



Jambura Geoscience Review

p-ISSN 2623-0682 | e-ISSN 2656-0380

Department of Earth Science and Technology, Universitas Negeri Gorontalo



Identification of Ore Mineral and Host Rocks in Balukang Area, Sojol District, Donggala Regency, Central Sulawesi Province

Nurhijah Awaludin Kacong¹, Asrafil¹, Riska Puspita¹¹ Department of Geological Engineering, Tadulako University, Jl. Soekarno Hatta, Palu, Central Sulawesi, 94148, Indonesia

ARTICLE INFO

Article history:

Received: 9 September 2025
 Accepted: 27 December 2025
 Published: 15 January 2026

Keywords:

Balukang; Hydrothermal Mineralization; Ore Mineralogy; Quartz Diorite; Quartz Porphyry Diorite

Corresponding author:

Nurhijah Awaludin Kacong
 Email: nurhijahawaludin@gmail.com

Read online:



Scan this QR code with your smart phone or mobile device to read online.

ABSTRACT

The Balukang area, Sojol District (Donggala Regency, Central Sulawesi), is characterized by dioritic intrusions and active artisanal mine workings that expose mineralized rocks. This study aims to identify the presence of ore minerals, determine their host rocks, and understand the relationship between geological conditions and ore mineral formation in the area. Sampling was carried out at several observation stations identified in the field. Limited exposure restricted the sampling process, so some samples were taken from man-made mining pits that were still accessible. From all the samples collected, four representative samples were selected for petrographic analysis and six representative samples for mineralographic analysis. Petrographic thin sections and polished sections were examined using transmitted- and reflected-light microscopy to characterize mineral assemblages and textures. The analysis results showed the presence of ore minerals such as silver, gold, pyrite, chalcopyrite, sphalerite, covellite, galena, and hematite, with observed textures including intergrowth, replacement, open space filling, and mutual boundary. These textural relationships indicate hydrothermal deposition and provide a basis for interpreting mineral paragenesis in the study area. The ore minerals are associated with quartz diorite and quartz porphyry diorite as host rocks, which are controlled by intrusion lithology and geological structures. Overall, the identified mineral assemblage and host-rock association offer an initial mineralogical baseline to guide exploration targeting along veins, fractures, and stockwork zones. This study is a preliminary study, so further research is needed through detailed geological mapping, geochemical analysis, and fluid inclusion studies.

How to cite: Kacong, NA. (2026). Identification of Ore Mineral and Host Rocks in Balukang Area, Sojol District, Donggala Regency, Central Sulawesi Province. *Jambura Geoscience Review*, 8(1), 120-128. <https://doi.org/10.37905/jgeosrev.v8i1.34381>

1. INTRODUCTION

The island of Sulawesi is one of the regions in Indonesia that has metal mineralization potential closely related to magmatic activity and the presence of intrusive rocks. In convergent-margin settings such as Sulawesi, intrusive magmatism commonly drives hydrothermal circulation that can concentrate Au–Ag and associated base metals. Establishing a first-order mineralogical and lithological baseline is therefore essential for interpreting mineralization style and supporting early exploration decisions (Park et al., 2021; Schirra et al., 2022).

Regional analogs from northwestern Sulawesi provide an important context for interpreting the Balukang mineralization system. Van Leeuwen and Pieters (2011) reported that the Malala deposit in northwestern Sulawesi is the only known porphyry molybdenum deposit in Indonesia and developed in a granitic intrusion system (Leeuwen & Pieters, 2011). The Malala area is the closest area to the northern part of the study area, indicating that the Balukang area is under the influence

of the same regional magmatic system (Leeuwen & Pieters, 2011). Such regional linkages suggest that intrusive emplacement and structural permeability may work together to focus ore-forming fluids and generate vein and stockwork-style mineralization.

