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Research Article

ANALYSIS OF THE REGULARITY OF THE LOCATION OF THE SAUTBAY TUNGSTEN DEPOSIT (EASTERN BUKANTAU MOUNTAINS, UZBEKISTAN)

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ABSTRACT
The Sautbay tungsten deposit is one of the main deposits in Uzbekistan, constituting the mineral resource base of rare metal deposits in Uzbekistan. It belongs to the aproskrn-skarnoid geological and industrial type. There are potential opportunities for expanding its mineral resources due to flanks and deep horizons. The article considers the patterns of placement of the Sautbay deposit and identifies the factors controlling mineralization.

Keywords*:* *Tungsten, Gold, Sautbay Deposit, Ore Zone, Patterns of Placement, Ore-Controlling Factors, Southern Tien Shan, Central Kyzylkum, Eastern Bukantau Mountains*

INTRODUCTION
In Uzbekistan, 9 deposits and more than 200 promising manifestations of tungsten are currently known. The main explored reserves of tungsten are concentrated in the Ingichke and Sautbay deposits (Muhammadiyev, 2024). The Sautbay tungsten deposit with gold is located in the Navoi region of Uzbekistan, 20 kilometer from the Kokpatas gold deposit.

MATERIALS AND METHODS
Modern views on the tectonics of the Bukantau Mountains (Central Kyzylkum, Southern Tien Shan) have

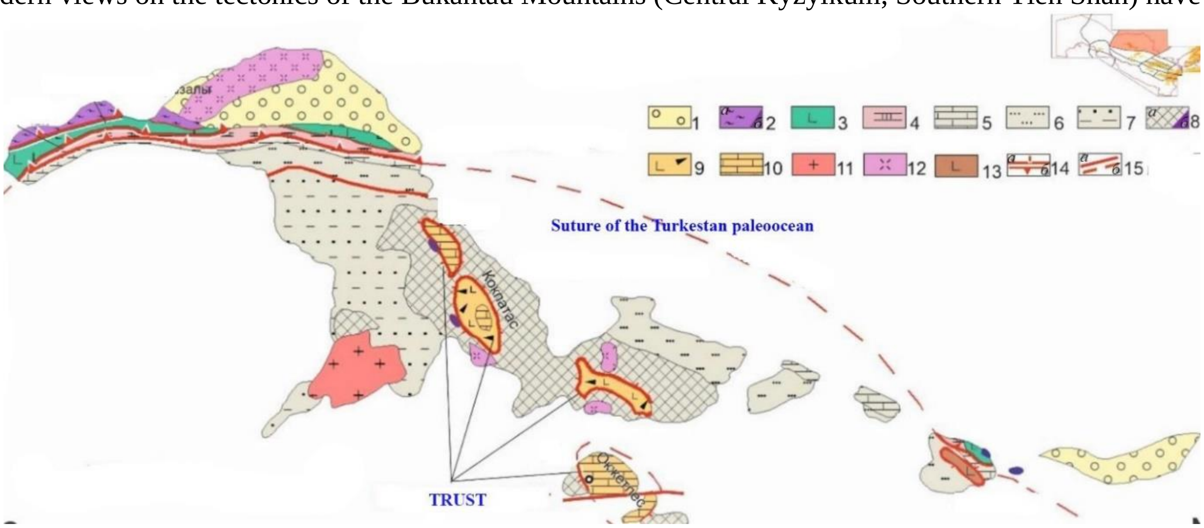

Figure 1: Tectonic zoning of the Bukantau Mountains . 1 – molasse C_3-P, ophiolite complex; 2 - siliceous-volcanogenic formation and gabbro-peridotite complex; 3 – siliceous-volcanogenic formation; 4 – terrigenous formation; 5 – carbonate formation, 6 – siliceous-carbonate-terrigenous formation, 7 – terrigenous formation: 8a – volcanogenic-carbonate-siliceous formation, 8b – peridotite; 9 – olistostrome formation, 10 – carbonate+metaterrigenous formations; 11 – suprasubduction igneous complexes; 12 – collision igneous complexes; 13 – Chimkurgan suite; 14 – thrusts (a), nappes (b); 15 – other faults (a), buried faults (b).

made it possible to identify the following main tectonic structures here: North Bukantau terrane, suture of the Turkestan paleoocean, South Bukantau terrane (Figure 1)

The North Bukantau terrane is associated with ophiolite and island-arc covers, and the South Bukantau terrane is composed of Caledonian accretionary complexes and a Hercynian carbonate cover (Divaev *et al.*, 2022). The South Bukantau terrane is divided into several ore zones with different metallogenic specializations.

