Basic Information:
Course Title: EPITHERMAL LOW-SULFIDATION PRECIOUS-METAL DEPOSITS: GEODYNAMICS AND GEOLOGY, WALL-ROCK ALTERATION, MINERALOGY, TEXTURES, GEOCHEMISTRY, AND ORE-FORMING PROCESSES

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Total Academic Hours: 35 (22 lectures, 9 exercises and 4 fieldwork)

Annotation

The course aims to provide comprehensive insights into epithermal, low-sulfidation deposits of precious metals, with a focus on examples from Bulgaria. Key topics covered include geodynamics, regional and local geology, wall-rock alterations, ore and gangue mineralogy, mineral macro- and micro-textures, geochemical signature of deposits and ore minerals, and sulfur isotopic composition of some sulfides and sulfates. Additionally, the course delves into ore-forming processes, highlighting mechanisms such as hydrothermal fluid cooling, rock/fluid interaction, fluid boiling, and fluid mixing. Special attention will be given to how these processes influence the ore mineralogy, textures, nanostructures, chemical composition of the main ore and gangue minerals, and sulfur isotopic fractionation. Various research methods will be explored, including powder X-ray diffraction, optical microscopy, scanning electron microscopy, electron probe microanalysis, laser ablation inductively coupled plasma mass spectrometry, isotope ratio mass spectrometry, and transmission electron microscopy. Intriguing results obtained from each method will be presented to enhance understanding. Practical exercises will be conducted in a laboratory featuring a digital stereomicroscope, a digital optical microscope, and mineral samples on display. Furthermore, the course offers field visits to representative deposits of this type in Bulgaria, providing firsthand experience and contextual understanding.

Course content (brief description by topics or modules)

Lectures
Topic 1: Geodynamic setting (2 academic hours);
Topic 2: Geological setting, magmatism, host rocks (3 academic hours);
Topic 3: Hydrothermal alteration (3 academic hours);
Topic 4: Mineralogy (3 academic hours);
Topic 5: Geochemistry – major and minor elements, and trace elements in ores (3 academic hours);
Topic 6: Chemical transport of precious metals in hydrothermal solutions and processes of ore deposition (3 academic hours);
Topic 7: Similarities and differences with other types of precious metal deposits (2 academic hours);

Topic 8: Representative examples of epithermal low-sulfidation precious metals deposits of: textures, mineral composition, indicative trace elements and indicative ratios of chemical elements in individual minerals (3 academic hours);

Laboratory exercises

All exercises are conducted according to the lecturer's instructions and are aimed at consolidating and practical application of the lecture material.

1. Mineral macrotextures – 2 academic hours;
2. Mineral composition – 4 academic hours;
3. Mineral microtextures – 3 academic hours;
4. Hydrothermal alteration – 2 academic hours.

Field study of a representative epithermal low-sulfide deposit: Visit to the Surnak deposit, Krumovgrad region, with on-site study of geological structure, mineralization styles, and mineral textures.

Teaching and assessment methods

- face-to-face learning
- practical assessment when working with mineral specimens
- written assessment

Competencies acquired as a result of training (3–5 points)

- Practical visual introduction to different textures in hand specimens.
- Knowledge for prospecting and exploring epithermal low-sulfidation deposits of precious metals.
- Knowledge about the indicative role of certain mineral textures – macro-, micro- and nano-textures.

Literature:

Browne P.R.L. 1978. Hydrothermal alteration in active geothermal fields. *Ann. Rev. Earth Planet Sciences*, 6, 229–250.

De Yoreo J, P. Gilbert, N. Sommerdijk, R. Penn, S. Whitelam, D. Joester, H. Zhang, J. Rimer, A. Navrotsky, J. Banfield, A. Wallace, F. Michel, F. Meldrum, H. Colfen, P. Dove. 2015. Crystallization by particle attachment in synthetic, biogenic, and geologic environments. *Science*, 349:6247; https:// doi. org/ 10. 1126/ scien ce. aaa67 60.

Dong G, G. Morrison. 1995. Adularia in epithermal veins, Queensland: morphology, structural state and origin. *Mineralium Deposita*, 30, 11–19; https:// doi. org/ 10. 1007/ BF002 08872.

Dong G, Morrison G, Jaireth S (1995) Quartz textures in epithermal veins, Queensland – classification, origin, and implication. *Economic Geology*, 90, 1841–1856; https:// doi. org/ 10. 2113/ gseco ngeo. 90.6. 1841.

Drummond S.E., H. Ohmoto. 1985. Chemical evolution and mineral deposition in boiling hydrothermal systems. *Economic Geology*, 80 (1), 126–147; https://doi.org/10.2113/gsecongeo.80.1.126.

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Fournier R.O. 1985. Silica minerals as indicators of conditions during gold deposition. In: Tooker E.W. (ed) *Geological characteristics of sediment- and volcanic-hosted disseminated gold deposits—search for an occurrence model*; USGS Bulletin 1646, 15–26.

Jones B. 2017. Review of aragonite and calcite crystal morphogenesis in thermal spring systems. *Sedimentary Geology*, 354, 9-23; https://doi.org/10.1016/j.sedgeo.2017.03.012.

Marinova I. 2017. Particular Distribution of Electrum Enrichments along Sinusoidal-Walled Veinlets and Geological Implications: A Case Study from the Eocene Low-Sulfidation Khan Krum Deposit, SE Bulgaria. *Horizons Earth Sci. Research*, 16, 121-155, Nova Sci. Publ., ISBN 978-1-53611-852-0.

Marinova I., V. Ganev, R. Titorenkova. 2014. Colloidal origin of colloform-banded textures in the Paleogene low-sulfidation Khan Krum gold deposit, SE Bulgaria. *Mineralium Deposita*, 49 (1), 49-74; https://link.springer.com/article/10.1007/s00126-013-0473-4.

Marinova I., A. Gadzhalov, G. Bozkaya, M. Tarassov. 2025. Ore and gangue mineral textures, fluid inclusions, mesoscopically structured quartz and pyrite, and their bearing on the genesis of hydrothermal breccias in the low-sulfidation Surnak gold deposit, SE Bulgaria. *Mineralium Deposita*, 60 (6), 1233–1259; https://link.springer.com/article/10.1007/s00126-024-01337-5.

McKibbenM. A., C.S. Eldridge. 1990. Radical sulfur isotope zonation of pyrite accompanying boiling and epithermal gold deposition: a SHRIM study of the Valles Caldera, New Mexico. *Economic Geology*, *85*, 8, 1917–1925; https://doi.org/10.2113/gsecongeo.85.8.1917.

Ohmoto, H. 1972. Systematics of sulfur and carbon isotopes in hydrothermal ore deposits. *Economic Geology*, 67 (5), 551–578; https://doi.org/10.2113/gsecongeo.67.5.551.

Saunders J.A. 1994. Silica and gold textures in bonanza ores of the Sleeper deposit, Humboldt County, Nevada: evidence for colloids and implications for epithermal ore-forming process. *Economic Geology*, 89, 628–638; https://doi.org/10.2113/gsecongeo.89.3.628.

Saunders J.A., P.A. Schoenly. 1995. Boiling, colloid nucleation and aggregation, and the genesis of bonanza Au–Ag ores of the Sleeper deposit, Nevada. *Mineralium Deposita*, 30, 199–210; https://doi.org/10.1007/bf00196356.

Simmons S.F., B.W. Christenson. 1994. Origins of calcite in a boiling geothermal system. *American J. Science*, 294, 361–400; https://doi.org/10.2475/ajs.294.3.361.

Requirements: Completion of the laboratory practicum and written exam.