WEATHERING CRUSTS OF SOUTH FAR EASTERN RUSSIA AND THEIR MINEROGENY?

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This work provides an account of investigations undertaken on the southern part of Far Eastern Russia and a part of Southern Yakutia. The Far East includes large parts of the middle and lower Amur basin, the eastern periphery of which is known as Primorie ("Near-Sea" or Pacific Coast region), while the Southern Yakutia area includes the Stanovoy Ridge Zone. All territories are described briefly below in terms of a region. Use of this usual term in other meanings will be clear in context.

The region is characterised tectonically by a unique crossing of Asian latitude and Pacific sub-meridianal (NNE) structures. Meridianal, NE and NW strike structures are also expressed. These structures are of early Archaean origin, and were inherited and expressed in relief by repeated Mezo-Cenozoic tectono-magmatic activation events, followed immediately by primarily vertical neotectonic movements. Activation migrated from West to East.

Such tectonics determined the lattice-like relief pattern. Most ancient are the latitude Stanovoy belt (and corresponding ridge) and meridianal Sette-Daban ridge composed of Archaean and Early Proterozoic crystalline rocks. The most southern structures are of Moldovo-Okhotian Mesozoic tectonic origin and comprise rocks of different age and character, ranging from Archaean Early Proterozoic crystalline and Early Palaeozoic sedimentary rocks to Jurassic and Early Cretaceous argillites and sandstones.

Mountainous terrain occupies approximately two-thirds of the territory. The ridges consist of stepped horsts, sometimes with foot-tilted blocks (arch-block mountains). Depressions represent block-brachysynclines: stepped grabens in middle parts with limbs - tilted blocks.

About one-third of the territory is differentiated uplift plain (300-350 m high). Several workers have called it a "peneplane", underlining peneplanation as a necessary condition for weathering crust formation. However, the application of the term "peneplane" in this situation oversimplifies the landscape. More precisely the terrain consists of a hilly plain, with denudation and accumulation surfaces, formed over a long period. Certain parts of this plain are typical of a pediplane with inselbergs. Blocks of the plain composed of Pre-Cambrian and Palaeozoic rocks have been differentially uplifted, sometimes with hilly, low- and middle-mountains which can be referred to as "plain projections" or "uplifts".

Planar parts of this landsurface merge in filled depressions forming their basement; while other parts exist as remnants on ridge crests. Typical pediplains also form the base of ridges. Their inselbergs appear to be somewhat denuded microhorsts, which rise to mountains and unite with their offspurs.

During the Pliocene the region was differentially uplifted with subsequent incision of rivers forming the present valley net. In some places new erosion removed the sediment cover from the periphery of the depression and exhumed the "basal surface".

All of these features determined the great complexity in formation and preservation of weathering crusts.

In the Far East weathering crusts are distributed widely but not evenly. They are found to varying thicknesses on "old projections", mountain bases, denudational plains, the fringes of superimposed depressions in the western part of region, and in their own depressions. In the largest Mezo-Cenozoic depressions: Amur-Zeia, Middle-Amur, Upper-Zeia, weathering crusts are found in boreholes and at fringes. In the Stanovoy zone, crusts are found locally on ridge, lower hilly and low mountainous parts of the Malo-Elgakan suture zone and similarly on other ridges. Their altitudes vary from 700-850 m or more in local parts of Amur-Zeia depression, up to 900-1000 m or more on "old projections".

As mentioned above weathering crusts in the Far East and Southern Yakutia are developed on a range of rock complexes, from Early Archaean up to Late Pliocene, with possibly younger ones. They are covered with sediments of different ages from Middle Devonian gritstones on the October uplift to Late Quaternary deposits of varying thicknesses.

