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***Research Article***

# MINERAL AND GEOCHEMICAL FEATURES OF THE OCCURRENCE OF TURQUOISE MINERALIZATION OF THE KALMAKYR (MIDDLE TIAN SHAN, UZBEKISTAN)

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**ABSTRACT**
This article discusses the mineralogical and geochemical features of turquoise mineralization at the Kalmakyr porphyry copper deposit. It was concluded that the turquoise of the Kalmakyr deposit in chemical composition is close to the theoretical.

***Keywords:*** *Turquoise, Chemical Composition, Optical Properties, Paragenetic Associations, Chalcosiderite, Dehydration*

## INTRODUCTION
Turquoise in Uzbekistan has been known since ancient times and has been exploited since ancient times, as evidenced by the numerous abandoned ancient workings that have survived to this day (Sosedko, 1933) in one of his works notes - "Even Pliny, a Roman scientist of the 1st century AD noted Kyzylkum as one of the five turquoise deposits known to him on the globe".
Turquoise - a traditional gem of the East, has not lost its value today. "For a long time, Central Asia supplied the whole world with this stone" (Fersman, 1922). Since ancient times, numerous deposits have been abandoned, and only here and there is artisanal extraction of turquoise. Only recently has geological exploration work on turquoise been resumed on a fairly large scale.
The Kalmakyr deposit administratively belongs to the Tashkent region of the Republic of Uzbekistan and geographically to the Kurama ridge, Middle Tian Shan (Fig. 1).

**Figure 1: Location of the Kalmakyr deposit**

## MATERIALS AND METHODS

Samples of turquoise (No. 12, 252, 246) taken from the Kalmakyr deposit were used as material for laboratory studies. Sample No. 12 is taken from a vein of turquoise in silicified rock, No. 246 and 252 are turquoise crusts that fill the voids in the host rocks. These samples were studied by chemical, optical and thermal analysis.

## RESULTS AND DISCUSSION

Turquoise at the Kalmakyr deposit is confined to intensely silicified and seritized syenite-diorites of the Middle Carboniferous ($\varepsilon\delta C_2$) and granodiorite-porphyries of the Upper Carboniferous ($\gamma\delta\pi C_3$) (Smolin, 1972). Turquoise is represented by forms in the form of nests and veins and colors from light blue to white (Nikolskaya *et al.*, 1974).

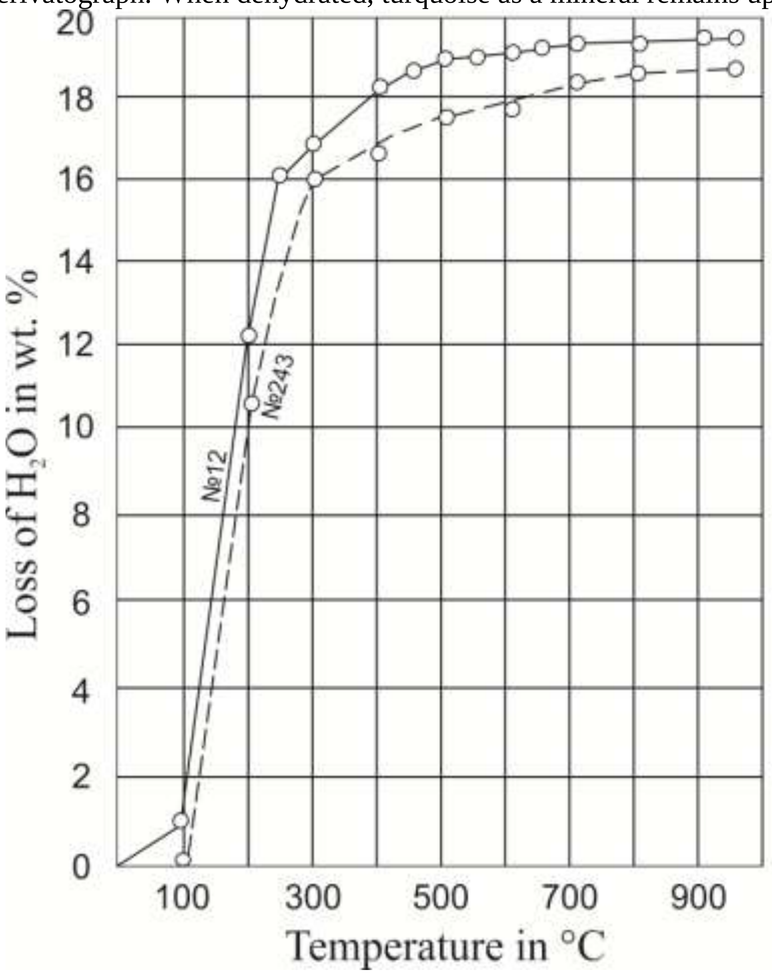
By the nature of the mineral aggregates at the Kalmakyr deposit, there is a dense turquoise of a cryptocrystalline appearance with a finely crusty fracture, hardness 6, rather brittle, specific gravity 2.86. Luster is waxy, weakly translucent in thin chips. The color is sky blue with varying degrees of density, bluish green and green. Its microcrystalline composition is revealed in thin sections. The grain size is 0.003 mm. Researchers often confuse turquoise with chalcosiderite ($CuFe\ [(OH)_8(PO_4)\ _4]]$ * $4H_2O$) due to its similar appearance and green color (Menchinskaya, 1989).

