

Study of Beach State and Coast Protection within Sochi City

R.Kosyan¹, M.Krylenko¹, V.Petrov², N.Yaroslavtsev²

¹The Southern Branch of the P.P.Shirshov Institute of Oceanology, Russian Academy of Sciences. Gelendzhik-7, 353467, Russia.

E-mail: kosyan@sdios.coast.ru

²Centre "Sea shores", 1, Fabritsiusa str., Sochi, 354002 Russia

Abstract

In 2004 the research of the gravel beach condition and that of the coast protection erections were fulfilled at the coast section of Sochi region. In the course of expeditionary works measurements, surveys and estimation of the coast state and coast protection objects have been done. Besides, fund material belonging to the Southern Branch of the P.P. Institute of Oceanology, RAS and those of the other institutions were used.

Main factors that determine the dynamics of wave damping beaches were distinguished and the efficiency of beach holding and coast protection constructions was determined. It was revealed that a degradation of natural gravel beaches takes place and coast protection constructions are not of much efficiency. An expediency of keeping of the wave damping beach stability by the help of gravel-pebble ripraps with the limited utilization of the other methods of beach preservation was founded.

The results of the research may be a basis for the coast protection strategy and elaboration of definite engineering measures.

Introduction

The Black Sea coastal zone contains the richest natural resources and is an object of intensive economical activity. Coastal region is densely populated. Within it there is huge industrial and civil building, and a recreation load is rather essential. At the same time coasts are very vulnerable, and study of their changeability and coast protection is necessary.

Coast section between Magri and Adler is one of the most peculiar parts of the Black Sea dynamical system. It should be noted, that thanks to its natural peculiarities, sedimentary flow at this

coast section is directed from the north-west to south-east. This circumstance is very important from the point of protection and restoration of the lost gravel beaches.

The presence of the railway which was built along the seashore in 1914 is a characteristic feature of a given coast section. When performing coast protection measures, the main attention must be paid to the protection of railway bed from wrecking influence of the sea. It was planned to implement the beach restoring and keeping with the help of beach protection constructions – groins and breakwaters. It was proposed that beach growing would be realised due to natural coastal processes, by means of sediment interception and conservation, and at the coast sections where amount of shifting material is not sufficient – by ripraps of imported beach forming stock. An intensive building of groins and breakwaters continued till the middle of 80-ies. Exhaustion of natural sedimentary flows and low rates of ripraps of imported material resulted in the fact that at some sections the beach broadness turned to be insufficient for the damping of storm waves, and at the other sections the beach completely disappeared.

The goal of performed research is to distinguish main factors, which determine the dynamics of wave damping beaches and efficiency of beach holding and coast protection constructions. And creation of the basis for elaboration of coast protection measures when projecting recreative complexes with regard for the modern processes in the coastal zone at the section under consideration.

Several tasks were solved when realizing the project. The first one is to collect a representative massive of data on the coast state and that of their changeability during the instrumental observations for coastal processes and the coast protection performing. The second – to carry out modern inspection of the coast state and coast protection condition. The third – to fulfill a comparative analysis of modern and future processes of coastal zone evolution. This task exceeds the limits of the present project, but it begins within it.

Investigating coast was divided into eight sections according to morphological features of the coast and lithodynamic processes taking place within it. Boundaries of the sections coincide with the river mouths. Characteristics of the beach belt and coast protection constructions are given for the every coast section.

Brief characteristics of the coast section between Magri and Adler settlements

Considered coast section, 105 km long, is in Sochi region. According to its geological conditions this section may be divided into four regions. The northern region between rivers Tuapse and Shakhe is composed of terrigenous-carbonate flysch of the Upper Cretaceous. Region between rivers Shakhe and Psakhe is presented by terrigenous sub-flysch of Paleogene. The section to the south of Psakhe river up to Kudepsta river is composed of molasses formation of the Upper Paleogene. Southward Imeretinskaya lowland is situated, which is the delta projection of Mzymta and Psou rivers. Recent marine deposits are presented by beach fine boulder-gravel-pebble sediments with sandy-aleuritic filler, and by sandy-aleuritic deposits of the continental slope down the depth of 20 m.

