

INTRODUCTION

Photos: all specimens of minerals and rocks are from Konder, Khabarovsk Krai, Russian Far East.

Photo: Alexander G. Mochalov, unless otherwise specified.

Today are known about 120 platinum-group minerals (PGM) and several dozen potentially new mineral phases, not yet approved by the CNMNC IMA¹ as mineral species. Platinum-group minerals consist of one or several platinum-group elements (PGE)². Most PGM grains do not exceed tenths of a millimeter in size and less frequently reach several millimeters. Their weight ranges from a fraction of a milligram to a few hundred milligrams, respectively. In the placers of platinum-group metals, a substantial proportion of the platinum-group minerals grains is more than 0.1 mm in size; in hypogene deposits, such grains are called *placer-forming* (Mochalov, 1997). Well-formed individuals and aggregates of only native PGMs and very rare native osmium and iridium minerals, such as zvyagintsevite (Pd₃Pb) and sperrylite (PtAs₂), reach 1 cm in size and more than 1 g in weight. Under the terminology adopted in this study, the native platinum-group includes intermetallic compounds of Pt and Fe: isoferroplatinum (Pt₃Fe, cubic symmetry, space group *Pm-3m*), tetraferroplatinum (PtFe), tulameenite (Pt₂FeCu), ferronickelplatinum (Pt₂FeNi) (all of them are tetragonal, space group *P4/mmm*), and proper native platinum, which is a disordered solid solution (Pt,Fe) (cubic symmetry, space group *Fm-3m*). Isoferroplatinum or cryptocrystalline aggregates of visually indistinguishable individuals of isoferroplatinum with tetraferroplatinum or isoferroplatinum with native platinum are the most abundant among placer-forming platinum minerals, where as native platinum is subordinate (Mochalov *et al.*, 1988). Occasionally, placer-forming platinum minerals form nuggets⁴, ranging from tens of grams to a kilogram in weight, very occasionally reaching a few kilograms. Orlov (2010) reported unique placer-forming platinum mineral nuggets from Ural in his article ‘*Platinum nuggets of the Diamond Fund of Russia*’ published in *Mineralogical Almanac*, volume 15, issue 3.

‘*Atlas of Morphology of Platinum Minerals*’, the main chapter of this study, seeks to show most of the placer-forming platinum minerals morphological types from unique Konder

0.1. Geographical location of Konder Massif, Ayan-Maya District, Khabarovsk Krai, Russian Far East.



and Uorgalan placers and their source at the Konder alkaline ultramafic massif⁵ in the part of the Aldan shield that belongs to the Ayan-Maya District, Khabarovsk Krai, Russian Far East (Fig. 01). Large placer-forming platinum mineral grains are very rare in primary rocks. They usually associate with chrome spinels. Most placer-forming platinum minerals were found in rock fragments and among mineral aggregates and individuals in concentrates, collected from residual, talus, and alluvial placers on slopes and in creeks, draining ultramafic, mafic, and alkaline bedrocks. Russian prospectors have long named placer-forming platinum minerals produced by water-gravitation recovery from placers as ‘*panned platinum*’ (Figs. 0.2, 0.3). Aggregates of placer-forming platinum minerals with other minerals and inclusions of those minerals are an integral part of the panned platinum. These aggregates and inclusions are silicates, oxides, sulfides, native metals, PGM, and rock chips. In addition, the placer-forming platinum mineral grains bear pores and gas cavities. Inclusions, overgrowing foreign phases, and gas cavities have a strong impact on the placer-forming platinum minerals density⁶.

First five chapters of this study review placer-forming mineralogical and geochemical types of PGM, analytical methods, brief geology and mineralogy of platinum-group elements deposits at the valley of Konder and Uorgalan rivers and Konder Massif. Principle results of previous and contemporary studies of platinum-group elements mineralogy of the placers and their provenance are mentioned in each chapter.

Abbreviations

- PGE – Platinum-Group Elements.
- PGM – Platinum-Group Minerals.
- PM – Platinum Minerals: isoferroplatinum, native platinum, tetraferroplatinum, and their aggregates.
- Gold minerals – native gold, tetraauricupride, and phase (Au,Ag,Pt)₃Cu.
- Konder Massif – Konder alkaline ultramafic massif.
- Pt-type – platinum mineralogical and geochemical PGM type of placer and placer-forming assemblage.
- Pt>Ir-type – iridium-platinum mineralogical and geochemical PGM type of placer or placer-forming assemblage.
- Pt>Os-type – osmium-iridium mineralogical and geochemical PGM type of placer or placer-forming assemblage.
- Pt>Pd-type – palladium-platinum mineralogical and geochemical PGM type of placer or placer-forming assemblage.
- Pt>Pd+Spl-type – palladium-iridium with chrome spinels magmatic-fluid-metasomatic PGM type of placer forming assemblage.

Mineral abbreviations

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| Am – amphibole | Cpx – clinopyroxene | Phl – phlogopite |
| Ap – apatite | Di – diopside | Spl – chrome spinel |
| Bt – biotite | Mt – magnetite | Srp – serpentine |
| Chl – chlorite | Ol – olivine | |

¹ Commission on New Minerals, Nomenclature and Classification of the International Mineralogical Association.

² In modern literature platinum-group elements of platinum (Pt), iridium (Ir), osmium (Os), palladium (Pd), rhodium (Rh), and ruthenium (Ru) are abbreviated as PGE and all minerals, containing PGE, as PGM (platinum-group minerals). These abbreviations are used in this study.

³ Major placer-forming platinum minerals of isoferroplatinum, native platinum, tetraferroplatinum and their aggregates are placer-forming platinum minerals (PFPM).

⁴ *Nugget* is a unique large natural individual of aggregate of native metal and intermetallic compound.

⁵ The Konder alkaline ultramafic massif is also spelled as the Konder massif.