In the region the following morphological types of weathering crust can be distinguished: 1 Areal, 2 Linear, 3 Linear-areal Linear crusts can be divided into sub-groups, but at present in the region it is difficult to recognise these types exclusively, as areal crusts merge so closely with linear crusts that, as a rule, they cannot be discriminated

Using all available materials and our own data we enunciated the scheme of weathering crust zonality for South-Eastern Russia The scheme has been tested in the region and can be assumed to be robust for distinguishing and mapping weathering crusts The scheme is based on the character of weathering and on distinguishing profiles containing consistent mineral associations Types of weathering crust are based on the more commonly found minerals within profiles (Table 1) On the whole in weathering crust profiles, 6 main zones are distinguishable; detailed characteristics of which are unnecessary and will not be presented here [6]

It is only possible to determine the prevalence of any morphological weathering crust type in a clearly defined region For instance, during the present epoch nearly 45% of Amur region is covered with crusts of various levels of preservation related to different "uplifts" where areal weathering crusts are up to 40-50 m thick Also developed are rather wide linear weathering crusts with thicknesses greatly exceeding 150-180 m

Table 1: *Zonality of weathering products for Russian Far East territory*

NN	WEATHERING CRUST ZONE CHARACTERISTICS			THICKNESS	WEATHERING PROFILE TYPE
	DOMINANT PROCESS	PRINCIPAL MINERALS	LITHOLOGICAL CHARACTER		
6	Complete hydrolysis and oxidation	Kaolinite-hematite -goethite, goethite -hematite- gibbsite	Loose or dense clay-like brown, red, yellow, with hematite-clayish concretions	From 1-2 up to15-25 m; in linear zones up to 100 m (?)	Lateritic
5	Hydrolysis and beginning of oxidation	Kaolinite, nontronite	Loose, clayish, sometimes "dried"; soiling, nearly structureless	From 1-2 up to 15-25 m; in linear zones up to 30-35 m (?)	Kaolinite
4	Complete leaching and beginning of hydrolysis	Hydromicas-kaolinite, montmorillonite	Loose, nearly complete-clayish with sparse inclusions, soiling, often with relics of original structures	From 1-2 up to 20-25 m; in linear zones up to 35 m (?)	Hydromica-kaolinite, montmorillonite-beidellite etc (clays of complex composition)
3	Hydrotation and development of leaching	Kaolinite-hydromicas, hydromicas-vermiculite	Loose, soft, sometimes dense, often with scree and rubble; well preserved structures of original rocks	From 1-2 up to 10-15 m; in linear zones up to 100 m , vermiculite and more	Kaolinite-hydromicas, hydromicas-(clays of complex composition)
2	Hydrotation and beginning of leaching	Hydromicas (?)	Scree, rubble with clayish inclusions, and touches, sometimes total pelitisation of rocks	From 1-2 up to 5-10 m, rarely more; in linear zones up to 100m and more	Of leaching or beginning of hydrotation (mixed-layer minerals)
1	Beginning of hydrotation	Disintegration	Fissured rocks, sometimes rubble, scree	From 1-2 up to 300 m (linear zones)	Disintegrated rocks

In all depressions of this region areal weathering crusts of different genesis and varying zonality and thickness are preserved as nearly continuous covers (Urkan, Near-Khankai, Evoron, Upper-Zeia and other depressions)

When weathering crusts of combined linear-areal type are developed their thickness regularly increases in the direction of the linear fault-controlled zones

Several workers studying the Southern Yakutia and Russian Far East believe that generally for the formation of deeply weathered crusts a global peneplane, or at least peneplanation of regional surfaces on large structural units with essentially uniform evolution of relief, is necessary [1,3]

Other workers, including Sorokin [7] and Khud'jakov [2] believe that weathering crust formation is restricted to the system: denudation - accumulation. In this case crust formation is possible only in depressions (at present buried) or on fringes of depressions where the various weathering crust zones can be preserved.

