Technologies of coastal restoration in the Eastern Black Sea

by

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The erosion and degradation observed during the last 100-120 years on the eastern Black Sea coast (mainly belonging to Georgia – 313 km) are due to several factors. The importance of these factors varies in space and time, combining natural causes and increasing technogenic influence.

Several factors have led to a sharp deficit of beachforming material in the coastal zone and to the release of wave energy now spent in destroying and washing away the coast: sea-level rise; sinking of relatively large river mouths along the accumulative coast; the duration of waves' influence over once gently sloping submarine slope resulting in the exhaustion of sediment supply; numerous constructions in the coastal zone completely or partially obstructing the sediment drift (ports, dams across the rivers, coast-protective constructions, etc.); the use of beachforming material for industrial purposes and so on.

The first coast protective works in Georgia were carried out around 1870. They grew in scale in the forties, along with the economical activities. Until 1982 the strategy of coast protection was centered on the elaboration and building of new coast protective structures, which dealt with the results rather than with the reasons of coast erosion, and thus could not be considered as nature preserving. Moreover the coast-protective constructions usually are the small analogs of port moles (differing by the size and consequently by the scale of side-effects). Thus they are "alien" to the coastal zone and interfere with the natural process of coast formation. There is no lack of examples demonstrating that landscapes overcrowded with constructions symbolize not only our impotency against the sea but mainly the limitations (in space and time) of the approach to the problem, ignoring the nature of coastal zone and the possibility of cooperating with it. The total length of eroding coast in Georgia was 155 km in 1961, 183 km in 1971 and 220 km in 1981. At the same time the total expenses of coast protection in towns (46 km) and along the railways (18 km) amounted to 45 million rubles during 1961-1971 and to more than 80 millions during 1972-1981. As more and more coast-protective constructions were built, more and more beaches were washed away and replaced with concrete.

The Scientific Industrial Association (SIA) of Seacoast Protection "Saknapirdatsva" was created by government decree in 1981 and was in fact experimental in the field of management. Its activities are directed by the Research Institute of coastal morphodynamics, which integrates scientific research, analysis, generalization of empirical data, experimenting and decision-making, and also plans their realization in space and time. According to its mission (study of seacoast nature) this institute developed qualitatively new strategy of transforming seacoast landscapes. The main goal of this strategy – instead of protecting some sections of coast (e.g. with constructions or artificial beach nourishment) – is to achieve and retain the balanced budget of beachforming sediment in each dynamic system.

From a scientific point of view, the novelty is the development and use for coastal classification of the concept of "discontinuous morpho-lithodynamic systems" almost autonomously and hence subject to regulation. This enabled us to work out the qualitatively new strategy of harmonizing the human activities with the nature of coastal zone. The idea is to achieve morphodynamic balance by regulating the lithodynamic processes within each region. This is especially important at accumulative and abrasion-accumulative coasts (respectively 62.3% and 37.7% of the total coastline of Georgia), where the dynamic condition of coast is completely (accumulative coast) or almost completely (abrasion-accumulative coast) determined by the balance of beachforming material. The reported thesis is based on the analysis of the reasons and consequences of breaking the lithodynamic conditions supporting the balanced budget of beachforming material (i.e. morphodynamic balance) during the evolution of coastal zone and also on the established general features of input and redistribution of sediment in space and time.

During the last five or six thousand years a large scale redistribution of material supplied to the coastal zone of Georgia took place. Initially there existed two long-range sediment drifts along the North-West and South-East sand-pebble shores of Georgia. Both of them were directed towards the mouth of river Rioni where they died away and supported the intensive promotion of coastline seawards. Along this easternmost part of the coast (60 km long sandy beaches), even today, instead of one-way transportation of beachforming material, short-range migration is observed. This is due to the shape of the coastline and to the prevailing west winds that are frontal only to the eastern coast.

The flattened contour of the coast at the initial phase of formation of the present relief indicates that the capacity and actual intensity of both above-mentioned sediment drifts remained equal and were gradually decreasing along the drift. At the same time the coastline was bordered by terrace formed by gradual accumulation of material.

So at the time of slowing down and stabilization of speed of sea level rise (6-5 thousand years ago) there were three morphodynamic regions on the Black Sea coast of Georgia – the Northern region, the Southern one and – just between these two – the Eastern one (or the Poti region). Each of them represented closed lithodynamic system evolving independently or, in the case of the Eastern region, almost independently. The changes in the described course of coastal processes were conditioned by increase of the volume of supplied beachforming material together with slowing down and stabilization of speed of sea level rise. The abundance of beachforming materials caused just further progradation of the coastline. The formation and the evolution of the island in the mouth of river Rioni illustrates the frontal exposition of this region to the prevailing direction of waves.

