DISCOVERY WORKSHEET – HIGH SCHOOL

Version en anglais « pratique du raisonnement scientifique pour résoudre un problème »

Taiaro atoll

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Conception Mobiscience.Briand avec la contribution et traduction de Sandrine Gayrard

Scientific approach
Setting the scene

The atoll formation origin is still debated today. This debate illustrates the development of scientific knowledge over time : in science, no model or truth is set in stone. A scientific theory can always be supplemented, clarified, modified, challenged or confirmed by the scientific community.

You are part of the Taiaro 2023/2024 scientific mission to study the global warming consequences with sea level rise studied by satellite (space altimetry).

Your mission, should you choose to accept it, is to participate in current scientific research.

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MISSION 1
Taiaro discovery and science history

Main issue

After describing the Taiaro atoll characteristics, present a succession of scientific theories explaining how atolls are formed and the arguments used to validate them. Then discuss their validity over time.

Instructions

- Draw a captioned diagram of the Taiaro atoll as seen by satellite.

- Realize a table showing the chronological succession of the atoll formation theories and the corresponding arguments.

- Discuss about the scientific knowledge evolution and its validity over time. Then discuss the likely consequences of rising sea levels on the atolls.

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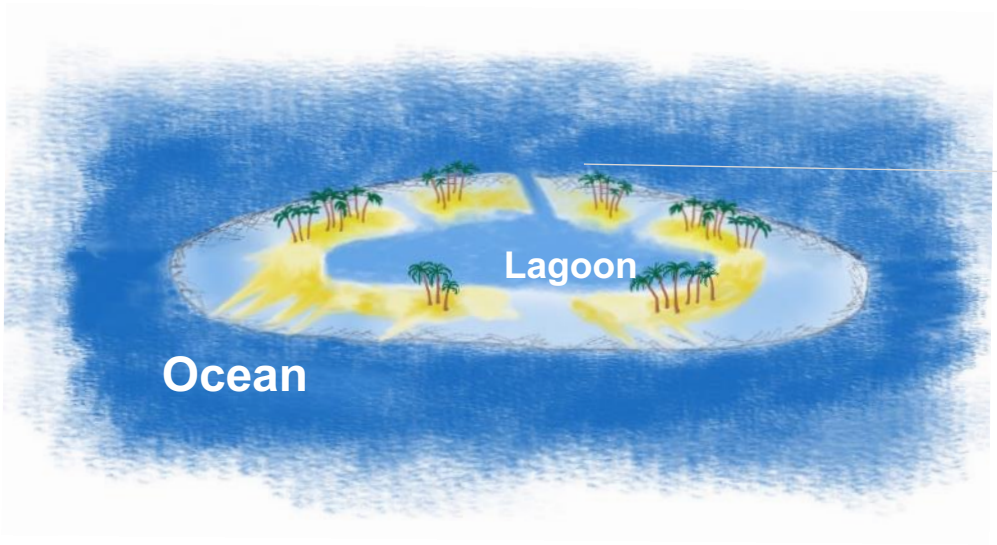
Document 1 Atoll morphology

An atoll is a low ring-shaped island with a lagoon often connected to the ocean by deep and shallow channels allowing permanent or punctual connections with the ocean.

