

**PETROLOGY, ALTERATION AND MINERALISATION OF MULTIPHASE
INTRUSION ROCKS IN THE BABAK RIVER AND SIGUNTU RIVER,
PALOPO, SOUTH SULAWESI, INDONESIA**

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Summary. The research was conducted along the Siguntu River and Babak River in the Latupa area, Palopo, South Sulawesi. This study aims to investigate the petrogenesis of granitoid rocks and their implications for hydrothermal mineralisation processes. Methods included detailed field observations combined with microscopic laboratory analyses, comprising petrography, mineralogy and X-ray fluorescence geochemistry of major rock oxides. The study area is dominated by plutonic rocks classified as granitoids, including quartz diorite, granodiorite, and porphyry quartz monzonite, as well as sub-volcanic rocks represented by porphyry andesite. Geochemical data from hydrothermally altered granitoids, particularly granodiorite and porphyry quartz monzonite, indicate derivation from acidic magmas with granodiorite to granite compositions. These rocks are classified as I-type granitoids with high-K calc-alkaline affinity, metaluminous to weakly peraluminous character, and magnesian composition. The presence of three granitoid types suggests multiphase intrusive activity within the study area. This activity generated potassic alteration assemblages characterised by secondary biotite, secondary K-feldspar, anhydrite, and magnetite; inner propylitic alteration with actinolite, epidote and diaspore; and phyllic alteration composed of sericite, quartz, chlorite and pyrite. Associated mineralisation of bornite, chalcocopyrite and covellite is typical of porphyry-type deposits. In contrast, sub-volcanic intrusions produced adularia alteration assemblages consisting of adularia, sericite, quartz and pyrite, accompanied by sphalerite and chalcocopyrite mineralisation characteristic of epithermal deposits. Overall, hydrothermal alteration and mineralisation indicate an overprinting of porphyry systems by epithermal systems formed in a syn-collisional setting evolving toward crustal extension, associated with granitoid exhumation to shallow crustal levels.

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1. Introduction

The presence of mineral deposits is related to a geological complex. One location that has geological complexity and proven mineral deposits is Sulawesi Island. Sulawesi with its distinctive K-shaped pattern is located between the Eurasian Plate, the Indian-Australian Plate, and the Pacific Plate which interact and collide (Katili, 1978) (Figure 1). The implications of these interactions resulted in Sulawesi with four arms of the mega-tectonic province, including the west-north arm which consists of volcanic magmatic product rocks (Sukamto, 1975; Katili, 1978; Hall, 2002; Satyana et al., 2011). Magmatic products in Sulawesi are partly distributed in the

south arm (Priadi et al., 1994; Polve et al., 1997; Surono and Hartono, 2013). The series of magmatic products in the form of granitoid rocks are associated with ore deposits, in the form of epithermal Au-Cu deposits, base metal mineralisation, and Cu-Au-Mo porphyry (Maulana et al., 2013).

The Palopo granitoid covers an area of about 30 km² and intrudes the Eocene-Oligocene age Toraja Formation and Lamasi Complex (Bergman et al., 1996; White et al., 2017). Historical exploration activities have been conducted by several parties to find mineralisation prospects in the Palopo Region (Van Leeuwen and Peters, 2011). The research will be undertaken in Babak River and Siguntu River as

part of the mineral deposit exploration process to analyse the relationship of granitoid rock petrogenesis to the presence of hydrothermal mineralisation in Latuppa Area, Palopo (Figure 2).

2. Regional Geology

The Palopo granitoids are located within a belt of calc-alkaline granitoids of the Miocene-Pliocene age (Polvé et al., 1997). Some samples from the Palopo Granite show the presence of milonites that developed after the crystallisation of the granite. This is confirmed by the microstructure, e.g. brittle-fracturing and mechanically induced grain size re-

duction of recrystallised feldspar and quartz. U-Pb zircon ages of 6.3 Ma were obtained from deformed granodiorite and 5.0 Ma from undeformed granodiorite indicating mylonitisation times between 6.3 Ma and 5.0 Ma (White et al., 2017).

The distribution of granitoid rock types in the form of granodiorite units in the Latuppa Area are characterised by consisting of holocrystalline crystallinity texture, faneritic granularity, euhedral-subhedral fabric shape, and equigranular relations. The mineral composition comprises quartz, plagioclase, biotite, and hornblend (Salang, 2022).

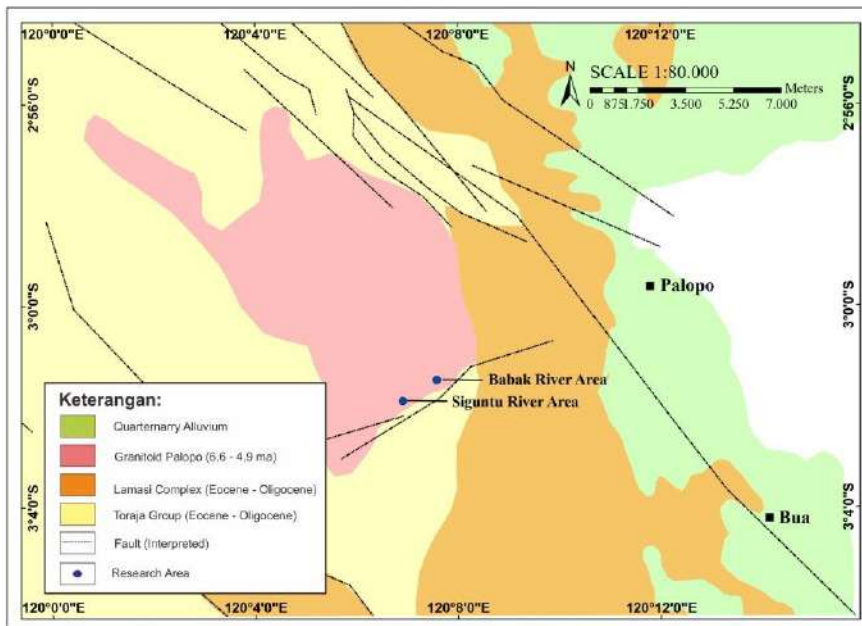


Fig. 1. Regional geology of the study area (White et al., 2017)