In the other regions the excess of beachforming material brought by rivers led to the formation of capes and promontories at the river mouths. The end of these promontories crossed the narrow shelf. As they were growing, more and more sediment was lost to large depths at distant parts of them. This process goes on even today (Fig. 1).

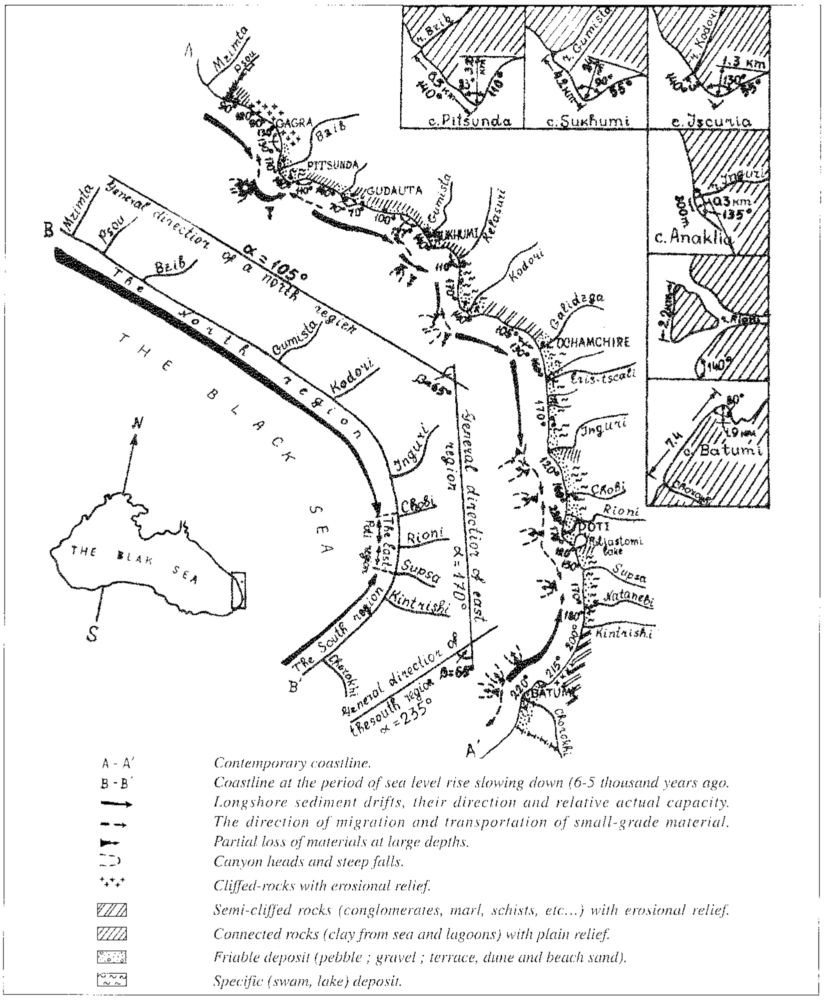

FIGURE 1 – Schematic map of the morpho- and lithodynamic coastal zone of Black Sea in Georgia (Kiknadze A. G.).

These accumulative formations at the river mouths as well as the bays between them reflect the common character of regularities and processes that lead to the formation of analogous morphodynamic structures. This common character is revealed not only in relief but also in formation and distribution of longshore sediment drifts which had conditioned the development of accumulative and abrasion-accumulative forms of coast.

So at the end of formation of contemporary coastal relief (2500 to 2000 years ago) the whole sediment drift accumulated over 6-5 thousand years along the 200 km of North-West coast of Georgia was intercepted by the accumulative formations at the river mouths of Mzimta, Bzyb, Gumista and Codori. As a result there appeared 4 shorter, but independent morphodynamic systems: Northern (Mzimta) system – 41 km long, Bzyb one – 67 km, Gudauta system – 35 km and codori system – 83 km. Interference between promontories and sediment drift increased, along with the loss of material to the large depths, causing a deficit of material on the beaches shaded from winds by these promontories. This and also the different firmness of components of abrasion-accumulative coasts condition the selective abrasion supporting the winding shape of coastline. The described process is intensified by insertion of artificial constructions (with unnatural mechanic and hydrodynamic qualities) on the way of longshore drift of beachforming material. These factors determine in turn the observed growth in breaking the structure of longshore drifts, the asynchronous changes of its capacity and actual intensity and also the disbalance between them.

