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MECHANISM OF PLACER FORMATION IN KRASNOKUTSK DEPOSIT AREA

МЕХАНІЗМ РОЗСИПОУТВОРЕННЯ НА ПЛОЩІ КРАСНОКУТСЬКОГО РОДОВИЩА

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Basing upon paleorekonstruktsions of Sub-Paratethys evolution Middle-Novi Petrivtsi phase, main conditions of placers forming (tectonic, hydrodynamic, geomorphological and sedimentation) have been revealed for Kharkiv-Sumy placers zone. The local scheme of placers forming has been founded for Krasnokutsk titanium-zirconium deposit. This scheme is based upon the concept of placer forming material provision mainly by river into placer forming area directly neighboring to delta in the frames of two facial zones coastal and marine shallow (shelf). The provision of placer forming material by lateral coastal streams and underlying sediments redeposition is also considered. Basing upon placers forming mechanism a set of criteria of placers prognosis in zonal scale has been developed: stratigraphic (the relation to Middle-Novi Petrivtsi subsuite); facial (the foundation of two facial zones with pertinent ores characteristics), lithofacial (lithological types of sands), hydrodynamic (the availability of pertinent hydrodynamic conditions), paleotransportation (the presence of delta), paleogeomorphological and phases-sedimentation (the connection with sequence cycles of basin evolution with pertinent conditions of sedimentation).

Keywords: mechanism of placer forming, titanium-zirconium placers, Krasnokutsk deposit, Middle Novi Petrivtsi subsuite, Miocene.

На основі палеореконострукцій середньоновопетрівського етапу розвитку Субпаратетису визначено основні умови розсипоутворення для Харківсько-Сумської розсипної зони – тектонічні, гідродинамічні, геоморфологічні і структурно-седиментаційні. Запропоновано локальну схему розсипоутворення для площі Краснокутського родовища, яка базується на концепції постачання розсипоутворюючого матеріалу (РУМ) переважно річковою артерією з утворенням області розсипоутворення у безпосередньому наближенні до дельти у межах двох фаціальних зон – прибережного мілководдя і морського мілководдя. Враховується також надходження РУМ за рахунок латерального руху вздовжбереговими течіями і перемиву підстилаючих та латерально прилягаючих товщ. На основі представленого механізму розсипоутворення розроблено критерії для прогнозування розсипів у зональному масштабі: стратиграфічний (приурочення розсипів до середньоновопетрівської підсвіти), фаціальний (виділення двох розсиповміщуючих зон з відповідними характеристиками зруденіння), гідродинамічний (необхідність відповідних гідродинамічних умов), літофаціальний, палеотранспортний (наявність дельти), палеогеоморфологічний і етапно-седиментаційний (зв'язок з секвенсними циклами еволюції басейну з відповідними умовами седиментації).

Ключові слова: механізм розсипоутворення, Краснокутське родовище, титано-цирконієві розсипи, середньоновопетрівська підсвіта, міоцен.

INTRODUCTION

For Ukraine the special role plays the problem of titanium-zirconium ores resources base. These ores have been considered as strategic types of minerals in the national program of mineral resources of Ukraine for the period 2030. Placer deposits are titanium ores base of Ukraine gradually decreases, but the exploration practically is not carried out. Therefore there is a need for a detailed study of the mechanism of placer formation of explored deposits to form criteria of commercial placer deposits prognosis in the zonal level.

The purpose of this work - the development of the theoretical model for Krasnokutsk area placer formation mechanism.

This purpose comprises the following issues:

- a brief description of the problem, methodology and research methods;
- regional-zonal scheme of placers forming compilation;

- the mechanism of placer formation in Krasnokutsk deposit area development.

