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THE OLVIOS, RETHIS AND INACHOS DRAINAGE SYSTEM EVOLUTION AND HUMAN ACTIVITIES INFLUNCE OF THEIR FUTURE EVOLUTION

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Abstract

Olvios, Rethis and Inachos Rivers are multistory drainage systems that occur in Northern Peloponnesus, and at the present day they have and a reversed, North to South, flow element. Dervenios, Skoupeikos and Fonissa Rivers are the misfit streams of Olvios and revealed as juvenile streams and discharge to the Corinth gulf. Agiorgitikos River is the misfit stream of Rethis River and Seliandros River is the juvenile stream. Asopos, Nemeas and Rachiani Rives are the misfit streams of Inachos River and they also discharge to the Corinth gulf. Asopos River characterized as re-established stream. Physical factors such as tectonic regime (active and inactive faults), lithology, erosion and distance from the source influenced the three drainage systems evolution and could be influence them also in the future. The increase of human activities both in their southern parts and in the distal parts close to the coast could be change the physical evolution of the studied drainages, producing a new wind gap in the coastal area and a lake or a lagoon backwards of the coastal area, destroying villages and towns.

Key words: *wind gap, multistory, reverse, misfit, human activities.*

1. Introduction

North Peloponnesus composes an area that liables to extensive uplift movements during the Quaternary period (Bousquet et al., 1977; Armijo et al., 1996). The dominant structure that affects North Peloponnesus as well as the study area is the Corinth graben.

Intrabasinal basement highs and transfer faults in a distance from the source area, and the underlying geology influence the drainage pattern and the evolution of the 3 drainage basins in the northern Peloponnesus. The river drainages of North Peloponnesus were classified according to Seger and Alexander (1993) while this classification was modified by Zelilidis (2000). We classified the drainage systems as multistory, re-established, and juvenile drainage patterns according to Zelilidis (2000) modified types.

A multistory drainage type consists of both re-established and reverse drainage. Reversed drainage is when the flow direction along a part of a river is reversed, caused by tectonic deformation of the river-bed. This consists of two opposing drainage components: a misfit and a reversed element; the area between these two elements that is the result tectonic deformation, is termed a "wind gap", is

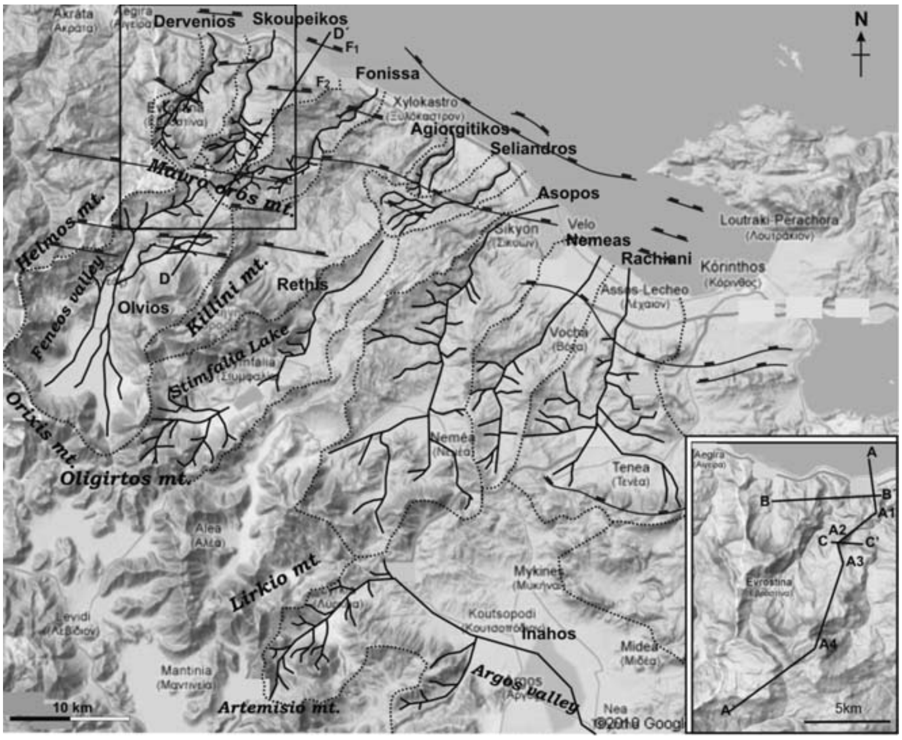

Fig. 1: Topographic map showing the three studied drainage systems with their individual river drainages and main tectonic structures that influence drainage evolution. The topographic relief based on Google map.