At present vast relics and fragments of weathering crusts of varying ages and thicknesses are preserved in such situations

Heterogeneity, not only of whole the territory but even of its large morphostructural units, complicated fold-and-block basement, repeated and different temporal tectono-magmatic activation, and burial of adjacent areas (sometimes 100-200 m distant) under deposits of different ages all exclude the possibility of global peneplanation

The proposition of "synchronism and paragenesis" of erosion planation with chemical weathering, and corresponding "platform and similar accumulation" cannot be applied to low mountains where weathering crusts are spread as widely as on Amur-Zeia and other depressions Evidently formation of planation surfaces with thick areal crusts was going on uniformly and synchronously throughout the whole territory, but migrating both temporal and spatially

Analysis of buried weathering crusts in the Amur-Zeia depression have shown that there is no evidence for denudation of ancient rocks "up common level", as crusts in adjacent areas are often covered with deposits of different ages

Adjacent areas have also revealed fragments of planation surfaces on rocks of different ages (Early Palaeozoic granite intrusions, Early Cretaceous effusives, etc), covered as though they were single-age deposits (Fig 1). This evidence supports the block differentiation of the territory after formation of planation surfaces. It is also possible to suppose that the duration of weathering crust formation on adjacent blocks was different Such a situation can exist if crusts are forming in a complex differentiated depression and burial involves deposits of various ages and thicknesses

Another picture is revealed at elevation on protracted inherited uplift of types Turana, Gondga, October, Khankhai and others In these locations formation of weathering crusts began under generally favourable climatic conditions, synchronously or near-synchronously to crust formation in depressions (T3-T1) However, unlike in the depressions, weathering crusts were rarely, if ever, covered with loose deposits, and crust formation was protracted On present relief (level of present denudation) no areal weathering crusts greater than 35-45 m thick exist Thus weathering crusts were forming over a long period of time, but were equally and nearly synchronously eroded; the waste products accumulating in depressions of various genesis and sizes These processes of weathering crust formation and erosion as whole were not uninterrupted

Probably every area of studied territory passed through the stage of erosion planation However, tectonic, structural and historical heterogeneity defined the processes of planation and weathering crust formation as being non-uniform in time and space [4,5] Therefore, different parts of this heterogeneous territory, as related to defined structures and tectonics, were exposed to planation for different time periods and to differing extents Non-synchronous planation, subsequent subsidence and burial under sediments of different age, was followed by later uplift of several buried blocks which underwent new episodes of planation and weathering crust formation. Evidence for this exists in the form of several different-aged horizons of weathering crusts in the same sections Weathering crust formation was not continuous but oscillated or underwent protracted "continuous-interruption" on relatively-steady uplifting morphostructures, and ceased in depressions Crusts buried under thick sediments of different age s were found On the fringes of depressions, weathering crust formation was weakened by expansion of sedimentation on adjacent parts of denudation plains Thus formation of planation surfaces with weathering crusts was happening non-uniformly and non-synchronously over the whole territory. Active crust formation continued on inner parts of relatively high denudation plains and low mountains ("uplifts")

This process was not uniform, however. Weathering was commonly superimposed on complete profiles, and more often involved erosion of older crusts (Early or Late Mesozoic) It was the quasi-continuation of profile formation of the same zonality, sometimes by environmental changes or rise of new geochemical barriers that commenced formation of new azonal weathering profiles As was repeatedly observed by workers in the region, the study of such azonal, "doubled" and superimposed profiles is difficult and requires a great number of analytical data Moreover under climatic changes or arising from a stagnant water regime, weathering crusts could be degraded (formation of kaolinite on gibbsite and others) Such events have been observed many times in the regions of Kazakhstan, Southern Urals and Middle Siberia

The process of weathering crust formation was essentially synchronous to erosion and accumulation of the eroded weathering crust waste in depressions In the sections of nearly all Palaeocene and Eocene sediment formations are found weathered pebbles, easily ground to powder, and "bellows" of vermiculite that could not be transported Thus the later weathering was during relatively stable periods on denudations plains, hills and low mountains, in synchronicity with depressions

Periodically stable depressions and slightly elevated "uplifts" can be considered as "jointed pairs" Moreover, as mentioned previously, several Mezo-Cenozoic and Cenozoic depressions were not only relatively stable over long periods of time, but also underwent relief inversion, creating accumulative-denudation and even denudation plains Weathering crust formation not only occurred on crystalline Late Archaean - Early Mesozoic rocks, but also on Jurassic and Cretaceous sedimentary strata. However, superimposition of weathering on the latter was, as a rule, relatively short. The spore and pollen complexes in these crusts are preserved; thereby excluding the possibility of long-term and profound chemical transformation of rocks

