Comparison of $^{230}Th/^{234}U$ Dating Results Obtained on Fossil Mollusk Shell from Morocco and Fossil Coral Samples from Egypt. Research of Methodological Criteria to Valid the Measured Age.

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ABSTRACT.

Radiochemical ages of 126 unrecrystallized coral samples from the Egyptian shoreline and 125 fossil mollusk shell samples from the Atlantic coast of Moroccan High Atlas are discussed.
For corals, the obtained ages are in good agreement with the ages reported previously on urecristallized corals except in some sites where some samples are affected by a cementation of younger aragonite.
For mollusk shells, the obtained ages are in the most of cases, rejuvenated. This rejuvenation is due eventually to a post-incorporation of secondary uranium that is responsible of the wide dispersion of apparent ages of mollusk shells.

Key words *: Sea level/fossil mollusc shells/corals/Quaternary.*

INTRODUCTION

The Egyptian coast of the Red Sea is characterized by fringing reefs, since at least the middle Pleistocene. The arid to hyperarid climate of the eastern Sahara desert certainly varied according to the glacial-interglacial cycles but the tropical latitudes (24°-30° N) appear to have favoured reef development during every interglacial highstand of sea-level (1-4).

The Pleistocene reefs of the Red Sea have been among the first references concerning raised reefs (5-7). A few Sudanese, Djibouti and Egyptian coral reefs were dated before 1980 (8-10) while more published dates appeared with the last decade, many of them producing extremely wide ranges of ages for the lower raised reefs confidently referred to late Pleistocene times: from 150 to 50 ka. The most recent detailed studies of Egyptian reefs (11,12) interpreted the younger dates as clues for 5c and 5a reefs being part of above sea-level outcrops, despite the absence of effective upheaval of the 5e reef. On the other hand, an assumed rift tectonic activity during Holocene times (rift shoulder surrection or diapirism induced to mistake a late Pleistocene (5e) reef for a raised Holocene reef (13) and to refer the gypsum residual tables (culminating more than 3 m above the present littoral sabkhas) to Holocene salinas or sabkhas.

In case of absence of corals and in spite of the seminal paper by Kaufman et al. (14) demonstrating that U-series ages derived from fossil mollusk are extremely unreliable, these samples have been used to determine the sea level fluctuation ages and to establish the stratigraphic scale of palaeoenvironmental change for some costs in the word. In the Western Mediterranean Basin, following an early study by Stearns and Thurber (15) in Morocco, a large body of U-series data, derived from several species of mollusk, has accumulate as a result of work by Bernat et al. (16), Goy et al. (17), Hillaire-Marcel et al. (18, 19), Causse et al. (20), Hearty et al. (21), El Gharbaoui et al. (22), Szabo and Rosholt, (23), Reyss et al. (24), Choukri (25) and Choukri et al. (26) amongst others.

In contrast to unrecrystallized corals regarded as ideal dating materiel in the marine environment, chronological data obtained on mollusk shells are often questionable because of open-system conditions. As a matter of fact, mollusk shells contain little authigenic U: their bulk U content essentially represents early diagenetic uptake (14, 23, 26). Kaufman et al. (14) ascribed the failure in reliability of mollusk shells dating to the postmortem migration of uranium into mollusk shells. The uranium concentrations of fossil shells are usually higher than of living mollusk shells and the $^{234}U/^{238}U$ ratios are, in the most of cases, higher than was possible if their uranium was incorporated from seawater conducting so to the rejuvenation of fossil samples.

In this work, we have analyzed 125 mollusk shell samples collected from the Atlantic coast of Moroccan High Atlas at the north of Agadir City in Morocco and 126 untecristallizer fossil coral samples from the Egyptian shoreline of the north-western Red Sea. This great number allowed a significant comparison of $^{230}Th/^{234}U$ ages for samples coming from cups assumed to be geologically developed during the emerged high sea level corresponding to Holocene, 5e and 7 and/or 9 climatic stages in two different regions of the word.