a dry valley. An antecedent drainage is when a river has maintained its course an area of the crust that was raised across its path by folding or faulting. A re-established drainage is when a reverse drainage establishes again its initial flow. Juvenile drainage basins consist of small incising and headward-eroding streams.

The aim of the present study is to present the evolutionary potential models of the above drainage networks (Olvios, Rethis and Inachos), based in the existence tectonic regime and the humanities interventions (Fig. 1, 3). For the accomplishment of the study structural, sedimentary and geomorphologic data were used. Topographic sections were constructed along lines parallel and perpendicular to the drainage networks (Fig. 2). The uplift and erosion rates of the study area were also calculated (Fig. 4). At the same time, the human activities and their consequences were also assessed in the aforementioned drainage systems. Eventually, a predictable evolution model of the drainage networks was created, exclusively depending on human act in the coastal zone of the studied area.

2. Geological setting

The Corinth graben is 100km long and 40km wide, and characterized an area of rapid subsidence that separates continental Greece from Peloponnesus. According to Poulimenos et al., (1989), Doutsos & Piper (1990) and Poulimenos (1993), WNW – trend listric faults are the major faults that influence the basin evolution, forming asymmetric grabens. Due to the (synthetic or counter) major faults that deep northwards, several tilted blocks dipping southwards were formed and a wedge – shaped terrigenous clastic sequence accumulated during tilting. Many major faults are accompanied by one to three minor faults that deep southwards, called “backward” or “antithetic faults”, showing smaller displacement, which tend to reduce the structural relief. Numerous WNW – trending master faults terminate abruptly at NNE – trending “cross – faults” or “transfer” faults. The synchronous activity of master (synthetic), minor (antithetic) and cross – faults (transfer) influenced the basin configuration and the depositional environments. As a result, several small sub – basins were formed at the southern margins of the Corinth graben (Poulimenos, 1993; Zelilidis & Kontopoulos, 1996) such as Egio and Kalavryta sub – basins (IGME, 1969, 1970, 1973, 1975).

During the Late Pliocene, the marine Corinth graben was almost twice the width of the modern Gulf of Corinth. Subsequently, the tectonic activity in northern Peloponnesus migrated basinwards, (northwards) with uplift and back-tilting of the footwall of active faults (Poulimenos, 1993). Tectonic activity seems to be stronger at the western parts of the Corinth basins than in the eastern parts.

Olvios River is located at the north of Peloponnesus, especially in the western margins of the Corinth district (Fig. 1). It is bounded from Mavro Mountain in the north, Oligirtos and Orixis Mountains in the south, Kyllini Mountain in the east and Helmos Mountain in the west. It runs through the Feneos valley and ends in the Corinth Gulf with a misfit element and two juvenile rivers. Olvios River flows from north to the south and in relation with the fact that the drainage basin is closed, the drainage is underground through three catavothres which occur in the southern part of the Feneos polje. Dervenios and Skoupeikos are the juvenile rivers and Fonissa is the misfit river. These flow in a direction opposite to the Olvios River flow and their drainages basins are smaller in relation to Olvios River drainage (Tab. 1)(Fig. 1). The three rivers flow into the south coast of the Corinth gulf and have developed in their river mouths small fan deltas (Gaki-Papanastasiou et al., 2006).

Rethis River is located eastern to Olvios River at the north Peloponnesus (Fig. 1). The modern Rethis River consists of a reverse element discharging into Stymfalia Lake, with a north to south direction flow, a misfit element Agiorgitikos and a juvenile Seliandros, which discharge into the Corinth gulf with an opposite in relation to Rethis river flow (Tab. 1)(Fig. 1).

