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Research Article

ON THE GENESIS OF TURQUOISE MINERALIZATION OF THE NOVOYE SITE OF VOSTOCHNOYE DEPOSIT (CENTRAL KYZYLKUM, UZBEKISTAN)

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ABSTRACT
This article discusses the geological and geochemical features of the turquoise mineralization of the Vostochnoe deposit. Turquoise mineralization is controlled by discontinuous faults, the role of which in its localization is different, and is also accompanied by hydrothermal metamorphism of the host rocks - alunitization, kaolinization, sericitization and graphitization.

Keywords: *Turquoise, Chemical Composition, Hydrothermal, Paragenetic Associations, Ore Control, Vostochnoe Turquoise Deposit*

INTRODUCTION
The deposit is located in the area of Mount Zimbyltau, on the southern slope of a small mountain range and, judging by the numerous ancient mine workings, has been known since ancient times (Sosedko, 1933). The object of the study is administratively confined to the Navoi region (Fig. 1). Its area is about one square kilometer.

Figure 1: Location of the Vostochnoye turquoise deposit

MATERIALS AND METHODS

On the Novoye site of Vostochnoye turquoise deposit, a geological survey work was carried out, with determination of host and turquoise bearing rocks. Samples of turquoise (14 samples) taken from the Novoye site of Vostochnoye deposit were used as material for laboratory studies. These samples were studied by chemical, spectral, phosphorimetric and thermal analyses.

RESULTS AND DISCUSSION

The structure of the field includes the deposits of the Zimbyltau (S_1sb) and Taskazgan (S_1ts) formations of the Lower Silurian (Smolin, 1972), presented by various slates and sandstones (Fig.2).

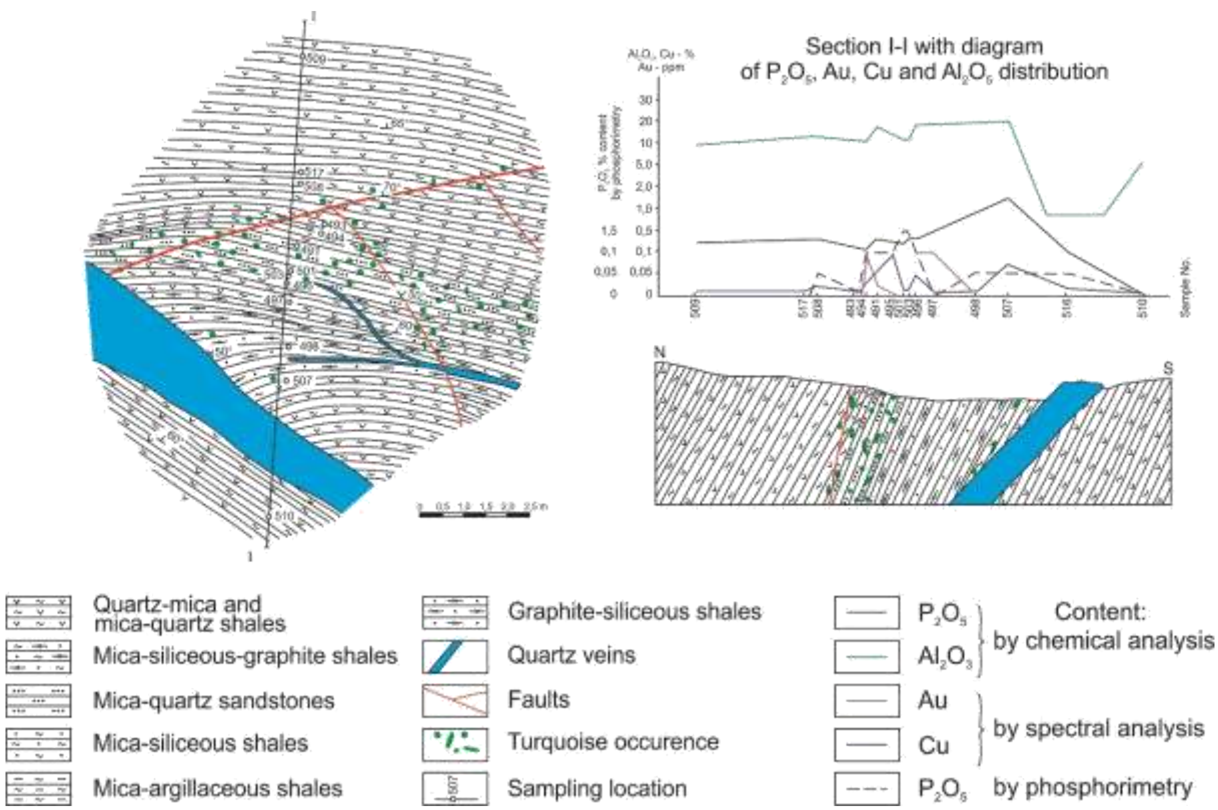

Figure 2: Geological plan of the Novy site of Vostochnoye deposit (Yu.K. Smolin, with the additions of the authors)