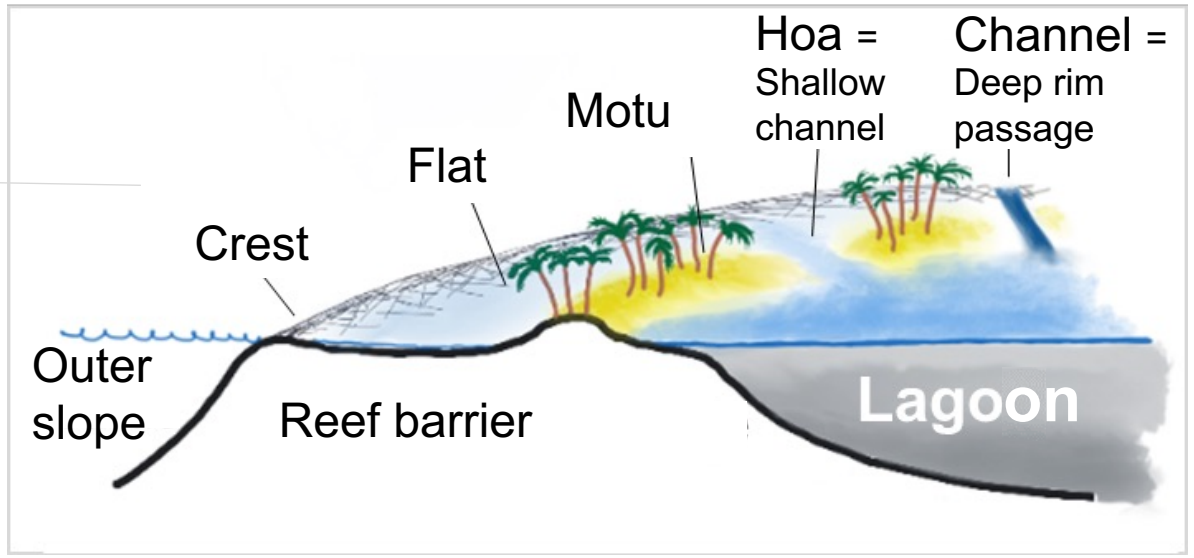
On shallow channels (named hoa in Tahitian language), water flows exclusively from the ocean to the lagoon.

On deep rim passage, water flows from the lagoon to the ocean to evacuate seawater entering through the shallow channels and outcropping flats. In some situations, the water can flow in both directions depending on the tides.

Some higher areas (Motu) are vegetated.



Atoll morphology (diagram)