Local field evidence further supports the need for systematic documentation of ore minerals and their geological controls. The Balukang area, Sojol District, Central Sulawesi, is located in the northern neck of Sulawesi, which is still regionally influenced by the development of intrusive rocks. Based on field observations, intense illegal gold mining activity was found in the Balukang area, suggesting that other metals accompanying gold may also be present. These indications motivate an initial ore-mineral inventory and host-rock characterization that can support follow-up studies and exploration targeting (Burrows et al., 2020; Schirra et al., 2022).

Regional geological information indicates that intrusive rocks dominate the study area and may provide the principal host for mineralization, while geological structures control fluid pathways and ore distribution. Geologically, the study area is included in the Toli-Toli Geological Map (Ratman, 1976). Stratigraphically, this area consists of two main units, namely the Alluvium and Coastal Deposits (Qal) Formation and the Intrusive Rocks (gr) Formation. Based on the stratigraphic composition of the research area, as reflected by the dominant lithological characteristics observed in the field, it is inferred that the host rocks of ore mineral deposits in the study area are derived from intrusive rocks. In addition, geological structures such as faults and fractures play an important role in directing hydrothermal fluids, thereby controlling the spatial distribution of ore mineralization in the study area (Schirra et al., 2022; Marchesini et al., 2024; Wiyuda et al., 2022; Raihana et al., 2023).

Despite limited mineralogical documentation for Balukang, particularly regarding ore-mineral assemblages, textures, and host-rock relationships, this paper provides a mineralogical-petrographic baseline by identifying ore minerals and textures, characterizing intrusive host rocks, and relating mineral occurrence to the local geological setting for future detailed studies. However, due to limited geological research in the area, this study aims to identify ore minerals and their host rocks.

2. METHOD

2.1. Study area and observation stations

This study aims to identify the characteristics of ore deposits and host rocks in the study area. The study was conducted in the Balukang area, Sojol District, Donggala Regency, Central Sulawesi. Observation stations were determined during fieldwork based on accessible outcrops and artisanal mining exposures; station locations are shown in Figure 1.

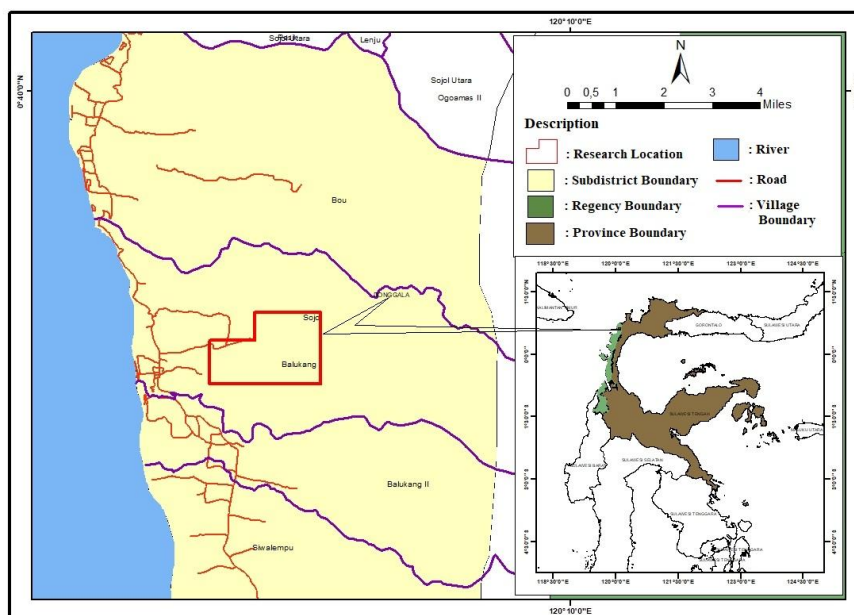


Figure 1. Map of the research area

A regional geological map (modified from Ratman, 1976) provides context for station distribution and host rock interpretation, as shown in Figure 2.