INVESTIGATION AREAS AND SAMPLING

126 coral samples were collected from the emerged coral reef terraces on the Egyptian shoreline of northwestern Red Sea extending over 500 km from the Ras Gharib-Ras Shukeir depression (28°10') in the north to Wadi Lahami (north of Ras Banas, 24°10') in the south (Fig. 1). The Egyptian coasts of the north-western Red Sea and Gulf of Suez are characterized by a series of spectacular Quaternary reef-terraces which have been geologically studied by several authors (3,8,11). Holocene Coral samples were taken from terraces situated at positions between 0 and 1 m relatively to the actual sea water level. Coral samples corresponding to the 5e climatic stage (27) were taken between 4 and 8 m except in the Zeit area known to be a tilted block rotated after Pleiocene deposition where samples were taken from terraces situated between 12 and 18 m. The older Coral samples corresponding eventually to 7 and/or 9 climatic stages were collected from apparent sections of terraces situated under the 5e terraces.

125 mollusk shell samples were collected on the Atlantic coast of Moroccan High Atlas in the north of Agadir city from Agadir Harbour in the south to Tamri village in the north extending over about 50 km (Fig. 2). The studied area is known by its geological importance and its fossil mollusc shells wealth and diversity. Several geological sections on the Coast of High Atlas at the north of Agadir City have been previously described (15, 22, 25, 28-30). Some of our radiochemical results have been used in a pervious work to prove the

rejuvenation of the mollusk shell ages before developing two models to establish relationships between the real and apparent ages related to the U post-incorporation mode. The collected samples belong to a variety of species that could be fossilized in the same place.

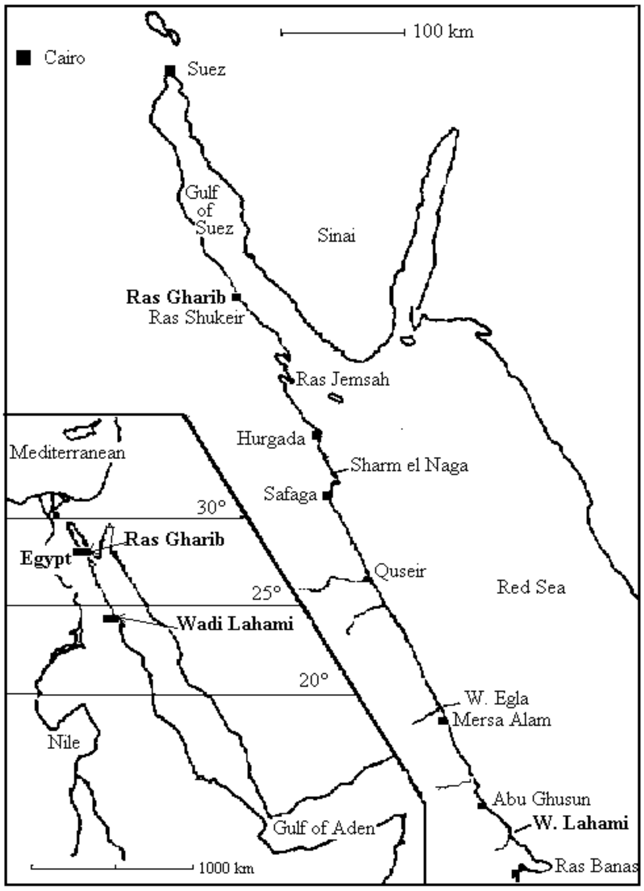

Fig.1. Localization map of studied sites on the Egyptian coast

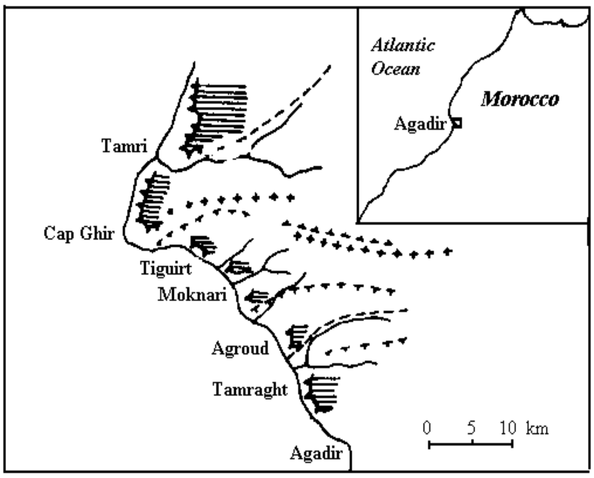

Fig. 2. Localization map of studied sites on the Moroccan coast

RESULTS AND DISCUSSION

Discussion of coral samples results

The results (ages, ^{238}U content, $^{234}U/^{238}U$ activity ratio) of radiochemical analysis obtained on coral and fossil mollusc shells samples are compared in given histograms. A study of Radiochemical data obtained by alpha spectrometry on unrecristallized fossil coral samples from the Egyptian shoreline of the north-western Red Sea has have already been realised previously (31). Radiochemical data obtained by alpha spectrometry on fossil mollusk shell samples from 5e shorelines on the Atlantic coast of High Atlas in Morocco have been also discussed (32).