Slope deposits of different genesis are rather widely presented, but abrasion rocky shelves prevail. Landslip deluvial and play the main part near the margin of the coastal zone. Today an interaction of these processes with abrasion ones is interrupted due to intensive reinforcing of the slope and coast along the railway. Fulfilled observations show that the erosion of loose deposits during cloudburst floods reaches 2 m/h, and that results in the formation of erosion grooves, development of caving-crumbling processes, and appearance of landslips and falls. To the

south of the Shakhe river valley landslip and falling processes are wide-spread the most dangerous.

In the presence of storms and cutting out of the beach width abrasion influence of surf flow becomes greatly important for the rates of coast evolution. Erosion and slope processes are greatly developed on the steep slopes of the abrasion shelf, and submerged slope within the Imeretinskaya lowland. The width of the beach at the given coast section varies from 0 to 60 m, and a mean width – 19,4 m. Along the length of 41 km beach broadness is less than 15 m, i.e. less than minimum value necessary for wave damping. Here and there the beach is washed-out completely. Average dimensions of beach strip were decreasing during a long time. Beginning from 1973, a tendency of the beach growing has taken shape, by 1982 its width has become 13 meters, but then it began to decrease again (Table 1). Beach growing during the period from 1973 to 1983 was connected with the ripraps of material obtained from the hill-sides cutting in front of baffle plate and partially by the increase of river solid run-off.

Table 1: Average broadness of beach (m)

| Locations | Length, km | 1956 | 1977 | 1999 | 2004 |
|--------------------|------------|------|------|------|------|
| Magri - Ashe | 12,0 | 9,3 | 8,3 | 12,0 | 11,8 |
| Ashe – Psezuapse | 8,9 | 23,7 | 15,5 | 15,2 | 15,1 |
| Psezuapse – Shakhe | 16,5 | 21,7 | 23,6 | 22,4 | 22,3 |
| Shakhe – Sochi | 31,9 | 23,6 | 24,2 | 21,8 | 21,6 |
| Sochi – Bzugu | 4,3 | - | - | - | 12,8 |
| Bzugu – Kudepsta | 13,6 | 11,9 | 12,9 | 16,2 | 16,5 |
| Kudepsta– Mzymta | 9,0 | 19,0 | 22,8 | 17,3 | 17,1 |
| Mzymta – Psou | 8,01 | - | - | - | 40,0 |

In natural conditions river solid run-off guaranteed stability of the beach belt owing to material carrying out and its further shift along the shore under the influence of waves. Investigations have shown that removal of beach material from the river beds and beaches, which is continuing until today becomes the principal reason of the beach degradation at a given coast section. Excavation of alluvium from rivers has resulted in changing of river channel slopes, and this has affected the amount of solid run-off. Modern run-off of beach forming sediments at the coast section between settlement Magri and river Mzymta (excluding the latter) is about 103 thousand cubic meters in year.

During the latest 10 years annual volume of rip-raps of beach forming material, that is performed by different institutions, roughly is 90 thousand cubic meters in year. Supply of beach material from along shore flow to the beach section may be estimated as being 3 thousand cubic meters in year. Beach volume reduction due to sediment attrition, which is 216 thousand cubic meters in year, is the main part of losses. Withdrawal of sediments of long shore flow out of the considered coast section is not more than 1 thousand cubic meters in year. The rest debit items of the beach material balance may be neglected. Thus, sediment balance at a given coast section is negative, and that results in continuing degradation of beaches.

Below a characteristic of a modern state of beach belt and coast protection constructions is given for a certain coast sections, borders of which are mainly coincided with the river mouths. The length of the coast section between the settlement Magri and the mouth of Ashe river is 12 km (Fig. 1).



Fig. 1: Coastline between Magri and Lazarevskoye

The coast is abrasion one along the whole length. Protection of the earthen bed of the railway and that of adjacent area from erosion by storm waves implemented by means of revetment-baffle plate and system of groins. In recent years its reinforcing was fulfilled. At some coast sections a new revetment-baffle plate has been built, it is displaced for 4-10 m off shore. Today a general length of baffle plates consists 84,2% from the whole length of the section, there are 33 groins of different design, time of building and extent of safe keeping, which can cover about 1.6 km of the coast. Besides mentioned constructions two fragments of wave damping berms have been built of tetrapods, each being 150 m long. The results of the beach broadness measuring are presented in Table 2.