The Sautbay deposit belongs to the Turbay-Sarytau ore zone, which has a gold-rare metal geochemical profile. The Turbay gold deposit, the West Turbay and Kumistau silver ore occurrences, the Katyrtas gold and tungsten ore occurrence, and numerous mineralized points of the Sarytau deposit and the Bektash and Kurgantau tungsten ore occurrences are confined to this ore zone (Mirkamalov *et al.,* 2010).

According to the classification of industrial deposits of Uzbekistan, the Sautbay deposit belongs to the tungsten aposkarn-skarnoid type (Golovanov I.M., Divaev F.K., 2005).

RESULTS AND DISCUSSION

The Sautbay deposit is confined to the metavolcanic-sedimentary stratum $R_{2\text{-}3}$ in the exocontact of the granitoid stock (Figure 2). The immediate continuation of the deposit to the southeast is the Burgut site, and to the west of it, 1-3 kilometer away, is the Sagynkan site. The host rocks of the ore field form a large volcanogenic structure with complex, not yet fully deciphered facies and tectonic relationships of volcanogenic, siliceous and terrigenous rocks.

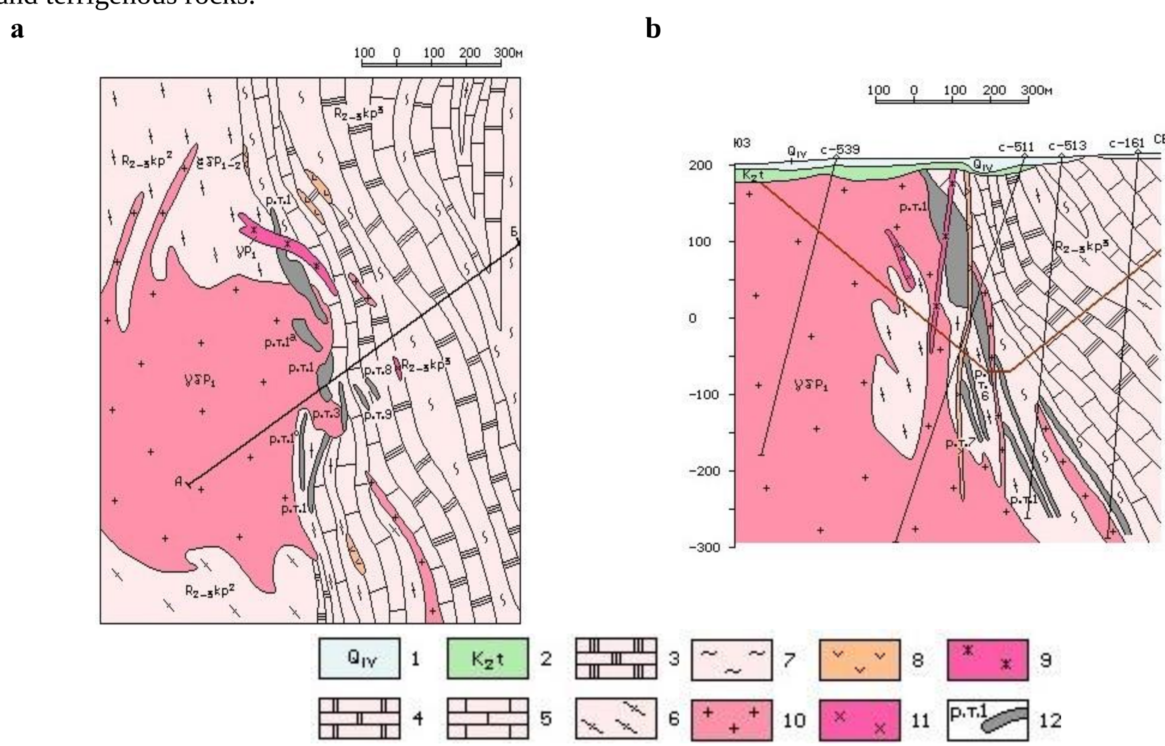

Figure 2: Schematic geological map of the Sautbay deposit (a); section along line A-B (b). 1-lemma-like rocks; 2-clays, sandstones of the Kokpatas suite R2-3; 3-chert quartzites; 4- dolomites; 5-limestones; 6-hornfelses; 7-shales, intrusive complex P1-2; 8-diorites, syenite-dtorites, diorite porphyrites, intrusive complex P1; 9-aplites, aplite granites; 10-granodiorites; 11-adamelites; 12- ore bodies and their numbers.

