Subsidence and uplift during the Plio-Quaternary in the Oued Laou and Tirinesse sectors (Internal Rif, Morocco)

Subsidencia y levantamiento durante el Plio-Cuaternario en los sectores de Oued Laou y Tirinesse (Zona Interna Rifeña, Marruecos)

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ABSTRACT

The Oued Laou area and the Tirinesse basin are filled with early Pliocene (Zanclean) marine sediments very slightly deformed but currently outcropping at different altitudes. In Tirinesse area Zanclean sediments reach high altitudes (+600 m), whereas coeval sediments appear near the coastal level in Oued Laou area and even more than 100 m under the sea level in a borehole near the coast. The difference of altitudes is explained by two successive processes. First there was an important regional subsidence permitting sedimentation. Moreover, in the Tirinesse basin, due to the combined movement of the two SW-NE conjugated normal faults, an additional tectonic subsidence took place. Later, a regional and not homogenous uplift, progressively more important to the west, occurred in the Rifian Internal Zone, then surpassing the effects of the subsidence. Differential vertical displacements also existed in a N-S direction.

Key-words: *Subsidence, uplift, Pliocene, Oued Laou-Tirinesse basin, Internal Rif.*

RESUMEN

El valle de Oued Laou y la cuenca de Tirinesse están rellenos de sedimentos marinos del Plioceno (Zancliense) débilmente deformados aunque afloran a diferentes altitudes. En Tirinesse, el Zancliense alcanza gran altura (+600 m), mientras que sedimentos equivalentes se encuentran al nivel del mar en Oued Laou e incluso a más de 100 m bajo este nivel en un sondeo cerca de la costa. Las diferentes alturas se explican por dos procesos sucesivos. Primero se produjo una importante subsidencia regional que facilitó la sedimentación. En la cuenca de Tirinesse, la subsidencia fue más acentuada por el efecto de fallas normales SW-NE. Después, en la Zona Interna Rifeña hubo un levantamiento regional, tanto más importante cuanto más al oeste, que en conjunto sobrepasó el efecto de la subsidencia. También hubo movimientos verticales diferenciales en la dirección N-S.

Palabras clave: *Subsidencia, levantamiento, Plioceno, cuenca de Oued Laou-Tirinesse, Rif interno.*

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Introduction

The Oued Laou valley is a depression developed on the stacked nappes of the Internal Rif (Fig. 1). The origin of this valley is still subject of controversy. For certain authors, it is tectonic in origin and the erosion played only a secondary role (Wildi and Wernli, 1977); other authors considered that it rather corresponds to an ancient fluvial valley formed only by erosion during late Miocene times, which was flooded during the early Pliocene (Loget and Van Den Driessche, 2006). The depression was filled by early Pliocene marine sediments that unconformably overlie a basement made up of Rifian internal units and outcropping at the northern border of the valley (the southern one is covered by Quaternary sediments). In this area, lower Pliocene sediments reach altitudes of 200 m, but equivalent deposits were found in holes drilled in the axis of the valley (Feinberg and Lorenz, 1970) at 145 m below the current sea level.

Further to the west (at 15 km from the Mediterranean coast) lower Pliocene sediments of the Tirinesse basin crop out 250 m above the Oued Laou. This basin is a NE-SW trending rectangular graben (Wildi and Wernli, 1977), 4 km long and ca. 1 km wide (Fig. 1). The SE and NW steep borders correspond to normal faults (Saji and Chalouan, 1995). These two faults belong to a much longer faulting system that transversally cut the entire Rifian Internal Zone. The latter consist of three tectonic complexes stacked as follows: a) the Sebtide (Federico and Filali units), is affected by Alpine metamorphism, b) the Ghomaride, not affected or weakly affected by metamorphism, is mainly formed by Paleozoic lutites and c) the Calcareous Dorsal, which mainly consists of Triassic-Liassic massive carbonate successions.

The present study tries to contribute to a better understanding of the geodynamic scenario of this region during and after the Pliocene.

