UDK 55
ISSN 0537-846X

GEOINSTITUT

R A D O V I

RADOVI Geoinstituta, knjiga 39, Beograd 2004.

Autori su naučno odgovorni za svoja izlaganja

U troškovima izdavanja ovog broja časopisa "RADOVI" učestvovalo je:
MINISTARSTVO ZA NAUKU I TEHNOLOGIJU, Beograd, Nemanjina 22-24

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RADOVI Geoinstituta, Knjiga 39, Beograd, 2004.
Bulletin of Geoinstitute, vol. 39, 2004, Belgrade

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Bulletin of Geoinstitute, vol. 39, 2004, Belgrade

BIBLID 0537-846X (2004), 39, p. 85-94
UDK 553.41+553.312(497.11)
Originalni naučni rad

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ZLATO U KVARCNO-HEMATITSKIM MINERALIZACIJAMA OKOLINE ALDINCA NA STAROJ PLANINI

Ključne reči: Stara planina, Aldinac, gabro, granodiorit, zlato, hematit, limonit.

Izvod: Rudnu zonu Aldinca pretežno izgrađuju gabroidne stene, predstavljene piroksenskim gabrovima i dijabazima, u koje su utisnute granodioritske stene, pretežno granodiorit-porfiriti, a u manjoj meri, kvarc-latiti i daciti. Rudonosnost ove zone se ogleda u pojavama Fe, Mn, Cu, Mo, W, Sn, Pb, Bi, Ag i Au. Kvarcno-hematitske mineralizacije imaju naročiti značaj, jer se u njima nalaze najveće koncentracije zlata. U ovom radu je definisan mineralni sastav ovih mineralizacija i način pojavljivanja zlata, pomoću rudnomikroskopskih i rendgenskih analiza. Takođe su prikazani rezultati hemijskih analiza šest pojedinačnih proba i monomineralnih koncentrata iz jedne probe.

UVOD

Jugoistočni deo zaglavačkog masiva gabra u kome su otkrivene veće mase granodiorita i njegovih žičnih ekvivalenata je značajna oblast Stare planine zbog pojava bakra, bizmuta, zlata, srebra i molibdena. Osim piroksenskih gabrova i granodiorit-porfirita, koji čine osnovno obeležje ove rudne zone, od ostalih stena zastupljeni su: biotit-amfibolski gnajsevi, mermeri, gnajs-graniti, metasedimenti, dijabazi, granodioriti, kvarc latiti i daciti (Slika 1).

U ataru sela Aldinac, koje se nalazi 34 km istočno od Knjaževca, i njegovoj široj okolini, utvrđene su rudne pojave Fe, Cu, Au, Mn žičnog i impregnacionog tipa, koje su genetski vezane za proboje granodiorit-porfirita u gabrovima, utisnutih duž regionalnog raseda Repušnice u vreme hercinske epohe (M i l o š a k o v i ć et al., 1986). Najnoviji rezultati potvrđuju ovu teoriju, ali ukazuju i na neke osobensti koje prilikom dosadašnjih istraživanja nisu konstatovane.

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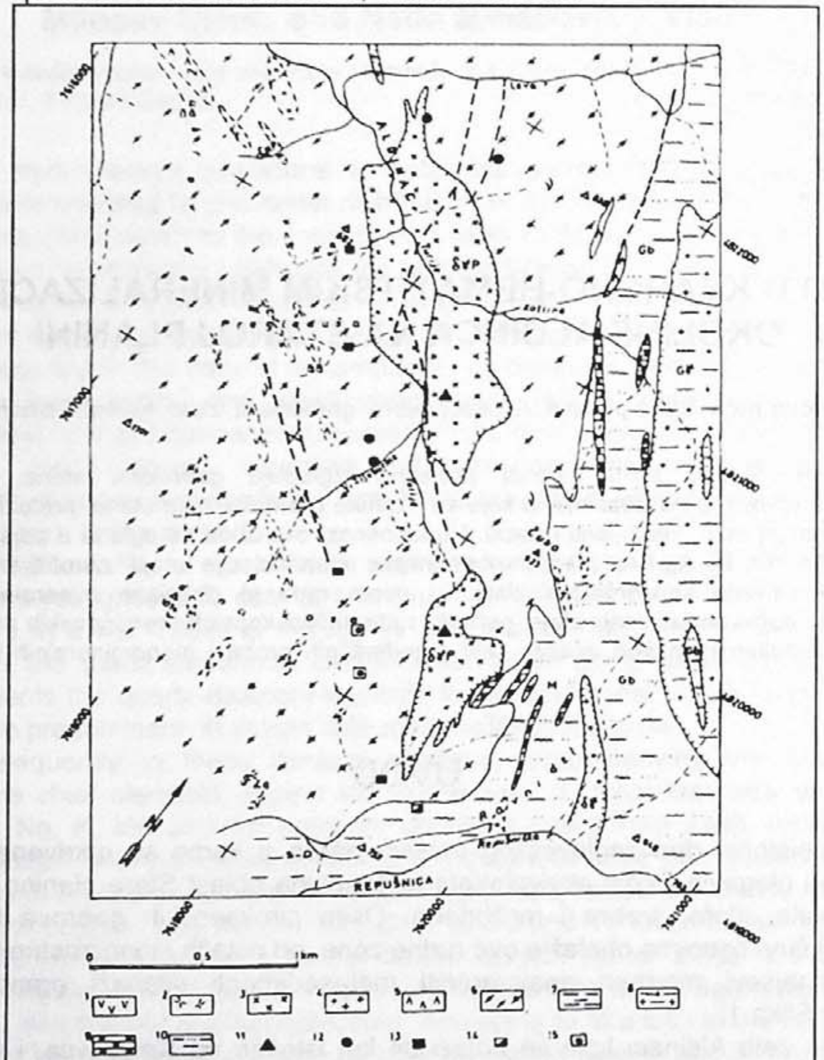
OPŠTE METALOGENETSKE KARAKTERISTIKE ALDINAČKE RUDNE ZONE

Rudne pojave Fe, Cu, Au, Mn Aldinačke rudne zone se nalaze u kontaktnom delu proboja granodiorit-porfirita u gabru, mikrogabru i dijabazu, a pojavljuju se u vidu žica i impregnacija, kako u gabru, tako i u samom granodioritu. Debljina otkrivenih rudnih žica je od nekoliko santimetara do par metara, a sreću se skoro čiste kvarcno-piritske žice, takođe i polimineralne kvarcne žice, sa ili bez kalcita.



Slika 1. Pregledna geološka karta Aldinačke rudne zone (K o v a č e v i ć et al., 2003)
1. daciti; 2. kvarclatiti; 3. granodiorit-porfiriti; 4. granodioriti; 5. dijabazi; 6. gabroidne stene; 7. metasedimenti; 8. gnajs-graniti; 9. mermeri; 10. biotit-amfibolski i amfibol-biotitski gnajsevi; 11. rudne pojave U, Mo; 12. rudne pojave Cu, W, Au; 13. rudne pojave Cu, Fe, Au, Ag; 14. rudne pojave Fe, Mn, Au, Ag; 15. rudne pojave Cu, Fe, Sn, W, Ag, Au.

Na osnovu dosadašnjeg, relativno skromnog nivoa istraženosti, moguće je izdvojiti nekoliko mineralnih parageneza pneumatolitsko-hidrotermalnog i hidrotermalnog načina postanka:

- magnetitsko-halkopiritsko-kasiteritska,
- hematitsko-halkopiritsko-volframitska,

- piritsko-halkopiritsko-šelitska,
- piritsko-magnetitsko-halkopiritsko-molibdenitska,
- piritsko-molibdenitska i
- hematitsko-magnetitska.

Takođe, treba napomenuti, da su prilikom ranijih istraživanja (C u k u ć a n, 1961) u pojedinim zonama Aldinačkog granodiorita konstatovani povećani sadržaji urana, koji ovom prilikom nije istraživan.

U celini posmatrano, rudnu zonu Aldinac-Repušnica karakteriše geohemijska specijalizacija na Fe, Mn, Cu, W, Mo, Sn, Pb, Bi, Ag i Au.

Prema relativnoj zastupljenosti primarni minerali su: pirit, halkopirit, magnetit i hematit, akcesorni su: molibdenit, šelit, volframit, kasiterit, galenit, tetraedrit i arsenopirit, dok su getit, psilomelan, piroluzit, halkozin, bornit, kovelin i malahit sekundarni minerali.

