Journal of the Georgian Geophysical Society,
Issue B. Physics of Atmosphere, Ocean and Space Plasma, v.14, 2010, pp. 85-95.

Main regularities of forming a new delta of Rioni River

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Abstract

Based on natural measurements and geodetic references of old cartographic materials the new Rioni River delta (which was formed after the river diversion in 1939) development tendency was defined. A large two-arm delta was formed during a period of more than 60 years. The mentioned delta was developing along with a relative sea level rising, construction of a hydropower station on the river, and minimal sediment losses in the greater depths. Studies have shown that, despite the relative rise in the sea level by 0.53 cm, the coastline extension over a 13 km long section is continuous since 1939 until the present time. Construction of the hydropower plant and annual removal dredging of sediments from the approach channel of the port of Poti port slowed down the progradation, but general tendency of the coast development has not changed. We can therefore conclude that even in the face of global warming and associated sea level rise, not only the coastline maintenance in a stable condition is possible, but also its progradation in the case of the accumulative coasts, where there is no significant loss of beach-shaping sediments at greater depths and which are characterized by excessive intake of river sediments.

In terms of global warming and rising sea levels it is timely to research an impact of this process on a coastal zone, and in particular on the development of accumulative deltaic ridges, formed by sand-muddy sediments. In this respect, it is interesting to trace the new Rioni delta development, which formed its new mouth in 1939. The new delta of Rioni River began to form in the autumn of 1939, as the river was transferred entirely to the north of the place of its former location. The reason for the transfer was frequent flooding of populated areas of Poti city during high waters and floods. In addition, due to large sediment accumulations a rapid advance of the underwater canyon tops, located near the former mouth of the northern branch, to protecting malls of the Poti port was observed, resulting in a very real threat of their destruction. Since that time until today an absolute sea-level rise relative to land area, taking into account a tectonic subsidence, made 0.53 meters [1]. Despite this, during this time a rather large two-armed delta was formed, which has transferred into a stage of many arms development since 2005.

Under natural conditions, i.e. before the Poti port breakwater construction, the coastal zone of central Colchida was developed as a single lithodynamic system [2]. Rioni River used to flow into the sea in two arms somewhere in the middle of this system. Hereby, one of the arms fell into the sea in a close vicinity of the Poti submarine canyon top, and the second – in 2,4-x. kilometres to the south, where the canyon is missing, and an underwater slope takes a normal profile with a slope of 0.007. By that time the solid flow of the river was estimated at 9.7 million m3 per year [3, 4]. For underwater slope and shoreline feeding was spent not more than 1 million m^3 of this amount. The rest went irretrievably to greater depths of the underwater canon. Today's solid flow of the river is about 5 mln.m^3/year. The faction diameter, mostly solid sediment runoff of the river, is less than 1 mm.

Beaches and the underwater slope of the coast are composed of only sand and silt deposits. The underwater slope is quite reclined, the average sloping is 0.0074. On the underwater slope in

2.5 km north to the actual urban channel estuary of Rioni River is located Poti submarine canyon. Its apex is characterized by a 10 m isobaths. Distance from the shoreline to the canyon top makes 600 meters. The underwater slope inclination before the canyon top is 0.013 (see Fig. 1).

Under natural conditions Rioni River flowed into the sea in two arms. One of the arms flowed into the sea before the canyon top. The second periodically changed its location and fell into the sea to the south or north of the canyon. The location of this arm was limited by Paliastomi Lake to the south and to the north by 5-6 kilometres from the top of the canyon [5]. Sediments of the arm that flowed into the submarine canyon vicinity reached mainly the top of the canyon and then moved permanently to greater depths [6]. Thus, they played a lesser role in the beach and underwater slope nourishment. Sediments of the second arm, remote to the canyon, were distributed over the underwater slope and along the coast. The coastline extension and accumulation were determined depending on the fact, on which side would the arm, remote to the canyon, flow. In 18th and 19th centuries the second arm flowed to the south of the canyon top, where according to materials of old cartographic surveys the coast extension was recorded [6]. In general, the coastline extension by a stable sea level was limited by the underwater canyon top and therefore these periodic extensions, in spite of such great hard flow of the river, were temporary.