Inachos River is located eastern to Olvios and Rethis rivers in the northern Peloponnesus (Fig. 1). The present Inachos consists of a reverse element, that springs from Artemisio Mountain (Malevo), runs through the Argos valley and ends in the Argolikos gulf, of a re-established river Asopos, a misfit river Nemeas and of a juvenile river Rachiani, discharging into the Corinth gulf (Tab. 1)(Fig. 1).

Table 1. The three studied drainage classification with wind-gap lithology.

RIVER DRAINAGE CLASSIFICATION						
MULTISTORY	**REVERSE**	**ANTECEDENT**	**MISFIT**	**JUVENILE**	**RE-ESTABLISHED**	**WIND GAP - LITHOLOGY**
Rethis	Rethis		Agiorgitikos	Seliandros		1st conglomerates
						2nd lacustrine marls
						3rd marine terraces
Olvios	Olvios		Fonissa	Skoupeikos Dervenios		1st cohesive conglomerates
						2nd cohesive conglomerates
Inachos		Inachos	Nemeas	Rachiani	Asopos	1st cohesive conglomerates
						2nd cohesive conglomerates

3. Methods

In order to estimate the future evolution of the three drainage basins and the southeast coastal zone of Corinth gulf, erosion, sedimentation and uplift rates were measured. For succeeding this, topographic sections were constructed along and across of the streambed (e.g. cross-cuts for Olvios drainage in Fig. 2). The geomorphology and lithology of the region were studied and the angle of slope as well, to estimate erosion rates.

Finally, the major faults were traced and the uplift rates were estimated of the extensive Central – North Peloponnesus area, in order to find the erosion – uplift ratio and moved on to the construction of the evolution models of the drainage networks (Fig. 3).

In order to estimate the erosion rate, we used the difference of the altitude between the uplifted areas (higher altitude) and the river banks (lower altitude) (geological maps IGME 1969, 1970, 1973, 1975), taking into account the knowledge of rivers age development (Fig. 2). The estimated erosion rates, which range from 0,027 to 2,4mm/year, and the presence of a wide area on which the produced sediments move, led us to accept that sedimentation rate is practically insignificant.

4. Paleogeographical evolution of drainage networks

Olvios, Rethis and Inachos River hydrographic networks were classified as multistory drainage with a dendritic distribution (Fig. 1). It is obvious, they indicate that the current flow is reversed compared to the initial flow. Their initial flow was northwards with an antecedent character. This northern flow changed due to the presence of three wind gaps, situated within the Plio – Pleistocene formations, at the northern ends of the Olvios, Rethis and Inachos basins, and could be related with Fonissa, Skoupeikos, Dervenios basins, with Agiorgitikos, Seliandros basins, and with Asopos, Nemeas, Rachiani basins, respectively (Tab. 1) (Zelilidis, 2000; Gaki-Papanastasiou et al., 2006).

These wind gaps indicate that the Olvios, Rethis, Inachos upstreams initially flowed in the present Fonissa, Agiorgitikos and Nemea Rivers, respectively. These last Rivers change to misfit elements in the new reverse drainages during this time period.

Especially, Olvios River comprised an antecedent river, during the Upper Pliocene. Its river mouth were placed over 20km southern than the present coastline of the Corinth gulf (Fig. 3). Later, during the Middle – Upper Pleistocene comprised an integrated drainage network primary with Fonissa River, later with Skoupeikos River and then with Dervenios River.

The Olvios River displacement to the north – northwest is attributed to the gradual and in large uplift rates of the eastern part of studied area, probably due to the effect of the Xylocastro fault that passes through the northern part of the area and presents large action to the east. The modern Olvios River is located in the southern part of the Olvios hydrographic network. During Plio-Pleistocene period Dervenios, Skoupeikos and Fonissa networks did not exist. The Olvios network flowed to the north in the old shaped Corinth gulf (Figs. 1,3)(Gaki-Papanastasiou et al., 2006).