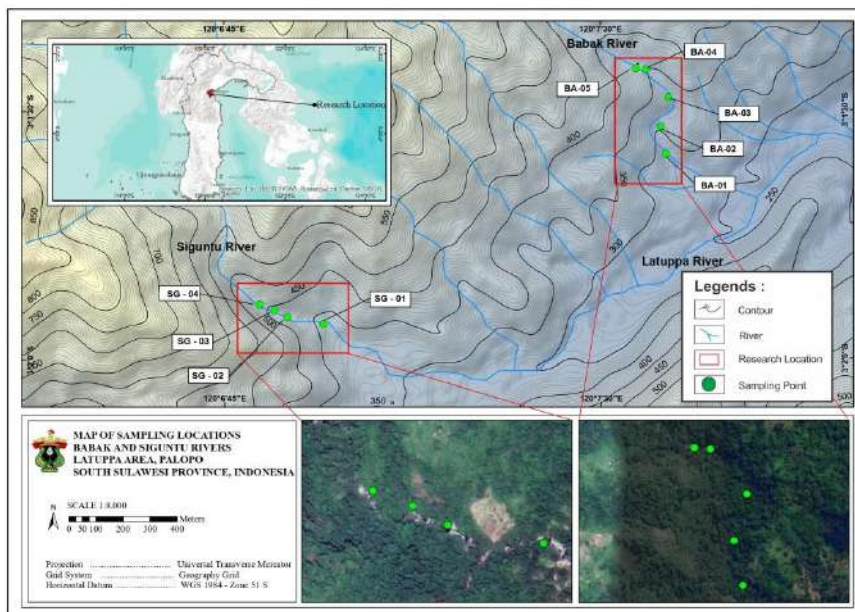


Fig. 2. Research location and sampling points

3. Data and Method

Field data collection stages through direct surveys in the field using geological mapping. Field identification is based on the presence of traces of hydrothermal solution activity in the form of the presence of altered, mineralised rocks and vein zones as well as in areas that have not undergone alteration to see the relationship. The study locations include the Babak River and Siguntu River in the Latuppa Area. Observation of outcrops and rock sampling were carried out in a representative in the research area. A total of nine samples were collected, consisting of five samples from the Babak River (BA-01, BA-02, BA-03, BA-04, and BA-05) and four samples from the Siguntu River (SG-01, SG-02, SG-03, and SG-04). The characteristics of the outcrops encountered show a massive rock structure, so the sampling method is chip sampling and at the outcrops with vein features, the direction and dimensions of the vein are measured.

Microscopic analysis through petrography is used to observe primary minerals and alteration minerals and their characteristics through rock samples (fresh rock and alteration) in the form of thin sections, with an incision thickness of 0.3 mm, and observed under a polarising microscope. Microscopic analysis through mineragraphy is used to determine the type of ore mineral, texture, and its relationship with other ore minerals through observation of rock samples prepared in the form of polished sections and observed under a refraction microscope. Geochemical analysis through XRF (X-Ray Fluorescence Spectrometry) was used to determine the ma-

ior element content values (SiO_2 , TiO_2 , Al_2O_3 , Fe_2O_3 , FeO , MnO , MgO , CaO , Na_2O , K_2O , and P_2O_5) through x-ray fluorescence emitted by atoms in the sample when exposed to x-rays performed on fresh rock samples.

4. Results

4.1. Lithology

Quartz diorite is found in the Babak River which shows intrusive contact with metagranodiorite. The rock shows a massive and slightly foliated structure. Petrographic analysis shows a faneritic texture, consisting of quartz (22%), plagioclase (30%), orthoclase (6%), biotite (8%), muscovite (6%), hornblende (10%), pyroxene (17%), and chlorite (1%) (Figure 4).

Granodiorite is found in the undeformed and mostly deformed form in the Babak River (Figure 3). There are parallel quartz veins, intersecting quartz veins, single quartz veins, pyrite and chalcopyrite, and diorite enclaves. Petrographic analysis shows a faneritic texture, consisting of quartz (21-25%), plagioclase (20-23%), orthoclase (10-18%), biotite (12-15%), muscovite (8-12%), hornblende (2-5%), pyroxene (5-8%), opaque (1-3%), titanite (1%), zircon (1%), sericite (3-6%), epidote (1%), actinolite (1-2%), chlorite (2%), and diasporite (1-2%) (Figure 4). Deformation traces showing ductile deformation observed under a microscope show characteristics of low-grade mylonitic such as the formation of fish texture in mica, porphyroclast from feldspar minerals, undulose extinction quartz texture, bulging texture, and lobate contacts.



Fig. 3. Outcrop and rock appearance of the study area a) Contact of granodiorite intrusion to quartz diorite, b) Contact of andesite intrusion to quartz monzonite, c) Sample of granodiorite with diorite enclave, d) Sample of quartz diorite, e) Sample of andesite and quartz monzonite, f) Sample of quartz monzonite with diorite enclave

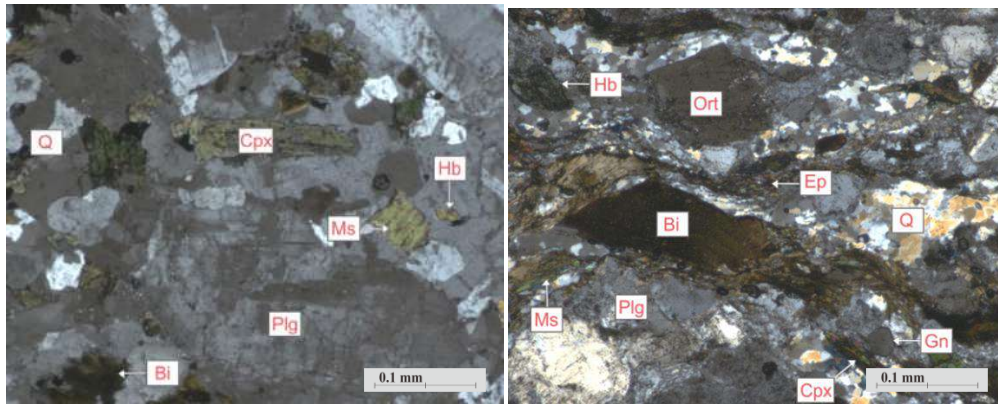


Fig. 4. The Petrographic appearance of rocks a) Granodiorite, b) Deformed granodiorite. Abbreviations: Q – quartz, Cpx – Clinopyroxene, Bi – biotite, Ms – muscovite, Plg – plagioclase, Hb – hornblende, Ort – orthoclase, Ep – epidote, Gn – garnet