These are the reasons why the five above-mentioned systems of Northern and Southern regions are fractured at the present stage of coast evolution. It is expressed in loosening of the ties between internal morphodynamic subsystems. Each of the five systems is divided into three subsystems. The first one – subsystem "**A**" – covers the sections with promontories at river mouths and represents highly developed coastal formation. Subsystem "**B**" is a continuation of subsystem "**A**" to the side shaded by promontory from dominating winds and covers abrasion-accumulative coast. Subsystem "**G**" – the last one – covers accumulative coast built by relatively small-graded sediment (Fig. 2).

The length of subsystems "**A**" is 28.6% of the total length of the five systems. As much as 93.7% of total discharge of beachforming material of the rivers enters these subsystems. However some sections of these subsystems are being washed out. This indicates a deficit of the beachforming material, due mainly to the loss of material at large depths. The volume of hard discharge within the subsystems "**B**" is only 4.1% while their length is almost half (46.9%) of the total length.

The conditions of coast evolution within the subsystems "**G**" (24% of sand-pebble beaches) are quite alike that of the Poti region: the exposure to waves; gentle slope at the small depths; the character of longshore sediment drift (having not one direction); relatively small-graded material compared to neighboring sections, etc. The difference is in the length (61 km in Poti region and, for instance in subsystem "**G**" of Northern region, 8 km) and in the way the beachforming material is supplied (from river mouths in Poti region and by two-way longshore drifts in subsystems "**G**").

According to the strategy of restoration of morphodynamic balance by controlling lithodynamic processes, the main problems are the following:

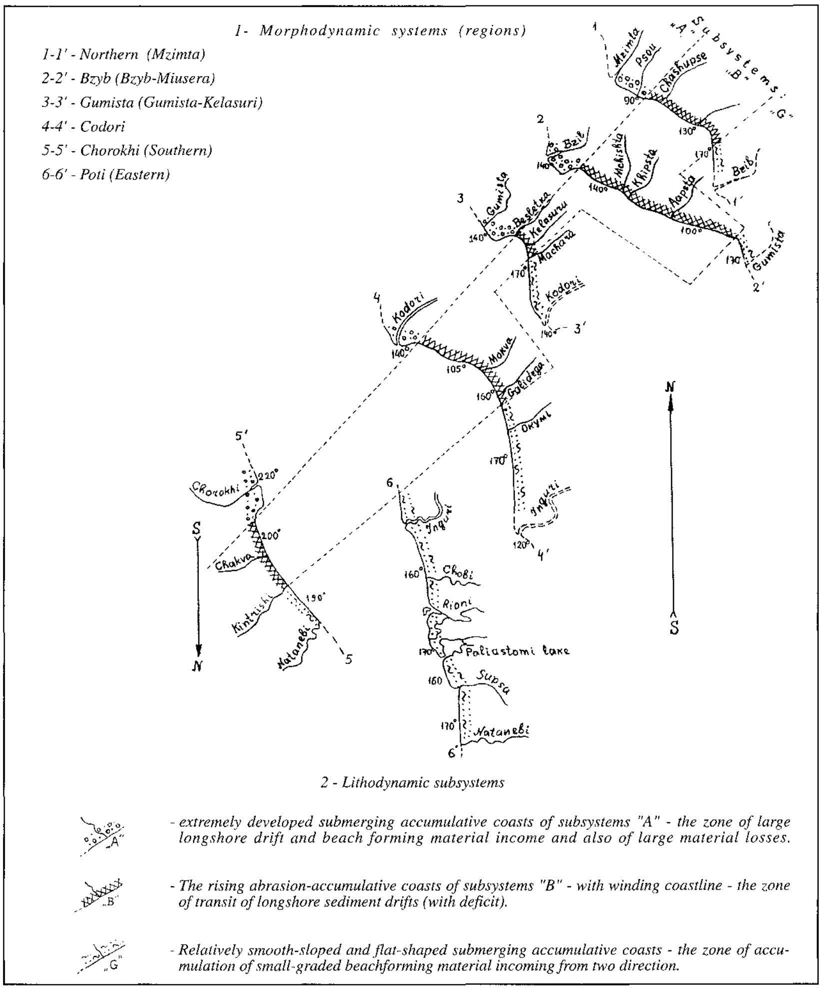

FIGURE 2 – The Scheme of Morphodynamic systems (regions) and subsystems within them (A. Kiknadze).

– within subsystems "**A**" – reducing the budget deficit by artificial regulation of the zones of hard river discharge of the rivers and reducing the losses of material to large depths at the heads of the canyons and steep slopes at distant parts of the promontories; increasing the volume of material transported to the subsystems "**B**" (up to 50 m³/year) by (partially) removing the promontories interfering with sediment drift; mechanical transportation of material from the zones of excessive accumulation to places of loss at large depths and so on (figure 3).