Table 2: Coast length with different broadness of beach

| Value | Beach broadness, m | | | | |
|-------|--------------------|-------|------|-----|-----|
| | >25 | 25-15 | 15-5 | 5-1 | <1 |
| Km | 2,6 | 2,5 | 8,5 | 1,4 | 2,1 |

Almost along the whole length of the coast section between mouths of Ashe and Psezuapse rivers is protected by coast protection constructions. They are absent in the places of remained broad beaches and in the places where the railway is far from the shore.

The absence of the beach or narrow beaches is filled in by baffle plate reinforcing by tetrapod berms. As the beach holding erections there are two old groins with a low crest and two intermittent breakwaters, 140 and 450 m long, built during the recent years. An average width of the beach is 15.1 m. From 1977 it reduced only for 0.4 m. The increase of beach broadness took place only in the zone of intermittent breakwater influence. Near the first breakwater the beach has restored to 13-19 m, and near the second one its width has increased from 8-15 v to 22-30 m. Today about 35% of the coast have a beach which broadness is less than 15 m, and 9.5% - less than 5 m (Table 3). At the length of 0.4 km the beach is absent at all.

Table 3: Coast length with different broadness of beach

| Value | Beach broadness, m | | | | |
|-------|--------------------|-------|------|------|------|
| | >25 | 25-15 | 15-5 | 5-1 | <1 |
| Km | 2,8 | 1,83 | 3,57 | 0,88 | 1,01 |

Coast section between mouths of Psezuapse and Shakhe rivers (Fig. 2), 16.5 km long, stretches to the south from an accumulative projection which is formed of run-off of Psezuapse river. The coastline is presented by variety of small bays with a slight cutting into the land.



Fig. 2: Coastline between Lazarevskoye and Shakhe

This coast section is characterized by free beaches without protection constructions. Beaches are replenished with sediments owing to watercourse and bottom erosion. Almost along the whole length the coast is protected by baffle plate. To estimate the change of the beach broadness at this coast section data of repeated measurements, including those obtained in the course of the present project, were used. A mean broadness of beach has reduced for 1.3 m and its reduction occurred due to the baffle plate moving by sea. During the latest twenty years an average broadness of the beach changed slightly at this coast section. Table 4 shows the data on the coast section length with different beach broadness.

Table 4: Coast length with different broadness of beach

| Value | Beach broadness, m | | | | |
|-------|--------------------|-------|------|------|------|
| | >25 | 25-15 | 15-5 | 5-1 | <1 |
| Km | 6,97 | 4,56 | 4,18 | 0,65 | 0,14 |

In the northern part of the section beaches are stable ones and their broadness is enough for the protection of railway bed from destruction. Especially broad beach is to the north from the groin of Chemitokvadge sanatorium. It is connected with the replenishment of beaches with material from alongshore sedimentary flow which is formed of run-off of Psezuapse river. Further to the south the beach broadness varies in the very large range (from 0 to 35 m). Beaches become mainly degraded, excluding small bays, which are usually coincided with watercourse. Material formed in result of beach erosion shifts to the south, in direction of groin complex and breakwater which is situated within the settlement of Golovinka. A broad beach (about 25 m). A broad beach (about 25 m) has filled in bays between the groins and covered groin defects such as holes and cracks through which beach material was going away. Intensive rip-raps performed on the northern end of considered coast fragment promoted this.

Comparison with the natural state of the given coast section revealed that considerable changes of intensity of gravel sediment shift along the shore occurred, they were caused by the reduction of river solid run-off, firstly Psezuapse river, and by constructions of several beach holding complexes, as well.

At the coast section between Shakhe and Sochi rivers (Fig. 3, 4) 7,3 km are without baffle plates. These are sections where railway track is far from the water edge. In different years 111 groins, 11 submerged and 4 intermittent breakwaters were built in this region. Total length of intermittent breakwaters is more than 16 km. At short coast sections wave damping berms were built of large boulders and concrete blocks. In recent years the volume of imported material rip-raps for creation of wave damping beaches increased.