Siliceous-quartz schists are composed of quartz and mica with small accumulations of carbonate and iron hydroxides. Thin and fine-grained quartz with a grain size of 0.01-0.1 mm, irregular shape and sinuous outlines. Clay-mica schists are composed of a clay-mica mass with a particle size of 0.03-0.005 mm, rare detrital quartz grains up to 0.2 mm in size, separate accumulations of jarosite in the form of earthy differences of brown-yellow color with brown hydroxides of iron and carbonaceous substances. Micaceous-quartz sandstones are represented by debris and cement.

The chemical composition of the described rocks is characterized by a high content of silica and the ubiquitous presence of phosphorus, reaching 0.5% P_2O_5 and more (Fig. 2).

The rocks composing the deposit are elongated in the latitudinal direction and fall to the north at angles of 50-70°. Near fault zones, their bedding changes.

Among the mica-quartz and carbonaceous shales of the Zimbyltau Formation, there are numerous quartz veins with a thickness of 1-2 m and a length of up to a few hundred meters. They lie, as a rule, in accordance with the bedding of rocks, only sometimes passing along strike or dip into intersecting.

Structurally, the deposit is located on the northern flank of the Taskazgan anticline in the hanging side of a large thrust fault dipping northward at an angle of about 70° (Fig. 2) and having a generally latitudinal strike. Along this thrust fault, as an ore-supplying structure, the manifestations of the turquoise Besapan-I and II and Pridorozhnoe also develop. It is characterized by bends along the strike, creating favorable conditions for the occurrence of ore-distributing plumage disturbances (Fig. 2).

The faults are straight or slightly curved; along the dip and strike, they often turn into intersecting.

Ore-distributing faults, in turn, are accompanied by various cracks, concordant or intersecting with respect to the bedding of rocks and being ore-bearing. Their length is designative and is determined by tens of meters. Displacements along them are small or not established at all. Crushing of rocks is very rare here. Thus, in the Novoye site (Fig. 2), ore-bearing faults develop at angles up to 45° to the ore-distributing structures of the east-north-east direction and are traced up to 10 m and more. Some of these violations are consonant with respect to the bedding of rocks, others are intersecting.

The ore bodies at the deposit lie among the rocks described above and quartz formations of the second type.

Turquoise mineralization is controlled by discontinuous faults, the role of which in its localization is different. Along the ore-feeding thrust, turquoise is unknown (Fig. 2). It is very insignificantly developed along the ore-distributing faults. So, on the Novoye site, for such a fault, only a rare dissemination of turquoise is noted.

The main part of mineralization develops along the ore-bearing faults and the accompanying fine fracturing (Fig. 2).

However, the development of mineralization, controlled by disturbances, equally depends on the nature of the host rocks, primarily on their physical and mechanical properties and the specificity of productive solutions, i.e. combinations of tectonic, lithological and hydrogeochemical factors.

The influence of the environment on ore deposition is clearly traced in the Novoye site (Fig. 2), where mineralization is controlled by the fault and develops mainly among the layer of dense mica-quartz sandstones and, when the fault passes into the underlying and overlying plastic fine-mica-graphite and clay-mica shales, wedges out quickly.

In massive and brittle siliceous shales, where faults of considerable extent are formed (Fig. 2), no mineralization concentration occurs and mineralization usually develops in the form of smears and small veinlets along fractures of various directions accompanying these faults, which is explained by the movement of solutions along numerous slightly open fractures in chemically inert environment.

The influence of the geochemical factor is the development of copper and phosphorus along the ore-controlling structures. At the same time, a necessary condition for the formation of turquoise is the combination of elevated contents of these elements within one zone, and if this condition is not met, turquoise mineralization does not develop.

So the Vostochnoye deposit is located in the zone of increased copper (up to 0.1%) and phosphorus (up to 1.5% and more P_2O_5 according to the results of phosphorometry) and where such anomalies are spatially separated, there is no turquoise. A similar situation is observed in the ore zone of the Novoye site (Fig. 2).

The zones of turquoise mineralization are also characterized by an increased content of gold (up to 0.4 g/t), lead (0.03%), zinc (0.1%), molybdenum (0.004%) and some other typical elements of hydrothermal deposits (Smolin, 1972).