The obtained ages on coral samples vary between 108.2 ka and 131.6 ka with an average of 122.2 ka. The results concerning the same sea level that have been reported by Edwards (33), Bard et al. (34) and Hamelin et al. (35) are in the range of our results. Except for samples from the Zeit area, the reef terrace is between 2 and 6 m above the present sea-level. This position is similar to the highest sea level from the last interglacial in the Caribbean and Bermuda islands as interpreted by Lambeck and Nakada (36) according to the glacio-isostatic rebound. This work proves that the large tectonic motions which affected the studied area after the Oligocene ceased since at least the last interglacial period.

On coasts tectonically stable, two sea levels are often established: the Holocene and 5e sea levels (dated respectively at about 6 ka and 122 ka). In addition to these two sea levels, an older sea level has been sometimes found (3,4). The deposits corresponding to this later was formed during sea water stagnation's before the last interglacial and a part or all of these formations have been destroyed or masked by repeated phases of erosion. The ages reported previously for these deposits are generally comprised between 170 and > 300 ka. The ages larger than 300 ka are not precise because they are beyond the dating limit of the method used.

Discussion of mollusc shell samples results

In the same way as for coral samples, results obtained for fossil mollusk shell samples from cups supposed formed during the three different stages (Holocene, 5e, 7 and/or 9) called, according to the Moroccan stratigraphy nomenclature, Mellahien, Ouljien and Harounien. In contrast to coral samples, the criteria of calcite cannot be used to cheque the closed system assumption which is the principal condition to valid the measured age. The measured calcite rates in analyzed mollusk shell samples are in the range of 0 to 100 % in independently of their species and of their origin. As for corals, the analyzed mollusk shell samples do not contain detrital material.

All the samples from the Mellahien climatic stage were taken from cups not higher than 2 m above the actual sea water. Ages measured are 0 ka for modern samples and between 6.3 and 9.7 ka with an average value of 7.51 ka for samples from the Holocene. The latter is in good agreement with Holocene ages from corals and with the previously measurements of mollusk shell samples.

All mollusc shell samples for 5e level sea were taken at altitudes between 4 and 8 m above the actual sea water on the Atlantic coast of High Atlas. The ages vary between 36.2 and 146 ka for the 5e sea level, while the ages obtained for unrecrystallized coral samples are about 122-125 ka. These results show that the ages of mollusk shell samples could be rejuvenated by a posterior incorporation of secondary uranium from the surrounding environment during the fossilization period (37).

The samples for older sea levels than 5e were taken at altitudes between 16 and 24 m above the present sea level. Deposits at these positions were recognized by some authors Weisrock (28), Stearns et al. (15), and Brebion et al. (29) at the Atlantic coast as Harounian sea level which correspond to 7 and/or 9 climatic stages. The average of ages reported previously for this level is about 260 ka (22,25,28,30). The 21 calculated ages vary between 180 and 511 ka and are in good agreement with the ages reported previously and with the average value obtained in this work for the same levels by means of coral samples.

Comparison of coral and mollusc shell samples results

The histograms of figures 3 to 6 allow a statistical comparison of the obtained ages for every level by means of both dated materials. A briefly discussion of statistical distribution of radiochemical results in coral samples from the Egyptian shoreline of the north-western Red Sea and in fossil mollusk shells from the Atlantic coast of High Atlas in Morocco and their Implications for $^{230}Th/^{234}U$ dating has already been reported (38).

The histograms of figure 3 allow the age comparison obtained in both regions for the level Holocene. They are, in spite of their small distance, comparable and the difference is also due to the uncertainties of determination of the age by alpha spectrometry. On the histogram of the mollusk shells, we also presented the results of the actual mollusc shells whose gave 0 ka.

The histograms of figure 4 allow a comparison of a significant number of ages obtained by coral samples and mollusc shell samples for the same level at two different regions.

