THE PO RIVER DELTA EVOLUTION

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Abstract. The aim of this work is to consider the influence of natural climatic changes on the evolution of the Po river delta (Adriatic Sea) and the possible implication of the man activity on the configuration of the present coastline.
Key words: Po river delta, coastal evolution, climatic changes.

INTRODUCTION

The Po river, delta which developed out of the Adriatic Sea, is surrounded by the Venice Lagoon in the North and the sandy littoral of the Romagna (Ravenna) with the Po plain on the back, at the South up to the promontory of Gabicce, where the Apennines mountains meet the Adriatic Sea (Fig.1).

Fig.1 The Po River delta (Adriatic Sea)

The Po river delta covers a surface of 73,000 hectares of which 60,000 are reclaimed land and the remainder are brackish lagoons, with dams or open foreshores and emerging sandy banks.

In ancient times, the uncontrolled river system, subject to periodical ruinous floods, caused serious problems to the first man settlements on the Po plain. Periodical breaches, caused by floods during periods of bad weather, modified the hydrology and morphology of the Po plain and the configuration of the Po delta.

The dynamic advancement of the Po river delta is quite simple. The sediments carried by the river to the sea are discharged at the river mouths, where they are reworked by wave action to form sand bars both at the front and at the sides of the mouths. If the supply of sediment is great and constant the bars tend to grow and emerge; they are fixed by marsh vegetation and join the mainland. Therefore we obtain an area of lagoons and small pockets of water behind the delta system. Such a process can be cyclical.

EVOLUTIONAL TREND

If we consider the evolutional trend of the Po river delta, in the Adriatic Sea, from 1600 up to the present time (Fig.2) we note that the coastline is continuously growing seaward, mainly in the past times.

We have a lower rate of growth in the earliest years of the 20th Century. This low increase is continuous as it testified by the 1953 survey. Then we have in the 1964 survey an inversion in the trend: this means that the coastline moved back toward the land in the external area of the delta.

If we examine the evolution of the river 1600 A.D., we note, from historical sources, some natural and artificial events changing the hydrography of the Po river and its delta in the coastal zone.

An important event, the "breach of Ficarolo", occurred in the twelfth century (1125) near Ferrara (Fig.3) in the left bank of the Po and caused the main riverbed to move northward with its abundant sediment yield. By 1500, the southern Venetian Lagoon was on the verge of being filled in, jeopardising port activity. To avoid this, the Venetian Republic around 1600 diverted the Po to the south (Fig.4-5) by constructing the 7 km long canal, "Taglio di Porto Viro". After its construction, the Po Delta began to take on its present

