



Research article  
UDC 553.072

## Geological and structural position of the Svetlinsky gold deposit (Southern Urals)

Alexander Yu. KISSIN, Mikhail E. PRITCHIN, Danil A. OZORNIN ✉

Zavaritsky Institute of Geology and Geochemistry, Ural Branch of RAS, Ekaterinburg, Russia

**How to cite this article:** Kissin A.Yu., Pritchkin M.E., Ozornin D.A. Geological and structural position of the Svetlinsky gold deposit (the Southern Urals). *Journal of Mining Institute*. 2022. Vol. 255, p. 369-376. DOI: 10.31897/PMI.2022.46

**Abstract.** The paper presents the geological and structural position of the large Svetlinsky gold deposit in the Kochkar anticline (Southern Urals), localized in the zone of the Late Paleozoic ( $D_3$ ) deep thrust of the western dip. The study confirms and clarifies the notion of its multiphase and polychronism. The thrust caused bending moments in its wings, subsidence of the lying crust, emergence of a shallow marine basin with rapid accumulation of terrigenous carbonate sediments ( $C_{IV}$ ), and formation of numerous landslide structures. The heating of rocks in the anticline core was accompanied by granitization and dome formation. A small Svetlinsky dome formed in the immediate vicinity of the thrust, creating a thermobaric gradient field ( $C_2$ ). The zone of dome dynamic influence also includes the adjoining thrust area, complicated by a series of sub-vertical thrusts of sub meridional strike and numerous steeply dipping subparallel cracks of the latitudinal strike, synchronously filled with vein quartz and accompanied by hydrothermal metasomatic rock transformations. The formation of the gold deposit occurred during the post-collisional relaxation stage (from  $P_1$  to, probably, the Early Jurassic). The association of gold mineralization with the Svetlinsky dome is indicated by the presence of native gold in Neogene ravine placers in the dome area and marbles of the Svetlinsky deposit, in association with fluorite, F-phlogopite, Cr-muscovite, pink topaz, pure quartz, and native sulphur. The presence of native gold in Neogene ravine placers in the dome area and marbles of the Svetlinsky deposit, in association with fluorite, F-phlogopite, Cr-muscovite, pink topaz, pure quartz, and native sulphur, indicates the association of gold mineralization with the Svetlinsky dome.

**Keywords:** gold; deposit; collision; structural geology; thrust; granite gneiss domes; Southern Urals

**Acknowledgments.** The work was carried out under the state assignment of IGG UB RAS (N AAAA-A18-118052590028-9 state registration).

Received: 07.04.2022

Accepted: 15.06.2022

Online: 26.07.2022

Published: 26.07.2022

**Introduction.** Svetlinsky gold deposit is located 100 km south of Chelyabinsk and 25 km southwest of Plast and is currently the largest in the Southern Urals. It was discovered in the 1970s and has been operated as an open pit mine since 1992. In 2021, the depth of the open pit was approximately 240 meters. Every year 4-4.5 t of gold is mined at the deposit; the remaining reserves of gold to the depth of 600 m are estimated at 75 t [1-3], and its total reserves including already extracted ones are about 130-135 t. The Svetlinsky gold deposit is distinguished by an abundance of various tellurides (Fe, Ni, Pb, Sb, Bi, Ag, and Au) [4]. Au-Te deposits include the following types: epithermal, porphyritic, orogenic, or associated with the magmatic intrusion. Examples of large Au-Te deposits are Golden Mile, Australia [5], Cripple Creek and Golden Sunlight, USA [6, 7], Emperor, Fiji [8, 9], Akupan, Philippines [10], and Sacarim, Romania [11]. The Svetlinsky deposit has been considered by researchers as a mesothermal low-gradient disseminated-vein type [12], polygenic and polychronic, formed by fluids from different sources [12-16] and in relation to granite magmatism [12, 13, 17]. Some researchers attribute the main role in the formation of the deposit to the processes of argillization, which is associated with Mz-Kz tectonic-magmatic activation [18].

The Svetlinsky gold deposit is confined to the tectonic boundary of the Trans-Ural synclinorium in the west and the Kochkar anticline in the east (Fig.1). The eastern flank of the synclinorium is 10-22 km