Zlato, srebro i bizmut se nalaze kao samorodni elementi i prirodne legure, ili pak u kristalnim rešetkama drugih minerala. Bakar je takođe konstatovan kao samorodan, ali neznatno.

Kvarcno-hematitske žice predstavljaju završne produkte hidrotermalnih aktivnosti koje su se dešavale duž pukotina i rasednih zona u gabru, na šta ukazuje njihov prostorni razmeštaj, kao i relikti "hematit-martita" (R a d u s i n o v i ć, 1988). Ove rudne žice sadrže povećane koncentracije zlata i srebra, koje su katkad i znatno veće u odnosu na kvarcne žice sa piritom, halkopiritom i šelitom. Takođe su karakteristični povećani sadržaji bakra, volframa, kalaja i bizmuta u vidu primesa, dok njihovi minerali nisu konstatovani u ovoj paragenezi.

MATERIJAL I METODE ISPITIVANJA

Pošto se hematit odlikuje nejednakim intenzitetom i srednjim do visokim ekstenzitetom pojavljivanja u rudnim žicama aldinačke rudne zone, u ovom radu su prikazani rezultati ispitivanja samo onih uzoraka, u kojima je upravo hematit dominantna, ili jedna od vodećih mineralnih komponenti. Uzorci su odabrani na osnovu rudnomikroskopske analize, vršene u sklopu prospekcijskih istraživanja i izrade geološke karte 1:10.000 (K o v a č e v i ć, 2001, 2002).

Od šest ispitivanih uzoraka izabran je jedan, na kome je izvršena određena mineraloška priprema, u cilju što kvantitativnijeg razdvajanja pojedinačnih mineralnih vrsta, u kojima su se potom zasebno hemijski određivali sadržaji zlata, srebra i bakra. Uzorak je ručno zdrobljen i odvojen u tri frakcije: (1) od 0,15-0,5 mm, (2) od 0,063-0,15 mm i (3) ispod 0,063 mm.

Frakcije (1) i (2) su razdvojene mokrim postupkom, a razdvajanje mineralnih komponenti je izvršeno na frakciji (1), i to ručnim magnetom i na elektromagnetu. Način srastanja mineralnih zrna je onemogućio potpuno razdvajanje magnetita od hematita, kao i kvarca od rudnih minerala, međutim, višestrukim ponavljanjem postupka razdvajanja je postignuta zadovoljavajuća "čistoća" monomineralnih frakcija, koje su potom kvantitativno sprašene za dalju analizu. Razdvajanje mokrim postupkom je vršeno u cilju postizanja veće čistoće monomineralnih uzoraka, a takođe, i da bi se izvršilo koncentrisanje limonitske materije u frakciji (3).

Uzorci su snimljeni na automatskom difraktometru za prah marke PHILIPS, tip PW-1710. Upotrebljena je dugo-fokusna (LFF), bakarna anoda (U = 40 kV i I = 30 mA), pri čemu je korišćeno monohromatsko $K\alpha 1$ zračenje (λ = 1,54060Å) i Xe proporcionalni brojač. Snimljen je opseg ugla 2θ od 5o do 65o, sa korakom 0,02o i zadržavanjem brojača u vremenu od 1 sekunde. Za merenje ugaonih položaja difraktovanih maksimuma i njima pripadajućih intenziteta, primenjen je bazni program PW-1877. Preciznost difraktometra kontrolisana je pre i posle eksperimenta pomoću Si standarda. Identifikacija prisutnih mineralnih faza urađena je upoređenjem međupljosnih rastojanja (d) i relativnih intenziteta (I) sa literaturnim podacima, odnosno odgovarajućom karticom iz JCPDS-ASTM datoteke.

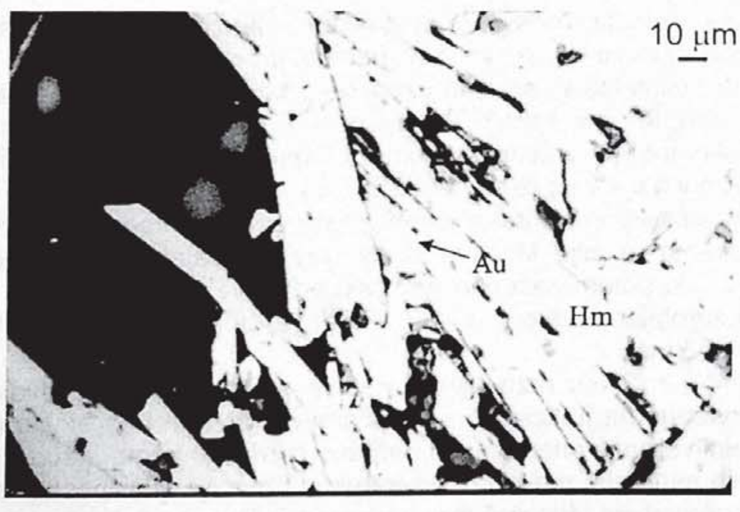
Ispitivanje sadržaja Au, Ag, Cu i W rađeno je metodom atomske apsorpcione spektrofotometrije, dok su sadržaji Sn i Bi dobijeni semikvantitativnom spektrohemijskom analizom. Sve analize su urađene u laboratorijama Geoinstituta.

REZULTATI I DISKUSIJA ISPITIVANJA MINERALNOG SASTAVA I HEMIJSKIH ANALIZA

Rudnomikroskopskim ispitivanjem je određen relativno jednostavan mineralni sastav, a količinska zastupljenost minerala u manjoj ili većoj meri varira.

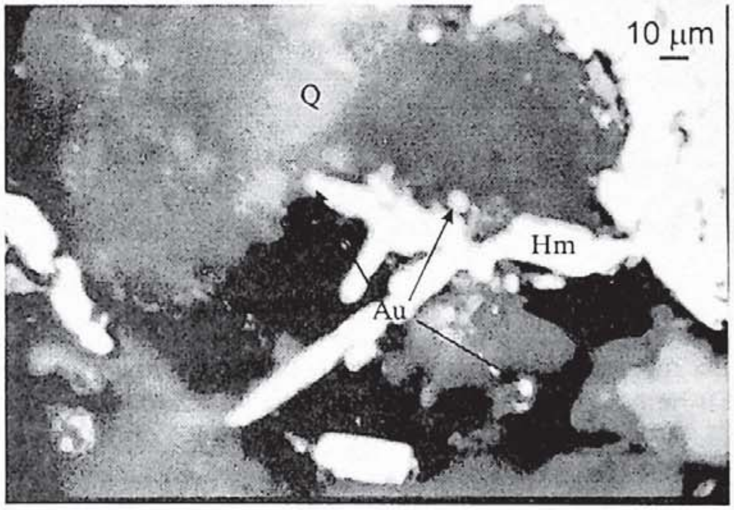
Primarni mineralni sastojci su: **hematit**, **magnetit**, **kvarc i zlato**, sekundarni su **getit** i **limonit**, a akcesorni minerali su **pirit** i **halkopirit**.

Hematit je nastao transformacijom **magnetita**, koji je započet duž njegovih oktaedarskih ravni, a zatim nastavljen po nepravilnim površinama. Ovaj preobražaj je razvijen u različitom stepenu, mada u ovim uzorcima hematit preovlađuje nad magnetitom koji uglavnom predstavlja relikt. Tanke pločice i liske hematita, zrakasto srasle u agregate, pod mikroskopom pokazuju pseudo-pritkastu (Slika 2), odnosno igličastu strukturu, u zavisnosti od ravni sečenja preparata. Pojedinačni agregati, u proseku veličine od 2-3 mm, narastaju jedan na drugi, formirajući zrakasto-zupčaste strukture i rozete, pri čemu međuprostore ovih agregata ispunjava **kvarc**. Agregati hematita izgrađuju kompaktnu mineralizaciju sa veoma malim učešćem kvarca i bez relikata magnetita. Lamelarno bližnjenje je skoro redovno prisutno na pojedinačnim pločicama i liskama, kao i na njihovim agregatima.

