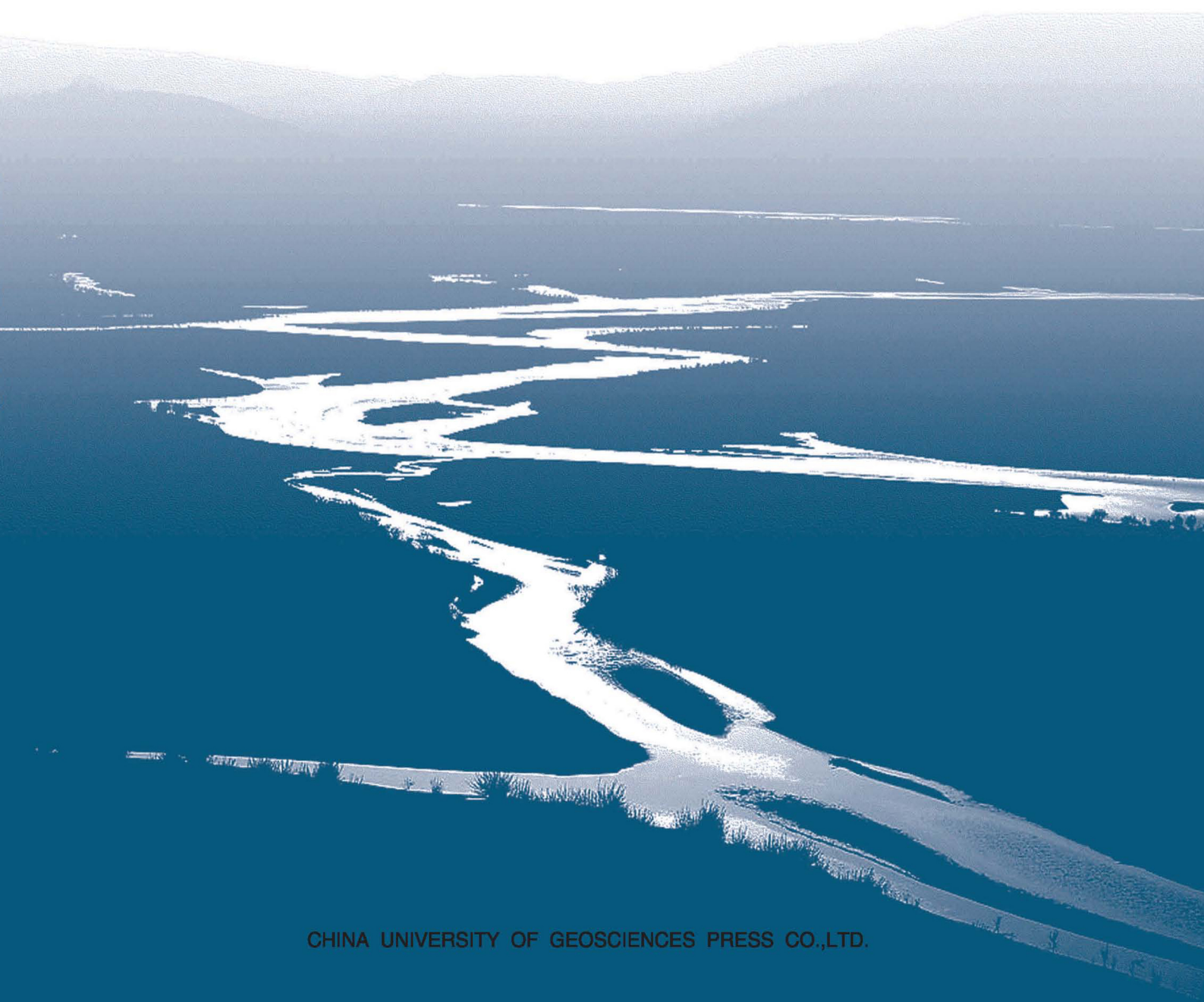


Proceedings of IGCP-514 “Fluvial Palaeo-systems: Evolution and Mineral Deposits”

Editors: Wen Meilan Luo Xianrong Shu Lixia



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China University of Geosciences Press CO.,LTD.