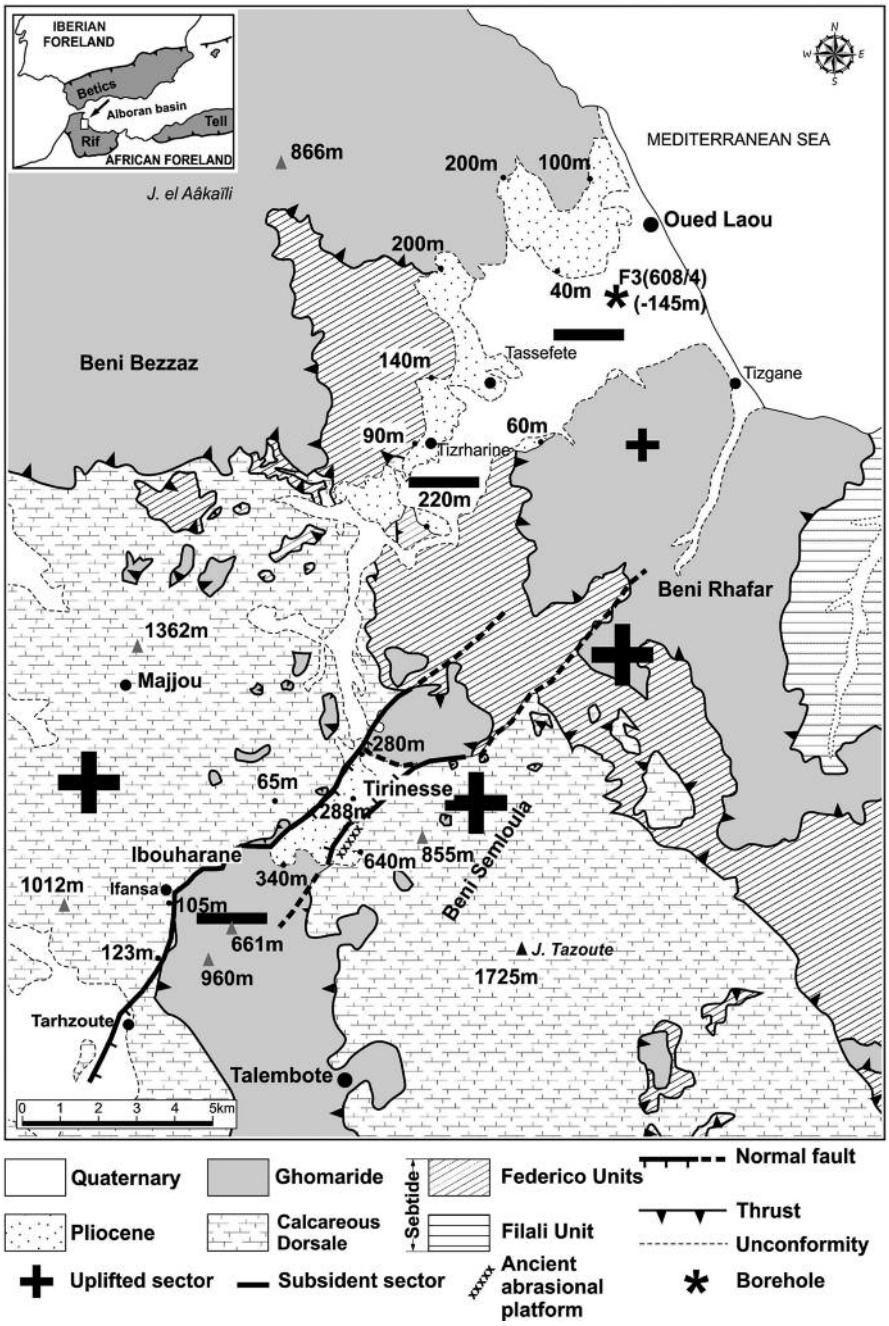

Fig. 1.- Regional geological scheme locating the Tirinesse Basin and the Oued Laou valley.