Fig. 3: Coastline between Shakhe and Dagomys

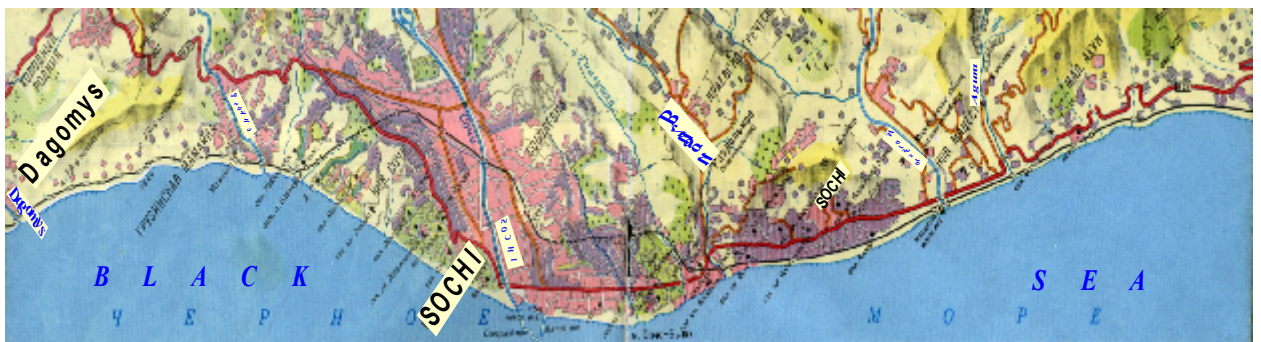


Fig. 4: Coastline between Dagomys and Khosta

A general notion about the beach state and its dynamics within the whole section was obtained on temporal changes of a mean broadness of a beach belt. During 26 years the beach width decreased for 2.5 m, this was caused by intensive withdrawal of pebbles from Shakhe river bed and water-meadow. Reduction of pebble carrying out by the river into the beach zone was not compensated by rip-raps of beach material to local coast sections, though they grew in the recent years. Maximum erosion and reduction of the beach width took place in the northern part of this coast section. Here and there the beach width reduced for 25-30 m, and in some places the beach was eroded completely. Today on the length of 11.3 km the beach width is less than 15 m, baffle plates, 25 km long, have no beach in front of them or its width is less than 5 m.

At the 3-km long coast section southward from the mouth of Shakhe river intermittent breakwater of concrete massifs was built to prevent erosion. This resulted in broadening of beach behind breakwater and on the adjacent upper coast section to 15-25 m (the length is 300 m). At the same time the beach about one km long at the low coast section was washed out almost completely. And this demanded urgent emergency-rescue measures. In four places stone and gravel rip-raps were being done for three years.



Fig. 5: Beach broadness at the closely-spaced coast sections

Coast section between rivers Sochi and Bzugu (Fig. 4), 3.6 km long, is one of the most rich in coast protection and beach holding constructions. There the sea port of Sochi is situated. Baffle plate is built along the whole coast section, it protects municipal and sanatorium embankments from erosion. In different years 52 groins and breakwaters, 2.2 km long, were built. Majority of mentioned erections is in a satisfactory condition.

During the latest 10 years reduction of the beach broadness took place, due to the absence of a natural along shore sedimentary flow and that of rip-raps, which can replenish a beach volume. Today the broadness of the beach in certain areas between groins is 6-18 m, and an average one for the whole section – 12.8 m. Appropriate data are added in Table 5.

Table 5: Coast length with different broadness of beach

| Value | Beach broadness, m | | | | |
|-------|--------------------|-------|------|-----|----|
| | >25 | 25-15 | 15-5 | 5-1 | <1 |
| Km | 0,4 | 0,85 | 2,15 | 0,2 | - |

The next section, 13.5 km long, stretches from Bzugu river to Kudepsta river (Fig. 4). Its characteristic feature is the presence of sanatoria and guest-houses. To create beaches and recreation complexes all the shore is covered by different hydraulic and coast protection constructions. About 200 groins were built in this region. They are situated roughly through every 67 m. Long baffle plate is built there. Besides groins here are breakwaters, including intermittent ones, temporary concrete guard made of blocks and concrete berms.

The absence of natural sources of the beach replenishment and consequences of low erosion after the construction of the port of Sochi had a great influence on the beach dynamics and the strategy of coast protection building at this coast section. During the latest 20 years a mean broadness of the beach changed little. Large recreation complexes have beaches with the width of more than 20-25 m, they are capable to damp completely the storm wave energy. On the rest part of this coast sections width of beaches is less than 10 m or there is no beach at all

(Table 6). Natural replenishment of beaches due to carrying material from Matsesta, Agura, Khosta rivers and owing to the bottom erosion is not considerable. Material carrying out by Matsesta river even cannot guarantee a stability of the beach which is situated to the south from the mouth of the river.