Analyzing the behavior of phosphorus in various rocks and fractured structures according to the results of phosphorimetry and chemical analyzes (Fig. 2), it can be concluded that in the area of the deposit it is associated with various compounds and if chemical analyzes show the gross contents of P_2O_5, then phosphorimetry establishes only phosphorus, which develops along the fault zones (epigenetic).

The geochemical diagrams presented based on phosphorimetry data (Fig. 2) show the dependence of turquoise mineralization on the development of epigenetic phosphorus. Regularities in the development of turquoise on the content of syngenetic phosphorus of sedimentary-metamorphic rocks in the studied areas are not observed.

The morphology of ore bodies at the deposit is different and depends on the occurence of faults and the physicochemical properties of the host rocks. Based on these factors, concordant, secant and complex bodies are distinguished here.

Concordant bodies in the field are subdivided into selective replacement bodies and bodies in separation of layers or interstratal disruptions.

Selective replacement bodies develop among massive and porous rocks - siliceous shales and sandstones. The shape and size of the ore bodies in these rocks are different.

Among the dense and chemically inert siliceous shales, solutions move through zones of increased fracture, about which ore accumulations are represented here by smears and small veinlets, up to 0.5-1.0 m long. Following each other, they are sometimes traced to 10-15 m. The thickness of such bodies does not exceed 1-1.5 m.

In the northern part of the deposit, the described bodies, separated by significant barren intervals (up to 100 m and more), form an ore zone along the latitudinal fault, with a total length of up to 2 km (Fig. 2).

Ore bodies in sandstones are formed not only due to deposition along cracks, but also due to the replacement of rocks, as a result of which vein-disseminated ores develop here. Turquoise in the form of various small forms and veins sometimes forms significant concentrations with a relatively consistent distribution of mineralization. The dimensions of such a body in the Novoye site along the strike are about 9m with a thickness of 0.7m. Along the dip, it was studied to a depth of 7 m without signs of pinching out. The content of turquoise here reaches 700 g/m^3 and averages 300 g/m^3.

Bodies in cleavage of layers or interstratal disruptions in the field are not significantly developed. The host rocks, although to a lesser extent than in the previous case, still influence the shape of the bodies. So, in siliceous shales, they are represented mainly by crusts and smears; in layered shales, linearly elongated bodies are formed in the form of contiguous precipitates of turquoise or their accumulations up to 1-1.5 m and more.

Secant bodies in the fault zones of the field are the most common and are represented mainly by nests occurring among the layered shales of various compositions. The sizes of the nests are usually small and do not exceed the first tens of centimeters in diameter, and the distances between them along the ore zones are sometimes several tens of meters. The ore bodies are less extended here and rarely reach hundreds of meters. Depending on the size of the nests, the content of turquoise can vary from a few to 600-700 grams.

Complex bodies are represented by various combinations of concordant and secant forms, as well as located at the intersections of ore-controlling cracks with layers favorable for ore deposition.

Thus, turquoise mineralization develops in different conditions, and the forms of ore bodies and the concentration of turquoise in them depend on a combination of tectonics and physicochemical properties of rocks. The most significant bodies are formed in sandstones. However, most of the ore bodies are located among various thin-layered shales along the faults. There are no noticeable concentrations of turquoise in massive siliceous shales.

Near-ore metamorphism of host rocks at the deposit is represented by granitization, silicification, alunitization and sericitization. The development of these processes is insignificant.

The forms of individual precipitates of turquoise in the deposit are varied and also depend on the physical and mechanical properties of the host rocks.

In siliceous shales, turquoise is most often found in the thickness of the thinnest smears with an area of up to several tens of square decimeters, developing along numerous cracks of various directions. Only sometimes small veins are noted here, the thickness of which depends on the thickness of the angles of inclination of the cracks filled with it, reaching 3-4 mm in steep cracks (usually 1-2 mm); in hollow falling, only crusts and smears are noted. The length of the veins is up to 10-15 cm. There are also separate isometric formations of turquoise up to several millimeters in diameter, confined to the crushing zones. The color of turquoise, which develops in siliceous shales, is most often of blue tones, sometimes bright blue; there are also green and greenish varieties (Nikolskaya et al., 1974).

In sandstones and quartz-mica shales, turquoise forms nodules, flattened lenses, beans and peas up to 3.0 x 1.5 x 1.0 cm in size, sometimes stretching out in chains or forming frequent inclusions. The color of turquoise is different here - from pale blue, almost white, to deep blue and light green, or from yellowish green to apple green. Bright blue and green turquoise is rare (Nikolskaya et al., 1974).