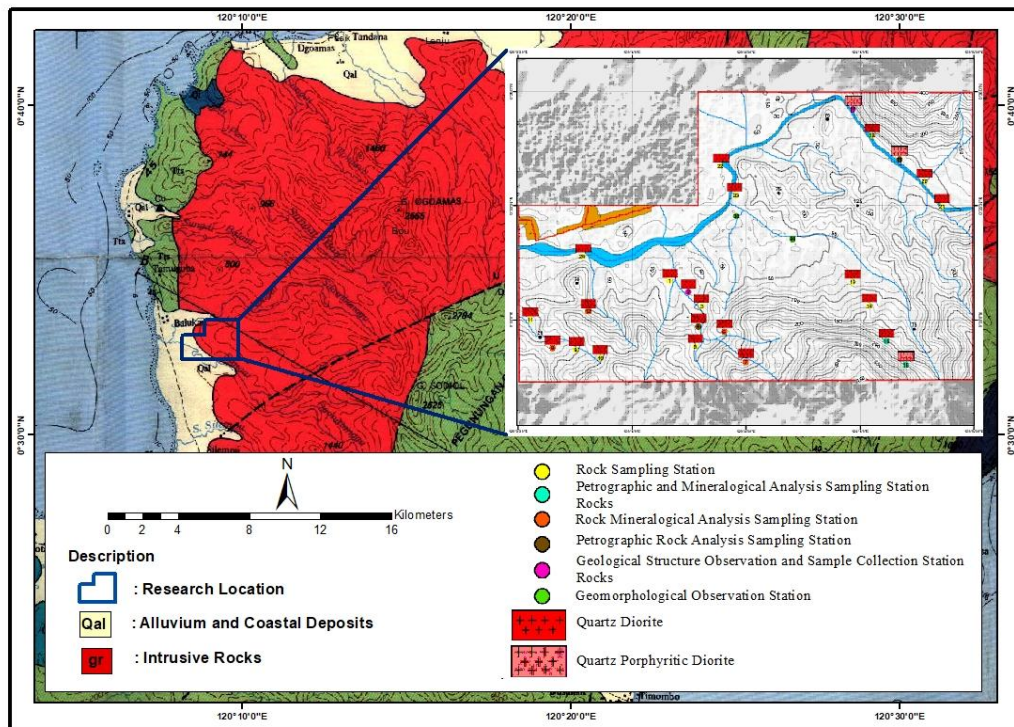


Figure 2. Regional Geological Map of the Study Area (Modified from Ratman, 1976)

2.2. Sampling

The research method was carried out in a structured manner through several stages. The initial stage involved preparation, including literature studies, permit processing, and preparation of equipment and base maps. The next stage was field data collection, which included surface geological surveys and rock sampling. Sampling was carried out at several observation stations identified in the field. Limited exposure restricted the sampling process, so some samples were taken from man-made mining pits that were still accessible. From all the samples collected, four representative samples were selected for petrographic analysis and six representative samples were selected for mineralographic (mineragraphy) analysis.

2.3. Petrography

Four representative samples were prepared as thin sections and examined under transmitted light to characterize host-rock lithology, textures, and alteration features relevant to hydrothermal processes. Observations focused on diagnostic igneous textures and modal mineralogy to support host-rock identification.

2.4. Mineragraphy

Six representative samples were prepared as polished sections and analyzed using reflected-light ore microscopy (mineragraphy) to identify ore minerals and ore textures. Textural relationships were recorded as key evidence for interpreting ore formation processes.

2.5. Data interpretation and workflow integration

Laboratory analysis involved preparing thin and polished sections for petrographic and microscopic analysis using an Olympus CX23 polarizing microscope at UPA Integrated Laboratory, Tadulako University. Results were correlated with field data and literature to interpret relationships between geology and ore mineralization. Interpretation linked field observations with petrographic host-rock analysis and mineralographic textures to understand mineral occurrence and guide future work.