The existed natural balance was disrupted in the late 19th century, as the Poti sea port breakwaters were built, which disturbed the natural sediment distribution. The south breakwater was built just north of the underwater canyon, where the Rioni River northern arm flowed to that time. The breakwater limited free sediment migration. As a result, large sediment masses began to accumulate at the canyon top. Reaching large weights the sediments shifted to greater depths of the canyon by gravity. Intensified erosion processes occurred for this reason, resulting in the canyon top extension to the shore and south breakwater, which had been built to this time. The threat of erosion for densely populated coastal area of Poti and the breakwater destruction appeared. To stop the canyon extension towards the coast old barges and ships were sank there, but there was no tangible result (see Fig, 2).

Before construction of the protection moles at Poti Sea Port (1873-1888) the coastal zone has developed in a natural mode, which was formed in the second half of Holocene, about 5-6 thousand years ago [5].

The Rioni River litho-dynamic system beaches are completely formed by fine-grained sand and silt sediments, and their width varies in ranges of 70-120 meters. The beach ridge heights vary in ranges of 0.8-1.5 meters. The alongshore sediment transport is directed from north to south, and its consumption is estimated at 300-400 thousand m^3 per year. The scale of migration is also significant, which provides presence of Rioni sediments in the northern direction up to the Hobi River mouth.

Existing surface beaches are composed of fine-grained sandy material. The underwater slope has a bias $tg\alpha = 0.007\text{-}0.008$ up to 10 m isobaths, i.e. 7.8 meter isobaths are 1 km away from the coastline. Within these limits several rows of alongshore ridges are situated at the underwater slopes. The most distant and powerful ridge is located in 400-500 meters from the encroachment line, and its shape is symmetric – inclinations in both directions to the sea and towards the coast are equal.

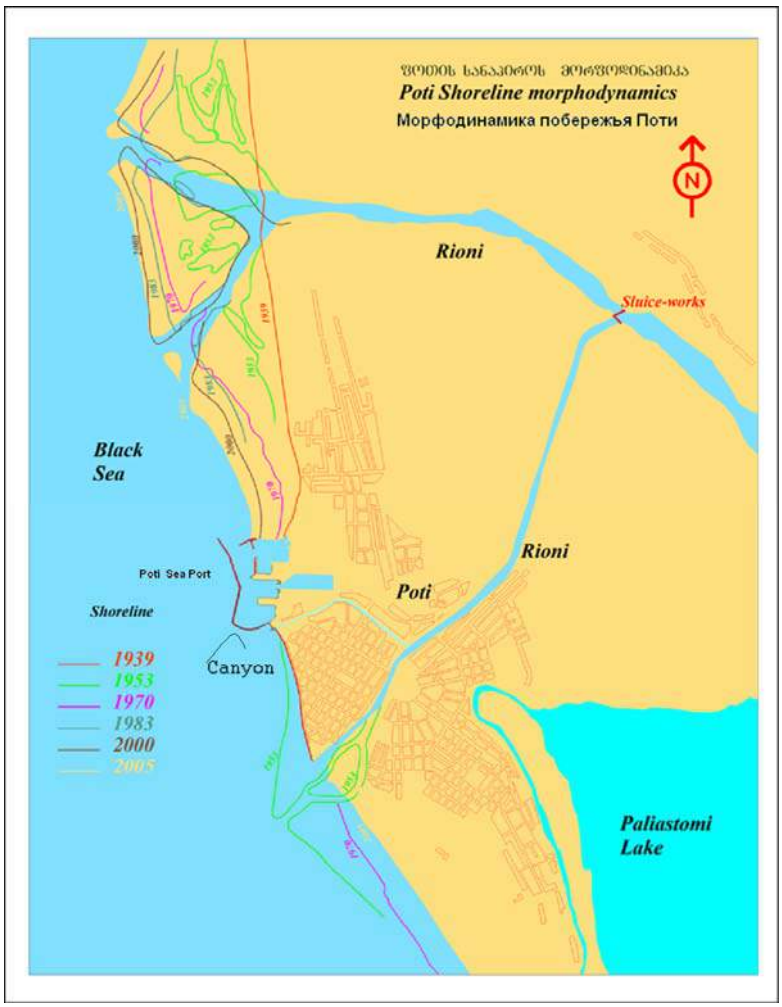

Fig. 1. Poti city coastal zone scheme

Fig. 2. Status of the underwater canyon top before (shot in 1937-1) and 2- after transfer of the river (shot in 1999)

