

The role of neotectonic activations in the formation of the Ukrainian sub-province of titanium and titanium-zirconium placer deposits (scientific and applied aspects)

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SUMMARY

Titanium and titanium-zirconium placer deposits of the USTTZPD were most actively formed in the middle Jurassic - early Cretaceous and the end of the Oligocene-middle Miocene, which is consistent with the initial stages of geomorphological and neotectonic stages. During the neotectonic stage, placers were most actively formed during tectonic activations at the end of the Oligocene - at the beginning of the Miocene, at the beginning of the middle Miocene. The placers were formed in the deposits of the Poltava series at all levels of the paleorelief. The titanium placers of the Irshansky ore field (relatively elevated denudation plain) and the titanium-zirconium Motrjna-Annyvske placer deposit (MAPD) of the Prydniprovsk ore field (denudation-accumulative and coastal accumulative plains of the US) were studied. It was found that the dynamics of neotectonic movements during activations significantly influenced the processes of morpholitogenesis and oregensis of placer deposits of USTTZPD. This is confirmed by quantitative indicators (coefficients) of the material composition of placers. They allowed us to study the vertical and horizontal structure of placers, to establish the rhythmic accumulation of productive strata. On different neotectonic blocks the number of rhythms was 1-6 (rhythms). In the sea basin where MAPD was formed, this caused permanent changes in the conditions of morpholitogenesis and placer oregensis. The conducted research of USTTZPD allowed to receive important scientific results, allow to improve development of placer deposits taking into account prevention of activation of negative geological processes (erosion, suffusion, formation of depression funnels, etc.).



Introduction

The Ukrainian sub-province of titanium and titanium-zirconium placer deposits (USTTZPD) is part of the placer province of the Eastern Europe. USTTZPD covers the Ukrainian shield (US), the Voronezh anteclisis (VA) and their slopes, which are connected with the Dnieper-Donetsk depression (DDD). In the history of USTTZPD there are 2 episodes of *active formation* of placer bodies, which fell *on the middle Jurassic - early Cretaceous* and *early-middle Miocene*. They are clearly correlated with the initial stages of the 2 stages of global tectonic activation of the Earth, respectively, *geomorphological* and *neotectonic*. Then the most suitable conditions for this were formed, when: at the ancient levels of denudation the formations of igneous rocks were brought out, in which geological "bodies" with a high content of placer minerals were contained and discovered; there were warm (and hot) humid paleoclimatic conditions that contributed (along with other factors) to the formation of planar chemical (kaolin) weathering crust; dominated by inversion tectonic movements, which controlled the erosion and accumulation of derivatives of the weathering crust in placers in the forms of ancient relief. Remains of titanium and titanium-zirconium placers of the middle Jurassic-early Cretaceous age are now preserved only in the depressions of the paleovalleys. Instead, early - middle Miocene placers are located on all elements of the buried relief. They are practically nutty, designed or prepared for use. This always creates a potential danger to the natural complex of these areas, leads to a violation of the surface layer, the activation of various exogenous processes. Therefore, even at the stage of studying placers, it is desirable to carry out zoning of their qualitative composition, which is necessary in the preparation of technological schemes for their development. USTTZPD is of global importance and should be studied on a systematic basis, taking into account all possible factors of its formation. USTTZPD arose on the site of the Sarmatian shield, after the collapse of which the US, VA and DDD were formed here. With the Paleozoic, they exist as integral geostructural and geomorphosystem ensembles and determine the processes of morpholitogenesis and oregonesis of sedimentary minerals, including placer deposits of the USTTZPD. Currently, the factors (paleogeographic, paleogeomorphological, structural-tectonic) formation, material composition of placers, physical and chemical features of placer minerals of USTTZPD are studied. The integrated use of these data allows to solve both applied and scientific problems, in particular to study the dynamics of neotectonic movements and its influence on the formation of placer deposits.

Method and Theory

- *General systems theory* allows you to identify elements of USTTZPD;
- *Structural and tectonic analysis* - selection of geostructural elements of USTTZPD;
- *Geomorphosystem analysis* examines the geomorphosystem of formation of USTTZPD;
- *Paleogeomorphological analysis* - detailing of the geomorphosystem of formation USTTZPD;
- *Morphostructural analysis* - identification of morphostructures of the USTTZPD;
- *Neotectonic analysis* - identification of neotectonic structures of the USTTZPD;
- *Cartographic method* - the use of general maps and the compilation of new special ones;
- *Analysis of the mineral composition* of placer deposits - the use of quantitative indicators;
- *Analysis of the mineral composition* of the heavy fraction of placers and the *chemical composition* of ilmenite - the use of quantitative indicators

Examples

Numerous works by Yu. Burmin, M. Vadymov, M. Veklych, E. Dudrovych, M. Dyadchenko, P. Zamoriya, V. Kondrachuk, O. Komliev, Y. Koshyk, Y. Mukhin, V. Ovcharenko, Y. Polkanov, G. Proskurin, O. Remezova, I. Romanov, V. Tarasenko, V. Timofeev, M. Ruban, A. Khatuntseva, S. Tsymbal, S. Shvaiberov are devoted to the study of the conditions of formation and material composition of the USTTZPD. In recent years, the direction of geoinformation modeling of placer



deposits, including titanium and titanium-zirconium placers of the USTTZPD (O. Remezova, D. Khrushchev, S. Vasylenko, O. Kravchenko, O. Komliev, O. Kovalevich) has been developing. They use various formalized data on the formation of the USTTZPD, in particular the spatio-temporal organization and the factors and conditions of the formation of placers.