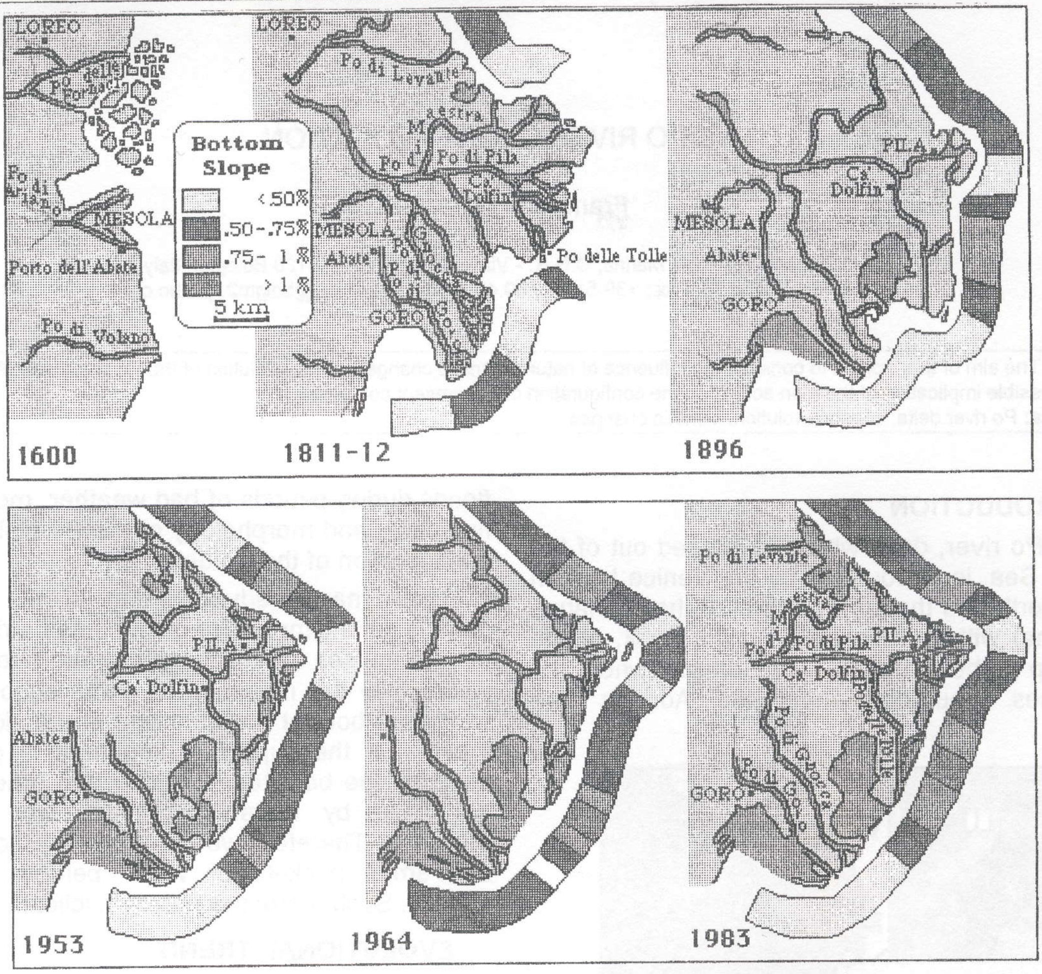


Fig.2 The Po river delta from 1600 to 1983 with the variations of the bottom slope from the shoreline to the 5 m isobath (Carbognin et Marabini, 1989)

Fig.3 The hydrography of the Po river after the "Ficarolo breach" (1125) (after Ciabatti, 1967)