3. RESULTS AND DISCUSSION

3.1. Ore Minerals in the Study Area

The study area in Balukang, part of Mandala Barat in Sulawesi Island, is influenced by magmatic activity in the convergent zone. The quartz diorite and quartz porphyry diorite rocks have holocrystalline-phaneritic textures with minerals including quartz, plagioclase, K-feldspar, biotite, and opaques, similar to North Sojol diorite. Field studies revealed accessible mine pits containing veins and stockworks, indicating ore deposit development in the area.



Figure 3. a) Appearance of quartz veins/veinlets forming a stockwork structure in quartz diorite lithology, b) Appearance of quartz veins in quartz porphyry diorite lithology

3.2. Ore Mineral Identification and Grouping

Ore minerals in the study area were identified through ore microscope analysis (mineragraphy) on six polished sections. The analysis results showed the presence of three groups of ore minerals, namely the native element group (silver and gold), the sulfide group (pyrite, chalcopyrite, sphalerite, galena, covellite), and the oxide group (hematite).

3.3. Native Element Group

Silver is found associated with pyrite, galena, sphalerite, and chalcopyrite. This mineral is microscopic in size and therefore invisible to the naked eye. Its optical properties are grayish white, high reflectivity, euhedral-subhedral in shape, and does not exhibit pleochroism. This mineral exhibits a replacement texture, which indicates the replacement of the original mineral without a change in volume (Ramdohr, 1969; Xing et al., 2021; Zhang et al., 2022)). This replacement process can occur through dissolution and precipitation, oxidation, and solid-phase diffusion. This texture is important in paragenesis studies because replacement minerals are usually younger than the minerals they replace (Figure 4a).

Gold was found together with pyrite, chalcopyrite, and silver, with micro sizes that were also not visible macroscopically. Gold minerals have a golden yellow color, very high reflectivity, subhedral shape, and show an open space filling texture (Figure 4b). This texture is formed in brittle rocks under low pressure, describing the filling of open spaces by hydrothermal fluids. This provides an indication of the geological conditions and temperature of mineral formation (Okada et al., 2025; Tripathi & Deb, 2025).

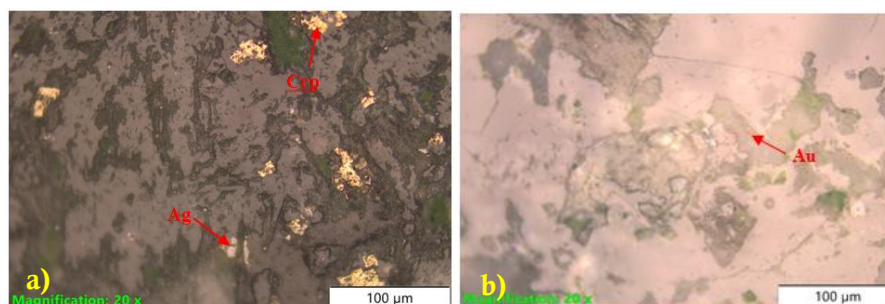


Figure 4. Photomicrographs of polished sections of native element minerals
a) Presence of silver (Ag) and chalcopyrite (Ccp) at station 12/DRT/NAK,
b) Presence of gold (Au) at station 6/DRT/NAK

3.4. Sulfide Group and Oxide Group

3.4.1. Sulfide Group

Pyrite (FeS_2) is the most common mineral, found in almost all samples and associated with other ore minerals. This mineral is fine-grained but still visible to the naked eye, pale yellow-orange in color with cleavage, and exhibits a replacement texture (Figure 5a). This texture shows a replacement process similar to that of native element minerals and plays an important role in determining the sequence of mineral formation.

Chalcopyrite (CuFeS_2) is found associated with pyrite and hematite, has high reflectivity, anhedral shape, and replacement texture (Figure 5b). The formation process of this mineral is similar to other associated sulfide minerals, indicating a close paragenetic relationship.

Sphalerite (ZnS) is micro-sized and associated with pyrite. It has a dark grayish-yellow color, very high reflectivity, and a replacement texture (Figure 5c). This mineral plays a role in the study of sulfide deposit paragenesis.

