



Study of the structural continuity from hinterlands to continental shelf in Larache area (NW Morocco): Morphostructural approach.

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Abstract

The study area is situated to the South-West of the Rif's domain (NW Morocco). It presents all characteristics of a coastal river basin, formed essentially by the low lands of the alluvial plain of the Loukkos River, and surrounded by relatively low, essentially marly hills and long sandy beaches. The evolution of the mentioned coastal area and its continental shelf is relatively complex and it depends mostly on its geodynamic context. The goal of the present study is to materialize the relationship between the mentioned continental shelf and its hinterland in the region of Larache. The applied methodology was the morphostructural analysis of the envelope surface in order to bring out the original geomorphological structures and slope failures axes. The overall results allowed us to develop a synthetic structural schema. The structural continuity from hinterland to continental shelf in the area.

Keywords: Morphostructural analysis, structural continuity, hinterland, continental shelf, structural schema.

1. Introduction

Since the sixties, the northwestern of Morocco has been the subject of several studies such hydrological, soil, tectonic and geophysical among others. Nevertheless, the morphostructural analyses have been only focused on hinterland areas in spite of the economic importance of continental shelf.

The purpose of the present study is to extend the application of the morphostructural analysis to the continental shelf. These results will allow us to develop a synthetic structural schema organization of the hinterland from Larache (NW Morocco) to the Atlantic continental shelf of this area.

1.1. Geographical context.

The study area is located in the northwestern of Morocco, between 35°28.7' N- 5°58'W and 35°12' N - 6°20' W. It is part of the Atlantic pediment of western Rif. It is bordered to the north and the east by the External Rif's formations, to the south by the Gharb basin, and to the west by the Atlantic Ocean. The area is characterized by a low relief whose elevation can reach up to 233 in the area of Khemis Sahel .

1.2. Geological context.

The study area is an integral part of the external Rif domain. It is dominated by the Intrarif nappes (mainly the Habt nappe) with the presence of internal Prerif nappes to the west and Pliocene – Quaternary deposits to the south [1, 2] (Figure 1). The Habt nappe (Intrarif) is presented locally by Oligocene sandstone formations known as Asila sandstone, which have accumulated in the external sub-basin of Habt nappe [3]. The internal Prerif is presented by stratigraphic series include limestone from the Lias-Dogger and Eocene sandstone known as the M'rayt sandstone [4] and platform carbonates and Kimmeridgian-Tithonian [1]. The study area represents the northern part of the sedimentary basin of Gharb. There are marine and continental deposits [5]. The foreland basins in response to the spread outward from the tectogenesis originated in the Upper Miocene. These basins were filled by mudslides and olistostromes with a marly matrix wrapping various elements of different age, size and nature, which came from the front of allochthones formations and other units of more internal position in the Rif's complex [6].