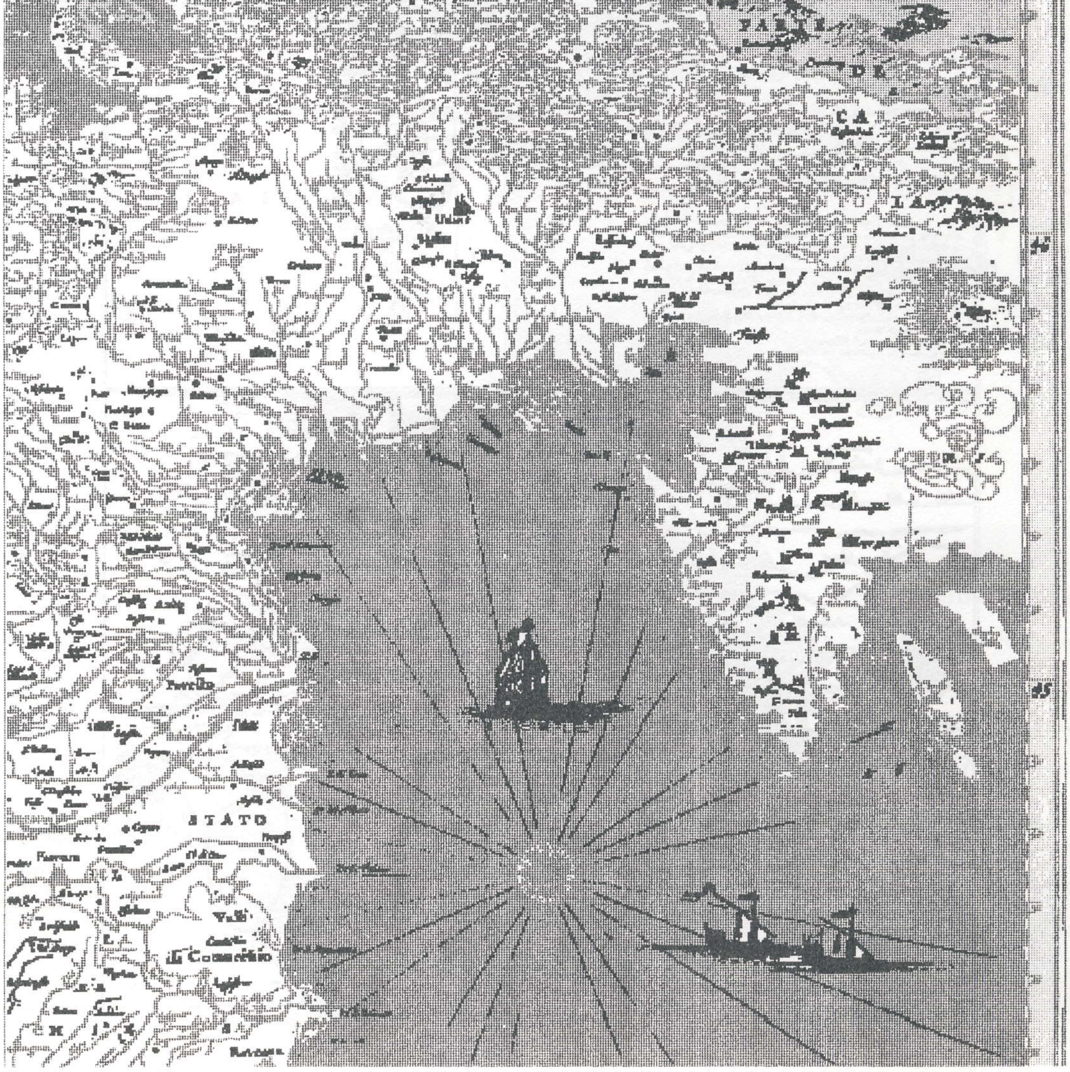


Fig.4 Old map (1600) showing the developing into the sea of the river mouths and the main mouth of the Po to Northwards before the diversion to South

