

OUTLOOK ON SEAWATERS DYNAMICS AND GEOLOGICAL SETTING FACTORS FOR THE ALBANIAN ADRIATIC COASTLINE DEVELOPMENTS

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Abstract

Results of integrated hydrographical studies and offshore and onshore geological-geophysical surveys in Albanian Adriatic Littoral are presented in this paper.

According to the evaluation of the discharge regime in Albanian rivers system and its impact on the hydromorphology of Adriatic Sea, the river bed deformation, migration and new river mouths investigations, seismic and geoelectrical marine and onshore surveys, geological onshore mapping and underwater offshore sampling, boreholes and oil and gas depth wells, geodesic and bathymetric mapping have been classified the segments which have different geomorphology with in mainland and in marine area of Albanian Adriatic Shelf. Accumulative coastlines are extended at plain areas. Beautiful sandy beaches and dunes are main elements of these areas. Marine Quaternary deposits from plain sea floor up to some kilometers in the land have e thickness from some to hundred meters. Narta, Karavasta, Viluni, Patoku and Kune-Vaini Lagoons are located in plain area of the littoral. These lagoons are formed in some sea bays, which are closed by solid sediments transported by rivers to the sea. Erosive coastlines are extended in the hilly base of some capes. The hills are presented northwestern part of the Neogene's anticlines. Sandstone banc are extended in the sea floor. Neotectonic development at the present has caused submergence of three sectors within the accumulative areas.

1. Introduction

The Albanian coastal area on the East of the South Adriatic and North Ionian has a length of 447 km long (Fig. 1). This area represents the Easter side of Otranto Strait. River mouths and deltas, lagoons system, abandoned riverbeds, marsh labyrinths, sandy beaches, dunes covered with vegetation, dense forests represent Albanian littoral.

According to the studies conclusions results that geomorphologic classification of the Albanian coastal area consist of two principal major paleogeographic zones (Fig. 2, 3):

1- Adriatic Coastline of Peri-Adriatic Depression in the central and northwestern part of Albania. There are three different segments:

- Accumulative segments, which represent main part of the coastline,
- Erosive segments, and
- Submerged littoral areas, where is observed marine ingression toward the mainland.

The Adriatic coastline dynamics geomorphology is conditioned by geological setting of the western side of Albanides, by the neotectonic developments, by the dynamics of the

seawaters, solid material discharge from Albanian River network to the Adriatic Sea, and their deposition along the coastal zone.

- 2- Erosion coastline of Ionian tectonic zone in the southwestern part of Albania

2. Material and methods

- Marine and onshore-integrated surveys and studies for the investigation, monitoring and estimation of the physical characteristics of the Albanian coastal area have been performed during the period 1958-2005.

2.1. Hydrological and hydrogeomorphological, were based on the information of the Albanian hydrometric network that consists more than 220 meteorological and hydrometric stations, during the observed period of 20-100 years data of Albanian Hydrometeorological Institute. There are also 8 coastal stations and 12 other stations installed in the flow of the most important Albanian rivers near the sea.

2.1.1. Hydrological studies: Multi annual hydrometric observations on water levels, temperatures, water discharge into the Adriatic Sea, suspended material discharge; alluvial granulometric composition, water chemical composition etc. were performed in main Albanian rivers. Water potential and run-off discharge regime of the Albanian Mountainous River System have been evaluated by a specific way for two categories of river basins (Pano N. 1984, 1998):

- 1) Drini, Mati, Ishmi, Semani , Vjosa River systems, etc., where the run-off discharge depends from the altitude of the water level river section.
- 2) Scutary Lake-Drini River-Buna River water system, where the discharge of the Buna River, which flows away from the Scutary Lake (Q_2) to the sea, depends from the level of the water (H_2), and by the Drini River discharge in to the Buna River (Q_4):

$$Q_2 = \left\{ 0.025 \cdot \left[H_2 - \frac{Q_4^2}{(0.0073 \cdot H_2^{1.61413})^2} \right]^{1.85} - Q_4 \right\} \quad (1)$$

The calculations have been performed for the models of dry and wet characteristic years. The evotranspiration potential have been calculated by different well-know methods.

Several physical-chemical parameters have been measured: the water velocity and discharge of the rivers and from the lagoons to the Adriatic Sea and to the Ionian seas, and the chemical water content.

2.1.2. Hydrogeomorphological studies were performed to evaluate the geomorphologic characteristics, the evolution and the migration of Albanian Adriatic coastline.

The marine current analyses are based on examination of the filed surveys data and oceanological calculation. The oceanological calculations are realized by dynamic method. This method based on formula:

$$u(z) - u(H) = \frac{10\Delta D}{2\omega h \sin \alpha} \quad (2)$$

- Where: $u(z)$ – the current speed in the sea surface ($z=0$)
 $u(H)$ – the current speed in the calculate surface
 ΔH - the difference of the dynamic altitude
 w - the vector of the speed
 L - distance from two hydrological stations
 α - geographical altitude

The wave refraction in the coastal area is analysed by wave refraction diagrams, by numerical methods solving of system of equations:

$$\left. \begin{aligned} \frac{d\theta}{dy} &= \frac{1}{C} \left(\frac{\partial C}{\partial x} - ctg\theta \cdot \frac{\partial C}{\partial y} \right) \\ \frac{dx}{dy} &= C \cdot tg\theta \end{aligned} \right\} \quad (3)$$

Where: $\theta(x, y)$ - is the angle between the x axis and the tangent of the wave rays at point M(x,y).

$C(x,y)$ – is the wave speed and the same point

(x,y) - is the coordinates of the region.

The geomorphological regime of the Adriatic Sea coastline, have been analyzed based on the examination of archival documentation (Topographic Map of Albania of Austro-Hungarian Institute, 1870, Military Geographic Institute, 1918 and 1938, Soviet Naval Institute, 1955, Albanian Military Topographic Institute, 1958, Land sat imagery of 1978, 2000, 2002 etc). Determination of littoral sediment transport and coastal sedimentation, the classification of erosion and accumulation processes under the wave refraction etc. are studied by analyzing of marine and onshore surveys data.

2.1.3. Limnological observations on the Albanian lagoon system were performed in hydrometric stations and by periodical expeditions for study of the water physic-chemical characteristics, measuring the discharge in the water channels with the sea, sediment granulometrical analyses, and the evaporation of the lagoon water surfaces

2.2. Oceanographic studies: Water levels, temperatures and chemical content etc., formation and circulation of the water mass, wave and wind regimes of the Adriatic and Ionian coastline have been study in the hydrometric station network since 1958. Two Albanian oceanographic expedition “Saranda-1963” and “Patos-1964”, and two joint Italian-Albanian expeditions “Italica I -2001” and “Italica II-2002” were organized in the Southern Adriatic and Northern Ionian.

2.3. Integrated geological-geophysical: onshore surveys of the Albanian littoral areas have begun since 1958. Offshore geological-geophysical surveys on the Albanian Adriatic shoal shelf have started from 1976 (Fig. 1, 2). Marine geological mapping has been performed using submarine surveys, shallow mapping boreholes and dredge’s sampling. Integrated offshore geophysical surveys have been carried out using reflection seismic of shoal littoral shelf, marine electrical soundings and profiling of apparent resistivity, marine magnetic recognition surveys and marine radiometric surveys. Offshore geological-geophysical surveys were performed in the shoal littoral shelf, with a width of 5-10 km parallel to the coastline. Electrical soundings have a depth of investigation is about 1000-1500 meters, and influence depth is up to 3000 meters.

2.4. Climate change was analyzed by inversion of the ground surface temperature history, using the temperature record in the deep wells and shallow boreholes, and by the meteorological observations data. Have been study the climate change impact on the Adriatic Sea hydrology and on the erosion process in the Albanian River Network.

3. Regional hydrographic outlook on the Albanian Littoral

The Albanian coastal area lies from Shëngjini to Vlora bays and Northern Ionian Sea, from Vlora to Saranda bays at the south (Fig. 1, 2).

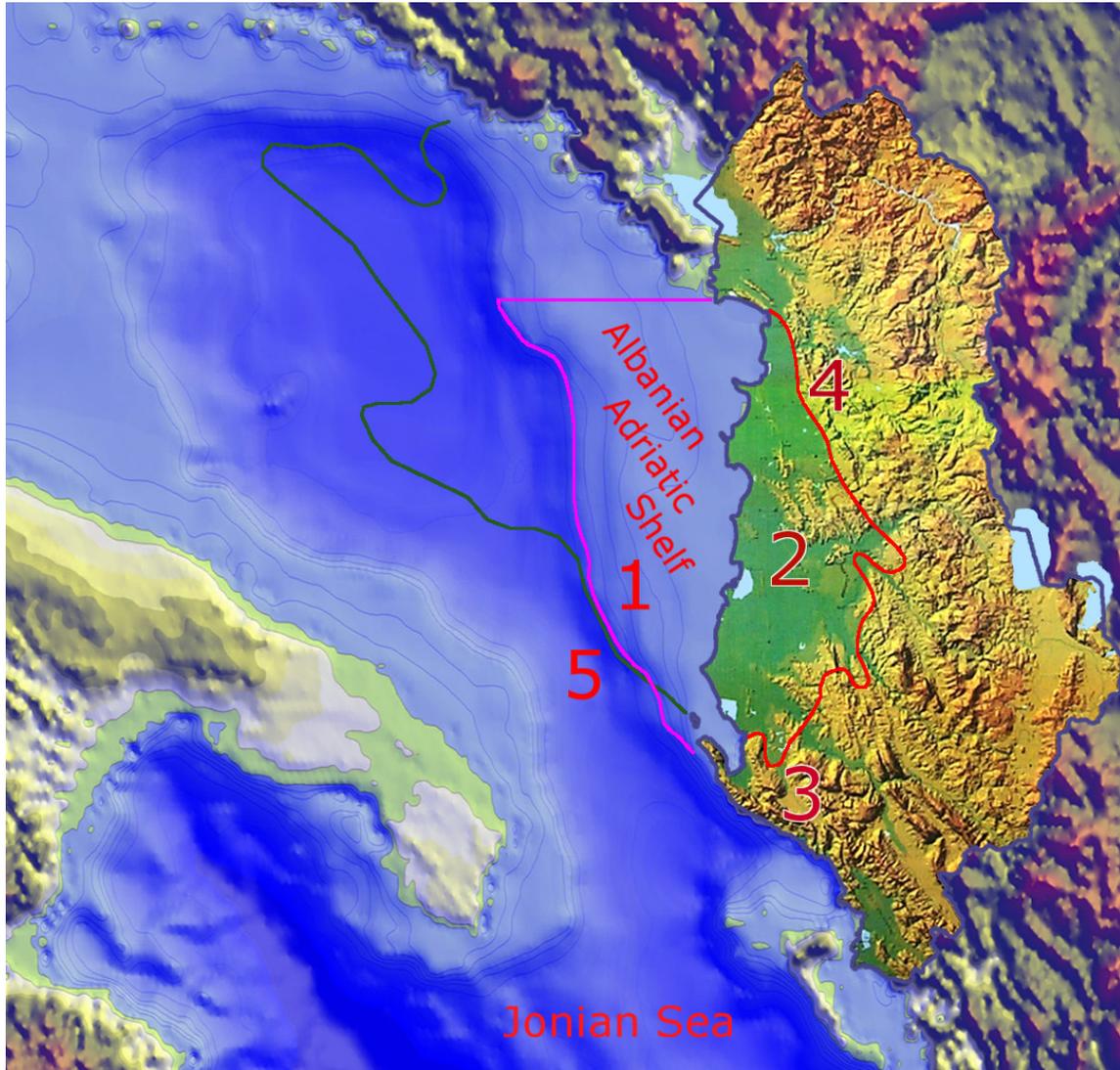


Fig. 1. Albanian Adriatic and Ionian Seas coastline area.