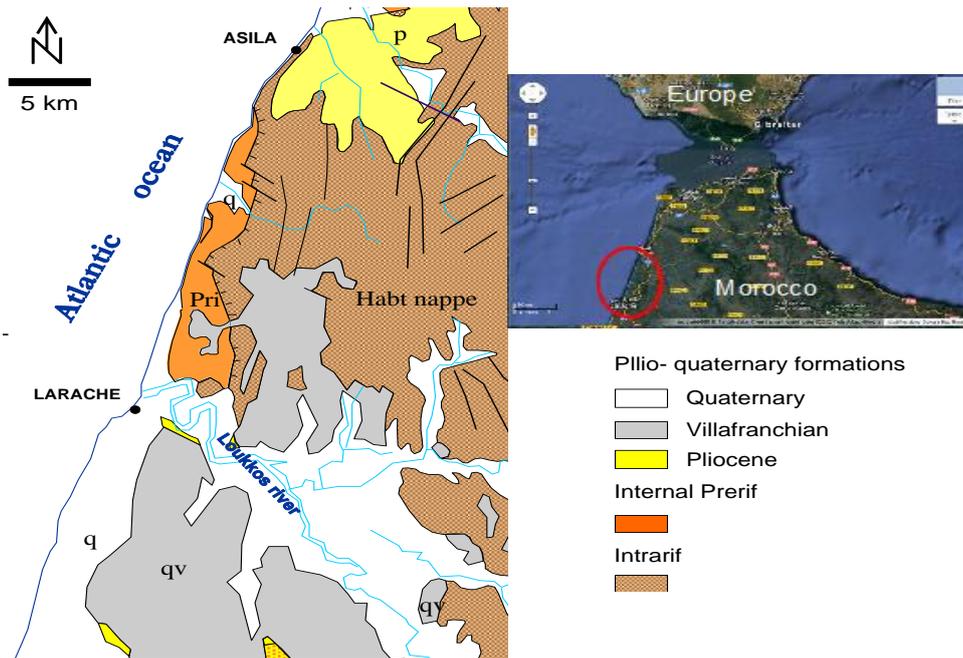


Figure 1: Structural schema of the study area [7].

1.3. Structural framework: Tectonics and neotectonics.

The tectonic and neotectonic history of the External Rif was the subject of several scientific studies such as [6, 8, 9, 10, 11, 12, 13, 14], among others. The bibliographic review of these works, allowed us to chronologically retrace the main phases of structural phases from the upper Eocene to present times in the study area (Table 1).

Table 1. Structural phases from the upper Eocene to present

Age	Tectonical regimes	Stress directions	Associated Structures
Ouljian	Compressive	E-W	- Inverse faults N 175 – 25 - Strike-slip faults NW-SE and NE-SW
Post Villafranchian	Extensive	N-S	- Normal Faults N 80 – 125
Upper Pliocene	Compressive	NE- SW	-Strike-slip faults (N 00 - 40) (N 90 - 115) -Inverse faults (N 150 at 10),
Pliocene	Extensive	NW - SE	-Normal faults N 50 – 70
Fini-Meocene	Extensive	N 175	-Normal faults N 60 – 80
Serravallian- Tortonian	Compressive Compressive	N - S E - W	-Axes folds N 120 and N 50 -Inverse faults E - W and N – S -Strike-slip faults NW - SE
Langhian	Extensive	E- W	-Normal faults (N – S)
Finiburdigalian	Compressive	E - W	-Large folds spilled into S- SE
Upper Oligocene Aquitainian	Extensive	N - S	-Normal faults (E – W)
Upper Eocene Middle Oligocene	Extensive	-----	-Foreland basins

1.3. Geomorphology

The study area consists of a low alluvial plain (Loukkos) surrounded by an area of marly hills with low altitudes (less than 250 m), and rocky and sandy coasts [15]. The low areas are represented mainly by the alluvial plain of

Loukkos. This drains the main river of the region (Loukkos River) and its tributaries. This plain is boarded by Neogene to Quaternary deposits. The elevated areas They are represented by marly hills generally with low to medium altitude (less Than 220 m). They surround a low, marshy plain. These elevated areas constitute the western extension of the Rif. In the sandy coasts, the direction of this coastline is NNE - SSW and the slope is comprised between 0.8 and 1%.

2. Methods

Given the general lack of available data about the continental shelf in the area between Asila and Larache, we decided to apply a morphostructural approach [16, 17, 18,19], to propose a primitive structural map that could show the structural continuity from hinterland to continental shelf.

In order to cover the Atlantic coastline and its hinterland between Asila and Larache, we used seven topographical maps at scale 1 : 25000 [20]. In addition, we used the bathymetric map of the North Atlantic (NW coast of Morocco between Asila and Larache) at scale 1 : 25000 [21]. After according the georeference system, using the ArcGis software, these maps provide a complete image of the area (Figure 2). That will allow us to detect the majority of the existing relations between landforms and geological structures associated.