Object of study – Krasnokutsk placer deposit of titanium-zirconium ores. The deposit is located within the northeastern slope of the Dnieper-Donets depression (DDD) and refers to Krasnokutsk placer field Kharkiv district of Kharkiv-Sumy placer zone. The deposit was discovered in 1957, preliminary exploration was conducted and resulted in reserves approval in 1961. The deposit as to the total structure is one placer scattering, which includes four ore sites – Stepanivka, Central, Southern and Koziivka. Ore mineral associations are very diverse and include ilmenite, rutile, zircon, leucocene, monazite, kyanite, sillimanite, staurolite, etc. The deposit is confined to the Novi Petrivtsi suite, Miocene.

STATE OF THE ART, METHODOLOGY AND METHODS
Refine search and study of titanium-zirconium placers in DDD northeastern slope have been carried out in 60-

70th years of the twentieth century by I.S. Romanov. At the time, detailed search and reconnaissance works on titanium and zirconium ores have been conducted throughout Ukraine and in the Kharkiv-Sumy placer zone in particular. Previous exploration of Krasnokutsk deposit has been executed, resulting in estimation of reserves by categories C_1 and C_2 . A number of papers and reports have been published (Romanov, 1976, 1977), which described the main features of the geological structure, lithofacies and mineral composition, conditions of the placer forming etc. However, due to the existence in Ukraine such titanium giants as Irshansk and Dnieper placers groups, the need for more detailed research and study of Kharkiv-Sumy placer zone was suspended.

Intensive development of modern methods and technologies of information support in all fields of geological activity as well as the development of new stratigraphic scheme provided the basis for actual analysis, complement and re-interpretation of existing points of view concerning placer forming and regularities of placer spread in northeastern slope of DDD.

In recent years the scientific and technical team (with the participation of the authors) has studied the problem of formation and forecasting for Novi Petrivtsi suite titanium-zirconium placers within DDD and neighboring areas. A repeated field researches, collection a lot of factual material, a bulk of laboratory tests and reinterpretation of existing data have been performed. These investigations provided a basis to complete the lithostratigraphical scheme for DDD northeastern slope Novi Petrivtsi suite, to realize the paleogeographic reconstruction of Sub-Paratethys with large-scale facies analysis, and finally to develop the structural-lithological model of Krasnokutsk field (Zosimovich, 1973; Zosimovich, Savron, 1978; Kravchenko, 2014; Laverov et al., 2014, Khrushchev et al., 2015 and others).

Scheme of the placer forming for Krasnokutsk deposit area is based on comparing the received specific data on paleogeography, lithofacial composition, paleofacial and paleolithotransport characteristics, paleohydrodynamics, sedimentation and other conditions of Sub-Paratethys (as sedimentary basin of placers forming) Middle Novi Petrivtsi subsuite (as placers containing) and the deposit area in particular with the main positions of theoretical scheme for coastal-marine placer deposits of titanium specialization forming.

REGIONAL-ZONAL SCHEME OF PLACER FORMATION

The deposit area refers to the area of alluvial Kharkiv placer district, belonging to placer Kharkiv-

Sumy zones. The primary sources of placer forming ore material (PFM) are hypothetically defined at least for this district, possibly – for all Kharkiv placer zone; these are metamorphic formations (between 2140 - 1930 million years) with their crust of weathering (Romanov, 1976, 1977; Tsymbal, Polkanov, 1975). Primary PFM paleotransport initially was realized by gravitation slope processes and temporary streams carried transfer and then by paleorivers arteries at a fairly broad watershed slope of Voronezh shield and boundary zone of DDD. Part of this material was redeposited in Cretaceous and Paleogene marine sediments. Formation of PFM intermediate collectors occurred intermittently in connection with the forming of continental (alluvial) and marine sediments, containing heavy minerals.

The main phases of intermediate PFM collectors are: Early Cretaceous, Late Cretaceous (especially – Cenomanian), Palaeogene (with the phases: Kaniv-Buchak, especially intense – Kharkiv, and low intense – Kyiv).