- 1- Albanian Sedimentary Basin;
- 2- Periadriatic Depression;
- 3- Ionian tectonic zone;
- 4- Kruja (Gavrovo-Dalmatic-Montenegro) tectonic zone;
- 5- Apulia platform, Paksos zone.

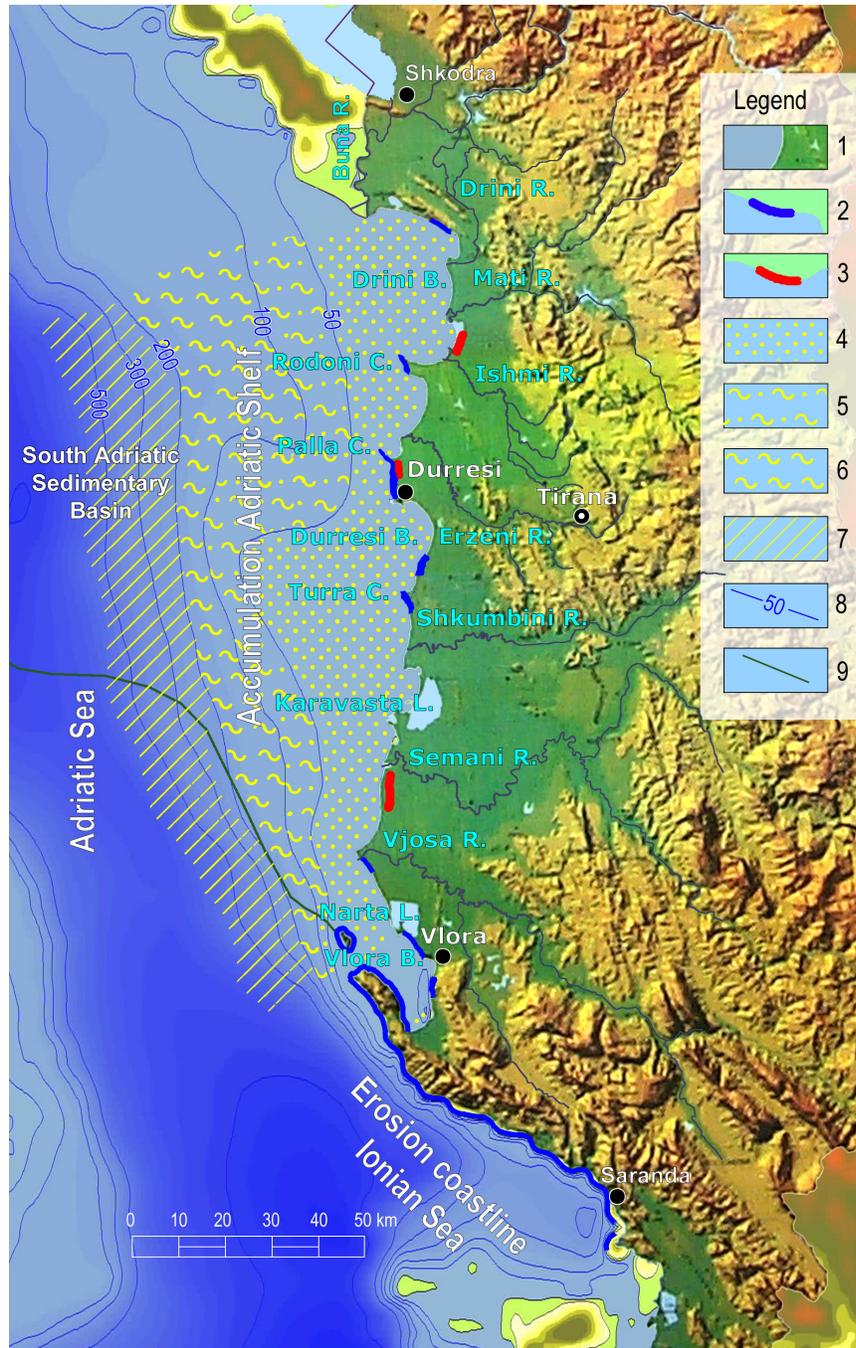


Fig. 2. Geomorphological Scheme of Albanian Adriatic and Ionian Seas coastline. (Digital Terrain Model, National Geophysical Data Center (NGDC), Geodas database, 2005.

1- Accumulative coastline; 2- Erosion coastline; 3- Submerged littoral zone; 4- Shoal shelf area with sand deposits; 5- Flat shelf area with sandy-silt deposits; 6- Inclined shelf area with muddy silt and deposits; 7- Continental slope with argillaceous sediments; 8- Isobaths; 9- Western flank of the South Adriatic Sedimentary Basin.

3.1. Adriatic coastline

Adriatic coastline lies over the Neogene Peri-Adriatic Depression, covered by Quaternary deposits, in western plain areas of Albania (Fig. 3, 4, 5). Flattened accumulative coast is general characteristic of this coastline. There are also some hilly marine caps with cliffed coast. The caps are located in the sectors where the Neogene structure of the Peri-Adriatic Depression are abrupt by coastline and continues in the Adriatic Sea, old river deltas or mouths and submarine coastal bar.

Adriatic coastline is divided in different characteristics zones:

1) Mouth of Buna River at the north to Rodoni Cap coastline. This unit has a length about 60 km and consists for almost 90% of beaches fed by fluvial imputes. The remaining 10% is cliffs. Four rivers outflow within this area: from north to south Buna, Drini, Mati and Ishmi rivers. All together they discharge on average 796 m³/sec of water. The total solid load of the last three rivers is about 21,680x110³ tons/year. Intensive change dynamics were observed in this area (Pano N. 1998).

2) Rodoni Cap, Durrësi Bay up to Shkumbin River mouth coastline. Cape Pallës, Cape Selitës, Lalëzi Bay, Durrësi Bay and Shkumbini River mouth are main sectors of this littoral area. Lalëzi Bay has a length of coastal line of 32 km, and 65% consists of sandy beaches fed by the sediment load of Erzeni River. The remaining 35% consists of rocky cliffs. Durrësi Bay has a length of 35 km from Pallës Cap to the Selitës Cap. Main part of the bay littoral, about the 54% of their length, by sandy beaches is presented. Frequently, with dune ridges, vegetate by pine trees, there are extended. Sediment inputs in to the bay are provided by Darçi River and from beach and cliff erosion.

3) Shkumbin-Seman-Vjosa rivers mouths up to Zvërneci hills coastline, is located in southern part of Central Albania, and have 40 km length. It expands in the western part of Ardenica and Divjaka hills (Photo 1). Karavasta Bay and Karavasta Lagoon are also part of this littoral area. From the geological viewpoint, this territory represents a new soil, constituted at the end of Pliocene and during Quaternary. The coastline in this region has a very intensive dynamics.

4) Vlora Bay, is represented southeastern edge of Otranto Strait (Photo 2) (Fig. 6, 7). The Upper Cretaceous- Triassic limestone mountains are encircled southwestern and southeastern shores of the bay. In the north, the mountain chain is continued with Neogene's deposits hills. Limestone coast of the Adriatic Sea in Vlora Bay is generally abrupt. At the northwestern direction of the Vlora City, there is a coastline of the Albanian Adriatic Shelf. Configuration the Vlora Bay has started to form from the Pliocene age, when the molasses of the Panaja Hills have been outcropped at surface (Fig. 6-b). Actually, Later Quaternary Marine deposits (Q₄^m) are created the present Vlora Bay (Fig. 6-a). Offshore these deposits (Q₄^m), according to the marine electrical soundings and boreholes, have 190 m thick (Fig.7).

Vlora Bay has a length of 36 km and 10 km width (Fig. 8). The maximal depth of this bay is 57 m. The coastline of Vlora Bay-Vjosa River Mouth area has continuously modified its configuration by sedimentation of alluvium transported by Vjosa River water and the swell of the Adriatic Sea. The coastal area is characterized by prevalence of winds blowing from the NW direction with a maximal speed 35-45 m/sec. The tidal range in this part of Adriatic Sea is low, reaching a maximum of 30-50 cm. The wave action is characterized by calm in 35% of the cases, by wave with a higher of less than 0.5 m in 20% of cases and waves higher than 2.00 m in 3% of cases.

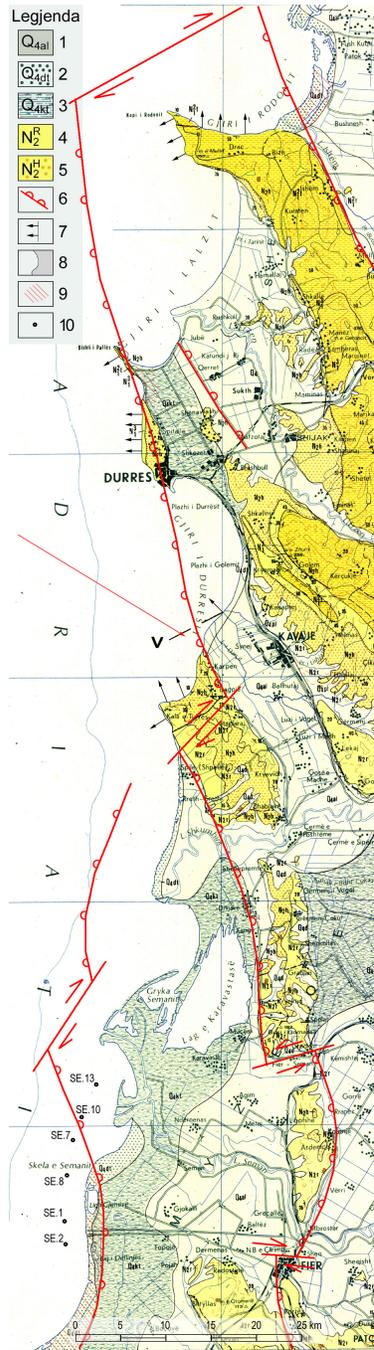


Fig. 3. General Geomorphological Evolution view of the Vjosa River Mouth- Mati River Mouth in the Albanian Adriatic Littoral. (Geologic Map of Albania, at scale 1:200.000, 1983, the neotectonics active reverse faults & thrusts after Aliaj Sh. et al. 2000).