Fig. 1.- Esquema geológico regional situando el valle de Oued Laou y la cuenca de Tirinesse.

Sedimentary filling of the Tirinesse basin and the Oued Laou area

It is in the Tirinesse basin where the early Pliocene sequences are more organized and complete (Fig. 2). The sedimentary succession filling the Tirinesse basin consists of four members:

Member 1: Ibouharane conglomerates (< 30 m thick) unconformably overlying the basement and predominantly formed by coarse-grained alluvial deposits.

Member 2: Marine silts and grey marls with interbedded sandstones (150 to 200 m thick). In agreement with Wildi and Wernli (1977), this formation strictly correlates with the Tassefete marls cropping out in the low Oued Laou valley. From these marls, a scarce planktonic assemblage with *Globorotalia margaritae* Bolli & Bermúdez points out an early Pliocene age (early Zanclean).

Member 3: Marine yellow sands and marls (15-20 m in thickness) overlying in stratigraphic continuity the previous unit, also likely early Pliocene in age. In the low valley of Oued Laou, similar sediments crops out in small hills on the left valley side.

Member 4: Deltaic Tamrabete conglomerates (< 30 m in thickness) appears only in the southeastern Tirinesse basin and is mainly made up of deltaic conglomerates, bearing bivalves and sourced from the Calcareous Dorsal. This member partially lies over old scarps of the basin and locally surpasses 640 m in altitude. These upper marine conglomerates probably still correspond to the early Zanclean.

The filling of the Tirinesse basin and Oued Laou valley shows an overall transgressive-regressive cycle, which seems to occur in a narrow flooded depression connected with the open sea. The diversified foraminifer assemblages through most of the marly sediments suggest that deposition occurred under normal marine salinity conditions. Open marine water rarely reached the basin, transporting scarce planktonic foraminifer assemblages mainly made up of dwellers of warm, surface water, i.e. *Globigerinoides extremus* Bolli & Bermúdez, *Globoturborotalita decoraperta* (Takayanagi & Saito), and *Orbulina universa* d'Orbigny. Regarding the benthic foraminifer assemblages, it can be concluded that subsidence mainly acted in a first stage, in which the basin reached the maximum depth (assemblages with *Lenticulina, Pullenia,* and *Heterolepa,* predominantly). Subsequent shallowing of the basin is evidenced by assemblages mainly made up of *Florilus, Valvulineria,* and *Ammonia*.

This sequence can be correlated with the PL-2 unit described by Guerra-Merchán *et al.* (2014) in the Betic peripheral basins of northern Alboran, which represents the maximum Pliocene marine transgression in the region.

Main morphologic features within the Tirinesse basin

A first remarkable landform corresponds to an old conspicuous abrasional platform carved on Dorsal dolostones along the south-western border of the Tirinesse basin near the normal Tamrabete fault (Fig. 1). The age of this marine abrasional platform is a debated question. Maurer (1968) considered it as Pontian (late Miocene). Nevertheless, in this paper we suggest a Pliocene, Zanclean age for three reasons:

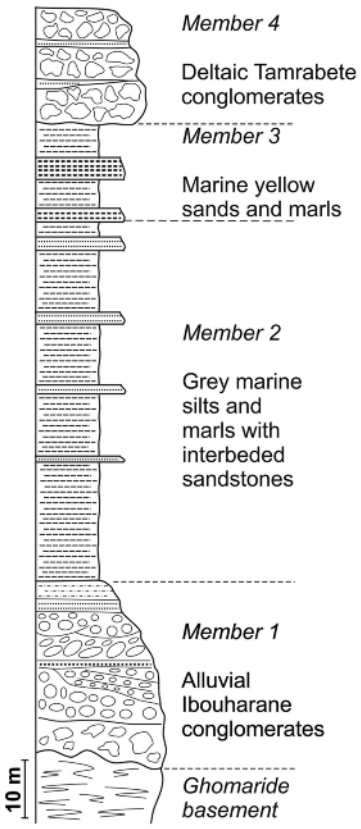

Fig. 2.- Stratigrafic column of early Pliocene sediments of the Tirinesse basin.