In Middle Novi Petrivtsi phase of Sub-Paratethys evolution the «critical» point for combining required set of conditions, necessary for placer forming (tectonic, hydrological, hydrodynamic, lithodynamic, geomorphological and structural locally sedimentation) have occurred.

Consider first. Since the beginning of Early Novi Petrivtsi time oppositely directed tectonic movements – upward in the areas of PFM formations (Voronezh shield, Ukrainian shield) and some intermediate collectors, and descending within sedimentation «sea» basin (Sub-Paratethys) have taken placer. These movements provided, first, the formation of sedimentation basin with the system of feeding rivers (geomorphological and hydrodynamic conditions), and secondly, the mechanism of lithodynamics which provided PFM input into the basin.

The hydrological regime of the basin – mode of transgressions-regressions – in need of special consideration. Given the usual sea basins it is managed by two factors: regional tectonic dynamics and eustatiks. In our case the action of eustatiks seems to be excluded. According to the nature of Sub-Paratethys the mechanism of the basin level was managed by volume of river water inflow (i.e. dependent on climatic conditions), and sedimentation result of fluctuations coincides with the usual transgressions-regressions ones (except for certain geochemical characteristics).

Morphological peculiarities of the basin (it's size and configuration) provided the action of two

determining factors of placer forming: along beach currents and wave movements. Circular currents in that elongated relatively narrow basin practically did not occur.

Structural-sedimentation conditions in Middle Novi Petrivtsi basin manifested in two major genetic forms, inherited and consedimentary. Inherited forms were caused by the presence of certain structural uplifts and expressed in the form of coastline curves, forming more or less open bays (Krasnokutsk field area, Samotkan group of deposits, etc.).

These curves have shaped the optimum hydrodynamic conditions for placer forming, with could be realized under favorable litodynamic conditions - more precisely, the supply of sufficient volumes of ore material. Consydementation forms, both accumulative and erosion, formed sedimentation traps.

THE MECHANISM OF PLACER FORMING WITHIN KRASNOKUTSK AREA

The scheme of Krasnokutsk deposit area is based upon the fundamental principle that the main source of PFM supply was a river. A certain role belongs also along beach streams and abrasion of laterally adjacent and underlying ore containing sediments. Evidence of this scheme are: the presence of deltaic sediments in Middle Novi Petrivtsi see; special location of lithofacials and facials, reflecting certain succession and zonality (from deltaic to shallow-marine); repartition of ore mineralization, that shows the spatial migration of maximum concentrations strips over time.

Delta facials were identified by means of following characteristics. They are represented by typical sets of layers; small- and fine-grained («background») sands, medium and coarse, rarely – gravels and clays. The sands are characterized by multidirectional, cross layering, caused with granulometric parameters change, availability of dark organic clay material etc. The concentration of ore material in the deltaic sediments is practically absent.

These lithological sets are located at the bottom of Middle Novi Petrivtsi subsuite and form lens and strata-lens forms of tiered arrangement.

Genetic diagnosis of delta facials is based not only on the specific features inherent for these facies in stable platform geostructures, but also is confirmed by the fact of the uniqueness of these lithological sets within monotonous deposits of Middle Novi Petrivtsi subsuite: within this sedimentary basin simply there are no other facial conditions responsible for the formation of such lithological sets.

Basing upon the determination of the spatial distribution of facies types (by interpretation of lithofacies and grain size model visualizations) the scheme of lateral repartition of dominant facies types within Krasnokutsk deposit area is presented (Fig. 1). This scheme shows three zones of prevailing basin facies spread: «sea» shallow water (south-western sector of the area), coastal shallow (littoral), forming a band of southeastern stretch with curved north-eastern border, and the delta that forms in plan a string of complicated shape, elongated in North-South direction, subnormal to the coastline. This zone crosses the external strip of coastal facies (which is also a feature of the river sediments).

