PROBLEMS OF THE COASTS EROSION IN THE NORTH - EASTERN BLACK SEA REGION

Ruben Kos'yan, Sergey Kuklev

The Southern Branch of the P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences. Gelendzhik-7, 353467, RUSSIA.

Abstract

As a whole the state of coasts of the Russian sector of the Black Sea can be declared as unsatisfactory one. At present a considerable part of the coast (~309 km from 476 km of the coast line total length) is routed by different exogenic processes: abrasion, landslide, fall, etc. In some cases such a situation is aggravated by technogenous impact upon the coastal systems which has been done earlier.

The seacoasts protection does not stand standard solutions. Every part of a shore needs to be approached creatively and its hydrodynamic, lithodynamic, geological, geomorphological and other peculiarities must be studied thoroughly for each particular situation. It takes a complex scientific approach considering not only local features, but also the reaction of the whole lithodynamic system in limits of which the coast protective activity is planned with consideration of calculated hydrodynamic parameters (waves, sea level, etc.).

INTRODUCTION

Coast and coastal zone are national treasure, having constant and rapid grows of their political, economical, ecological and even esthetical value in Mediterranean countries. The main factors determining the coasts development are natural dynamic processes. Due to possible rise of World Ocean level, their intensification might be expected. Depending on the depth of people's knowledge of the dynamics and the professionalism of its application, human activity in the coastal zone may make these processes both creative and destructive.

Depending on the local conditions, waves and wave flows either erode the original rocks in the coastal zone moving the coast landwards, or build up it by means of sediment accumulation along the shore, and keep a stable outline and profile of the coast manifesting a mobile equilibrium between acting factors.

However, the research of the bottom profile and a stable coastline evolution process cannot be accomplished isolately, since it greatly depends on an economic activity of a man. Among the mechanisms of anthropogenous transformation of physical processes in the Black Sea coast zone we can single out the following: influence of waterside structures upon the coastal processes; influence of the mineral mining upon ecosystems of the coastal zone and upon the coast; consequences of the river run-off regulation.

STUDY AREA

On the Black Sea coast the very first negative factors are transformations of the coastal processes resulting in the change of the cross profile features and the shore

outline evolution, caused by hydraulic constructions of various economic importance and different direction to the shoreline (longitudinal constructions - mooring and baffle walls, quays, slope shoring and breakwaters; cross ones - port moles, piers, groins).

The Black Sea eastern coast is composed with the Upper Cretaceous and Lower Tertiary aged flysch strata. Its typical feature is the proportional alternation of soft, easily destructible argillaceous rocks and dense sandstone, well resistant to wave erosion. Cliff height varies from zero up to 100 meters. The type of the coast evolution is abrasion-denudation one. The wave erosion cuts cliff basement and denudation erodes its surface.

Until the end of the 19-th century coastal processes were occurring without human participation (Kaplin et al,1991; Safyanov, 1978). At that time the average beach width reached 46 meters, which was enough to suppress waves (generally, for suppression of waves with 1% probability, 25 meters width of beach is enough). The coast was in the stage of stable dynamic balance, when the amount of incoming detritus material was approximately equal to the abraded gravel amount.

Active economic development of the Black Sea East coastal zone has started at the beginning of 20-th century. Those days the pebble taken from beaches was used for construction of buildings, rail and motor roads. Active consumption of pebble from the beaches and river banks had caused a sharp increase of sea shores abrasion and washout rate, number of landslides had also increased.

Contemporary Caucasian shores of Black Sea are being developed under increasing man-caused load. Favorable natural conditions, their variety and uniqueness determine the exceptional role of these shores as very important recreational zone of Russian South. Waste urbanized areas, agricultural territories and National Parks are located in immediate neighborhood with the sea. Important industrial facilities and federal and international communications, including major seaports are located in the shore zone. At present time major gas and oil transportation facilities are commissioned and being constructed in the area.

Due to the change of geopolitical situation the Russian shoreline had significantly reduced in comparison with Soviet period, especially in most developed regions. Large resort complexes in Georgia, Crimea and Baltic area were lost. Russia had also lost many major seaports. This fact, together with the structural change of economy and growth of the export, had caused the necessity of building new industrial facilities in the Black Sea coastal zone, and, consequently, had stimulated active human invasion into natural coastal processes.

At the time being, a major part (three hundred nine kilometers) of Black Sea coast within Krasnodarski Krai is subject to abrasion and landslide processes (Fig.1). Abrasion process and beaches wash-out, landslides cause destruction of industrial and transport facilities, living and public buildings, resort complexes and valuable agricultural areas. In this light, the challenge of estimation of effective methods of shores protection against wave-induced erosion becomes crucial (Kosýan, Magoon,1993; Yesin et al, 1980).