Table 6: Coast length with different broadness of beach

| Value | Beach broadness, m | | | | |
|-------|--------------------|-------|------|-----|------|
| | >25 | 25-15 | 15-5 | 5-1 | <1 |
| Km | 2,46 | 4,53 | 5,13 | 1,0 | 0,38 |

It should be noted, that taking into consideration a large number of coast protection constructions on the whole section between Bzugu and Kudepsta rivers, one cannot say a word about any single sedimentary flow.

Coast section between mouths of Kudepsta and Mzymta rivers (Fig .4), being formed by loose ancient delta deposits, is reinforces almost all length long. There is no along shore sedimentary flow. There is transportation of gravel-sandy material round the groin heads but its amount is not large, about 1-2 thousand cubic meters in year.

Baffle plate and groin complex counting 104 groins and 3 breakwaters have been built. Today at the coast fragment where the railway runs 23 groins have deformations mainly in the head part, they are lowering of some blocks owing to the washing away of the basement. Sagging of the blocks leads to the increase of clearances between them and to the losses of beach material under waves. Designed broadness of the beach remains in the places where groins are not deformed. At the coast sections 1.5-2 km southward from the mouth of Kudepsta river berms with vertical with steep front side were built. This causes intensification of the beach erosion, bottom deepening within the section and berm and groin deformation in the margin parts of the section. In the places, where the broadness of the beach belt was kept less than 10 m, or was eroded completely, deterioration of concrete slope plates has happened. Within some sections between groins through holes were formed, 1 m in diameter. Ground is washed out, and the baffle became hovered. In the future the loss of stability and collapse is inevitable. Construction of a barrier with vertical face in front of baffle not only stopped the beach erosion but even accelerated it. A mean width of the beach is 17.1 m, but in many places it is less than 15 m (Table 7).

Table 7: Quantity of the groin sections with different beach broadness

| Year | Beach broadness, m | | | | | |
|------|--------------------|-----|-------|------|-----|----|
| | Average | >25 | 25-15 | 15-5 | 5-1 | <1 |
| 1983 | 21,9 | 16 | 44 | 5 | 0 | 0 |
| 1999 | 17,3 | 18 | 15 | 27 | 2 | 3 |
| 2004 | 17,1 | 16 | 13 | 29 | 4 | 3 |

An area between rivers Mzymta and Psou (Fig. 6) is a classical example of an accumulative coast formed on the steep slope. Here is the only accumulative coast within Large Sochi. A total length of the coastal line is about 8.1. km. Coast outline is formed by two capes and two gently sloping asymmetrical bays. Within these bays there are smaller analogous forms.

At this section a balance has periodically happened between the supply of material due to solid run-off and its losses (mainly along the talwegs of submerged canyons and as submerged landslips) to the continental basement. Then fans and such deposits like turbidities are formed. Continental slope begins almost from the beach foot and is a transit zone.