The base of the section consists of an intensively tectonized pack (presumably this is a mélange), represented by carbonaceous metasandstones, siliceous siltstones, argillites, saturated with angular and "pulled" fragments of various rocks, including quartz and sulfides, which is why these formations resemble the "zero" breccia horizon of the Kokpatas ore field. The well capacity is more than 100 meter.

Above lie the formations of the Cholcharatau suite (PR?) with a thickness of 400-450 meter, the lower parts of which are essentially metavolcanogenic basalts, basaltic andesites with cover and subvolcanic components, including agglomerate lavas; the middle parts are rocks of variegated composition (alternation of lithocrystalloclastic tuffs, tuffites, green schists, quartzites, sandstones, siltstones with a significant proportion of dolomites, dolomite limestones, calcareous tuffites, shales). The upper part of the section is sharply variable in facial features. In the Sagynkan area, closer to the volcanic center, bomb and psephitic lavas, tuffs, lenses of basalts and basaltic andesites, quartzites are widely developed. On the periphery (Sautbay, Burgut) the role of carbonate rocks sharply increases (up to 50-70% of the section), interspersed with shales of various compositions.

The section ends with a carbonate-siliceous layer with a thickness of more than 500 meter (Kokpatas suite $_{R2-3}$), consisting of flints, dolomites with layers of carbonaceous shales and siltstones, and is essentially terrigenous (Khojaakhmet suite V?). The Cretaceous-Paleogene cover developed in the south of the ore field with a thickness of 30-50 meter is composed of ferruginous-siliceous calcareous gravelites, sandstones, and clays. The host rocks are broken through by stocks, dikes, flexure-like bodies of adamellite-granites C_3-P_1 with a rich complex of pre- and post-granitoid dikes of variegated composition, which are concentrated mainly in two arc magma-controlling structures facing each other and forming an ellipse in plan, generally reflecting the deep projection of the hidden granitoid intrusion. The most ancient dike formations are microdiorites, kersantites and spessartites, which are hornfelsed in exocontacts with granitoids and intersected by veins of leucogranites. They form a series of closely spaced thin dikes of northwestern strike.

The adamellite-granite complex on the surface is represented by three isometric outcrops 200-300 meter wide, confined to the eastern part of the northern arc structure. Boreholes have exposed numerous dyke- and finger-shaped injection-dome apophyses filling latitudinal and northwestern structures, flexures and exfoliations of host rocks. Biotite granites predominate in the complex; veins and dykes of leucogranites and aplites are widely manifested in the apical parts of the stocks.

Lower Permian diorites, diorite porphyrites, tonalite porphyry, quartz diorite porphyrites form separate dikes, their bundles, extended branching dike-like bodies up to 1-8 meter thick, traced in the form of a latitudinal belt with parameters of 2x1 kilometer. They are represented mainly by biotite varieties, often chloritized and albitized. They occupy a cross-cutting position in relation to folded structures, are noted among granitoids. The density of dikes reaches 5-10 per 100 running meters. Alkaline basaltoids of conditionally Lower Triassic age are noted in the western part of the field. They are represented by single dikes of minettes and spessartite-vogesites.

Metamorphic transformations of the ore field occurred in two stages. The first stage of regional dynamometamorphism was expressed in the foliation of the main mass of volcanic rocks and tuffs and their transformation into green schists of quartz-albite-zoisite-chlorite composition. It should be emphasized that coarse-grained volcanic breccias of the near-vent facies were affected by these processes to a much lesser extent. Contact metamorphism covers the entire mass in the vertical range of up to 500-600 meter from the intrusion. The internal facies is amphibole-hornfels (cordierite, andalusite, diopside, biotite), 30-50 meter wide, the external facies is muscovite-hornfels (tremolite, forsterite, muscovite, phlogopite) (Tsoy V.D., Koroleva I.V. ,2007).

The structure of the ore field is determined by a large S-shaped bend of the anticlinal fold, complicated by a block system of normal-slip faults and a magma-controlling arc structure. The anticlinal fold in the core part is composed of metavolcanic-sedimentary formations, on the wings - carbonate-siliceous formations. The western wing of the fold and its hinge smoothly (10-20^0) plunge to the west and north, respectively. The eastern wing is steeper (up to 50-80^0) and is complicated by a system of north-northwestern faults.

The Sautbay deposit is localized in the eastern wing of the anticlinal structure, in the exocontact of the stock of the same name, and is represented by multi-tiered steeply dipping stratified deposits with complex morphology and wedging nature, barren windows and powerful bulges. The ore-bearing deposits are composed of calcareous skarns, developed mainly along layers and lenses of dolomite limestones, partially capturing adjacent bands of hornfels, quartzites, and dolomites.