Atoll cross-section

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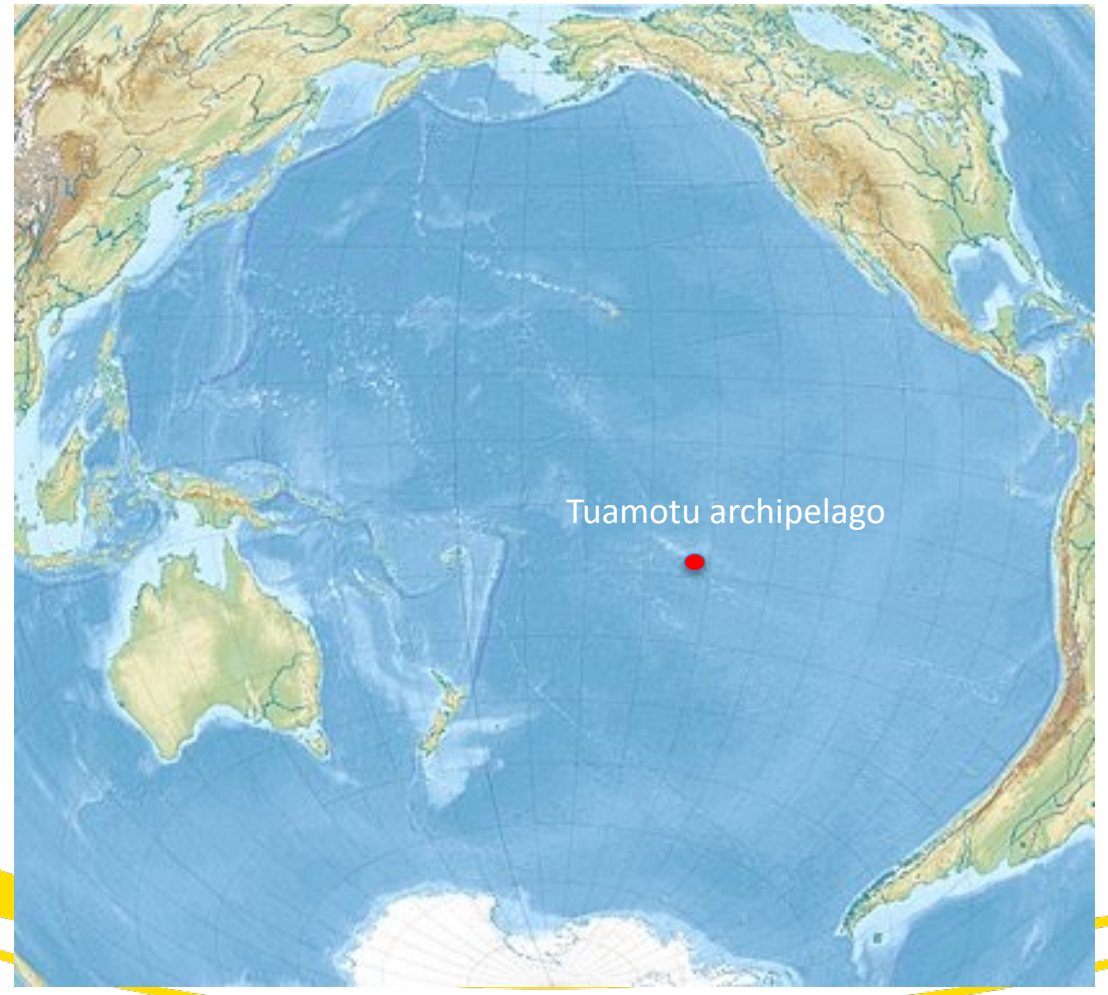
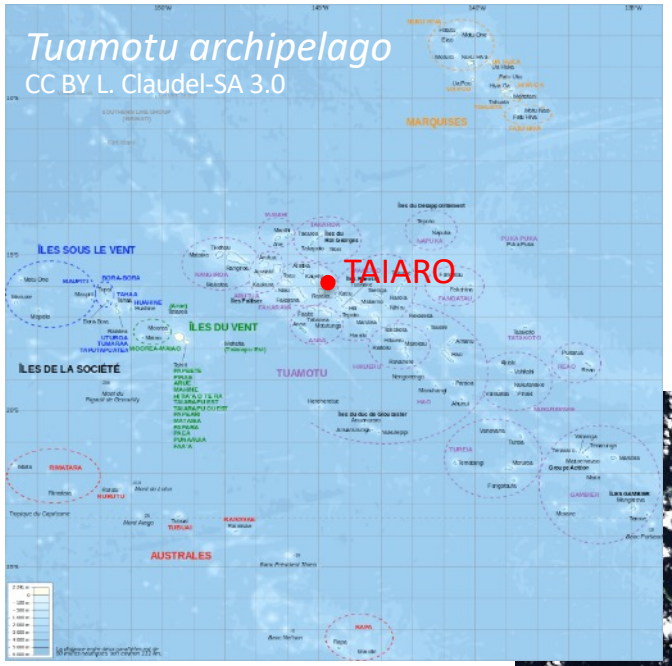
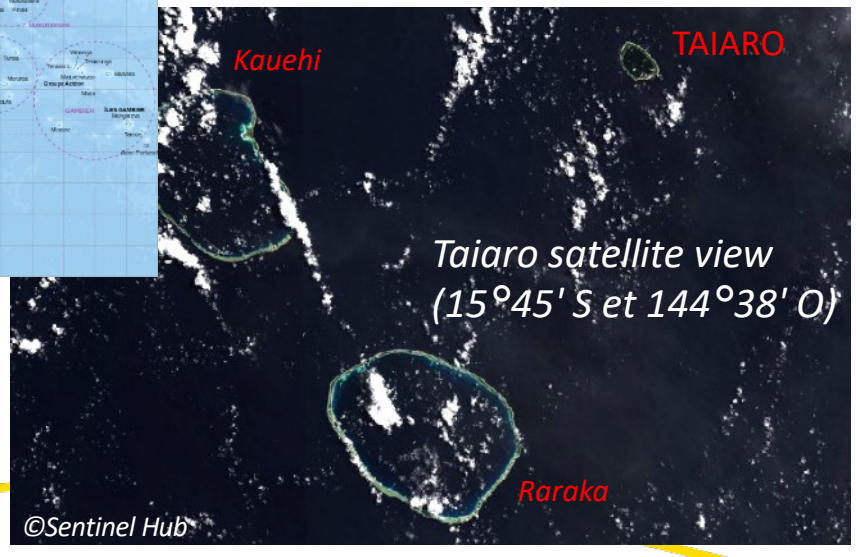
Document 2 Choosing Taiaro
a – Geographical location

There are dozens of isolated atolls in the middle of the Pacific Ocean, all very different in size. Taiaro is in the Tuamotu archipelago, composed of around 80 atolls.







