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Method of complex analyses of the compositions of kimberlite indicator minerals to assess the presence of large diamonds

ABSTRACT. Based on the statistical analysis of data on the contents of the complex of major and impurity elements in the minerals of diamond satellites (MSD) in the kimberlites of Africa and Yakutia – pyropes, ilmenites, chromites, and diopsides – regions of their compositions have been identified that are indicative of the presence of especially large type IIa diamonds, which can be used to predict their presence in kimberlites at an early stage of exploration.

INTRODUCTION. Large diamonds IIa as a factor in stabilizing the global diamond market.

- The instability of the world diamond market during periods of global economic crises gives rise to two opposite tendencies that level it out. The demand and price for small gem-quality diamonds of the "Indian" dimension is growing. At the same time, large producers are actively trading in lots of especially large diamonds, the cost of which reaches tens of millions of USD per stone (**Fig. 1**). This will stabilize the diamond market and the entire global diamond-brilhante complex from mining to sales of products. The sources of especially large gem-quality stones – type IIa diamonds – are several deposits in Africa and Russia. The search for their new sources based on new methods of geological forecasting is extremely urgent.
- The problem of forecasting and estimating reserves of deposits with large diamonds is that it cannot be solved by the well-known methods of exploration and geostatistical modeling due to their "nugget" nature. Mineralogical and geochemical modeling of the crystallization conditions of such diamonds in the kimberlite process seems to be a real way to advance this problem.



Jewelry diamond IIa weighing 108.38 ct
(Griba mine)



Diamond IIa weighing 998 ct
(Karowe mine)



Jewelery diamond weight 1111 ct
(Karowe mine)



Jewelry diamond IIa 910 ct
(Letseng mine), \$ 40 million



Jewelry diamond 1109 ct
(Letseng mine), \$ 53 million



Semi-gem diamond 1758 ct
(Karowe mine), the second after
Cuillinan, 3106 ct.

Fig.1. World of giant type IIa diamonds (Rough&Polished; Lucara Diamond Corporation)

Research methods

- For industrial deposits, which contain especially large and expensive diamonds, a diagram of the compositions of **BCIs (MSD)** (satellite minerals of diamonds) for five elements **Cr, Al, Fe, Mg, Mn** is proposed.
- The closeness or, rather, the convergence of the compositions of **BCIs (MSD)** is also complemented by a high correlation of the frequencies of occurrence of their cluster groups of **MSD** (Ivanov, 2017), such as **pyropes, chromites, picroilmenites, and pyroxenes**.
- The increase in oxygen content in all mineral varieties of **MSD** is mostly due to an increase in **titanium** and **iron** contents; this fact can also explain the intensity of metasomatism of kimberlites, which is clearly displayed on the proposed graph by the increase **in ilmenite** contents.
- This type of diagrams was proposed by **Mitchell (1986)** for the compositions of **chromites**, which the authors supplemented with the compositions of other minerals – **picroilmenites, pyropes, and pyroxenes**.
- The fifth element **manganese** (its concentration) is shown by the size of the figurative point of the mineral analysis – a bubble chart. For better perception, the drawing is supplemented with different colors of the composition groups of the four **BCIs (MSD)**.
- Below are presented diagrams for two kimberlite diamondiferous deposits that contain expensive and large diamonds – **Griba** and **Karowe** pipes (**Fig. 2**).