However as a whole the analysis of distribution and thickness of weathering crusts permits the proposal that weathering also continued after filling of the depressions by sediments Weathering crusts were formed, and above all preserved, over vast areas, even in central parts of Tukurigra-Dgagdy, Sikhote-Alin and the Dgugdgur-Stanovoy Mountains. Weathering crust formation was predominantly active in less active blocks and transition zones between mountains and plains

The intensively uplifting morphostructures, block and fold-block middle mountains (Fig 2) are almost fully deprived of weathering crusts There are solitary small patches revealed mainly on indirect indications, with thicknesses of about 3-5 m, rarely more. These represent a zone of disintegration or patches of areal crusts not defined as weathering profiles or zones Based on available data, these relics constitute a sparse mosaic without visible regularities This can be explained not by insufficient initial weathering but by latter denudation.

The preservation of weathering crusts is a general principal problem There are two criterion determining their preservation status, namely their protection from erosion and denudation, and degree of epigenetic transformation The first is determined by geomorphologic structure and evolution of the region, and further by individual character and evolution of each morphostructure or morphostructural zone. **Thus are conditioned general preservation of weathering crusts, their length of time of their formation, short (single-event) formation, synchronous or multiple-event denudation and deposition of weathering crust waste in depressions.**

Weathering crusts of the study region are loose and easily transported by rill and sheet erosion, creep etc Denudation is the origin of relatively rare and, as a rule, local presence of weathering crust material on older strata (Palaeozoic and others)

Evidence of intensive erosion is given by the fact that nearly all the weathering crusts studied in the Russian Far East are part of incomplete (eroded) profiles

Thus detailed analysis of present distribution and preservation of weathering crusts on this territory, allows the supposition that duration of formation and subsequent preservation of crusts was determined not by global factors such as climate, but essentially by local ones, acting within the limits of a particular palaeo-geomorphological and geomorphologic situation

It is necessary bring to attention the assumption made by authors of work on synchronism (or near-synchronism) of weathering crust formation and erosion, with subsequent deposition of the waste in depressions. It becomes difficult to separate formation and erosion, and it is possible only to define the prevalence of one or other of these processes during evolution of the region. When any large morphostructure rises rapidly the increased erosion partly or fully destroys weathering crusts of the preceding epoch. If the rise is minimal, weathering crusts may be preserved on uplifted remnants of low relief. **More favourable are differentially uplifted surfaces, naturally, the blocks retarded in general however differentiated uplift.**

The main parts of the regions of Far East and Southern Yakutia are best summarised as areas where preservation and maximal extension of weathering crusts occurs under shallow, unconsolidated cover or where they have been exhumed from the latter on moderately uplifted fragments of planation surfaces (peneplains or pediplane), and along boundaries of various denudation plains.

The data mentioned above show that correlating weathering crusts of different ages and planation surfaces (partly pediments) is rather difficult. It is pertinent to first take into account the general conditions of planation and weathering crust formation existing in Russia throughout the studied time period. Favourable climates were established during the Silurian and Devonian, maintained from the Late Triassic to the Early Jurassic and then, essentially continuously, from the Early Cretaceous to Early Miocene. From the end of the Early Jurassic to the Late Jurassic the climate became rather arid, and generally unfavourable for weathering crust formation. Separate periods of aridity are marked for the Oligocene, end of the Eocene and other epochs, but they were regional and did not influence the whole Russian Far East. The main episodes of weathering crust formation began at the end of the Triassic and continued, with several interruptions ("continuously - interrupted"), until the end of the Miocene and beginning of Pliocene. During the Pliocene climate changed dramatically, with a decrease in temperature and reduction in precipitation. Following these changes, weathering crust formation became minimal, and in places ceased completely.