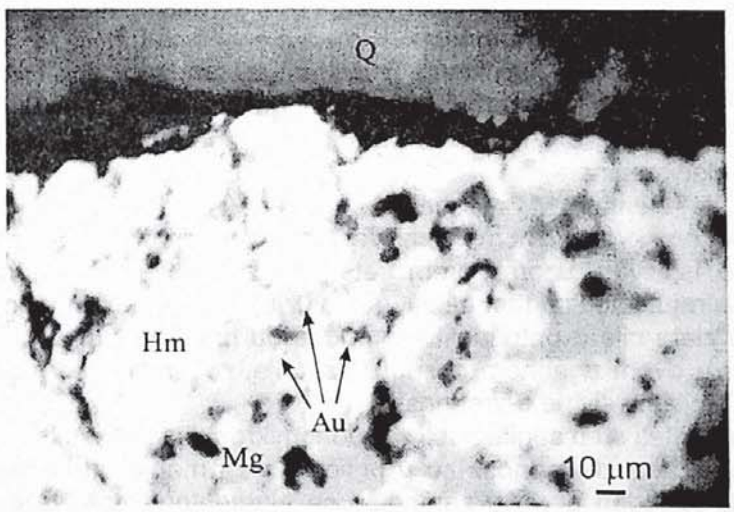


Slika 2. Uklopak zlata (Au) u agregatu hematita (Hm).

Zlato je potvrđeno, kako hemijskom analizom, tako i rudnomikroskopskim proučavanjem. U ispitivanim uzorcima njegov prosečan sadržaj je 7,19 ppm, a njegova najveća koncentracija iznosi 31,71 ppm (Tabela 2). Zlato je u različitom količinskom odnosu redovno legirano sa srebrom, a moguće i sa bizmutom, na šta ukazuju rezultati hemijskih analiza, kao i optičke osobine proučavanih zrna, tj. njihova boja i sjajnost. Način pojavljivanja zlata je raznovrstan, a veličina determinisanih zrna varira od submikronskih vrednosti do oko 30 μm, pri čemu se obično nalaze pojedinačna ksenomorfna zrna ili poluzaobljene kristalne forme. Izuzetno su prisutne grupacije od nekoliko zrna, veličine od 1-10 μm, uklopljenih u kvarcu (Slika 3). Submikronska zrna su uklještena na kontaktnim površinama pojedinačnih liski hematita, a krupnija zrna, veličine oko 30 μm, zapunjuju šupljine u pojedinim hematitskim agregatima (Slika 2). Kapljičasta zrna su ponegde grupisana u reliktnom magnetitu, koji je u manjoj meri pretrpeo transformaciju u hematit (Slika 4). Žiličaste grupacije mikrometarskog zlata su konstatovane i u limonitskoj materiji (Slika 5).

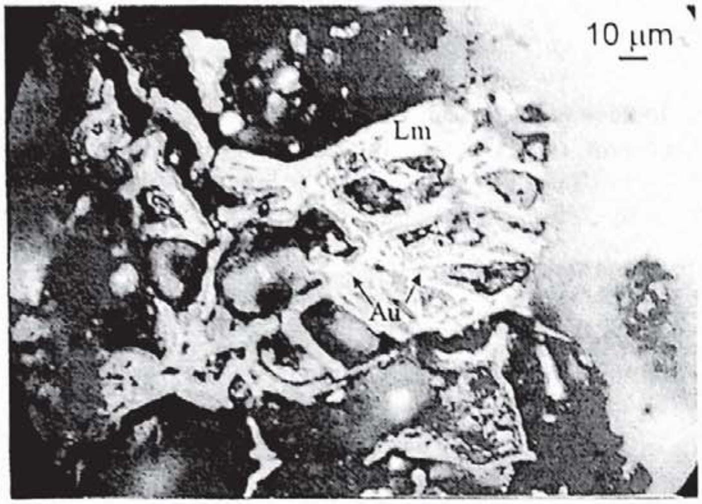


Slika 3. Uklopci zlata (Au) u kvarcu (Q) koji cementuje pritkasti hematit (Hm).



Slika 4. Uklopci zlata (Au) u reliktnom magnetitu (Mg) transformisanom u hematit (Hm).

Getit obrazuje mikrokolomorfne finofibrozne agregate, koji oblažu zidove šupljina i smenjuju se sa finovlaknastim i tankožiličastim limonitom (Slika 5). Agregati hematita su ponegde delimično obloženi limonitom ili u potpunosti njime zahvaćeni, u zavisnosti od izloženosti orudnjenja atmosferilijama. Ukoliko postoje pukotine, one su takođe zapunjene limonitom, dok se kvarcna zrna odlikuju crvenkastom nijansom u boji koja potiče od finodispergovanih čestica limonitske materije.



Slika 5. Žilica zlata (Au) u limonitu (Lm)

Kao prateći minerali pojavljuju se **pirit i halkopirit**, koji su vezani za kvarc, a ređe su uklopljeni u hematitu. Nalaze se u pojedinačnim mikronskim zrnima nepravilnih kapljičastih formi, naročito halkopirit, dok pirit ponegde obrazuje i poluzaobljene idiomorfne kristale.

Zastupljenost i veličina njihovih zrna u ovoj paragenezi je izvanredno mala i meri se tragovima. Iz tog razloga je moguće pretpostaviti, da se znatno povećane koncentracije bakra (i do 0,62 %), određene hemijskom analizom, nalaze u magnetitu i limonitskoj materiji. Na ovu konstataciju ukazuju i uzorci u kojima su dominantni minerali - magnetit i halkopirit u tesnoj paragenetskoj vezi, a gde se halkopirit intenzivno pojavljuje, kao kapljičasta inkluzija u zrnima magnetita (K o v a č e v i ć, 2002).

U okviru rendgenskih ispitivanja indiciran je rendgenski difraktogram praha jednog reprezentativnog uzorka kvarcno-hematitske mineralizacije (prikazan na Slici 6), u opsegu 2θ od 5° do 65°, sa izmerenim vrednostima međupljosnih rastojanja (d_{obs}) i identifikovanim sledećim mineralima:

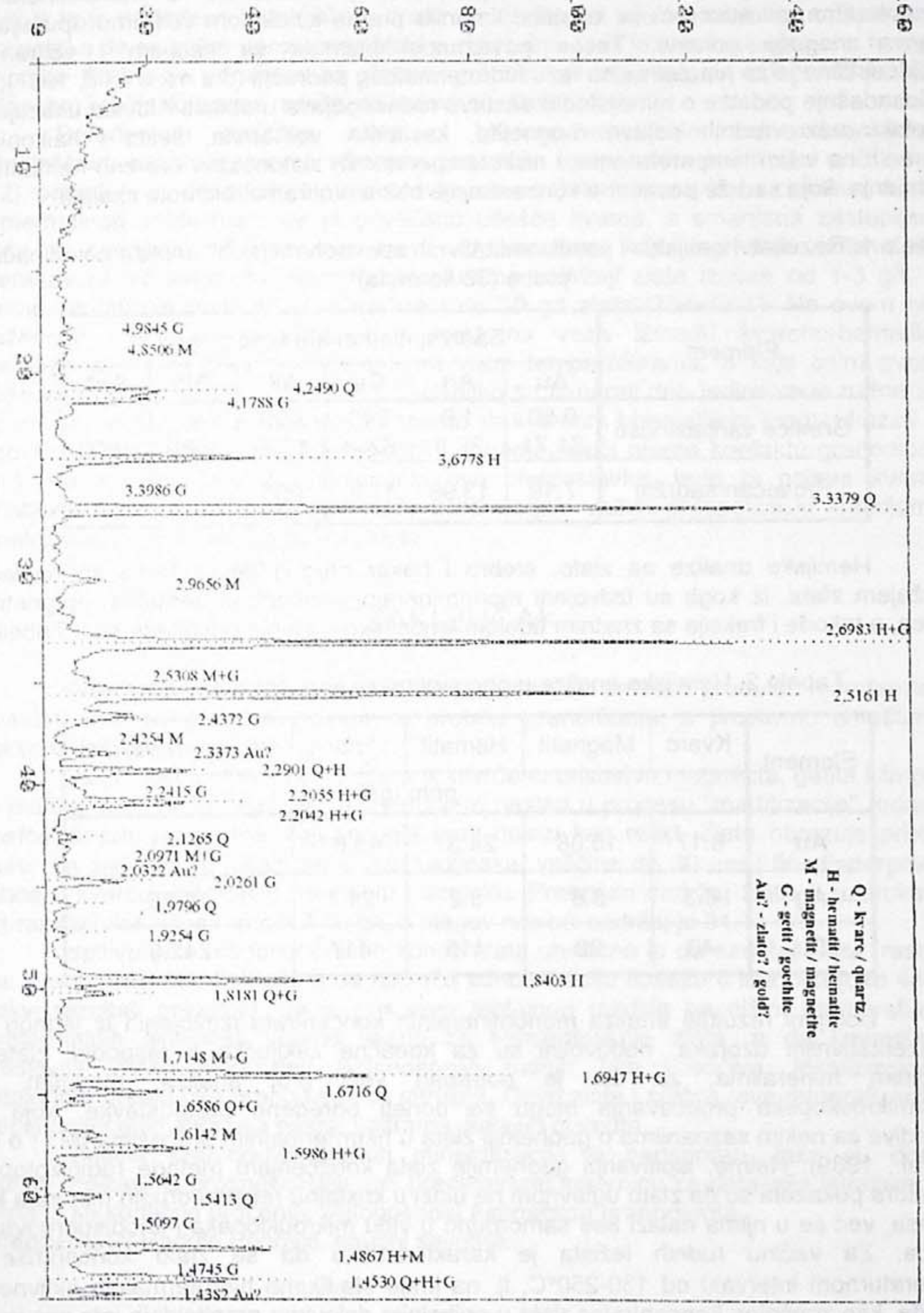
Q - kvarc, H - hematit, M - magnetit, G - getit i Au? - zlato?.