The porphyry quartz monzonite encountered at Siguntu River contains parallel quartz veins, intersecting quartz veins, single quartz veins, pyrite and chalcopyrite, and diorite enclaves (Figure 3). Petrographic analysis shows a faneroporphyritic texture, consisting of quartz (14-15%), plagioclase (23-25%), orthoclase (20-22%), biotite (10-12%), muscovite (9-12%), hornblende (2-3%), pyroxene (2-3%), opa (1-3%), garnet (1%), titanite (0.5%), zircon (1%), sericite (2-8%), adularia (1%), epidote (1-2%), actinolite (1%), diasporite (1-2%), and anhydrite (1%) (Figure 5).

Porphyry andesite is found in Siguntu River which shows intrusive contact with porphyry quartz monzonite rocks (Figure 3). Petrographic analysis shows a porphyroafanitic texture, consisting of quartz (8%), plagioclase (30%), orthoclase (6%), biotite (9%), hornblende (10%), pyroxene (16%), groundmass (12%), opaque (3%), sericite (2%), adularia (1%), and epidote (1%) (Figure 5).

4.2. Alteration

Petrographic analysis can show changes in the mineralogy of rock constituents, to identify changes

in primary minerals from magma crystallisation to alteration minerals formed later due to reactions with hydrothermal solutions. Lawless et al. (1997) classify the level of alteration and the results of petrographic observations show the level of rock alteration with a value of 5% to 13% is included in the weakly altered category with a standard value of <25%. The results of petrographic analysis (Table 1) and (Figure 6) show an overprint of alteration zones between potassic-inner propylitic, phyllic, and adularia. The potassic alteration type is characterised by the presence of secondary biotite and secondary K-feldspar minerals associated with anhydrite minerals, while the association of actinolite and epidote reflects the inner propylitic alteration type. The potassic and inner propylitic alteration zones are overprinted with phyllic alteration characterised by the presence of sericite and quartz, and overprinted with adularia alteration characterised by the presence of adularia, quartz, and sericite. It is estimated that the alteration process has occurred in the temperature range of 280-350°C with three alteration episodes.

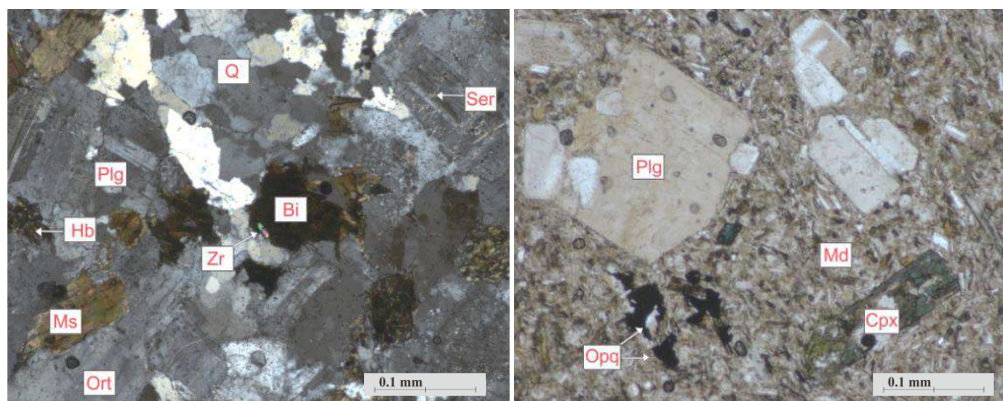


Fig. 5. The Petrographic appearance of rocks a) Porphyry quartz monzonite, b) Porphyry andesite. Abbreviations: Q – quartz, Plg – plagioclase, Bi – biotite, Ms – muscovite, Ort – orthoclase, Hb – hornblende, Ser – sericite, Zr – zircon, Cpx – clinopyroxene, Opq – opaque mineral, Md – groundmass