Basing upon the data considering we have to present a principal scheme of dynamic system of PFM input – separation – sedimentation for Sub-Paratethys northeastern coast (Fig. 2). Under the proposed concept common genetic scheme of the object should reflect two aspects: spatial zoning system for a certain time span and the evolution of the system in space over time.

Spatial zoning system comprises two functional elements: the source of PFM supply and the area of separation (with two facial zones: coastal and shallow marine).

Ore characterization of these elements is as follows. For the area of separation it is consistent with generally accepted theoretical notions: in the zone of shallow water - dispersed, in shallow coastal zone - uneven, with the highest concentrations and reserves, including commercial. Delta deposits contain small, scattered, more or less homogenous mineralization.

The evolution of this system spatial shift zoning over time consisted in progressive migration from north to south (according to shore line PFM migration), and from lower horizons of subsuite section to the middle and upper (with redeposition of underlying strata) in accordance with the transition from transgressive to regressive rhythms of Middle Novi Petrivtsi sedimentation cycle.

Reflecting this migration is the formation of three strips of ore fields in the deposit area - the north (Koziivka), central (Central and Stepanivka) and South (South). These strips correspond to three stages of interim shoreline stabilization with appropriate facial zones of placers formation, and the most «productive» middle stage was characterized both by the maximum concentration of the ore material and specific and general reserves.

The mechanism of heavy minerals separation was fully responsible for placer «coastal sea» geological-genetic type (considering peculiarities inherent