Rendgenskom kvalitativnom, semikvantitativnom difrakcionom analizom praha utvrđeno je da se ispitivani uzorak prema stepenu zastupljenosti sastoji od kvarca i hematita koji dominiraju, kao i od magnetita, getita i zlata? kojih ima mnogo manje.

Prisustvo zlata nije u potpunosti sigurno zbog male zastupljenosti, kao i malog broja refleksija (3) u ovom ugaonom opsegu. Takodje, ove refleksije mogu biti i od Al-nosača preparata, koji ima slične d-vrednosti.

Dobijeni rezultati su u saglasnosti sa rudnomikroskopskim ispitivanjima.

Što se tiče zlata, d-vrednosti su u priličnoj meri manje od literaturnih, tako da pretpostavljamo da je jedan deo Au zamenjen sa elementom manjeg jonskog radijusa (npr. sa Ag, Cu, Bi), a na šta ukazuju ostala ispitivanja prikazana u ovom radu.



Slika 6. Indicirani rendgenski difraktogram praha ispitivanog uzorka.

U proučavanoj mineralnoj asocijaciji, osim bakra, hemijskom analizom su konstatovane povećane koncentracije volframa, a u nekim uzorcima kalaja i bizmuta, međutim, prisustvo njihovih minerala nije potvrđeno. Srednji sadržaji ovih elemenata u ispitivanim uzorcima, kao i njihove minimalne i maksimalne koncentracije su prikazani u Tabeli 1. Pošto semikvantitativnom spektrohemijskom analizom nije dokazano prisustvo bizmuta i kalaja u pojedinim uzorcima, prosečni sadržaji ovih elemenata nisu prikazani.

Ovom prilikom nije proučavan sadržaj navedenih elemenata u monomineralnim koncentratima, ali adsorpcione osobine limonita prema koloidnom volframu upućuju na njegovo moguće poreklo. Tesna povezanost bizmuta sa kalajem i volframom karakteristična je za hipotermalnu fazu hidrotermalnog područja (J a n k o v i ć, 1967), što uz dosadašnje podatke o mineralnom sastavu rudnih pojava u oblasti Aldinca ukazuje na genetsku vezu rudnih pojava magnetita, kasiterita, volframita, šelita i halkopirita, stvaranih na višim temperaturama, i niskotemperaturnih zlatonosnih kvarcno-hematitskih orudnjenja, koja sadrže povećane koncentracije bakra, volframa, bizmuta i kalaja.

Tabela 1. Rezultati hemijskih i semikvantitativnih spektrohemijskih* analiza pojedinačnih proba (36 komada)

Element	Sadržaj elemenata u ppm (g/t)					
	Au	Ag	Cu	W	Bi*	Sn*
Granice varijabilnosti	0.50 31.71	1.0 30.0	240 6244	400 1630	- 1080	- 1000
Prosečan sadržaj	7.19	13.98	1730	955	-	-

Hemijske analize na zlato, srebro i bakar drugog dela uzorka sa najvećim sadržajem zlata, iz koga su izdvojeni monomineralni koncentrati hematita, magnetita i kvarca, a takođe i frakcija sa znatnim udelom limonitske materije prikazane su u Tabeli 2.

Tabela 2. Hemijske analize monomineralnih koncentrata (3 uzorka)

Element	Kvarc	Magnetit	Hematit	Limonit	Prosečan sadržaj
	ppm (g/t)				
Au	8.17	15.08	24.37	45.63	23.31
Ag	6.3	5.8	8.2	21.1	10.35
Cu	40	98	415	417	242.5

Dobijeni rezultati analiza monomineralnih koncentrata izdvojenih iz jednog od reprezentativnijih uzoraka, nedovoljni su za konačne zaključke o raspodeli zlata u pojedinim mineralima, za šta je potreban veći broj analiza, međutim, uz rudnomikroskopska proučavanja mogu se doneti određene pretpostavke, koje su uporedive sa nekim saznanjima o geohemiji zlata u hidrotermalnim procesima (M i r o n o v et al., 1989). Naime, ispitivanja geohemije zlata korišćenjem metode radioizotopnih indikatora pokazala su da zlato uglavnom ne ulazi u kristalnu rešetku drugih minerala kao primesa, već se u njima nalazi kao samorodno u vidu mikrouklopaka i finodispergovanih čestica. Za većinu rudnih ležišta je karakteristično da se zlato koncentriše u temperaturnom intervalu od 130-250°C, tj. na kraju stadijuma hidrotermalnih aktivnosti. Takođe, kao značajan koncentrator zlata u apikalnim delovima granitoidnih intruzija javlja se magnetit i može ukazati na njihovu potencijalnu rudonosnost.

Rezultati prikazani u ovom radu pokazuju da sadržaj zlata raste po sledećem redosledu: kvarc - magnetit - hematit - limonit, što znači da prisustvo metalnog gvožđa u završnim fazama hidrotermalnih aktivnosti znatno utiče na obaranje zlata i njegovu koncentraciju u magnetitu i hematitu. Sekundarnim procesima u uslovima oksidacione zone vrši se dalja koncentracija zlata. U hematitu i hidroksidima gvožđa se vrši koncentracija srebra i bakra, a najverovatnije i bizmuta, volframa i kalaja. Rudnomikroskopskim proučavanjem pojedinih uzoraka konstatovani su mnogobrojni mikrometarski uklopci halkopirita u krupnijim zrnima magnetita, što u ovom uzorku nije bio slučaj, a to je potvrđeno i hemijskom analizom. Halkopirit nije konstatovan u ispitivanom uzorku, tako da se bakar verovatno nalazi u vidu primese ili je finodispergovan u hematitu i limonitu. Srebro je udruženo sa zlatom, gradeći prirodnu leguru, pri čemu je njihov međusobni količinski odnos različit, ali redovno u korist zlata.

Poređenjem sadržaja zlata u kvarcno-hematitskim mineralizacijama i polimetaličnim mineralizacijama stvaranim na višim temperaturama (K o v a č e v i ć, 2002), potvrđuje se dosadašnja pretpostavka, da se zlato koncentriše u završnim fazama hidrotermalnog stadijuma, gde je povećano učešće kvarca, a smanjena zastupljenost sulfida ili svedena na najmanju meru. U uzorcima koje izgrađuje polimetalična mineralizacija, stvarana na višim temperaturama sadržaji zlata iznose od 1-3 g/t, dok kvarcno-hematitske mineralizacije sadrže i do 30 g/t zlata (Tabela 1). Na ovom nivou istraženosti može se pretpostaviti i prostorna veza između kvarcno-hematitskih mineralizacija i onih koje su stvarane na višim temperaturama, a koje osim gvožđa, sadrže znatno više bakra (i preko 1 %). Ukoliko su minerali deo jedinstvene rudne žice, tada povećane koncentracije zlata u zonama sa kvarcom i hematitom mogu ukazati i na njegovo značajno prisustvo u bakronosnim zonama, idući prema kontaktu granodiorita i gabra. Kada bi se potvrdila zakonitost ove pretpostavke, tada bi pojave kvarcno-hematitske mineralizacije sa sigurnošću predstavljale važan prospekcijski kriterijum za pronalaženje korisnih ležišta bakra i zlata.