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Document 2 Choosing Taiaro
b – Biosphere reserve

Taiaro was classified as an Integral Scientific Reserve in 1972 and then as a Biosphere Reserve by UNESCO in 1997. In 2006, under the French Polynesia directive, this atoll became part of the Fakarava Biosphere Reserve with 6 other atolls.

In this context, Taiaro has already been the location of former scientific missions. The 1972 mission revealed that Taiaro had undergone a tectonic uplift of 1.3 m 1,000 years ago, which would have disable the hoas…

Atoll characteristics on satellite imageries

Hoas : A shallow depth of water and the bottom appears light-coloured.

Channels : a significant depth appears dark.

Motu : the vegetation appears green.

Taiaro Satellite view: atoll and morphological features

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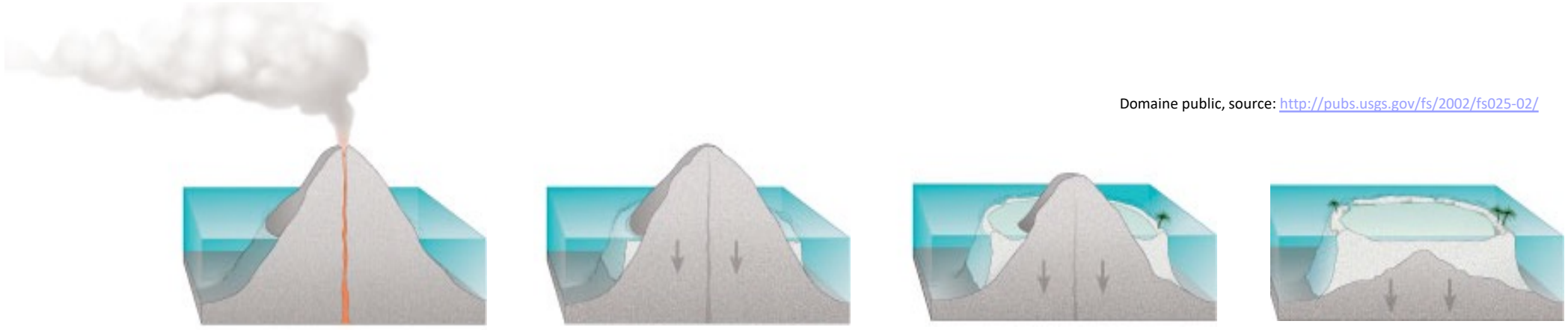
Document 3 Darwin theory

During his voyages aboard the Beagle, the scientific exploration ship, Charles Darwin is fascinated by this kind of island. In 1842, he proposed a model to explain their formation: volcanic islands would gradually sink, while corals would continue to grow towards the surface, a growth area. These corals, secreting a very hard substrate based on calcium carbonate, enable the buiding of a raised "barrier" at the edge of the atoll. Once the island has sunk, the coral reef maintains an atoll with a lagoon at its center. The coral supports a rich ecosystem development, providing food and protection for numerous marine animals.



Domaine public, source: http://pubs.usgs.gov/fs/2002/fs025-02/

Atoll formation according to Darwin (diagrams)
A sinking volcanic island is surrounded by a fringing reef, which eventually becomes a barrier reef protecting the atoll lagoon.

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Document 4 The "hot-spot" model

In the 1960s, as part of the plate tectonics theory, the "hot spot" model proposed that volcanic islands, built in depth on a fixed hot spot, move with the lithosphere, following its sinking as it cools with age.

(1) Subaerial step – shield volcano construction (2) fringing reef step – lithospheric collapse (3) raised fringing reef – lithospheric bulging (4) Barrier reef (5) almost atoll (6) atoll (7) raised atoll – asthenospheric bulging (8) sunken atoll (9) guyot (Scott et Rotondo, 1983, in Guilcher, 1988)