Main results

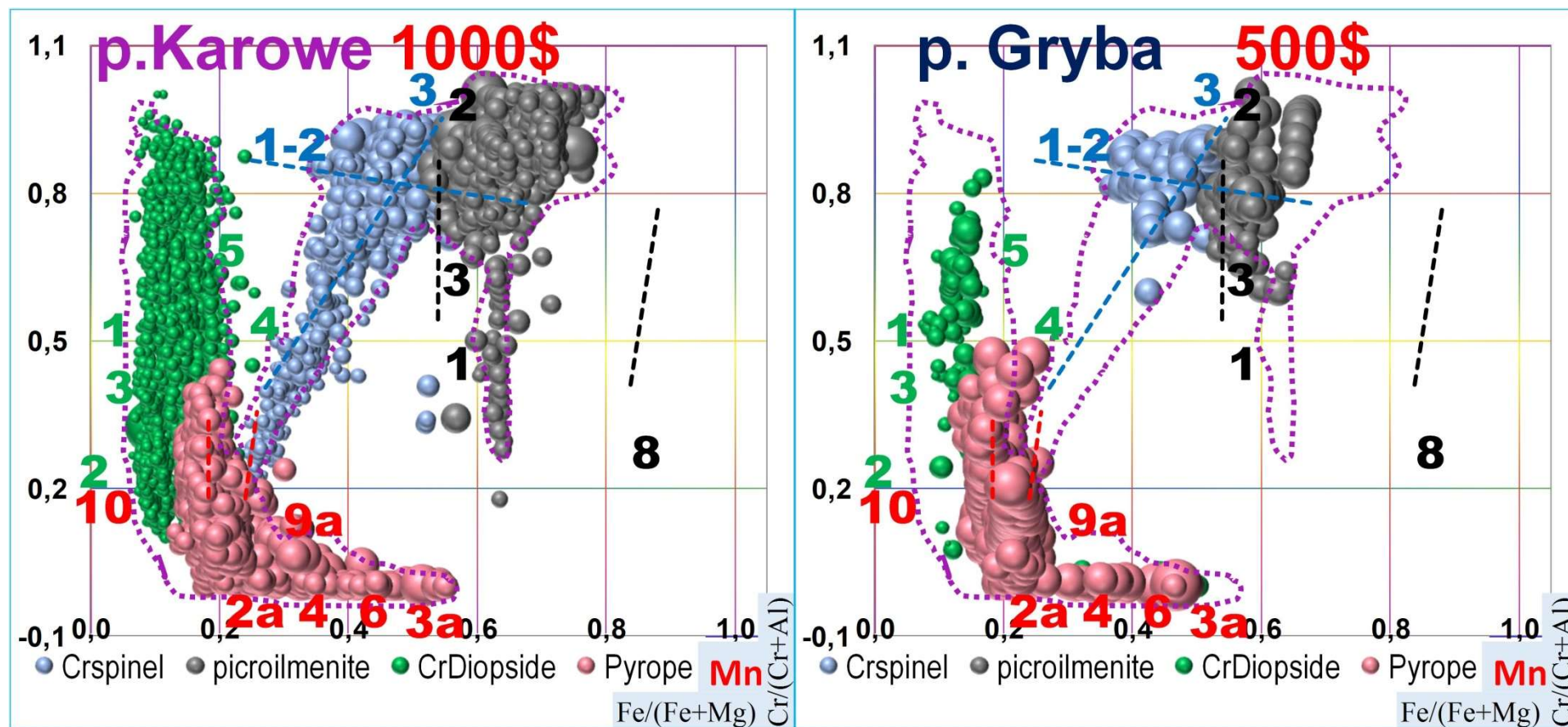


Fig. 2. Compositions of MSD of Griba and Karowe pipes on the $\text{Fe}/(\text{Fe}+\text{Mg})$ - $\text{Cr}/(\text{Cr}+\text{Al})$ 5E diagrams; 500\$ - diamonds price, USD/ct.

- In the diagrams of **Griba** and **Karowe** pipes compositions of **BCIs (MSD)**, red asterisks show approximate regions of diamondiferous parageneses for the compositions of **chromites** and **pyropes (Fig.2)**.
- The blue lines show two main trends in **chromite** compositions, horizontal – **picrite** and vertical – **kimberlite**.
- For **picroilmenite** compositions, the diagram shows two main trend lines: a grey line for **paramagnetic compositions** and a black line for **ferrimagnetic compositions**.
- For **pyrope** compositions, trend lines are shown in red for a number of cluster groups **G10** and **G11** according to (Dawson J.B., Stephens W.E., 1975) for groups in black.

