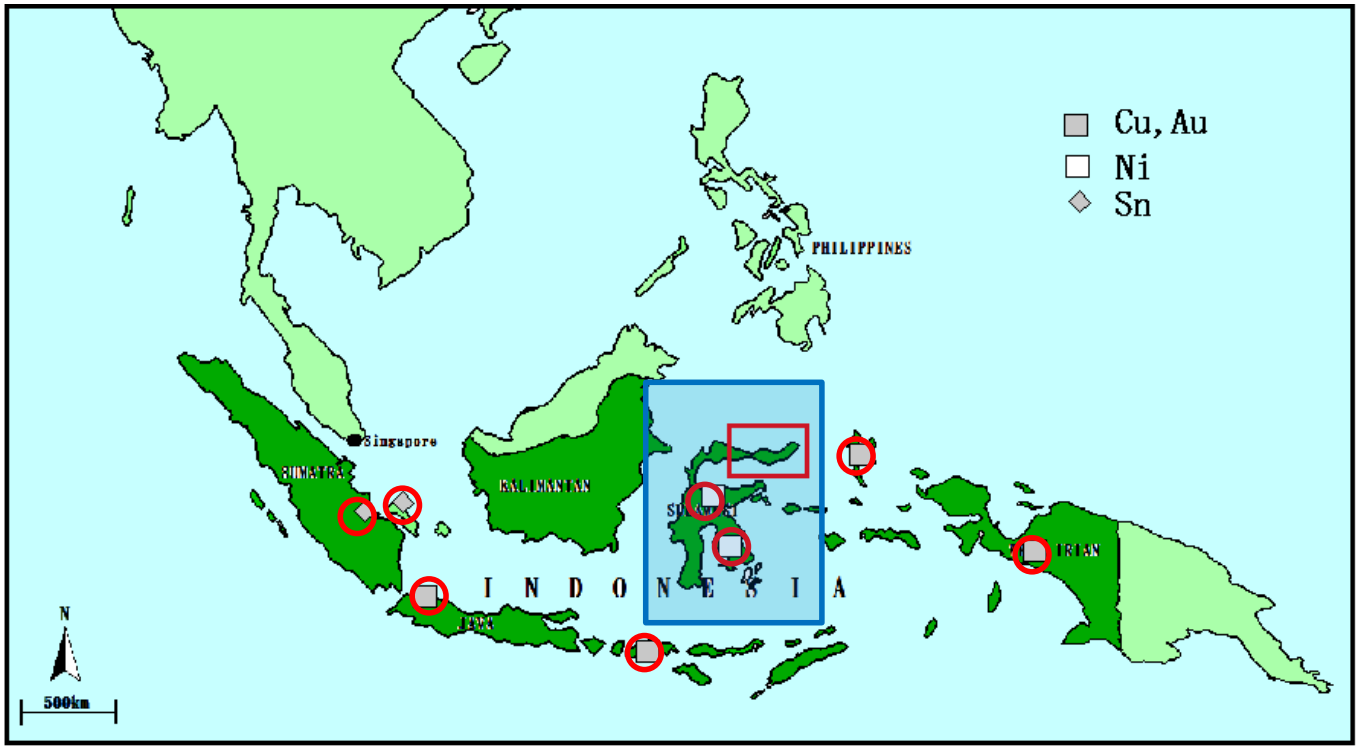
COPPER-GOLD MINERALIZATION CHARACTERISTICS OF THE SUNGAI MAK DEPOSIT IN GORONTALO, NORTHEN SULAWESI, INDONESIA

Economic Geology Laboratory,
Department of Earth Resource Engineering,
Kyushu University
Masanori Yamamoto

INTRODUCTION



(JOGMEC)

