Crystallographic Determination of Titanite from Smilevski Dol in Selečka Mountain, Macedonia

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Key words: titanite, morphology, crystal forms, Smilevski Dol

On 30 crystals of titanite, goniometrically measured, the appearance of faces of 25 forms was determined. Crystallographic elements were calculated and morphology and paragenesis of minerals were described. The shape of the crystals was represented by ten parallel perspective figures. Two types of crystals were separated.

1. INTRODUCTION

Numerous pegmatitic and pegmatite-hydrothermal veins were found in the granites and gneisses of Selečka Mountain. Some of them often contain well-formed crystals. One such vein was found about 2.5 km south-west from the village Dunje on the southern side of the hilllock Gorni Kamen (elevation 636) near the spring Sohlehov Kladence in Smilevski Dol. This vein contains hydrothermally deposited well-formed crystals of albite, epidote, titanite, amphiboles with somewhat less of quartz, muscovite, heulandite and stilbite, pyrite, apatite, microcline and chlorite. Lj. BARIĆ (1958) gave the short description of some minerals from this locality. Crystals of albite (RAFFAElli, 1961), epidote (ZEBEC, 1984) and stilbite and heulandite (TIBIJAS et al., 1987) have been in detail elaborated up today. On one of specially yellow and clear crystal of titanite BARIĆ (1958) determined the following forms: \{100\}, \{110\}, \{021\}, \{111\}, \{112\}, \{111\}, \{212\} and \{132\}.

2. EXPERIMENTAL PROCEDURE

The investigated material was chosen after the review of all collected crystals by stereomicroscope. The crystals chosen for the quality of their faces could be a solid basis for the precise determination of the crystallographic constants which were estimated by goniometric measurements. Goniometric measurements were performed on the two-circular reflecting goniometer (model A by Goldschmidt). Measurements were performed at a polar setting of both sides of a crystal, if it was possible. The obtained data were middling and if conditions of the observations allowed, were used for determination of the crystallographic elements. The remaining data were used for identification of the measured faces.

3. MATERIAL

The material was predominantly collected by prof. Lj. Barić in 1952., whereas a certain part was collected and ceded by M. Galeski and Z. Gruevski. The elaborated material is being kept in the collection of Mineralogic-petrographic Department of Croatian Museum of Natural History in Zagreb, inventory numbers:

- 600:ZAG;5781:MP1
- 600:ZAG;5782:MP1
- 600:ZAG;7711:MP1
- 600:ZAG;7712:MP1

4. THE RESULTS OF GONIOMETRIC MEASUREMENTS

30 crystals of titanite, size from 2 to 8 mms, were chosen for goniometric measurements. The orientation by Descloizeaux was taken. Determination of the faces was performed by gnomon projection. The faces of 25 forms were determined on the measured crystals of the titanite. A review of form combinations on single crystals is shown in Table 1.

The faces of the forms \{410\}, \{364\} and \{564\} were not determined up to now, in the reference which was disposable to as (Mineraly III/I, 1972). The results with the optimal conditions of measurements are shown in Table 2.

5. CALCULATION OF CRYSTALLOGRAPHIC ELEMENTS

The elements of gnomon projection were calculated from the best values obtained by measurements (Table 2) as suggested by GOLDSCHMIDT (1934):

\[
\begin{align*}
\chi' &= 0.570260 \\
p' &= 1.303487 \\
q' &= 0.854633
\end{align*}
\]

Then, the polar elements were calculated from elements...
| simbol of form (simbol forme) | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|-----------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 001                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |    |
| 010                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 100                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 410                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 310                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 520                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 110                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 130                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 101                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 102                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 101                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 111                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 113                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 141                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 142                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 113                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 212                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 131                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 122                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 364                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 564                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 132                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 312                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 354                         | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| fig. (sli.)                 | 6  | 9  | 7  | 8  | 1  | 2  | 5  | 3  | 4  | 10 |

Table 1. Titanite, Smilevski Dol, review of combination of the forms on single crystals
Tablica 1. Titanit, Smilevski ol, pregled kombinacija formi na pojedinim kristalima
of gnomon projection:

\[ x_0 = 0.4954, \quad \beta = 119^\circ 41', 5' \]

Linear elements of the titanite from Smilevski Dol, calculated from polar elements, were:

- \( a:b:c = 0.7548 : 1 : 0.8540 \)
- \( \beta = 119^\circ 43' \)

The obtained result corresponds well with the data found in literature:

- \( a:b:c = 0.7547 : 1 : 0.8540 \)
- \( \beta = 119^\circ 43' \) (Goldschmidt, 1897).

6. MORPHOLOGY OF CRYSTALS

Titanite and epidote form the best shaped crystals of the vein association, and this was the reason why quantitative crystallographic determination was done. Crystals are of different size, from 1 to 40 mm, and are predominantly elongated in direction of zone made by the faces of form \{111\}, that is, in direction [101].