Galena (PbS) is gray in color with a replacement texture and shows a slight triangular pits texture (Figure 5d). This mineral is associated with pyrite and is micro-sized, reinforcing the sulfide mineral complex in the study area.

Covellite (CuS) is found together with hematite and pyrite with a mutual boundary texture, meaning that the minerals do not penetrate each other (Figure 6). This granular texture indicates simultaneous mineral formation (Ramdohr, 2013).

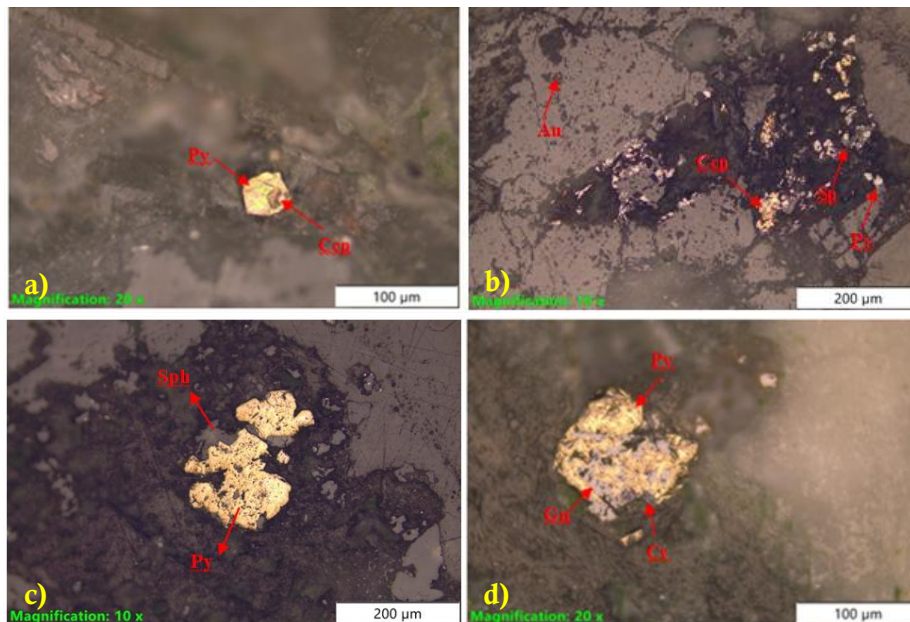


Figure 5. Photomicrographs of polished sections of sulfide minerals, a) Presence of chalcopyrite (Ccp) and pyrite (Py) at station 15/DRT/ANAK, b) Presence of chalcopyrite at station 12/DRT/ANAK, c) Presence of sphalerite (Sph) and pyrite (Py) at station 6/DRT/ANAK, d) Presence of galena (Gn) and pyrite (Py) at station 12/DRT/NAK

Sulfide mineral assemblages shown in Figure 5 indicate close textural and paragenetic relationships among Py, Ccp, Sph, and Gn across multiple stations. These associations highlight sulfide precipitation within the same hydrothermal system and provide a textural basis for interpreting mineral sequence using replacement features and mineral–mineral boundaries observed in polished sections (He et al., 2025; Tang et al., 2022). Figure 6 provides a detailed view of the Cv–Py–Ccp association, emphasizing the mutual-boundary texture that supports near-synchronous mineral growth in the observed microdomain.

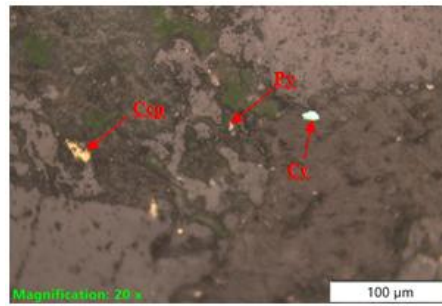


Figure 6. Photomicrograph of polished sections of ore minerals kovelite, pyrite, and chalcopyrite at station 16/DRT/NAK

3.4.2. Oxide Group

Hematite (Fe_2O_3) is reddish in color and associated with covellite and pyrite. This mineral is visible to the naked eye with a replacement texture (Figure 7). This texture is important for determining the order of mineral formation and helps identify earlier and later minerals in paragenesis (Ramdohr, 2013).