Metal mineral production in Indonesia（2011）

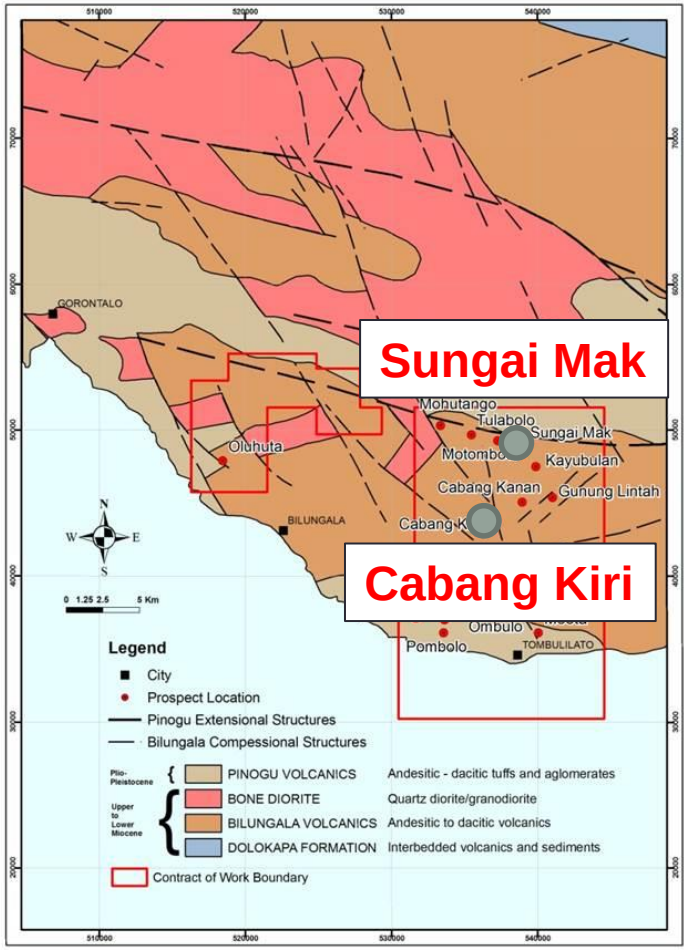
	Ni	Cu	Au	Pb
Production volume(10^3t)	230	625	0.1	51
W	2位	8位	8位	2位

(U.S.Geological Survey, Mineral Commodity Summaries, January 2012)

