The Caspian Deltas Changes in Period of Sea Level Rise: Monitoring by Space Imagery

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Abstract – The Caspian Sea level fluctuations are rendering strong impact to coastal zone and rivers mouths processes. Deltas on the Caspian Sea coasts are characterized by large-scale changes connected with deep fall of the sea level in 1930th to 1970th and fast rise by 2.4 m in 1978-1995, changed by gradual falling and some stabilization in 1995-2004. Monitoring of this stage of Caspian delta's dynamics was provided by space surveys. Maps of delta's dynamics have been compiled. Materials for deltas of Ural, Terek, Sulak, Kura rivers are presented and analyzed in the paper.

Keywords: delta's changes, sea level rise, Caspian Sea.

1. INTRODUCTION

River deltas are among of the most changeable geographical objects on the Earth. Their evolution depends on interaction between river (sediment discharges, at first) and sea factors (waves activity, tides, large-scale sea level changes). Natural and anthropogenic variations of these factors lead to acceleration or retarding of delta's protruding into the sea or to wave abrasion and degradation of deltas. Therefore deltas can be considered as effective indicators of changes in regime of rivers and seas.

The Caspian Sea level fluctuations are rendering strong impact to coastal zone and rivers mouths processes. Deltas on the Caspian Sea coasts are characterized by large-scale changes connected with deep fall of the sea level in 1930th to 1970th and fast rise by 2.4 m in 1978-1995, changed by gradual falling and some stabilization in 1995-2004, as well as with anthropogenic reduction of the sediment discharges (especially for the Sulak and Kura Rivers). Monitoring of this stage of Caspian delta's dynamics was provided by space surveys. We investigated practically all large deltas (except of the largest Volga delta) of Caspian coasts – deltas of Ural, Terek, Sulak, Kura rivers (Fig.1A).

2. METHODS AND MATERIALS

Dynamics studies require to use imagery with good resolution, which were variable in different periods of space investigations. During the sea regression there were photo pictures from orbital stations "Salut-4", KATE-140, R=60 m (1975); "Salut-6", MKF-6, R=20 m (1978) and "Landsat-1,2", MSS (R=80 m) images; during the fast sea-level rise – photos from "Resurs-F" satellites, KFA-1000, R=10 m (1982, 1983), MK-4, R=10 m (1991) and scanner images from "Resurs-O" satellite, MSU-E, R=35 m (1997); and for last period of the sea level stabilization and slow level lowering – "Landsat-7", ETM+, R=30 m, "IRS", LISS, R=23 m, "Terra", ASTER, R=15 m, "Meteor-3M", MSU-E, R=35 m images (2001-2004).

Satellite images were used for compiling a series of dynamics maps for the Ural, Terek, Sulak and Kura deltas. Maps of the coastal zone (including deltas areas) statement in 1977-78, 1991-92, 1996-97, 2000-02 and maps of transgressive changes in the coastal zone for periods 1978-1991, 1991-1997 and of post-transgressive changes for period 1997-2002 were compiled (at scale 1:200 000) by computer processing of multitemporal satellite images. Materials for these deltas mapping are presented and analyzed in the paper.

3. RESULTS OF IMAGES ANALYSIS

3.1. The Ural river delta

As other Caspian deltas, Ural river delta changed it's position and dimension for a long period of sea regression. The formation of modern delta begun from XVIII century. Delta's growth was stipulated by sea level falling and with sedimentation of deposits.