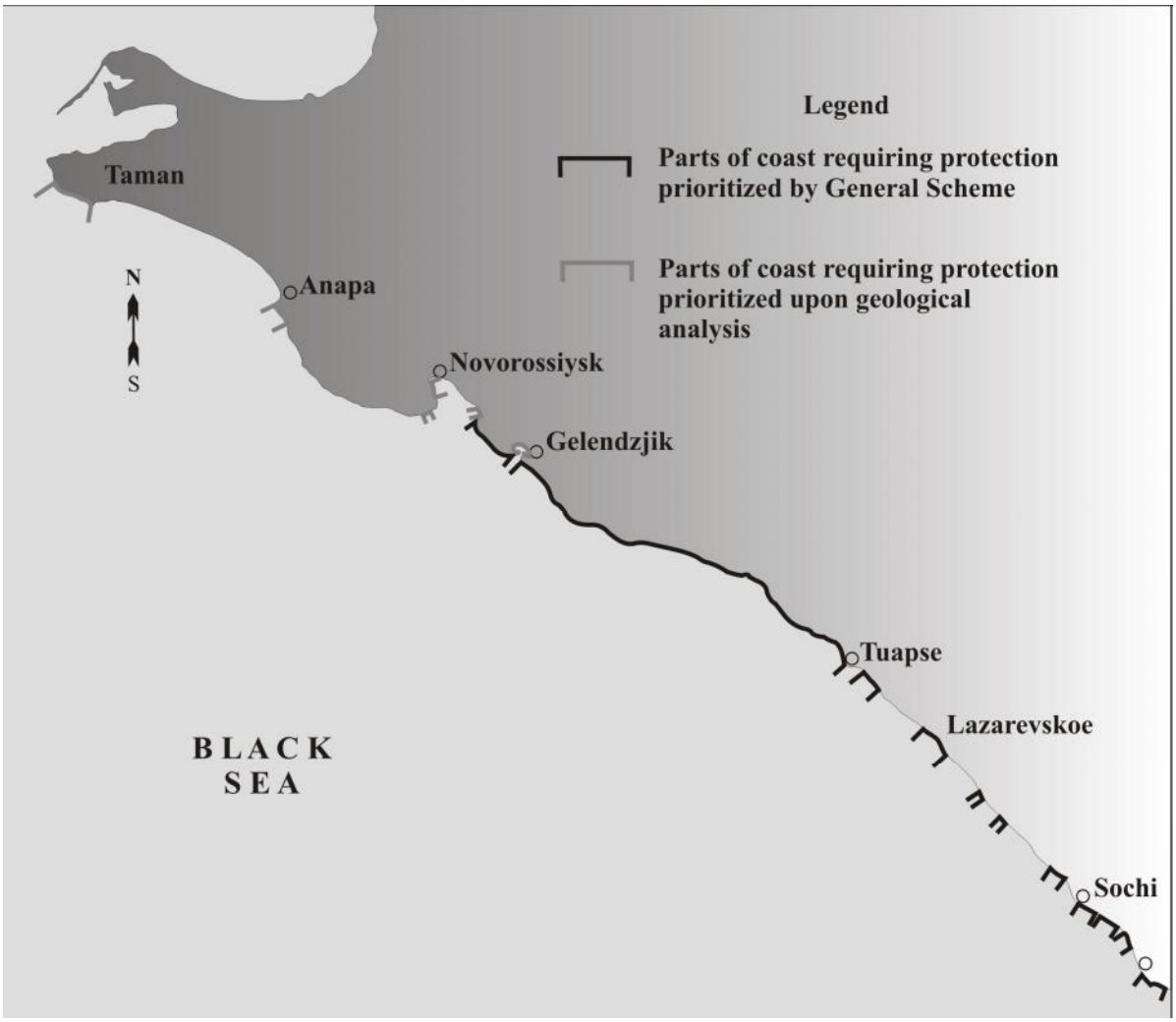


Fig. 1. Parts of the shore that require immediate protection.

First coast protection structures, such as sea walls made of a rubblework or a concrete, were built in 1914 - 1916 to protect the railroad between Adler and Tuapse and a number of seaports. The construction was performed without due technical and scientific justification and was aimed at protection of a local part of shore, where the facility to-be-protected was located. Capital construction was carried out right on the beach, that seriously impacted its wave suppressing capacity and disrupted the alongshore sediments flow, forming the bottom washout. Regular backfill of natural and artificial beaches with non-metallic material was not organized. That is why the problem of active abrasion of shore was not solved with the coast protective measures taken those days. Moreover, the parts of the shore adjacent to the protected ones occurred in even worse condition (Fig.2).

Fig.2.Empty sections between bunas in the area of Tuapse – Sochi railroad.

Wide application of reinforced concrete did not result in stabilization of the shore. It sounds paradoxical, but the parts of the shore being under protection for longest period of time happened to end up in the worst state.

The section of the shore between Adler and Tuapse served as a kind of training grounds for working out the different methods of protection of steep shores with gravel beaches (Fig.3).

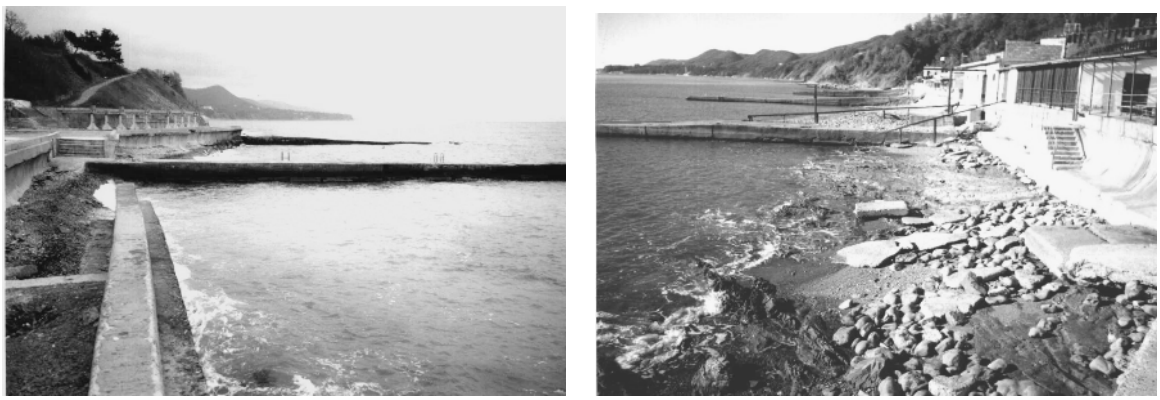
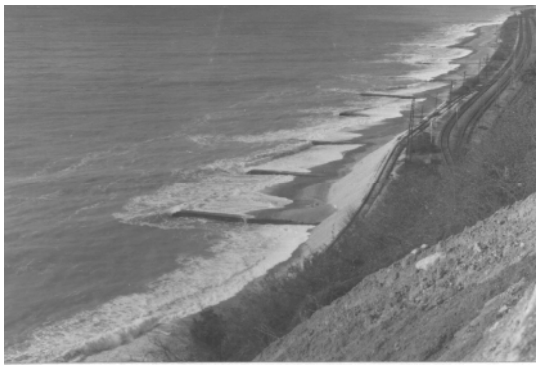


Fig.3. Existing state of coast protective constructions in Tuapse – Adler area.

A part of coast protection was performed with breakwaters and berms made of concrete blocks. Fifty-seven breakwaters were built at a section of beach with thirteen kilometers length. Generally, they proved to be a low-efficient mean for retaining of beach material. In addition, they do not comply with sanitary requirements to the water in the area behind the breakwaters.

Berms made of concrete blocks are efficient as a wave suppressing constructions, but aesthetically and ecologically are unacceptable in the recreational zones, such as the big part of the Black Sea East coast (Fig.4a,b).



a

b

Fig.4.Condition of bunas and interbunas filling (a. Tuapse–Adler section, b. Matsesta area).

Summarizing the Adler-Tuapse coast protection experience, we have to note that generally the coast protection occurred to be extremely inadequate. Construction of bunas was made always well ahead of filling in the intervals with beach-forming material. However, without beach, bunas are absolutely useless as a protective structure. Underwater breakwaters are of especially low efficiency; they do not protect the coast and spoil the sanitary condition of the sea in the zone of swimming.

There are no enough beaches on the open parts of Black Sea coast to satisfy the increased demands for resort civil construction. Many sanatoriums and hotels are trying to solve the problem using their own resources, but most of such attempts turn to be of no success. Frequently, trying to retain the beach on small sections of the shore, they use the outdated methods of concrete bunas and seawalls.

REGIONS OF THE NORTH-CAUCASIAN COAST OF THE BLACK SEA

The basis of the modern knowledge about coasts has been laid by V.P. Zenkovich (1962). According to this knowledge the coast should be considered as an entire body and only some individual systems or cells could be singled out within it. Therefore, the key question in the elaborating the coast reinforcing strategy is its division to regions, picking out separate systems and cells.

In the present paper coast division to regions was done based on a number of determining criteria: morphological and geological structure, modern lithodynamic and hydrodynamic processes and so on.