Due to the uplift of Northern Peloponnesus, the Corinth coastline was migrated northern and then followed the elongation of the hydrographic network. The high uplift rates exceed the Olvios River ability to erode vertically upstream during the Upper Pleistocene. So, the initial stream course was destroyed and a reversal flow is produced to the south, forming an internal – close drainage basin. This basin was developed in a closed carstic cavity (Feneos polje). During the continual evolution of the downriver of Olvios, owed to the uplift of North Peloponnesus, and the consequent elongation – extension of the hydrographic network in the north in the floated continent, the hydrographic

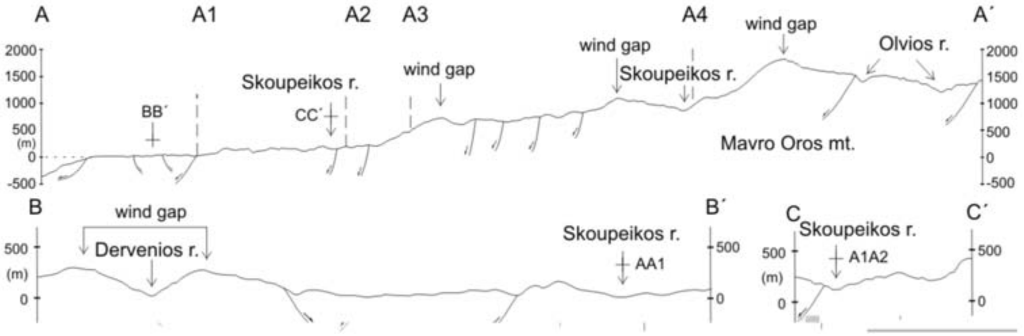

Fig. 2: AA' cross-section along Olvios-Skoupeiko rivers, whereas BB' and CC' are perpendicular to AA' (for details see Fig. 1)(I.G.M.E., 1973, Dervenion Sheet).

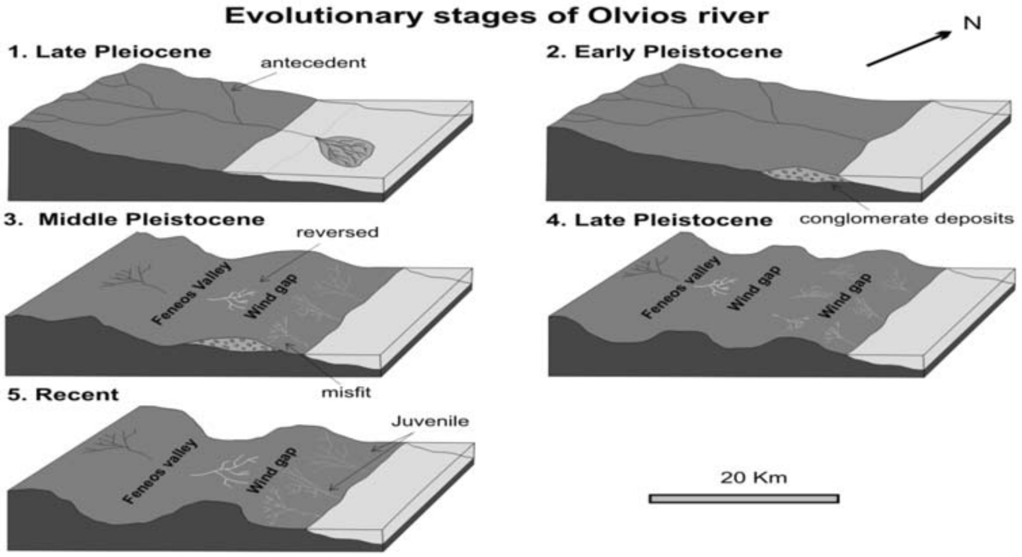

Fig. 3: Multistory drainage evolution models.

networks of Fonissa, Skoupeiko and Dervenio were configured (Fig. 3).

The Rethis River changed to a reverse drainage during Middle Pleistocene (Doutsos & Piper, 1990) and Agiorgitikos was the misfit element. Later, during Late Pleistocene Agiorgitikos River changed again to a reverse drainage system. The reverse element was restricted between the two wind gap areas which were created due to these two successive reverse drainage stages. Human activities (an underground channel) joined the old and the new reverse elements forming the modern Rethis River. During the second reverse drainage evolution Seliandros was developed as a juvenile river. As the tectonic activity migrated basinwards (Corinth gulf), Agiorgitikos and Seliandros changed to reverse drainages, with backtilting of marine terraces, and then returned again to their original flow (northwards) to the Corinth gulf, forming re-established drainages (Zelilidis, 2000).