ZAKLJUČAK

Kvarcno-hematitske mineralizacije predstavljaju završne produkte hidrotermalnih aktivnosti koje su genetski vezane za proboje granodiorita, a prostorno smeštene u piroksenskom gabru.

Osim kvarca i hematita, u njima je utvrđeno prisustvo magnetita, getita i limonita, a u manjoj meri, pirita i halkopirita. Hematit je nastao u procesu "martitizacije", odnosno transformacijom magnetita, koji se uglavnom nalazi kao relikt. Zlato obrazuje prirodnu leguru sa srebrom, a nalazi se u vidu uklopaka, veličine do 30 μm i finodispergovanih čestica u kvarcu, magnetitu, hematitu i limonitu. Prosečan sadržaj zlata u uzorcima sa šest različitih lokalnosti iznosi 7,19 g/t, a njegov najveći sadržaj je 31,71 g/t.

Ispitivanjem monomineralnih koncentrata utvrđeno je da sadržaj zlata raste po nizu: kvarc, magnetit, hematit, a da najveću koncentraciju dostiže u limonitu (oko 45 g/t). Ovakvi rezultati pokazuju, da je prisustvo metalnog gvožđa na nižim temperaturama hidrotermalnih aktivnosti veoma važno za koncentrisanje zlata, a da limonitizacija predstavlja važan pokazatelj zlatonosnosti rudnih žica i sočiva, lokalizovanih u kontaktnom oreolu oko granodioritske intruzije. Osim zlata i srebra, ove mineralizacije su nosioci povećanih sadržaja bakra, volframa, kalaja i bizmuta.

Značaj kvarcno-hematitskih mineralizacija je neosporan. Iako su dobijeni rezultati proizašli iz prospekcijskih, oni predstavljaju smernicu za detaljnija istraživanja, u kojima bi se konačno procenila zlatonosnost Aldinačkog granodiorita.

Recenzent: Dr Radule Popović, naučni savetnik

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Bulletin of Geoinstitute, vol. 39, 2004, Belgrade

BIBLID 0537-846X (2004), 39, P. 95-104
UDK 553.41+553.312(497.11)
Originalni naučni rad

GOLD IN QUARTZ HEMATITIC MINERALISATIONS OF THE ALDINAC AREA AT STARA PLANINA MOUNTAIN

by

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Key words: Stara planina, Aldinac, gabbro, granodiorite, gold, hematite, limonite.

Abstract. The Aldinac ore zone consists mostly of the gabbroic rocks, represented by pyroxene gabbros and diabases, in which granodioritic rocks are intruded, mostly granodyorite-porphyrite, and lesser with quartz-latites and dacites. Ore bearing potential of this zone is represented by Fe, Mn, Cu, Mo, W, Sn, Pb, Bi, Ag and Au occurrences. Quartz-hematitic mineralizations have a special importance, because the largest gold concentrations can be found there. In this paper there were defined mineral content of this mineralizations and the mode of gold occurrences with the ore microscopic and X-ray analysis. Results of the chemical analysis of six separate samples and monomineral concentrates from one sample are also presented.

INTRODUCTION

Southeastern part of the Zaglavak gabbroic massive in which large masses of granodiorite and its vein equivalents are discovered, is an important area of Stara planina mountain because of the copper, bismuth, gold, silver and molybdenum occurrences. Beside pyroxene gabbros and granodiorite-porphyrites, which make the basic characteristic of this ore zone, other present rocks are: biotite-amphibolitic gneisses, marbles, gneiss-granites, metasediments, diabases, granodiorites, quartz-latites and dacites (Figure 1).

At the Aldinac village area, 34 km eastern from the Knjazevac city and its wider surrounding, Fe, Cu, Au, Mn vein and impregnation type of ore occurrences are discovered, which are genetically connected to granodiorite-porphyrites intrusions in gabbro, intruded along the Repušnica regional fault in Hercynian epoch (M i l o š a k o v i ć et al., 1986). Latest results confirm this theory, but they also point at some peculiarities that are not noticed during researches up to now.

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GENERAL METALLOGENIC CHARACTERISTICS OF THE ALDINAC ORE ZONE

Polymetalic (Fe, Cu, Au, Mn) ore occurrences of the Aldinac ore zone are placed in the contact part of granodiorite-porphyrites intrusions in gabbro, micro gabbro and diabase and they appear as veins and impregnations, in gabbro as well as in granodiorite itself. Thickness of uncovered ore strings is from several centimeters to a couple meters. So, almost pure quartz-pyrite veins can be meet, as well as polymineral quartzitic strings, with or without calcite.

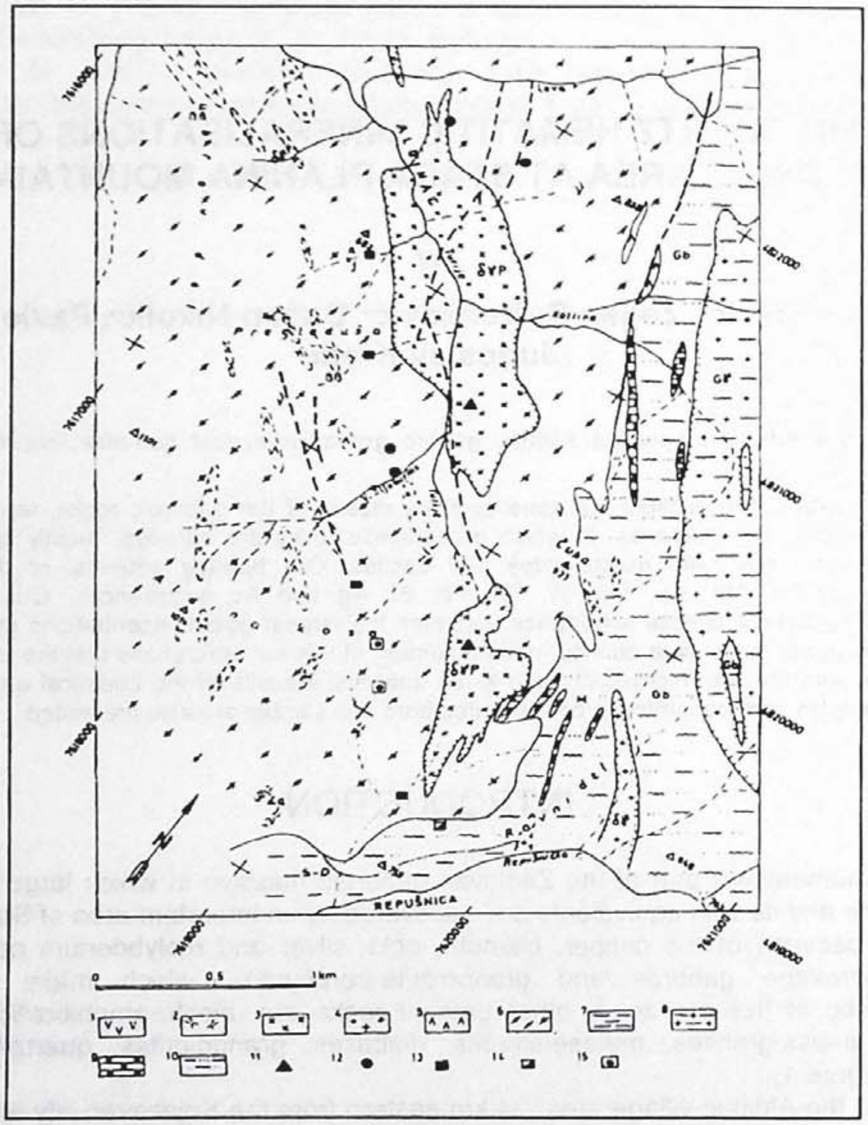

Figure 1. Geologic map of the Aldinac area (K o v a č e v i ć et al., 2003)
1. dacites; 2. quartzlatites; 3. granodiorite-porphyrites; 4. granodiorites; 5. diabases; 6. gabbros; 7. metasediments; 8. gneiss-granites; 9. marbles; 10. biotit-amphibole and amphibole-biotite gneisses; 11. U, Mo ore occurrences; 12. Cu, W, Au ore occurrences; 13. Cu, Fe, Au, Ag ore occurrences; 14. Fe, Mn, Au, Ag ore occurrences; 15. Cu, Fe, Sn, W, Ag, Au ore occurrences.