Climatic features and hydrography

The increase of precipitation amount and of mean annual temperature occurs gradually from north-west to south-east and is accompanied by changes of landscape. In many respects, dynamics of the coast changes also depends on the amount and composition of alluvium drifted by rivers.

There are a number of marked climatic borders mainly connected with the area relief, but this does not transgress common regularities of climate change. Climate change is caused by the difference of orographic conditions. Namely, the height of both the main ridge and the coastal relief increase from the north-west to south-east. At the same time the distance between the main watershed divide and the sea becomes larger in the same direction. As a result, the change of the nature of hydrography and that of beach forming material stocking takes place.

Aggregate amount of beach forming material washed out by all rivers at the coast section between Tuapse and Adler was 335.8 thousand cubic meters per year, or on average, about 3 thousand cubic meters of gravel material for 1 linear kilometer. (Peshkov, 2003). At the section from Novorossiysk to Tuapse (153 km) rivers supplied 94 thousand cubic meters of beach material in a year, i.e. about 0.6 thousand cubic meters for 1 linear kilometer. Rivers between Novorossiysk and Anapa (64 km) bring to a coastal zone quite a negligible amount of material. According to the data, the total run-off of these rivers can be estimated as being about 6 thousand cubic meters per year.

As it was mentioned before, a sharp decrease of river run-off due to the mass removals and other kinds of human intervention has resulted in a general erosion of the beach. Today at the section between Tuapse and Adler a total amount of run-off of beach-forming material by all rivers is 241 thousand cubic meters per year. River run-off at the section from Novorossiysk to Tuapse also decreased, and now it is about 60 thousand cubic meters per year.

Orography

One of the essential differences of the Caucasian coast are peculiarities of orography of researched region. The most common regularity of this, as it was mentioned above, is the growth of height of relief-forming structures from the north-west to the south-east.

The northern section of the Caucasian coast between Panagia cape and Zheleznyi Rog (Fig.5) promontory is characterized by coast steps with a height from 14.5 to 65 m.

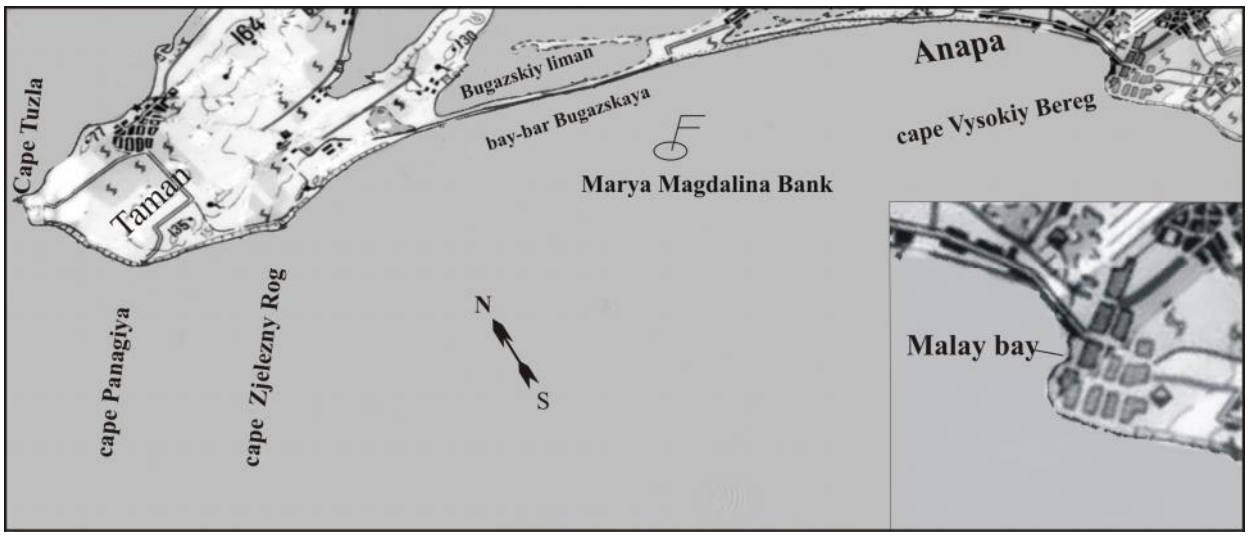


Fig.5. Coast section between Cape Tuzla and Anapa.

The northern coastal extremity of the Caucasian mountains at the coast section between Novorossiysk and Anapa projects to sea as Abrau peninsula. It has a very indented relief with maximum height being 500 m.

Fig.6. Coast section between Anapa and Cape Idokopas.

To the south of the Abrau peninsula there is so called flycsh zone having the rocks presenting the alternation of limestones, marls, sandstones and slates.

A broad low-laying area stretches between Anapa and Novorossiysk, a vast Tsemess Bay lies on its extension. To the south of it a large mountain-mass of Doob is faced to the sea, and further Gelendzhik Bay comes to light. Within mentioned bays the sea penetrates behind the heights of near-shore anticlinal ridge. Beginning on the north-west of Novorossiysk, more three anticlinal ridges run parallel to the shore. The largest of them is Markhot (having the heights more than 700 m), its slopes frame Tsemess and Gelendzhik bays.

The region consists of mountains greatly cut by erosion and having average heights, stretches from Tolstiy (thick) cape up to Tuapse (Fig. 6,7), in general keeping similar nature. Rather large rivers, namely: Pshada, Vulan, Dzubga, Tenginka, Shapsuho, Nechepsucho, Too, run at this coast section, so far as the watershed divide is at the distance of 20-25 km from the sea. Everywhere the coast is of abrasion nature, but in some places spurs are at a certain distance form the sea, and in front of them

there is a belt of ancient marine terraces, which is not broad yet. Coast outline presents a number of broad open arcs. Small near-issue bays are formed near the mouth of the largest rivers. Rivers are not capable yet to fill them with own sediments, and abrasion cannot smooth out roughness of the coast. Bench, being without sediment, is well marked all over the whole length.

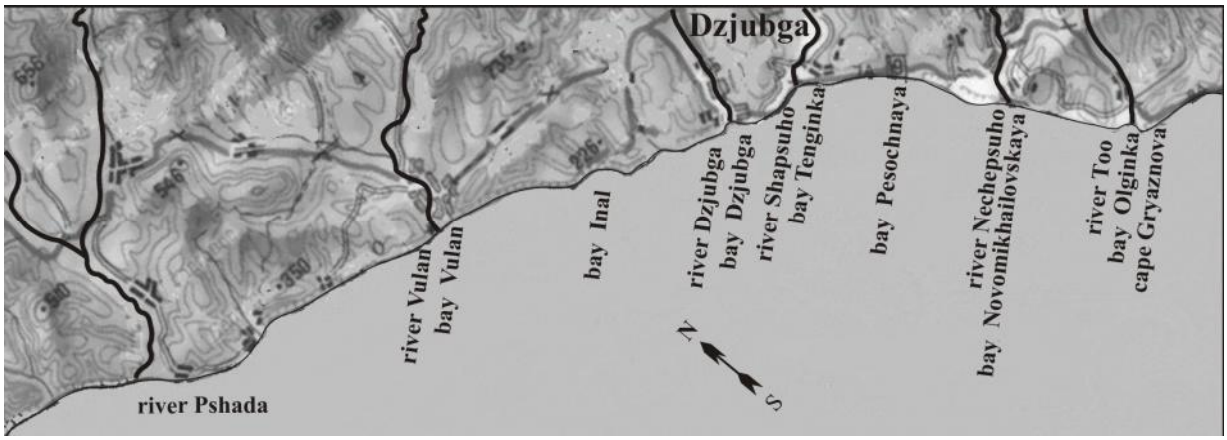


Fig.7. Coast section between Cape Idokopas and Tuapse.