The wallrock alterations are extremely widespread in the form of fine-veined zones of scheelite-containing metasomatites and adjacent blocks of altered rocks. Depending on the primary composition of the latter, the following associations are formed: amphibole, phlogopite, quartz, pyrrhotite (on metavolcanogenic rocks); quartz, microcline, muscovite, pyrite with molybdenite and fluorite (on metaterrigenous rocks). Such fine-veined zones cover the host rocks in a vertical range of up to 300-400 meter from the surface of the intrusion. In the case of their combination with skarn bodies, an increase in the thickness of the ore bodies and an increase in the concentration of tungsten are noted.

The mineral composition of the ore bodies is multicomponent. Magnesian skarns are composed mainly of diopside, less often of forsterite with superimposed phlogopite, tremolite, serpentine, calcareous skarns – of salite, less often of garnet, quartz, calcite, plagioclase. Hypogene ore minerals include scheelite, molybdenite, pyrrhotite, pyrite, chalcopyrite, arsenopyrite, sphalerite, galena, bismuthinite, antimonite, native gold, silver, bismuth.

There are 33 ore minerals identified at the deposit. The mineral composition of the ore bodies is multicomponent. According to production reports by researchers who studied the deposit (V.N. Ushakov, A. Babadzhanov, R.I. Koneev, V.D. Tsoi, I.V. Koroleva, M.M. PirnazarovM.S. Karabaev, A.Kh. Turesebekov, R.A.Kholmatov, etc.), the main ore minerals are scheelite, molybdenite, pyrrhotite, and pyrite; secondary ones are marcasite, chalcopyrite, bismuthinite, magnetite, ilmenite, native bismuth, sphalerite, wurtzite, and hematite. A large group of minerals are classified as rare and very rare**.** Some of them were not encountered during this study. These are thorite, franckeite, stephanite, etc. Scheelite is the main ore mineral. It is constantly present in skarn-skarnoid ore deposits, vein and stockwork bodies among skarns, skarnified hornfels and shales, dolomites, quartzites, granitoids in various quantitative ratios.

The content of WO_3 in ore zones is directly dependent on the content of scheelite in them, since scheelite is practically the only tungsten mineral in the deposit. Analysis of the distribution of scheelite in ore-bearing zones, rocks and metasomatites, its form, age relationships of minerals allow us to distinguish three positions of the mineral (Tsoy V.D., Koroleva I.V., 2007).

- Scheelite 1 associated with the process of transformation of apomagnesian calcareous skarns,
- Scheelite 2 associated with the formation of high-temperature vein, veinlet and stockwork quartz and quartz-feldspar mineral associations and
- Scheelite 3 associated with the deposition of a lower-temperature quartz-carbonate stockwork (with sulfides).

These three types of scheelite represent a kind of facies varieties (by analogy with stratigraphy) and are associated with the superposition of quartz-scheelite mineralization (scheelite-2) on apomagnesian calcareous skarns (scheelite-1) and carbonate rocks (scheelite-3). Figures 3 show raster images of the distribution of some mineral-forming elements.

The geochemical composition of the ore bodies is characterized by an increased concentration of, in addition to tungsten, copper (0.1%), zinc (0.03%), bismuth (up to 0.04%), gold (0.25-1.5 grams per ton), silver (1-5 grams per ton), molybdenum (0.01%). The main associated useful components of the ores are gold, bismuth, copper, which, according to technological studies, can be extracted from the sulphide concentrate. Geochemical zoning, generally corresponding to the distribution features of ore minerals, corresponds to the sequence (bottom-up): molybdenum-tungsten-copper-zinc-lead, antimony, arsenic-silver.

A sharp increase in gold concentrations in skarn bodies and near-ore metasomatites (up to 5-9 grams per ton) is also noted on the southeastern flank of the ore field (Burgut site). The vertical extent of mineralization is more than 500 meter (the deposit is slightly eroded).

The Sautbay deposit includes two areas - Sautbay and Burgut, located 0.5 kilometer from each other. Only the Sautbay area has been explored in detail by wells, as well as pits up to 25-37 meter deep with cross-sections. Three ore bodies have been identified on the Sautbay area, for which tungsten reserves have been calculated. The ore bodies occur in the depth range from several meters to 400-500 meter from the surface. They are mainly represented by steeply dipping (up to 70-90^0) sheet-like and lenticular bodies. Only in some places is a change in dip to 30^0 noted. The largest is ore body No. 1, which is associated with about 90% of explored reserves, including more than 70% of reserves in category C_1. The traced length of the ore body along the strike is 370 meter, along the dip up to 250 meter, the thickness is from 1-5 to 87 meter. The content of WO_3 in individual samples is from 0.05 to 3.5%, on average for the ore body with a cut-off grade of 0.09% - 0.52%.