Based on the past, relatively modest level of researches, it is possible to differentiate several mineral paragenesis of pneumatholite-hydrothermal and hydrothermal origin type:

- magnetite-chalcopyrite- cassiterite,

- hematite-chalcopyrite-wolframite,
- pyrite-chalcopirite-scheelite,
- pyrite-magnetite-chalcopyrite-molybdenite,
- pyrite-molybdenite and
- hematite-magnetite.

Also it should be mentioned that during the past researches (C u k u ć a n, 1961), in particular Aldinac granodiorite zones, an increased uranium content have been noticed, which is not researched on this occasion.

Observed in the whole, Aldinac-Repusnica ore zone is characterized by the geochemical specialization for Fe, Mn, Cu, W, Mo, Sn, Pb, Bi, Ag and Au.

By their relative quantity primary minerals are: pyrite, chalcopyrite, magnetite and hematite, accesorry are: molybdenite, scheelite, wolframite, cassiterite, galena, tetrahedrite and arsenopyrite, while secondary minerals are: goethite, psilomelane, pyrolousite, chalcocite, bornite, covellite and malachite.

Gold, silver and bismuth are present as native elements and natural alloys or within crystal grates of other minerals. Copper is also noticed as native, but slightly.

Quartz-hematitic veins represent the final products of hydrothermal activities that took place along fractures and fault zones in gabbro. That indicates their spatial distribution as well as relicts of "hematite-martite" (R a d u s i n o v i ć, 1988). These ore veins contain increased concentrations of gold and silver, which are sometimes quite larger compared to quartz veins with pyrite, chalcopyrite and scheelite. Increased contents of copper, tungsten, tin ore and bismuth as ingredients is characteristic but their minerals have not been noticed in this paragenesis.

MATERIAL AND RESEARCH METHODS

Since the characteristic of the hematite is different intensity and medium to high extension of occurrences in the ore veins of the Aldinac ore zone, in this paper there were represented the results of only that samples in which the hematite is dominant or one of the main mineral components are presented in this paper. The samples are chosen at bases of the ore microscopic analysis that have been done in the frame of prospecting researches and producing the geologic map, scale 1:10000 (K o v a č e v i ć, 2001, 2002).

Among six analyzed samples, one was chosen and necessary mineralogical preparation was done in order to differentiate particular mineral types as quantitative as possible. After that, gold, silver and copper contents were separately determined in them. The sample was manually crumbled and separated into three fractions: (1) 0.15-0.5 mm, (2) 0.063-0.15 mm and (3) less then 0.063mm.

Fractions (1) and (2) were separated by a wet process, and the separation of mineral components was done at fraction (1), with the manual magnet and at electromagnet. The way of coalescence of mineral grains and a regular presence of "hematite-martite" disabled thorough differentiation of magnetite from hematite, and quartz from the ore minerals. However, by the multiplied repetition of the differentiation process, satisfactory "pureness" of the monomineral fractions has been accomplished. Then they are quantitatively powdered for the further analysis. Separation by a wet process was done in order to achieve more pureness of monomineral samples and to concentrate limonite substance in fraction (3).

The X-ray investigations were performed by automatically diffractometer for powder "PHILIPS", model PW-1710. There was used long-focus (LFF), Cu-anode (U = 40 kV and I = 30 mA), with monochromated $K\alpha_1$ radiation (wave-length λ = 1,54060Å) and Xe proportional counter. Diffraction datas were collected in angle range 2θ from 5° to 65° with keeping back with 1 second on every 0,02°. For measurement the angle positions of diffraction maximums and their belonging intensities there was used base program PW-

1877. Precision of the diffractometer was controled before and after experiment with metallic Si powder. Identification of the present mineral phases was done with comparison interplanar spacings (d) and relative intensities (I) with literature datas, that is corresponding card from JCPDS-ASTM database.

The research of Au, Ag, Cu and W contents was done by the atomic absorption spectral photometry and Sn and Bi contents was obtained by the semi guantitative spectral chemical analysis. All of the analyses were done in the laboratories of Geoinstitute[1].

RESULTS AND DISCUSSION OF THE MINERAL COMPOSITIONS AND CHEMICAL ANALYSIS

A relatively simple mineral content is determined by the ore-microscopic analysis and quantitative presence of minerals more or less varies.

Primary mineral contents are: **hematite, magnetite, quartz** and **gold**, secondary are **goettite** and **limonite**, and accesorry minerals are **pyrite** and **chalcopyrite.**

Hematite originated by the transformation of magnetite that began along its octahedral planes and then was continued at irregular planes. This transformation is developed with different degree, although in the samples hematite predominates over magnetite which is mostly a relict. Thin small plates and foliage of hematite, with ray-shaped coalescence into the aggregates, show pseudo sticky shaped (Figure 2) or needle shaped structure in a microscope, depending on a plane of specimen cutting. Single aggregates of average size 2-3 mm, coalesce at one another forming ray cog

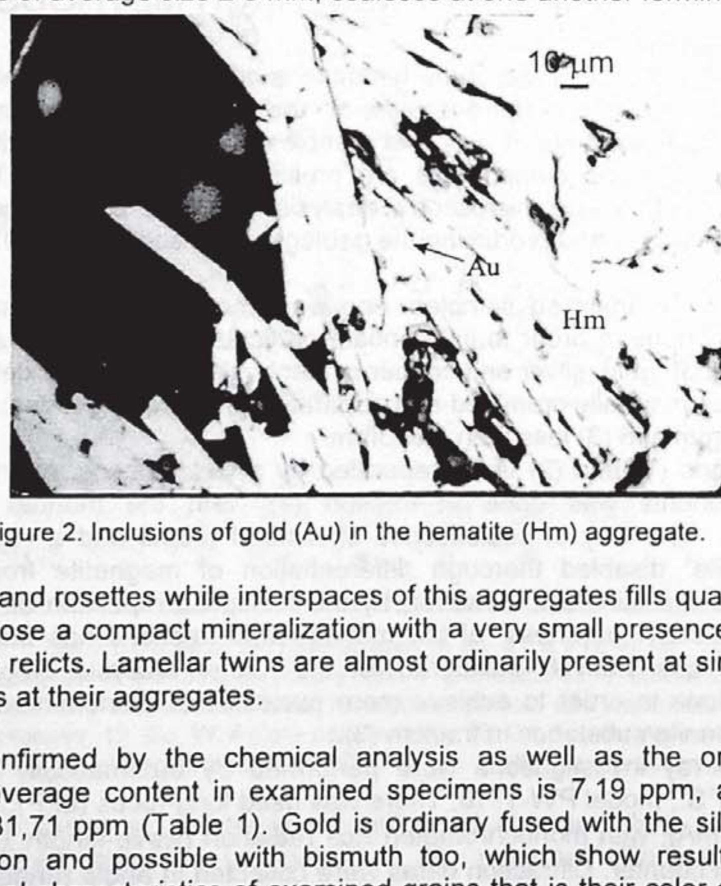

Figure 2. Inclusions of gold (Au) in the hematite (Hm) aggregate.

shaped structure and rosettes while interspaces of this aggregates fills quartz. Hematite aggregates compose a compact mineralization with a very small presence of quartz and without magnetite relicts. Lamellar twins are almost ordinarily present at single plates and foliages as well as at their aggregates.