1- Alluvium Quaternary Deposits; 2- Marine Quaternary deposits; 3- Boggy Quaternary Deposits; 4- Pliocene Rogozhina conglomerate suite; 5- Pliocene Helmësi suite; 6- Neotectonics active reverse fault & thrust; 7- Coastal erosion; 8- Accumulative area; 9- Submerged littoral area; 10- Marine Electrical Sounding center.



Fig. 4. Geomorphological Evolution view of the Drini Bay-Durrësi Bay coastline in the Albanian Adriatic Littoral after satellite images of the period summer 1977 & 2002 (Global Land Cover Facility Landsat, 2005; the neotectonics active reverse faults & thrusts (after Aliaj Sh. et al. 2000).
 1- Active reverse fault & thrust; 2- Dextral strike-slip; 3- Sinistral strike-slip; 4- Old Mati River bed; 5- Wetlands; 6- Erosion and marine ingress; 7- Lagoon extension; 8- Coastal deposition; 9- Lagoon surface diminishing.



Fig. 5. Geomorphologic view of Shkumbini River-Vjosa River mouths coastline after satellite images of the period August 1981 & July 1989 & October 2001 (Global Land Cover Facility Landsat, 2005; the neotectonics active reverse faults & thrusts (after Aliaj Sh. et al. 2000).

1- Active reverse fault & thrust; 2- Dextral strike-slip; 3- Sinistral strike-slip; 4- Old Shkumbini River bed; 5- Coastal deposition with predecessor erosion; 6- Coastal deposition; 7- Coastal erosion; 8- Submerged littoral area.

3.2. Ionian coastline

5. Karaburun to Saranda Bay coastline represents Albanian Riviera (Fig. 1, 2). Mostly erosive coastline lies along 112km of Lower-Upper Jurassic and Upper Cretaceous limestone, and Oligocene flysch formation piedmonts. There are predominating emerged coast and estuary coast in some sectors of streams. High mountains rise up to 2045 m, immersed coast and very clear marine blue water are presented a very beautiful area. Cluffed coast by outcropped limestone layers are characterized western side of the caps. In the beautiful along the some sectors of the coastline are lies, mostly Quaternary proluvial, gravel beaches.

6. Butrinti Bay: An accumulative coastline from Butrinti Lagoon channel to the Pavlë River mouth represents southern edge of the Albanian Ionian littoral. It is western edge of the Vrina field, where flow Pavlë River that has a $6.51 \text{ m}^3/\text{sec}$ averagely water yearly discharge to the Ionian Sea.

3.3. Outlook on Albanian Littoral hydrology

The water flow of the hydrographic network of the Albanian rivers to the seas varies in wide limits. The discharge of the Albanian rivers into the Mediterranean Basin varies in very wide limits, from $Q_0=700-850 \text{ m}^3/\text{s}$ for the hydrological years of a lower precipitation to $Q_0=1850-2150 \text{ m}^3/\text{s}$ for the years of a higher precipitation. The volume of suspended material, which is transported through river network, is $65,7 \cdot 10^6 \text{ ton/year}$, while the turbidity $Q_0=1-260 \text{ g/m}^3$ (Pano N. 1984).

The river suspended matter deposits itself the river mouth in the Adriatic Sea. This process is very dynamic, making the Albanian river's mouths very active. Many changes of the riverbeds position formation of the coastal lagoon, etc. are observed time after time in these mouths. The wind regimes, wave refraction, sea currents, littoral sediment transport, have determined the general dynamics of the change of the Albanian coastline (Pano N. 1994). The period with the wave height of $H_1=(0,1-0,2)\text{m}$ represents about 80% of the general cases, while the height of $H=(0,2-4,5)\text{m}$ about 20% of them for the average multi annual year. The highest waves have a direction from Northwest to West and a maximum wave height about $h=3,5-4,5$ meters near shore (Pano N. et al. 1974, Meçe B. 1978). Sea level has an average daily amplitude 0,30-0,40 meters and a multi annual maximal amplitude $h=1,14-1,53$ meters.

The winds in the Adriatic Sea change their direction and speed during a year period as a result of the typical Mediterranean climate. Intensive winds with their maximal speed of 40 – 45m/s particular of NW, W and SW direction were observed in the coastal area. Winds with varying speed form 10 to 20 m/s, have a bigger frequency on waving process. The average annual temperature of the water varies from $t=17,7^\circ\text{C}$ in Shëngjini to $19,2^\circ\text{C}$ in Saranda bays (Albanian Climate (Tables), 1978, Mici A. etc. 1975).

4. Geological settings of the Albanides littoral

The Albanides represents the assemblage of the geological structures in the territory of Albania form the southern branch of the Mediterranean Alpine Belt. The Albanides are formed by two major palaeogeographic domains: the *Internal Albanides* in the eastern part and the *External Albanides* in the western part of Albania. The Internal Albanides are characterized by the presence of the immense and intensively tectonised ophiolitic belt. The External Albanides developed on the western passive margin and continental shelf of the Adriatic plate (Fig. 1).

Albanian Adriatic Littoral area is located in Albanian Sedimentary Basin, which extends widely into the Adriatic Sea (Fig. 1, 3) (Aliaj Sh. 1989, Frasherri A. 1991, Leci V. et al. 1986, Papa A. 1985). Towards the East, in the mainland, Albanian sedimentary basin is

superposed to the western board of Albanides orogen. In Adriatic shelf, this basin is superposed to the Pliocene-Quaternary platform, which has a basin facies. Albanian sedimentary basin represents a foredeep depression filled with Miocene and Pliocene molasses, and covered by Quaternary deposits (Geological Map of Albanian, 1984). Sandstone-clay Serravalian (N_1^{2s}) deposits transgressively overlies older layers. Tortonian and Messinian sections are represented by sandstone and clay. Pliocene deposits consist of clay and sandstone conglomerate.

Quaternary deposits (Q) at Albanian Adriatic littoral are represented by different genetic types: -clay-silt-sand of marine deposits, which have a thickness which ranges up to 200 meters in the Albanian Adriatic littoral areas. Marine Quaternary suite is composed by gray-yellow silty-clay, clay and quartzose fine-coarse sand, and in any case with heterogeneous dispersed small granule. The Albanian Adriatic coastline has many beautiful sandy beaches. These beaches have different geomorphology, depend on the geology and tectonics of the area. There are located also lagoons and coastal marsh deposits, and alluvial deposits.

Sea-floor geomorphology, the distance from shores, the marine currents, the wave process, the shore lithology and geomorphology, the erosion and accumulation processes, have determined the distribution of the Adriatic Sea floor Quaternary sediments:

In Adriatic Sea Shelf are located some molasses Neogene asymmetric anticlines. The Neogene geological structures of the Peri-Adriatic Depression continued from mainland to the Albanian Adriatic shelf for 5-10 km.

Evolution of Albanian Adriatic coastline has a very intensive dynamics. There is observed old and present shoreline migration up to 5-10 m/year, during the period from 1918 up to 1998. According to submarine geological mapping and geoelectrical survey data, has been determined that marine deep erosion is developed in accumulation littoral of Adriatic shoal. The sandstone banks have been mapped in western submarine anticline limbs.

The Ionian Sea littoral is represented western edge of the Çika anticline belt in Ionian tectonic zone (Io). This zone occurs the southwestern part of Albania and developed in a deep pelagic environment the Upper Triassic. The Permian-Triassic evaporites are the oldest rocks in this zone. Overlying are thick deposits formed by Upper Triassic-lower Jurassic dolomitic limestone and Jurassic-Cretaceous-Palaeogene pelagic cherty limestone. The limestones are overlain by Palaeogenic flysch, an Aquitanian flyschoidal formation and a thin section of Burdigalian-Langhian. Structures are fractured by longitudinal tectonic faults on their western flanks, with thrusting of 5-10 km horizontal displacement.

Paleomagnetic studies have demonstrated that assemblage of the Albanides margin has supported a clockwise rotation with amplitude about 45° , after upper Oligocene. Shkoder-Peje transversal is represented a transition zone between the clockwise rotation of the Albanides and Hellenides and counterclockwise of the Dinarides. Horizontal displacement is about 173 km in southern Albania, for the rotation pole located at Shkoder-Peje transversal. This palaeorotation have important influence on Adriatic Sea morphology.

Geomorphological processes have determined the sea floor topography. Consequently, bathymetric configuration of Albanian Adriatic coastline is similar to the geomorphological configuration.

5. Analyze and results

5.1. Albanian Adriatic Sea Littoral and Quaternary Evolution

Adriatic coastal line from southern city Vlora up to Shëngjini Bay, in the north, have the marine accumulation flattened littoral, the marine erosion coast, and the submerged areas, where is observed marine ingression toward the mainland. In some areas there is cliffed coastline.

5.1.1 .Accumulative areas represents main part of the coastline

Accumulative areas of the Albanian Adriatic Sea Littoral are extended over the edge of western Albanian plains (Photo 1). This littoral is characterized by presence of the different Quaternary (Q) deposits genetic types (Frasheri A. 1961, Frasheri A. et al 1991, Leci V. et al. 1986, Ostrosi 1977):

Marine Quaternary littoral deposits, presented by fine, medium, and coarse gray—white, gray-yellow sand, silty clay and mud interbeds present marine Quaternary littoral deposits. Interbeds thickness varies from 1-10-15 meters. Present days micro and macrofauna of seawaters comes across everywhere (Photo 3).