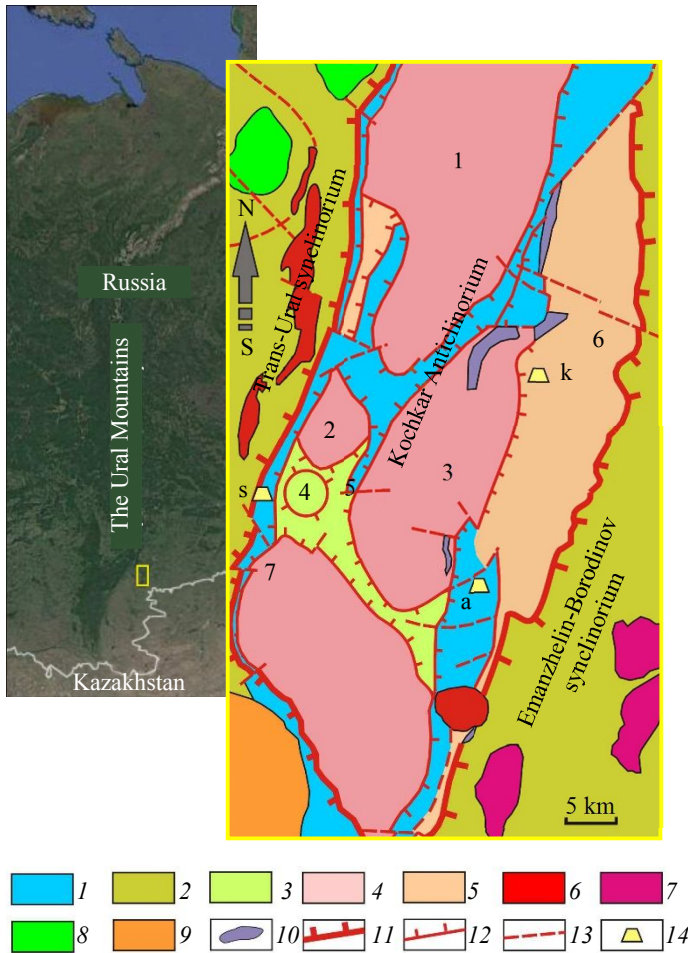


Fig. 1. Geographical location (a) and schematic geological map of the area (b) (State Geological Map of the USSR of the pre-Mesozoic formations, Sredneural'skaya series, scale 1:200,000, 1981)

1 – marble, marbled limestone (C<sub>1v</sub>); 2 – volcanogenic-sedimentary sequence (S<sub>2</sub>-D<sub>2</sub>); 3 – crystalline schists, sometimes with kyanite, sillimanite, staurolite (S<sub>1l3</sub>?); 4 – gneiss, amphibolites, granites (C<sub>3</sub>-P<sub>1</sub>); 5 – plagiogranites, granodiorites (D<sub>3</sub>-C<sub>1</sub>); 6 – granites (C<sub>1</sub>); 7 – granodiorites (C<sub>1</sub>); 8 – gabbro (S<sub>1</sub>); 9 – syenites, granite syenites, alkaline granites (C<sub>1-2</sub>); 10 – ultrabasic serpentinized rocks (S<sub>1</sub>?); 11 – thrusts; 12 – boundaries of dome structures (Pz<sub>3</sub>); 13 – tectonic disturbances; 14 – gold deposits (s – Svetlinsky; a – Andreevsky; k – Kochkarsky); domes: 1 – Varlamovsky; 2 – Eremkinsky; 3 – Borisovsky; 4 – Svetlinsky; 5 – Sanarsky; intrusions: 6 – Plastovsky; 7 – Stepninsky

- formation of gold-telluride mantle mineralization (C<sub>2m</sub>-P<sub>1</sub>);
- supergene stage with formation of weathering crust and large gold placers (M<sub>Z</sub>-K<sub>Z</sub>).

The deposit is thought to be controlled by the intersection of the sub meridional Svetlinsky thrust fault and the Sanarsky deep fault [13, 24]. The idea is focused on the thrust as an ore-supplying and ore-bearing structure. This thrust extends along the entire western side of the Kochkar anticline (about 140 km), which makes it promising for prospecting new gold deposits.

An alternative point of view is given by A.Yu.Kisin and V.A.Koroteev [25], which explains the ore minerageny of Kochkar anticline, including gold, from the position of the block folding model. According to this model, the Kochkar Anticline is a block of positive crustal curvature resulting from the Late Paleozoic collision. In the process of deformation, metamorphism, and metasomatism, granite gneiss domes are formed, and gold is accumulated in rocks of inter- and near-dome structures. In this case, the thrust zone has no direct relation to the location of gold deposits.

wide and its stratification dips westward at 15-60° [19, 20]. The length of the anticline in the sub meridional direction is 140 km and its width is up to 27 km. The boundary between two structures is a west-dipping thrust fault laid in the late Devonian [21]. Volcanogenic-sedimentary strata of Devonian-Silurian age, composing synclinorium, are considered to be thrust over faultally characterized early Carboniferous terrigenous-carbonate rocks of marginal part of anticline.

The existing ideas about the geological structure and genesis of the deposit were developed based on geological exploration work results in 1970-1985 and by the scientific ideas of the time. Their most detailed and complete presentation was given by V.N.Sazonov et al. [13, 22] and clarified in articles [4, 23]. According to these researchers, the deposit is polygenic and polychronic, formed in five stages:

- accumulation of terrigenous and volcanogenic-clastic rocks with elevated Au Clark (D<sub>3f</sub>-C<sub>1v</sub>);
- low-gradient greenstone metamorphism with scattered redistribution of sulphides (C<sub>1t</sub>);
- metamorphism in the amphibolite facies associated with collision, and formation of a synorogenic tonalite-granodioritic pluton, pegmatite and quartz veins in its apical part; gold-scheelite-sulphide-quartz veins accompanied by beresite-listvenite metasomatic rocks (C<sub>1v</sub>-s) form at a distance from the pluton;



The annual monitoring of the Svetlinsky quarry by the authors of this article since 2009 and the study of the deposit geology by methods of structural geology and kinematic analysis have allowed us to collect new factual materials and refine this geological-genetic model.