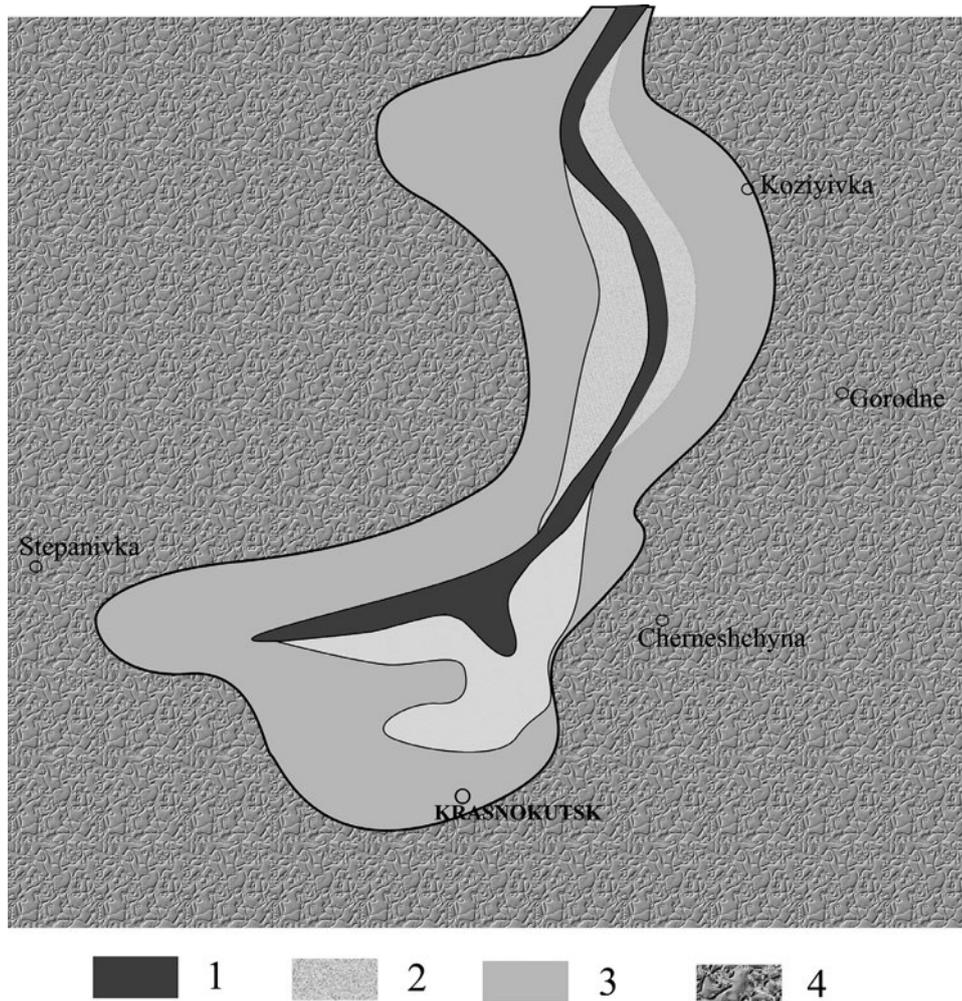


Fig. 1. Paleofacial scheme of Krasnokutsk deposit area, Middle Novi Petrivtsi time. 1-3 – delta (zones of main lithofacies); 4 – coastal-marine facies.

to costal and shallow marine zones), as evidenced by structural and textural characteristics of ore-bearing sands. This is due to the fact that Sub-Paratethys hydrodynamics at the phase of placer forming (Middle Novi Petrivtsi time span) almost completely meet the condition of ordinary sea basins. In particular it should be noted the restriction of ore bodies strips to flexures deflections in relief of Middle Novi Petrivtsi subsuite floor. The nature of these flexures (inherited or consedimentary) is not installed, but in any case their strikes coincide with the band of heavy minerals maximum concentrations in the border between shallow costal zone and surface beach facies (Laverov et al., 2014; Lalomov, Tabolich, 2013).

Understanding of this pattern unravels the fact of full compliance of cited above scheme and theoretical scheme of placer forming during the phase of a basin regression (Fig. 3). This scheme is the basis of structural and sedimentation criteria for large-scale placers prognoses.

Basic geological commercial characteristics of placers – total volume of ore resources and richness of the ore bodies have been managed by such factors. The total amount of resources was controlled by the volume of ore material which has been delivered into the basin of placer forming. The degree of saturation of ore bodies (the concentration of heavy minerals) was controlled by local hydrodynamic and structural-sedimentary conditions.

Hence, the limited resources total volume of Krasnokutsk deposit (compared to Samotkan group of placers) defined with two conditions: the limited volumes of ore material having been delivered by the river feeding artery and a small role of PFM having been transported in by along beach streams. The relatively low saturation of ores is explained by, first, the same factor of limited amounts of ore material, and secondly, the lack of sedimentation traps of lower rank.