Coast character considerably changes at the border of Tuapse river (Fig.8). To the south-east of it the height of the main ridge reaches 1000 m. Coastal line becomes practically even one and stretches almost strictly to the south-east (~140^0). The shore here is also a region of mean height mountains with a greatly cut erosion net. The watershed divide of the main Caucasian ridge is at the distance of 30 km from the sea. Owing to this a number of large rivers: Tuapse, Ashe, Psezuapse, Shakhe, Sochi, Khosta, etc. (Figs.8,9) appears at this coast section. An essential rise of the precipitation amount results in increasing of the amount of both liquid and solid run-off. As it was shown in the paper by N.Yesin (Yesin et al., 1983), the latter factor (the presence of enough amount of beach-forming fragmentary material) promotes the smoothing of the coastal line. This phenomenon takes place at the coast sections with relatively homogeneous geomorphologic features of rocks.

Between Khosta and Uch-Dere cape a coastal line has several juts. Beginning from Shakhe river, terrace zone considerably extends. A prominent arc of a large delta plain of two rivers: Mzymta and Psou, is a new element of this coast.

In conclusion, let's mention some peculiarities of the sea bottom relief of researched coast section, as far as it has a great influence on the shore morphology.

Kerch-Taman jut of the shelf gets abruptly narrow towards Anapa. To the north of the Tsemess bay its wideness does not exceed 7 km. Further to the south-east the shelf again becomes wider up to 10-12 km, and it borders coast with continuous belt up to delta jut of Mzymta and Psou rivers. But, the edge of the shelf is rather uneven.

Fig.8. Coast section between cape Tuapse and Lazarevskoe.

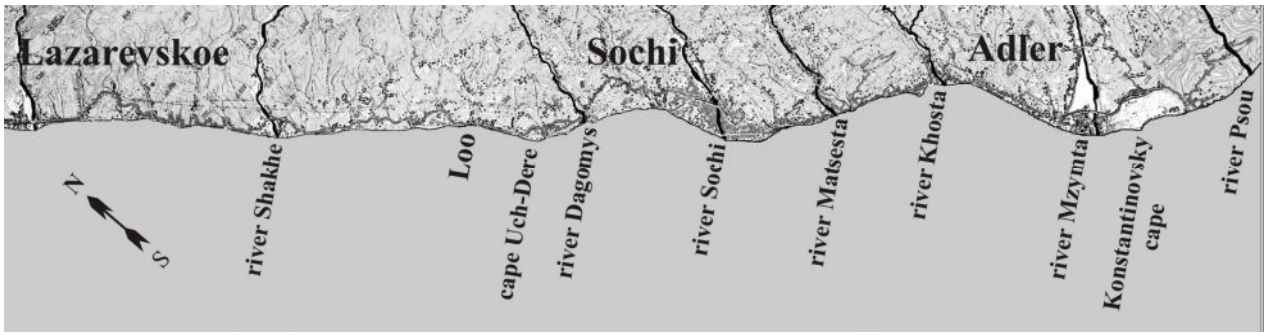


Fig.9. Coast section between Lazarevskoe and river Psou.

In its southern part there is a trough with steep slopes almost approaching the shore near the mouth of Chemitokwadzhe river, small canyon opposite Sochi, etc.

The most remarkable feature of the shelf is that it comes quite to naught near the promontory of Mzymta delta. And at a small section slopes, 30^0- 40^0 steep, the shelf fall almost directly from a gravel beach. As it was mentioned before, canyons play an important role in the redistribution of sediment balance in the near shore zone.

Geological structure

Flysch facies, widely spread from Anapa to Adler, play a predominant part in geological structure of the coasts of the Western Caucasus. All over the large length of the coast flycsh facies of the Upper Cretaceous are repeatedly replaced by Paleogenic deposits, that is caused by a complex tectonics of the region. Relative homogeneity of the flycsh belt of the described region (together with the other reasons) determines a considerable leveling and smooth contour of the coastal line. But flycsh geological structure with intensively dislocated strata occupies a great place in general morphology of the north-western Caucasus coast.

Large bays (Tsemess, Gelendzhik, etc) coincide with the transitional zones between different structures, small bays usually are connected with “slots” along the line of tectonic ruptures, being in many cases a characteristic feature of antyclinal structures. Capes were formed in the places of synclinal arcs, where flycsh suites are consolidated, or in the places of a steep fall of layers. Lithological difference of

deposits is of a big importance too. Often formation of small capes is connected with a large resistance of rocks to a destroying impact of waves in a given place. As a rule, on the submerged slope flycsh series forms ridge relief. A degree of the rock's cementation is the main factor determining the morphology of the coast and submerged slope in the south-eastern part of researched region, where tertiary clays and conglomerates are spread.

Landslide processes greatly affect on the dynamics and morphology of coasts. Due to the inclination of the layers towards the sea, sometimes landslides may be of huge dimensions and power (peninsula Abrau, Sochi). Origin of islands and peninsulas and a definite break of the coastal line in the north-western part of the region are connected with the ancient landsliding phenomena (Utrish island, Utrishonok peninsula).

Recent exogenetic processes and morphostructural regions.

Abrasion and fall-slide processes are the most dangerous natural processes of exogenetic nature that provoke the destruction of the coasts. On the Black Sea coast in Krasnodar region 21 types of recent exogenetic processes have taken place (Kos'yan et al, 1997; Yesin et al., 1993). The main part in the development of landslides on the coast play abrasion and physical-chemical erosion, especially at the sections where beach is absent, or its wideness is insufficient for suppressing of storm waves. Ancient accumulative coasts undergo the erosion too. Side by side with abrasion, weathering and erosion actively influence upon the cliff, and all this results in falling, crumbling and landsliding. A rate of the retreat of a native coast, composed of Paleocene flycsh, is averagely 0.35 m/yr.

Falling-crumbling processes are observed mainly on the benches and cliffs, on steep river and gully slopes. Technogenic crumbling and falling are formed along the motor and rail-way roads (between Tuapse and Magri, near Lazarevskoe settlement) and along the other artificial cuts. Activation of mud-flows on the Black Sea shore is mainly connected with the technogenic activity. The main areas of mud-flow formation coincide with Novorossiysk quarry, Tuapse river valley (zone of agricultural activity), and so on. Mud-flows are caused by abundant atmospheric precipitation, especially in summer.