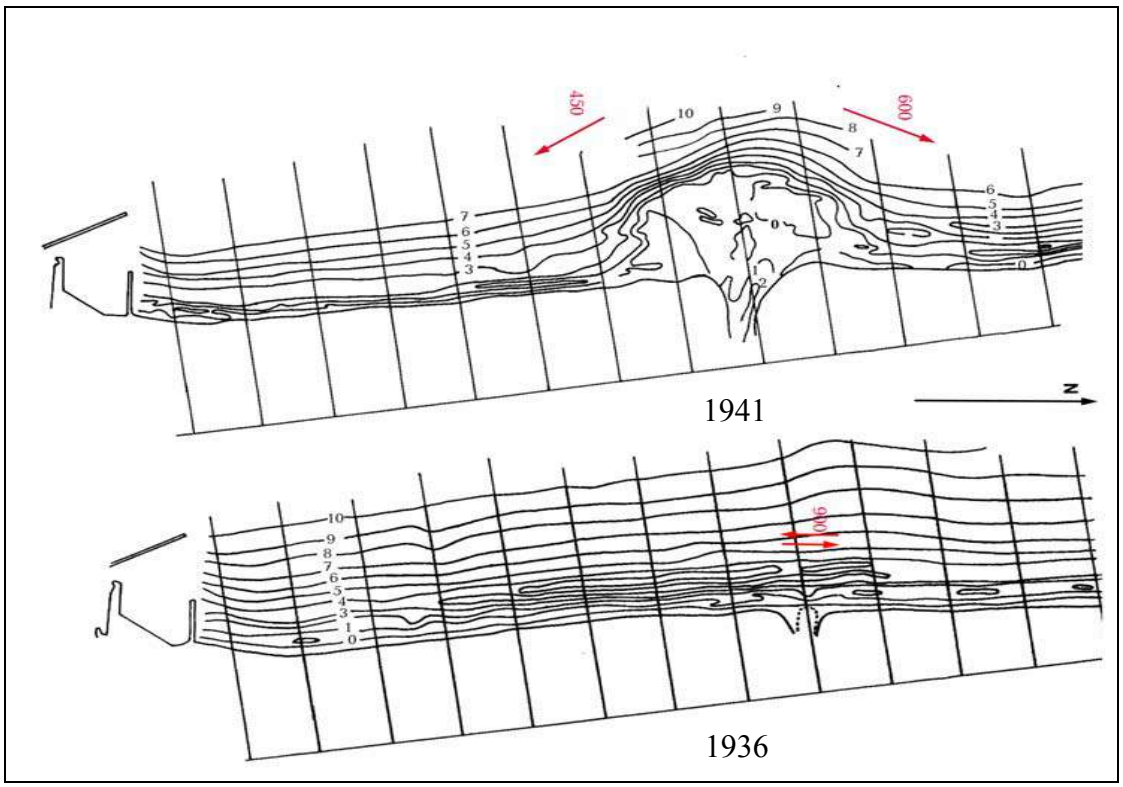

Fig. 3. Status of the coast and underwater slope north to the port of Poti before formation of Rioni River new estuary (1936) and after 1941.

The ridge top is at a depth of 3.7-4.3 meters. Distances between the ridge troughs range from 250 to 300 meters. The ridge volume is ca 770-800 thousand m3 per linear kilometre. The shore nearby ridges are less powerful, and they are asymmetrically shaped. Internal ridges change their shape and move even by small sea waves. The most distant ridge moves during heavy sea storms. The scale of the ridge cross-migrations relative to the coastline varies between 150-200 meters - according to the NIF "Gamma" researches.