**Results.** The uppermost horizons of the eastern side of the quarry revealed landslide structures in dark bituminous marbleized limestones containing a fauna of crinoids, single corals, nautilus and other organic remains characteristic of  $C_{IV}$ . Even gas-water pockets – slit-shaped cavities at the boundaries of mudflows – are preserved (Fig.2, *a*). Occasionally, small lenses of quartzitic sandstones are found (Fig.2, *b*), indicating the inflow of terrigenous material into the shallow marine basin. In other cases, landslide structures are observed in the appearance of lenses of light, intricately deformed marbleized limestone on the background of dark limestone. The angle of the stream incidence reaches  $60-70^\circ$  in the western direction. With depth, the degree of metamorphism of the limestones increases sharply, and after 20 m they are already represented by marble, but with the pattern of landslide structures preserved. So far, such structures in the marble have been traced to a depth of about 100 m.

The contact of carbonate rocks with the volcanogenic-sedimentary strata is irregular in both strike and dip. Occasionally, the marble bodies deform the volcanogenic-sedimentary rock layers to form anticlinal folds of transverse curvature. Such folds have been observed in the upper horizons of the quarry. The contacts are sharp, usually sub-vertical,  $\pm 10-20^\circ$ . The volcanogenic-sedimentary strata in the contact are strongly altered by hydrothermal-metasomatic processes and argillized. Only talc schists are reliably identified here; their bodies are numerous, but rarely are they thicker than 0.5 m. The rocks are strongly foliated. Small fractures and undercutting indicate the uplift of the eastern block composed of marble.

Terrigenous volcanogenic banded rocks dipping westwards at a  $50-60^\circ$  angle have been uncovered in the western part of the quarry. The banding is mineral, and crystalline and probably reflects the overthrust fault cleavage rather than sedimentary layering. Often, thin talc schist bodies are observed, deposited either according to the rock banding or in the form of steeply dipping bodies up to several meters thick. Serpentine bodies are less frequent than talc bodies, up to 30 m thick. The dip is steep to the west, cutting strips. Talc schists and coarse-grained actinolite rocks are sometimes observed in contact with serpentinites [13].

Ore bodies at the deposit are represented by zones of hydrothermal-metasomatic processing of volcanogenic-sedimentary strata near contact with the terrigenous-carbonate sequence. The main ore-bearing zone, identified by sampling, is located 50-80 m to the west of the contact between the marble and volcanic rocks. The strike of the zone is submeridional, 80-120 m long and about 10 m wide (in lenses up to 20-25 m), and the dip is westerly at  $70-80^\circ$  (in the upper horizons, the dip was gentle and even changed to easterly). Several other smaller-scale ore zones are known at the deposit. The boundaries of the zones are indistinct. The mineral composition of gold-bearing metasomatic rocks has been described in detail in the sources [1-4, 13, 17]. In the axial part of the main ore zone, secondary quartzites are usually observed, accompanied by plagioclase-quartz-biotite metasomatic rocks with sulphide mineralization. The rocks are partly schistose and deformed. Cliff cracks, undercuts, steps and ramparts, and tensile cracks indicate the uplift of the eastern flank (Fig.3). The pressure source was located at depth, north-east (linearity in the form of steps and shafts falling southwards at an angle of  $15-30^\circ$ ).

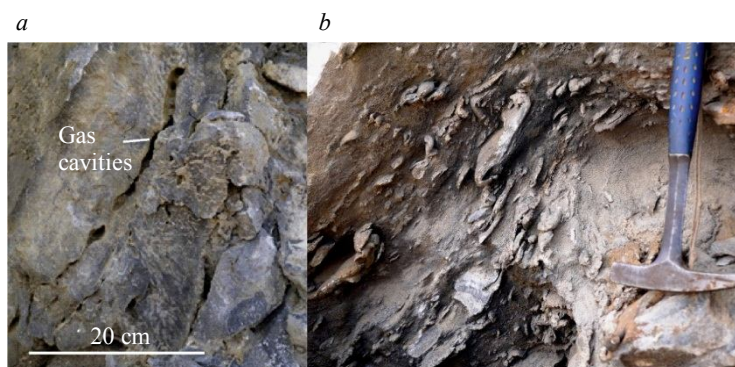


Fig.2. Landslide structures in marmorized limestone with slotted cavities (*a*) and lenses of quartzite-sandstone (*b*) (limestone subjected to karstification)



Quartz veins are common in the deposit. Three types of veins have been identified in the ore zone and beyond [26, 27]:

- sub meridional steeply dipping (strike azimuth 270-280°, dip angle 70-80°) to the west;
- sub-latitudinal, north-facing (strike azimuth 270-280°, dip angle about 70°, (the most numerous);
- sub meridional, falling to the west at an angle of about 30° (the smallest and rarest) (Fig.4).

The veins of the first type are usually close to each other, spaced 5-20 cm apart, up to 10 cm thick, rarely more. The veins cut secondary quartzite bodies along the strike; contacts are indistinct. The quartz is strongly cataclased. The orientation of the cleavage cracks in quartz and host rocks indicates an uplift of the eastern flank.

The second system is represented by a set of sub-latitudinally oriented, subparallel lens-shaped quartz veins that cut across the ore zone. The strike azimuth is 270-280°, the dip angle is about 70° to the north. The average thickness of the veins is 10-15 cm, and the distance between veins ranges from 15-20 cm to 1 m (Fig.4), rarely more. The vertical and horizontal extent of the veins has not been determined, except for the small bodies of echelon-like occurrence. Their greatest number is observed within the ore body, but they are also common outside it. The distinct lenticular shape of the veins suggests that the quartz here has been exposed by thrust fractures, probably associated with low-amplitude upwelling of the northern face. Sub-latitudinal quartz veins cut sub meridional ore zone veins and secondary quartzites but they themselves were also deformed. The quartz is coarse-grained and milky-white. Biotitization of rocks and sulphide mineralization are common in zalbands.