Sediment transport.

Flow of sediments is one of the most important factors that determine dynamics of the coast. Petrographic analysis gives the fullest idea about the shift of beach material. Using the result of some investigations V.P. Zenkovich (1962) fulfilled such an analysis in 1952 for the Caucasian coasts of the Black Sea. He made the following conclusions. In the region from Tuapse to Gelendzhik a series of characteristic petrographic types has shown "insular" allocation of sediments: either in one any concavity of the coast, or in several adjacent ones. Therefore, a conclusion was made about the absence of a constant sedimentary flow. Material of separate concavities of the coast and that of the near-mouth bays does not exchange each other.

A pronounced flow of sediments begins at the coast section between Pseuzapse and

Ashe (in earlier paper Zenkovich pointed out Tuapse as such a boundary), and it spreads further towards the south, only partially being interrupted by the moles of Sochi port.

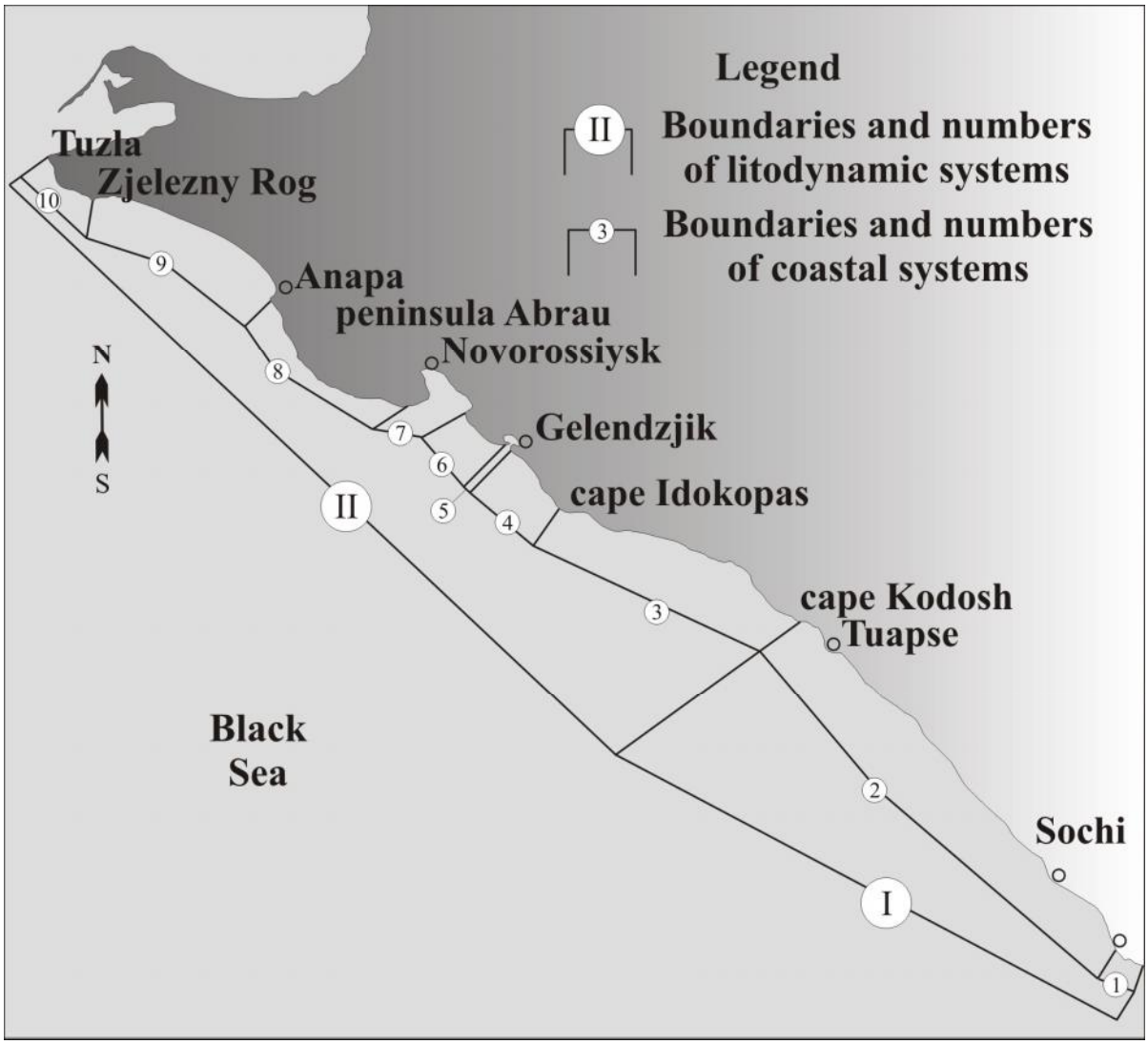


Fig.10. Boundaries and numbers of coastal systems

1. Inter river spacing Psou and Mzymta rivers (8 km)
2. Mzymta river – Kodosh cape (106 km)
3. Kodosh - Idokopas capes (83 km)
4. Idokopas - Tolstiy capes (20 km)
5. Gelendzhik bay (11 km)
6. Tonkiy cape – Doob (11 km)
7. Novorossiysk bay from Doob cape to Myschako (11 km)
8. Myschako – Anapa (52 km)
9. Anapa – Zeleznyj rog cape (58 km)
10. Zeleznyj rog cape – Tuzla (16 km)

COASTAL SYSTEMS

According to the above mentioned criteria it turned to be possible to single out the following coastal systems (Fig. 10).

Selection of coastal systems or cells has been done based on the following criteria. The most northern section of searched coast, Zheleznyj rog cape – Tuzla (№ 10), was singled out into a separate system on geomorpholohical criteria: the section is bordered by natural capes, and as it was shown by field research fulfilled by SBSIO RAS there is no beach material exchange through it. They have similar geological structure of coasts.

The coast section between Zheleznyj rog cape and Anapa (system № 9) is presented by sand beaches with the admixture of shells and products of abrasion from the section Zheleznyj rog cape – Tuzla. Their presence indicates to the ancient lithodynamic processes when there was an exchange between given coast sections. As it was mentioned above, there is no such an exchange today. Formation of sand beaches takes place near the ancient bed of Kuban river. At present time there is no beach replenishment at the researched section. Beaches are in the stage of natural degradation.

It is necessary to single out coast of Abrau peninsula (coastal system №8) as a certain area, taking into consideration both their isolated position and a wide development of ancient landsliding processes, which are not observed on other places of the researched Black Sea coast.