Fig. 2.- Columna estratigráfica de los sedimentos del Plioceno inferior de la cuenca de Tirinesse.

a) This surface is restricted to the Tirinesse basin, filled with Zanclean sediments.

b) The platform was formed after the Ghomaride rocks were practically eroded in the Béni Semloula mountains (in which the Tamrabete fault is located), where the Ghomaride nowadays crops out only at 900-1000 m of altitude. Clastic material produced by that erosion was transported to the basin, together with Zanclean sediments.

c) The platform does not show clear features of unevenness, something to be expected if it was older, because the movements of the Tamrabete fault, according to our interpretation, were not homogeneous along its strike owing to its different throw, progressively diminishing to the SW. Thus, it should be also considered that at least part of the movements of these faults also affect Zanclean sediments, crushed in some points in the contact with the faults. But the platform is not tilted. This suggests that the platform was formed during the early Pliocene transgressive event.

Similar abrasion platforms were developed in the southern border of the Malaga basin on Alpujarride marbles of Sierra of Mijas, in relation to the highstand of the PL-2 unit dated to 4.6-4.7 Ma BP (Guerra-Merchán *et al.*, 2013).

The second particular morphologic feature of the basin appears along the western border (hanging block) of the Tamrabete fault. It corresponds to a depressed band unrelated to the present-day fluvial topography. Although this longitudinal elongated depression could be interpreted as a consequence of present-day subsidence of the hanging block of the fault, apparently there are not data of associated seismicity (although the seismic record is not complete). In any case, a part of fault displacement could be accommodated by creep.

Evolution of the Oued Laou area and the Tirinesse basin since the end of the Miocene

According to Haq *et al.* (1987), at the beginning of the Pliocene the mean sea level was at + 90 m with respect to the present height. Consequently, coastal and shallow marine lower Pliocene sediments, now at altitudes of about 90 m, have practically experienced neither elevation nor sinking. But, there are sediments in the Oued Laou sector cropping out at higher positions. Moreover, some of the Pliocene marine outcrops in this sector conserve thickness larger than a hundred meters, which evidences significant subsidence in this area. These data are complemented by those of Feinberg and Lorenz (1970), who indicated the presence of lower Pliocene deposits (i.e., Tassefete marls) at 145 m below the present-day sea level, in a well (F3, 608/4) drilled in the Oued Laou sector, at less than 2 km inland (Fig. 1). But, on the other hand, the existence of marine lower Pliocene sediments in this sector at altitudes over 200 m, in which the youngest sediments are not conserved, needs –in addition to the cited previous lower Pliocene subsidence– a later uplift process.

In the Tirinesse basin, the sedimentary filling preserved is at least 200 m thick, despite its small spatial extension (the original thickness could be more than the double). It was formed during Zanclean times between two nearly parallel and antithetic faults (Hlila *et al.*, 2014). Moreover, these faults practically cut the entire Internal Zone in this area, while the prolongation to the NE of one of them also controlled the movement of the southern border of the Oued Laou depression (Fig. 1). This explains the existence of Zanclean sediments near Oued Laou, clearly located under the present-day sea level.

At the end of basin infilling, erosion of upthrown blocks supplied the coarse-grained clastic material of the upper-Member in deltaic thickening-upward sequences.

The regional uplift then initiated was not homogeneous (as previously occurred with the subsidence). It was more accentuated to the west, but at the same time it was different in the North and in the South of the area. Owing to the movements of the cited faults, the NW sector was more uplifted in comparison to the SW one, while for SE sector occurred the same in relation with the NE sector. In the last case, the relief situated south of the Oued Laou depression underwent additional uplift, so that relative subsidence of the basin continued (Fig. 1). This differential process cuts the Internal Zone in a progressive and transversal way.