Very beautiful sandy beaches are extended in Drini, Lalezi, and Durrësi bays, Divjaka, Semani and Vjosa River mouths and at the Vlora Bay (Photo 4, 5). Present time shore sand knolls have a length up to 4-5 km, width 35-80 m and some meters highs. At the northern bays, the coarse sand is predominated. Toward the southern part of Adriatic coastal line, fine and medium sand are predominated. This sand belt are composed by two or three parallel onshore dunes: the first dune is extended directly at the water line, the second at the distance 90-100 m and the third dune 150-200 m. There are concentrated placers of heavy rare and precious minerals (Photo 6). Placers lens have a western dipping with an angle about 5-10°. According to the integrated marine geological-geophysical surveys, in the shore shoal zone, which represents a flat depression up to –50m depths, the Pleistocene up to actually Quaternary sand and sandy silt sediments were distributed, under the waves process and marine currents (Fig. 2) (Leci V. et al. 1986, Papa A. 1985). Towards the flat shelf depression, up to –100m depths, the sandy-silt sediments are representative. In inclined shelf area, up to –200 m depths where are also some submarine hillocks, the muddy silt deposits are distributed. Continental slope by argillaceous sediments is characterized. Lithological changes from the shore to the continental slope area are gradually. There are observed some peculiarities, of river solid load distribution in shelf area, conditioned by marine currents. Typical is “Black sand” zone that is located about 40 km from shore, at the sea depth about 100m. The actually sand sediments have formed a low submarine hillock, where has been old Shkumbini River Mouth (Papa A. 1985). Up to continental slope at the west of the Albanian Adriatic Shelf zone, were observed sand load, which have been transported by marine currents (Pigorini B., 1969). Epidote and other heavy minerals have contented in this load, which are demonstrated that have an origin from ophiolitic Albanides Belt.

The maximal thickness of the Marine Quaternary deposits is observed at the central part of the marine bays, according to the marine electrical soundings and mapping boreholes data (Frashëri A. 1987, Leci V. et al. 1986). In the fig. 6 is presented the thickness map of the Quaternary marine deposits in the Durrësi Bay. The maximal thickness is 48m at the central zone of the bay, about 6 km south of the Durrësi city. Toward the sea depth, the thickness is increased by a gradient 4.5-12 m/km. In the fig. 9 is presented the thickness map of the Quaternary marine deposits in the Vlora Bay, at the western of the Zvërneci area, about 2.4 km from the coastline. In this sector, the Quaternary thickness varies from 65-180 m (Fig. 7). At the marine electrical sounding centers and the deep wells Seman-1 and Seman-3 in mainland of the Semani area shelf, the thickness varies 50m up to 200m.

Buried sand knolls are situated along littoral belt at the mainland. Sandy littoral belt along the accumulative littoral have a width up to 5 km (Photo 7). Sand dunes belts have a length of 25 km. Dunes have a length 2-5-6 km and an average width more of 50-100 m.

Generally, the granulometry of quartzite sand deposits represented by very fine up to medium sand. Thickness of the sand dunes is some meters (2-10 m). Under the sand, the silty-clay or clay layers are located, with a thickness some meters. In many sections, the fine, polymictic, gray sand lays under the clay, which have a thickness more than 10 meters. Loose

sand in the coastal line and clay mud is layered far from coastline lagoons and coastal marsh deposits. These deposits are presented by thin alteration of compact clays, silt-clays and silt beds, with vegetable debris and blue-gray fine organic mater, and saline water macrofauna. These entire Holocene marine deposits layers lies horizontally or with small western dip angle, 7-8° (Photo 6). Alluvial deposits and clayey earth are layered far from the coastline.

Filling process is intensive, generally, in river mouths.

In these accumulative coastline areas there are some relatively small erosion sectors, which are located at the Mati, Erzeni, Shkumbini, Ishmi and Vjosa river mouths. Typical is shore erosion that developed by Darçi River flow in Golemi-Karpen beach sector in the Durrësi Bay, with an erosion rate of 0.5 m/year.

In the shoal shelf zone, at the alluvial sea floor are observed the sandy splits. Typical is a submarine bar, which has been formed by solid load discharged by Buna River in Drini Bay. This split is extended up to Drini River Mouth.

5.1.2 .Erosive zones

Marine deep erosion zones were developed over some sectors in accumulation littoral of Adriatic shoal. These zones are located in the uplifted side of the active reverse fault & thrust (Fig. 3, 4, 5).

The Rodoni, Palla, Selita and Zvërneci capes of the molasses bedrocks of the littoral anticlines of the Periadriatic Depressions have represented the erosion configurations of the Albanian Adriatic sea coastline.

Rodoni Cape. Erosive area is located at the western and northern part of the Cape. Tortonian sandstone-clay banks have been mapped in Adriatic shelf over these sectors.

Durrësi-Pallë Cape area is one most typical erosive segment of the Albanian Adriatic littoral. Durrës-Kepi Pallës coastline is extended along the western flank of the Miocene-Pliocene molasses anticline. Northern pericline and western fold flank are lies under the Adriatic Sea waters. The structure is asymmetric and eastern flank is tectonically abrupt. Anticline top is located under the seawater, about 1600 m at the west of the shoreline. Molasse deposits are covered by different kinds of the Quaternary loose deposits. Seashore is abrupt and the sandstone banks have been mapped in western submarine anticline limbs . The sea-floor sandy belt, of 2.5 km width, which lies parallel to the coastline in the shoal zone. According to the integrated marine geological-geolectrical surveys there are observed, submarine Miocene-Pliocene bedrock banks (Photo 8, Fig. 10, 11 (Frasheri A. 1977, Leci V. et al. 1986, Papa A. 1985).

Geodynamics of the coastline is demonstrated also by historical and old shoreline migration. At erosional Currila sector, northern of Durrësi city was observed an ingression of the shore during post Alerodiane glacier period and later up to present coastline location. Marine geological surveys have observed gravel and coarse sands under 20 m thick a silty-clay layer, and 20 m sea depth, at 2 km from the shore. Gravel and sand transgressively have covered the Tortonian bedrocks (Leci V. et al. 1986, Papa A. 1985). These depositions are represented Pleistocene old shore. Generally, Durrësi coastline has an ingression averagely of 2 km during the Pleistocene. There are observed also some archeological objects covered by seawaters in Currila zone.

Selita Cape, in the northern edge of the Kryevidhi Pliocene Hills.

Zvërneci hilly zone is located at northwestern direction of Vlora city (Fig. 2, 8). The old sand split from Vjosa River mouth to the northern edge of the Zvërneci Tortonian hills and these hilly chain separated Narta lagoon from the Adriatic Sea. The southward shift of the Vjosa River mouth during the XX century has created serious erosion problems in the northern coast of the Narta lagoon. The sediments input to the old delta ceased, the latter has almost been completely eroded and the sediment was removed to create a split, which formed

an accumulative zone in the southern part of the Vjosa River old mouth (Fig. 8) (Thereska J. 1981).

In the Rodoni, Selite and Zverneci caps of the shoal shelf zone, are observed the same sea floor morphology and sediments that in thje Durresi-Palla Cape zone, with many bedrocks submarine banks.

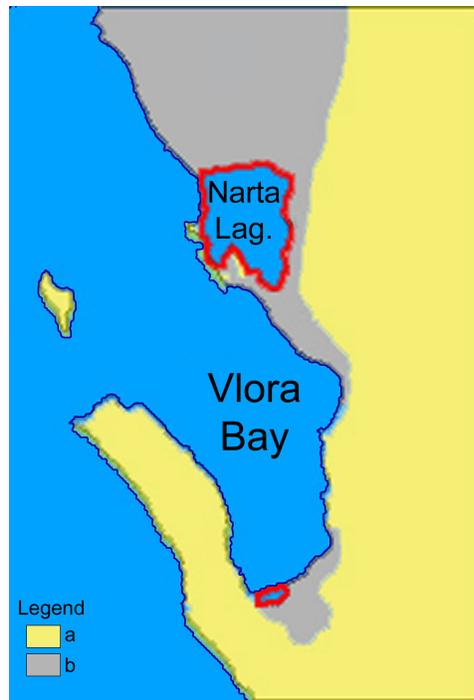


Fig. 6. Paleogeographic evolution of the Vlora Bay from end of Pliocene Age (a) up to Present days (b).

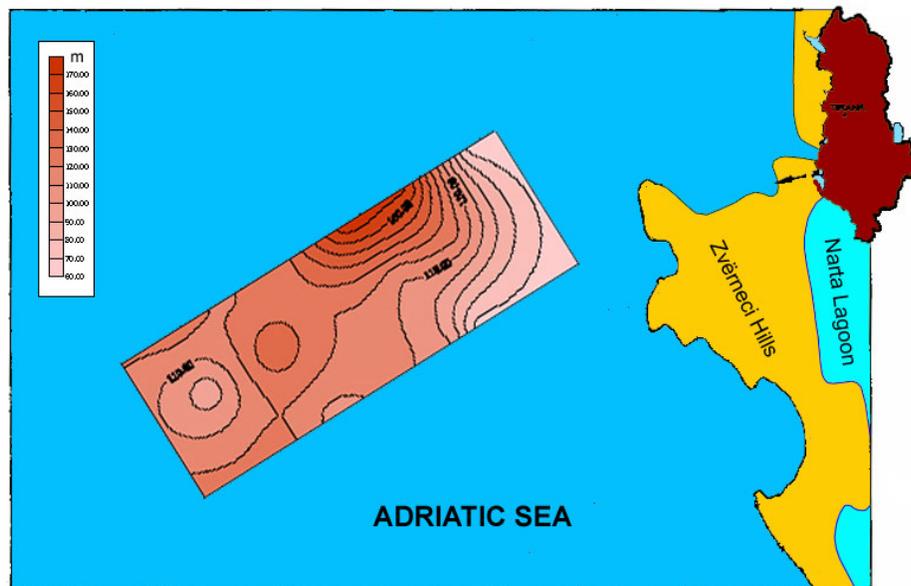


Fig. 7 Thickness Map of Quaternary Deposits in Vlora Bay, at Zverneci area, according to the Marine electrical soundings.