Comparison of mapping surveys the early 19th century with later surveys before the port construction showed significant changes in the coastline. In particular the bank moved intensively forward in the area of current location of the city channel mouth. Apparently, this process occurred due to migration of one of the river mouths. There is a reason to believe that the southern arm was formed shortly before the accumulation processes begun. Morphological analysis shows that up to this time, Rioni River either flowed in one arm into the sea directly in front of the canyon top, or in two arms (branches), the second of which was located further in the north. In the latter case, the river delta also formed an island, which was located north to the now existing one. Such movements of the mouth apparently occurred periodically for a long period. Hereby, one of the mouths was always located directly in front of the canyon apex. At the time when one of the branches was situated in the north, accumulative processes and accordingly coastal extension occurred north to the canyon top; vice versa when the southern arm was active, the coast build-up south to the canyon top took place. Hence, erosions prevailed, when sediment transport to the discussed sections of the shore was stopping. In these cases stability of the banks was maintained just directly in front of the canyon apex. Thus, accumulations and erosions occurred south or north to the canyon top location, depending on where the river arm, remote to the canyon, formed its mouth. Periodicity of the process is not entirely clear, but one can assume that it happened once in two or three hundred years.

Until 1939 the shoreline north to the port was directed perpendicularly to the resultant wave pattern. Therefore, opposing alongshore sediment migrations of approximately equal amounts dominated in this part of the coast. Even before the construction of a new northern breakwater very

intense shore build-up had taken place near the old northern breakwater. This process occurred due to the strong influence of port facilities, particularly the northern and south-western breakwaters. Northern storms transported sediments to the south; however, their subsequent movement in that direction occurred in smaller scopes, as the south-west breakwater created a wave "shadow". Intensive accumulation processes began at the new pre-estuary coastland immediately after the river transfer (see Fig. 4).

Since there was no canyon on the submarine slope at the river inflow point, and the underwater slope receives the bias characteristic of this coast, the sediment losses do not occur in greater depths.

Over the last 72 years a two-arm delta with total area of 1300 hectares was formed in the new mouth. The central part advanced into the sea at 1900 meters. Several bathymetric surveys, covering an area of 13 km from the port of Poti to Hobi River estuary were carried out during the NIF "Gamma" field studies. Obtained maps were transformed into the UTM system after corresponding geodesic transformations and compared with surveys of 1939, 1952, 1983 and 2000. On the basis of these materials amounts of the accumulation were calculated. In just past 60 years 263 million m3 of sediments were accumulated in up to 20 m isobaths. Also deposits have to be taken into account, extracted during dredging activities of the Poti port approach channel. These sediments are flushed to greater depths of the underwater canyon, from where their return to shallow waters is excluded. Thus, the total volume of accumulated sediments was more than 300 million m^3, and the annual average - about 5 million m^3/year.