Fig.3. Structural scheme of the tectonic zone indicates an upward extension of the eastern flank. View to the south. Svetlinsky quarry, 2020

The third system is formed by small quartz lenses of sub meridional strike, dipping westwards at an angle of 35-45°. They appear only in some parts of the ore zone. Their thickness is only 1-2 cm, and their length is up to 1 m. Their shape is distinctly lenticular (Fig.4), which allows them to be classified as tensile fractures. The relationship with sub-latitudinal veins is not clear. The quartz of these veins does not differ from the quartz of the sub-latitudinal veins in appearance.

**Discussion.** The sub meridional fault (thrust zone), opened by a quarry, separates two major structures: the Trans-Ural and Kochkar anticlines (see Fig.1, b). According to the geological section based on the results of exploratory core drilling, Silurian-Devonian deposits are thrust over Early Carboniferous deposits. It was assumed that the deposit is located at the intersection of the thrust by a deep fault of the northwest strike [13, 24]. The authors of the article did not find a northwest-trending fault in the quarry. The overthrust zone in the quarry is confirmed by numerous serpentinite and talc bodies, distributed immediately to the west of the marbles. The banding of the rocks in the western face of the quarry dips 50-60° to the west, which probably corresponds to a fault (thrusting) cleavage. But near the marbles, the banding is thin and the dip is sub-vertical, which cannot be explained by thrusting. The cleavage cracks and underthrusts point to the upward extension of the marble.



Fig.4. Types of quartz veins in the Svetlinsky quarry  
1 – sub-meridional zone of secondary quartzite and adjacent quartz veins (in the image plane); 2 – sub-latitudinal quartz veins; 3 – sub-meridional small west-dipping veins



The ore body also has a very steep dip to the west of 70-80°, which is no longer consistent with the overthrust zone. There is a tendency for the dip of the ore zone to increase with increasing pit depth. In the upper horizons of the deposit, the occurrence of the body was gentle and even had an easterly dip, which during exploration works was explained by subsidence during the development of Mz-Kz karst and weathering crusts. Based on new investigations, a new cross-section was constructed in the quarry along line 13 (Fig.5). Fig. 6 shows the results of satellite images decoding of the nearest surroundings of the deposit, which explain our approach to the construction of the section. According to the interpretation results, two kilometers to the northeast of the deposit there is the apical part of the Svetlinsky dome, which controls the pure quartz deposit [24, 27, 28], extending westward to the marble boundary. The south-eastern wing of the dome is steep (shale dip angle 50-60°) and the western and south-western ones are gentle (shale dip angle 10-20°, near the marbles 40-45°). The metamorphism level in the dome reached the epidote-amphibolite or lower amphibolite facies according to the distribution of fibrous sillimanite. According to the biotite-garnet geothermobarometer, the metamorphism temperature was 580-630 °C at pressures up to 3.2 kbar [24]. The ravine pure quartz Neogene placers on the dome and its western slope are gold-bearing [24]. The karstic deposits of the eastern marble contact are mined for gold. Ore gold of hydraulic size in association with muscovite, F-phlogopite, Cr-pargasite, fluorite, pink topaz, pure quartz, native sulphur, pyrrhotite, pyrite, sphalerite has been found in ducts of the Svetlinsky pit marbles. Closer to the Svetlinsky dome, in the eastern part of the marble body, red corundum (ruby) appears [29, 30], indicating higher PT conditions of metamorphism than in the section uncovered by the quarry. It is noteworthy that rubies, red spinel, pink topaz, fluorite, tourmaline, phlogopite, chrome-bearing muscovite (fuchsite), and chromio-pargasite are found in marble in the frame of all granite gneiss domes of the Kochkar Anticlinorium. In the Andreevsky quarry, located on the eastern wing of the Borisov dome, gold aggregates up to 10 mm