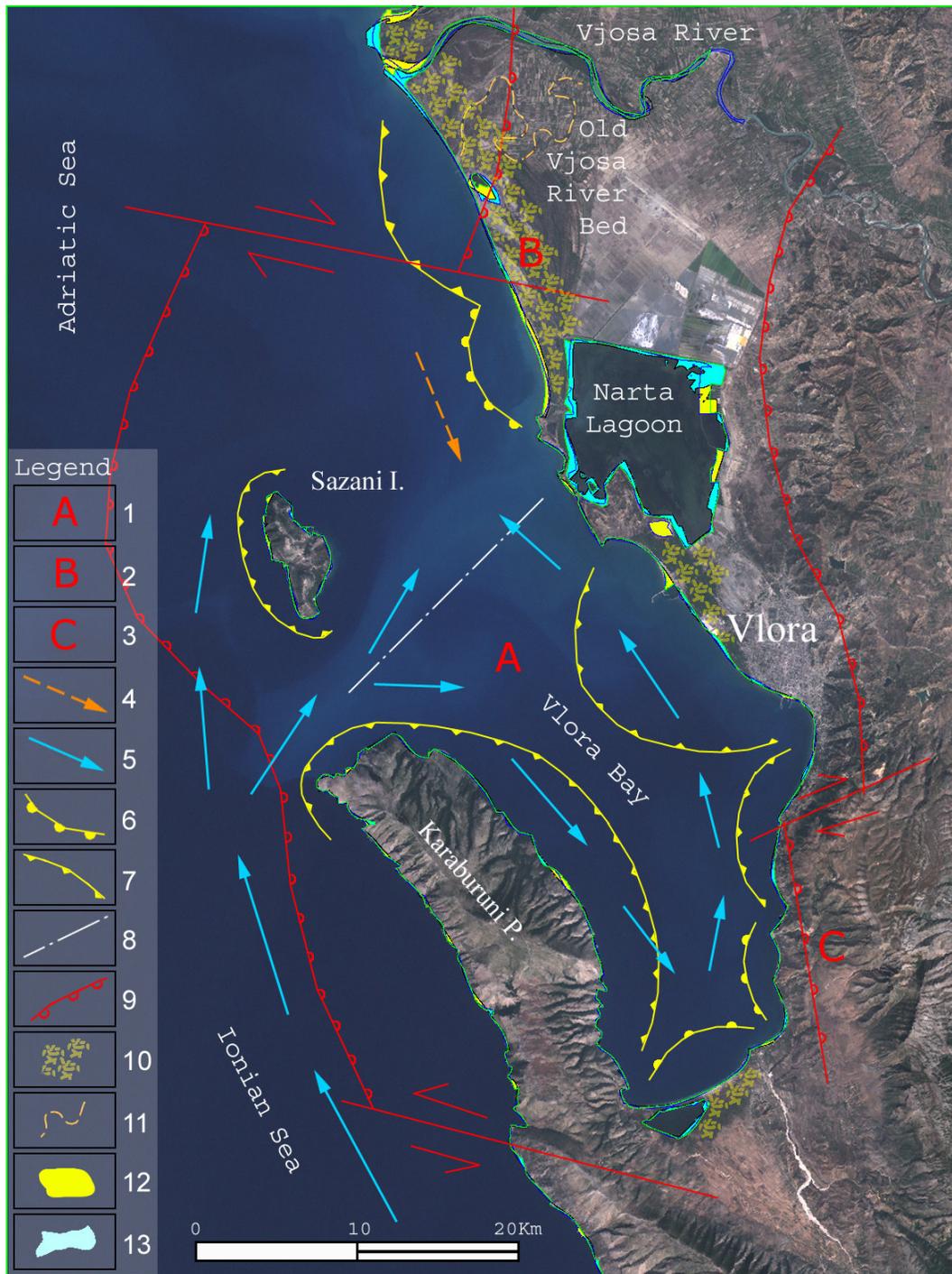


Fig. 8. General Evolution view of the Vlorë Bay after satellite images of the period August 1981-July 1989-October 2001 (Global Land Cover Facility Landsat, 2005; Neotectonics active reverse faults & thrusts (after Aliaj Sh. et al. 2000).
 1- Marine shoal with sand deposits; 2- Littoral with sand beaches; 3- Rocky coastline; 4- Alluvium flow; 5- Marine current direction; 6- Accumulation area; 7- Erosion area; 8- Southern edge of the sediment replacement; 9- Active reverse fault & thrust; 10- Sand; 11- Old Vjosa River bed; 12- Filling coastline; 13- Erosion coastline.

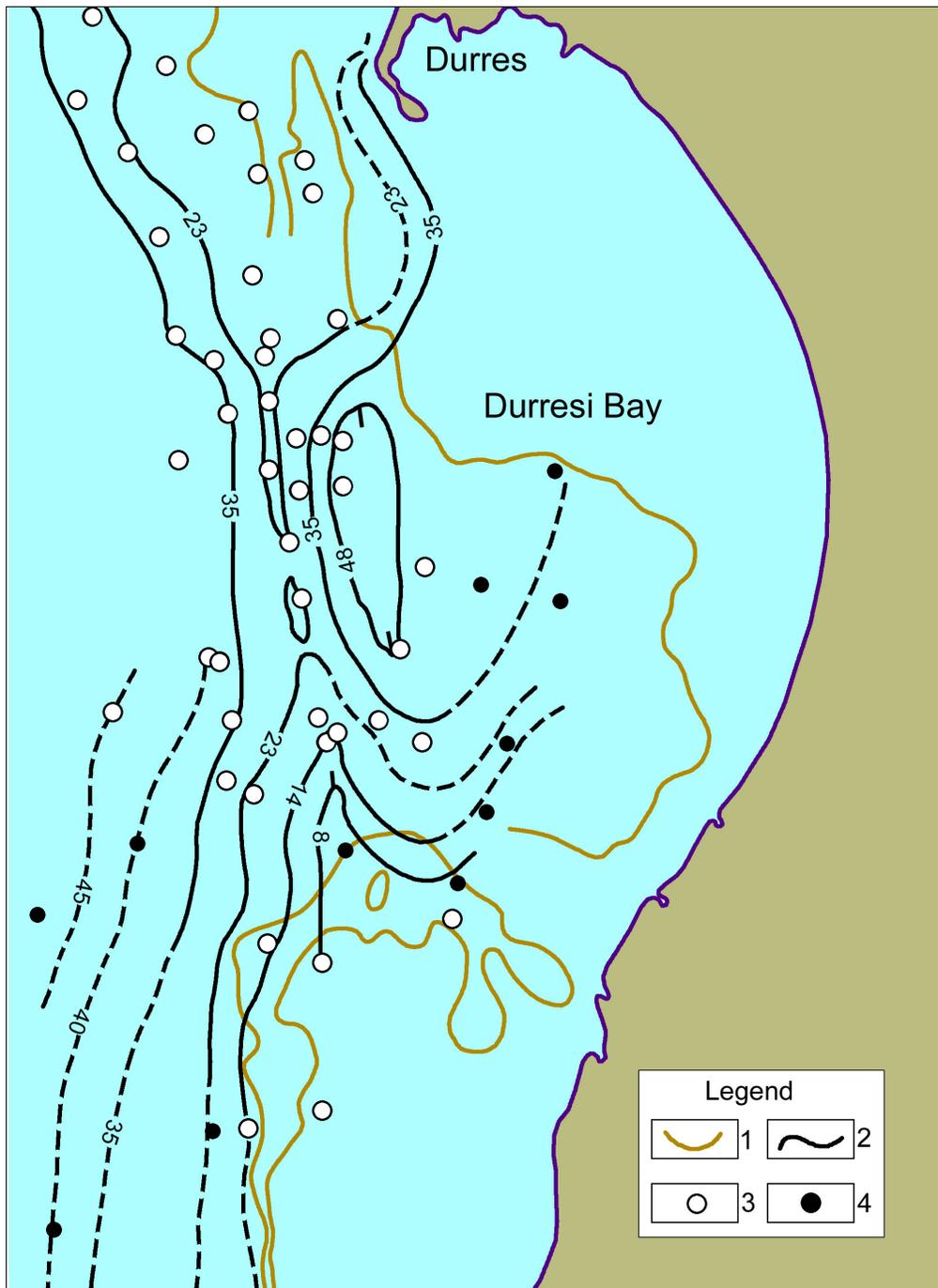


Fig. 9. Thickness Map of Quaternary Deposits in Durrësi Bay, according to the marine electrical soundings.
 1- Boundary of distribution of sand-argillaceous sediments; 2- Contours of the Quaternary deposits thickness; 3- Marine mapping boreholes; 4- Marine electrical sounding centers.

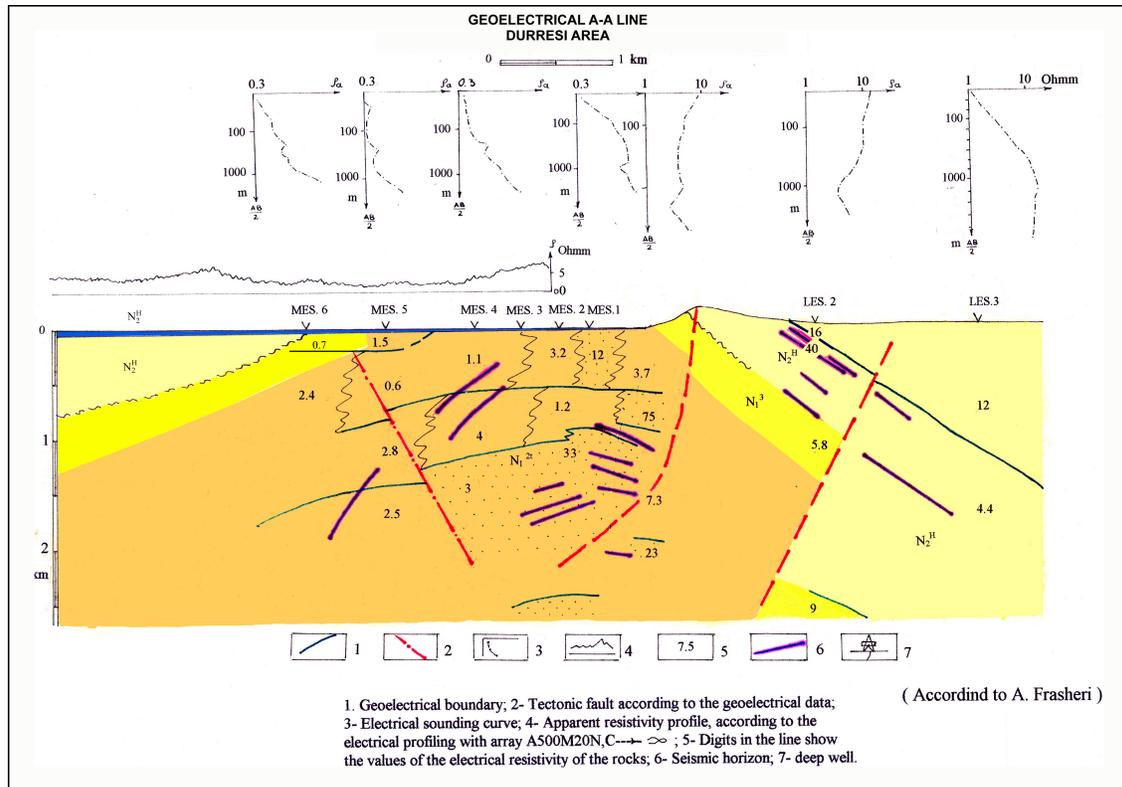


Fig. 11. Geoelectrical Line, erosive littoral at Durrës-Kepi Pallës area.