The Inachos River was poured in its first stages at Corinth gulf. The activity of synthetic and antithetic faults produced a wind gap area, which changed Inachos River to a reverse drainage. Due to this drainage evolution Rachiani and Asopos Rivers were developed as juvenile streams and Nemeas River was the misfit element. As the tectonic activity migrated northwards a second wind gap area was formed. This wind gap area was changed only the Asopos River to a reverse drainage. Later the Asopos River returned to its original flow by eroding the wind gap area, forming a re-established drainage.

Figure 3 is an example from Olvios river drainage and presents the evolutionary stages through the time, of the hydrographic networks from Upper Pliocene till now. The Corinth coastline has approximately plotted, by taking into consideration the present Plio – Pleistocene conglomerates margin, the upper deposits of fans deltas with the Pre-Neogene formations.

5. Discussion and Results

The flow direction of Olvios, Rethis and Inachos multistory drainages and the outcrops aligned in a NNE direction. Synthetic and antithetic faults form intrabasinal highs, while the tectonic activity migrates to the north. The uplift rate in the central part of the Corinth basin is 1,5mm/year (Doutsos & Piper, 1990), which contributes to the intense relief of the adjacent regions. The approximate rate of erosion of the area between the river valley and the adjoining regions about the complex flow systems fluctuates from 0,8 to 1,2mm/year (Zelilidis, 2000).

Generally, the present Olvios river system comprises the area of Feneos Valley, which consists of Pre-Neogene basement, and occurs in altitudes 700 up to 1700m. Additional, the Fonissa, Dervenios and Skoupeikos River drainages, occupy the region from Mauro Mountain up to the coastline of the Corinth gulf and where Plio – Quaternary sediments were accumulated.

Olvios River is evolved in a wide basin which is affected from WNW-directed listric faults, which led to its widening and deepening. The Feneos basin has filled with Plio – Pleistocene sediments, mainly conglomerates, marls, sandy marls and sandstones.

Olvios river in order to recapture its original flow must cover the altitude difference between the lowest point of Feneos valley and the lowest point of wind gap, which is 700m. Based on the measured erosion rate which is over 0,4mm/year and with the assumption that tectonic uplift and sedimentation are zero factors, as the Mauro Mountain area and the Feneos valley were totally uplifted on 1,5mm/year (Doutsos & Piper, 1990) and sedimentation is spread in a large area, Olvios River will approach the wind gap and recapture its first northwards flow in 1.750.000 years (Fig. 4).

Rethis river must cover the altitude difference of the lowest point of Stymfalia Lake and the lowest point of wind gap, which is 230m. Based on the measured erosion rate which is over 0,15mm/year, Rethis River can recapture its first flow direction after 1.533.000 years (Fig. 4).

Inachos River must cover the altitude difference of the lowest point of Lyrkio valley and the lowest point of wind gap, which is 600m. Based on the calculated erosion rate which is over 1,6mm/year can be estimated in what time Inachos River can recapture its first flow direction. Consequently, Inachos River will approach the wind gap and recapture its first northwards flow in 108.750 years (Fig. 4).

From the previous measurements we could conclude that Olvios, Rethis and Inachos rivers are impossible to change naturally due to:

The existent tectonic conditions: The general tectonic of the wider region that is migrated northwards shows a relatively high rate of uplift which have estimated at 1,5mm/year. This suggests the presence of an active tectonic regime. The absence of transfer faults in the region behind the first