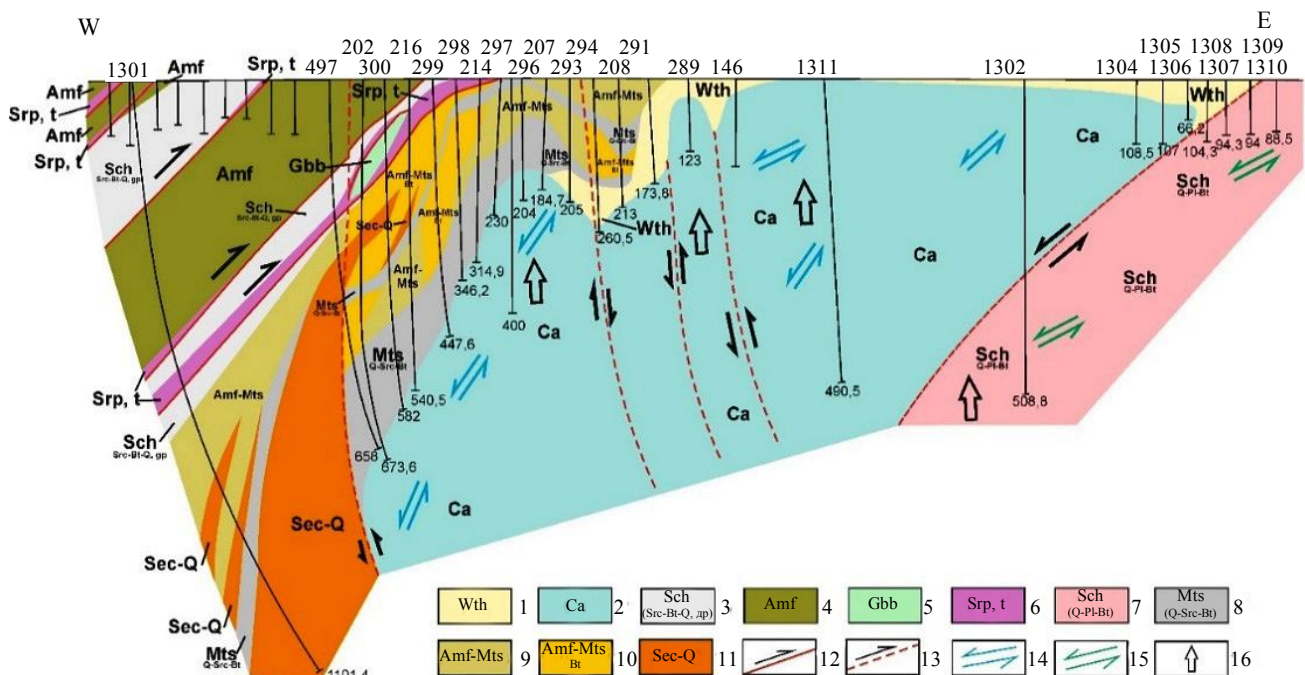
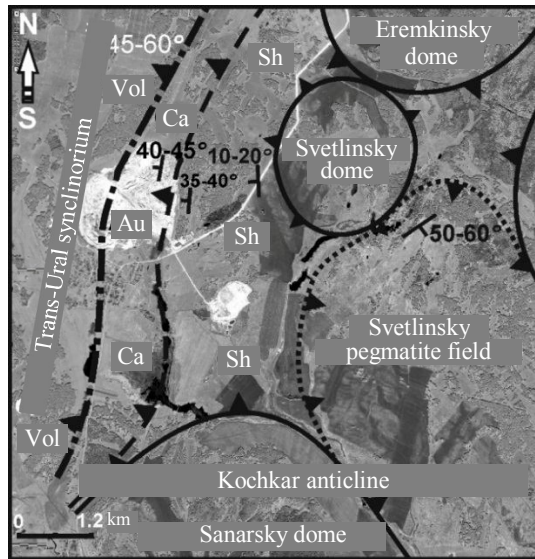


Fig.5. Schematic geological cross-section along the line of 13 core drill holes including structural investigations in the Svetlinsky quarry

- 1 – karst sediments and unstructured weathering crusts; 2 – marble and marbleized limestone (C<sub>1</sub>v); 3 – sericite-biotite-quartz and coal shales (S<sub>1</sub>-D<sub>2</sub>); 4 – apovolcanic amphibolites (S<sub>1</sub>-D<sub>2</sub>); 5 – gabbro metamorphosed (with amphibolite, epidot and chlorite metasomatic processes); 6 – talc shales, serpentinites; 7 – quartz-plagioclase-biotite schists with almandine and staurolite; 8 – quartz-sericite-biotite metasomatic mylonitized rocks; 9 – metasomatic amphibolites; 10 – metasomatic biotitized amphibolites; 11 – secondary quartzites; 12 – thrust; 13 – tectonic disturbances associated with dome structure; 14 – cleavage in marble and direction of shear; 15 – rock schist and direction of shear; 16 – direction of rock movement



▲ 1 ▲ 2 ▲ 3 ...▲ 4 Au 5 Ca 6 Бун 7 Сп 8 10° 9

Fig.6. Satellite image interpretation of the Svetlinsky gold deposit

- 1 – Svetlinsky thrust; 2 – tectonic boundary of terrigenous carbonate rocks with crystalline schists; 3 – boundaries of dome structures;
- 4 – boundary of inter-dome depression, containing pegmatite field;
- 5 – Svetlinsky gold deposit; 6 – terrigenous-carbonate sequence;
- 7 – amphibolites and crystalline schists with staurolite; 8 – volcanogenic-sedimentary sequence; 9 – dip and strike of schistosity

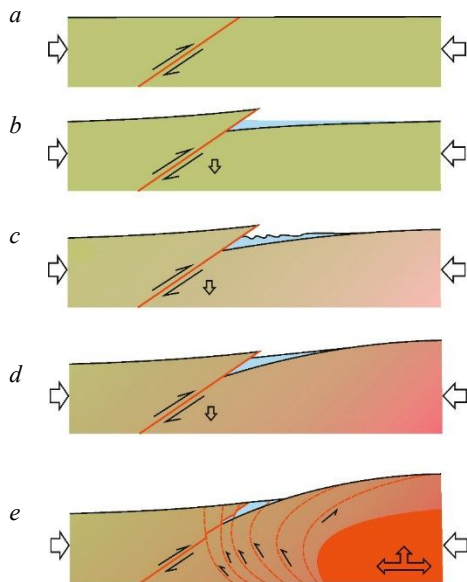


Fig.7. Geological evolution of the Svetlinsky thrust area:  
 a – start of collision and overthrust building  $D_3$ ; b – subsidence of the lying side of the thrust and appearance of shallow marine basin  $D_3-C_1$ ; c – formation of positive curvature block and formation of landslide structures  $C_1$ ; d – warming of rocks in the core of the anticline, regional metamorphism  $C_2$ ; e – uplift of heated plastic material, formation of domes and zonal metamorphism, transformation of the thrust zone (formation of fluid conduits)  $C_2$

in size are found in marbles [31]. We should also note the similarity of “tabashki” biotites of the Kochkar gold deposit (northeastern framing of the Borisov dome) with biotites of the Svetlinsky ore body [32].