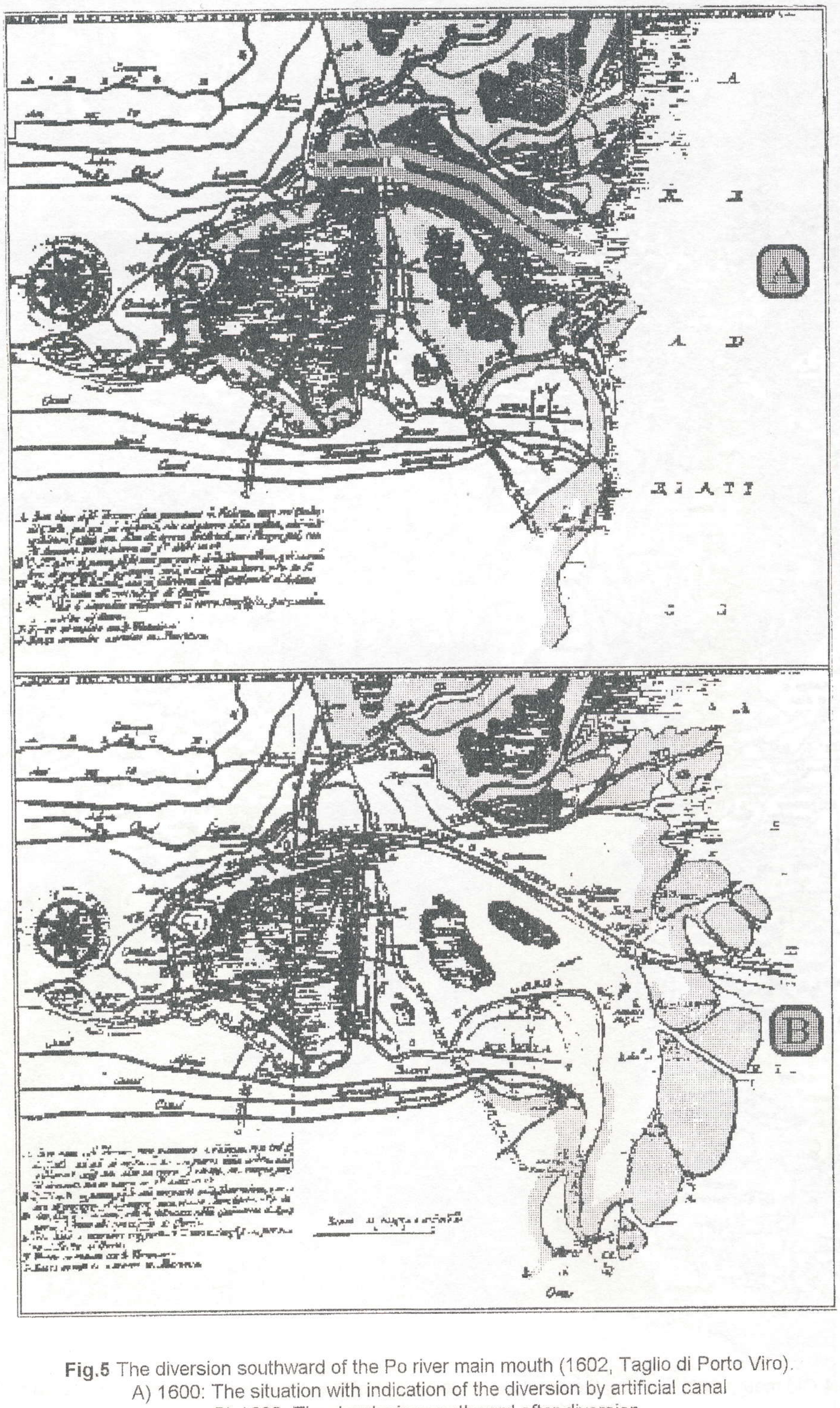


Fig.5 The diversion southward of the Po river main mouth (1602, Taglio di Porto Viro).
A) 1600: The situation with indication of the diversion by artificial canal
B) 1690: The developing southward after diversion.

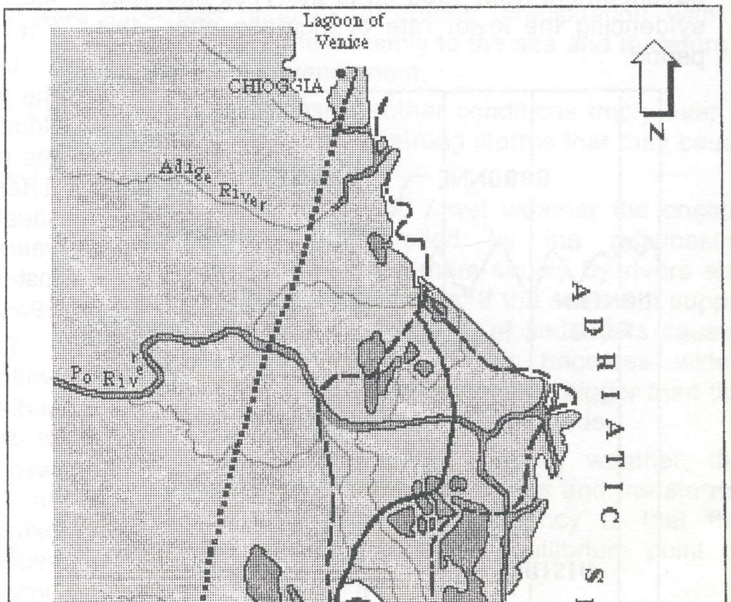


Fig.6 Evolution of the Po river delta (Nelson, 1970)

Fig.7 Dendrochronological standard curve from 436 A.D. up to the present time (Bartholin, 1984).

configuration with an accretion velocity much greater than the previous one toward the south.