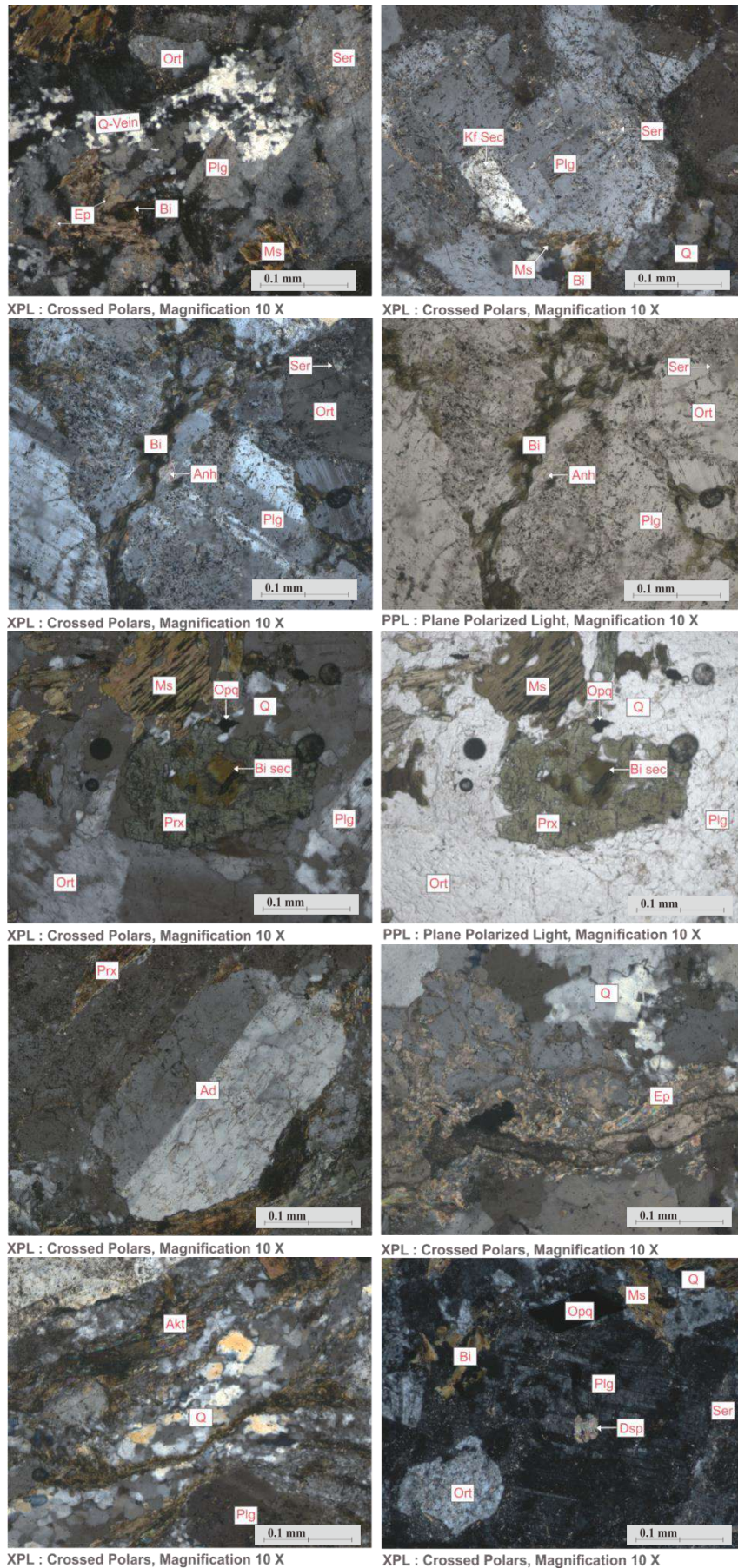


Fig. 6. The appearance of alteration minerals in the petrographic results consists of quartz veins (Q-Vein), secondary K-feldspar (Kf sec), secondary biotite (Bi sec), sericite (Ser), anhydrite (Anh), adularia (Ad), epidote (Ep), actinolite (Akt), and diaspore (Dsp)

Table 1

Temperature range of formation of potassic - inner propylitic, phyllic, and adularia overprint alteration minerals (*White, Hedenquist, 1995; *Thompson, Thompson, 1996; *Corbett, Leach 1998)

Alteration Type	Alteration Minerals	Temperature (celcius degrees)			
		0	100	200	300
Overprint potasik, inner propilitik, phyllic, adularia	Sec Biotite*				—————
	Sec K-feldspar*				—————
	Quartz**		—————	—————	—————
	Anhydrite**			—————	—————
	Actinolite**				—————
	Epidote**			—————	—————
	Diaspore*		—————	—————	—————
	Sericite*			—————	—————
	Adularia*		—————	—————	—————

4.3. Mineralisation

The ore minerals found are formed under certain physiochemical conditions, so the mineralisation process has a sequence of mineral formation in this case paragenesis. Some minerals are formed primarily from the crystallisation of magma, some are carried by hydrothermal solutions and precipitated during the cooling process, and some are due to oxide-hydroxide process due to interaction with meteoric water-dominant conditions.

The stages of ore mineral formation can be identified through observation of the texture of each mineral (Table 2) and (Figure 7). It is estimated that magnetite minerals are formed at the beginning of mineralisation related to magmatic-hydrothermal conditions. Under transfer conditions, hydrothermal solutions that carry sulfides, oxides, and metal elements, then interact with magnetite, so that it will undergo a replacement process by pyrite, arsenopyrite, bornite, and hematite minerals characterised by partial replacement of the rim of magnetite. The ongoing hydrothermal transfer process results in the

replacement of pyrite and bornite by chalcopyrite and covellite, and chalcopyrite and covellite minerals infilling with quartz veins and disseminated in the rock. The same process takes place in magnetite-hematite which is replaced by the oxide-hydroxide mineral goethite under meteoric water dominant conditions. The formation of sphalerite is attributed to hydrothermal solutions brought by the intrusion of porphyry andesite under epithermal conditions that intruded porphyry quartz monzonite. Sphalerite then undergoes replacement by pyrite minerals, further pyrite minerals will undergo replacement by chalcopyrite.

4.4 Geochemistry

Rock geochemical analysis in the form of main oxide elements was carried out on granitoid rock types associated with the presence of hydrothermal solution activity results in the form of quartz veins, alteration minerals, and ore minerals. This aims to analyse the geochemical characteristics of granitoid rocks that carry hydrothermal mineralisation (Table 3).

Table 2

Paragenesis of ore minerals in the Siguntu River and Babak River

Mineralization	Stage I	Stage II	Stage III
	Magmatic-Hydrothermal	Hydrothermal	Hydrothermal
Pyrite	—————	—————	—————
Chalcopyrite		—————	—————
Covellite		—————	
Bornite		—————	
Arsenopyrite		—————	
Sphalerite	—————		—————
Magnetite		—————	—————
Hematite		—————	-----
Goetite		—————	-----