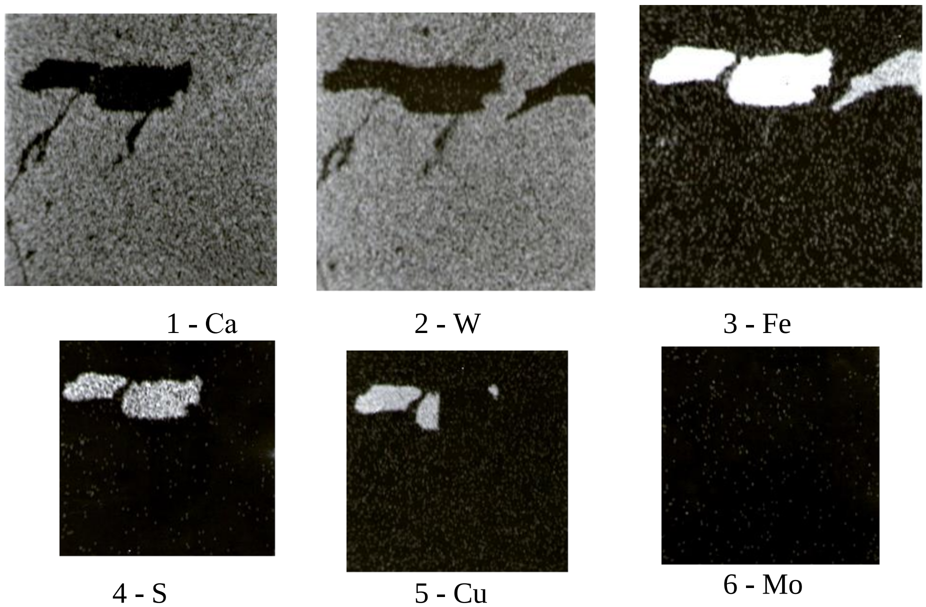

Figure 3. Sautbay deposit (well 4, depth 283.5-290 meter, polished section 35a), scheelite with inclusions of pyrrhotite and chalcopyrite. Characteristic X-ray images: 1- calcium, 2- tungsten, 3- iron, 4- sulfur, 5- copper, 6- molybdenum (based on materials by Tsoy *et al.* 2007)

with a cut-off grade of 0.15 - 0.65%. The remaining ore bodies are small in size - the length along the strike is up to 100-180 meter, along the dip - from 20-60 to 400-470 meter with a thickness of 1 to 19 meter. The average content is 0.25 - 0.49%. The ores are composed mainly of aluminosilicate minerals (pyroxene, amphibole, less often garnet, feldspars), quartz and carbonate. The amount of carbonate (calcite) is from 10 to 15-20%. The amount of sulfides is up to 5%, less often up to 10 - 15%. Pyrrhotite predominates among sulfides. Chalcopyrite, molybdenite, and bismuthinite are noted in small quantities. The copper content is 0.05-0.12%, bismuth - up to 0.01-0.04%, molybdenum - up to 0.001-0.004%. The content of P_2O_5 is 0.1-0.5%. Gold is contained in the amount of 0.2-0.6 grams per ton, in some samples up to 1.3 grams per ton. The bulk of the gold extracted during ore enrichment ends up in flotation copper concentrate (gold content is about 7 grams per ton).

CONCLUSION

The main ore-controlling features and indicators (factors) typical for the Sautbay deposit are: 1. carbonate-bearing horizons and section types generally confined to the boundary of the Karashakh and Kokpatas suites;
2. facies joints with the corresponding variegated section types;
3. screening role of flints;
4. endocontact zones (up to 100-150 m) of spike-shaped projections of C_3-P_1 granitoid intrusions with a low level of erosional shear;
5. arcuate belts of increased permeability with increased density of the zonal complex of post-granitoid dikes of variegated composition, their anomalous strikes and morphology;
6. polychronicity of dike belts;
7. hornfelses of the internal facies of contact metamorphism.
8. zones of fine-veined high-temperature quartz-muscovite-feldspar-amphibole metasomatites with scheelite;

9. flexural-folded structural paragenesis, arc structures;
10. intraformational subconformable shear zones;
11. complex morphology of granitoid bodies, systems of closely spaced steeply and gently sloping apophyses, "pockets" of host rocks in granitoids;
12. halos of tungsten, molybdenum, bismuth in the nearest exocontact; zinc, arsenic, silver – in the distant one;
13.local gravity minimums combined with a locally elevated and alternating magnetic field.

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