If climatic factors determined the general epoch of weathering crust formation, then the planation surfaces with areal crusts were formed as a result of local variations in climate. These were determined by tectonic evolution and corresponding relief in parts of the region. Following from this, the optimum conditions for weathering crust formation were not synchronous on different morphostructures and morphostructural zones. In nearly all the large depressions of the study region, weathering crust formation began at approximately the same time - Early Cretaceous. However, it ceased at different times since parts of the planation surfaces forming the basement of depressions subsided differentially and asynchronously, even on immediately adjacent blocks. For blocks of lengthy inherited uplift containing denudation plains, hilly and low mountainous relief, determining weathering crust ages is more difficult. It is only possible to suppose an analogy with sunken morphostructures that the majority of weathering crust formation was, in general, synchronous. Most parts of denudation plains can be considered as a complex pediplane formed differentially, but during whole period. Areal and linear-areal weathering crusts are exposed on the surface or under a very thin Late Pleistocene cover.

The importance of useful deposits genetically related to weathering crusts, and redistribution of matter in their profiles hasn't yet been definitively studied.

The role of hypergenic processes in the formation of many metallic and non-metallic deposits as residual and redeposited has been established. There are available data on redistribution of released gold and formation of "new" gold and other minerals by lateritic weathering (Australia - Mt Gibson deposit; Brazil - Quiba, Sierra Pallada), and by kaolinisation processes (Kazakhstan - Maikam ore field, Far East - Kurovskoe, Belaya Gora deposits) among others.

Concentration of ore minerals in weathering crusts is related to the properties of different elements, their initial mineral form in fresh rock, and conditions of weathering. Formation of alluvial placers proceeds at certain stages in the disintegration of rocks, but for certain minerals also by leaching during stages of intensive chemical weathering.

It is has been established that the relative friability of eluvium, its heterogeneity, essentially clayish composition and various sizes of rubble, stagnant water regime is carried on the transference of weathering products as chemogenic as mechanical ones [6]. These origins determine the specific sorting of eluvium during its formation and evolution and essentially any concentration of useful weathering crust components.

Hydrolysis and oxidation of fresh rock, with subsequent formation of secondary minerals determine the other type of ore accumulation. The formation of oxidation zones can be considered as particular in the case of weathering crust formation since hypergenic changes have the same geochemical direction.

In most cases useful components are concentrated in upper zones of weathering crusts (dominated by kaolinite and clays of complex composition). In such zones, besides weathering and intensive sorption by clay minerals, another essential component is sheet wash derived clayish material. Just in these zones is observed, as a rule, multiple enriching of weathering crusts with ore minerals (3-5 times or more than in initial rocks)

Increased concentrations of useful components are noted sometimes not only in upper-most, profoundly transformed zones of weathering profiles, but also in lower, less modified ones. The origins of these events are not yet clear. Evidently they are determined by many factors including the geomorphologic (palaeogeomorphological) specifics of ore-bearing weathering crust formation (types and evolution of morphostructures and relief). Other factors can be geochemical barriers.

In the Russian Far East territory, there are large minerogenic provinces of gold, tin, platinum, polymetals, diamonds, kaolin, vermiculite and other metallic and non-metallic mineral raw materials. The detailed characteristics of this minerageny represent a far greater depth of study, and hence only their most typical features are considered here

Formation of weathering crusts in this region on rocks of different composition and ages, including orebearing ones, determined the presence of corresponding groups of useful deposits formed by chemical transformation of initial rocks and redistribution of initial and new-formed components of weathering profiles

The deposits and ore concentrations recognised can be divided into 3 main groups

1. Residual - in situ weathering crust.
2. Sedimentary - redeposition products of weathering crust materials.
3. Placers - formed by erosion of weathering crusts as sources of intermediate collectors of placer-forming minerals

Among residual groups the following are distinguished: 1) deposits of weathering crusts and oxidation zones (including of "iron hats" formed by superimposing of weathering on initial ore- and poor ore-bearing rocks), and 2) residual non-metallic concentrations of definite weathering degree on certain rocks. Residual deposits are often connected by gradual transitions with sedimentary ones.

The most widely distributed deposits are of the infiltration type. In the region such deposits of silicate nickel, uranium and others are observed. These deposits are formed, as a rule, synchronously with residual weathering crusts by intensive filtration and migration of solutions in zones of ground water discharge, in the presence of geochemical barriers

Residual weathering crusts and oxidation zones are represented in the region by deposits and concentrations of gold, tin, manganese, nickel, iron and etc., and non-metallic: kaolinite, phosphorites, and vermiculite. Below we consider the minerageny of certain metals.

