Gold in Accessory Zircon (the Kozhim Massif, Subpolar Urals)

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Abstract. The crystals of zircon due to their resistance to external impact of various processes can reveal information about the environment of their formation and the inclusions observed of them. Zircon contains different mineral inclusions: biotite, plagioclase, quartz, apatite, etc. However, there is no information about gold inclusions in the zircons from granites of the Sudpolar Urals. The study results of the inclusions of gold in accessory zircon of the Kozhim granitic massif are presented in this paper. The studied mineral is a dark-brown translucent short-prismatic crystal containing the inclusion of gold and the allocations of quartz. According to studies, the inclusion of gold formed during the growth of zircon and it is the gold covered with a thin film of oxide gold. It was confirmed that the crystallization of the studied zircon occurred at a temperature of 800°C and above on the stage of formation of granites of Kozhim massif. The assumption is made about the additional temperature in the course of which was caused by decreasing of temperature up to 700° C and below during postmagmatic stage.

1. Introduction
Crystals of zircon are resistant to external impact and are able to store information about the features of the environments of mineralformation. Some of this information (phase composition, temperature, pressure of the mineral-forming environments and other) is obtained by the study of inclusions in the mineral. Zircon from the granites of the Subpolar Urals can contain different mineral inclusions: biotite, plagioclase, quartz, apatite, chlorite, hornblende, etc. [5]. For the first time, the inclusion of gold was found in the study of accessory zircon from Kozhim granite massif (the Subpolar Urals). The results of the study are presented in this paper.

2. The object of study
The Kozhim granite massif is located on the left and right banks Kozhim in river basins with Osya and Ponyu (Figure 1). Granites of this massif are medium-grained pink leucocratic rocks with massive texture probability. The accessory zircons in the granites are represented by three morphological types. The first morphological type of the zircons are light yellow transparent short-prismatic zircons. The crystal size 0.05 - 0.15 mm, aspect Ratio of 1.0 - 1.8. Facets (100), (110) developed. Dipyramid (111) is present. The surface of the faces is smooth and shiny. The individual crystals contain the inclusions of quartz, epidote, apatite. The zircons of this morphotype have the highest average content of Nb, U, Th, and TR. The chemical composition of the zircons is characterized by the highest values of Y and...
Hf. This suggests that type I crystallized in the later stages of formation of granite. The content of these zircons is 80 - 90% of the total content of the mineral in the rock. The second morphological type are brown translucent matte and short-prismatic zircons. The size of these crystals is 0.03 - 0.10 mm. aspect Ratio 1.0 - 2.0. Faces (100), (110), (111) marked.

Figure 1. The Kozhim granite massif
1 – isinglass - quartz shales, green ortoshales, quartzite; 2 – isinglass - quartz shales, porphyries, porphyrites, interlayers of marbles and quartzites; 3 – granites; 4 – gabbro; 5 – the geological boundaries: stratigraphic and igneous, b – tectonic; 6 – the occurrence of planar structures. The massifs (numerals in circles): 1 – the Kuzpuayu massif; 2 – the Kozhim massif [4]

The surface of the faces is smooth and shiny. The individual crystals contain the inclusions of quartz, epidote, apatite, gold (the one grain). The content of the type II are 5 - 10% of the total content of the mineral in the rock. The third morphological type are light yellow transparent long-prismatic zircon crystals. Size of crystals 0.4 - 0.8 mm, aspect ratio 2.0 - 4.0 (- 6.0). Under a binocular microscope visible smooth, shiny surface. The zircon minerals contain the inclusions of quartz, apatite and epidote. The content of the zircons of this type are 5 - 10% of the total volume of mineral in the rock [1].

3. Results and discussions
In the present work, we consider the zircon of the type II. The zircon of this type were discovered as the inclusion of gold with microprobe study. The studied zircon is a dark brown translucent short-prismatic crystal (Figure 2, a). The size of the mineral is 0.04 mm. Aspect Ratio of 1.65. The appearance of the crystal due to the development of faces (110), (111), (100). The crystallization of this zircon occurred at the early stage of formation of the Kozhim granite massif at a temperature of 700 - 900°C and high alkalinity of the environment [2].