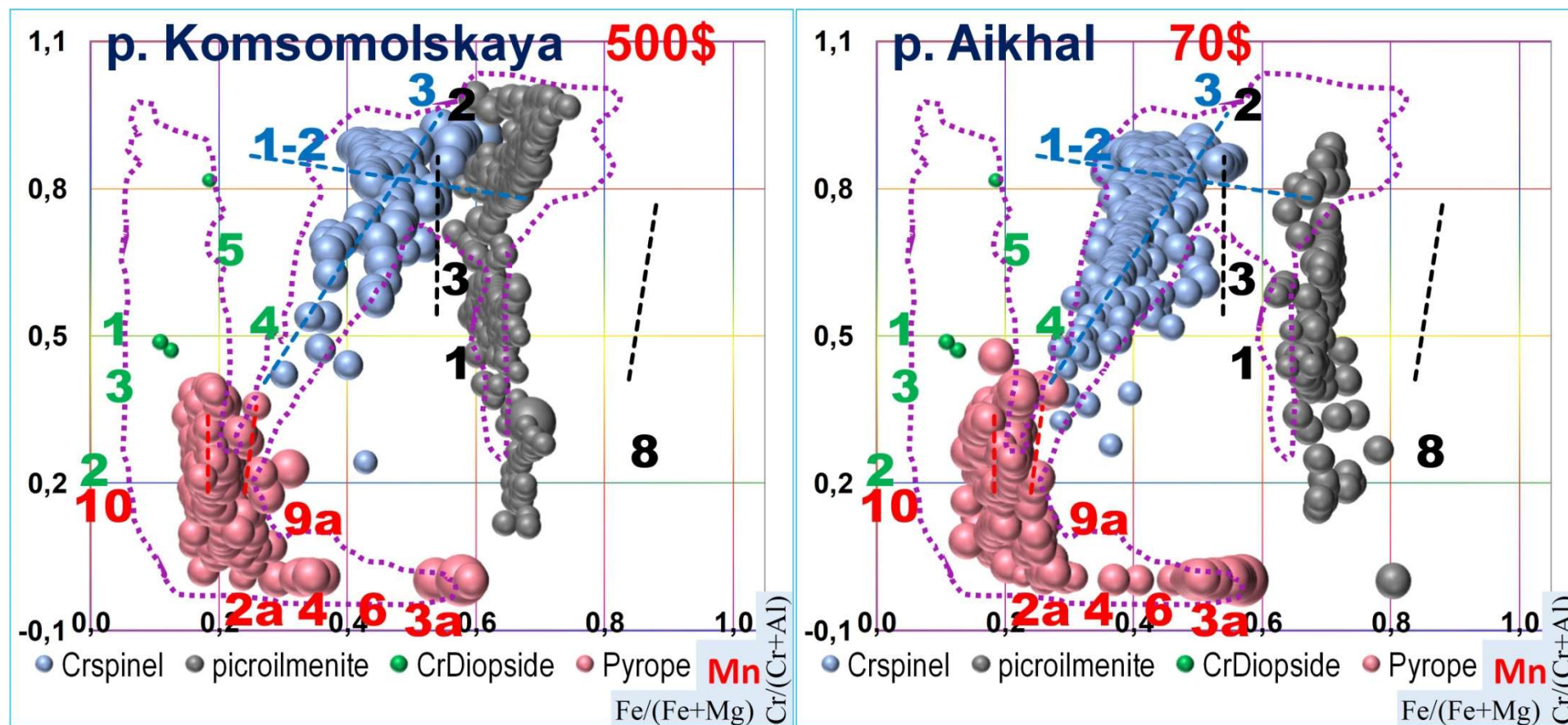


Fig. 3. Compositions of MSD from Komsomolskaya and Aikhal pipes on the $\text{Fe}/(\text{Fe}+\text{Mg})$ - $\text{Cr}/(\text{Cr}+\text{Al})$ 5E diagrams; 500\$ - diamonds price, USD/ct.

- The diamond content in the kimberlites of the ***Aikhal pipe*** is several times higher than in the ***Komsomolskaya pipe***, but the cost of diamond crystals from the latter is several times more expensive than in the ***Aikhal pipe*** (***Fig.3***).
- A distinctive feature of the compositions of the ***IMCs (MSD)*** of the ***Komsomolskaya pipe***, as well as the above proposed reference kimberlite pipes (***Griba*** and ***Karowe***), is the presence of diamondiferous ***websterite*** parageneses of ***chromites*** and ***pyropes***, which correspond, as shown in the diagram, to regions with increased values of ***chromium*** and ***iron*** (***Fig.3***).
- The kimberlite of the ***Aikhal pipe*** is characterized by a higher degree of metasomatism, which is recorded on the diagram by the trend of more ***ferruginous*** compositions of ***picroilmenites***, which affects the quality of diamonds.

CONCLUSIONS

- The proposed method is based on a comprehensive assessment of the BCI compositions.
- The diagram makes it possible to assess the presence of expensive and large diamonds in kimberlite pipes at the stage of exploration, as well as to reconstruct the composition of deep mantle rocks, traces of which are revealed and reflected in the compositions of the IMCs when graphically representing analyzes of their compositions for five elements (5E method).
- The Table and Histograms in Fig. 4 show the distribution of indicator MSD for the presence in kimberlites of giant and special sizes diamonds of the IIa type.