Southward is located so called flycsh zone of the Northern Caucasus. In its general morphology the flycsh geological structure plays an important part. Its strata are intensively dislocated. Large bays (Novorossiysk № 7), Gelendzhik (№ 5) are within the transitional zones between different structures, small bays usually are connected with “slots” along the line of tectonic ruptures what is in many cases the characteristic feature of antyclinal structures. For example, Blue bay, that can be singled out as a separate sell. Capes were formed in the places of synclinal arcs, where flycsh suites are consolidated, or in the places of a steep fall of layers.

Coastal system № 6 coincides with the exposure of a large mountain massif of Doob directly to the sea.

Between Tolstiy and Kodosh capes the shore is characterized by two large concavities and this affords to single out two coastal systems at this coast section, namely: between Idokopas and Tolstiy capes (№ 4) and Kodosh – Idokopas capes (№ 3). The structure of these systems includes a number of small bays, having not large spatial dimensions. They also, the same way as Rybatskaya bay, can be singled out as separate cells: Praskoveevka, Dzankhot and Divnomorsk, Olginka, Novomikhailovskaya, Pesochnaya, Shapsuho, Dzubga, Bzid, Vulan.

To the south from Kodosh cape alongshore sedimentary flow becomes pronounced one, and this affords to consider the whole section of the coast as an entire coastal

system (№ 2).

As it was noted before, it is necessary to single out Sochi coast section as a separate sub-system Mzymta river - Kodosh cape, where the construction of the port of Sochi resulted in interruption of alongshore sedimentary flow.

The last coast section (system № 1) is located in the place of ancient deltas of Mzymta and Psou rivers.

MODERN STATE OF COASTAL SYSTEMS AND PROBABLE WAYS TO SOLVE THE COASTAL PROTECTION PROBLEMS

Site between Tuzla and Zheleznyj Rog capes.

The condition of coast section between Panagiya and Zheleznyj Rog capes is the matter of the greatest trouble in this coastal system. Coast benches, having an average rate of their retreating 0.7 m/yr, experience strong fall-landsliding processes. In the end of 90-ies of the last century the impact upon the coastal line grew very much, owing to the building of two large terminals (for ammonia and petroleum transshipment). Therefore the problem of stabilization of coastal processes became very actual for this coast section. Investigations performed by the department of coastal zone in the Southern Branch of the Institute of Oceanology, Russian Academy of Sciences in 2002 gave a possibility to elaborate recommendations for probable scenarios of coast reinforcing. It was recommended to stabilize coastal processes by means of terracing of benches, rock filling and construction of artificial gravel beach with the width being sufficient for damping wave of proof parameters. These ideas have been taken into account in the coast protection project that is being elaborated nowadays. But, unfortunately, when trying to realize this project we conflicted with departmental and local interpretation to solve this problem. The project was admitted for protection of buildings and communications only in the 21 km long central part. Neighbor coast sections keep being unprotected, it is not difficult to predict their evolution: fall-landsliding processes will become more intensive. To all appearance, for the solution of this problem is necessary the interference of the coast owner, i.e. State bodies.

Anapa beaches.

In the end of last century Kuban river completely became a part of the Sea of Azov, and coastal line from Zheleznyj Rog cape to Anapa town turned cross the resultant waves. In the course of these natural processes sand beaches near Anapa lost their source of feeding. At present they are degradating bodies. The reason of their further degradation in modern conditions is the human factor: with the purpose to equip with services and utilities in the urban area an embankment with concrete retaining walls has been built. Retaining walls were placed almost near the water edge, and they considerably intensified erosion of beach forming material, when damping waves.

It was recommended to remove all capital constructions from the beach, and first of all to move the embankment at larger distance from the sea, to replenish city part

with sand from Marya Magdalina Bank. Unfortunately, recommendations of the scientists did not meet a proper admission. Fine-grained sand was supplied from the nearest dunes; it was not kept on the beach. And a number of capital houses, such as private cafes, shops and so on greatly grew, and this finely resulted in more intensive beach degradation. In such a situation sand filling will be not enough for the restoration of the beach. The most effective one can be its restoration under the protection of above-water breakwaters, made of stone boulders. And coarse sand must be filled: river sand or sand from the same Marya Magdalina Bank.

The same problem has a beach of Malaya Bay. In 80-ies marl filling was done for its nourishment. Marl was very quickly abraded, this resulted in silting of the surf zone, and recreation value of the beach became worse. The way of keeping beach material within the bay was not considered. Therefore, during south-eastern storms pebble began to leave the bay and to drift water area of yacht club. The real solution of this problem seems to be rather simple: to fill beach with crusted stone of more hard rocks and to build a sediment keeping construction (rock-fill groin or surface breakwater, for example) on the northern promontory of the bay. After the creation of artificial coastal belt composed of local chippings it was intended to fill in the beach with imported hard gravel. The construction of well-equipped embankment was planned too.

Coast between Anapa and Tsemess bay.

Coastal benches at the section under consideration underwent abrasion-landsliding processes. Sedimentary flow here is of a migratory nature. Sediment migrations were observed in some bays or in one-two concavities of the coast. Beach here is not broad enough to protect the coast. Therefore, in this case the most reasonable way to protect the coast will be the broadening of concavities beaches existing in coast by means of artificial ripraps. It should be noted that this part of the coast area has an exclusive value for resort construction. Therefore beach filling up to designed parameters will secure not only safe coast protection, but will increase essentially its recreation value.

To protect coast on the open sections, which are characterized by an acute shortage of sediments, wave-damping ripraps of natural stones may be recommended (Kos'yan et al.,2005a). Stone riprap will safely protect the foot of the coastal bench from destroying influence of waves, and this will result in decreasing of the rates of abrasion. Artificial beaches building can be recommended for increasing the protection features of such constructions. Beach building within recreation zone will be the most suitable one. Beaches may be created together with sediment-holding complexes (rock fills will be preferable). It should be noted, that in the case of migrated sedimentary flow the sediment-holding erections will not essentially affect on neighbor coast sections.

Coast section between Tsemess bay and Idokopas cape.

A problem of mentioned coast can be defined as restoration of existing beach and protection of coast sections having prospective recreation value.

Coast near Novorossiysk is almost completely assimilated. Heaping up of different

concrete erections (port piers, jetties, etc.) can be explained by its industrial importance. We will not touch this question. The only coast section, which is used by inhabitants of the city as a recreation zone, is a city beach near Malaya Zemlya. Today this beach has no natural nourishment, it is degrading and, obviously, it does not answer requirements of the city. Creation of artificial beach belt, filled will local coarse fragmentary stone and with imported hard gravel, may be recommended here. This coast section is open to the most intensive South-Eastern storms, and gravel losses due to attrition may be essential ones. Therefore compensatory ripraps should be included into the project of the beach operation.

Beaches in Gelendzhik and Kabardinka have similar problems. Instead of beaches we can observe here heaps of coarse fragmentary material together with reinforced concrete groins, baffle plates. Some of them has been already partly wrecked. Town beach in Gelendzhik is the only exception. It was built of sand from the central part of the bay in 1972. This beach degrades gradually (~ 5 cm/yr) but till now it serves as protection and recreation system.