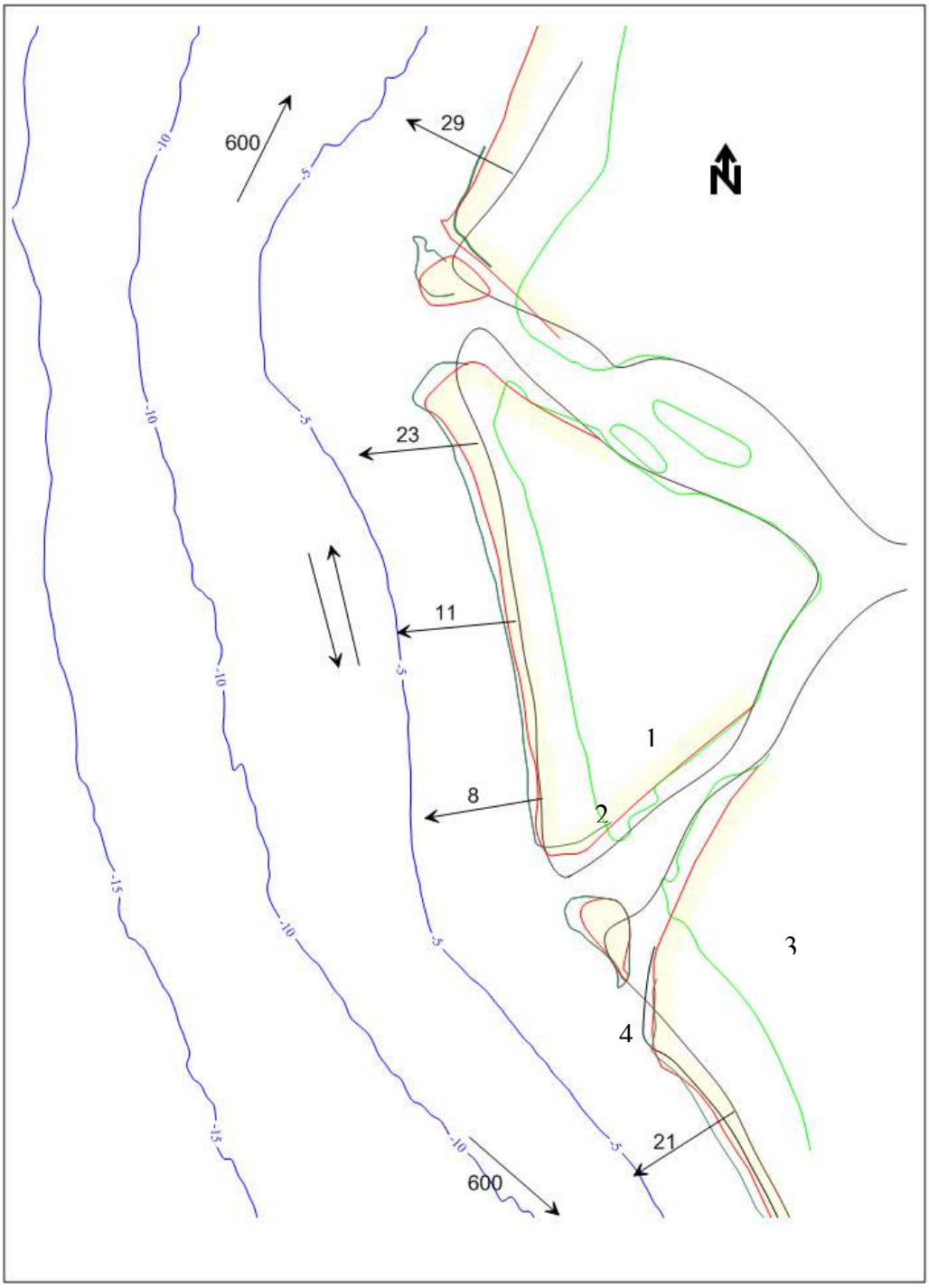

Fig. 4 Rioni River new delta scheme.

Coastal lines: 1983, 2000, 2005, 2007

600 → The coastline extension rate, meter / year

21 → Silt flow direction and flow rate in thousand m^3 per year

It should be noted that the sediment accumulation occurred very unevenly, due to the commissioning of Gumati (1953) and Vartsikhe reservoirs. For example, between 1939 and 1952 the volume of accumulations was 114 million m^3, on average annual amounted to almost 9.0 million m^3 per year. After commissioning of Gumati and Vartsikhe HPPs, annual savings fell to 2.0 million m^3.

Later, by 80s of the last century the volume of accumulations increased and reached 3.6 million m^3. In 2000-2010 the volume of accumulations, excluding dredged volumes from the approach channel, was approximately 3.5-4.0 million m^3. Gradual increase of accumulations is caused by increased solid sediment runoff of the river, which is associated with sedimentation of the existing reservoirs – the sediment saturated water is periodically discharged through their dams (See Fig. 5 and 6 and Table 1).

Thus, we can say that, despite a relative rise of the sea level by 0.53 cm, the coastline extension after 1939 until the present time occurs continuously over 13 km long coastal section. Construction of the hydropower plant and annual sediment dredging from the Poti port approach channel slowed down the coast extension, but the overall direction of the coast development has not changed. Development of this process will not change in the future if the sea level increase and today's solid runoff volumes of Rioni River are maintained. However, in the case of a significant reduction of the river sediment runoff, which, for example, may happen in the case of Namakhvani HPP dam construction, a degradation of the formed delta protrusion will be unavoidable [7].

It has to be mentioned in conclusion that even facing the global warming and the sea (world ocean) level rise associated with it, at accumulative shores, where there is no significant loss of beach-building sediments at greater depths, with an excessive intake of river sediments, not only maintenance of the coastline in a stable condition is possible, but even its extension.