Percentages of cluster groups of MSD allow calculating the probability (P) of finding large diamonds

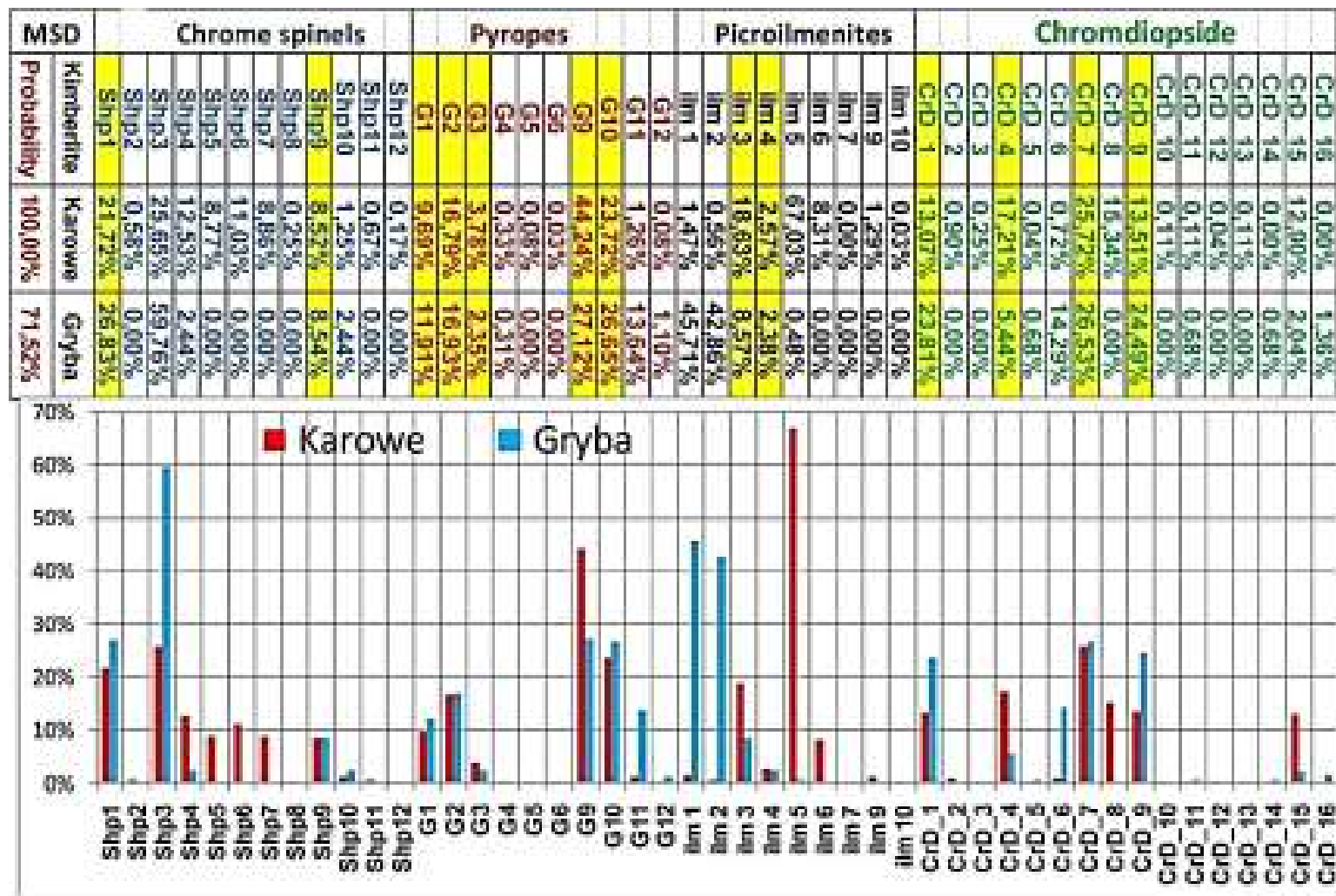


Fig.4. Histogram of cluster groups of MSD indicating perasteresis with large type IIa diamonds

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Fig.5. Seven large diamonds IIa type weighing 498 ct, mined by Lucara Diamond at the Lulo alluvial mine in Angola, were sold in 2019 for \$ 16.7 million at \$ 33,530 / ct (Segundo SODIAM; Rough&Polished). .

THANKS FOR ATTENTION