1- Geoelectrical boundary; 2- Tectonic fault according to the geoelectrical data; 3- Electrical sounding curve; 4- Apparent resistivity profile, according to the electrical profiling with array A500M20N, C→∞; 5- Digits in the line show the electrical resistivity values of the rocks; 6- Seismic reflector.

5.1.3 .Submerged areas, where is observed marine transgression toward the mainland

Semani beach at western Albanian region and Patoku beach in the southern side of the Shwngjini Bay represent submerged areas within accumulative coastline. Submerged process is caused by the neotectonics activity, consequently there are observed a marine transgression.

Re-activation of the disjunctive tectonics at the littoral area Vjosa River mouth to mati River mouth is observed. In the littoral segment Seman beach - Karavasta Lagoon -Shkumbini River mouth, in the both flanks of the Semani asymmetric anticline structure the disjunctive tectonics, with small amplitudes of 200-400m, are reactivated. According to the neotectonics studies, an active reversed fault with western thrust direction, from Vjosa River Mouth to south of the Semani River Mouth, is laid in the mainland, parallel with the coast (Fig. 3) (Aliaj Sh. 1998, 2000, Aliaj Sh. et al. 2000). According to the marine electrical resistivity tomography, performed by marine electrical soundings, the morphology of the marine Quaternary loose deposits has a horizontal layering (Fig. 12) at the western side of the Semani beach. In south and east northern sides of the geoelectrical line is observed reversed fault impact. Consequently, the Semani sandy beach, which is located at western side of this fault, in the submerged process, is found, from 4 km of south of the Semani River Mouth up to Semani Beach area, in the about 10 km long segment (Fig. 3, 5). So many objects that 20-35 years ago have been constructed in the mainland, at the present under the seawaters are found, ex. the Seman-3 deep oil and gas well basement (Photo 9). Semani-3 well has been drilled in

1969 in the mainland, 265m from the coastline. During the period 1969-1983 coast water line has a ingress of 135 m toward the mainland, with a gradient 9.4 m/year. From 1983 up to 2004 the ingress has amplitude 170 m, with a gradient 8.1 m/y. In this are, submerged process was started about 160 years ago. There are some small sectors, with a length about 4km, where the marine waters for about 2.5-3 km in the mainland are seeped.

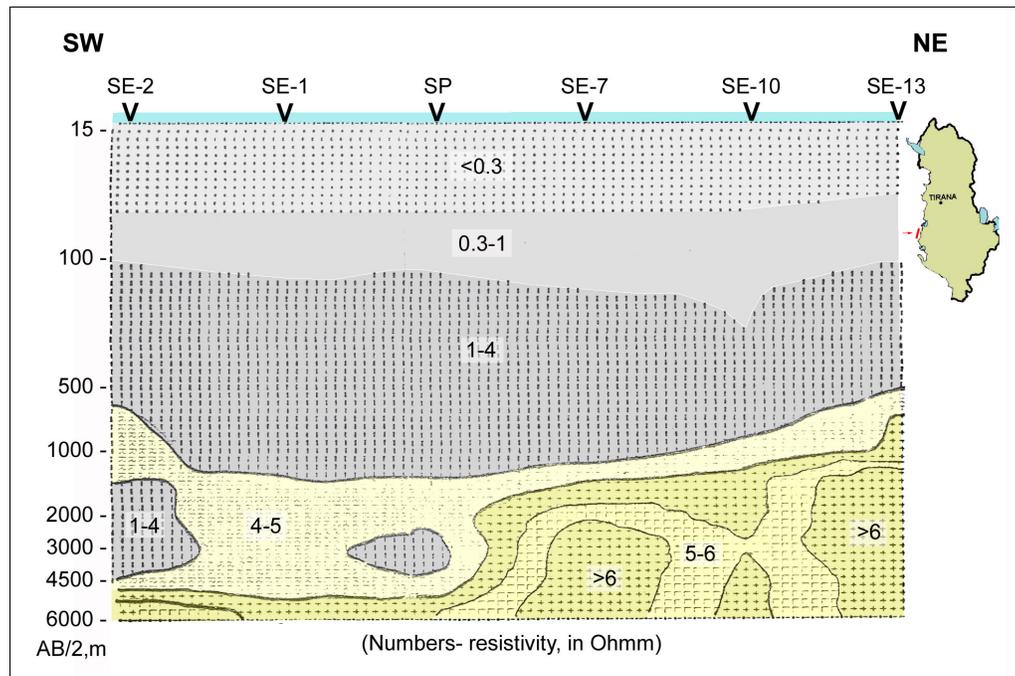


Fig. 12. Marine Electrical Resistivity Tomography Line, Semani Adriatic Shelf.

In fig. 5 can be observed that submerged process is not developed in same time along all length of active reverse fault & thrust line. Toward the Vjosa River Mouth, is not observed such intensive submerged process that in the Semani Beach.

Uplifted side of the reverse fault & thrust, at northeastern Semani River Mouth-Karavasta Lagoon and Shkumbini River Mouth, under the neotectonics uplift process is found. There are observed marine regression.

Second submerged area at the Adriatic littoral is observed at the Patoku beach, between Ishmi River Mouth at the south and Mati River Mouth at the north (Fig. 3, 4). This area is located at northern direction of the Rodoni Cape. This submerged area has more complicated development. In 1972, the sand beach there has a width about 175m. In 1982, the width of the beach only 100m was. Actually, beach hotels and other buildings, under seawaters are found (Photo 10). Patoku beach area is located at submerged side of the active reversed fault with eastern thrust direction. This fault is located in lowered wall of the Neogene molasses of Rodoni monocline (Fig. 3). Uplifted side of the reverse fault & thrust, at southwestern direction is found, between the Ishmi River Mouth, southern of the Patoku beach, and Rodoni Hills.

Small submerged area in the Porto Romano area is observed, too, which is located between Durrësi City and Palla Cape.

In the submerged zone are observed integrated factors of the coastline evolution: neotectonic, erosion by marine currents and accumulation of the solid river discharge and eroded shore sediments. This factors complex has caused important changes on the coastline geomorphology, marine shoal and littoral landscape. Typical are Patoku and Semani area. Submergence in Patoku area has caused replacement of the Mati River Mouth towards the south, start from the 1978 year. From the 1982 year, the river solid discharge has started to form sand split, from the mouth up to 300 in southeast direction (Fig. 4). According to the satellite images of 2000 year, this bank has been with a length about 1400 m and has been emerged over the sea surface. In 2005, this sand slit has a length over 2 km and is covered by dense vegetation (Photo 11).

5.1.4 .Lagoon area

Lagoons have a total surface of about 150 km² while the volume over 350-million m³ water. Albanian lagoons represent crypto-depressions, with the floor under the level of the sea's bottom. The lagoons represent the new lakes. Its creation started during Pliocene Period, some 4-5 million years ago, and its creation lasted during the Quaternary Era till our days. The neotectonic phenomena also characterize the lagoon area.

Karavasta Lagoon, is the biggest and the most important lagoon system on the Albanian coastal area. It is located between the mouths of Shkumbini River (in the north) and Seman River (in the South). Lagoon has a surface of 43,3 km², with a maximal depth of 1.5m. It communicates with the Adriatic Sea through three short channels (Pano N. et al. 2004). They were created during the closing of old marine bays by sandy belts as results of the accumulation of solid discharge of Semani and Shkumbini Rivers.

New split is formed in Karavasta Bay, which has formed Karavasta Godulla.

Narta Lagoon, is situated in the northern part of the Vlora Bay, about 3 km from Vlora City. Narta Lagoon has a surface of 41.8 km², the maximum depth 1.5 m and the average depth is 0.7 m. (Photo 11) (Pano N. 1983). Lagoon was formed in a sea bay, which is closed by solid sediments transported by Vjosa River to the sea. Old Zverneci split bar separated Narta lagoon and sea area.

Butrinti Area is located at southwestern part of Albania. This area represents most beautiful part of Albanian Ionian Rivera (Photo 12). The ancient Butrinti City has been built in this area. A chain of hills separates Butrinti Lake from Ionian Sea (Photo 13). Shores around these hills represent rocky and abrupt lakeside. Lake has a tectonic origin. It represents water filled graben.

5.2. Outlook on coastal evolution

Adriatic coastline has an intensive changes and continuously modifying its shape (Boçi S. 1981, Pano N. 1994, Simeoni U. et al. 1997, Shuitsky Yu. D. 1999).

There we are analysed three most representative areas:

Drini Bay. Intensive change dynamics, Viluni Lagoon and Shëngjini portal town characterized this littoral area. The decreased sediment load of the Drini River, caused by its diversion into the Buna, has triggered coastal recession between Shëngjini and Tale, with greater intensity on the southern lobe of delta. Moving southwards, the coast becomes part of the sedimentary system of Mati River. The coastal area between Tale and Patok can be considered as having a positive sediment budget (Pano N. 1998).

Karavasta Bay. The Seman and Shkumbini rivers are the main source of coastal sediments in Karavasta Bay. The average water discharge is 62 m³/s. The average annual water discharge of the Semani River (Q_0) to the Adriatic Sea is 0.9m³/s; and the annual load sediment discharges is $R_0=399\text{kg/s}$, which has a correlation with the water discharges- Q_0 (in m³ s⁻¹) for

two main branches (Pano N. et al. 2003, 2004):

$$R_o = 0,605 \cdot Q_o^{1.46} \quad \text{- for Osumi River, and}$$

$$R_{o,2} = 0,219 \cdot Q_o^{1.69} \quad ; \quad \text{- for Devolli River}$$

The total sediment discharge by this river to the Adriatic sea is $W_T = 15,7 \cdot 10^6$ tons/year. About 19% of total sediment load is equivalent to $W_F = 3,15 \cdot 10^6$ tons/year is carried bad load, and 81%, equivalent to $W_F = 12,6 \cdot 10^6$ ton/year, is suspended sediments. The wave highest in the Seman River mouth observed along the coastline, have a deep-water direction from the NW and the W and a maximum wave height of 4.0 m seashore. The dominant winds are southeasterly, easterly, and northwesterly winds. Maximum waves converge towards northeastern zone of coastline. This coastline corresponds to an extensive delta coast (microtidale: 0,50 tidal range) with a large alluvial plain of Myzeqe.