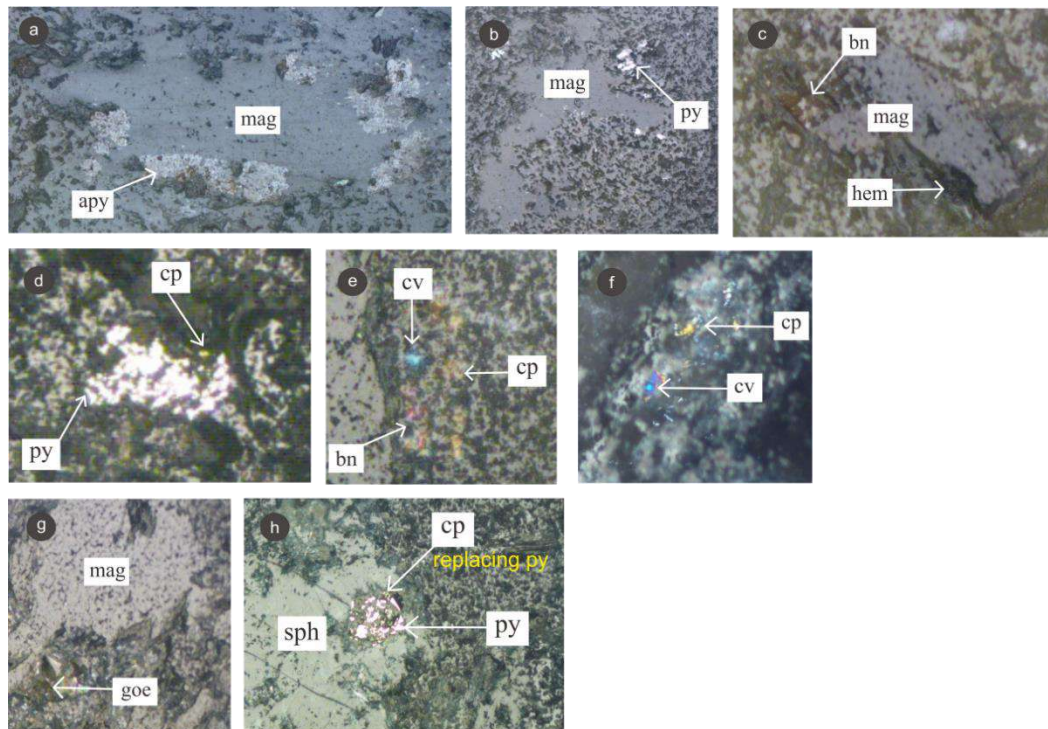


Fig. 7. Microscopic appearance of ore mineral texture a) Replacement of magnetite by arsenopyrite, b) Replacement of magnetite by pyrite, c) Replacement of magnetite by bornite and hematite, d) Replacement of pyrite by chalcopyrite, e) Replacement of bornite by chalcopyrite and covellite, f) Infilling of chalcopyrite and covellite in quartz veins, g) Replacement of magnetite-hematite by goethite, h) Replacement of sphalerite by pyrite and replacement of pyrite by chalcopyrite

Table 3

Major oxide content of the granitoid rock samples of the study area

Mayor Elements	Id Sample		
	BA-01A (wt%)	BA-04 (wt%)	SG-04 (wt%)
SiO ₂	65,02	64,31	67,37
Al ₂ O ₃	16,43	16,71	15,92
Fe ₂ O ₃	3,61	4,25	3,07
CaO	3,96	4,63	3,02
Na ₂ O	3,65	3,58	3,47
K ₂ O	3,61	2,83	3,93
MgO	2,57	2,42	1,81
MnO	0,05	0,07	0,04
P ₂ O ₅	0,17	0,174	0,15
Cr ₂ O ₃	0,06	0,07	0,06
TiO ₂	0,48	0,53	0,42
LOI	0,39	0,43	0,74
Total	100	100	100

The major oxides in rocks can be applied in determining rock characteristics such as magma type and affinity, determining rock names, alumina variations, and rock formation environments.

The basis for classification the rocks refers to the TAS classification according to Cox et al. (1979), based on the ratio between silica value (SiO₂) and alkali value (Na₂O + K₂O). Samples BA-01A and BA-04 are classified as granodiorite and sample SG-04 is classified as granite (Figure 8a).

Determination of magma affinity type refers to the classification according to Paccerrillo and Taylor (1976), with a comparison between silica (SiO₂) and alkali potassium (K₂O). Based on the ratio of silica and alkali potassium values, the three samples belong to the high-K calc-alkaline series (Figure 8b). Based on the comparison of A/CNK and A/NK values according to Shand (1943), it is known that samples BA-01A and BA-04 with A/CNK < 1 or A/NK > 1 are metaluminous and sample SG-04 with

$A/CNK > 1$ or $A/NK > 1$ is peraluminous (Figure 8c). The results of the analysis of the aluminous level of rocks show a metaluminous level in granodiorite rocks and a weak peraluminous level in granite. According to Frost et al., (2001) granitoid rocks with metaluminous to weak peraluminous levels with silica content of 56-77 wt% are included in I-type granitoids. Based on the comparison of silica and

ferro-magnesian values based on Chappel and White (1974), the three samples belong to the magnesian type (Figure 8d). The results of determining the tectonic environment based on Batchelor and Bowden (1985), the formation of granitoid rocks in the R1 and R2 multication diagrams indicate a pre-plate collision environment towards syn-collision (Figure 8e).

