Protecting the Black Sea - Georgian S.S.R. Gravel Coast

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ABSTRACT


The gravel beaches of the western Georgian S.S.R. coast have long been undergoing severe erosion. Construction of passive concrete structures had seriously depleted the sediment supply. Following local sediment budget studies and a review of beach replenishment techniques employed around the world, artificial nourishment was successfully employed by trucking in gravel or by depositing gravel on the nearshore bottom from self-unloading barges. Beaches in the northern Psou-Cape Pitsunda and southern Batumi regions have been restored in this manner and their case histories are outlined here.

ADDITIONAL INDEX WORDS: Artificial nourishment; beach restoration, Black Sea, coastal engineering, coastal protection, Georgian S.S.R., gravel beaches, sediment budget, shore drift, Soviet Union.

INTRODUCTION

The Black Sea coast has suffered significantly because of the use of beach deposits as construction material for cities, summer resorts, and roads. More than 30 million m³ of sand and gravel were removed from the Georgian beaches, total length 312 km (Figure 1), during the 20-year period between 1945 and 1965. This resulted in very extensive narrowing of the beaches; and in some cases, complete loss of the beach. Coastal recession at rates up to 3-5 m/yr has been recorded, with the process extending to depths of 15 m (KIKNADZE, 1981, 1984).

A variety of passive coastal protection measures were widely used in the past to stop this process. These included stone bulkheads, 100-ton concrete blocks, and figured forms (tetrapods, etc.) In addition, coast-parallel breakwaters, of both the submerged type and protruding above water level, were constructed in some places (KAPLIN and NIKIFOROV, 1985). In the 1950's, wide-scale investigations of the characteristics and dynamics of the Georgian coastal zone were carried out (ZENKOVICH, 1958, 1973). These studies now provide a basis for radical changes in technical policy and organization of coastal protection.

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REGIONAL SETTING

The coast of Georgia is divided into several natural systems with quite independent sediment budgets (ZENKOVICH, 1982, 1985). The major east-west fetch across the Black Sea causes the approach of predominant waves to be at an optimum angle to exposed portions of the coastline. This in turn generates sediment transport, within several drift cells, towards the central part of the Kolkhida lowland (ALEXANDER and ZENKOVICH, 1976; MOIGN and PASKOFF, 1977).

Most drift cells have their sediment source, mainly from river mouths, in the west. In some of the cells, sediment transport continues to the next river mouth, where bars or spits form, or to the steep subaqueous slopes of prograded coastal features such as Cape Pitsunda (Figure 2). Other drift cells, the Kodori and Batumi in particular, end at the upper extent of submarine canyons (LEONTIEV and SAFYANOV, 1973). Sand and gravel are transported down the canyons to depths in excess of 1 km.

Eight drift cells of different lengths (from 5 to 40 km) and volumes have been identified along the Georgian coast (KIKNADZE, MELADZE and SAKVARELIDZE, 1984). The drift cell between the mouth of the Bzyb' River and Cape Pitsunda has the maximum volume at 150-200 thousand m³/yr.
Loss to submarine canyons is greatest in the Batumi drift cell. The cell begins at the Chorokhi River mouth, which delivers approximately 2 million m$^3$ of sediment per year. About 1.900 thousand m$^3$ of the sand and gravel descends more than 1 km down a submarine canyon near the river mouth. The other 100 thousand m$^3$ of sediment is transported 8 km to the north, only to disappear completely into the Batumi submarine canyon (KANDELAKI, 1976).

For twenty years these unusual dynamics and characteristics of the Georgian coast were ignored in the design and construction of shore protection. Each agency that built a waterfront sanatorium or resort installed generally acceptable passive coastal-protection devices to protect its own sector of the shore. Groynes caused updrift sediment accumulation; but, as a rule, downdrift erosion, which seriously affected the shore of other waterfront developments farther down the coast. The length of the eroded Georgian coast increased quickly; reaching 155 km in 1961, 183 km in 1972, and 220 km in 1981. Depending on the composition of the substratum, the erosion reached depths of 10-15 m.