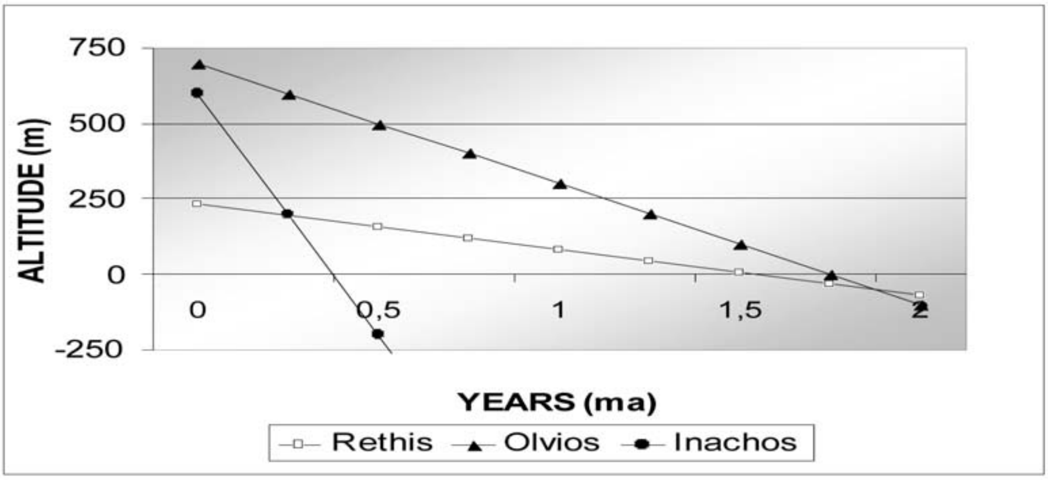

Fig. 4: Re-capture flow diagram for the 3 drainage systems. It shows the time that they need to recapture their original flow correlating with the corresponding erosion rates.

wind gap obstructs the flows of the rivers systems and prevents the regaining of their flow northwards.

The existent lithology: In the north of the Feneos and Lyrkio valley cohesive conglomerate exist, which make the erosion difficult and as a consequence prevent the regaining of the flow of the reversed Olvios and Inachos Rivers because the pace of erosion is slower than the one of lifting.

The human activity: Human activities contribute to the increase of erosion, because of the increasing cultivating activity, the creation of settlements, the uncontrolled pasturing and the construction of a dam in the Feneos valley, strengthening the human impact. Only if human activities which affect the mountain section of the river, that is the source area, erode the area of the wind gap, there is a possibility of regaining its initial flow.

Studying the coastal zone we focus on the active tectonic regime and the depositional conditions, especially in the region between the F1 and F2 faults (Figs 1, 5), in order to establish a future evolution of Dervrnios, Skoupeikos, Fonissa, Agiorgitikos, Seliandros, Asopos, Nemeas and Rachiani river flow.

The northern offshore fault (F1) is placed over 100m from coastline, while the southern onshore fault (F2) is placed over 1km from coastline. (Figs 1, 5) These faults are normal, with a listric geometry producing an uplift rate on their footwall of the order of 1,5mm/year (Doutsos & Piper, 1990). Taking into account the uplift rate on the footwall (1,5mm/year) and in relation to results concerning the uplift/subsidence ratio, estimated 1/2, which corresponds to the Egio and Helike faults (Koukouvelas & Doutsos, 1996; Koukouvelas et al., 2001), we could estimate that subsidence rate of the studied F1 and F2 hangingwalls is about 3mm/year. During the tectonic activity, the block between F1 and F2 faults turns backwards, due to uplift of the footwall of F1 and the subsidence of the hangingwall of F2. The hangingwall of the southern fault (F2) altitude is 80m above sea-level (IGME, 1973), and according to the previous results we could estimate that this region due to subsidence will reach sea level in 26.600 years, without further human influence. This part between the two faults has a sedimentation rate that act against subsidence and was estimated more than 0,2mm/year, as the erosion rate in the footwall of the fault is over 1mm/year. So, finally the hangingwall of F2 will reach the sea level in more than 28.600years.