– within subsystems "**B**" (figure 4) – artificially increasing the input of beachforming material from the subsystems "**A**" and ensuring the saturated sediment drift towards subsystems "**G**" by optimization of coast exposition

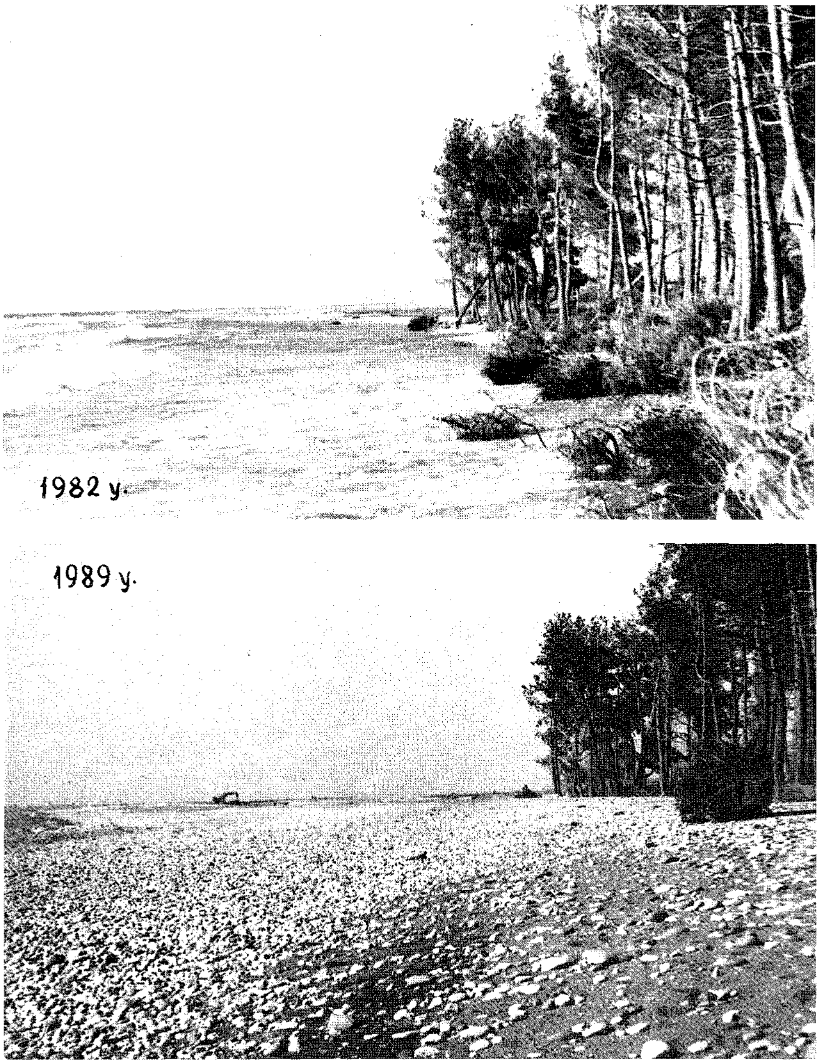

FIGURE 3 – Section of restored coast within subsystem "**A**".

to the waves by removing or burying under sediment the natural or artificial obstacles which slow down the longshore sediment drift (cliff ledges including submarine ones, small concavities of coastline, breakwaters, etc.) or speed it up (cliffs, walls etc.) within the whole cross-section of moving parts of the beach.

– within the subsystems "**G**" in eastern region – to retain the balance of budget of beachforming material which, in case of restoration of natural processes of material income (from subsystems "**B**" and river mouths) will be preserved automatically (figure 5).

FIGURE 4 – Section of restored coast within subsystem "**B**".