Gold confirmed by the chemical analysis as well as the ore microscopic researches. It's average content in examined specimens is 7,19 ppm, and it's largest concentration is 31,71 ppm (Table 1). Gold is ordinary fused with the silver in different quantitative relation and possible with bismuth too, which show results of chemical analysis and optical characteristics of examined grains that is their color and shine. The mode of gold occurrence is various, the size of determined grains varies from submicron values to about 30 μm and at the same time, there are usually particular xeno-morphed grains or half-rounded crystalline forms. Exceptionally, groups of several grains are present, size from 1-10 μm, inserted in quartz (Figure 3). Submicron grains are comprised at contact plains of particular hematite foliage plains, and the larger grains,

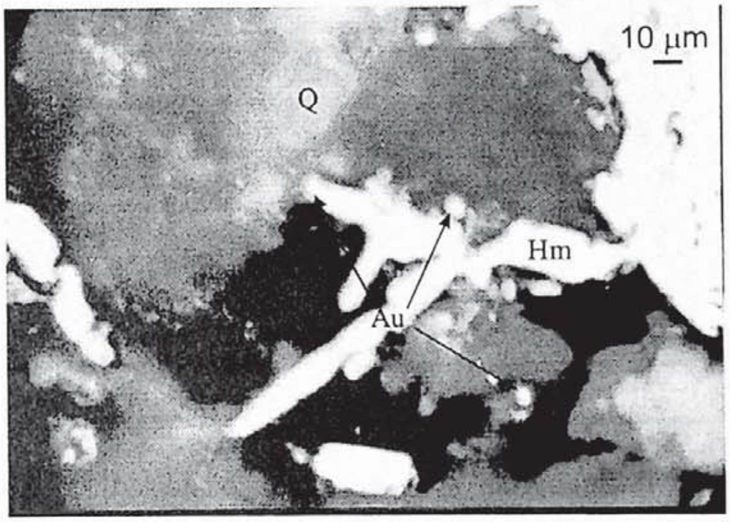

Figure 3. Inclusions of gold (Au) in the quartz (Q) which cements sticky shaped hematite (Hm). V

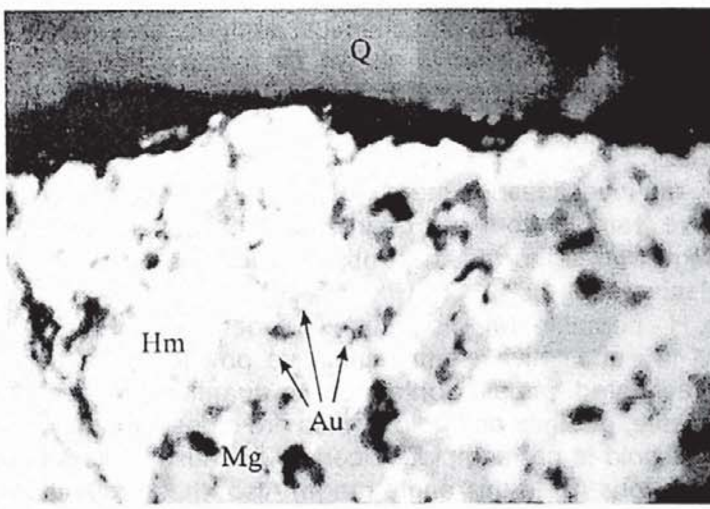

Figure 4. Inclusions of gold (Au) in the relict magnetite (Mg) transformed into the hematite (Hm).

size about 30 μm fill the cavities in particular hematite aggregates (Figure 2). A drop shaped grains are here and there grouped in the relict magnetite, which is slightly transformed into the hematite (Figure 4). Thin vain groups of the micron gold are noticed in the limonite matter too (Figure 5).

Goethite forms micro colomorphic fine fybrosic aggregates, which plaster the cavity walls and exchange with fine fibrous and thin vein limonite (Figure 5). Hematite aggregates are here and there partly plastered by limonite or entirely filed by it, depending on exposure of the ore to atmospheric influences. In the case of fissure existence, they are filled by limonite too, and quartz grains are characterized by red color shade which origin of fine dispersive particles of limonite matter.

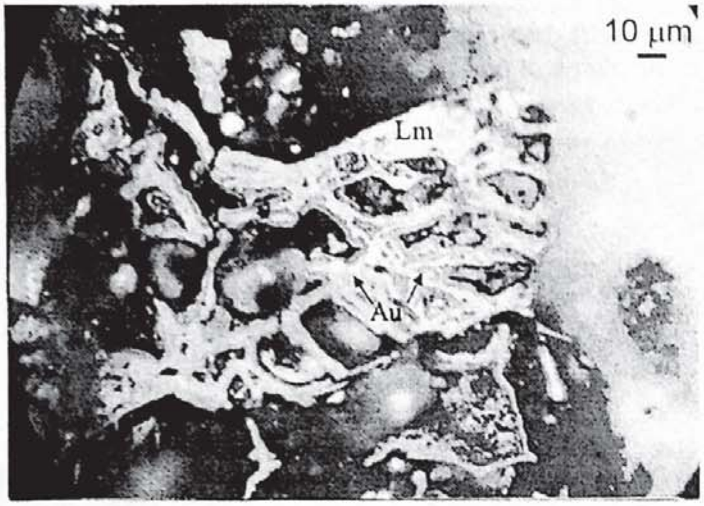

Figure 5. Thin vain of gold (Au) in the limonite (Lm)

Pyrite and chalcopyrite appears as accompanied minerals, which are connected to the quartz, and rarely they are inserted in the hematite. They are present in particular micron grains with irregular drop shaped forms especially chalcopyrite, while pyrite here and there compose half-rounded idiomorphic crystals. Presence and size of its grains in this paragenesis is extremely small and it is measured by the traces. This is the reason that it is possible to presume that considerably enlarged concentration of the copper (up to 0,62 %), determined by the chemical analysis, are present in the magnetite and limonite matter. This conclusion is shown by the specimens in which dominant minerals are magnetite and chalcopyrite in a close para-genetical connection in which chalcopyrite is intensively appearing as drop shapped inclusions in the magnetite grains (K o v a č e v i c, 2002).

Through X-ray investigations there was indiced X-ray powder diffraction pattern of one representative sample from the quartz-hematite mineralisation (represented at Figure 6), in 2θ range from 5^o to 65^o, with observed values of the interplanar spacings (d_{obs}) and identified minerals:

Q - quartz, H - hematite, M - magnetite, G - goethite, and Au? - gold?.

With the X-ray qualitative, semiquantitative powder diffraction analysis it was established that investigated sample contain by its quantity quartz and hematite which dominate, and magnetite, goethite and gold? which are of less quantity.

Presence of gold is not completely certain because of its smaller quantity and small number of reflections (3) in this angle range. Also, these reflections could be from the Al-sample carier, which have similar d-values.