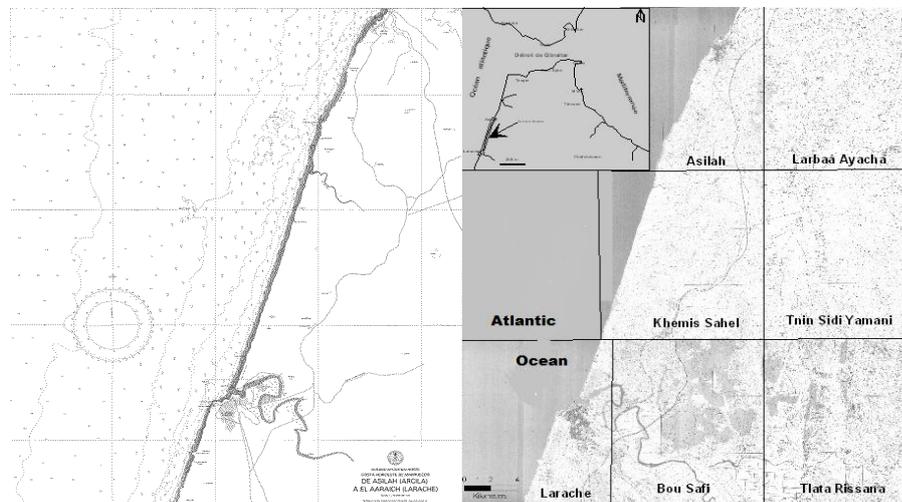


Figure 2: Topographical maps (ANCFCC, 2006) and bathymetric map of the North Atlantic (NW coast of Morocco)

3. Results and discussions

The topographic map of Larache region obtained from the aforementioned cartography data have shown the topographical features of the following geomorphic units (Figure 3A):

- An area where the highest altitude (more than 100 m) characterizes the regions of Khemis Sahel and Tnine Sidi Lyamani. On the contrary, the lowest elevations (less than 50 m) characterize the alluvial-marine plains, essentially the Loukkos estuary that covers most of the surface area of the regions of Larache, Bou Safi and Tlata Rissana with a general direction NW - SE. We also note the existence of some abrupt direction NNE - SSW that determines most of cliffs along the coastline in subject area.
- A continental shelf, which shows a water column depth from 0 to 110 m of depth. Furthermore, the depth contour lines are almost parallel to the shoreline. These contour curves get closer to each other near the coast and they are becoming growing further away from each other. Therefore, the continental shelf slope decreases towards offshore.

We note that the topography appears complex in its original state. For that reason, the creation of a simplified surface was necessary for a better interpretation of the morphological structure in the study area. Therefore, the gradual smoothing of contours and bathymetric curves gradually up an envelope surface map perfectly smoothed (Figure 3B) that shows the follow structures:

- A central compartment with antiforms axes with directions: N - S, NW - SE, NNW - SSE and NNE - SSW. It is bordered by slope failures WNW - ESE, N - S, NW - SE, NNW - SSE, NNE - SSW, NE-SW and E - W. It presents the highest altitudes of the region Asila - Larache with more than 200 m.

- A compartment in the south west of the plain of Loukkos consisting of antiforms whose axes are oriented NW - SE, NNW - SSE and N - S. It is marked by slope failures NNW - SSE and NNE – SSW. It is characterized by low altitude about 80 m.
- A compartment in the southeast of the study area, consisting of spangle of antiforms that follow NNW - SSE and NE – SW. It is limited by slope failures of the same direction.
- Slope failures that are parallel at the coast along the Atlantic coastline between Asila and Larache and its continental shelf. These slope failures are separated by zones of relaxation of depth contours reflecting gentle slopes.