Figures 1 and 3 illustrate the different altitudes of the basal levels of the Pliocene successions in several points situated in the Oued Laou and Tirinesse sectors. Figure 3 shows that in most sites the altitudes of the early Pliocene outcrops are clearly above the maximum eustatic level (+90 m).

Precisely, in the Tirinesse basin, the minimum thickness of sedimentary filling is 200 m, shallow marine sediments being nowadays situated circa 640 m. Thus, the first process of subsidence was very important (more than 500 m) followed by a tectonic uplift of the same order, at least to the SW, in the Tamrabete Fault. The result is a scissor like movement along the overall Tirinesse fault zone (Fig. 1).

Such movement essentially occurred during the Zanclean. It probably began at the end of the Miocene, and was progressively achieved during the subsequent isostatic rebound of the region. The time of kinematical shifting from the period of subsidence to the generalized rebound probably coincided with the formation of the abrasional platform, formed in the southern block of the Tamrabete Fault, precisely when the Tirinesse basin was totally filled-up by Zanclean sediments. From this time onwards, the uplift progressively forced its sig-

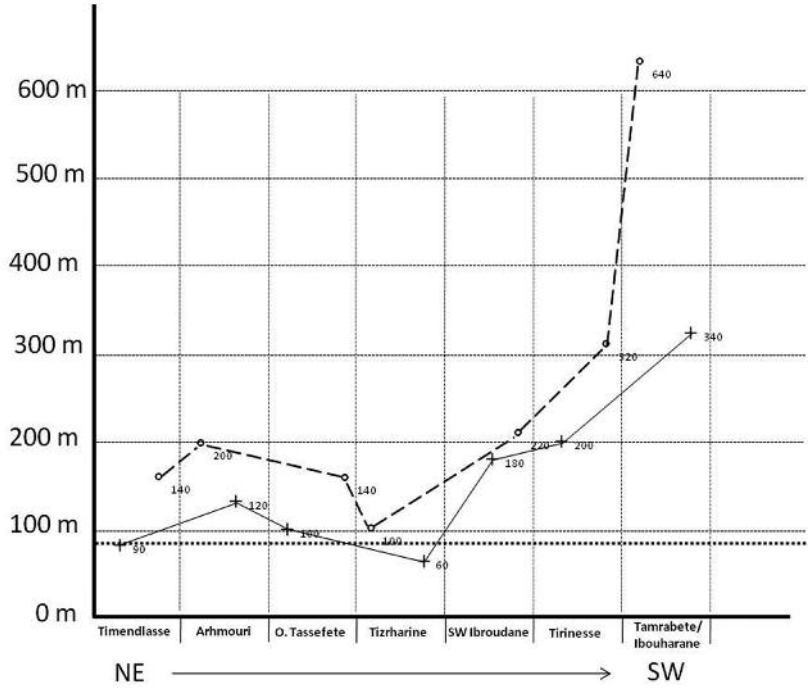

Fig. 3.- Uplift regional gradient from the Oued Laou coast to the SW, till the Tirinesse Basin.

Fig. 3.- Gradiente de levantamiento regional desde la costa de Oued Laou hacia el SO, hasta la cuenca de Tirinesse.

nature over the whole Internal Zone, more accentuated westward.

Conclusions

In the Tirinesse basin, the early Zanclean sediments are located at altitudes up to 640 m, whereas the coeval outcrops situated to the NE, in the Oued Laou sector, are near the present-day sea level. Considering an early Pliocene mean sea level at + 90 m, this difference of altitude indicates two successive processes. First, during the early Zanclean the region underwent an important subsidence, allowing sedimentation in the region, including the Tirinesse basin, where the subsidence had a clear tectonic origin. Soon after, regional uplift took place. The Internal Zone was progressively elevated, uplift generally being more important to the West. The rate of the resulting tectonic movements clearly surpassed that of the eustatic changes.

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