Thus, geological facts indicate a genetic connection of the Svetlinsky gold deposit with the dome of the same name. However, some researchers associate this ore gold deposit with the Sanarsky massif [33], although the structural control with it is not established.

Some conclusions can be drawn from the findings regarding the formation of the deposit. As a result of the Ural collision that began in the Late Devonian, a system of deep thrusts of opposite dip with bending moments and crustal deformation according to the block folding model was formed [25]. Such west-dipping thrust was Svetlinsky thrust (Fig.7, a). The sinking of its lying side was accompanied by generating a shallow marine basin (Fig.7, b), which was rapidly filled with terrigenous carbonate sediments ( $D_3-C_1V$ ). Progressive sinking of the block, alteration of the basin floor slope, and, possibly, earthquakes were accompanied by formation of numerous landslide structures resulting in increased sediment thickness (Fig.7, c). Heated rocks in the core of the growing anticline under stress conditions caused regional metamorphism, upward movement of fluid and heated plastic masses, dome formation (Fig.7, d), and granitization with removal of Ca, Mg, Fe, Si, and some other chemical elements, including Au [28, 34, 35]. Thus, according to our idea, Sanarsky, Borisovsky, and Eremkinsky granite gneiss domes appeared, which became centers of zonal metamorphism of amphibolite and epidote-amphibolite facies. Near the thrust, a small Svetlinsky dome was formed that created a thermobaric gradient field ( $C_2$ ). The adjoining section of the Svetlinsky thrust has also fallen within the dynamic influence zone of the dome. As a result, the thrust has been deformed and complicated by a series of sub-vertical thrusts of sub meridional strike, controlling secondary quartzites and accompanying biotite metasomatic rocks (Fig.7, e); simultaneously, numerous steep-dipping sub-parallel cracks of latitudinal strike-slip extension with a syntectonic filling of veined quartz have occurred. Based on the total thickness



of the quartz veins of the second system, the sub meridional extension of the rocks of the observed quarry wall was 15-20 % in places. The growing Svetlinsky dome also lifted individual large blocks of marble, which deformed amphibole and biotite metasomatic rocks (see Fig.5). By the end of the Carboniferous, the Ural collision had ended [36, 37], and the thrust had lost its activity.

At the collisional stage gold could have been mobilized during granitization and deposited in the basification zone (framed by granite gneiss domes). This is confirmed by the wide spreading of placer gold in inter- and near-dome areas in the Kochkar anticline. Relief of stresses during the transition from collisional stage to post-collisional relaxation led to a drop in all-round pressure and the start of the pneumatolithic-hydrothermal stage. A rock crystal deposit was formed in the apical part of the Svetlinsky dome and on its slopes. As a result of hydrothermal-metasomatic processes, including argillisation, gold may have experienced redeposition with the formation of commercial concentrations. The post-collisional phase probably ended in the early Jurassic, with the start of peneplanation of the area.

**Conclusions.** The formation of the Svetlinsky gold deposit began in the Late Devonian, when the collisional stage the laying of the west dip thrust occurred, generating bending moments, the sinking of the crustal block in its lying side with the formation of a shallow marine basin, rapidly filling with terrigenous-carbonate sediments. In the thrust zone, metamorphism at the bottom of the greenschist facies due to frictional heat, fault cleavage, recrystallization, and the formation of quartz-biotite-sericite schists are observed. Focusing on bending moments of tectonic energy of horizontal compression led to the formation of the anticlinorium, warming of rocks in its core with subsequent squeezing upwards, and formation of domes. The process was accompanied by metamorphism and granitization. The thrust was located in the zone of dynamic influence of the growing Svetlinsky dome and experienced additional deformation, while rocks of the thrust zone underwent hydrothermal-metasomatic transformations. It is assumed that granitization caused gold accumulation in the metamorphic frame of the dome and subsequent hydrothermal processes led to its redistribution and formation of the deposit. In the post-collisional phase, the thrust has lost activity and some gold and tellurium may have been introduced through the thrust zone from the lower crust and upper mantle.