**Table 1: Chemical composition of turquoise (wt.%)**

| **Components** | **Kalmakyr** | | |
|---|---|---|---|
| | *Sample #12* | *Sample #252* | *Sample #246* |
| $Al_2O_3$ | 35.34 | 32.95 | 37.55 |
| $Fe_2O_3$ | 1.53 | 4.70 | 1.26 |
| FeO | 0.00 | - | 0.00 |
| MnO | 0.00 | 0.00 | - |
| MgO | 0.00 | 0.00 | 0.00 |
| CaO | 0.00 | 0.00 | 0.00 |
| CuO | 9.57 | 7.91 | 7.23 |
| $K_2O$ | - | - | - |
| $Na_2O$ | - | - | - |
| $SiO_2$ | 1.36 | 1.32 | 4.16 |
| $TiO_2$ | - | - | - |
| $P_2O_5$ | 30.65 | 33.45 | 30.38 |
| $SO_3$ | 0.20 | - | 0.48 |
| $H_2O$ | 21.37 | 19.30 | 19.63 |
| Сумма | 100.02 | 99.63 | 100.69 |
| $Cu^{2+}$ | 1.03 | 0.84 | 0.82 |
| $Fe^{2+}$ | - | - | - |
| $Al^{3+}$ | 6.10 | 5.58 | 6.06 |
| $Fe^{3+}$ | 0.16 | 0.42 | 0.14 |
| $P^{5+}$ | 3.80 | 4.06 | 3.88 |
| $S^{6+}$ | 0.02 | - | 0.10 |
| $OH^-$ | 8.00 | 8.00 | 8.00 |
| $H_2O$ | 5.44 | 5.24 | 5.08 |

*Note: Sample #12 is a vein of sky-blue turquoise in silicified rock. When recalculating, $SiO_2$ associated with quartz was removed from the analysis. Sample #254, 243 - crusts of earthy light blue turquoise. From the first analysis, $SiO_2$ associated with chalcedony was removed, and from the second, $SiO_2$, $H_2O$, and $Al_2O_3$ associated with halloysite were removed.*

The optical properties of turquoise have been insufficiently studied due to the very fine-grained aggregate structure. Average refractive indices were obtained: Ng (1.62), Np (-).
Turquoise dissolves in hot hydrochloric acid. When $NH_4OH$ is added, the solution turns blue and a white flocculent $Al(OH)_3$ precipitate forms. With molybdenum-acid ammonium, the solution gives a positive reaction to phosphorus. When heated, water is released in a closed tube.
The chemical composition of turquoise from Kalmakyr is close to theoretical (Dana, 1973; Milovsky and Kononov, 1985). The results of chemical analyzes were recalculated to structural formulas for the anhydrous part.
In turquoise, trivalent iron is constantly present in varying amounts, isomorphically replacing aluminum in the spatial lattice of the mineral (Frost *et al.,* 2006), $Fe_2O_3$ content - 1.37-4.78%.
The content of molecular water in the mineral formula in different sources is shown to be different: 4 (Dana *et al.,* 1973; Strunz, 1957), 5 (Betekhtin, 1950; Li *et al.,* 1984). Recalculations of analyzes of turquoise showed some fluctuation in the water content in turquoise from 4 to 5 molecules.
On samples from Kalmakyr, the behavior of turquoise on heating was studied on a TGA / DSC1 derivatograph. When dehydrated, turquoise as a mineral remains up to 100-150°C.




| Temperature in °C | Absolute loss of $H_2O$ in wt.% #12 | #243 |
|---|---|---|
| 50 | 0.44 | 0.06 |
| 100 | 0.92 | 0.06 |
| 200 | 12.16 | 10.53 |
| 300 | 16.92 | 15.92 |
| 400 | 18.22 | 16.64 |
| 500 | 19.00 | 17.48 |
| 600 | - | 17.68 |
| 700 | 19.29 | 18.36 |
| 800 | 19.28 | 18.55 |
| 950 | 19.48 | 18.72 |

**Figure 2: Dewatering Curves of Turquoise from Kalmakyr**

Above this temperature, it begins to lose water, the release of which continues up to 650°, and the most violent release occurs in temperature ranges of 150-350° (17.6%), which corresponds to eight water molecules. As water is lost, the color of the mineral changes from blue, through bluish-green, green, grayish-green, dark gray to chocolate brown.