In quartz and intensely silicified rocks, isometric precipitates up to 2-3 cm^2 in area or small branching veins with irregular outlines, up to 5-6 mm thick and up to 10-15 cm long are known. Color of turquoise is greenish, green, bluish, greenish blue.

Thus, the color of turquoise is different and does not depend on the composition of the rocks, but most often dense turquoise of bright blue, bluish-greenish and green colors are found in siliceous shales, silicified and other dense rocks, which protected it from destruction.

In the rocks along the faults, turquoise most often has a pale, in some places almost white color and reduced hardness.

When comparing the data on the chemical composition, it is established that the host rocks, which differ significantly from each other in the content of individual components, do not have any effect on the composition of turquoise mineralization, which is characterized by relative constancy.

Under the microscope, turquoise is cryptocrystalline, fine-grained aggregates, isotropic to weakly anisotropic, with high birefringence (Frost et al., 2006). Its hardness is 4-5. The specific gravity is 2.55-2.7. Luster is earthy or waxy (Dana et al., 1973; Strunz, 1957; Betekhtin, 1950).

The heating curves of turquoise record an intense endothermic effect within the temperature range of 100-500°, indicating a gradual release of a large amount of water (Li et al., 1984). At the same time, it was found that the decrepitation temperature of blue turquoise lies in the range of 90-450° C, and that of green turquoise - 120-380° C. The most active region in the first case refers to the temperature range 240-440° C, in the second - 270-340° C and in one case 20-500° C (Fig. 3). Similar thermal properties are typical for turquoise in China (Jiang et al., 1983).

The temperature of the formation of turquoise in the fields of Uzbekistan by the method of homogenization was determined by T.I. Menchinskaya and B.A. Dorogovin (Menchinskaya, 1989) and is 125-195° C for primary inclusions and 95-135°C for secondary inclusions.

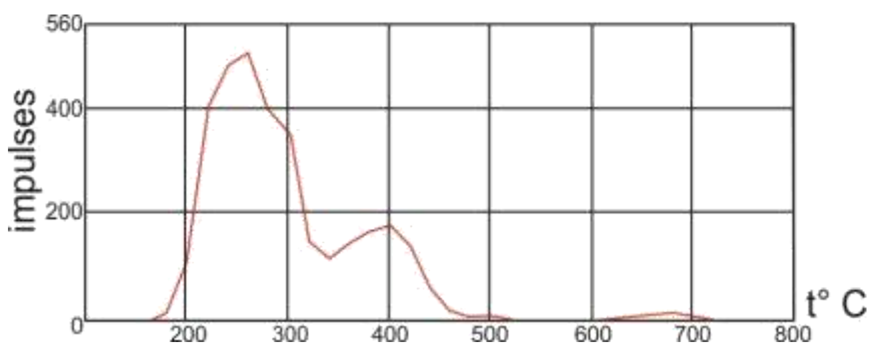

Figure 3: Heating curves of turquoise

Turquoise is often replaced by kaolinite, halloysite, and alunite (Dana, 1973; Milovsky and Kononov, 1985), which develop from the periphery. Sometimes it is found in the form of relict precipitates in halloysite, or in a mixture with kaolinite, halloysite and iron hydroxides. Iron hydroxides are usually unevenly distributed, giving turquoise a mottled color. The replacement of turquoise with the listed minerals is accompanied by its whitening.

Within the ore-bearing bodies, in addition to turquoise and noted kaolinite; halloysite, alunite, wavelite, allophane, variscite, opal, chalcopyrite, gypsum, calcite, jarosite, iron and manganese hydroxides are slightly developed.

CONCLUSION

Based on the foregoing, the following specific features of the field can be noted:

1. Within the described area, turquoise mineralization is controlled by tectonic faults, among which ore-supplying, ore-distributing and ore-localizing types are distinguished.
2. The main components of turquoise, copper and phosphorus, are transported by productive solutions and deposited along fault zones.
3. The morphology of turquoise-bearing bodies is fundamentally different from bodies of hypergenic origin.
4. The formation of turquoise mineralization is accompanied by hydrothermal metamorphism of the host rocks - alunitization, kaolinization, sericitization and graphitization.
5. Turquoise is replaced along with other minerals by alunite, which is a relatively high-temperature formation.
6. The decrepitation temperature of turquoise from the Vostochnoe deposit reaches 300-320°C and can be taken as the gradient of turquoise formation (Fig. 3).

In conclusion, it should be noted that as a result of prospecting and exploration work at the Vostochny deposit, the most promising Novoye site was identified, which significantly expanded the industrial value of the deposit as a whole, and the subsequent studies of the quality of raw materials confirmed its applied value.

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