In ten last years, the coastline has advanced some hundred meters. Semani River mouth has changed in position in the last centuries six times and this displacements have covered on area of the littoral about 15-20 km long in a direction North-South; South-North during period 1870 to 1994 years. In these conditions in the coast area there are two important sources of coastal sediments: the actual rivers mouth and the olds rivers mouths (Fig. 13). The outlet of Semani River was shifted from position A and A_1 , the old mouths, to the actual position B", that is up date position. The old mouths of this river (coastal area A' and coast A") is undergoing on important submerged process under the neotectonics activity and erosion from the wave action.

Vjosa River Mouth-Vlora Bay. The general evolution map of coastline in fig. 8 is presented (Pano N. 1994). Vjosa River Mouth has changed its position in the last century two times and these replacements have covered an area of the littoral about 10 km long in the northern direction. The old mouth of this river is undergoing on important erosion process under the wave action. There are two sources of coastal sediments: first, the present Vjosa River Mouth, and second the old Vjosa River Mouth.

5.3. A correlation between geological setting Adriatic Albanian Shelf and sea hydrology

Two Albanian Oceanographic Expedition "Saranda-1963" and "Patosi-1964", have presented data, which have argument that the total discharge of the Albanian rivers system in the Adriatic and Ionian Seas have a minimal discharge is 700-800 m³/s during the hydrological dry years of low precipitation and maximal values 1900-2200 m³/s during the hydrological wet years of high precipitation (Pano 1974, 1984, 1994). Buna River, together with Po River in Italy, is determinant in the water balance of the Adriatic Sea (Photo 14).

Ground surface history after geothermal inversion and meteorological data were observed a climate worming for about 1°C during the first half of XX century. Thirty quart of this century has been characterized by a cooling for 0.6°C. Later, up to present a worming for 1.2°C is observed (Frashëri A et al. 2004). The warming period in Albania is accompanied with changes of the rainfall regime, wind speed and wetness. There are observed a decreasing of the total year rainfall quantity, for about 200-400 mm. This warming is part of the global Earth warming during the second half of XX century. These climate changes have their impact on country water system, on and water resources, and in the erosion processes (Pano N. et al. 2004). Inland water resources change has its impact on the hydrographic regime of the Adriatic Sea (Frashëri A. and Pano N. 2003).

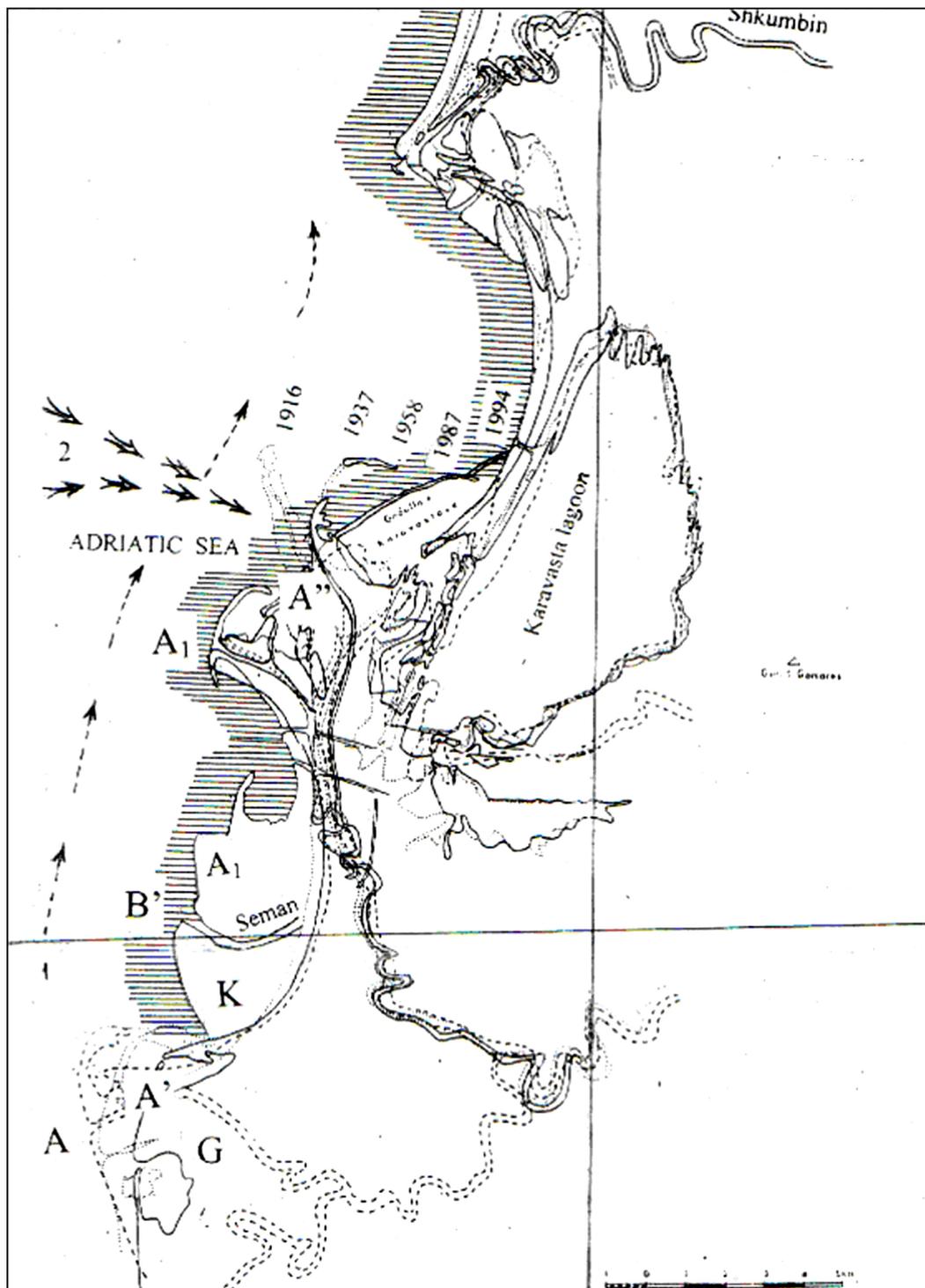


Fig. 13. The general map of the evaluation of the coastline from 1870 to 1994 in the Semani-Karavasta area (A and A1—old river mouths; B'—actual river mouths; A A' A''—sources of coastal sediments; 1—marine currents; 2—wave processes; G—submersed area; K—accumulation area)

The oceanographically situation of the wet years 1963-1964 has been characterized by formation of “The Bridge” of low salt content and density, and higher temperatures of the seawaters in the Adriatic Sea. A higher surface water temperature in the Drini Bay is confirmed also by satellite observations, with a higher temperature of 3-4°C (Fig. 17) (Adriatic Sea Water Surface Temperature, restored from NOAA satellite data 19.08.2005).

. The "Bridge", includes surface water layer, and the Levant Intermediate Water (LIW) up to 600 m. depth. This phenomenon has a complex and an important influence on many dynamics aspects of the formation Adriatic Deep Water (ADW), and the monitoring mechanism of water into Otranto Street.

This “Bridge” is correlated with the heat flow density anomaly at the sea bottom (Geothermal Atlas of Europe, 1992) (Fig. 18). The “Bridge” direction is corresponds also with the prolongation into Adriatic Sea Albanian Shelf of well-known Scutary-Pec regional tectonic transversal over the Albanides, which is outcropped in Albanian mainland, with a SW dextral strike-slip direction.

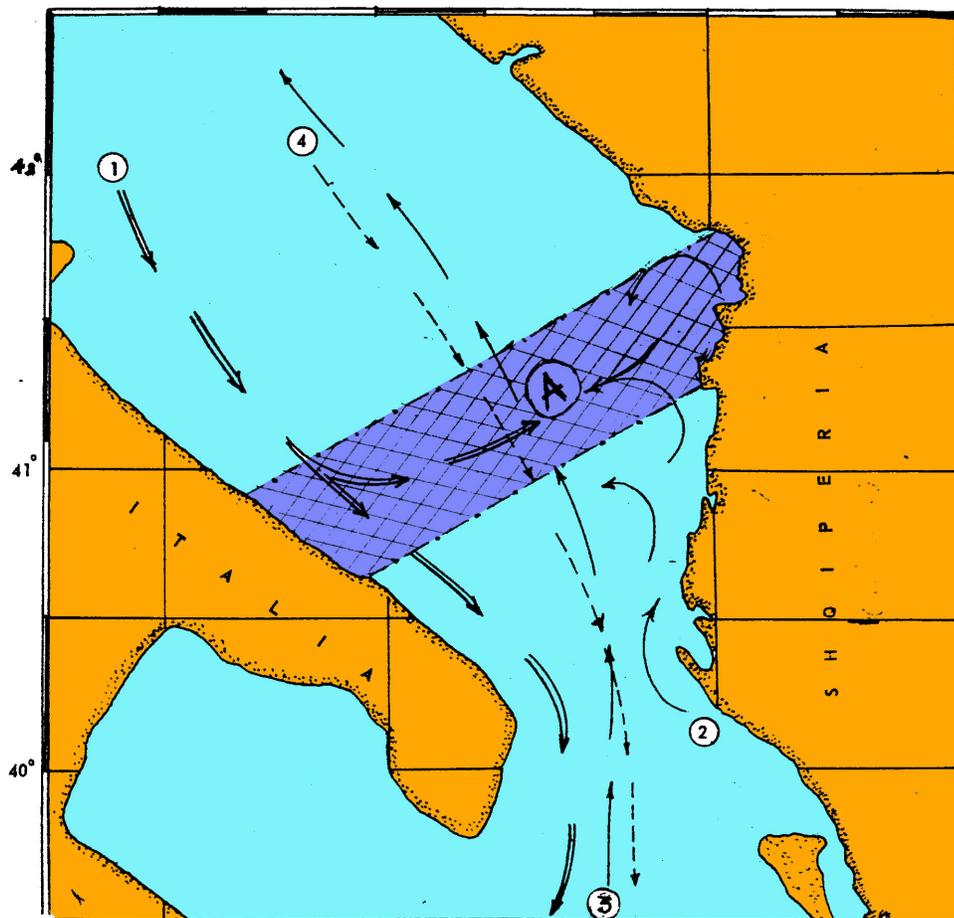


Fig. 14. “The Bridge” of continental water in the Adriatic Sea.
 1. Adriatic Deep Water Mass; 2. Eastern Adriatic Superficial Water mass; 3. Intermediate Levantine Water mass; 4. Northern Adriatic Water mass.