图书在版编目(CIP)数据

第四届国际地质对比计划项目“古河道系统构造和古气候演化与资源勘查”(IGCP-514)会议论文集 = Proceedings of IGCP-514 “Fluvial Palaeo-systems: Evolution and Mineral Deposits”: 英文/文美兰,罗先熔,舒立霞主编.——武汉:中国地质大学出版社有限责任公司,2012.12

ISBN 978-7-5625-2979-8

I. ①第…

II. ①文…②罗…③舒…

III. ①河道-构造-影响-砂矿床-成矿规律-国际学术会议-文集-英文②古气候-气候变化-影响-砂矿床-成矿规律-国际学术会议-文集-英文③砂矿床-地质勘探-国际学术会议-文集-英文

IV. ①P611.2-53

中国版本图书馆 CIP 数据核字(2012)第 274552 号

Proceedings of IGCP-514 “Fluvial Palaeo-systems: Evolution and Mineral Deposits”

Editors: *Wen Meilan, Luo Xianrong, Shu Lixia*

Responsible Editors: *Shu Lixia, Wang Rong*

787mm × 1 092mm 1/16, number of words:170 000

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Published by China University of Geosciences of Press CO., LTD.

388 Lumo Road

Wuhan, Hubei, 430074

China



Fluvial Palaeo-Systems: Evolution and Mineral Deposits



**Organized by ICP-514 Project Committee Co-organized by
Guilin University of Technology, Guilin
Beijing Research Institute of Uranium Geology, Beijing
October 14 — 18, 2009 Guilin, China**

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Experimental Research of Erosion of Consolidated Soils by High-speed Water Flow Applied to Paleochannels

G. Berthault^①, A. Veksler^②, A. Lalomov^③

①International Association of Sedimentologists, French Branch (Meulan, FRANCE);

②Vedeneyev Russian National Research Institute of Hydraulic Engineering,
(St. Petersburg, RUSSIA); ③Institute of Geology of Ore Deposits, Petrography,

Mineralogy and Geochemistry, Russian Academy of Science,
(Moscow, RUSSIA) (lalomov@mail.ru)

A closed loop circulation hydraulic high pressure pipe system capable of providing an average water-flow velocity up to 27m/sec within the working area has been designed and constructed to investigate erodibility of consolidated soils caused by high-speed water-flow. Five samples of semi-solid rocks (3 limestone and 2 sandstone samples) have been tested. The research has found that limestone monoliths (calcareous monoliths) are not susceptible to erosion by water flows with velocities of up to 26m/sec, and erodibility of limestone depends on its strength features. Obtained results allow reconstruction of hydraulic condition of the paleochannel's formation.

Analysis of existing methods applied to estimate the onset of consolidated soil erosion caused by water-flow shows that the methods now in use provide a certain knowledge of conditions under which erosion of cohesionless (sandy, pebble gravel) and cohesive (clay, sandy loam, clay loam) consolidated soils starts under impact of a flow. The speed of which does not exceed 2.5 ~ 3.5m/s.

The data on interaction of flows running over rock and semi-solid rock channels were used only in theoretical considerations related to the effect of both rock block sizes and conjugated fractures dissecting rock mass on the critical erosion velocity responsible for the beginning of erosion process.

Experimental evidence of the obtained results turned out to be presented by fragmentary and accidental field data usually of a roughly approximate nature with no information on hydraulic conditions, i. e., on velocities and depths of the flows involved in erosion process.

Scientific significance of the work are connected with an attempt to determine erodibility for some types of consolidated (semi-solid) rocks under impact of high-speed flow moving over their surface.

Five types of the rocks used for the experiment (Figure 1) from left to right;

- (1) Sandstone, glauconitic, light grey, fissured;
- (2) Limestone dolomitic, glauconitic, pink-grey;
- (3) Limestone dolomitic, glauconitic, with rare large pores, pink-grey;
- (4) Sandstone, glauconitic, weathered, brownish-brown;
- (5) Dolomite calcareous, fissure-free.



Figure 1 Tested samples

Experimental equipment consisted of a pump and closed loop circulation hydraulic high pressure pipe system (Figure 2) allows reach an average flow speed in the working area up to 27m/sec.

Erodibility of soil samples under impact of water-flow was estimated visually and determined instrumentally as a difference in their masses before and after experiments.