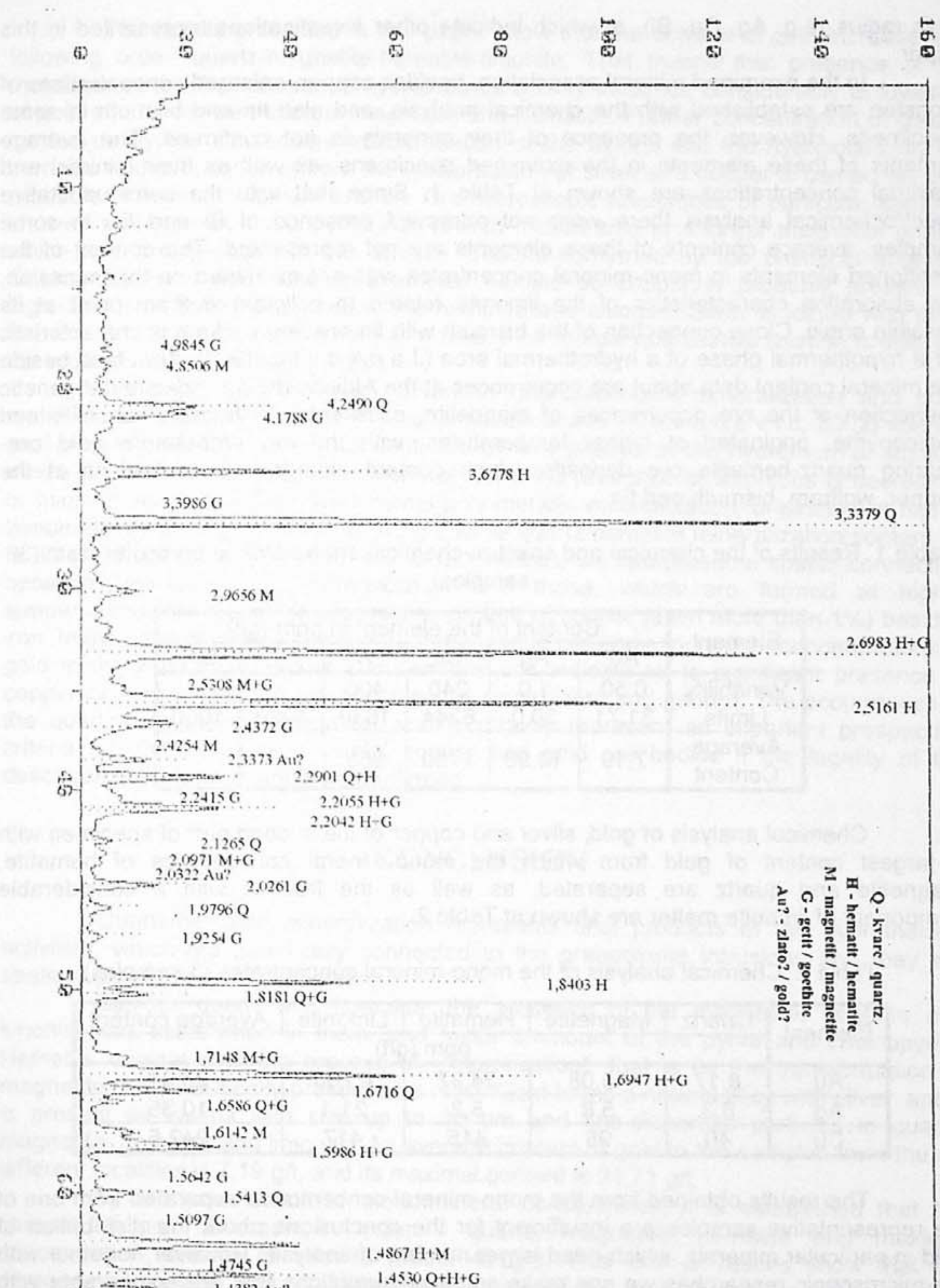

Figure 6. Indiced X-ray powder diffraction pattern of the investigated sample.

Obtained results are in very good agreement with the ore-microscopy investigations.

Relay to the gold, d-values (Figure 6) are considerably less than the literature datas, and so we presume that the one part of Au exchanged with element of smaller ionic radius (e.g. Ag, Cu, Bi), at which indicate other investigations represented in this paper.

In the examined mineral association, besides copper, enlarged concentrations of tungsten are established with the chemical analysis, and also tin and bismuth in some specimens. However, the presence of their minerals is not confirmed. The average contents of these elements in the examined specimens, as well as their minimal and maximal concentrations are shown at Table 1. Since that with the semiquantitative spectrochemical analysis there were not approved presence of Bi and Sn in some samples, averace contents of these elements are not represented. The content of the mentioned elements in mono-mineral concentrates was not examined on this occasion, but absorption characteristics of the limonite related to colloidal wolfram point at its possible origin. Close connection of the bismuth with tin ore and wolfram is characteristic for a hypothermal phase of a hydrothermal area (J a n k o v i ć, 1967). That fact, beside the mineral content data about ore occurrences at the Aldinac region, indicate the genetic connection of the ore occurrences of magnetite, cassiterite, wolframite, scheelite and chalcopyrite, originated at higher temperatures, with the low-temperature gold ore-bearing quartz-hematite ore deposits, which content enlarged concentrations of the copper, wolfram, bismuth and tin.

Table 1. Results of the chemical and spectral-chemical analysis ofthe particular tests (36 samples)

Element	Content of the element in ppm (g/t)					
	Au	Ag	Cu	W	Bi*	Sn*
Variability Limits	0,50 31,71	1,0 30,0	240 6244	400 1630	- 1080	- 1000
Average Content	7,19	13,98	1730	955	-	-

Chemical analysis of gold, silver and copper of the second part of specimen with a largest content of gold from which the mono-mineral concentrates of hematite, magnetite and quartz are separated, as well as the fraction with a considerable component of limonite matter are shown at Table 2.

Table 2. Chemical analysis of the mono-mineral concentrates (3 samples)

Element	Quartz	Magnetite	Hematite	Limonite	Average content
	ppm (g/t)				
Au	8,17	15,08	24,37	45,63	23,31
Ag	6,3	5,8	8,2	21,1	10,35
Cu	40	98	415	417	242,5

The results obtained from the mono-mineral concentrates separated from one of the representative samples are insufficient for the conclusions about the distribution of gold in particular minerals, which need larger number of analysis. However, together with ore-microscopic researches we can make some presumptions that are comparable with certain knowledge about the geochemistry of gold in hydrothermal processes (M i r o n o v et al., 1989). Researches of the gold geochemistry by the use of the radioisotope indicator method showed that gold mostly is not present in a crystal net of the other minerals as ingredient but it is present as authigenous as micro-insertions and fine-dispersed particles. For the most of ore beds it is characteristic that the gold concentrates at the temperature range 130-250^{0}C, that is at the end of a hydrothermal activity stage. Also, as an important concentrator of gold at the apical parts of granitoids intrusions appears a magnetite that can indicate its potential ore bearing.

The results presented in this paper show that the content of gold increase in a following order: quartz-magnetite-hematite-limonite. That means that presence of the metal iron at the final phases of hydrothermal activity influence considerably at lowering of gold and its concentration in magnetite and hematite. Further concentration of gold is carried on by the subsequent transformation of the oxides into the hydroxides. In the hematite and hydroxides of iron, the concentration of silver and copper is carried on, and probably of bismuth, wolfram and tin. Ore-microscopic researches of particular samples showed a numerous chalcopyrite inserts with micron size in a larger magnetite grains, which was not the case in this sample. That is confirmed by the chemical analysis. Chalcopyrite was not found in examined sample so copper is probably present as ingredient or it is fine dispersed in the hematite and limonite. Silver is joined with gold, forming a natural alloy, and at the same time, their mutual quantitative relation is different but regularly with advantage of gold.

Comparison of the gold content in quartz-hematite mineralization and poly-metallic mineralization originated at higher temperatures (K o v a č e v i ć, 2002) confirm past presumption that gold is concentrated at final phases of the hydrothermal stadium where the participation of gold is increased and the presence of sulphides is decreased or minimal. In the samples which forms poly-metallic mineralization, originated at higher temperatures, a content of gold is 1-3 g/t, while quartz-hematite mineralization content up to 30 g/t of gold (Table 1). At this level of research, we can presume spatial connection between quartz-hematite mineralization and those, which are formed at higher temperatures with a considerable higher content of copper (even more than 1%) besides iron. In the case of minerals as a part of the unique ore body, increased concentrations of gold in the zones with quartz and hematite can indicate to its significant presence in copper-bearing zones, towards a contact of granodiorite and gabbro. The occurrences of the quartz-hematite mineralization would certainly represent an important prospecting criteria for the discovery of useful copper and gold ore bodies if the legality of the described presumption would be confirmed.

CONCLUSION

Quartz-hematite mineralization represents final products of the hydrothermal activities, which are genetically connected to the granodiorite intrusions and they are spatially placed in pyroxene gabbro.

Besides quartz and hematite, the presence of the magnetite, goethite and limonite was established in them, and minor ammount of the pyrite and chalcopyrite. Hematite originated in the process of "martitisation", that is by the transformation of magnetite, which is mostly present as a relict. Gold forms a natural alloy with silver, and it is present as inserts with size up to 30 μm and fine-dispersed particles in quartz, magnetite, hematite and limonite. An average content of gold in the samples from the six different localities is 7,19 g/t, and its maximal content is 31,71 g/t.

By the examination of mono-mineral concentrates, it is established that the content of gold increase in order – quartz, magnetite, hematite and maximal concentration reaches in limonite (about 45 g/t). This kind of results show that the presence of metallic iron at lower temperatures of the hydrothermal activities is very important for the concentration of gold and that limonitisation represents an important indicator of gold-bearing ore veins and lenses, which are localized in the contact around the granodiorite intrusion. Besides gold and silver, these mineralizations bear increased content of the copper, tungsten, tin ore and bismuth.

The importance of the quartz-hematite mineralizations is indisputable. Although the results come from prospecting, they represent guidance for further researches by which the gold bearing of Aldinac granodiorite would be evaluated.

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