Figure 7. Photomicrograph of a polished section of ore minerals Hematite (Hm) associated with ore minerals pyrite (Py) and covellite (Cv) at station 6/DRT/NAK Host Rocks for Mineral Ore Deposits in the Study Area

3.5. Host Rocks for Mineral Ore Deposits in the Study Area

Host rocks are rocks that contain ore deposits or rocks that can be permeated by solutions, where ore deposits are formed. Intrusions and rock walls can act as host rocks. Petrographic and mineralographic analysis results show that quartz diorite and quartz porphyry diorite rocks in the study area act as host rocks for ore mineral deposits. These two rocks are products of intermediate magma intrusion in an active subduction zone environment, which subsequently became the main medium for hydrothermal fluid migration.

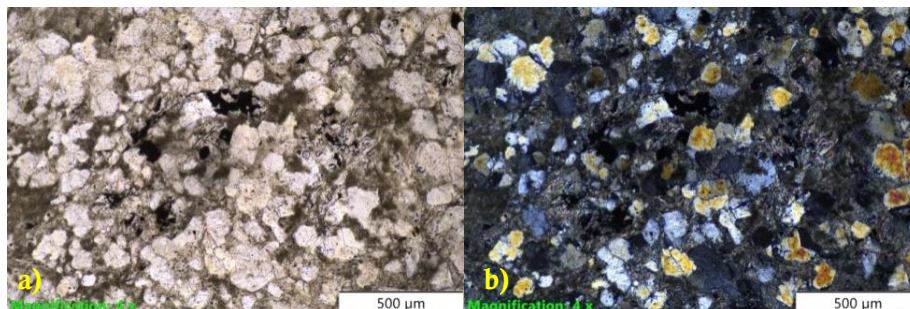


Figure 8. Microscopic appearance of quartz porphyritic diorite lithology at station 15/DRT/NAK showing the presence of sericite (Ser) minerals: (a) photomicrograph illustrating the general porphyritic texture and mineral framework of the host rock; (b) annotated photomicrograph highlighting sericite alteration (Ser) associated with quartz (Qz) and opaque minerals (Opq). Scale bar = 500 µm.

As intrusive rocks, quartz diorite and quartz porphyry diorite have sufficient porosity and fractures to be traversed by hydrothermal fluids, making them sites for hydrothermal alteration and metal ore precipitation. This is evidenced by the discovery of ore mineral associations such as chalcopyrite, pyrite, gold, silver, sphalerite, galena, covellite, and hematite in these rock bodies. The identified alteration zoning, namely potassic, phyllic, and sericitic (Figure 8), supports the existence of a strongly developed hydrothermal system in these rocks. In addition, the mineralization structures in the form of veins (Figure 9) and stockworks (Figure 3) that developed in quartz diorite and quartz porphyry diorite indicate that the fractures in these rocks have functioned as pathways for the movement of mineralizing fluids.



Figure 9. Appearance of quartz veins at station 12

Based on observations of texture, structure, and mineralogy, the presence of quartz diorite and quartz porphyry diorite intrusions accompanied by quartz-sulfide veins and stockwork patterns indicates the development of a magmatic hydrothermal system in the study area. The presence of porphyritic texture in intrusive rocks, the spatial relationship between intrusions and mineralization, and the development of veins and stockworks are common features widely reported in hydrothermal systems associated with intrusions, particularly in porphyry and epithermal environments (Sillitoe, 2010; Jhon et al., 2010).

Texturally, the network of quartz veins and stockworks cutting through the intrusive rocks reflects the movement of hydrothermal fluids through fractures and zones of high permeability, which are characteristic features of porphyry systems and the root part of epithermal systems.