Analysis and interpretation of the results

The results of all experiments are summarized in Table 1; the table shows that limestone (samples 2) and dolomite (sample 5) were not scoured by water-flow moving over their

Table 1 Results of the experiments

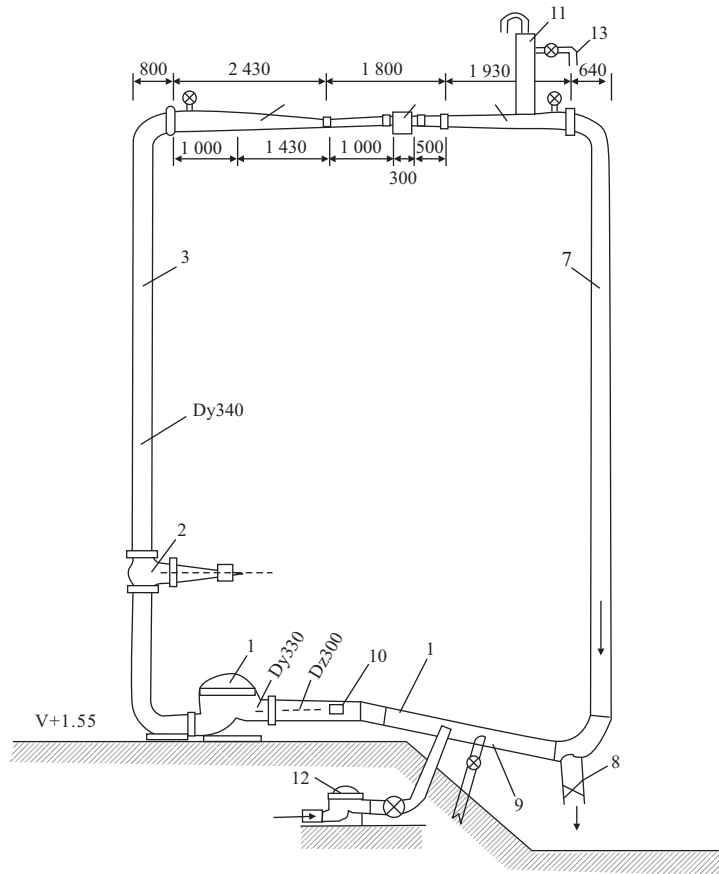


Figure 2 Schematic view of the installation for soil erosion rate research

1. Pump; 2. Control valve; 3. Water supply pipe; 4. Transition areas; 5. Working area of the installation; 7. Return pipeline; 8. Outlet branch; 9. Feed pipe to fill the system; 10. Device to measure and control water discharge; 11. Expansion unit; 12. Auxiliary pump; 13. Branch pipe; 14. Hose to discharge cooling water into the reservoir; 15. Horizontal dimensions are given in mm, vertical dimensions in m

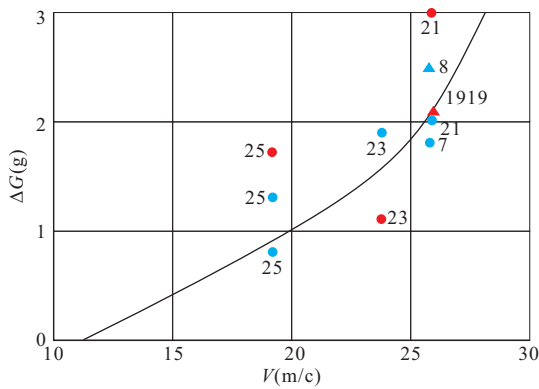
Number of the sample	Dry initial mass (g)	Velocity of the flow (m/sec)	Total duration of the experiment (hours)	Loss of mass of dry sample	
				Visual	By weighing ΔG , (g)
1	6 322.9	23.8 ~ 25.9	105.2	Yes	11.7
2	6 759.8	25.9	22.5	No	0
3	6 631.2	20.1 ~ 26.0	68.0	Yes	6.6
4	4 802.8	4.4 ~ 22.5	138.0	Yes	167.3
5	6 571.3	25.6 ~ 25.8	15.5	No	0

surface with a velocity of $V \leq 26$ m/sec. Sample 3 (limestone) shows moderate erosion. General

duration of action of the flow on the sample surface facing the flow was 22.5 hours-for sample 2 in a series of experiments, 15.5 hours-for sample 5 in a series of experiments. Initial 50 hours of experiments with the sample 3 did not reveal erosion, and only last 18 of experiments registered small erosion under the velocity of the flow up to 25.8m/sec.