An optimum choice for all researched bays is the creation of an unbroken belt of free beach. For Gelendzhik bay (the same as for town beach) the material can be taken out of the central deep part. For Kabardinka – it can be the imported hard gravel. In the places where groins and baffle plates have been constructed, it is desirable to fill material into a full capacity of a cell. Head part of some groins should be broken, as far as it is difficult and expensive to dismantle them completely.

Coast from Doob cape to Blue Bay is presented by flycsh bench, 15-20 m high. Today it is not of especial recreation value due to its bad access. But, taking into consideration the prospects of its utilization in future, it must be protected also. The rate of the cliff retreating now is 1-2 cm/yr. Due to such rate of abrasion, during ten years the State loses about 0.3 hectares of the most valuable nearshore land. To protect the given coast section, it would be sufficient to build the gravel beach (without rock-fill berm). There is no need to construct a beach of a full profile. The rate of abrasion-denudation coast retreat may be essentially decreased by fills of sufficiently less amount (Kuklev et al., 1993; Kuklev et al., 1995).

Flycsh benches from Blue bay almost come to naught near Tonkiy cape. Coast is not elaborated from recreation point of view, but in future it has a large potential for such utilization. Creation of natural bays by building of intermitted breakwater or by cutting in the coastal benches can be a possible version of its exploitation. Recommended coast protection measures are the same as for the coast section between Doob cape and Blue bay.

Coast between Tonkiy and Idokopas capes.

This region includes 3 bays: Praskoveevka, Dzankhot and Divnomorsk. Two former bays have gravel beaches, 35-45 m wide, and they do not cause any troubles. In Divnomorsk a broad beach is situated near the mouth of Aderba river. In the south-eastern part of the bay coast protection structures (baffle plates and groins) were built in different time. Time by time beaches here are nourished by fill but their width is not enough for wave suppressing. Coast protection constructions are deformed to a great extent. More regular and larger fills of beach forming material can be

recommended for this beach. As to coast protection structures, it would be better to replace groins by rock fills (if only partially – head parts), and build rock berms in front of baffle plates. This will afford to decrease a negative affect of baffle plates on the sediment regime.

At the other coast sections there are narrow leaned beaches having the width varying from 3 up to 10 m. Similarity to geological structure, lithodynamic processes make it possible to give the same recommendations as those for the coast section between Doob and Tonkiy capes.

Coast section between Idokopas and Kodosh capes.

This area includes 8 bays. Here, at some open sections, the artificial beaches protected by rock fill groins and surface breakwaters have been built and are planned to be constructed nowadays. As far as alongshore sedimentary flow is not well pronounced at this coast section, such an approach seems to be reasonable (Kuklev et al., 1997).

In the majority of bays the beach broadness is not sufficient for the coast protection. Its restoration up to calculated broadness demands additional fill. Inal bay is the only exception; artificial beach was built in 1992, till now it functions as protection and recreation structure.

The beach in Pesochnaya bay arouses the greatest apprehension. This beach is of exclusive recreation value. It was formed during the last Holocene transgression as a result of conversion of a large sandy body. Today it has no nourishment. The beach becomes degraded. The intensification of its degradation in the 20th century was provoked by the human interference: sand was removed for construction needs, and this was continued till now. Withdrawal was made form the surf zone, where sand of most coarse fractions was removed. Remained fine-grained sand was easily washed out during storms. The construction of vertical wall of embankment accelerated the beach erosion. As it was seen from the investigations fulfilled by the coastal zone department of SBSIO, during the period from 1992 to 2003, water edge was retreating averagely for 2 m/yr.

The restoration of the beach in its former shape is not reasonable from economical point of view, since the sources of coarse-grained sand are at the large distance from this place. The beach can be aggraded by means of sand withdrawal from the depth (all amount of washed out sand is at the depth of 15-20 m). But it would be only a half-measure. Construction of gravel beach seems to be the most efficient measure. Now the beach is filled-up but not sufficiently. It is also necessary to eliminate the affect of the embankment wall, what is one of the reasons of beach erosion. It can be made by building of a rock-fill berm in front of embankment.

Common recommendations on coast protection between Anapa and Tuapse.

Shallow bottom, the absence of large sedimentary flows, coast concavity and the presence of bays create rather unfavorable conditions for a vast performance of coast protection by means of artificial beaches. Beach must be built, firstly, in the places where it is necessary and where beach cannot form naturally. Such beaches

may be free ones (in bays). At the open sections beach should be built together with sediment-holding complexes. One of the most effective methods of regulation of along shore sedimentary flow shift is the cutting of coastal line by means of artificial dikes in small lithodynamic cells. Creation of wave suppressing elements, reefs, for example, will increase greatly the beach resistance of the capes and promontories.

In the places where existing baffle plates do not guarantee an effective protection or negatively affect to the beach dynamics, it is reasonable to dismantle them and to build rock-fill berms in front of them. It would be better to dismantle concrete groins (or their head parts) and replace them by rock-fill berms.

Coast section between Tuapse and Sochi.

Mentioned coast section was a kind of testing ground for different concrete coast protection constructions. The practice demonstrated the full bankruptcy of such a method of the problem solution. Sooner or later the coast must be set free from concrete structures. The first step should be dismantling the head parts of groins and building the continuous belt of full-profile beaches under the protection of intermittent dikes. Along shore sediment flow is pronounced here, and this fact can be taken into consideration when building hydraulic erections and during the period of their operation. By all means, the project must include compensative fills and by-passing from the places of accumulation of beach-forming material to the eroded sections.

Sochi beaches.

The construction of the port jetty became the reason of Sochi beach degradation, because it interrupted a powerful north-western sedimentary flow, which existed there before. Basing on the prime reason, it is quite logical to restore beaches to their former broadness and then keep them in such a state by artificial feeding. The amounts of material will be 30 thousand cubic meters per year. Partially the material can be supplied in the course of by-passing from the north-western part of the port of Sochi (Kos'yan et al.,2005b).

A central part of Sochi coast needs the basic reconstruction. Most likely, it is necessary to dismantle concrete bodies and replace them for the rock constructions. At the first stage beaches may be created at the local sections, 2-3 km long, together with the wave suppressing structures. For example, intermittent breakwaters made of fill of natural stones can give good results.

Coast section between Mzymta and Psou rivers.

A total length of the coastal line of Adler jut is about 8 km. Its counter is complicated by Konstantinovsky cape and by two symmetrical bays. Here, natural sandy-gravel beaches were about 50-60 m wide, and the solid run-off of river Mzymta was the main source of their feeding. After the construction of the dam of Krasnopolyanskaya water power plant and control of river run-off, the amount of solid sediment decreased and became about 30-35 thousand cubic meters per year. Beaches between those rivers for a long time were used as an ordinary quarry, about 2 million cubic meters of gravel and sand was removed from it (it is the most rough

calculation). Besides, due to the construction of continuous rows of groins sediment supply by north-western flow has completely ceased. This resulted in scarcity of the beaches at this coast section. In this case we may recommend the dismantling of concrete groins (partially it has been done at the distance of 0.6 km from Mzymta mouth), regular nourishment in the place of saturation of the sedimentary flow, i.e. near the mouth of Mzymta river.