Regarding the coral samples, the ages of this level were possible to determine. Except the rejuvenated ages because of the posterior cementation of recent aragonite, all results are in a good agreement with other studies on unrecristallised coral samples in some regions of the word. The rejuvenated ages could be avoided by detecting the secondary cementation of the recent aragonite which brings some uranium responsible for this rejuvenation.

For mollusc shell samples, the range of 5e level age is large between 36 and 146 ka, while the ages obtained for unrecrystallised coral samples are about 122 ka. These results show that the ages of mollusc shell samples could be rejuvenated by a posterior incorporation of secondary uranium from the surrounding environment during the fossilization period. They are obviously affected by the variability of values of ^{238}U contents and $^{234}U/^{238}U$ activity ratios.

The average of the obtained ages from mollusc shell samples could not be used to determine an age for the studied level because of the rejuvenation of some of them. The obtained results must be confronted to a geological context before attributing it to the formation having livered the sample.

The histograms of figure 5 show a statistical distribution of older sea levels than 5e often attributed to the 7 and/or 9 level. The ranges are in the two cases dispersed and cannot supply precise statistical ages for these levels. Furthermore, when the age exceeds 200 ka, the $^{230}Th/^{234}U$ ratio activity used to calculate the age aims gradually towards 1 and the method becomes very sensitive to the small variations, what gives wide intervals of uncertainties and contributes to obtain a wide spectre of results either for corals, or for the mollusc shells.

Nevertheless, both ranges tend to show the existence of, at least, two age groups: between 180 and 260 ka often attributed to the 7 level, between 300 and 340 ka often attributed to the 9 level and the ages oldest that 400 ka. If we take into account the reasoning made for the mollusc shells for 5e level, these ages could be also rejuvenated and the real ages could be older than apparent ages.

We have presented, separately for corals and mollusc shells, all the ages measured for the high marine levels: Holocene, 5e, 7 and/old 9 in the same histogram (figure 6).

The figure 6(a) shows that it is possible to distinguish statistically groups of age corresponding to the Holocene, the highest marine level during the last interglacial period (5 e) and two under groups corresponding possibly to older high marine levels than 5e (levels 7 and 9).

Contrary to the figure 6(a), the figure 6(b) does not allow a statistical study of the existence of these levels because of the rejuvenation of mollusc shell samples ages due to the secondary incorporation of uranium during their fossilisation.

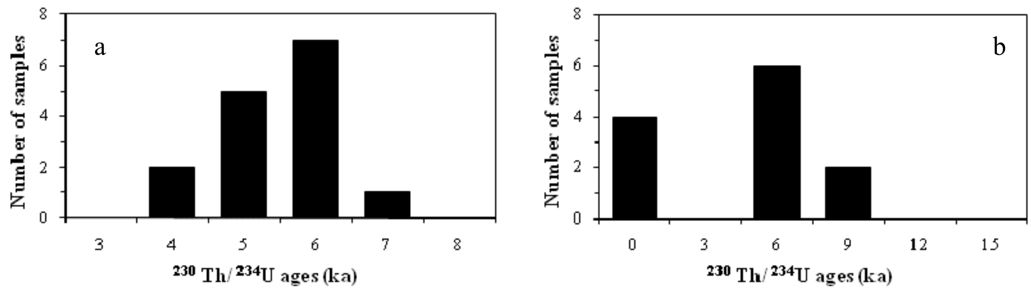

Fig. 3. Distribution histograms of ages in Holocene samples (a: corals, b : mollusc shells)

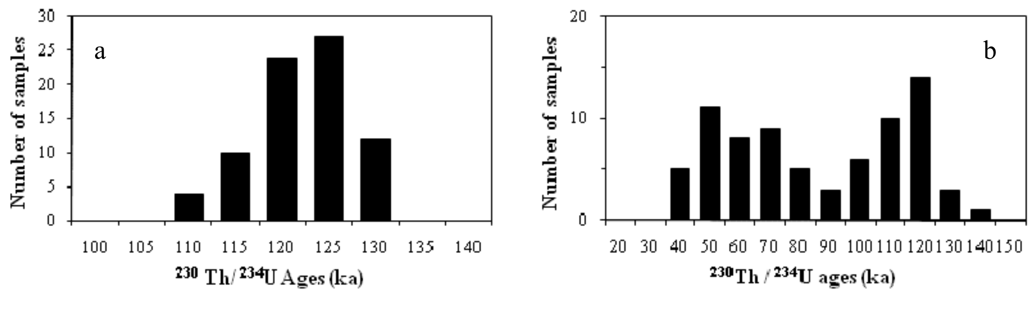

Fig. 4. Distribution histogram of ages in 5e sea level samples (a: corals, b : mollusc shells)