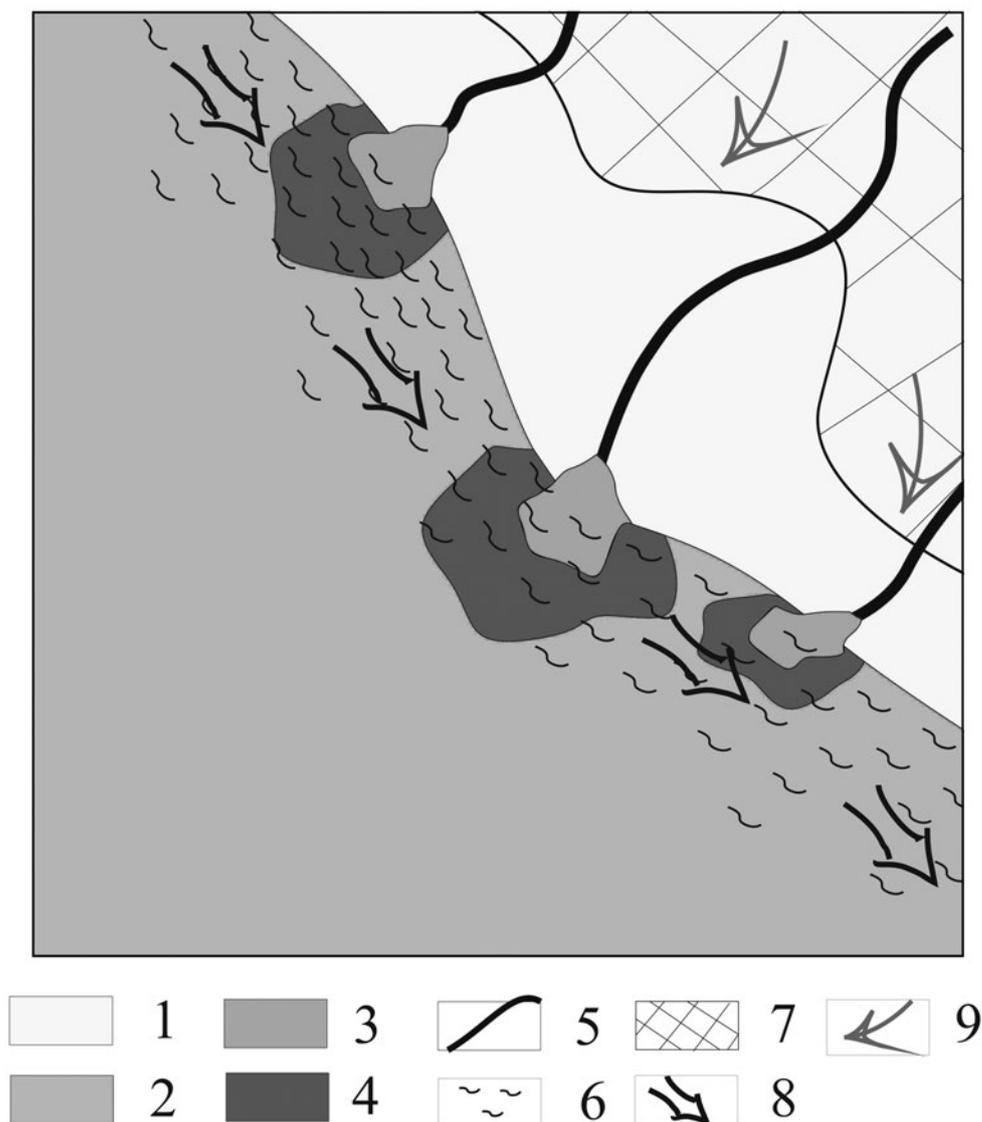


Fig. 2. Schematic map of the dynamic system of PFM «input - separation - sedimentation» for Sub-Paratethys northeastern coast.

1 - land, 2 - the final basin, 3 - delta 4 - PFM separation area, 5 - paleorivers, 6 - waves surf activity, 7 - primary PFM sources, 8 - direction of along beach flows, 9 - direction of ore material (PFM) transportation.

CRITERIA FOR PROMISING AREAS PROGNOSIS

According to our definition, Kharkiv placer district represents a certain part of conceptual petrographic sedimentary province, for which there are defined: a typical object of local scale (Krasnokutsk deposits area), mineralogical characteristics, conceptual source of PFM delivery, main types of PFM transportation and fundamental mechanism of placer forming.

The compiling of scheme for placer forming in the final «sea» basin by the example of Krasnokutsk deposit provides the formulation of additional criteria for placers predicting in the scale of placer zone. We have to remind that a set of regional scale general criteria includes: stratigraphic (placers connection with

Middle Novi Petrivtsi subsuite), facial (defining two placers containing zones with corresponding characteristics of mineralization), hydrodynamic. This set of criteria is also effective for zonal scale prognoses. An additional list of criteria, destined for zonal and local scale placers prognosis, includes: lithofacial, paleotransportation, paleogeomorphological and sedimentation ones. Consider one by one.