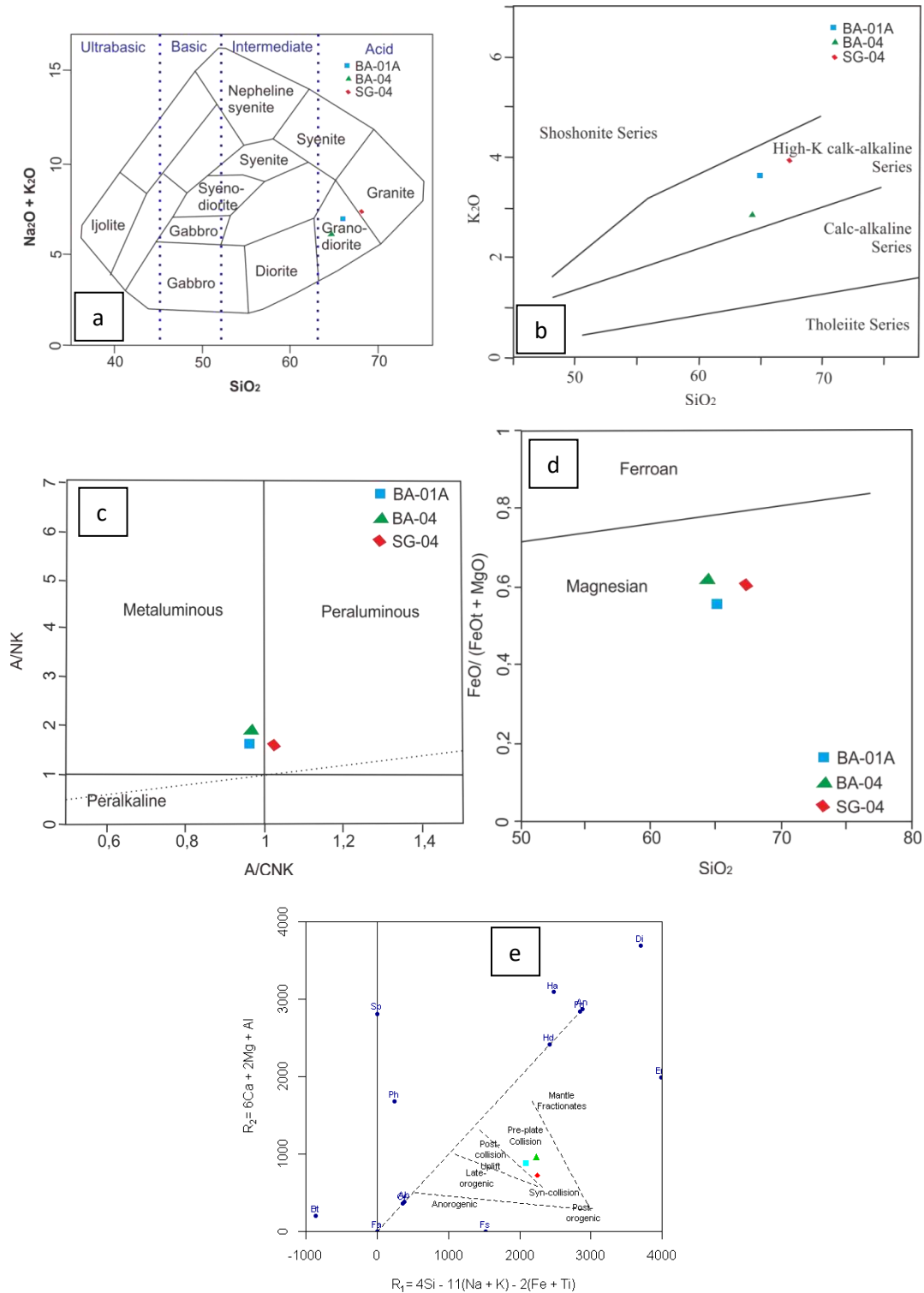


Fig. 8. Results of geochemical characteristics determination a) Rock name determination, b) Magma affinity, c) Alumina variation, d) Ferro-magnesian, e) Tectonic environment

5. Discussion

Based on petrological and geochemical data, the granitoid of the study area was formed at the transition of the tectonic process from pre-plate collision to syn-collision in the compression setting between the West Sulawesi Microcontinent and the Sula-Spur Microcontinent to late-collision in the extension setting due to the Banda Sea plate roll back (Figure 9). Based on the age of the oldest granitoid rock, the quartz diorite, which is 6.4 Ma (Zhang et al., 2020), the granitoid magma formation process occurred before 6.4 Ma, which is interpreted as Middle Miocene to Late Miocene.

The initial pre-plate collision tectonic process was associated with the subduction of the Indo-Australian Plate beneath the West Sulawesi Microcontinent which resulted in partial melting of the mafic rock component and mantle component to produce mafic magma. Hildreth and Moorbath 1988; Richards, 2003, explained that hydrous mafic magma from the mantle wedge will be transferred to the mash zone (melting, assimilation, storage, homogenisation) at the base of the continental crust, followed by the rise of magma to shallower levels to form granitoid rocks. The mafic magma undergoes differentiation to form plagioclase, pyroxene, magnetite, and other non-hydrous minerals that increase the H₂O content in solution and will undergo assimilation with lower crustal components to form more intermediate magmas which are thought to be related to the formation of quartz diorite. Geochemical analyses comparing SiO₂ and other oxide content indicate fractionated crystallisation at the beginning to form plagioclase, hornblende, and pyroxene minerals while K₂O-containing minerals will crystallise at the end to form orthoclase, biotite, and muscovite. During syn-collision, intermediate magmas undergo fur-

ther differentiation and assimilation with potassium-rich crustal components such as metasediments to produce acidic magmas that move up to the middle crust where magmas mingling with quartz diorites to eventually form granodiorites containing biotite and muscovite. The syn-collision process associated with compression forces caused some of the granodiorite to deform in the ductile zone. Meanwhile, the late-collision process associated with the extension force produces asthenospheric upwelling and delamination of the lower crust so that there is assimilation between the potassium-rich lower crustal components and the mantle which is the source of porphyry quartz monzonite or granite.

Hydrothermal fluid activity in the Latuppa area occurs at mesozonal depth (Musri et al., 2011). The rock intrusion process of the study area consists of early intrusive forming quartz diorite, inter-intrusive forming early porphyry from granodiorite, late-intrusive forming late- mineral porphyry from porphyry quartz monzonite, and intrusive post porphyry forming porphyry andesite which is tectonically associated with the process of exhumation due to crustal extension resulting in stages of hydrothermal fluid penetration and environmental changes to become shallower resulting in alteration overprints and ore mineral replacement (Figure 10).

The alteration process shows an overprint between potassic-phyllitic-adularia, inner propylitic-phyllitic-adularia, also shown replacement of magnetite ore minerals by pyrite, bornite, arsenopyrite, replacement of pyrite by chalcopyrite, and replacement of sphalerite by pyrite followed by replacement of pyrite by chalcopyrite. Maulana et al., (2019) estimated the exhumation of Granitoids related to the Palopo Granitoids in Mamasa and Masamba at a rate of 0.37 and 1.6 mm/year.