Recent studies indicate that hydrothermal quartz textures, including repeated veins and fracture filling, are important indicators for interpreting fluid evolution and the environment of magmatic-hydrothermal mineral deposit formation (Phillips et al., 2023). Furthermore, the presence of quartz diorite and quartz porphyry diorite as host rocks is also consistent with many Cu-Au porphyry systems that are generally associated with dioritic to granodioritic intrusions (Sillitoe, 2010; Jhon et al., 2010).

However, although characteristics such as quartz diorite intrusions, veins, and stockworks indicate that mineralization in the study area is hydrothermal in nature, the type of deposit cannot be determined with certainty, including porphyry systems, intermediate epithermal sulfidation, or other hydrothermal types. Limitations in rock and ore geochemical data and fluid inclusion analysis mean that parameters such as the temperature and composition of the deposit-forming fluids are unknown. Therefore, further research in the form of geochemical analysis and fluid inclusion studies is needed to confirm the type and evolution of the mineralization system in the study area (Sillitoe, 2010; Phillips et al., 2023).

4. CONCLUSIONS

Research in the Balukang area, Sojol District, Central Sulawesi, identified the presence of ore minerals consisting of native gold (Au) and silver (Ag), as well as sulfide minerals including pyrite (FeS_2), sphalerite (ZnS), chalcopyrite (CuFeS_2), galena (PbS), covellite (CuS), and oxide minerals, namely hematite (Fe_2O_3). These minerals are found in replacement, intergrowth, mutual boundary, and open space filling textures, reflecting deposition by hydrothermal fluids.

Ore mineralization is spatially associated with quartz diorite and quartz porphyry diorite rocks that act as host rocks. This is indicated by the presence of ore minerals and alteration minerals in petrographic and mineralogical observations, as well as the presence of veins and stockwork patterns that cut through the intrusive rocks. This relationship indicates that the intrusive lithology and geological structure control the distribution of mineralization. This research is still a preliminary study, so determining the characteristics and potential of mineralization in more detail requires further research through detailed geological mapping, geochemical analysis of rocks and ores, and fluid inclusion studies.