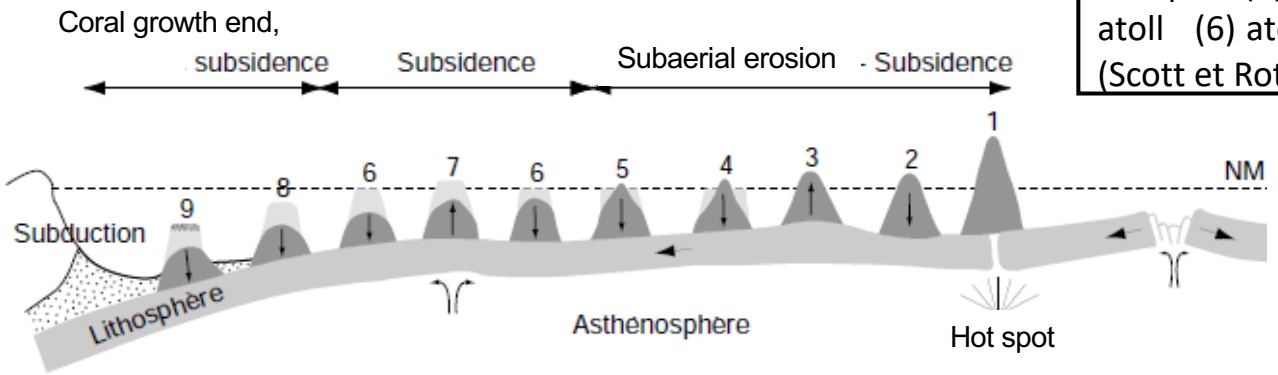

Image DR - Caroline Rufin-Soler. Evolutions environnementales des littoraux des atolls coralliens dans les océans Indien et Pacifique : le cas des archipels Maldivien et Tuvaluan. Océan, Atmosphère. Université de Bretagne occidentale - Brest, 2004.

At the end of the 20th century, improved technologies revealed the structure, nature and age of the deep rocks within the coral edifices. Boreholes often several hundred meters deep, from the atoll surface to the top of sunken volcanoes, revealed carbonate and reef formations at the volcanoes summit.

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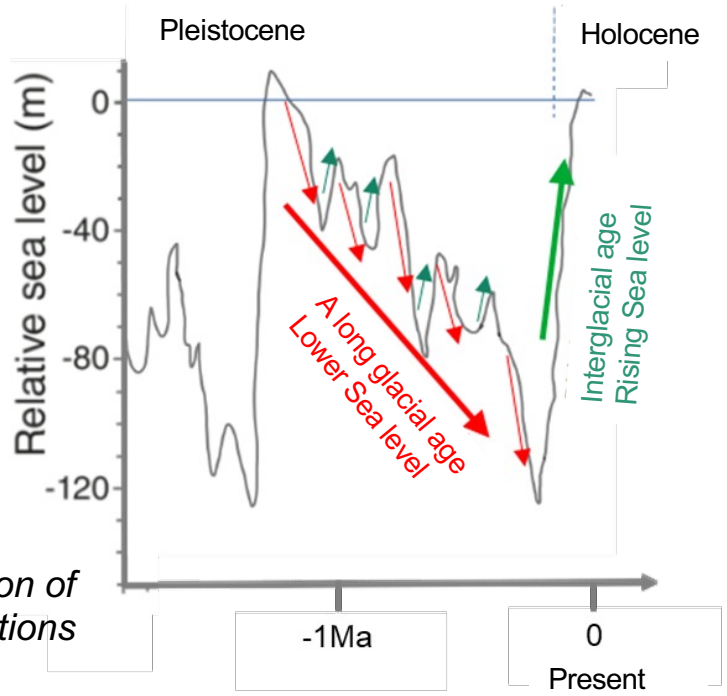
Document 5 Climatic variations and sedimentation

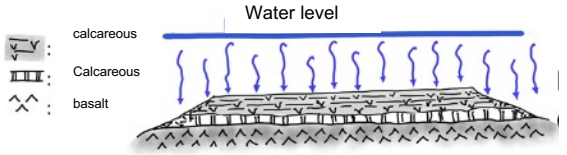
The ice ages theory, formulated in 1840, was validated at the end of the 19th century. It shows past climatic variations that led to changes in sea level: in high temperature periods, melting continental ice and dilating water raise sea level, while in glaciation periods, progressive ice thickening and the water cooling leads to lower sea level.

In the 20th century, this knowledge is enhanced by modern technologies. Boreholes, carbon-14 dating and seismic reflection profiles beneath the atolls show that ancient sedimentary series were formed under variable water depths and are separated by discontinuities (erosion surfaces).