## REFERENCES

- Berger R.V., Fedoseev V.V., Saraskin A.V. State-of-the-art and prospects of mineral and raw materials supply base expansion at UGC Gold Mining Company in the South Ural. *Gornyi Zhurnal*. 2017. N 9, p. 6-11 (in Russian). DOI: 10.17580/gzh.2017.09.01
- Fedoseev V.V., Gadzhieva L.A. Experience and results of re-evaluation of gold deposits of the Chelyabinsk Region for open development and leaching by reducing onboard content. *Izvestiya Tulskogo gosudarstvennogo universiteta. Nauki o Zemle*. 2020. N 1, p. 328-339 (in Russian). DOI: 10.46689/2218-5194-2020-1-1-328-339
- Fedoseev V.V., Ryabov Yu.I., Gadzhieva L.A. Experience of Revaluation of Gold Ore Deposits of the Chelyabinsk Region: Improvement of Parameters of Open Pit Mining. *Izvestiya Tulskogo gosudarstvennogo universiteta. Nauki o Zemle*. 2020. N. 4, p. 547-560 (in Russian).
- Vikent'eva O., Prokofiev V., Borovikov A. et al. Contrasting Fluids in the Svetlinsk Gold-Telluride Hydrothermal System, South Urals. *Minerals*. 2020. Vol. 10. N 37. DOI: 10.3390/min10010037
- Shackleton J.M., Spry P.G., Bateman R. Telluride mineralogy of the Golden Mile deposit, Kalgoorlie, Western Australia. *The Canadian Mineralogist*. 2003. Vol. 41, p. 1503-1524.
- Kelley K.D., Romberger S.B., Beatty D.W. et al. Geochemical and geochronological constraints on the genesis of Au-Te Deposits at Cripple Creek, Colorado. *Economic Geology*. 1998. Vol. 93, p. 981-1012. DOI: 10.2113/gsecongeo.93.7.981
- Spry P.G., Foster F., Truckle J.S., Chadwick T.H. The mineralogy of the Golden Sunlight gold-silver telluride deposit, Whitehall, Montana, U.S.A. *Mineralogy and Petrology*. 1997. Vol. 59, p. 143-164. DOI:10.1007/BF01161857
- Ahmad M.N., Solomon M.V., Walshe J.L. Mineralogical and geochemical studies of the Emperor gold telluride deposit, Fiji. *Economic Geology*. 1987. Vol. 82, p. 345-370. DOI: 10.2113/GSECONGEO.82.2.345
- Pals D., Spry P. Telluride mineralogy of the low-sulfidation epithermal Emperor gold deposit, Vatukoula, Fiji. *Mineralogy and Petrology*. 2003. Vol. 79, p. 285-307. DOI: 10.1007/S00710-003-0013-5
- Cooke D.R., McPhail D. Epithermal Au-Ag-Te mineralization, Acupan, Baguio district, Philippines: Numerical simulations of mineral deposition. *Economic Geology*. 2001. Vol. 96, p. 109-131. DOI: 10.2113/GSECONGEO.96.1.109
- Ciobanu C.L., Cook N.J., Capraru N. et al. Mineral assemblages from the vein salband at Sacarim, Golden Quadrilateral, Romania: I. Sulphides and sulphosalts. *Mineralogy and Petrology*. 2005. Vol. 43, p. 47-55.
- Bortnikov N.S., Murzin V.V., Sazonov V.N. et al. The Svetlinsk gold-telluride deposit, Urals, Russia: Mineral paragenesis, fluid inclusions and stable isotope studies. In *Mineral Deposits: Processes to Processing*, Proceedings of the Fifth Biennial SGA



Meeting and the Tenth Quadrennial JAGOD Symposium, 22-25 August 1999, London, UK. Rotterdam, The Netherlands: Balkema Publishers, 1999. Vol. 1, p. 21-24.

13. Sazonov V.N., Popov B.A., Grigor'ev A.N. et al. Crust-mantle mineralization in Salish blocks of eugeosyncline. Sverdlovsk: UrO AN SSSR, 1989, p. 113 (in Russian).

14. Bortnikov N.S. Geochemistry and origin of the ore-forming fluids in hydrothermal-magmatic systems in tectonically active zones. *Geology of Ore Deposits*. 2006. Vol. 48, p. 1-22. DOI: 10.1134/S1075701506010016

15. Snachev V.I., Rykus M.V. Geology and history of the formation of Svetlinskoye gold-sulphide field (East-Uralian Uplift). *Petroleum Engineering*. 2013. Vol. 11. N 2, p. 10-16 (in Russian).

16. Tevelev A.V., Kosheleva I.A. Geological structure and development history of the Southern Urals (East Ural uplift and Trans-Ural). Moscow: Izd-vo Moskovskogo gosudarstvennogo universiteta, 2002, p. 124 (in Russian).

17. Vikent'eva O.V., Bortnikov N.S. The large Svetlinsk Au-Te deposit, South Urals: Telluride mineralization for genetic reconstructions. Proceedings of the 13th SGA Biennial Meeting, 24-27 August 2015, Nancy, France. 2015. Vol. 2, p. 851-854.

18. Gryaznov O.N., Barannikov A.G., Savelyeva K.P. Non-traditional types of gold-argillite mineralization in Mesozoic structures of the Urals. *News of the Ural State Mining University*. 2007. N 22, p. 41-53 (in Russian).

19. Geology of the USSR. VOL. XII. Perm, Sverdlovsk, Chelyabinsk and Kurgan Regions. PART I. Geological Description. Book 2. Moscow: Nedra, 1969, p. 304 (in Russian).

20. State Geological Map of the Russian Federation. Scale 1:200 000. Edition 2nd. Southern Urals series. Sheet N-41-XIII (Plast). Explanatory note. Moscow: Moskovskiy filial VSEGEI, 2018, p. 205 (in Russian).

21. Keyl'man G.A., Boltyrov V.B., Buryan Yu.I., Gorozhankin V.T. The structural evolution of the Kochkar Anticline (South Urals). Geologiya metamorficheskikh kompleksov Urala: trudy Sverdlovskogo Ordena trudovogo krasnogo знамени gornogo instituta im. V.V.Vakhrusheva. 1973. Iss. 91, p. 38-45 (in Russian).