The inclusion of the gold (Figure 2, b) was formed during the growth of the zircon. This gold deposition from a melt could happen by increasing the viscosity of a siliceous melt and a slow drop of solubility and temperature. It is important to mention that the gold, when recovering from melts, does not precipitate, but it forms hydrosols. These hydrosols could be part of a complex silicate thermofluid environments with a temperature of about 800°C. The massive formations of quartz formed in these environments. This is confirmed by the presence of segregations of quartz in the studied zircon. Thus, the presence of the gold inclusions in the zircon indicates the high temperature (800°C and above) of the mineral-forming medium and confirms the anticipated temperature range of the crystallisation of the zircon in the early magmatic stage of formation of the Kozhim granites [2].

As a rule, the composition of gold in appreciable quantities has always celebrated the silver. The content of this impurity increases from early generations of gold to later. Even a small admixture of Ag does not exist in the studied inclusion (see table 1).
Figure 2. Accessory zircon from granite of the Kozhim massif
a) Zircon with the secretions of quartz (Qu) and the inclusion of gold (Au),
b) The inclusion of gold
1-4 – the point determination of the chemical composition of the mineral.

The bitmap images obtained in the research Geosciences Institute of Geology, Komi science centre, Urals branch of RAS (complex Vega3 Tescan, analyst Shevchuk S. S.).

Table 1. Chemical compositions of zircon and the inclusion of gold, weight %.

| Element | The zircon | The gold | σ |
|---------|------------|----------|---|
| Zr      | 46.49      | 46.44    | 46.01 | 21.62 | 0.12 |
| Si      | 16.55      | 16.74    | 16.93 | 8.05  | 0.17 |
| O       | 32.02      | 31.55    | 31.47 | 18.15 | 0.08 |
| Na      | 0.11       | 0.02     | 0.01  | 0.15  | 0.11 |
| Al      | 0          | 0.02     | 0.08  | 0.06  | 0.09 |
| K       | 0.01       | 0.02     | 0.01  | 0.06  | 0.08 |
| Fe      | 0.14       | 0.08     | 0.01  | 0.02  | 0.14 |
| Se      | 0.06       | 0.05     | 0.04  | 0.25  | 0.18 |
| Y       | 0.46       | 0.48     | 0.47  | 0.26  | 0.25 |
| Ce      | 0.13       | 0.51     | 0.31  | 0.33  | 0.21 |
| Gd      | 0.18       | 0.19     | 0.34  | 0.06  | 0.25 |
| Dy      | 0.01       | 0.09     | 0.15  | 0.11  | 0.25 |
| Er      | 0.05       | 0.04     | 0.06  | 0.41  | 0.48 |
| Yb      | 0.01       | 0.05     | 0.06  | 0.11  | 0.25 |
| Hf      | 1.18       | 1.24     | 1.36  | 0.27  | 0.25 |
| Th      | 0.22       | 0.28     | 0.26  | 0.26  | 0.25 |
| U       | 0.58       | 0.52     | 0.54  | 0.05  | 0.25 |
| Au      | 0          | 0        | 0     | 48.22 | 1.75 |
| Amount  | 98.2       | 98.32    | 98.11 | 98.44 | -    |

Designation: 1-4 - the point determination of the chemical composition of the mineral.
σ – the instrument characteristic systematic errors of the analysis techniques.
Note: Sampling site: on the left bank of the river Kozhim in 30 meters from the watershed and 1,200 meters below the mouth (massive grey-green granite). Microprobe analysis is performed at the Institute of Geology KSC UB RAS (Vega3 Tescan, analyst Shevchuk S. S.).

This suggests that a small amount of gold already present in the high temperature parent melts. The zircon and the inclusion of gold (with additional composition of zircon) contain traces of rare elements of the yttrium group. The inclusion of gold in accessory zircon is very small. At microprobe analysis of the chemical composition of the inclusion was determined only one point (the compositions at other points were characterized by very poor amounts). It is not allowed to reveal peculiarities of distribution of rare earths [3].

When the samples are polished, the investigated inclusion of gold were not opened fully. The presented chemical composition of gold contains the "overlapping" zircon composition. The chemical composition of gold was recalculated by removing the additional zircon. Excess oxygen was found. It has allowed to assume, that the inclusion is gold with a thin film of the oxide of gold. The formation of such oxide is possible at 500-700°C. It is the result of the interaction of oxygen with gold atoms on its surface. This suggests that the temperature of the mineral-forming environment could be reduced to 700°C and below during the growth of zircon.

4. Conclusions
In that way, discovered the inclusion of gold and its chemical composition allow us to conclude about the studied crystallization of accessory zircon at a temperature of 800°C and above at the early magmatic stage of formation of granite of the Kozhim massif and further by reducing temperature up to 700 ° C and below during post magmatic stage.

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