Gold. Gold concentrations are widely spread in the region. They are represented mainly by oxidation and secondarily enriched zones of bedrock ores of different formations (including mineralised zones with vein-impregnating gold - Zolotaya Gora, Kurovskoe, Bielaya Gora, Bogulikan, Tokur and others) and also in gold-bearing "iron hats" of oxidation zones of gold-quartz-poor sulphide deposits and concentrations

In zones of hypergene enrichment the gold content is 2-4 times greater than in primary rocks; with occasional enrichments containing a "**hurricane**" content of more than 10 kg/tonne. In the process of "freeing out" gold from its host rocks and redistribution in weathering crusts, the gold particles increase in size up to nuggets. Enrichment of crusts on poor gold-bearing rocks (e.g. 0.01-0.4 g/tonne) forms eluvium with commercial contents of up to 8.2 g/tonne

High concentrations of gold have also been identified in deeply buried weathering crusts, e g 124 g/tonne at depths of greater than 70 m Another example shows a weathering crust oxidation zone more than 70 m thick, composed of quartz-calcite veins ("red sands") with a gold content greater than 1 kg/tonne

Such gold-bearing crusts are of variable gold content, but generally contain more gold than the primary rocks of the Russian Far East and Southern Yakutia These crusts also occur, but have been less studied, in the Khabarovsk region and Primorie (Pacific coast region) For example, an ore deposit with gold content 100-120 g/tonne, far greater than in primary rock

Manganese Manganese bodies have been discovered in the Amur basin and small deposits in the Khabarovsk region and Primorie, where they often have complex compositions The commercially importance deposits have formed, as a rule, under conditions of weathering on manganese-bearing bedrock or manifestations containing primary oxidised carbonate or siliceous ores "Manganese" weathering crusts are developed on volcanic-terrigenous siliceous and neutral intrusive rocks Crusts are from 5-10 up to 50 m thick The manganese content in kaolinite-hydromicas found in crusts on an effusive deposit in the Amur basin was from 1 3-1 4% Manganese content in oxidised rodochrosite ore in Primorie is from 4-26%, while in other deposits where main ore minerals are psilomelane and pyrolusite, contents in the oxidised zone range from 15-35% A series of manganese hydroxides are known in the Southern Khingan region Manganese concentrations of 1 5-1 9% have been established in oxidised iron ores, where the hypergenetic minerals siderite and goethite, and main manganese minerals psilomelane and pyrolusite are heavily represented

Tin In the Far East residual concentrations of tin are known in linear oxidised zones and also in areal weathering crusts The latter produce weathering crusts that form the "bedrock" part of placers and provide the source of redeposited cassiterite Residual enrichment of tin is most evident in in situ formed crusts Transport is predominantly via mechanical movement of mobile weathering products, producing 2- to 5-fold increases in tin concentration Moreover in oxidation zones of deposits of certain composition, clusters of secondary tin minerals (varlamovite, hydrostannate) form

Placers The importance of weathering crust evaluation has increased in recent years following further research into newly discovered morphogenetic types of placers (tectonic suture-scarps and others - Table 2) Most large placer deposits of Russia and the former USSR: gold, tin, platinum (platinum - group minerals), diamonds and others in their structure include weathering crusts, as a rule, profoundly developed, in situ or as redeposited waste products

In many cases the age, degree of weathering, zonality and preservation of weathering crusts are determined by climate (palaeoclimate) and morphostructural evolution of the locality

The length of formation of any placers inevitably signifies the corresponding duration of the types and forms of related relief The presence of ore-bearing weathering crusts as separate productive layers acting as intermediate collectors of minerals have been recognised for a number of large placers of different morphological types such as tin: Tyrekht'iakh, gold: Kuranakh, Nagimin, Petrovskaya and many others Diamond placers are also genetically related to weathering crusts