(KIKNADZE, MELADZE and SAKVARELIDZE, 1984).

Until recently, construction of massive walls and emplacement of concrete blocks or tetrapods was still a common practice. This caused the loss of valuable resort beaches for many kilometers along the coast. The situation became even worse as rivers were dammed for hydroelectric power and irrigation of arable land, thereby abruptly decreasing the volume of sediment carried to the sea, and the subsequent intensification of shore erosion. All of these changes were investigated in detail by the Coastal Zone Laboratory at the Vakhushti Bagrationi Institute of Geography, Academy of Sciences of the Georgian S.S.R. (ZENKOVICH, 1977).

PROCEDURES

Discussion

At the initiative of coastal specialists, and approved by the Government of Georgia, the independent Science-Industry Organization (S.I.O.) GRuzmorberegozashchita was formed in 1981. It
took on the responsibility, not only of coastal protection, but also of the restoration of the coast to its pre-erosion condition.

S.I.O. is situated in Tbilisi, the capital of Georgia. A.G. Kiknadze is the General Director. The scientific department, headed by V.V. Sakvarelidze, is the main department among the several S.I.O. departments, which include design, project-estimating, finance, and construction (SAKVARELIDZE, 1984). Former specialists in the Institute of Geography continue their work in the S.I.O. laboratories.

The scientific department includes the following laboratories: land-surveying and map-making, sea research, river-mouth research, lithology, geomorphology, and Quaternary geology. Six field observation stations, with permanent staff, have been established at the coast. Monitoring the coastal zone, the staff make repeated beach profiles, measurements of depths, and collect and analyze sediment samples.

Taking into account the failures of the previous coastal protection methods, the directors of the S.I.O. aimed at restoring eroded beach sectors by artificial nourishment with appropriately sized sediment. Experience in beach restoration and protection widely used in the U.S.A., West Germany, Denmark, Australia, and Japan was taken into consideration. However, in these countries and some others, artificial beach nourishment has been used mainly to restore sand beaches, whereas it is gravel beaches that needed restoration first of all in Georgia*. For that purpose, SAVKARELIDZE (1984) worked out new calculation methods for the required amount of ballast per unit of beach length for various bottom slopes, sediment composition, wave regimes and other relevant factors. In addition, attrition of the gravel had to be taken into account, its average value being assumed to be 5%/yr in volume (VOLKOV and IONIN, 1962).

First of all, sediment budgets were determined for each sector of the coast. Beach-forming sediment load at river mouths, and its transportation by currents and waves, was found with the help of the new method. Taking into account the whole complex of natural factors, it was calculated that the restoration of one kilometer of beach length would require from 100 to 150 thousand m³ of gravel. As quarry material usually contains finer fractions (silt and sand), the amount sometimes has to be increased beyond that.

Psou-Pitsunda Coast

The effectiveness of the S.I.O. work and its results is exemplified by the achievements obtained in the 35-km-long Psou-Pitsunda sector. The Psou River formerly discharged about 35 thousand m³ of gravel per year. This beach material was augmented by sediment from the small Zhovekvara River in the Gagra resort area; however, there was some attrition in the volume by the time the shore drift reached the mouth of the Bzyb' River.

A series of groynes was constructed 7 km to the south of the Psou River mouth in 1972-76, which had the effect of trapping virtually all of the shore-drifted material. Then, too, earlier a dam was built across the Zhovekvara River, causing its sediment load to decrease to a minimum. Following these two events, the subaerial portion of the gravel beaches disappeared completely, though some subaqueous transport of the sediment continued along the nearshore bottom (ZENKOVICH and PESHKOV, 1978).

As a result, the Gagra resort beaches were deprived of sediment replenishment. By 1980, more than 2 million m³ of sediment had been transported to the south from this sector, and the formerly 30-m-wide beach had nearly disappeared. Storm waves were then breaking upon the seawalls that had previously protected the resort facilities.