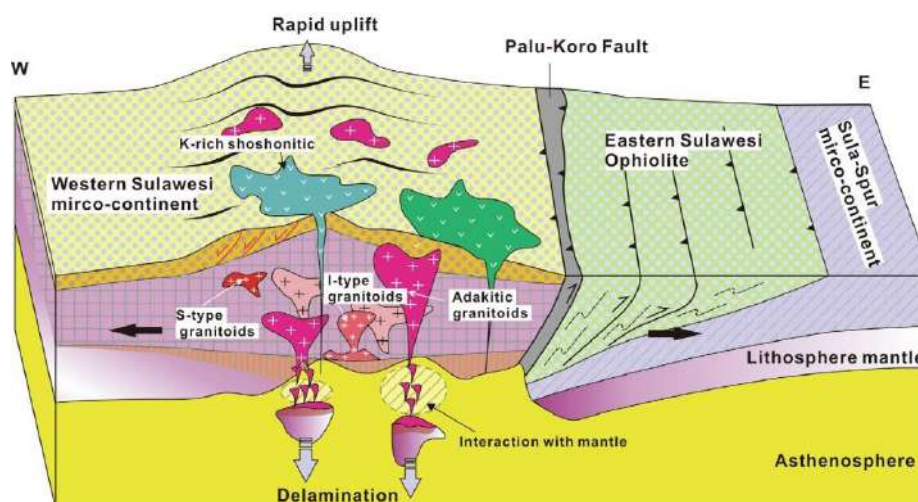


Fig. 9. Illustration of the tectonic evolution of Miocene-Pliocene pre-plate collision, syn-collision, and late-collision (extension) related to granitoid magma formation in the West Sulawesi Microcontinent (Liu et al., 2020)

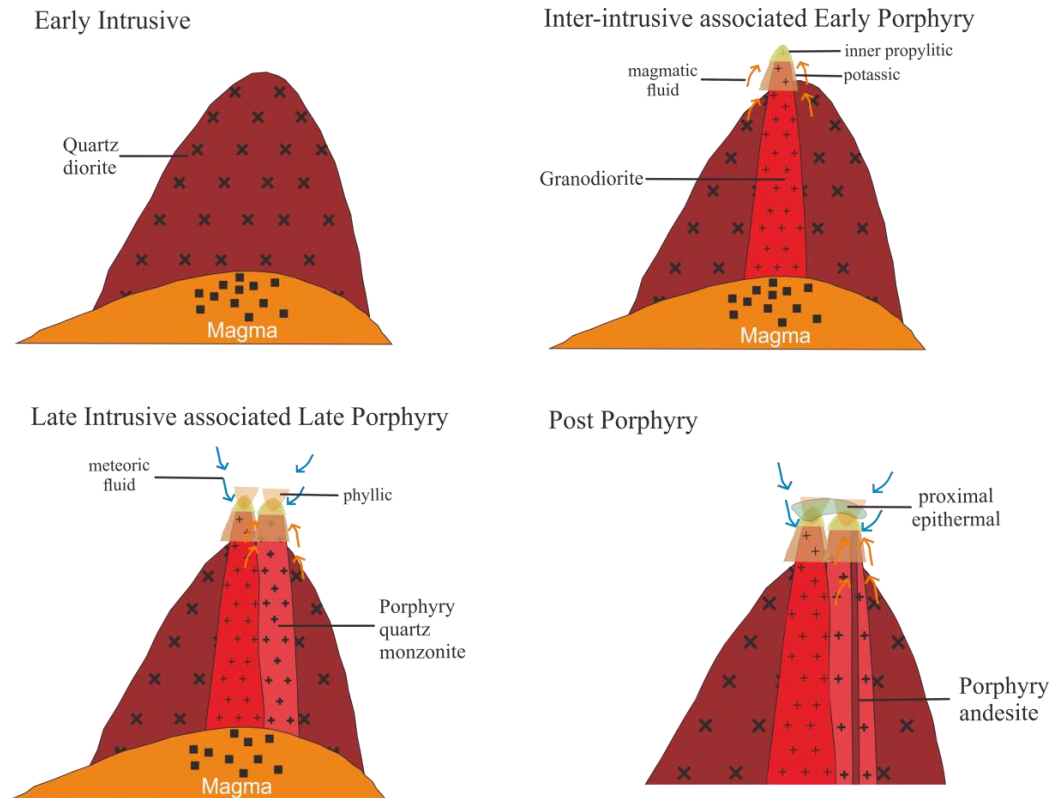


Fig. 10. Illustration of the genetic model of alteration and mineralisation stages of the study area (Illustration adapted from Sillitoe (2010); Musri et al. (2011))

The types of deposits formed are associated with potassic, inner propylitic and phyllic alteration and mineralisation of bornite, chalcopyrite and covellite belonging to the porphyry deposit type. The porphyry deposit type is associated with magmatism of granodiorite and porphyry quartz monzonite I-type granitoids containing high-K calc-alkaline with metaluminous to weak peraluminous. The exhumation process places the granitoids associated with porphyry deposits into shallower crustal levels which are then overprinted by deposit types associated with adularia alteration and sphalerite-chalcopyrite mineralisation characteristic of epithermal deposit types in proximal environments associated with late magmatism in the form of porphyry andesite subvolcanic intrusions. Shallower conditions led to the formation of hydrothermal fluids from the epithermal system flowing through the zone of alteration and porphyry mineralisation. These fluids added new alteration minerals and mineralisation, creating a complex combination of minerals from both systems.

6. Conclusions

From the compilation of field data and laboratory analysis, it was concluded:

1. The lithology of the study area consists of granitoid-type plutonic rocks in the form of quartz diorite and granodiorite in Sungai Babak and granit-

oid-type plutonic rocks in the form of porphyry quartz monzonite and sub-volcanic rocks in the form of porphyry andesite in Sungai Babak.

2. The geochemistry of granitoid rocks associated with hydrothermal mineralisation in the form of granodiorites and granites which are I-type granitoid, high-K calc-alkaline, metaluminous to weakly peraluminous, formed in pre-plate collision to syn-collision, and late collision environments associated with compression to extension forces that produce acidic magmas from the melting of mafic rocks that undergo differentiation and assimilation with the lower crust.

3. The study area experienced multiphase intrusion associated with mineralisation in the inter-intrusive (granodiorite) to late-intrusive (porphyry quartz monzonite/granite) forming overprints of potassic alteration, inner propylitic, phyllic, and bornite-chalcopyrite-covellite mineralisation belonging to the porphyry deposit type, and post porphyry intrusive forming adularia alteration and sphalerite-chalcopyrite mineralisation belonging to the epithermal deposit type. The porphyry deposit type is overprinted by epithermal deposits.