The general conditions for gold-bearing weathering crust formation does not differ principally from normal weathering Geological and geomorphologic structure, climate and the relationship between stages of primary ore and crust formation determine the direction and degree of hypergenic transformation of primary ores

In the Far East territory it is possible to quite accurately trace gold placers, especially older buried and deeply buried and of length formation (Jalinda karst type placers) in relation to weathering crusts. So at placer clusters, where zonal areal and linear-areal weathering crusts of different profile types and thickness have formed, as a rule, the large placers have formed over long periods Such clusters are also characterised by areal distribution of placers of different morphological types: from eluvial, gully-, eluvial-deluvial up to "glacis-terrace" and old deeply buried ones (Solov'ievsky, Central-Dambukyn and other placer clusters) These

Table 2. *Morphogenetic types of placer deposits (in Russian territory)*

MORPHOGENETIC TYPE	DOMINANT TYPE AND COMPOSITION OF CRUST	AGE OF CRUSTS	AGE OF PLACERS	PART OF CRUST IN INFORMATION OF PLACERS / OCCURRENCE OF PLACER TYPES
Eluvial and eluvial- slope	A, L-A; up to lateritic	K_1; K_2; P; N_1 (or K-N)	K_2-Q_1	+++ / regular
Slope-proluvial and slope-alluvial (vavine)	A, L-A; up to kaolinite	K_1; K_2; P-N_1 (or K_2-N_1)	N_1-Q	++ / often ; +++ / rare
Alluvial of valleys of inherited evolution	L, L-A; clays of complex composition	K-N_1	P_3 -Q_4; N_1 -Q; Q_1 -Q_4 often	++ + / single ; +++ / ; /
Alluvial placers in garden-valleys	A and L-A; up to kaolinite	T-J_1(?) K-P(N_1?)	K2-P(?); N-Q_1; Q_{2-4}	+++ / regular
Alluvial of young valleys	L, L-A; mixed-layered minerals, more rarely clays of complex composition	P-N_2	Q_{3-4}	+++ / single ; + / rare
Alluvial-deltaic	From L up to A; up to kaolinite	K_2; P; N_1 (or K_2-N_1)	P; N; Q; (P-Q_4)	+ / rare
Placers of tectonic scarps	L-A, L; clays of complex composition	K; K_2-P; K_2-N_2(?)	P_1 -Q4; N_1 -Q_1; N_2-Q_4	+ ++ / often ; / single
Placers of depressions (gold)	From L to A; up to kaolinite-gibbsite	T-J_1 (?); K-N K; P-N; P(N)-Q;	Q_{3-4}	++ + / often ; / single
Placers of planation surfaces-planiform	A, L-A; clays of complex composition	P-N_1	N_1-Q_3	+++ / regular
Placers of karst and structural-karstic-denudational depressions	L-A, L; up to kaolinite-gibbsite	T-J_1; K_1; K-P	J_{2-3}; K-P; P-N	+++ / regular
Proluvial-lacustrine diamonds placers	A, L-A; clays of complex composition and up to kaolinite	T-J_1; Kl-P	J;K-P(?)	+++ / regular ; ++ / single
Sea-beach shelf placers	A; more rarely L-A; clays of complex composition	K_2-P; K_2-N; K_2-N	N-Q(?); Q_1 -Q_4; Q_{3-4}	++ + / often ; /
Sea-beach, beach) placers (Ti-Zr)	L-A and A; up to Lateritic	D;T-J_1;K-P(N_1?)	D_2;J_1;K-P	+++ / regular
Fluvioglacial placers	L, L-A, A; up to kaolinite	T-J_1(?); K-P;P-N_1(?)	Q_{2-4}	+ / single

Crust Types: L-linear, L-A-linear-areal, A-areal.
Part of crust: +++ -dominating,++-considerable,+-auxiliary.

placers are characterised by gold of relatively high standard (900 and higher), often without any admixtures. The gold of placers in these clusters possesses the characteristics indicative of a "weathering crust" origin. In many placers the gold is observed in a limonite "shirt" with fringes of gold of higher standard and new-formed gold. Sometimes complex, fragile "structures" of the finest gold particles cemented by limonite are observed. The lithological composition of the lacustrine - alluvial deposits containing the placers is also evidenced by the presence of weathering crust material. In a number of regions the buried gold placers lie immediately over different zones of weathering crust.