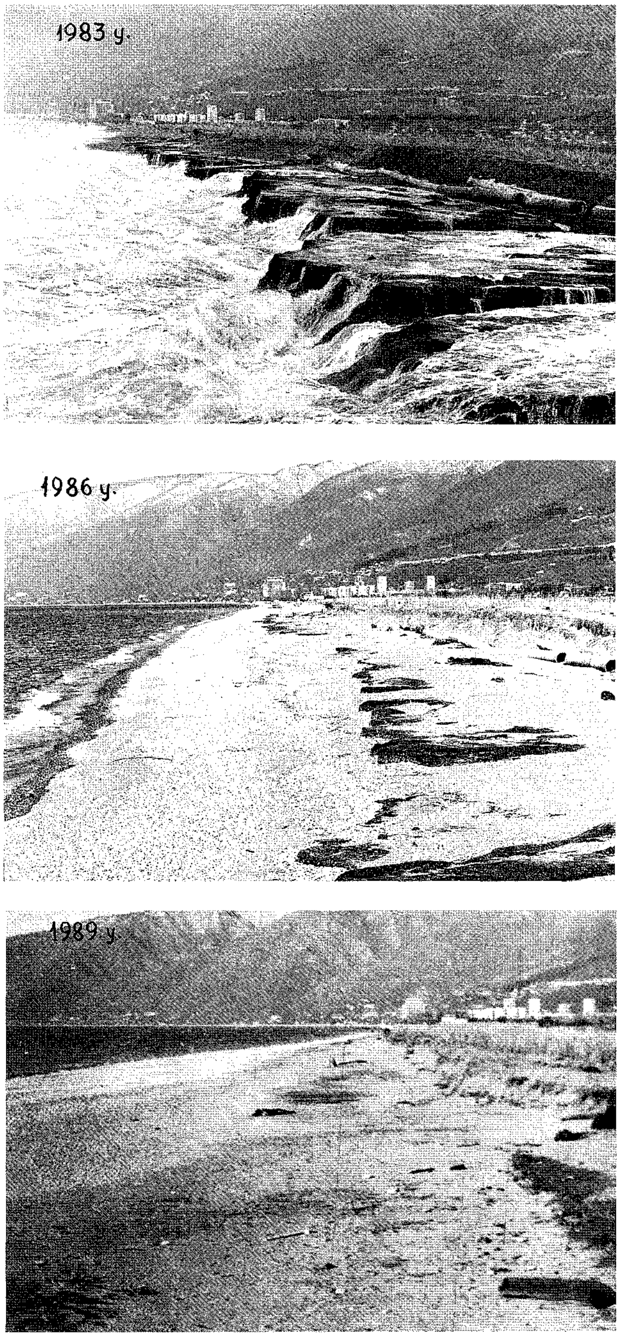

FIGURE 5 – Section of restored coast within subsystem "**G**".

In order to reduce the influence of port moles blocking up the sediment drift (which cuts the natural length of longshore drift down to 33% of the coastline of Georgia), the artificial transportation of beachforming material from the windward sides of the moles to the opposite ones is necessary.

As a result the energy of waves will be spent only in sediment transportation and will become creative instead of destructive. At the same time the weakened or intersected interactions of adjacent sectors of shore are restored and the processes of self-regulation of mobile beach zones along the whole morpho- and lithodynamic subsystems and systems are gradually reanimated. The use of constructions for coastal protection is considered as a "surgery" to be applied only in exceptional cases – when it allows to speed up and achieve the above-mentioned goals at a reduced cost.

The scientific basis, economical expediency and social necessity of the proposed strategy of cooperating with nature are confirmed by the results of work carried out in 1982-1990: the length of eroding coast in that period was cut down to 80 km (more than 30%), at the same time 110 hectares of beaches were restored, spending only 93.2 million rubles without using any kind of construction materials (concrete, metal, etc.). Besides, the natural landscapes were restored in place of concrete constructions. While until 1982 there appeared nearly every year some 8 or 10 government decrees concerning the restoration of sea-storms damages, since 1982 there have been none. Moreover, the May 1988 storm in the neighboring of Bolshie Sochi Russian coast (more than 100 km long) caused significant destructions and several million rubles' damage despite the "battle" with the sea "from a position of force" (during the last 40 years various constructions were built: walls – more than 80 km altogether; more than 900 moles, breakwaters – over 50 km, etc., costing more than a quarter of billion rubles). The same storm in Georgia restored 10 hectares of land. It is worth mentioning that in cases like the Georgian seacoast – with steep pebble beaches, large length of sediment drift (tens of kilometers with capacities more than 100 thousand m^3 and velocities up to 200 m/day, etc), numerous submarine canyons, etc – even the artificial beaches nourishment was considered inexpedient, not to mention the regulation of beachforming processes.

The above-mentioned results, along with additional work carried out by SIA on other coasts allow us to conclude that in principle the proposed strategy of management of coastal processes can be applied everywhere. The specific natural conditions of beachforming and coast evolution in other seas and coastal zones determine only the tactical scheme of realization of the strategy, making it expedient from the economical and technical point of view. But what is essential is not the specific natural conditions or the technology of coastal protection, but the approach to the problem, integrating scientific and organizational principles to harmonize human activity with nature. The experience of SIA confirms that optimal exploitation of natural resources must be based on the theoretical foundations of the science.