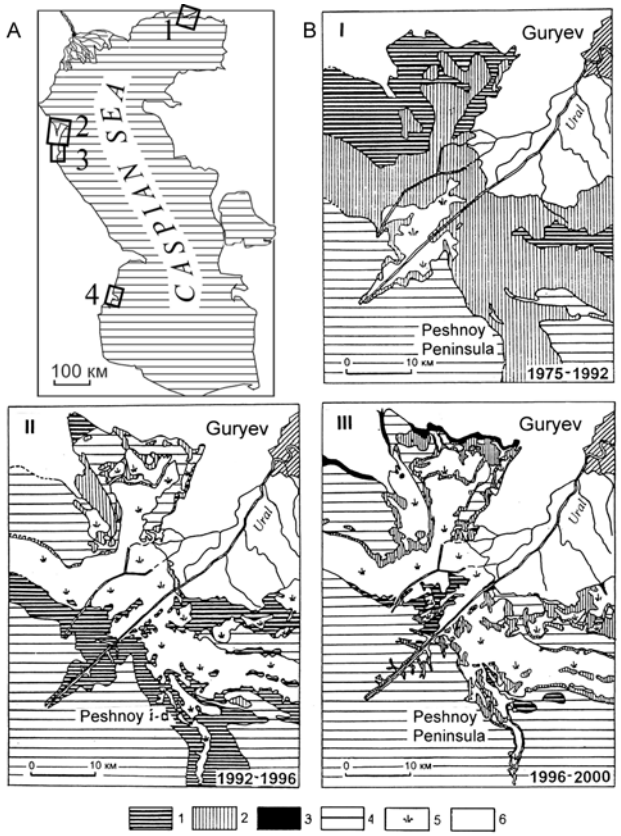

Figure 1 A. Test Rivers deltas: 1 – Ural; 2--Terek; 3 – Sulak; 4 – Kura;
B. Changes of the Ural River delta in 1977-1992 (I), 1992-1996 (II), 1996-2000 (III): 1 – water instead of land and reed; 2 – reed instead of land and water; 3 – land instead of water and reed; 4 – water; 5 - reed; 6 – land.

Rapid protruding of delta in 1940-1960's was also caused by construction of Ural-Caspian Sea channel. To 1977, when the sea level was the lowest, Ural river delta was prolonged at 32 km, it's area was 522 km^2 and included Peshnoy Peninsula, before having been an island.

In 1977-1995 sea level rise has lead to flooding the periphery part of delta and to growth of reed, which formed wide belt along shore line (Fig.1B). To 1992 this reed belt was of 15 km wide (including Peshnoy) to the east of river mouth and of 30 km wide to the west of it. Open water windows – lagoons - at the back site of reed belt were formed; they were of 3-5 km wide. Thou the dry delta became to wetting, turned to wet marches. If to account the boundary between sea and reed as a coast line, there were no significant changes in coast line position for the first part of this period in spite of rapid sea level rise; the coast line even moved a little in sea direction due to reed expansion. But after 1992, when sea level rise exceeded 1,7 m, reed belt began to destroy at sea side and so the coast line began to move in land direction. It was stipulated by waves activity and ice breaking. In 1992-1996 that retreat of coast line reached 3-5 km. Open water windows in marches (lagoons) were widen to 7 km. River channels, having been dry before, were filled with water.

In 1996-2000, when sea level gradually began to fall down, reed belt again widened and it's outer boundaries moved to sea direction for 1 km; reed expanded into lagoons and windows of open water turned into narrow stripes of 1-2 km wide. Wet river channels again became dry.

So in Ural delta region the specific reaction to sea level fluctuations takes place: formation of reed belt along the shore, expansion or reducing of reed weeds in dependence of water depth.

3.2. The Terek river delta

Terek river delta has long and very complex history. Seven various stages of delta's formation for last 500 years have been investigated [Mikhaiov, 1997]. After Kargalinsk break in 1914 it became one-channel delta; it's northern channels died and rivers discharge was concentrated in main eastern channel. To the time of the Caspian Sea lowest level in 1978 the eastern branch of Terek – Alikazgan – discharged itself into Agrakhan Bay and rapidly protruded it's delta into the bay. The dangerous of flooding caused the construction of artificial cannel through the Agrakhan Peninsula in 1960's years. In 1973 water braked throw it, and this event sent formation of new delta. But it also sent erosion in upper part of valley and drying of Agrakhan bay; artificial channel was closed to prevent undesirable consequences. In 1977 it again was opened and at the eastern coast of Agrakhan Peninsula the formation of new Terek delta prolonged.

In 1978-1991, at the period of rapid sea level rise, delta changed significally (Fig.2). The Agrakhan bay, being before nearly dry and weeding with reed, again filled with water and widened. The barrier-lagoon complex was forming along the coasts of Agrakhan Peninsula at the place of reed marches, that is a typical reaction of low Caspian coasts to sea level rise. Rising of ground water level sent the appearance of green vegetation at sand dunes of Agrakhan Peninsula and along Agrakhan Bay coasts.

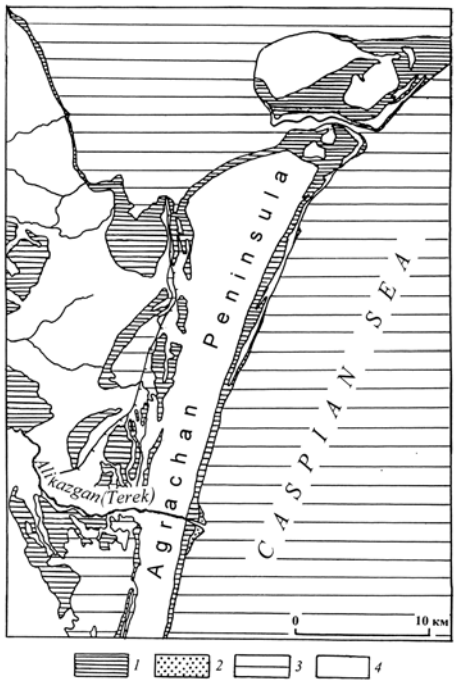

Figure 2. Changes of eastern part of Terek river delta with Agrakhan Bay and Agrakhan Peninsula in 1978-1991: 1 – water instead of land; 2 – land instead of water; 3 – water; 4 – land.