Quite different conditions identify uplifted clusters where old weathering crusts were formed but later intensively eroded, with only old linear weathering crusts preserved. Crusts of areal and linear-areal type were formed only locally and did not obtain great thicknesses. These are mainly the young (P3-N1,) weathering crusts. Here are observed, as a rule, only young shallow placers of Q3-Q4 age, mainly of valley types: gully, river channel and flood-plains and less commonly, of terraces. Their gold is generally of low standard, often containing quartz. The evolution of these clusters is discrete.

Thus the role of weathering crusts in placer formation changes from dominant where crusts are the only source of metal, to auxiliary if placers were formed relatively quickly by erosion of primary ores or intermediate collectors.

Weathering crusts are known as independent commercial gold deposits but more often as (sometimes major) components of commercial layers of heterogenic placers. Weathering crusts, even with non-commercial contents of useful minerals, can be the only source of derivative commercial placers or represent the additional sources of complex placers of long multi-stage formation (in valleys of inherited evolution zones, on tectonic scarps, etc.).

The ascertained morphogenetic spectrum of placers related to formation of weathering crusts is wide: from eluvial (residual) through eluvial-slope and various slope-fluvial and fluvial, to lagoon-deltaic, lacustrine and sea-beaches (Table 2). Placers related to weathering crusts are mainly characterised by heterogeneity conditioned somewhat asynchronously by stages of weathering crust and placer formation under changing activation of various groups of exogenic factors.

The influence of weathering crusts on placer formation has occurred over a long period of time, from Early Jurassic (as intermediate collectors) and maybe earlier, up to and including the Holocene. The part weathering crusts play in the formation of placers of different ages and the preservation of the latter were defined by the evolutionary regime (the degree of inheritance) of ore-bearing morphostructures. **The maximum length of influence of weathering crusts on placer formation was during the earliest epoch, and on the placers of long polystadial history; minimum - as shown at first on the number of objects - on the Holocene placers.**

All the placers of different morphogenetic types related to weathering crusts have commercial importance, thus weathering crusts are favoured as a principal factor in placer formation. The distribution of weathering crusts in the Russian Far East is wider than previously considered, and can be appreciated as a positive precondition for new commercially based research.

Thus, establishing the relationship between weathering crusts of different profiles and the distribution of placers bearing different metals (gold, platinoids, cassiterite, rare metals and others) rises as a major aim of further investigations.

BIBLIOGRAPHY

Chemekov, Ju F (1964) The history of river net evolution in river in Amur basin Izvestia Acad Sei USSR Geographical series NI pp 81-94

Khud'jakov, G I (1977) Geomorphology of South of Far East Moscow, Nauka 258 p

Nikonova, P I (1981) On peneplane on platform basement Morphotectonic of Far East Vladivostok Far East Branch of Ac Sei USSR pp 10-18

Orlova, N I (1987) Specification and aims of geomorphological mapping for study of exogenic ore fields Geomorphological cartography for economics Moscow, Moscow University Press pp 54-62

Orlova, N I., Nechipasenko, E Ju., Vasiliev, E A and Derbeco, I. N (1994) The analysis of crusts of weathering of Amur region as related to prognose evaluation of research perspectives of gold placers The placers of crusts of weathering - the object for investments at present time Moscow pp 154-158

Orlova, N I, Sporykhina, L V and Petrochenkov, A A (1998) Methodic recommendations on compilation of maps of weathering crusts for territory of Meso-Cenozoic activation in scales 1:500 000 - 1:1 000 000, with elements of minerogeny (an example of South-Eastern Russia) Moscow VIMS 106 p

Sorokin, A P and Khud'jakov, G I (1979) On weathering and conditions of weathering crusts formation on North-Western part of Amur-Zeia depression Morphostructure and Palaeageography of Far East Vladivostok Far East Scientific Centre Acad Sci USSR pp 95-99