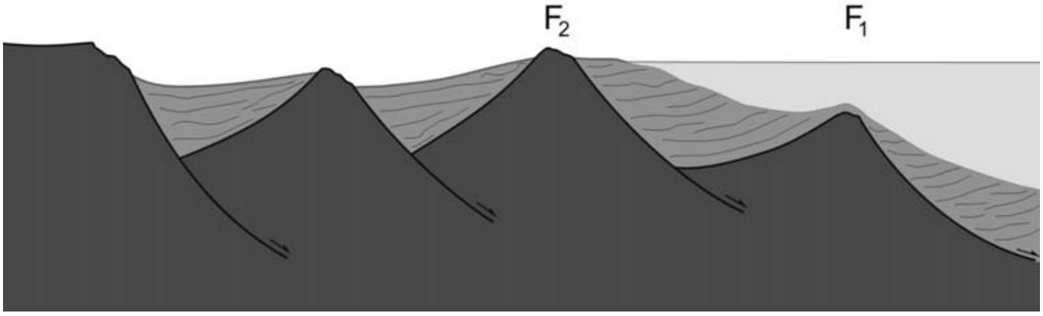

Fig. 5: Schematic cross-section D-D‘ (Fig.1). It shows wedged basins that bounded from listric faults, showing backward turn of the blocks due to surface curve of these faults. The block which bounded between the two faults turns backwards, due to the uplift of the footwall of (F1) and the subsidence of the (F2) fault hangingwall. The above scenario based on the decrease of the erosion on the hangingwall of (F2) and the increase of the erosion on the footwall of (F2).

The measurements with respect to the subsidence rates are the result of natural processes but if taken into account the human factor, that protects the coastal zone by the wave erosion, intensifies the erosion progress to the part that is sung and prevents the sedimentation process in this part, all could be changed. So, considering that the natural erosion rate is 1,2mm/year, the difference subsidence of this region is 4,5mm/year (1,5mm/year uplift rate in coastal zone and 3mm/year subsidence rate in the dipping part) (Fig. 7), the human rate erosion which is 1mm/year and the zero sedimentation, we could estimate that this region will reach in the same altitude in 11.900years (in detail, the dipping part from 80m altitude, will subside 62m, while the raising part from 0m, will uplift 17m) (Fig. 7).This scenario will bring the whole area in a same level, producing a lake. Meanwhile, after 15.380 years the subsiding part will reach the sea level, when the coastal zone will be in a 23m altitude, and so the area could change in a narrow lagoon. Obviously, as human activities increase the erosion rate will also increase. If we will suppose that the human erosion rate will increase at 2mm/year in the next 50years, then the above changes will take place in 10.380years. Concluding we could estimate that every millimeter erosion increase, we decrease about 1500years by the time of change and the creation of a lake in the studied area (Figs 6, 7).

6. Concluded remarks

Considering the above, the coastal zone of North Peloponnesus subsides continuously due to the active tectonic regime. The improvident human interferences can increase the subsidence regime. That event will lead the area behind the coastal zone to become a topographic lower area and as a result the rivers flow direction will shift creating a lake. It is obvious that precaution and the fight of natural disasters which a river system creates, depends on the community will to adjust their inspirations and activities within the framework of constant living and development. This means that communities have to be informed about the dangers, which involved in the uncontrolled exploitation and downgrading of natural resources. Thus they will design adopt and apply policies and strategies of precaution and confrontation of the phenomenon. The achievement of such target demands the common effort of the Government and citizens. This must be within the frame of natural Plans of action against the flooding phenomena, according to the relative Contract of the European Union. The action scheme must comprise a series of technical and social-economic measures and suggestions on the way of their application.

The river ecosystem must be developed without restrictions and it also needs to be acceptable that