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ПЕТРОЛОГИЯ, ИЗМЕНЕНИЯ И МИНЕРАЛИЗАЦИЯ МНОГОФАЗНЫХ ИНТРУЗИВНЫХ ПОРОД В РАЙОНАХ РЕК БАБАК И СИГУНТУ, ПАЛОПО, ЮЖНЫЙ СУЛАВЕСИ, ИНДОНЕЗИЯ

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Резюме. Исследование было проведено вдоль рек Сигунту и Бабак в районе Латуппа, город Палопо, Южный Сулавеси. Целью данного исследования является изучение петрогенезиса гранитоидных пород и их влияния на процессы гидротермальной минерализации. В работе использовались методы детальных полевых наблюдений в сочетании с микроскопическими лабораторными исследованиями, включающими петрографический и минераграфический анализы, а также геохимический анализ основных оксидов пород методом рентгенофлуоресцентной спектроскопии (XRF). Район исследований преимущественно сложен плутоническими породами, классифицируемыми как гранитоиды, включая кварцевый диорит, гранодиорит и порфировый кварцевый монзонит, а также субвулканические породы, представленные порфировым андезитом. Геохимические данные по гранитоидным породам, подвергшимся гидротермальной переработке, в частности по гранодиориту и порфировому кварцевому монзониту, свидетельствуют об их образовании из кислых магм с составом от гранодиорита до гранита. Данные породы относятся к гранитоидам I-типа, характеризуются высококальциевой кальций-щелочной серией, мета-алюминиевым до слабо пералюминиевым составом и магнезиальной природой. Наличие трех типов гранитоидов указывает на многофазную интрузивную деятельность в пределах исследуемой территории. В результате этой деятельности сформировались калиевые ассоциации гидротермального изменения, характеризующиеся вторичным биотитом, вторичным калиевым полевым шпатом, ангидритом и магнетитом; внутренняя пропиловитовая ассоциация с актинолитом, эпидотом и диаспором; а также филлитовая ассоциация, представленная серицитом, кварцем, хлоритом и пиритом. Ассоциированная минерализация борнита, халькопирита и ковеллина характерна для месторождений порфирового типа. В отличие от этого, субвулканические интрузии обусловили развитие адулярных измененных ассоциаций, включающих адуляр, серицит, кварц и пирит, сопровождаемых минерализацией сфалерита и халькопирита, типичной для эпитермальных месторождений. В целом, гидротермальные изменения и минерализация указывают на наложение эпитермальных систем на более ранние порфировые системы, сформированные в синколлизивной тектонической обстановке, которая эволюционировала в сторону растяжения земной коры и сопровождалась эксгумацией гранитоидных пород к приповерхностным уровням коры.

Ключевые слова: петрогенез, альтерация, минерализация, гидротермальный гранитоид, р. Сигунту, р. Бабак

İNDONEZİYADA CƏNUBİ SULAVESİNİN PALOPO ƏYALƏTİNDƏ BABAK VƏ SİQUNTU ÇAYLARINDA ÇOXFAZALI İNTRUZİV SÜXURLARIN PETROLOGİYASI, DƏYİŞDİRİLMƏSİ VƏ MİNERALLAŞMASI

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Xülasə. Tədqiqat Cənubi Sulavesinin Palopo şəhərinin Latuppa bölgəsindəki Siguntu və Babak çayları boyunca aparılmışdır. Bu tədqiqatın məqsədi qranit süxurların petrogenezini və onların hidrotermal minerallaşma proseslərinə təsirini öyrənməkdir. Əsərdə petroqrafik və mineraloqrafik analizlər, həmçinin rentgen flüoresan spektroskopiyaya (XRF) üsulu ilə süxurların əsas oksidlərinin geokimyəvi analizi daxil olmaqla mikroskopik Laboratoriya tədqiqatları ilə birlikdə ətraflı mədən müşahidələri metodlarından istifadə edilmişdir. Tədqiqat sahəsi əsasən kvars diorit, qranodiorit və porfir kvars monsonit və porfir andezit ilə təmsil olunan subvulkanik süxurlar da daxil olmaqla qranitoidlər kimi təsnif edilən plutonik süxurlardan ibarətdir. Hidrotermal emaldan keçmiş qranitoid süxurları, xüsusən qranodiorit və porfir kvars monsoniti üçün geokimyəvi məlumatlar, qranodioritdən qranitə qədər olan tərkibi olan turşu magmalardan əmələ gəldiyini göstərir. Bu süxurlar I tip qranitoidlərə aiddir, yüksək kalium kalsium-qələvi seriyası, metalüminiumdan bir qədər peralumin tərkibinə və maqneziya təbiətinə malikdir. Üç növ qranitoidin olması tədqiq olunan ərazidə çox fazlı müdaxilə fəaliyyətini göstərir. Bu fəaliyyət nəticəsində ikincil biotit, ikincil kalium feldispat, anhidrit və maqnetit ilə xarakterizə olunan hidrotermal dəyişikliyin kalium birləşmələri meydana gəldi; aktinolit, epidot və Diasporla daxili propilit əlaqəsi; serisit, kvars, xlorit və pirit ilə təmsil olunan fillit Dərnəyi. Bornit, xalkopirit və kovellinin əlaqəli minerallaşması porfir tipli yataqlar üçün xarakterikdir. Bunun əksinə olaraq, subvulkanik müdaxilələr epitermal yataqlara xas olan sferit və xalkopiritin minerallaşması ilə müşayiət olunan adulyar, serisit, kvars və pirit daxil olmaqla adulyar dəyişdirilmiş birləşmələrin inkişafına səbəb oldu. Ümumiyyətlə, hidrotermal dəyişikliklər və minerallaşma, yer qabığının uzanmasına doğru inkişaf etmiş və qranitoid süxurların qabığın səthə yaxın səviyyələrinə eksqumasiyası ilə müşayiət olunan sinkollizasiya tektonik şəraitdə əmələ gələn əvvəlki porfir sistemlərində epitermal sistemlərin üst-üstə düşməsinə göstərir.

Açar sözlər: petrogenez, alterasiya, minerallaşma, hidrotermal qranitoid, River Siguntu, River Babak