Fig.6 shows a synthesis of the long term evolution of the Po river delta (Nelson, 1970) from 1000 B. C. up to the present time. The comparison among the shorelines points out the main advancement from 1600 up to the 1750 and 1820 evidencing the lower rate of increase after this period.

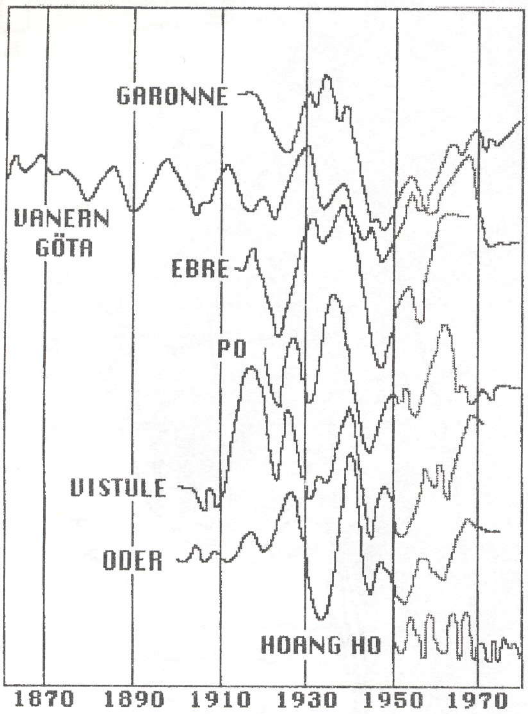


Fig.8 Discharge of the European rivers (Tardy, 1986) and the comparison with the Yellow river in China.

To explain the different rate of advancement in different periods it is necessary consider the climatic changes.

At the end of the last century, Brückner (1890) published a study pointing out a sequence of climatic fluctuations based on the comparison of meteorological data which resulted similar, for the same period, in different parts of the Northern Hemisphere. Using geological, geomorphological, glacio-logical, palaeobotanical, archaeological and historical investigations, it has been possible to reconstruct the sequence of climatic variations with god accuracy for the period in question.

The identified climatic fluctuations of some hundred years are cold/wet periods alternated with warm/dry periods.

These cold/wet periods alternated with warm/dry periods have been well identified by the dendrochronological curves (Fig.7). Within these "large scale" periods, small climatic fluctuations of 10-35 years continued with cold/wet and warm/ dry cycles up to the present time.

It is interesting to note the correspondence between the major development of the Po delta system and the cold/wet weather conditions. It is particularly evident for the Ficarolo breach (XII Century) due to a bad climatic period.

Another example is the large advancement of the Po delta building from 1600 up to 1820 (see Fig.6) during the " little ice age".

In the present time, from the end of the '70s, the warm/dry weather without abundance of rain, floods and storms indicates a calm situation along the coast after the precedent cold/wet period. The difference between the present and the past situation is that the last critical period; around 20 years, produced a regression of the shoreline instead of an advancement, evidenced by maps 1953-1964 in Fig.2.

This means that the violence of the storms waves prevailed on the natural nourishment of the sediment yield by the river. This new result is due to the man activity on the coastal zone (artificial rash removals of river bed material, destruction of sand dunes, the subsidence by the artificial extractions of fluids, etc.) that diminished the sediment yield to the sea and permitted the prevailing of the storm attack during the cold/wet weather conditions. This reconstruction valid for the Po river delta may be utilised even for other very far coastal stretches. It is very interesting to consider how the climatic changes noted by Brückner and other scientists in Europe are present, in the same periods, everywhere in the world.