An exception was a crystal which was shortened in this direction (Fig. 10). Roughly, speaking, two types of crystals can be separated: one with well-formed faces of prism of general position \{114\}, and strongly well-formed faces of form \{001\} and the other without the faces of form \{114\}, with slightly outstanding faces of form \{001\}. Among measured crystals predominant are those from the second group (4/5 of measured crystals). Faces of the forms \{102\} and \{212\} give specific habitus to crystals. The faces of the forms \{001\}, \{100\} and \{111\} were noticed on all crystals. The faces of the forms \{310\}, \{110\}, \{021\}, \{102\}, \{112\}, \{111\}, \{212\} and \{132\} were very frequent. The faces of the forms \{014\}, \{152\}, \{101\}, \{114\} and \{221\} were rarely observed. The faces of forms \{410\}, \{130\}, \{113\}, \{131\}, \{122\}, \{364\}, \{532\} and \{354\} were observed on only one crystal. The quality of the faces, even of the faces of the same form on the same crystal was usually different. This was, particularly evident on different crystals. Some crystals were partially subjected to dissolution. Together with shiny faces the faces corroded by dissolution were also found, especially in their central parts. The best example was the face of the form \{100\} which could range in quality from shiny and ideal smooth to striated and even hieroglyphically corroded ones. The curving of described elongation zone in the plane of symmetry was noticed on bigger crystals. A free part of one crystal was curved for about 20° toward \{100\} (600; ZAG: 5781: MP1). So, in the attempt to better show the morphology of titanite crystals from Smilevski Dol, besides apart from the Table 1, which shows the presence of the combination of faces of particular forms, parallel perspective figures of first (Figs. 1-4) and second type of characteristic crystals (Figs. 5-10) were constructed.

It is interesting that in whole material, in neither of the cases the twins of titanite were registered.

7. PARAGENESIS

The beginning of crystallization of titanite, in our case, began after the crystallization of muscovite, pyrite, older and main parts of plagioclases, amphiboles and older epidote. The youngest minerals (albite, apatite, part of amphiboles, epidote and chlorites) were crystallized together with titanite. Microcline and zeolites were younger of titanite.

Titanite appears abundantly, predominantly with amphibole, which, by its optical characteristics, can be determined as hornblende.

The interacting relation between the two noticed types of crystals of titanite could not have been determined.

For the other titanite minerals, very rarely, tiny crystals of rutile could have been found.

On some crystals of titanite, chlorite inclusion were found abundantly.

8. CONCLUSION

Well-formed crystals of titanite from Smilevski Dol near Dunje in Selečka Mountain originated from hydrothermal veins of alpic type with the following paragenesis: muscovite, albite, pyrite, hornblende, epidote, apatite, chlorite, microcline, heulandite and stilbite. On the examined crystals a presence of the faces of 25 forms were determined (Table 1). These crystallographic elements were determined:

- \( a:b:c = 0.7548 : 1 : 0.8540 \) \( \beta = 119^\circ 41', 5' \)
- Two types of titanite crystals were separated. The first type is shown in Figures 1-4, and the second one in Figures 5-10. Their interacting relation was not determined.
9. REFERENCES


Fig. 5-8. Titanite, Smilevski Dol, crystals of the second type.
Slika 5-8. Titanit, Smilevski Dol, kristali drugog tipa.
Kristalografaska određivanja na titanitu iz Smilevskog Dola na Selečkoj planini, Makedonija

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U granitima i gnajsevima Selečke planine nalaze se brojne pegmatitne i pegmatitno-hidrotennalne žice. Jedna takva žica otkrivena je oko 2,5 km jugozapadno od sela Dunje, na južnoj strani uzvisine Gorni Kamen (kota 636), u blizini izvora Šošlor Kladenc u Smilevskom Dolu. Ta žica sadrži, vrlo razvijene kristale albita, epidota, titanita, amphibola sa nešto manje kremenca, muskovita, heulandita i stilbita, pirita, apatita, mikroklin i klorita.


Na temelju najboljih, mjerenjem polučenih vrijednosti, izračunati su kristalografski elementi:

\[ \text{abc} = 0,7548 : 1 : 0,8546 \quad \beta = 119° 41',5' \]

Krstali titanita iz Smilevskog Dola uglavnom su izduženi u pravini simetrije. Slobodni kraj kristala pritom je savinut za oko 20 prema [100]. Početak kristalizacije titanita, u ovom slučaju, treba smjestiti izu kristalizacije muskovita, pirita te starijeg i glavnog dijela plagioklasa, amphibola i starijeg epidota. Zajedno sa titanitom kristalizirali su i mikroklin i zeoliti.

Od drugih titanitskih minerala vrlo rijetko može se naći na sitne kristalice rutila.

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