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Mid Brunhes origin of modern atolls: a model developed in the Maldives and Moruroa atolls

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The Maldives archipelago includes 22 main atolls characterized by a marginal rim surrounding a lagoon commonly less than 50-60 m deep, though some lagoons reach depths of more than 80 m. The overall evolution of the carbonate system in the Maldives Archipelago clearly shows that the slow subsidence of hypothetical volcanic edifices buried under the atolls cannot explain their typical ringed morphology. On the contrary, the atolls in the Maldives, as most likely the majority of the modern atolls, are probably young (less than 0.5 My old) carbonate edifices. Our research in the Maldives was developed based upon the interpretation of two Elf-Aquitaine and Royal Dutch Shell MCS grids, groundtruthed by ODP Sites 714, 715, and 716 and two deep exploration wells.

Several seismic profiles across the modern atoll margins clearly illustrate a shift from middle Miocene-early Pliocene sigmoid lateral margin progradation of flat-topped carbonate banks to late Quaternary bank top vertical aggradation evolving into the modern atoll physiography. This well-marked transition is first illustrated by a regionally observed initial downward shift of the depositional system dated at 3.0-2.5 Ma. This downward shift of onlap and subsequent deposition in sedimentary wedges below the early Pliocene bank margins are explained by a late Pliocene-early Pleistocene (3.0-0.5 My) gradual sea level regression tied to the onset and successive expansions of major continental ice sheets in the northern Hemisphere. This regression is clearly defined in several Pliocene-Quaternary high resolution benthic isotope records, best proxy for ice volume variations in the past 5 My, at ODP sites such as 659, 677, 846, and 849.The early Pliocene flat-topped carbonate banks, exposed for about 2.5 My in the late Pliocene and early Pleistocene, were fully re-flooded for the first time at

the glacial MIS 12 to interglacial MIS 11 transition. This sea level transgression is unique by its highest amplitude among the multiple sea level transgressions in the past 5 My and by its occurrence directly after a 2.5 My-long sea level regression The unique character of the MIS 12 to MIS 11 sea level transgression is clearly shown in the Karner et al.(2002) stack of six tropical high resolution 18-O records from the Atlantic and eastern Pacific oceans.

Moruroa is a typical open atoll of 155 square km that lies in the southeastern part of the Tuamotu Archipelago (French Polynesia). The architecture of this atoll has been investigated through accurate dating by high-precision U-series and Sr age measurements and magnetostratigraphic data coupled with sedimentologic study of vertical cores and continuous drill holes 300 m in length, with seaward inclinations of 30 to 45˚, carried out through the modern reef rim and in the lagoon by the French Commissariat à l'Energie Atomique. The volcanic basement has been dated at 11 to 10.5 Ma and the subsidence rate of Moruroa atoll has been estimated at 7 to 8 mm/kyr. The overlying sedimentary pile ranges in thickness from 330-570 m below the modern reef rim to 130-230 m beneath the lagoon. It consists of a basal volcano-sedimentary series overlain by late Miocene dolomites and Miocene to Quaternary reef limestones. High-precision U-series and Sr age measurements of drill cores have demonstrated that the sharp transition from a flat-topped carbonate bank to modern atoll physiography occurred around 0.5 My ago.

In conclusion, the atolls in the Maldives and probably most of the modern atolls, such as the ones in Moruroa, are very young, less than 0.5 My old, edifices. Early Pliocene flat topped bank remained mostly exposed and were karstified during a late Pliocene to early Pleistocene 2.5 My.-long sea level regression. This karst morphology served as substratum and, therefore, template for the atoll development first during the unusually high amplitude MIS 12 to MIS 11 sea level transgression. Subsequently the successive exposures and floodings related to the series of late Brunhes, 120 m high amplitude, sea level transgressions and regressions, enhanced the initial mid Brunhes ring-shaped morphology, so typical of the modern atolls observed in the Maldives Archipelago.