Fig.8 (tardy 1986) shows the discharge of main European rivers from 1870 and the comparison with the Yellow river in China. The coincidence of events in the same periods in Europe and China is evident. The comparison between the variations of temperature from 1500 up to the present time in England and China (Fig.9) shows the coincidence again in the same periods. Fig.10 shows a comparison among two dendrochronologic curves, of white mountains in California and northern Europe respectively, and the variations of world temperature from 1000 A. D. up to the present time; even in this case the coincidence is evident.

On the other hand if we compare the shape of the Nile with a dendrochronological curves (Fig.11), we note a corresponding warm/dry periods with floods and cold/wet periods with the lower Nile from 500 B.C. up to the present time. This is in contrast with the general trend evidenced before: cold/wet weather=rainless, floods of the rivers, and high sediment yield, but if we consider the course of the Nile river born in the equatorial area, where receive the main supply of water and then cross, from South to North, the desert region of Sudan and Egypt before arriving to the

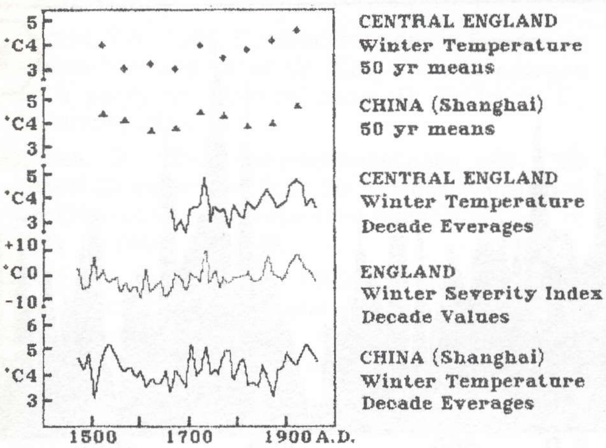


Fig.9 Comparison between the winter temperature records for England and China since 1500 A.D. (Lamb, 1982).

Mediterranean Sea, it is possible to find the reason for this behaviour.

Fig.12 shows the variations of climatic zones during cold/wet and warm/dry periods in Europe and Africa (F. Ortolani, S. Pagliuca, 1995).

The results of the comparison, according to the available data, indicates that the climatic zones can shift 8°-10° latitude northward and southward, owing to an enlargement of the equatorial area, during the warmer periods and to an enlargement of the ice capes during the colder periods.

The major extension of the cold climatic conditions during the cold/wet periods to the South produces a contraction of the areal dimensions of the equatorial zone with a consequent decrease in rain amount. On the contrary, the retire to the northern regions of the cold climatic conditions, during the warm/dry periods, produces and increase of the areal dimension of the equatorial zone with consequent increase of rain amount increasing floods arriving to the Nile delta in the Mediterranean Sea (F. Ortolani, S. Pagliuca. 1995).

It means that the environmental effect of the same climatic phases is different, according to the latitude, and for this reason there are the same shapes for the Po river (Italy) and the Yellow river (China) (Fig.8) and a different shape for the Nile river (Fig.10).

It means that rivers comprised between the latitudinal stretch 30°-50° have same effects on the environment following the short-time climatic fluctuations.

This result starting from the study of the Po river delta evolution, points a new and more complete vision of the evolution of the coastal environment, not only for the Adriatic Sea, but extended to a large latitudinal stretch of the northern hemisphere.

Our conclusion is that the effect of climatic changes on the evolution of the natural environment is of primary importance today like in the past. But one cannot simply state that cold/wet climate induces a greater precipitation with a greater sediment supply to the sea and therefore a shoreline advancement.

In fact, these weather conditions imply even a greater frequency of strong storms that may cause a shoreline regression.

In a period of cold / wet weather the coastal equilibrium is controlled by the relationship between the large sediment supply by rivers and frequency of strong storms. If the sediment supply is greater than the removal of sediments caused by wave action, the beach becomes wider. Instead, if the sediment removal is bigger than the supply, the coastline moves backwards.