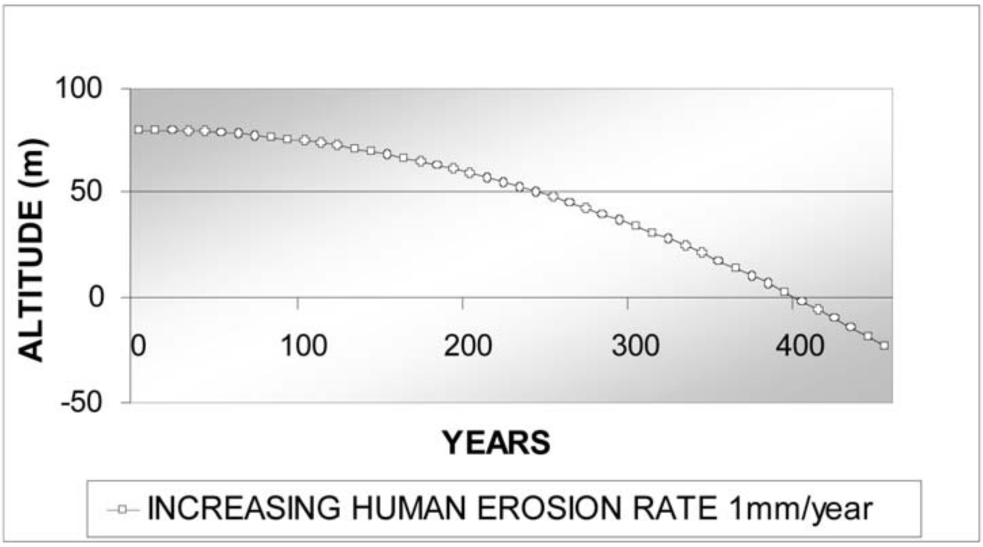

Fig. 6: The diagram represents human erosion rate that increasing 1mm/yr. It is revealed that in over 400yr the altitude will reach the sea level, resulting the transform of coastal zone into a lake.

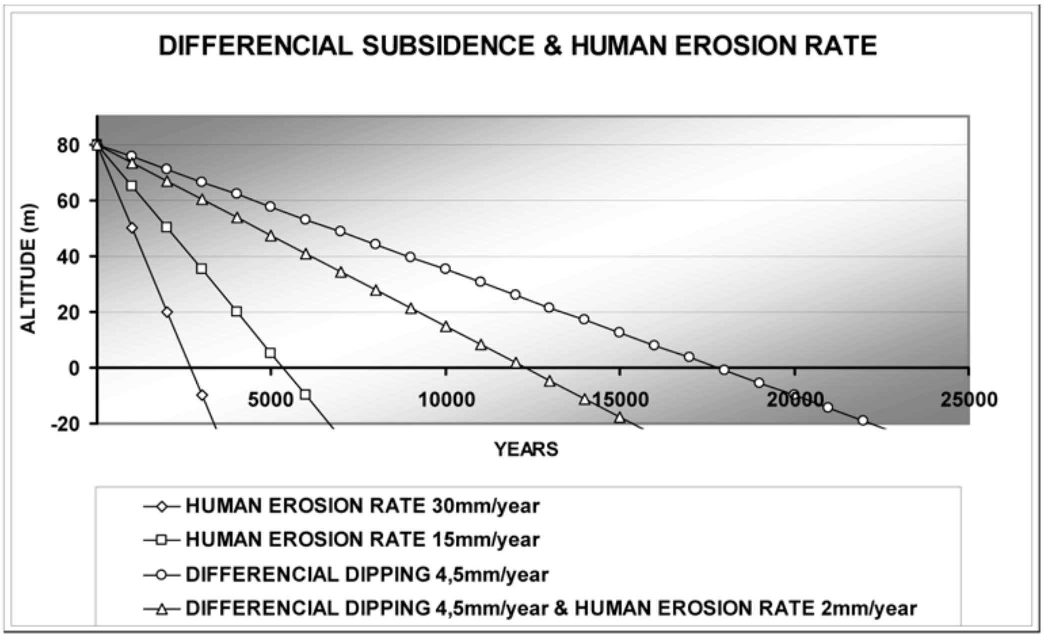

Fig. 7: Differential subsidence and human erosion rate diagram that represent the altitude–ages correlation. The max altitude of the coastal zone is 80m.

the disastrous phenomena are totally essential for the cycle of life and it must not be obstructed by human. Human must organize communities according to their needs but with respect, understanding towards natural – geological processes.

Settlements must be construction according to a city scheme which bans the construction on the floodplain of the river and only specific activities must be permitted on this, like parks, sports stadiums, parking, e.t.c. Boxing of bank of the rivers must be forbidden or any kind of interference on the bank of the river channel, as well as the uncontrolled collection of the bank's materials.

The development of a delta is a natural process which balances the river system and with the contribution of the wave erosion it spread the fertile sediments by building the coastal zone, balancing the wave erosion of coasts.

Consequently, we are all called to take over our responsibilities.

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