Multiscale facial criteria are based upon the principle scheme of placer forming dynamic system PFM «input - separation - sedimentation», designed for the North-east coast of Sub-Paratethys (Fig. 3). This scheme is based upon acknowledged axiomatic idea that the primary way of ore material delivery into the

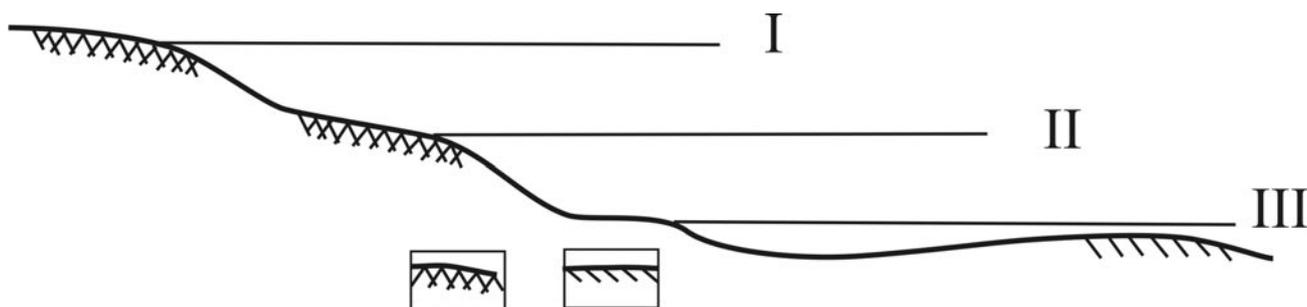


Fig. 3. Scheme of the formation of placer ore bodies series at the phase of a basin regression. I, II, III - consistent levels of basin stabilization. 1 - littoral deposits; 2 - sublittoral deposits (Lalomov, Tabolich, 2013).

basin of placer forming is a river artery (N.A. Shilo, N.G. Patyk-Kara (Patyk-Kara, 2008; Shilo, 2002) and others) (excluding specific abrasion type of deposits). Placer (ore) realization of river PFM flows occur in two facial and hydrodynamic zones of terminal basin – costal shallow and marine shallow. Thus, it should be considered placer forming facial parahenez: delta – shallow coastal zone – a zone of shallow sea. Taking into account that significant concentrations of heavy minerals for sublittoral in this case is not reliably identified, one can simplify the composition of promising facies complex formula to «delta – littoral».

Definition of PFM paleotransportation is an important auxiliary tool for deltas forecasting, as so as deltas diagnosing in DDD lithological sections (at least Neogene age) is difficult. To solve this problem the most efficient method is geomorphological, which provides rather reliable results of ancient river valleys tracing. In the neighboring to DDD area Voronezh shield appropriate researches have been started by V.P. Palienko, but they were not completed. Methodology of paleovalleys reconstruction has been developed by V.P. Palienko, O.O. Komlev and other. The prediction of paleovalleys entry into the terminal basin (of placer forming) provides a basis for defining the zones of separation of heavy minerals in accordance with the scheme, i.e. the prognosis of sites, favorable for placers forming.

Phase-sedimentary criterion involves the activity of several phases of placers forming in the terminal basin. For example of Krasnokutsk deposit shows that in the course of sedimentary basin evolution occurred at least three stages of placer forming that meets certain regressive rhythms. Thus,

the detection of one ore deposits subparallel strip of coastline, can predict the possibility of other ore bands with a spatial placement under the above scheme facies migration.

CONCLUSION

The scheme of placer forming mechanism for Krasnokutsk deposit is developed. This scheme show that the main source of ore material input into the placer was river flow. The role of along beach marine streams and shore sediments abrasion was subordinate.

The proposed mechanism of placer forming is available for specific conditions of Sub-Paratethys northeastern coast, i.e. at least within the Kharkiv placer district, so it was a basis to found prognosis criteria in the zonal level, i.e. for Sumy-Kharkiv placer zone. The zonal scale criteria set includes: stratigraphic (placers localization in Middle Novi Petrivtsi subsuite), facial (identification of two facial zones with corresponding mineralization characteristics), hydrodynamic, lithofacial, paleotransportation, paleogeomorphological and phase-sedimentation.

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