Table 1

Area and accretions volumes in the new Rioni delta during the period from 1939 to 2001

Survey years	Accumulation till the depth metres	Accumulation volume(mln.m3) and accretion areas(hectares) of the south flank				Accumulation volume(mln.m3) and accretion areas(hectares) of the centre				Accumulation volume(mln.m3) and accretion areas(hectares) of the north flank				Σ			
		Volume	Aver. annually	Area	Aver. annually	Volume	Aver. annually	Volume	Aver. annually	Volume	Aver. annually	Volume	Aver. annually	Volume	Aver. annually	Area	Aver. annually
1939 - 1952	10	3,25	0,25	26	2	45,69	3,51	397	31	15,13	1,16	115	9	64,07	4,93	537	41
	20	6,37	0,49			80,92	6,22			26,33	2,03			113,6	8,74		
1952 1983	10	5,75	0,16	68	2	18,45	0,53	173	5	9,94	0,28	86	2	34,14	0,98	327	9
	20	10,73	0,31			42,0	1,2			18,03	0,52			70,76	2,02		
1983 - 2000	10	4,35	0,31	23	2	15,76	1,13	124	9	8,18	0,59	77	6	28,29	2,02	224	16
	20	10,96	0,78			28,1	2,01			12,59	0,90			51,65	3,69		
1939- 2000	10	13,35	0,22	117	2	79,9	1,29	694	11	33,25	0,54	277	4	126,51	2,04	1088	18

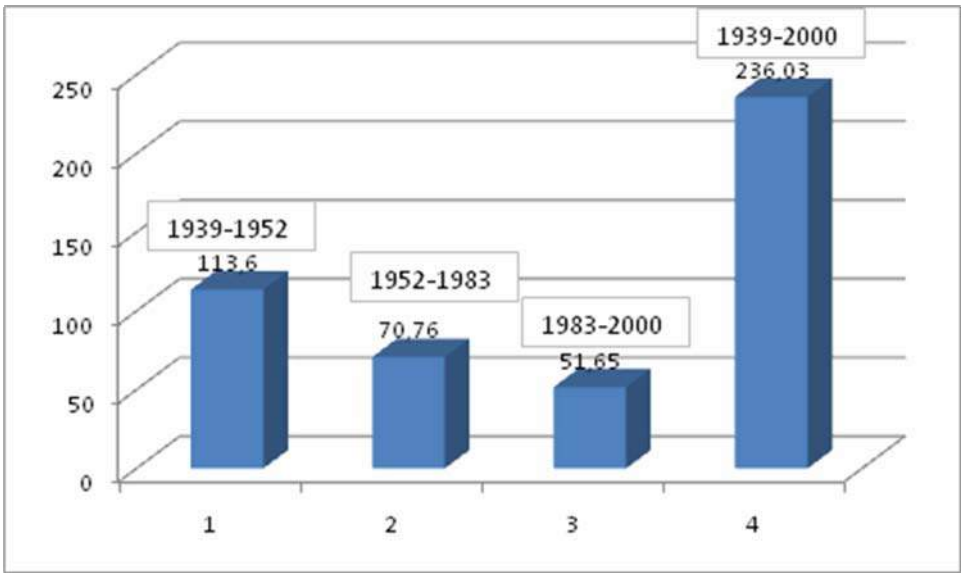

Fig.5. Accumulation volumes in the new delta in different observation periods.

