Tahiti: the study of fossil reefs as a way to determine the evolution of the sea level in the last 14 000 years

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ABSTRACT
Coral reefs are biological constructions built from elements dissolved in sea water. This mechanism needs a symbiosis between colonial animals and algae; then, a reef is formed by precipitation of calcium carbonate (CaCO$_3$). This structure evolves with the variations in the sea level. Thus, the curve illustrating the rise of the sea level can be inferred by measuring the reef growth. Given that the deepest drillholes reach 90m and, taking into account the subsidence phenomenon corresponding to the natural sinking of the island of Tahiti, we can determine the rise in sea level. Thus, in 14000 years, a rise in the sea level of more than 70 meters can be observed.

Keywords
Coral, Tahiti, sea level elevation

1. CORAL REEFS
Coral reefs are formed by symbiosis between cnidarians - colonies of individuals similar to jellyfish known as polyps - that draw elements dissolved in the ocean (calcium, magnesium, strontium ...) and green single-celled algae called zooxanthellae. There are several exchanges between these two symbionts (polyps provide CO2, phosphates and aminoacids to the zooxanthelles which through photosynthesis use them to produce sugar which is the polyps’ main source of energy). These exchanges cause the precipitation of calcium carbonate (CaCO$_3$) which is the basis of the coral reef skeleton. Other algae fill up the empty spaces and ensure a better cohesion of the coral stabilizing the reef structure (Figure 1). Coral growth depends on several environmental factors which are:
- Salinity of the water: Indeed, reef channels are located opposite to rivermouths where sea water is more diluted and where the alluvium present particularly during rainy periods, prevent a proper coral development.
- Temperature: The ideal for development is between 25 and 29°C. In Tahiti it varies between 24 and 29°C.
- Solutions: Corals need a large amount of dioxygen which is found in clear and shallow water.

- Water level: the upward growth of corals stops at the low tide level except for Porites and Platygyra, which produce mucus to protect themselves from dehydration.

Thus, we can determine the level of the sea at different periods through the study of coral reefs.

Figure 1 : Reef profile

2. DRILLINGS IN TAHITI
Drilling place: The choice of Tahiti as the place to observe and extract fossil coral was due to the fact of it being an area of the Pacific which is tectonically stable and where the remaining coral in the warm ocean waters are very demanding ecologically and particularly sensitive to any environmental change. Therefore, they are excellent recorders of past changes of the sea level and climate (Figure 2). In 2002, drillings were conducted on the Papeete coral reef among which drillholes P6 and P7 located at a distance of 700m from each other: a first drillhole called P6, reaching 50 m. and a second drilling, called P7. Uranium 234/thoriumm 230 dating has been used to date the different coral reefs.

The results obtained are presented on a graph « y function of x » in which the curve represents the reef growth in terms of time (Figure 3). Thus, we notice that between 6 000 and 14 000 years, the growth of the Tahitian coral reef has greatly increased (from 7 m to 85 m in 8 000 years, so a 12% increase in the sea level)
3. CORAL REEF GROWTH CURB

The study of algae-coral associations makes it possible to deduce the sea level at a given period. The presence of different types of algae and corals depends on the depth of the water. Thus, by determining the types of algae and corals present, we can deduce the height of the reef according to the sea level within a 5-meter precision range. We can therefore obtain the rising curb of the sea level.

The figure 3 shows us the variations of the sea level, as deduced from the growth of the Tahitian coral reef from 14,000 BP to 3,000 BP. Drillings indicate that associations dated 14,000 BP are located 85 meters underwater while those dated 3,000 BP can be found 2 meters underwater, which gives us an 83-meter rise of the sea level in 11,000 BP.

4. SUBSIDENCE

French Polynesia was formed thanks to several hot spots. Those volcanic islands were then subjected to tectonic moves which took them away from the hot spot. During the journey, the ocean floor happened to cool down so that its density increased. As a consequence, Tahiti sinks into the asthenosphere at a rhythm of 0.7 mm per year: that’s what’s called the subsidence phenomenon.

Nevertheless, subsidence cannot account for the variation of the sea level in Tahiti because it has sunk by 9.8 meters in 14,000 years, while the rise of the sea level measured over that period is 85 meters. (see reef growth curb).

The rise of the sea level is due to the increasing volume of water disposable (Figure 4).
5. COMPARISON WITH OTHER ISLANDS

Sea level variation curbs have been reconstituted in other parts of the world where similar studies have been led. Thus, in Barbados and New-Guinea can be found a similar variation, although they are geographically apart (Figure 5). That thus demonstrates a sea level rise of 75 meters worldwide in the past 14,000 years.

6. POSSIBLE ORIGINS OF THE RISE OF THE SEA LEVEL

Ocean ridges activity plays a part in the rise of the sea level. Indeed, when they are very active, their volume increases and generates a rise of the sea level. But that is not the case at the moment. When the temperature rises, the density of the water decreases and consequently, the volume of the water increases: this is called the thermal dilatation of the water. Though a rise of the air temperature all around the globe is undeniable, it is not sufficient to cause a rise of the sea level such as has been measured. The rise of the air temperature on earth causes the melt of the ice cap. Although the ice cap is melting at a fast pace, it does not influence the level of the sea (Archimedes' principle).

The major ice caps are the continental ice caps, whose total volume is estimated at slightly more than 30 million cubic kilometers, mainly spread in the Antarctica. Antarctica: 29 million km³, Greenland: 2.5 million km³, other ice cap: 0.2 million km³.

If the continental ice caps melted, there would be a global rise of 84 meters of the sea level. The oceans' surface represents about 70% of the surface of the earth (6,370 km radius, that is to say a total surface of 4x...= 510 million km²), that is to say 357 million km³ of water. Therefore, if all the continental ice caps melted, the 30 million km³ of ice would cause a rise of the sea level of 30/357=0.084 km, namely 84 meters above the present sea level. That is to say a rise as high as the rise measured in Tahiti in 14,000 years.

7. REFERENCES

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Source : INRP (Paléoclimat) http://www.inrp.fr
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