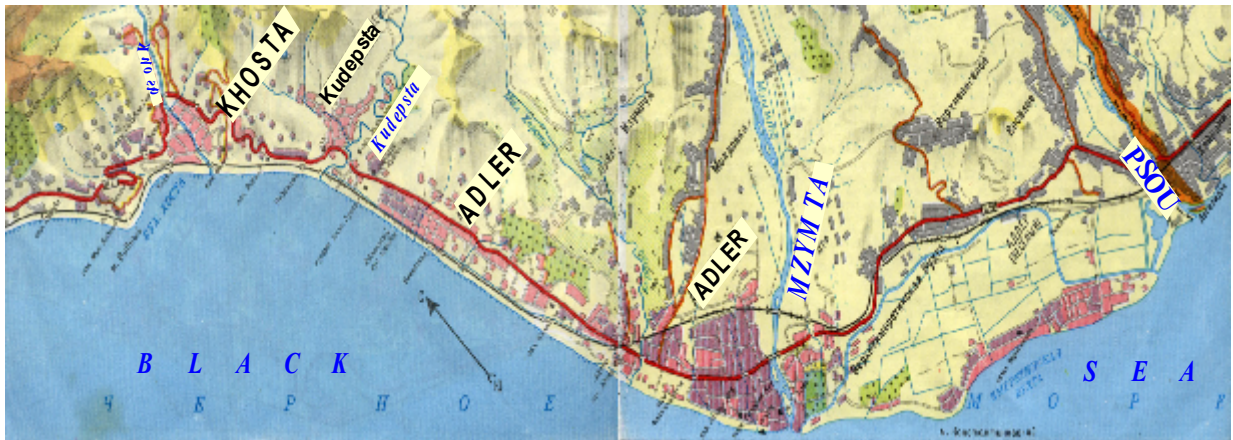


Fig. 6: Coast section between Khosta and Psou rivers

In the phase of the storm development sediments being drawn to the surf zone get on the steep slopes and sink down the depth which exclude their coming back. As a result, the loss of material is large.

Within the 8 km long section there are four zones of sediment sinking to the depth – opposite the Mzymta river mouth at the near mouth spits, in front of Novy canyon, Konstantinovskiy cape, Psou cape. A long evolution of these forms is of a pulsation nature. Cape position does not change essentially. A considerable change of wave regime is necessary for a radical reconstruction. Values of pulsations are 100-120 m. Beaches of the region were the sources of quarry material for along time. After the cessation of material withdrawal the coastal line began to restore slowly, but owing to a sharp decrease of solid run-off of Mzymta (caused by withdrawal of bed alluvium) a full restoration is hardly possible. Today an average broadness of the beach at this section is 40 m.

Conclusions

The analysis of the material on the state of the coastal line between settlement Magri and Psou river has shown that a steady reduction of the width of natural gravel beaches takes place. Works directed to the beach stabilization and replenishment by imported material lower rates of degradation. But they are not capable to stable or broaden the beach belt at the whole section. Recreation complexes with broad beaches are built only on local places of the coast. There are kept only several fragments of natural gravel beaches within the mentioned coast section: near the settlements Lazarevskoye, Loo and southward from the mouth of Mzymta river.

It should be noted that such an index as an average width of the beach is not sufficient for the whole section. A beach of necessary broadness (not less than 15 m) must be at every coast section, in this case its wave damping efficiency and recreation value is highly enough. When the beach broadness is less a direct storm impact on the baffle plates and on the shore is possible, and a danger of their destruction or erosion is great.

During the latest years the intensity of technogenous impact on the nearshore zone and on the object feeding it is essentially increased. Solid run-off of large rivers is reduced, sedimentary flow is interrupted by a system of groins and breakwaters, which practically intercept all gravel-pebble material migrating along the shore. In such a situation a restoring of a beach belt by a natural way is impossible.

Results of the work must be the basis for creation of strategy of coast protection and for elaboration of definite engineering measures.

References

- Kos'yan R.D., Magoon O.T. (1993), "Coastlines of the Black Sea", Publ. by ASCE, New York.
- Kos'yan R.D., Magoon O.T., Yesin N.V. (1999), "The modern exploitation of the Russian Black Sea coast", *Proc. of the Fifth International Conference on Coastal and Port Engineering in Developing Countries*, Cape Town, South Africa.
- Kos'yan R.D., Podymov I.S., Pykhov N.V. (2003), "Dynamic processes of the seacoast zone", Moscow, 325 p.
- Kos'yan R.D., Pykhov N.V., Edge B. (2000), "Coastal Processes in Tideless Seas", Publ. by ASCE, New York.
- Kos'yan R.D., Yesin N.V. (1994), "About environmental management of coast zone", *Oceanology*, T. 34, № 4.
- Kos'yan R.D., Yesin N.V. (1996), "An anthropogenic impact upon the Black Sea coast of Russia", *Proc. of the International Conference "Coastal Change'95"*, Bordo, France.
- Kos'yan R.D., Yesin N.V. (1998), "Fight against erosion of the Caucasian black sea coast", *California and the World Ocean, V.1*, Virginia, Publ. By ASCE, USA.
- Kos'yan R.D., Yesin N.V., Peshkov V.M. (1997), "Erosion of the Caucasian Black Sea coast", *Proc. of the International Conference "BORDOMER'97"*, Bordo, France.
- "Results of nature investigations and modelling of Black sea coast processes in Krasnodar region" (1984), Report ЧО ЦНИИС. Moscow.