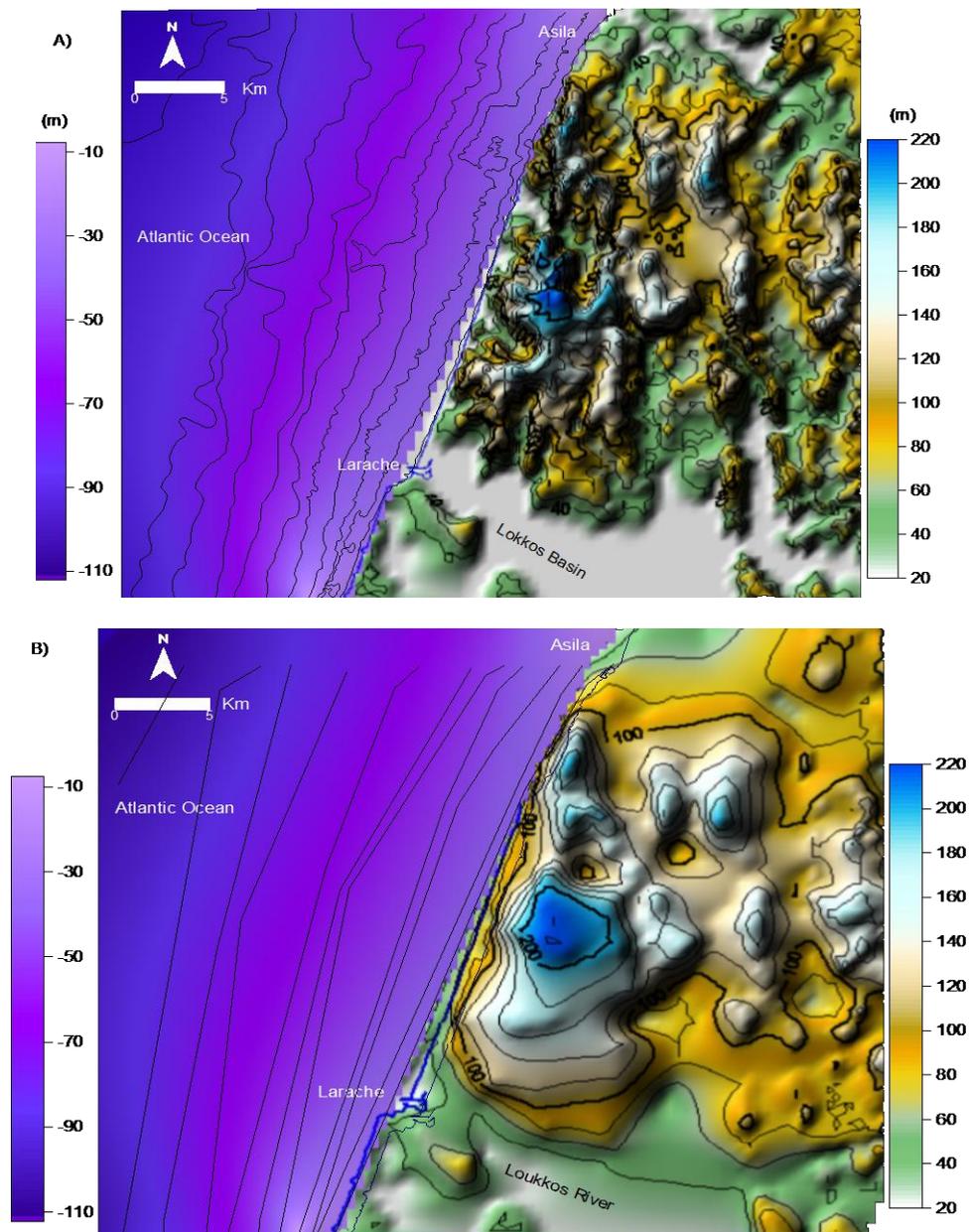


Figure 3: A) 3D topographic and bathymetric surface map. B) 3D surface smoothing map

In order to link the obtained structures to the regional geodynamic context, we were based on: 1) in situ measurements taken in the hinterland; 2) bibliographic references of previous studies that concern in the region and others that were conducted in neighbouring areas. Therefore, according to Abdelkhaliki (1997) [13], the unit of Hapt and internal Prerif (external zone) have very remarkable deformations with:

- A depreciation's system folds axis direction N - S.
- A sinistral or dextral offsets direction N 70 to N 140.
- Overlapping reverse faults of direction from N 170 to N 15.

Furthermore, in situ measurements, discontinuities and tectonic alignments performed in the area near continent, showed a dominant directions NNE –SSW, and the secondary directions are WNW - ESE, NW - SE and NNW – SSE (Figure 4)

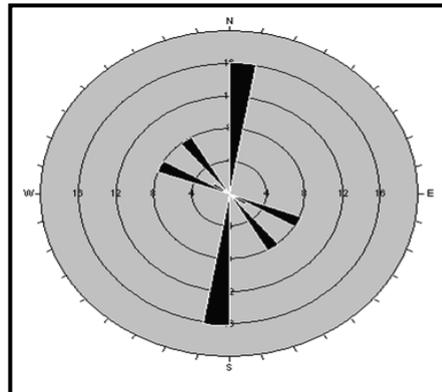


Figure 4. Rose directions measured in the discontinuities.

The continental shelf may be affected by parallel and oblique faults. They would be related to the present coast main Triassic - Liassic structures which had been generated during Atlantic rifting (Figure 5) [22, 23].