During 1965-1975, groynes were constructed along the Gagra resort coastal sector. However, they failed to accumulate any significant amount of gravel; and, in fact, the situation worsened. After a while, the groynes were destroyed by wave action, and the resort area was further imperilled. Some sanatoriums were separated from the sea by a narrow strip of land scarcely 20 m wide.

Sand and gravel quarries were quickly located, and the material was hauled by truck directly to several beach dump sites. At each location, the artificial nourishment sediment was spread, fan-like, into the sea, building what has been called a ground groyne. Waves breaking upon these features then carried the material in the direction of the former shore drift, thus reconstructing the eroded beach sectors.

By 1982, 510 thousand m³ of beach nourishment sediment had been added to the coast in this fashion; and the beaches were restored along a 15-km-long stretch of the coastline. Within two years of this, the newly-restored sector extended to Cape

*The U.S. Army Corps of Engineers has been successfully replenishing the beach at Ediz Hook, at Port Angeles, Washington, with coarse gravel during the present decade. Approximately 15 thousand m³ of fill are required annually to maintain the spit.
Pitsunda; with a width, in places, of 60-90 m (Figures 3 and 4).

The total volume of artificial nourishment exceeded 2 million m$^3$ in 3 years. To compensate for gravel attrition, supplemental artificial nourishment will be required every few years. According to S.I.O. calculations, the annual amount of artificial nourishment will not exceed 70 thousand m$^3$. Thus, the method of coastal protection for gravel beaches described above is less expensive, by a factor of 2, than the construction of groynes. Furthermore, the method is much more attractive visually.

During the time when the beaches in this region were being seriously eroded, thick peat layers were exposed in the foreshore southeast of Gagra. Fragments of peat littered the beach as far south as the mouth of the Bzyb' River, near Cape Pitsunda. With the artificial beach nourishment in the Gagra area, a 40-m-wide sand and gravel beach was built up in front of the peat exposure (Figures 5 and 6).

**Discussion**

Before undertaking S.I.O. investigations, there was a thorough review of analogous projects in other countries. However, though there were, as stated here earlier, successful projects in the reconstruction and preservation of sand beaches in the U.S.A., West Germany, Holland, Australia, etc., no information could be found relating to the same for gravel beaches. And yet, at the same time, some of the problems accompanying the restoration and protection of sand beaches became apparent. In particular, the proceedings of the Coastal Society’s annual meeting (PSUTY, 1980) illustrated the difficulties in finding some consensus among coastal process specialists, coastal engineers, private interests, and government agency representatives.

In the opinion of Soviet scientists, when dealing with a large complex of complicated dynamic coastal processes over a huge area, it is not appropriate to incorporate a variety of approaches; for
example, the stabilization of a large single form such as Long Island. S.I.O. experience, illustrated by the two case histories outlined here, shows that coastal protection should proceed under a single management system, in control of all phases of the complex processes of study, restoration and protection of the coast. This assertion can be illustrated by the example of coastal enhancement carried out to the north of Batumi.

**Batumi Coast**

North of Batumi the mountains extend close to the Black Sea; with only a north-south railroad track perched in between, and no automobile road to the beach. The 17 km coastal sector between Makhindzhauri and Tsikhisdziri has been protected by seawalls from wave attack since the turn of the century. Yet two, and in some places three, generations of construction were completely destroyed. The railway could not be relocated farther inland, and tunnels were required at two sites.

One-hundred-ton concrete blocks were fabricated, delivered, and piled at the places where the seawall was destroyed, in order to protect the coast. Erosion of the backshore ceased, but the beach disappeared as a result, and this beautiful subtropical coast could not be utilized for resort purposes.

Supplies of gravel in this region are abundant, because the Chorokni River flows into the sea only 20 km to the south, discharging over a million m$^3$ of sand, gravel, and rock fragments annually (Kandelaki, 1976). Since 90% of the sediment discharge is lost into the head of a submarine canyon directly in front of the river mouth, huge amounts of sediment may be removed from the lower reaches of the river to protect the coast in the Makhindzhauri-Tsikhisdziri region without the risk of affecting the coastal sector in between.