Results

The neotectonic stage is considered one of the main in the history of geological development and morphogenesis of the Earth. The neotectonic stage is associated with the final, "folded" stage of the Alpine tectonic cycle. With its beginning, at the end of the Eocene - at the beginning of the Oligocene, a qualitative change in the geodynamic situation and global activation of tectonic processes began. Neotectonic movements are characterized by periodicity and changes in intensity over time caused by global, crustal, intracrustal, surface (ocean level fluctuations, hypergenic and glacioisostasis) processes. On the scale of the Earth, the activation of neotectonic movements are observed: at the beginning of the Oligocene; at the end of the Oligocene and at the beginning of the Miocene; at the beginning of the Middle Miocene; in the late Miocene - early Pliocene; in the late Middle - early Pleistocene (Palienko, 1992). According to the stratigraphic schemes of the regions of Ukraine, the formation of placers was most active at *the end of the Oligocene - at the beginning of the Miocene* and at *the beginning of the middle Miocene*, the time of accumulation of deposits of the Poltava series. This is confirmed by the geological materials of dozens of placer deposits and manifestations of USTTZPD. Paleogeomorphological data show that placers of this time were formed at different levels of paleorelief - on the relatively elevated denudation plain of the US, denudation-accumulative, coastal and coastal accumulative plains on the slopes of the US, VA, adjacent to the DDD (Atlas..., 2001). We studied ilmenite placers at 16 deposits of *the Irshansky ore field*, which were located on the relatively elevated denudation plain of the US and the coastal-marine titanium-zirconium Motrjna-Annyvske placer deposit (MAPD) of *the Prydniprovskye ore field* formed in north-eastern slope of the US.

Within the placer deposits of the Irshansky ore field, the root springs are clearly established (unlike many other placer areas). Therefore, there is an opportunity to study the spatial relationships of root sources and placers and to develop methodological criteria necessary for the study of factors and conditions of placer formation. Comprehensive use of these data allows us to study the dynamics of neotectonic movements in the late Oligocene - early Miocene and early Middle Miocene and their impact on the formation of placers. Neotectonic uplifts at the beginning of the Miocene were accompanied by the introduction to the level of denudation of root sources of placers, significant erosional dismemberment, formation of valley forms, and crust formation. In studying the processes of morpholitogenesis and ore genesis of ilmenite placers, we have widely used the results of analyzes of *ilmenite monofraction* - its granulometry and chemical composition, complete and abbreviated analyzes of the mineral composition of placer bodies.

They were selected by the method of interval testing of the well core along the lines of intersection of placer bodies at 9 placer deposits. Quantitative indicators (coefficients) of material composition were calculated according to the developed methods. They were effectively used together with other data, in particular, paleogeomorphological. Neotectonic analysis performed on placers took into account the data on the spatial relationship of placers with root sources, vertical and horizontal zonation of ilmenite placers. The root springs of placer bodies are separate formation bodies (the thickness of which is from the first centimeters to several tens of meters), which are left from the destroyed dome-like structures of the foundation. These layers form whole series, subparallel, directed towards and at an angle to the surface. In terms of indigenous roots are *narrow elongated, isometric, irregularly shaped*. They were exhibited on all levels of ancient relief. Indigenous bodies and placers may coincide in plan *completely, partially, not coincide*. Analysis of the spatial relationships of placers and root bodies shows that the useful component from the latter to the places of formation of placers moved a distance of several meters - several hundred meters, which largely depended on the ancient relief. According to the criterion of the ratio of indigenous and placer bodies, it can be concluded that



the late Oligocene-early Miocene placers of the Poltava series had eluvial, eluvial-deluvial, deluvial, deluvial-alluvial, proluvial, and alluvial genesis. Features of paleorelief could significantly affect the process of transition of ilmenite into placer, and even contributed to their enrichment and the formation of industrial concentrations. The vertical zonation of ilmenite placers of the Irshansky placer field was studied according to the data of average size, sorting, chemical composition of ilmenite. They allowed to establish the tendencies of morpholitogenesis in the ancient valleys, on the slopes for the time of accumulation of sediments of the Poltava series, which were caused by the peculiarities of the dynamics of neotectonic movements. Thus, the *average size* (Md) and *sorting* (So) of the ilmenite monofraction allowed to distinguish 8, and the coefficient of *variability of the chemical composition of ilmenite* 10 types of sections. Features of changes in the content of ilmenite in the ancient valleys allowed us to identify 2 main trends: a steady increase in the content in one direction (Figure 1 a, b, d, e,); rhythmic alternation of packs (2, 3) of rocks with different trends of change in their content of useful component (in the figure f-k, m, n) (Komliev, 1988). The horizontal zonation of lithological, granulometric, and material composition is clearly manifested in the sediments filling and overlapping the paleovalleys.