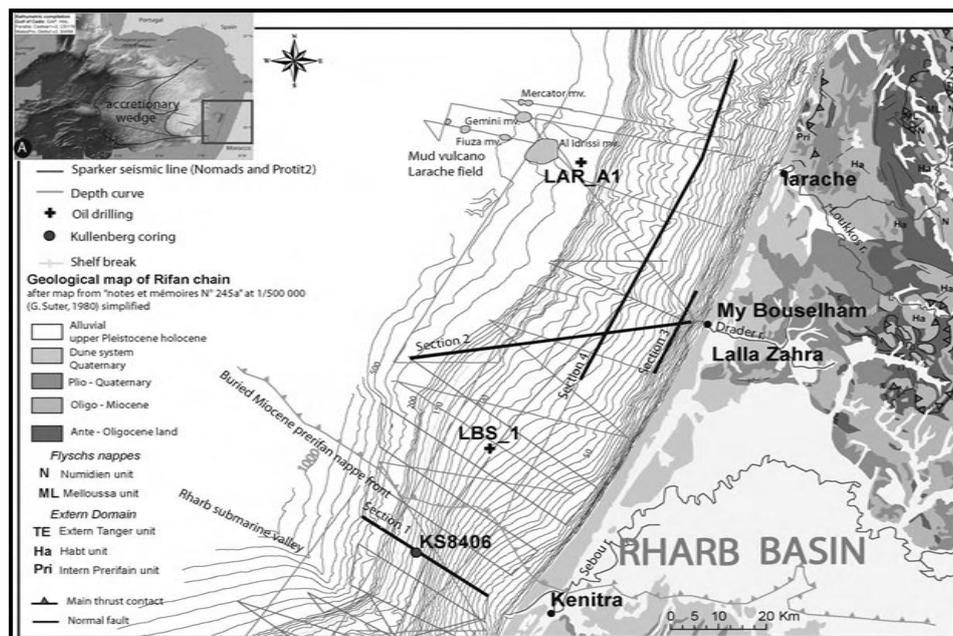


Figure 5. Geological and bathymetric map of the continental shelf in the area between Asila and Kenitra [23, 24, 25]

Data obtained allowed us to establish a synthetic morphostructural map (Figure 6). This map reflects the existence of some number of structural elements. These can be correlated with the bibliographical data as follow:

- The antiforms with NNE – SSW, NNW - SSE, N – S, NW - SE and NE – SW direction, distributed on both sides of the two synforms. They are related mainly to the structures of nappes that characterize the field of external Rif.
- The synforms with NW- SE direction corresponds to the Neogene basin that has collapsed during the Rif formation.
- The slope failures with NE - SW, NW - SE, N - S, WNW – ESE, NNW - SSE, NNE - SSW and E - W directions. All these directions are similar to the directions of tectonic structures (and fractures fold axes). This highlights the main phases of tectonic deformations of the upper Eocene until the present in the external Rif.

- The slope failures with NNE - SSW direction, just outside the coastline between Asila and Larache are distributed parallel to the coast on the continental shelf forming a half-graben. This appears to be linked to the Atlantic rifting.

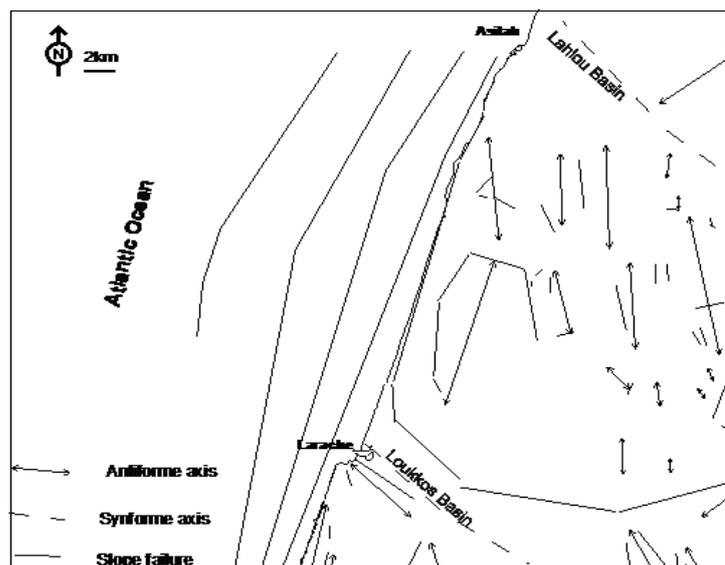


Figure 6: Synthetic schema of formal structural organization from the nearest continent to the Atlantic coastline in Larache area

Conclusions

The summary of bibliographic data about the tectonic history of the area, confirmed that the evidence obtained by the morphostructural analysis is actually the result of multiphase tectonic structures, compressive and extensive, that affected the external Rif.