Because restoration could only be approached from the sea, it was decided to transport gravel and rock fragment ballast to the eroded beach sites by self-unloading barges (Bruun, 1985), and unload them
directly onto the nearshore bottom (ALPENIDZE, 1985). The steepness of the subaqueous slope there is 0.03-0.05 down to depths of 6 m.

This decision was based on a number of examples of other Black Sea coastal zones, where beaches are naturally replenished by bottom sediment. Two such places are the coasts of the Tarkhankut Peninsula and the Gudunta shallow. Similar experiments have been carried out in both the Black and Baltic seas (ORVIKU, 1976). SAKVARELIDZE (1984) has made special calculations for the Batumi area. Summing up all the data, it was hypothesized that in the area in question, gravel would be moved shoreward from depths of 4-6 m.

Dumping of gravel down to these depths from self-unloading barges began in the spring of 1982, with I. Papashvili supervising the work. A mound about 3 m in height and up to 60-100 m in width was deposited on the bottom. The mound was irregular in form, consisting of separate heaps with a steeper slope on the shoreward side.

During 1982-1983 not a single strong storm occurred in the area. The subaqueous gravel mound became only slightly deformed; the slope facing the shore became steeper, but no material was transported above sea level. Needless to say, this caused some anxiety as the total volume of unloaded gravel was 800 thousand m³ and the work was rather expensive.

Finally, spring storms came in December of 1984. Within a few hours, as 5 m waves reached the shore, a beach 2-3 m wide developed above sea level and considerable gravel was thrown over the concrete blocks.

After a period of calm weather, a series of strong storms occurred until April, 1985; with attendant remarkable changes in the beach form. Portions of the exposed beach reached 30 m width in front of the concrete blocks (Figures 7-8), and the subaqueous gravel mound disappeared completely.

Figure 5  Erosion of the coast southeast of the Gagra resort area during 1982 (photo V M Peshkov)
The nearshore bottom became sandy again, and the previous slope was restored.

The new beach and general coastal regime are now under systematic monitoring. Gravel on the beach is moving slowly alongshore towards Cape Tsikhisdziri, which projects significantly seaward and the gravel will obviously not be able to bypass it. In most places, the concrete blocks are completely covered by gravel. Where the concrete blocks are exposed, there is some risk of seaward backwash transport of sediment; but any deficit and beach narrowing can be offset by further unloading of replenishment gravel on the nearshore bottom.

CONCLUSIONS

Beach construction by artificial nourishment on the Psou-Pitsunda and other regions of coastal western Georgia have proven to be 2 times cheaper than the building of passive concrete structures; though in the case of the Batumi region, such comparisons can not be made. During past years, large sums of money were wasted on passive coastal protection. Now, nearshore bottom gravel nourishment has revived the coast, providing ideal recreational conditions. Experience in the very near future will show how long the new conditions will prevail, and allow estimates of necessary expenses in the event that some portion of the beaches need to be restored.

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☑ RESUMEN ☐

Las playas de gravas de la costa Oeste de la República Socialista Soviética de Georgia han sufrido graves erosiones. La construcción de estructuras de hormigón ha acabado con el aporte suplementario de sedimentos. Siguiendo estudios de sedimentos locales y técnicas empleadas en todo el mundo de regeneración de playas, se ha realizado una alimentación artificial con éxito empleando camiones o depositando grava en el fondo cerca de la costa con barcazas autodescargables. Se han regenerado playas en las regiones del Norte de Psousa y del Sur de Batumi de esta manera y sus casos históricos son los que en este artículo se detallan.--Miguel A. Losada, Universidad de Santander, Santander, Spain

☑ ZUSAMMENFASSUNG ☐


Figure 8. The same site as Figure 7, during 1985. The beach had prograded 15-20 m, due to replenishment dumped on the nearshore bottom (photo: I. Papashvily).