22. Sazonov, V.N., Herk van A.H., Boorder de H. Spatial and Temporal Distribution of Gold Deposits in the Urals. *Economic Geology*. 2001. Vol. 96, p. 685-703. DOI: 10.2113/96.4.685

23. Bortnikov N.S., Vikentyev I.V. Endogenous metallogeny of the Urals. 12th Biennial SGA Meeting, 12-15 August 2013, Uppsala, Sweden, p. 1508-1511.

24. Ogorodnikov V.N., Sazonov V.N., Polenov Yu.A. Minerageny of suture zones of the Urals. P. 1. Kochkar ore district (Southern Urals). Yekaterinburg: Uralskaya gosudarstvennaya gorno-geologicheskaya akademiya, 2004, p. 216 (in Russian).

25. Kisin A.Yu., Koroteev V.A. Block folding and oreogenesis. Ekaterinburg: IGG UrB RAS, 2017, p. 349 (in Russian).

26. Burmistrov A.A. Main paleotectonic stages of structural formation of the Svetlinsky gold deposit (Southern Urals): Sbornik tezisev dokladov. Lomonosovskie chteniya. Sektsiya geologii. Moscow: Moskovskiy gosudarstvennyy universitet im. M.V.Lomonosova, 2021, p. 4-7 (in Russian).

27. Kissin A.Yu., Pritchkin M.E. Fault Tectonics of the Svetlinskoye Gold Deposit (South Urals) and its Role in Ore Control. *Bulletin of Perm University. Geology*. 2015. Vol. 3. N 28, p. 34-42 (in Russian). DOI: 10.17072/psu.geol.28.34

28. Kisin A. Y., Ogorodnikov V.N., Polenov Y.A. et al. The role of the Svetlinskaya granite-gneiss dome structure in the formation of quartz-vein deposits (South Ural). *News of the Ural State Mining University*. 2019. Iss. 4 (56), p. 53-63 (in Russian). DOI: 10.21440/2307-2091-2019-4-53-63

29. Kisin A.Y., Murzin V.V., Tomilina A.V., Pritchkin M.E. Ruby-sapphire-spinel mineralization in marble of the middle and southern urals: geology, mineralogy, and genesis. *Geology of Ore Deposits*. 2016. Vol. 58. N 4, p. 344-359 (in Russian). DOI: 10.7868/S0016777016040031

30. Kisin A.Yu., Polenov Yu.A., Ogorodnikov V.N., Tomilina A.V. The first finding of noble spinel in the Svetlinskoye deposit of rhinestone (the South Urals). *News of the Ural State Mining University*. 2015. Iss. 3 (39), p. 21-27 (in Russian).

31. Kisin A.Yu., Murzin V.V., Pritchkin M.E. Gold in marbles of Svetlinsky quarry (Southern Urals). Trudy Instituta geologii i geokhimii im. akad. A.N.Zavaritskogo. 2017. N 164, p. 223-226 (in Russian).

32. Sazonov V.N., Murzin V.V. Kochkar tabashki and Svetlinsky metasomatic rocks of the femic profile – genetic relatives (Southern Urals). Trudy Instituta geologii i geokhimii im. akad. A.N.Zavaritskogo. 1995. N 142, p. 97-98 (in Russian).

33. Kisters A.F.M., Meyer F.M., Seravkin I.B. et al. The geological setting of lode-gold deposits in the central Southern Urals: A review. *Geologische Rundschau*. 1999. Vol. 87, p. 603-616. DOI: 10.1007/s005310050234

34. Letnikov F.A. Ore-generating essence of granitization processes and metallogeny of granite gneiss domes. Metallogeniya ranego dokembriya SSSR. Leningrad: Nauka, 1984, p. 57-65 (in Russian).

35. Belyavtsev Ya.N., Buryak V.A., Kulish E.A. et al. Metamorphogenic ore formation in Precambrian. Regularities of Accommodation and Prospecting Criteria of Metamorphogenic Deposits. Kiev: Nauk. dumka, 1986, p. 188 (in Russian).

36. Vikentyev I.V., Belogub E.V., Novoselov K.A., Moloshag V.P. Metamorphism of volcanogenic massive sulphide deposits in the Urals. *Ore Geology Reviews*. 2017. Vol. 85, p. 30-63. DOI: 10.1016/j.oregeorev.2016.10.032

37. Puchkov V.N. General features relating to the occurrence of mineral deposits in the Urals: What, where, when and why. *Ore Geology Reviews*. 2017. Vol. 85, p. 4-29.

**Authors:** Alexander Yu. Kissin, Doctor of Geological and Mineralogical Sciences, Head of Laboratory, <https://orcid.org/0000-0002-4020-3182> (Zavaritsky Institute of Geology and Geochemistry, Ural Branch of RAS, Ekaterinburg, Russia), Mikhail E. Pritchkin, Research Engineer, <https://orcid.org/0000-0002-4544-6781> (Zavaritsky Institute of Geology and Geochemistry, Ural Branch of RAS, Ekaterinburg, Russia), Danil A. Ozorin, Research Engineer, [mr.ozorin@mail.ru](mailto:mr.ozorin@mail.ru), <https://orcid.org/0000-0002-8254-8162> (Zavaritsky Institute of Geology and Geochemistry, Ural Branch of RAS, Ekaterinburg, Russia).

The authors declare no conflict of interests.