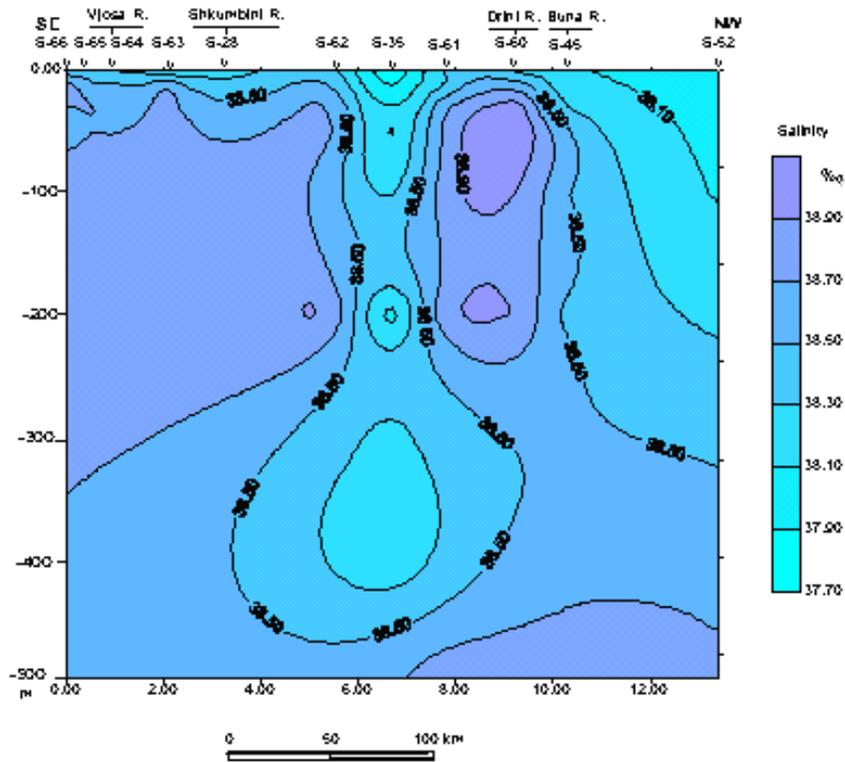


Fig. 15. Vertical salinity section 1-1, Adriatic Sea, wet hydrographical year 1963.

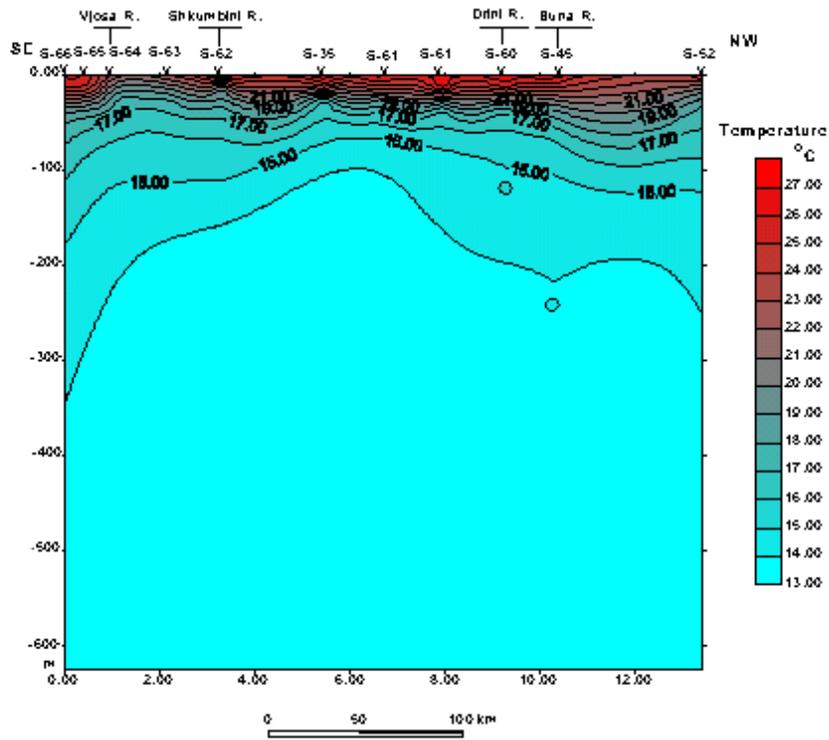


Fig. 16. Vertical temperature section 1-1, Adriatic Sea, wet hydrographical year 1963.

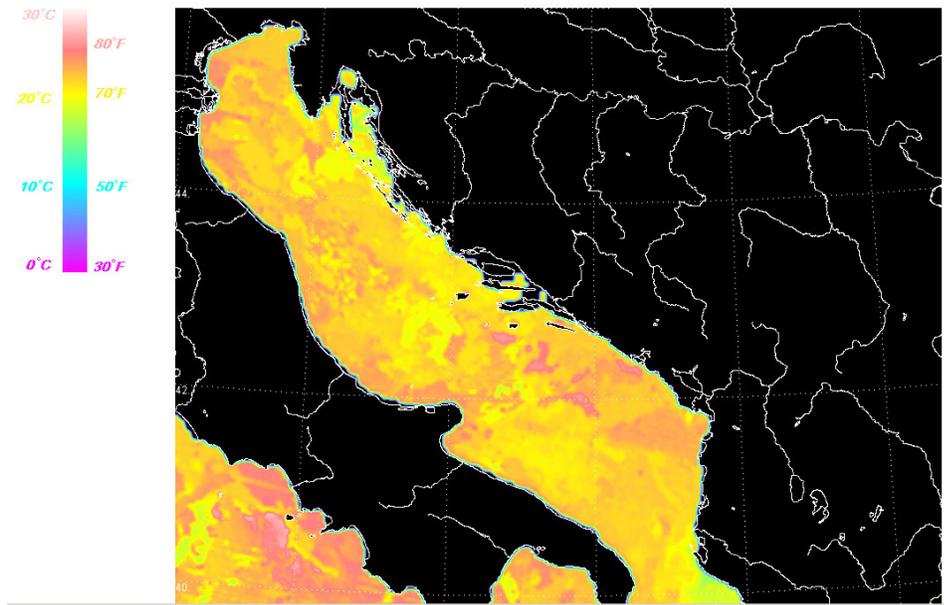


Fig. 17. Adriatic Sea Surface Temperature, restored from NOAA satellite data 19.08.2005 3:50 (GMT) NOAA 12 (Sputnik.SST, 1999 SMIS IKI RAN, Moscow, Russia).

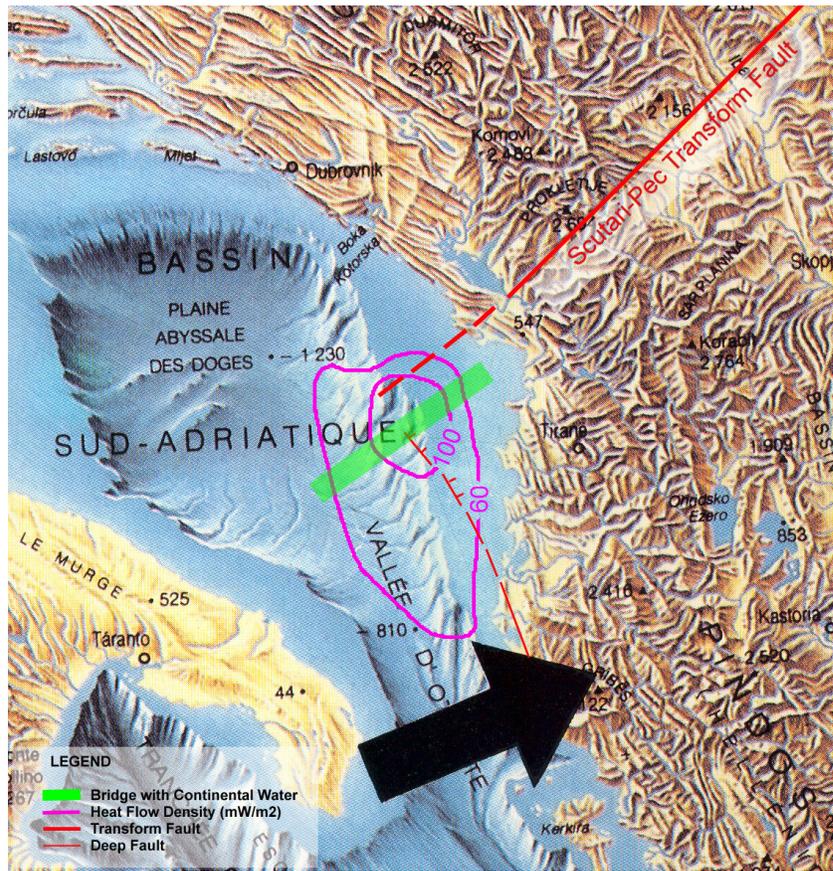


Fig. 18. Adriatic Heat Flow Density Anomaly (Geothermal Atlas of Europe, 1992).

6. Conclusions

- Albanian littoral has two major units: accumulative Adriatic coastline and erosive Ionian seaside.
- Albanian Adriatic coastline has an intensive change and continuously modifying its shape.
- Submerged process, caused by neotectonic activity, is observed in some sectors within accumulative Adriatic coastline.
- The climate at coastal plane region of Western of Albania has a warming of 0.6 K occurred, from last quarter of 19th until present-day. These climate changes have their impact on country water system, on and water resources, on the erosion processes, and on the hydrographic regime of the Adriatic Sea.
- The oceanographically situation in the Adriatic Sea is characterized by the formation of "The bridge" with continental water in the Adriatic Sea. "The bridge" is closely linked with the intensity of the Albanian rivers flow to the sea.

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10. Pictures Album



Photo 1. Albanian Adriatic Sea Littoral, Semani-Karavasta area.



Photo 2. View of Vlora Bay.



a)



b)

Photo 3. Velipoja Beach (a) and Buna River Mouth Split (b) (After Alikaj P.).



a)

Photo 4. Durrësi Beach (4-a After ARBA).



b)

Photo 4. Durrësi Beach.



c)

Photo 4. Accumulative coastline, Golemi Beach, Durrësi Bay.



Photo 5. Present day's macro fauna in the solonchak Quaternary littoral deposits, Rrushkulli area.



Photo 6. Heavy and rare minerals placer in sand dunes, Rrushkulli area.



a)



b)

Photo 7. Buried sand knolls, Rrushkulli (a) and Semani (b) areas.



Photo 8. Erosive Currila coastline area, northern of Durrësi city.



a)



b)

Photo 9. View of submerged Semani beach area.

a) Semani coastline panorama;

b) Semani deep well basement



Photo 10. View of submerged Patoku Beach area.



Photo 11. View of the new sand spit at the Patoku area.



Photo 12. View of Narta Lagoon.



Photo 13. View of Butrinti Lagoon area.



Photo 14. Erosion Ionian Sea coastline, Ksamil area at the Albanian Riviera.



Photo 15. Solid discharge of the Buna River to the Adriatic Sea.