In a period of warm and dry weather, the sediment supply to the sea is less and the storms are rare. Therefore, the tendency is that the coastline moves around an equilibrium point or moves slightly seawards.

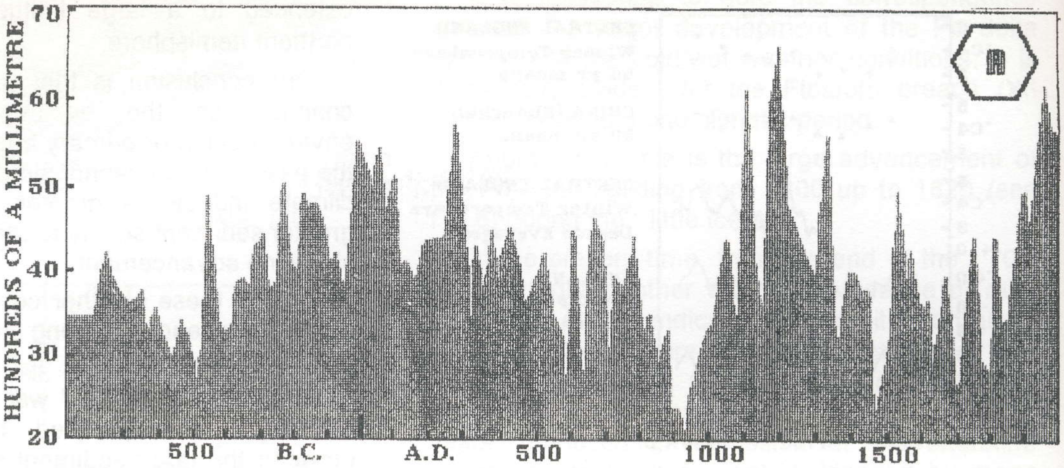
From that one can say that cold and wet weather conditions are determinant for coastal evolution.

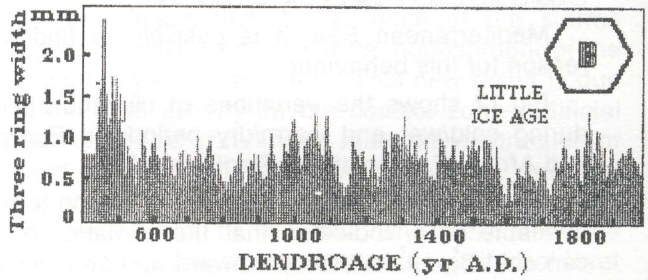
The reason of the big development of the coastal zone from 1600 up the last century is that the fluvial sediment input, connected with the "little ice age" climate condition, has been much greater than the output caused by the attack of the waves in storm conditions.

The smaller climatic variations, with a 10 -35 year period, have induced a progressive reduction in the coastline advancement, since the beginning of the present century reaching its full development during the '50s, when the sediment supply, typical of cold periods, became inadequate because of the man activity on the coastal zone and on the areas lying behind.

This caused that in such an environment with lack of sediment supply from the rivers, the wave action has become the control parameter which causes erosion.

This first attempt to examine the coastal area and understand the evolutional trend under a new and more comprehensive point of view, suggests that if it is possible to predict bad weather conditions and danger for coastal environment, it becomes possible to undertake preventive actions on the coastal zone which have, as yet, never been made.