It is then, in a context where it alternates:

- the extensive phases that were responsible, firstly, for formation of foreland basins, trace Aquitanian and probably even less Burdigalian. Secondly, for Normal Faults direction N-S, E- W, and N 50– 125
- the compressive phases responsible for the implementation of thrust sheets and various folded structures of the external Rif. The essentially structures of this phase are the inverse faults E - W and N – S, N 150 – 25, Strike-slip faults NW-SE and NE-SW and axes folds N 120 and N 50.
- the continental shelf is similar to semi graben structures related to Atlantic rifting.

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References

1. Durand Delga M., Hottinger L., Marcais J., Mattauer M., Millard Y., Suter G., *M.h. Geol. ser. Soc. French (mem. book P. Fallot) t.1* (1960- 62) 399-422.
2. Suter G., Fiechter G., *Note & Mem. Geol. Serv. Morocco*, t. 26. 188 (1966) 15- 20.
3. Chalouan A., Michard A., El Kadiri Kh., Negro F., Frizon De Lamotte D., Soto J.I., Saddiqi O., *Earth science, Springer*. (2008) 424.
4. Tejera De León J., *PHD, Univ. Pau, French* (1993) 323.
5. Snoussi M., *3th cycle thesis, Univ. Mohammed V, Rabat. Morocco* (1980) 5-17.
6. Benyaich A., *PHD. Univ. Pau.French*. (1991) 308.
7. Geologic map of Larache. *Notes & Mem, Geol. Serv. Rabat. Morocco*, 382 (1994).

8. Andrieux J., *Notes & Mem. Geol. Serv. Rabat. Morocco* (1971) 2.
9. Leblanc D., *PHD. Univ. Paul- Sabatier, Toulouse* (1975). 294.
10. Leblanc D., *Notes & Mem. Geol. Ser. Morocco*, 281 (1979) 160.
11. Frizon De Lamotte D., *PHD. Univ. Paris- Sud. Paris, French. 1 vol.* (1979) 175.
12. Wildi W., *Rev. Geol. Dyn. Geogr. Phys, Paris* 24, 3 (1983) 201-259.
13. Abdelkhaliki L., *3th cycle thesis. Univ. Mohammed V. Rabat* (1997) 176.
14. Chaouni A., *PHD, Université Mohamed V, Rabat* (1999) 284.
15. El Gharbaoui A. *Climates. Big Encyclopaedic of Morocco*, vol 3 (1989) 231.
16. Griboulard R. *BULL, Inst, Bss, Aquit, 33, Bordeaux* (1983) 25-37
17. Collina-Girard J., Griboulard R., *Geol. Medit. XVII, 2* (1990) 153-171.
18. Naudin JJ., Prud'homme R., *Bull, Inst, Geol, 10, Bss, Aquit* (1971) p.111-114.
19. Naudin JJ., *PHD, 694, T2, Univ Bordeaux1* (1981) 472.
20. ANCFCC (National land conservation agency). *Topographic maps of Asila, Larbaâ Ayacha, Khemis Sahel Tnin Sidi Yamani, Larache Bou Safi and Tlata Rissana, scale 1:25000. Rabat- Morocco* (2006)
21. IHM (Spanish Navy Hydrographic Institute). *Nautical chart number 447 (scale 1:52500)* (1950)
22. Missenard Y., *PHD. Univ. Cergy Pontoise, French*, (2006) 236.
23. Maad N., Le Roy P., Sahabi M., Gutscher M.A., Hssain M., Babonneau N., Rabineau M., Van Vliet, Lanoe B., *C. R. Geoscience* 342 (2010) 731–740.
24. Suter G., *Notes & Mem. Geo. Serv. Morocco* 245 a & b (1980).
25. Vanney J.R., *SEDES. Paris* (1977) 473.

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