5. REFERENCES

- Burrows, D. R., Rennison, M., Burt, D., & Davies, R. (2020). The Onto Cu-Au discovery, eastern Sumbawa, Indonesia: A large, Middle Pleistocene lithocap-hosted high-sulfidation covellite–pyrite porphyry deposit. *Economic Geology*, 115(7), 1385–1412. <https://doi.org/10.5382/econgeo.4766>
- He, Z., Qian, G., Pring, A., & Harmer, S. (2025). The mechanism and kinetics of the replacement of chalcopyrite by covellite under mild-hydrothermal conditions (120–200 °C). *Geochimica et Cosmochimica Acta*, 372, 1–18. <https://doi.org/10.1016/j.gca.2025.05.041>
- Marchesini, B., Tavani, S., Mercuri, M., Mondillo, N., Pizzati, M., Balsamo, F., Aldega, L., & Carminati, E. (2024). Structural control on the alteration and fluid flow in the lithocap of the Allumiere–Tolfa epithermal system. *Journal of Structural Geology*, 179, 105035. <https://doi.org/10.1016/j.jsg.2023.105035>
- Okada, S., Torimoto, J., Kuribayashi, T., Nagase, T., Owada, A., Ishibashi, J.-i., et al. (2025). Microscopic evidence for nanoparticle-mediated growth of native gold in sulfide deposits at the Higashi–Aogashima Knoll Caldera hydrothermal field. *PLOS ONE*, 20(1), e0317220. <https://doi.org/10.1371/journal.pone.0317220>
- Park, J.-W., Campbell, I. H., Chiaradia, M., Hao, H., & Lee, C.-T. A. (2021). Crustal magmatic controls on the formation of porphyry copper deposits. *Nature Reviews Earth & Environment*, 2(8), 542–557. <https://doi.org/10.1038/s43017-021-00182-8>
- Phillips, G. N., Vearncombe, J. R., Clemens, J. D., Day, A., Kisters, A. F. M., & von der Heyden, B. P. (2023). Formation of Cu–Au porphyry deposits: Hydraulic quartz veins, magmatic processes and constraints from chlorine. *Australian Journal of Earth Sciences*, 70(7), 1010–1033. <https://doi.org/10.1080/08120099.2023.2237105>
- Raihana, H., Sinaga, J. E. E., Cahyani, A. G., Halaududin, Suhendra, Hutauruk, A., & Sugianto, N. (2023). Identification of alteration zones based on resistivity and induced polarization geoelectric survey. *Jambura Geoscience Review*, 5(2), 119–126. <https://doi.org/10.34312/jgeosrev.v5i2.17931>
- Ramdohr, P. (2013). *The ore minerals and their intergrowths*. Elsevier.
- Ratman, N. (1976). *Geological map of Tolitoli, Sulawesi*. Center for Geological Research and Development, Geological Agency.
- Schirra, M., Laurent, O., Zwyer, T., Driesner, T., & Heinrich, C. A. (2022). Fluid evolution at the Batu Hijau porphyry Cu–Au deposit, Indonesia: Hypogene sulfide precipitation from a single-phase aqueous magmatic fluid during chlorite–white-mica alteration. *Economic Geology*, 117(5), 979–1012. <https://doi.org/10.5382/econgeo.4921>
- Sillitoe, R. H. (2010). Porphyry copper systems. *Economic Geology*, 105(1), 3–41.
- Tang, W., Ye, H., Wang, C., Li, X., & Shi, H. (2022). Textures, trace elements, sulfur, lead and He-Ar isotope analyses of pyrite: Implications for ore-forming processes and the origin of the Shenjiayao gold deposit, southern margin of the North China Craton. *Ore Geology Reviews*, 150, 105195. <https://doi.org/10.1016/j.oregeorev.2022.105195>
- Tripathi, S., & Deb, M. (2025). Decoding imprints of hydrothermal alteration around Imalia polymetallic sulphide deposit, Central Indian Tectonic Zone, and its implications on ore genesis. *Geological Magazine*, 162, e12, 1–27. <https://doi.org/10.1017/S0016756825000056>
- John, D. A., Vikre, P. G., du Bray, E. A., Blakely, R. J., Fey, D. L., Rockwell, B. W., Mauk, J. L., Anderson, E. D., & Graybeal, F. (2010). Descriptive models for epithermal gold–silver

- deposits (Scientific Investigations Report 2010–5070-Q). *U.S. Geological Survey*. <https://doi.org/10.3133/sir20105070Q>
- Van Leeuwen, T. M., & Pieters, P. E. (2011). Mineral deposits of Sulawesi. Geological Agency of Indonesia.
- Wiyuda, M. A., Samodra, S. B., & Utami, P. (2022). Investigasi bawah permukaan pada area Kawah Sikidang, Dieng, Jawa Tengah menggunakan metode geolistrik. *Journal of Applied Geoscience and Engineering*, 1(2), 82–92. <https://doi.org/10.34312/jage.v1i2.17343>
- Xing, Y., Brugger, J., Etschmann, B., Tomkins, A. G., Friedrich, A. J., & Fang, X. (2021). Trace element catalyses mineral replacement reactions and facilitates ore formation. *Nature Communications*, 12, 1388. <https://doi.org/10.1038/s41467-021-21684-5>
- Zhang, Z., Xie, G., & Olin, P. (2022). Texture, in-situ geochemical, and S isotopic analyses of pyrite and arsenopyrite from the Longshan Sb–Au deposit, southern China: Implications for the genesis of intrusion-related Sb–Au deposit. *Ore Geology Reviews*, 142, 104781. <https://doi.org/10.1016/j.oregeorev.2022.104781>