# $ZrO_2/HfO_2$ in zircon from the Kozhim massif (Subpolar Urals)

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Most accessory zircon crystals in rocks of the Kozhim massif are well-light faceted. Type I (about 80–90 vol% of all zircon): Transparent colourless, short-prismatic crystals with smooth and shiny faces. Sizes 0.05–0.15 mm; aspect ratios 1.0–1.8; developed faces (100), (110), (111). Type II (about 5–10 vol% of all zircon): Transparent brown, short-prismatic crystals with smooth and shiny faces. Sizes 0.05–0.10 mm; aspect ratios 1.0–2.0; developed faces (100), (110), (111). Type III (about 5–10 vol% of all zircon): Light transparent, long-prismatic crystals with smooth and shiny faces. Sizes 0.4–0.8 mm; aspect ratios 2.0–4.0; developed faces (100), (110), (111) (Denisova, 2014, 2015).

The quantity of the $ZrO_2/HfO_2$ were calculated and histograms of the $ZrO_2/HfO_2$ distribution compiled (Fig.1). Type II zircon is an early generation (the largest average value of $ZrO_2/HfO_2$ is 53,91). This type was formed in a tectonically quiet conditions (monomodality of the histogram 1. a). Type I is a late generation (the smallest average value of $ZrO_2/HfO_2$ is 43,90). The graphs of types I and III are bimodal and indicate the difficult conditions of crystallization.

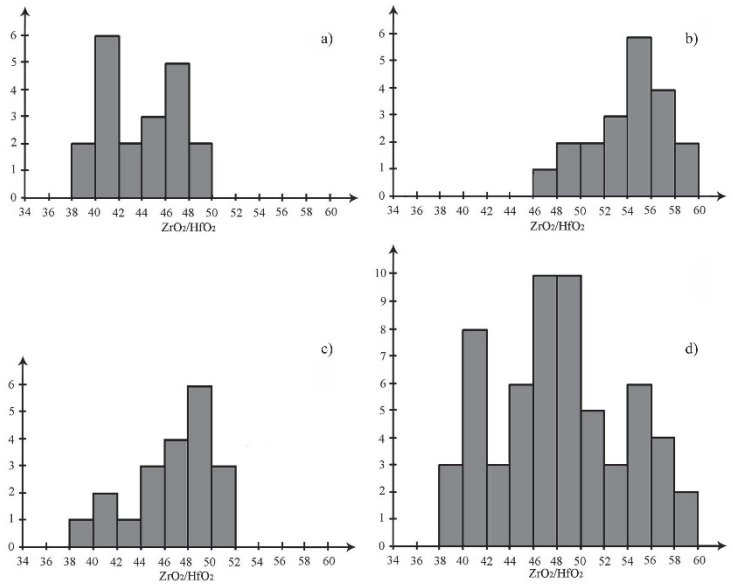


***Fig. 1.*** *Incidence of $ZrO_2/HfO_2$ in zircons of the Kozhim massif: (a) Type I; (b) Type II; (c) Type III; (d) Cumulative distribution (Types I+II+III)*

***Table 1.*** *Testing of the hypothesis about the normal distribution of $ZrO_2/HfO_2$*

| Type | Number of intervals | $\chi^2_{calc}$ | $\chi^2$ |
|---|---|---|---|
| I | 6 | 6.93 | 7.81 |
| II | 7 | 2.67 | 9.49 |
| III | 7 | 4.28 | 9.49 |

Note. $\chi^2_{calc}$ – calculated Pearson criterion; $\chi^2$ - table value of the Pearson criterion

Check the observed distribution of $ZrO_2/HfO_2$ for normality. According to the Pearson criterion, the studied distributions are normal (Table 1; or each type: $\chi^2_{calc} < \chi^2$). This allows you to apply various statistical methods of analysis of distribution.

Check the bimodality of the histogram for I and III morphotypes (table 2) by Goldin. Suppose that these histograms have the material of unimodal distribution of values of $ZrO_2/HfO_2$. According to the data obtained, the magnitude of the $ZrO_2/HfO_2$ for the I type in contrast to the III type have a bimodal distribution ($t_{calc} > t$). This distribution shows the heterogeneity of the environment of mineral formation during crystallization of an early generation of zircon.

***Table 2.*** *Testing of the hypothesis about monomodality the distribution of $ZrO_2/HfO_2$*

| Type | Incidence | | | $t_{1\ calc}$ | t |
|---|---|---|---|---|---|
| | First max | Second max | Min | | |
| I | 6 | 5 | 2 | 2.41 | 2.02 |
| III | 2 | 6 | 1 | 1.89 | 2.02 |

Note. $t_{1\ calc}$ – the calculated Styudent criterion; t - table value of the Styudent criterion

Each studied type of zircon is defined as a separate generation. However, the first and third types are similar in the distribution range of the $ZrO_2/HfO_2$, and the similar peaks. Check hypothesis about equality of average values (table. 3). The hypothesis of equal values was not confirmed ($t_{calc} > t$). Thus, all types of Kozhim zircon can be considered as a separate generation of the mineral.

***Table 3.*** *Testing of the hypothesis about equality of mean values of $ZrO_2/HfO_2$*

| Type | *mean values of* $ZrO_2/HfO_2$ | Dispersion | $t_{2\ calc}$ | t |
|---|---|---|---|---|
| I | 43.90 | 8.94 | 2.64 | 2.02 |
| III | 46.54 | 11.94 | | |
| III | 46.54 | 11.94 | 4.29 | 2.02 |
| II | 53.91 | 10.50 | | |

Note. $t_{2\ calc}$ – the calculated Styudent criterion; t - table value of the Styudent criterion

The beginning of the formation of the Kozhim massif is breaking through rocks of granite magma. The type II zircon started to crystallize during this stage. A sharp increase in the temperature of the melt led to the increase in uniformity of the mineral-forming medium. A change in the conditions contributed to the formation of long-prismatic crystals of zircon (type III). Next, the temperature decreased , the viscosity increased, fluidnation the mineral-forming medium was changed. As a result, the hafnium unstable to accumulate. All these changes led to the formation of later generation of mineral (type ii).

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## References:

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