The heating curves show two pronounced temperature effects. The first stop with a maximum at 325-350° corresponds to a loss of water; exometric peak at 725-800° - corresponds to the formation of new compounds (Fig. 2 and 3). The dehydration and heating curves are similar. Similar thermal properties are typical for turquoise in China (Jiang *et al.*, 1983).

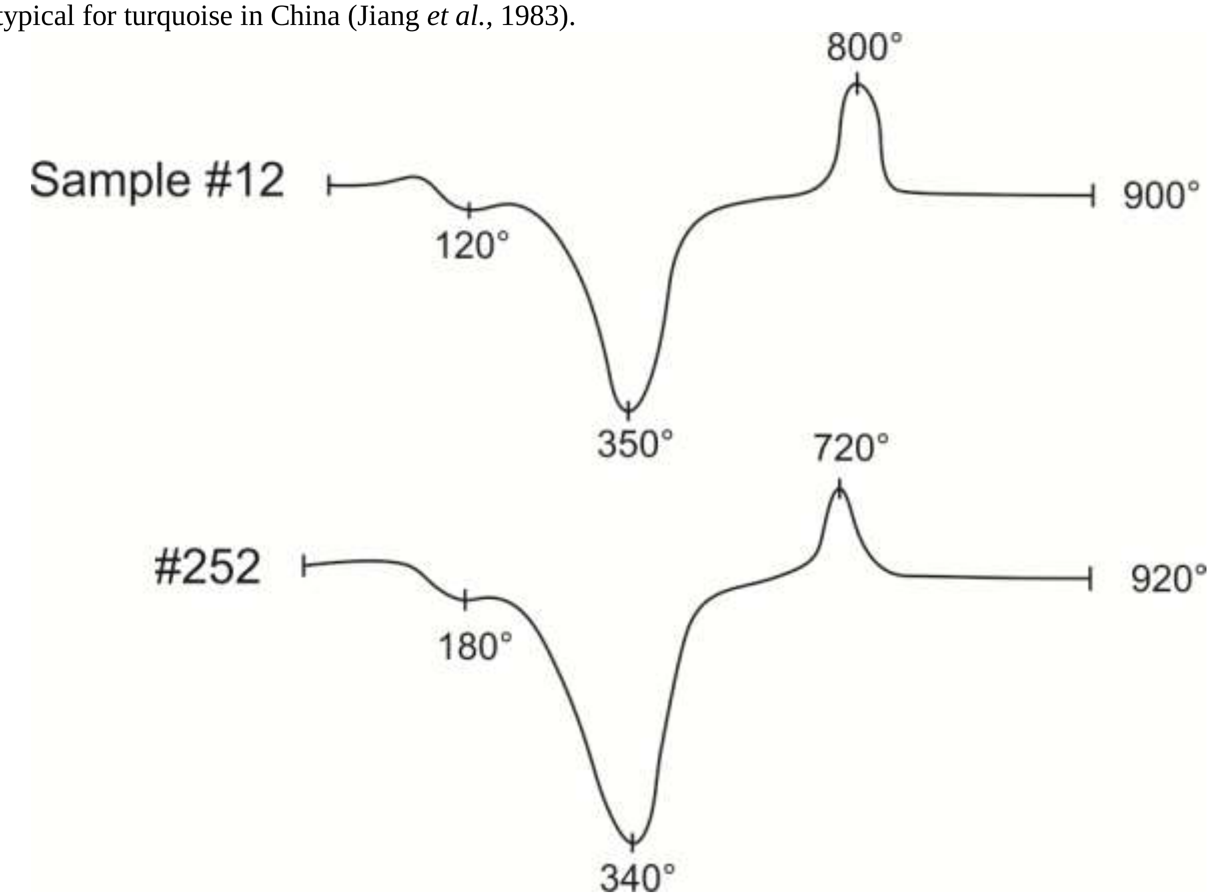



**Figure 3: Turquoise Heating Curves**

In the paragenetic association with turquoise, kaolin, brown iron ore, and oxidized copper minerals are found.

## CONCLUSION

Turquoise at the Kalmakyr deposit is confined to intensely silicified and seritized syenite-diorites of the Middle Carboniferous ($\varepsilon\delta C_2$) and granodiorite-porphyries of the Upper Carboniferous ($\gamma\delta\pi C_3$). Turquoise is represented by nesting and veining shapes and colors ranging from light blue to white. The chemical composition of turquoise from the Kalmakyr deposit is close to theoretical. In turquoise, trivalent iron is constantly present in varying amounts, isomorphically replacing aluminum in the spatial lattice of the mineral. Recalculations of analyzes of turquoise showed some fluctuation in the water content in turquoise from 4 to 5 molecules. The heating curves show two pronounced temperature effects. The Kalmakyr turquoise deposit has significant potential in terms of turquoise volumes, but due to the development of an open pit for copper, mass production of turquoise is possible along the way during stripping operations.

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