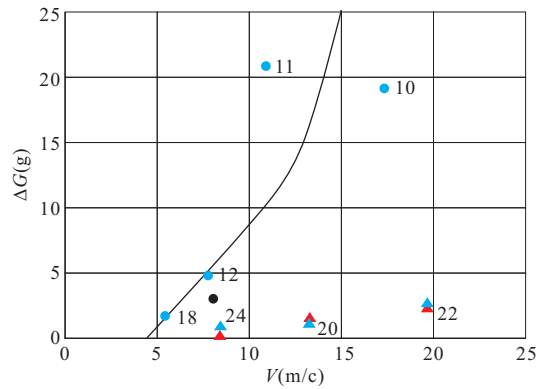
It should be noted that the fluctuations of the water discharge in these experiments accounted for $\pm 5\%$ of its average value; the maximum velocity of the flow which did not produce any scouring of these samples (critical erosion velocity) reached $V_{max} = 27.3\text{m/sec}$.

For control the experiment results, two types of weighting were used: “dry weighting” after wearing out the samples after series of experiment and “soggy weighting” for receiving of relative corrosion of the samples within the series. Dependence of loss in mass ΔG on flow velocity V of samples 1 and 4 are shown on Figure 3 and Figure 4.



● after heating up to 68~76°C; 'A' ● after cooling to 18°C; 'A'
▲ after heating up to 68~76°C; 'B' ▲ after cooling to 18°C; 'B'

Figure 3 Dependence of loss in mass ΔG of sample 1 on flow velocity V . 7-25- numbers of experiments



● after heating up to 68~76°C; 4 ● after cooling to 18°C; 4
▲ after heating up to 68~76°C; 4k ▲ after cooling to 18°C; 4k

Figure 4 Dependence of loss in mass ΔG of sample 4 on flow velocity V . 9-22- numbers of experimen

The research conducted on erodibility of five consolidated soil samples (each of which is a fragment of fissure-free monolith) under impact of high-speed water-flow, has allowed drawing the following conclusions:

- (1) Calcareous and dolomitic monoliths are resistant to eroding action of water-flow with velocities $V \leq 26\text{m/sec}$.
- (2) Sandstones depending on strength properties of rock can have critical erosion velocities (non-eroding velocities) V_{cr} varying over a very wide range $4.5 \leq V_{cr} \leq 11.0\text{m/sec}$.
- (3) Decisive factor of the flow channel erosion is preliminary weathering of the rocks rather

than power of the water-flow.

(4) In real conditions of the flow erosion occurs as the result of deleting fractured block of the rock and due to impact of transported clastic material (sand and pebbles) rather than erosive ability of pure water-flow.

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Statistical Analysis of Mineralogical Characters and Lithological-facial Zoning of Fluvial System

Anna Bochnerova, Alexander Lalomov, Roman Chefranov

The Organization of Russian Academy of Science Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry Russian Academy of Science (IGEM RAS) Staromonetny per. 35, Moscow, 119017 Russia

This paper devotes to lithological-facial and statistical investigations of Oligocene complex of sediments in order to single out the most perspective on titanium-zircon placers areas in Khanty-Mansiisk administrative region, in particular, in the Mansiisky area.

From the west – northwest to the southeast on the Mansiisky area are consecutive allocated faces of paleo delta, beach and submarine delta zone, zone of shallow sea and zone of absence of wave influence. The beach drift is focused from the south – southwest to the north-northeast. The most perspective face is represented faces of beach and submarine delta zone and zone of shallow sea with moderate hydrodynamic activity.

The analysis of structure of Oligocene sediment mineral assemblages, which was based on modification of Factor Analysis—Method of the Principal Components (MPC), shown that Oligocene complex is characterised by well-ordered mineral assemblages on investigated area. Also MPC has proved on revealing various paleofacial zones. Done grain-size, mineralogical analyses, and also studying of structures and textures of investigated thicknesses have confirmed the received results by MPC.

The complex of sediments, which are perspective on revealing the titanium-zircon placers of Oligocene-Miocene of Khanty-Mansiisk administrative region. Its western part is presented mineralogically as mature sediments, which had littoral genesis; the source of placers were both directly weathered crusts of Ural Mountains, and placer concentrations of earlier sedimentary formations.