ANALYSIS

Summarizing the analysis of coastal protective activities executed on the East coast of the Black Sea, we may conclude the following:

For a long period of time the coast protective activity was concentrated on elimination of localized zones of washout, without consideration of lithodynamic system in which the protected area is located, that led to disturbance of sediments flows, and, consequently, to acceleration of abrasion on the related parts of the shore.

Wide usage of enforced concrete did not stabilize the coast. It might sound paradoxical, but those parts of the shore, which had been protected for the longest period of time, turned to be in the worst shape. Inconsistency of purely technical approach became to be especially evident, when a repair works costs started to exceed the cost of the facilities under protection.

Main technical solutions regarding coast protection constructions for creation of artificial beaches are borrowed from the experience of coast protection (construction of bunas, breakwaters and wave walls) at Caucasus and Crimean shores of the Black Sea. Application of bunas and breakwaters is formally divided by the steepness of the underwater slope equal to 0.03. However, this division did not and does not have any physical grounds and is not confirmed by materials of study of surf zone's hydro- and lithodynamics. Types of constructions and their composition in the coastal protective complexes were assigned subjectively.

Absence of guaranteed sources of non-metallic materials and regulatory base for design and civil construction did not allow developing a protection of coast with help of free artificial gravel beach. So, the available experience is limited by several examples and it requires very thorough investigation, particularly for creation of appropriate regulatory basis.

We need to mention, that available materials of studies can be used for justification of modern coast protective measures, especially in regard to the expediency of enforced concrete constructions, etc. Accumulated experience quite evidently votes for flexible systems of coast enforcement and artificial beaches in conjunction with sediment preserving rock fills (berm-type non-continuous breakwaters, wave-dissipating rock fills, etc.).

Because of general deficit of the sediments, the free beaches with big length were difficult to create. It was necessary to build the sediment retaining constructions like bunas, on the landslide sections – underwater breakwaters. Thus, the beaches in the coast protective complexes were having a primary role, and the constructions -

secondary. It is obvious, that the positive effect of such coast protection complex is the construction of wave dissipating beach with width no less than twenty five – thirty meters in the Tuapse – Psou part of the coast.

CONCLUSION

As a whole the state of coasts of the Russian sector of the Black Sea can be declared as unsatisfactory one. At present a considerable part of the coast (~309 km from 476 km of the coast line total length) is routed by different exogenic processes: abrasion, landslide, fall, etc. In some cases such a situation is aggravated by technogenous impact upon the coastal systems which has been done earlier.

A strategy of coast protection must be based on the idea that coast should be considered being an entire system within what only some coastal systems can be singled out. The seacoasts protection does not stand standard solutions. Every part of a shore needs to be creatively approached and its hydrodynamic, lithodynamic, geological, geomorphological and other peculiarities must be thoroughly studied for each particular situation. It takes a complex scientific approach considering not only local features, but also the reaction of whole lithodynamic system in limits of which the coast protective activity is planned with consideration of calculated hydrodynamic parameters (waves, sea level, etc.).

In conditions of the North-Caucasian coast it is intolerable to implement additional coast protection measures such as building of tetrapode berms in front of wall, different kind of ripraps of figure concrete massive, etc. They limit the possibility of recreation use of the coast. As far as climate is favorable, any version of coast protection measures must be elaborated with regard for future extension of coast usage as resort-sanatorium region. In this case the same ripraps but consisting of rock fills are preferable.

Construction of artificial beaches is the most effective method of coast protection. Beaches can be free one or those created under defense of sediment keeping constructions. The use of sediment keeping constructions is efficient at the coast sections with weak alongshore sedimentary flow or within spatially limited coastal systems (natural concavities, bays). Designing of sediment keeping constructions at the coast sections with pronounced alongshore sedimentary flow by all means must include compensative measures (for example, by-passing). Coast protection systems would be flexible ones and combine beaches with sediment keeping constructions, and beaches in such complexes must be of principle importance.

Every coast protection measure must be based on the up-to-date knowledge about the coast process evolution, on systemic dividing of the coast for regions, on more detailed and reliable information about factors which influence upon the coast erosion, efficiency and duration of hydraulic erection operation. Engineering solutions shall be preceded with forecasting estimations of shores' evolution under natural conditions and after completion of coast protection measures. This, in turn, requires organizing of special studies in the field, and wide usage of mathematical, computer and hydraulic modeling during design stage.

-

ACKNOWLEDGEMENT

This work was executed under financial support of the Russian Foundation for Basic Researches, projects 05-05-64145 and 06-05-96649.

REFERENCES

Kaplin P.A., Leontiev O.K, Loukyanova S.A., Nikiforov L.G. 1991. The shores. Moscow. Mysl. 265 p. (in Russian).

Kosýan R.D., Magoon O.T. 1993. Coastline of the Black Sea. New York. Publ. by ASCE. 573 p.

Kosýan R.D., Kuklev S.B., Yesin N.V., Khanukaev S.B. 2005a. Black Sea East Coast wave-induced erosion protection experience. Proc. of the Second International Conference "California and the World Ocean". Reston. Virginia. Publ. by ASCE. 204 - 216.

Kosýan R., Krylenko M., Petrov V., Yaroslavtsev N. 2005b. Study of Beach State and Coast Protection within Sochi City. Proc. of the Seventh International Conference on the Mediterranean Coastal Environment, "MEDCOAST' 05". Turkey. 1007-1016.

Kosýan R.D., Yesin N.V. 1997. Fight Against Erosion of the Caucasus Coast. Proc.of the First International Conference "California and the World Ocean". Reston. Virginia. Publ. by ASCE. 753 – 769.

Kuklev S.B., Yesin N.V. 1997. Adaptation of model of dynamics of gravel beach contour in the conditions of the Black Sea North-Caucasian Coast. Proc. of the Third International Conference on the Mediterranean Coastal Environment, "MEDCOAST' 97". Malta. 1089-1097.

Peshkov V..M. 2003. Sea Coastal Zone. Krasnodar. "Lakont". 350p. (in Russian).

Safyanov G.A. 1978. Coastal zone in XX century. Moscow.Mysl. 263 p. (in Russian)

Yesin N.V., Kuklev S.B. and Savin M.T. 1993. Coast evolution under global sea level rise. Proc. of the First International Conference on the Mediterranean Coastal Environment, "MEDCOAST' 93". Turkey. 961-971.

Yesin N.V., Savin M.T., Zhilyaev A.P. 1980. Abrasion process on the seashore. Leningrad., Gidrometeoizdat. 200 p. (in Russian).

Zenkovich V.P. 1962. The Principles of Sea Shore Evolution Doctrine. M., USSR Ac.Sci.Publ. 701p. (in Russian)