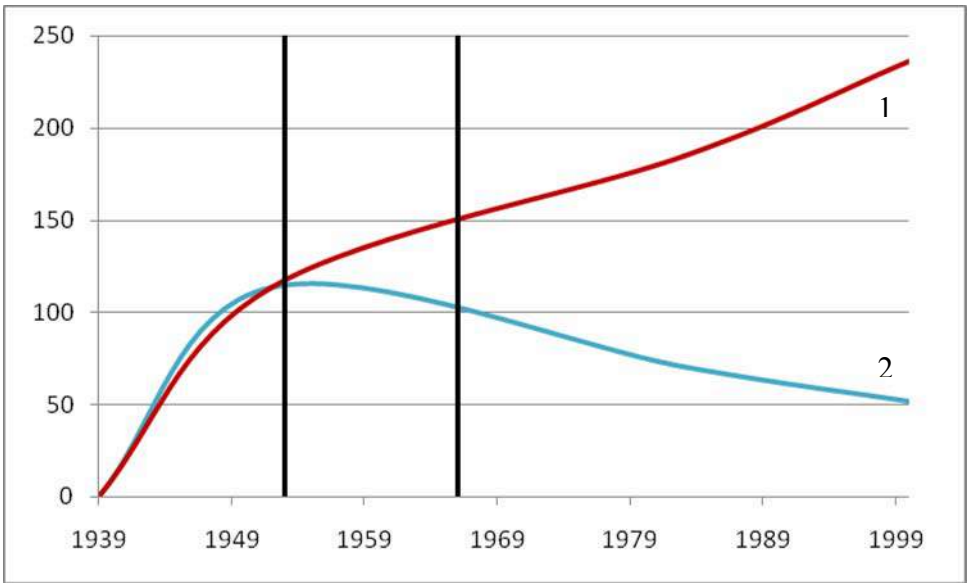

Fig.6 . Curves of sediment accumulation in Rioni River new Delta. Vertical lines indicate commissioning dates of Gumati HPP in1953 and Vartsikhe HPP in 1967.

1 - Cumulative curve of sediment accumulation in the new Delta
2- Annual sediment accumulation, mln m^3

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Основные закономерности формирования новой дельты реки Риони

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Резюме

На основе натурных измерений и геодезической привязки старых картографических материалов определена тенденция развития новой дельты р. Риони, которая образовалась после переброски реки в 1939 году. За период более чем 60 лет, была сформирована обширная двухрукавная дельта. Указанная дельта сформировалась в условиях относительного повышения уровня моря, строительства ГЭС на реке, и минимальных потерь наносов на большие глубины. Исследования показали, что, несмотря на относительное повышение уровня моря на 0,53 см. выдвижение береговой линии после 1939 года до настоящего времени на протяжении 13 километрового участка берега происходит непрерывно. Строительство ГЭС и ежегодные изъятия наносов из подходного канала порта Поти снизили темпы выдвижения, однако общее направление развития берега не изменилось. Отсюда можно заключить, что даже в условиях глобального потепления и связанного с ним повышения уровня Мирового Океана, на аккумулятивных берегах, где не происходят значительные потери пляжеобразущих наносов на большие глубины, с избыточным поступлением из рек наносов, возможны не только сохранение береговой линии в стабильном состоянии, но и его выдвижение.

მდ. რიონის ახალი დელტის ძირითადი კანონზომიერებანი

ირაკლი გ. პაპაშვილი, ბექა ვ. ლებანიძე, ვახტანგ გ. გვახარია

რეზიუმე

ნატურული გაზომვების და ძველი კარტოგრაფიული მასალების გეოდეზიური მიბმის საფუძველზე განისაზღვრა მდ. რიონის ახალი დელტის განვითარების ტენდენცია, რომელიც შეიქმნა მდინარის გადაგდების შემდეგ 1939 წელს. 60 წელზე მეტი პერიოდის განმავლობაში შეიქმნა ორტოტიანი დელტა. აღნიშნული დელტა განვითარდა ზღვის დონის შეფარდებითი აწევის, ჰესების მშენებლობის და ნატანის მინიმალური დაკარგვის დიდ სიღრმეებზე პირობებში. კვლევებმა გვიჩვენეს, რომ ზღვის დონის შეფარდებითი აწევის 0.53 სმ. სანაპირო ხაზის წინსვლა 1939 წლის შემდეგ დღევანდელ დრომდე ნაპირის 13 კილომეტრიან მონაკვეთზე მიმდინარეობს უწყვეტად. ჰესების აშენების და ფოთის ნავსადგურის შემოსავლელი არხიდან ყოველწლიურად ნატანის ამოღების რამდენადმე შეამცირეს ნაპირის წინსვლა, თუმცა სანაპიროს ზოგადი განვითარება არ შეცვლილა. აქედან შეიძლება დავასკვნათ, რომ გლობალური დათბობის პირობებშიც და მასთან დაკავშირებული მსოფლიო ოკეანის დონის აწევა, აკუმულაციურ სანაპიროებზე, მდინარეებიდან ჭარბი ნატანის შემოსვლის პირობებში, შესაძლებელია არა მარტო სანაპიროს სტაბილურ მდგომარეობის შენარჩუნება არამედ მისი წინსვლა.