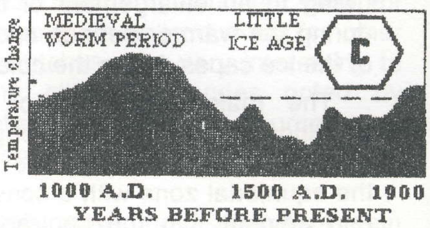
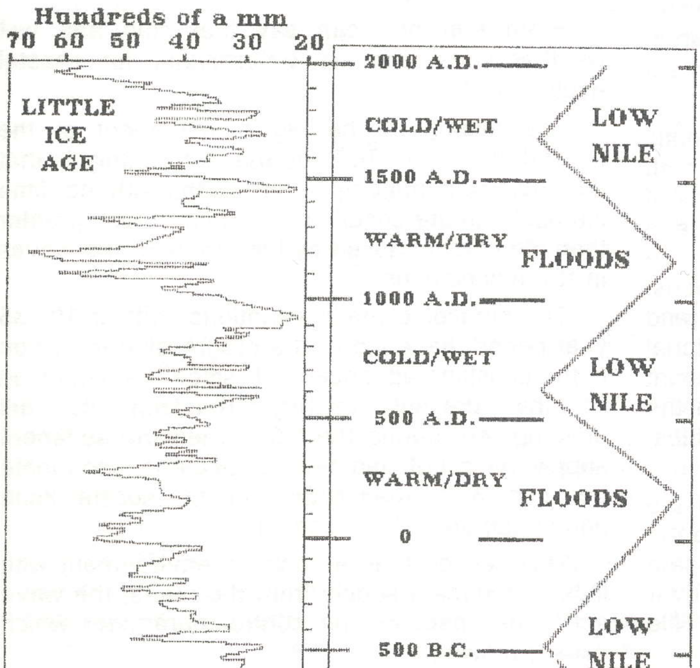


Fig.10 A) Dendrochronological curve of the White Mountains in California (Lamb, 1982). B) Dendrochronological standard curve in Sweden (Bartholin, 1984). C) Diagram of the global temperature variations from 900 A.D. up to the present time (Lamb, 1982).

Fig.11 Schematic reconstruction of the floods and low Nile from 500 B.C. up to the present time correlated with the climatic fluctuations of the dendrochronological curve.



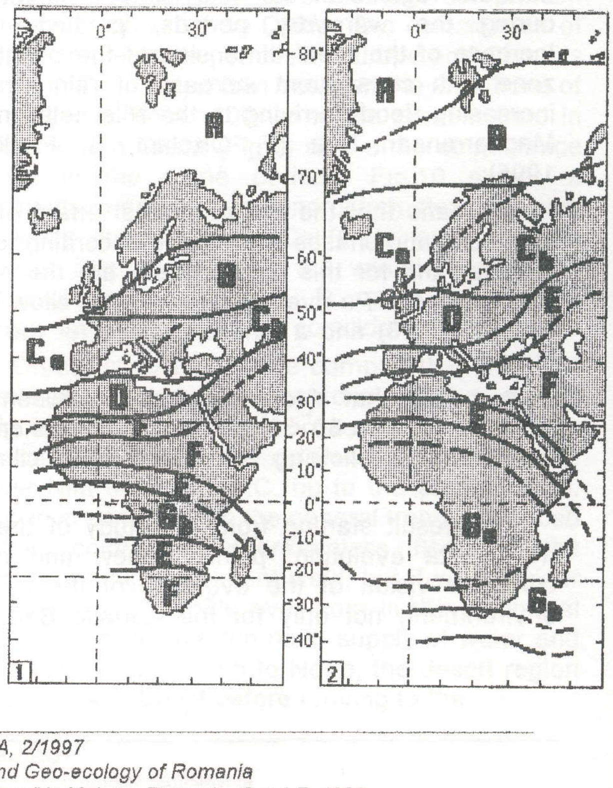


Fig.12 The variation of the climatic zones (Ortolani-Pagliuca, 1995):
1) Climatic zones position during the cold-humid period.
2) Climatic zones position during the warm-arid period. Scheme of the climatic zones according to Koppen-Geiger classificatio. A = polar zone of the tundra and permafrost; B = cold-humid transitional sub-arctic zone; C = oceanic (C_a) and continental (C_b) humid-temperate zone; D = warm-temperate (with dry summer) Mediterranean zone; E = semiarid transitional steppe zone; F = warm-arid desert zone; G = equatorial zone of the pluvial forest (G_a) and Savannah (G_b).

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