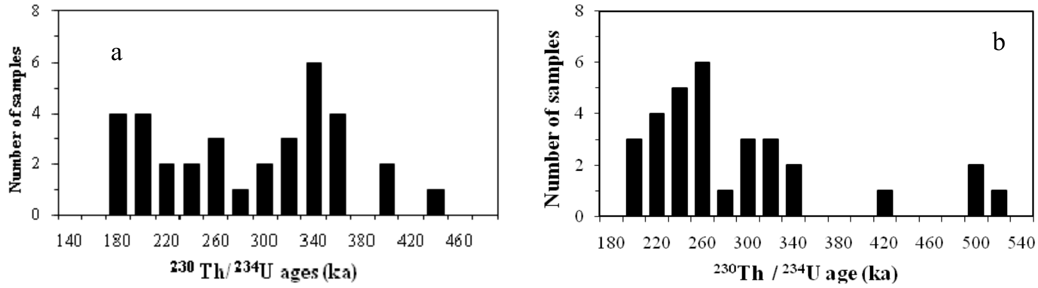

Fig. 5. Distribution histogram of ages in 7 and/or 9 level samples (a: corals, b : mollusc shells)

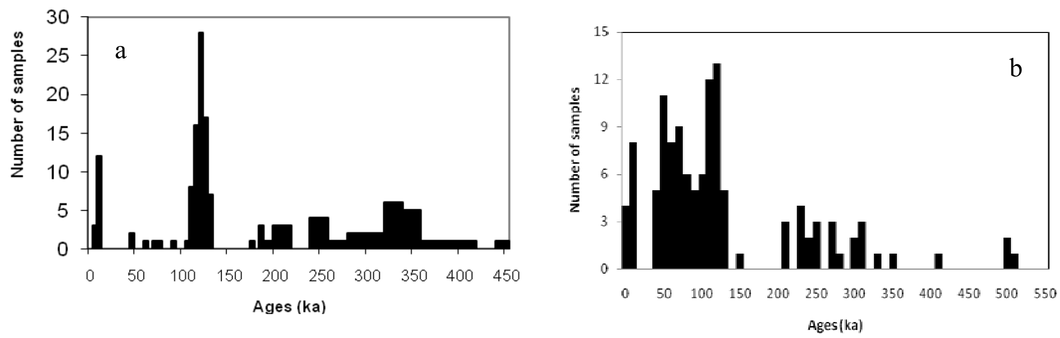

Fig. 6. Distribution histogram of all ages (a: corals, b : mollusc shells)

CONCLUSION

A study of radiochemical analysis results of 126 unrecrystallized coral samples from the Egyptian shoreline of northwestern Red Sea and on 125 fossil mollusk shell samples from the Atlantic coast of Moroccan High Atlas at the Nord of Agadir City obtained by alpha spectrometry have allowed to conclude that:

The unrecristallized corals constitute the reliable means of determining the timing of Pleistocene sea level fluctuations in the past. A statistical study of the measured ages allowed to distinguish statistically groups of age corresponding to the Holocene, the highest marine level during the last interglacial period (5e) and two under groups corresponding possibly to older high marine levels than 5e (levels 7 and 9). The average of obtained ages for each level are in good agreement with the previous measurements on the unrecristallized corals on some regions of the word. Precautions on the ground are necessary to avoid samples showing a secondary cementation of a recent aragonite which is responsible of the rejuvenation of the sample ages affected by this cementation.

For mollusc shells, the dispersed ages often found for the Ouljian level on the Moroccan coasts, do not correspond to real ages, but only to a rejuvenated ages due to a posterior incorporation of secondary uranium during the burial period. This incorporation could be continuous during the burial as it could be episodical, which explains the range of rejuvenated ages obtained sometimes for the same level. The degree of reliability of the dating varies from a site to another according to its position and its conservation with respect to inland waters and sea water.

Contrary to the corals where some methodological indications could inform about the validity of the age, no methodological criterion is still well established. Precautions must be taken during the sampling to be able to confront the measured age to the geologic context of the formation having delivered the analyzed sample.

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