At the eastern coast of Agrakhan Peninsula "new" Terek delta, which was protruded at 0,4 km to the beginning of transgression, continued it's growth in spite of sea level rise; processes of sediments accumulation overgrowth the sea level rise (Fig.3). To 1991 the mouth protruded for 1,8 km; delta spits and barriers have been formed along the shores, lagoons were separated by them. To 1997, when sea level began stabilized and gradually lowered, the growth of "new" delta prolonged for 2 km, new spits and barriers were formed and new lagoons were separated: former lagoons were overgrown by reed and became marches and lands.

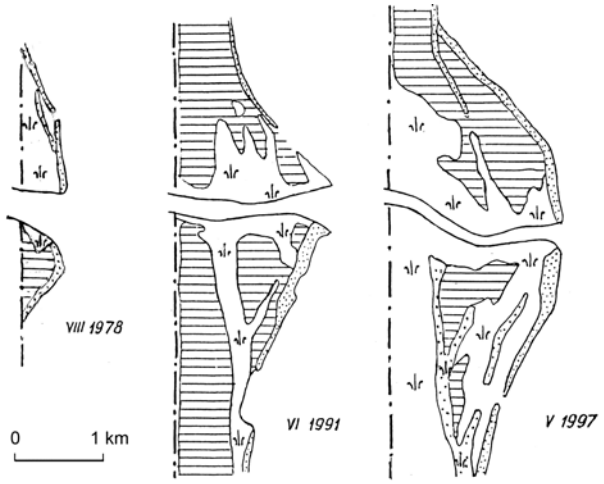

Figure 3. Evolution of "new" Terek delta in 1979-1997.

3.3. The Sulak River Delta

The Sulak River delta on the western coast of the Caspian Sea is one of the most changeable delta region. It is caused by repeatedly changes of river channel direction and mouth place. Contemporary delta began to form 200 years ago. The stages of its formation had been analyzed in details [Leontyev, 1951; Leontyev et al, 1987; Mikhailov, 1997; Mikhailova, 1988]. During the long period of the sea level drop from the middle of XVIII-th century, four cycles of the delta formation took place: up to 1920 - pioneer delta formation; after river break in the northern-eastern direction - formation of the first lateral delta; after break in the northern direction in 1929 - formation of the second lateral delta ("old"), which separated the Sulak Bay; after water diversion by artificial cannel in the eastern direction in 1957 - formation of the third lateral delta ("new") [Mikhailov et al, 2004].

A series of delta's maps, reflected these stages, now is supplemented with new maps of the delta changes in the period of the sea level rise. A series of delta's landscape maps was compiled by space images [Kravtsova et al, 2000]. The map of delta's dynamics in 1978-1991 (Fig.4) shows the main features of the Sulak delta reaction to sea level rise.

1978-1991. In the period of the fast sea level rise, sea water flooded the main part of the "old" and "new" deltas. The eastern delta coast was washing away and the coast line moved by 1 km to the west and the coastal barrier formed here. The Sulak Spit has been shorten by 4 km due to processes of inundation and abrasion and replaced by 1 km in the western direction. So the Sulak Bay in 1991 was open to the sea. The area of the "old" delta reduced by 21 km^2. The "new" delta was nearly washed out, its area reduced by more than 3 km^2, the river channel length was shorten by 1,5 km. Lagoons formed at the both sides of the mouth. The whole delta area reduced during this period from 70,6 to 46,4 km^2 (34%). Annual decrease of the area was 1,86 km^2/year.

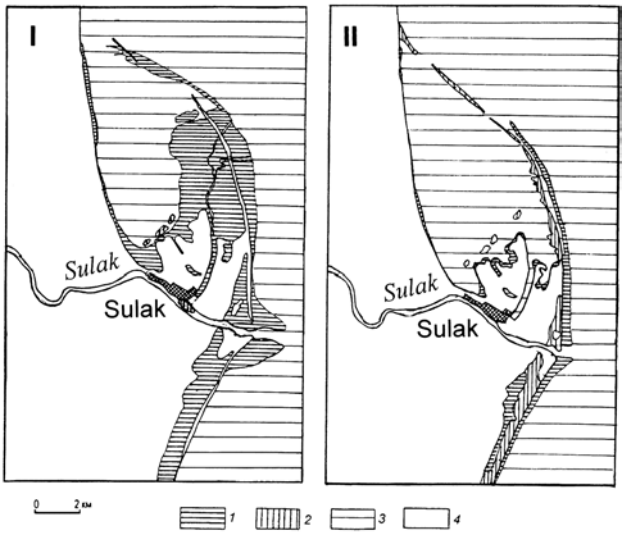

Figure 4. Changes of the Sulak River delta in 1978-1991 (I), 1991-2000 (II): 1 – water; 2 – water instead of land; 3 – land instead of water; 4 – land.