a	b	c	d	e	f	g	h	i	k	l	m	n
	^	v	^	v	v	^	v	^	v	v	v	^
	^	v	^	v	v	^	^		^	v	v	
	^	^	^	v	v			^	^	v	v	v
		^			v			^		v	v	v
v			^	v	v	v	v					v
v			^	v	^	v	v	v	v	v	^	v
v			^	v	^	v	v	v	v	v	^	v
c, t	c, i	i, s, c, t	c	C	c, t	s, c	t	C	C	c	s, c	C

Figure 1 Tendencies of changes of ilmenite content of paleorelief of late oligocene – early miocene placers (c - channel, t - terrace, s - slope, i - interflue, (v ^) – directions of growth of ilmenite content)

At the late Oligocene-early Miocene stage of neotectonic activation on the territory of the axial part of the DDD there was an accumulative lake-swamp plain (up to 150 km wide), which stretched from northwest to southeast for 600 km from Slavtych to Lozova. Adjacent to it was a low accumulative denudation plain. In the Middle Dnieper there was a relatively elevated paleorelief dissected by erosional forms, the weathering crust was formed and the Samotkan group of titanium and titanium-zirconium placers of the Prydniprovskoe ore field of the USTTZPD.

The Motrjna-Annyvske placer deposit (MAPD) of titanium-zirconium ores at the time of formation is consistent with the neotectonic activation that occurred at the beginning of the middle Miocene. The field was formed in shallow sea conditions (Vasylenko, 2015). Before the transgression of the water basin there was a denudation-accumulation plain. In the structure of the historical-dynamic geomorphosystem of this territory, MAPD is located in the Lykhiv and Verkhivtsev historical-dynamic basin morphosystems (Komliev, 2005). The border between them ran along the watershed of the southwestern - northeastern extension and divided the MAPD into 2 parts, the main of which was located in the east. Watersheds were declining in some places, and interception of hydraulic systems of neighboring basin morphosystems could occur here. On the paleogeomorphological map of the time of MAPD formation, the thalwegs of the pretransgressive hydrogrid are well reconstructed, their “merger”, “confluence”, “twins”, “tees”, etc. are observed. Even before the beginning of transgression, and then with its development, neotectonic uplifts of the vaulted structure of the foundation over which the “body” of MAPD is located began. These uplifts had a differentiated block character. The areas of individual blocks are hundreds of m² - the first km², they form larger groups. In the paleorelief they corresponded to the islands, shoals, raising the bottom of the reservoir. Valleys, valley-like extensions, and isometric forms are dated to the blocks and their groups that lagged behind in the uplifts. Databases of 1135 exploration drilling wells were created at the MAPD site by the



method of interval testing of 18,947 analyzes of mineral composition. Different mineralogical coefficients can be used in the study of neotectonic movements. We investigated the vertical zonation of the structure of the MAPD placer “body» by the *yield of the heavy fraction*. On the selected neotectonic blocks 1-6 rhythms of accumulation of a productive stratum reflected in its structure are allocated. This indicates repeated changes in the intensity and, possibly, the direction of movement of the blocks, which affected the hydrodynamic processes of placer processing. The root sources of MAPD were small, scattered and revealed when the vault was raised. A necessary condition for the formation of placers was the kaolin crust of weathering of the Paleocene-Eocene age. Neotectonic activations caused its erosion and, at the same time, the formation of a new one. High clay content, the presence of glauconite in the deposits containing placers indicate their active hydrodynamic processing in marine conditions.

Conclusions

Titanium and titanium-zirconium placer deposits of the USTTZPD were most actively formed in the middle Jurassic - early Cretaceous and the end of the Oligocene-middle Miocene, which is consistent with the initial stages of geomorphological and neotectonic stages. During the neotectonic stage, placers were most actively formed during tectonic activations at the end of the Oligocene - at the beginning of the Miocene, at the beginning of the middle Miocene. The placers were formed in the deposits of the Poltava series at all levels of the paleorelief. The titanium placers of the Irshansky ore field (relatively elevated denudation plain) and the titanium-zirconium Motrjna-Annyvske placer deposit (MAPD) of the Prydniprovskie ore field (denudation-accumulative and coastal accumulative plains of the US) were studied.

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