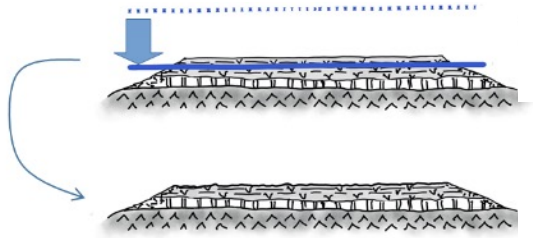
Sea level and sedimentation as a function of climatic variations

Interglacial period (warm) : high water level



calcareous deposit

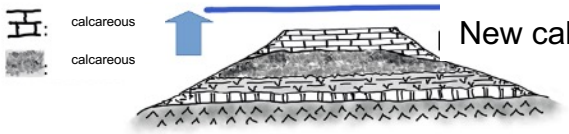
Glacial period (cold) : lower water level



Land surface erosion

Surface discontinuity

Interglacial period (warm) : high water level



New calcareous deposit

illustration Mobiscience.Brian

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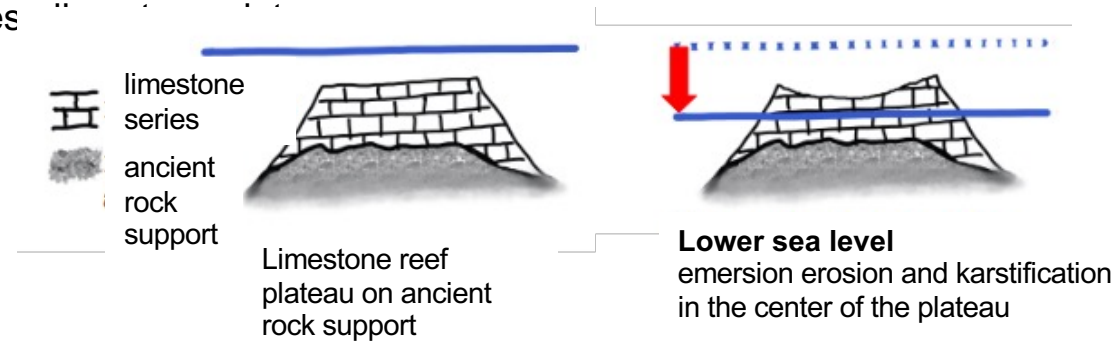
Document 6 « Karts » theory

Since 1930, the "karst" theory is developed: the atolls observed today were formed not on the tops of volcanoes, but on carbonate platforms that would have undergone significant dissolution during emersion. This karstification, caused by the acid rainwater action, would have been accentuated in the limestone central part. This theory was argued by :

At the and of the Tertiary period, thick limestone reef plateau may have formed above the deep sea during a warm period when sea levels were very high. Successive glacial episodes during the Quaternary may have led to emersion, erosion and karstification of thes



At the end of the Quaternary period, the sea level rise of 1 to 4 cm.yr-1 was compatible with continued coral growth and the reef structures maintaining

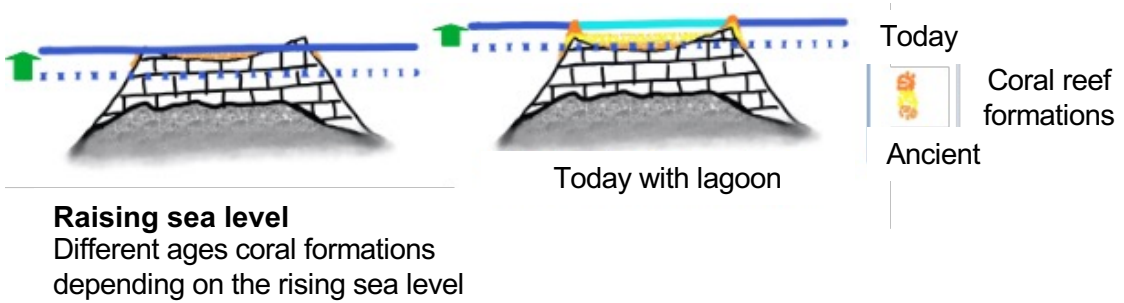


illustration Mobiscience.Briand

The today's atolls construction is therefore recent on a geological scale, It began during the last glacial cycle. Most atolls would have developed on karstified limestone, rather than directly on volcanic bedrock.

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