This research is concerning to the territory of West Siberia adjacent to Ural Mountain System (west part of Khanty-Mansiisk administrative region). Researched placer bearing area (Mansi-

isky area) has intermediate location between east piedmont of Ural Mountain System and west setting of Siberian plain that determine special features of regional stratigraphic scales. The Mansiisky area locates on the regional zone of shoreline of Oligocene sedimentary basin (Paryk-Kara and etc. , 2008). The investigation was made on two perspective areas: Mansiisky and North Sosvinsky. In the given work we will consider only the Mansiisky area.

On the basis of textural, grain-size, mineralogical analyses of investigated thicknesses have been allocated four adjoining facial zones on the Mansiisky area (Lalomov and etc. , 2008; Paryk-Kara, 2008). From west to east these zones are:

(1) Transit zone of fluvial paleovalleys and sub-aerial delta. Sands of this zone are characterized by cross-bedding with east orientation of the dips. Because of imperfect separation of sand deposits, sporadic significant concentrations of TZM were revealed in this zone, but it do not form united placer body.

(2) Beach and submarine delta zone that locates farther to the east from fluvial transit zone is characterized by cross beds with opposite dips of north and south orientation that reflect regular changing of along-shore sediment flow direction. This zone is perspective for HMP with relatively coarse mineral grains (mainly 0.25 ~ 0.1 mm) and low content of clay and detrimental impurities, but usually they have relatively small volume and lateral dimension.

(3) Zone of shallow sea with moderate hydrodynamic activity. Here we often see small symmetric and asymmetric ripple marks up to 2 ~ 3 cm high and 10 ~ 15 cm long. This is zone of submarine bars and shallow banks with sea depth several meters. While facies of shallow sea are more extended in both alongshore and seaward than beach facies, placers of this area have extensions of several kilometers width and tens kilometers long. In spite of relatively small size of TZM (mainly less than 0.1 mm) and higher content of clay fractions, HMP of this zone are more promising for discovering placers of economic importance.

(4) Farther from the paleo shoreline zone of moderate hydrodynamic activity change to zone of local depressions where wave activity had no influence on the bottom sediments. TZM-bearing sediments were eroded and transported from zone 3 to zone 4.

For the Mansiisky area two relative factors for first three zones have been calculated: the relation of the sum of titanium minerals to zircon (K_1) and the relation of heavy mineral fraction in a class 0.25 ~ 0.1 to heavy mineral fraction in a class 0.1 ~ 0.01 (K_2).

The character of ore Ti-Zr assemblage at change facial complexes delta-beach-sea shoal varies slightly: the average relation of the sum of titanium minerals to zircon on a zone varies within 12

~ 14. Some increase of this indicator in a beach zone, connected, first of all with content increase in heavy mineral fraction rather larger ilmenite, explains the general increase of grain size of detrital material in this zone.

As you can see from Table 1, the zircon content goes down from delta to beach and raises from beach to shoal. It explains that there is material separation on border of delta and beach.

Table 1 Statistical values of facial zones

	Paleo delta		Beach and submarine delta		Zone of shallow sea with moderate hydrodynamic activity	
	K ₁	K ₂	K ₁	K ₂	K ₁	K ₂
Average	12.1	5.8	14	5.8	12.9	0.7
Minimum	5.6	0.2	5.8	0.2	7.7	0.1
Maximum	32.9	37.2	31.4	23.8	25.1	4.7

Factor K₂ behaves according to classical representations about separation and redeposition of a sandy material; the greatest value is characterized in paleo delta, the least in a shallow zone.

On the Mansiysky area, statistical researches on the basis of a method of MPC have been conducted, allowing not only to curtail multicomponent space (Devis, 1990) and to allocate the most ordered mineral assemblages, but also to reveal the most perspective sites of prospective placer.

The analysis of structure of mineral assemblages of Oligocene sediments, which was carried out by MPC has shown that analyzed Oligocene complex is characterised by well-ordered mineral assemblages, into which structure enter ilmenite, rutile, zircon, leucoxene, sphene, anatase. High “weight” of 1st Principal Component (1PC), and also its structure show us that there was effective ore-forming process, capable to create concentration of ore minerals close to industrial level. It confirms by comparison of calculated “weights” of 1PC (62% ~ 65%) with the similar parameter which has been counted up directly for ore bed of industrial titanium-zircon placers (70% ~ 78%) (Patyk-Kara and etc., 2001; Patyk-Kara, Ivanova, 2003).

