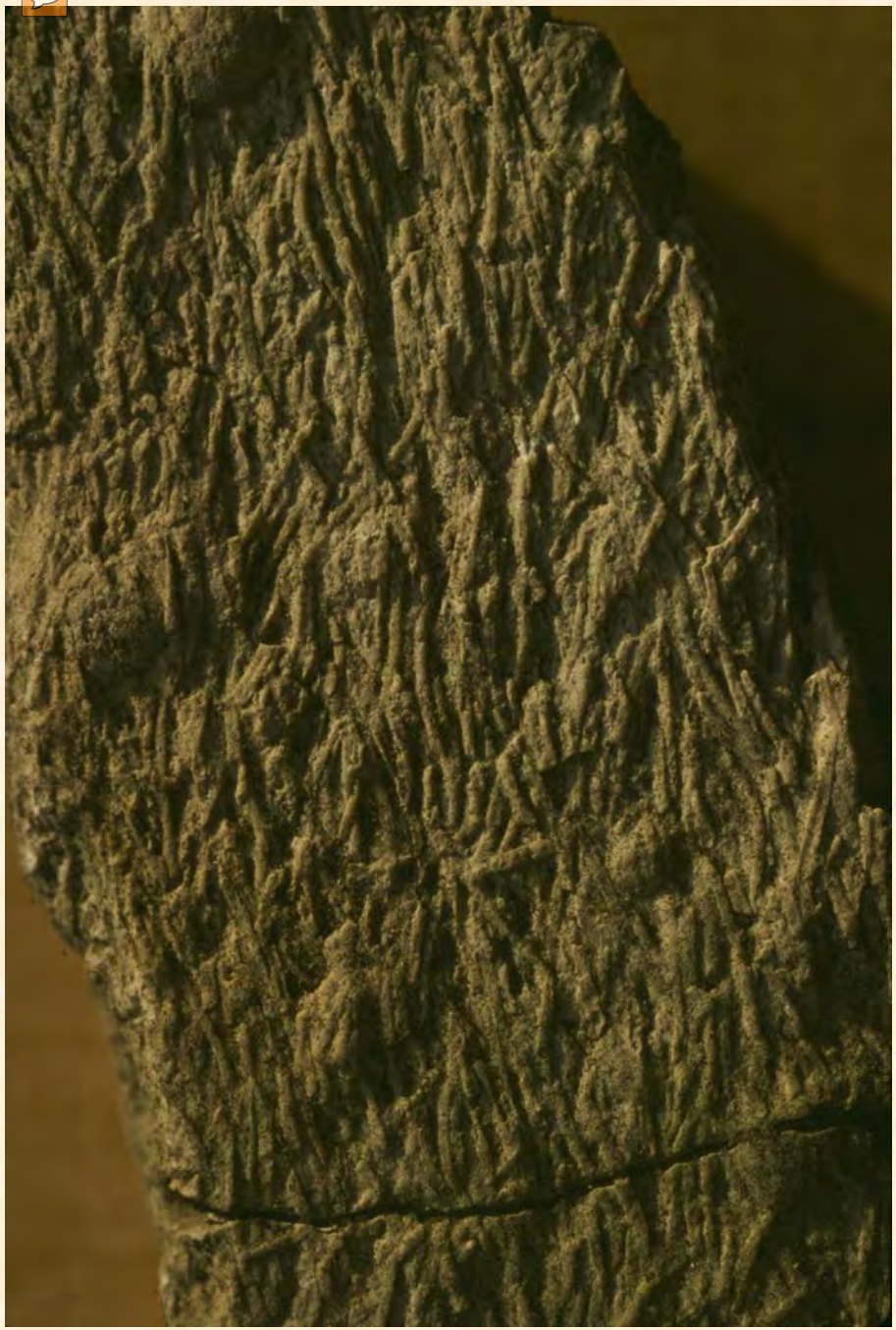
THE MAGNESIAN LIMESTONES



Boulby Halite & Potash Formations Named after Boulby, North Yorkshire where the potash is currently mined.	3rd EVAPORITES	CYCLE 3
Billingham Anhydrite Formation Named after Billingham, where it was formerly mined		
Seaham Formation Named after Seaham, Co. Durham	3rd MAG LIMESTONE	
Fordon Evaporites (Anhydrite & Halite) Named after a borehole at Fordon, North Yorkshire	2nd EVAPORITES	CYCLE 2
Roker Dolomite Formation Named after Roker, Sunderland.	2nd MAG LIMESTONES	
Concretionary Limestone Formation Well exposed on the coast at South Shields and at Fulwell Quarries, Sunderland		
Hartlepool Anhydrite Formation Named after Hartlepool where it was formerly mined.	1st EVAPORITES	CYCLE 1
Ford Formation Named after Ford Quarry Sunderland, Tyne & Wear	1st MAG LIMESTONES	
Raisby Formation Named after Raisby Quarry Coxhoe, Co Durham		
Marl Slate		



Cliff section at Seaham, Co. Durham



Fossils from the Seaham Formation. Mussel shells (above), and numerous small tubes (left), of algae.