1991-1997. In this period delta's changes were not so significant, as in previous one, due to the sea level rise stopping in 1995 and its some stabilization and even falling. Decrease of the delta area slowed down to 0,2 km^2/year. Washing out of the eastern part of the "old" delta was continued, the Sulak Spit increased by 12 km and jointed to the Agrakhan Peninsula coast. Only some small breaks in the Spit open the Sulak Bay to the sea. The "new" delta's destruction was continued too, the coast line replaced to the west by 700 m, and delta's overflows were smoothed out; lagoons were overgrown with reed, that is the evidence of their shallowing. In this period delta area at whole reduced only by 1,2 km^2.

So the analyses of multitemporal space images shows the processes of inundation and abrasion of the "old" and "new" Sulak River deltas, formation and then overgrowning lagoons, washing out the Sulak Spit and formation of a new long Spit from material of abrasion of the "new" Sulak delta.

3.4. Kura river delta

Contemporary Kura River delta in the southern part of the western Caspian Sea coast, advanced to the sea, at the mouth of river with large sediment dischsrge. Dynamics of the Kura River delta in XIX-XX centuries was mainly depended on the Caspian Sea level changes. At the period of sea level drop up to 1976, it was protruded far to the sea. In spite of sediment discharge decreasing after the Mingechaur reservoir construction (1953), delta protruding was continued, because the sea level fall compensated sediment discharge decrease [Mikhailiv et al, 2003]. To 1976, the delta area reached 189 km^2.

During 1978-1995, evolution of the delta was determined by the sea level rise by 2.35 m. Low laying perifery part of the delta began to be flooded. Images show also formation of barrier along the north-eastern coast of the delta. It is typical consequence of the sea level rise at the low laying Caspian Sea coasts. Extreme changes of the Kura delta took place up to 1993 (Fig.5) - just before maximum of the recent sea transgression. The main part of the delta promontory was flooded, the delta length decreased by 10 km. Along former river channel some long narrow islands remained.

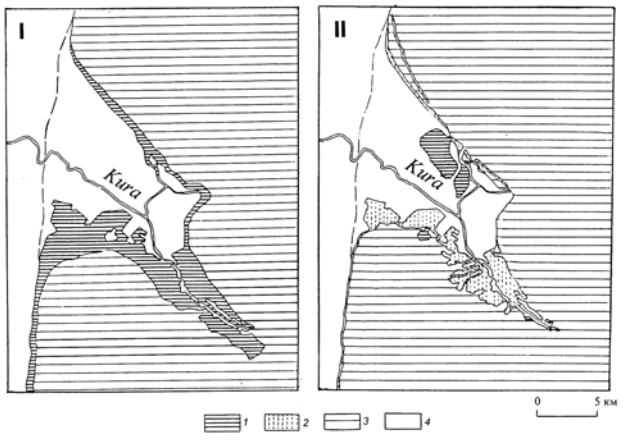

Figure 5. Changes of the Kura River delta in 1978-1993 (I), 1993-2000 (II): 1 – water instead of land; 2 – land instead of water; 3 – water; 4 – land.

In comparison with 1978, delta area decreased by 78 km^2 (34%) and equaled 111 km^2.

After 1995, a slow drop of the sea level (0,54 m up to 2001) led to new changes in delta morphology. Shallow water parts of flooded delta became more dry, overgrowned with reed. Delta area increased by 25 km^2, and in 2001 reached 136 km^2.
Barrier-lagoon complex along the north-eastern coast of the delta still conserved. Wide depressions within the delta were flooded by water breaked through barriers. Important changes in hydrographic network of the delta took place. During the period of the high sea level, river water broke through the right bank and turned to the south-west. Water flow through the former south-eastern delta channel ceased, the former channel was overgrown with reed. In the sea, at 3 km distance from former mouth, a new spit oriented in the south-western direction is forming from material of the old delta abrasion by waves. In 2001, it had 3 km in lenght.

4. CONCLUSIONS

The analyzing of created maps shows that the following changes during the sea level rise period are typical for protruding deltas of the Caspian Sea: flooding of low laying periphery parts; wave abrasion of more deep parts of nearshore slope and formation of spits from material of abrasion; formation of barrier-lagoon complex; possibilities of hydrographic network reconstruction.

The reaction of deltas to the Caspian Sea level rise (realised in partly inundation and abrasion of the delta coasts, and changes of their landscapes) can be used as an analogue fenomenon for forecasting of processes which can take place in world river deltas in the case of proposed global sea level rise.

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