As we can see from Figure 1, areas of the 1PC maximum values are concentrated in northern and northeast parts of beach zone and in the zone of sea shoal. It means that the areas of the most ordered mineral assemblages locate in these zones. Thus, on the Mansiysky area in a greater degree, beach zone, in smaller—a zone of shoal with moderate dynamics can be considered by perspective on the titanium-zircon the raw material area.



Content of 1 PC: Ilm0.95 Ru0.88 Zr0.86 Sph0.80 Leu0.77An0.65 /-

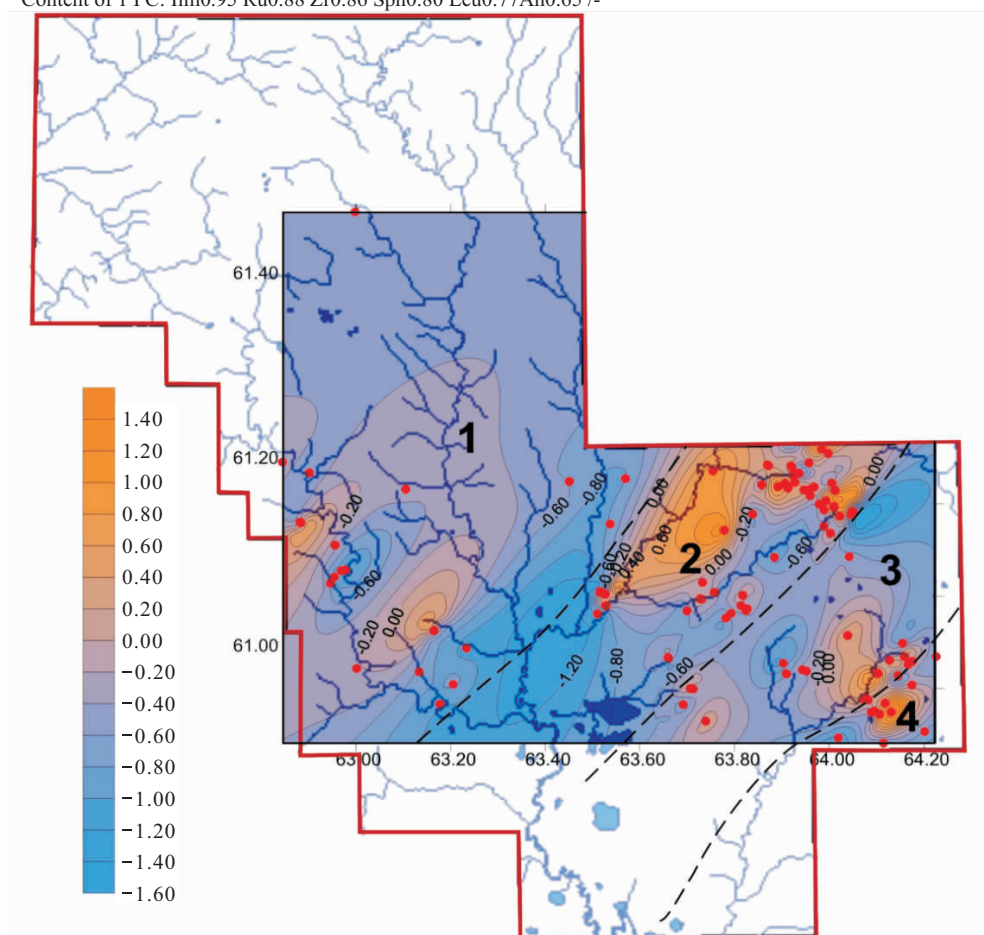


Figure 1 The scheme of distribution of values 1PC on the Mansiysky area

Note: by numbers are designated facial zones: 1.a zone of distribution of paleo delta fa-cies; 2.beach zone; 3—4.zones of distribution of facies of the shallow sea: 3.a zone of moderate wave influence;4.a zone of absence of wave dynamics. By a dashed line bor-ders of these zones are shown

The work was done under partial support of Russian Found of Fundamental Research (RFFR) No. 09-05-00268-a and Scientific School (NSh-147. 2008. 5).

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