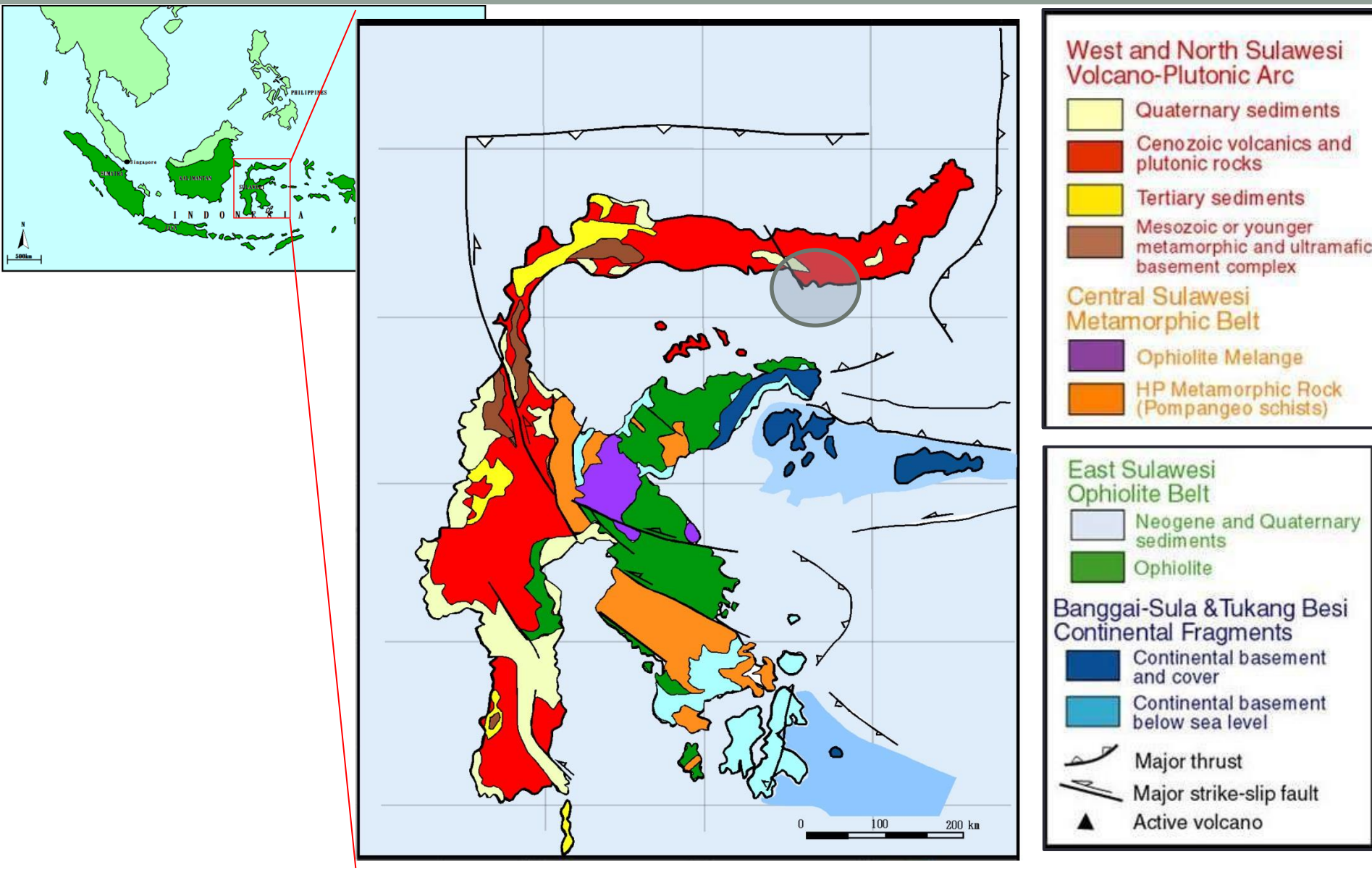
Sungai Mak Deposit

- The exploration works of Sungai Mak is doing now.
- PT. BUMI RESOURCES has obtained the Exploration Borrow & Use Permit in December 2010 and exploration drilling works commenced in November 2011 at the Block-1 Cabang Kiri and Sungai Mak sites.
- Average grade: copper(0.67%),gold(0.47g/t)
- Sungai Mak mines stored 1.68million tons in resources, and Cabang Kiri is 1.24 million tons .

(PT. BUMI RESOURCES press report)



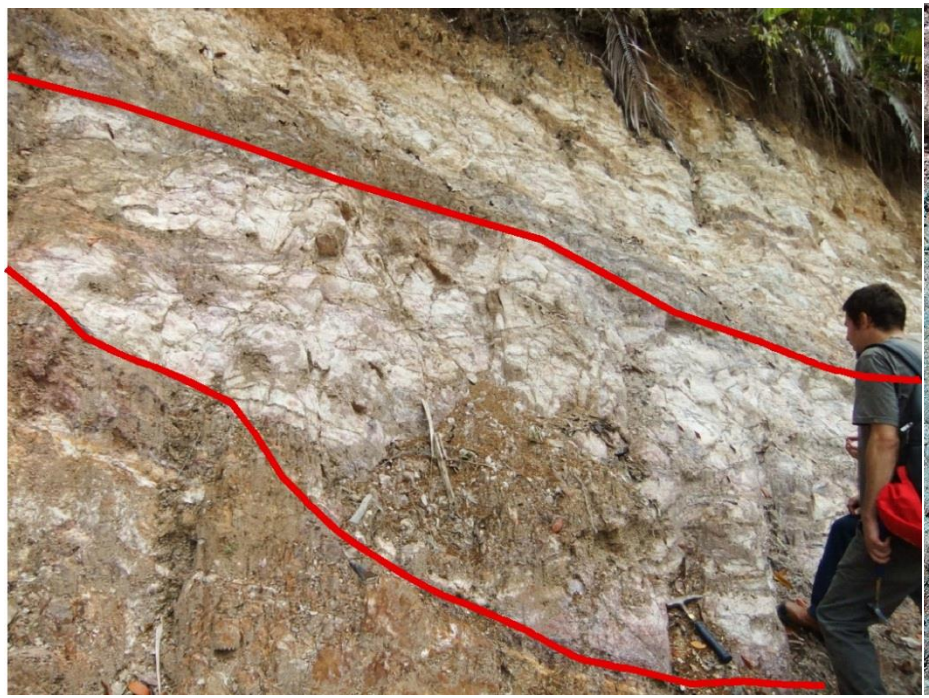
REGIONAL GEOLOGY



(Kadarusman et al, 2002; Maulana et al, 2009)

Quartz vein

Malachite layer ($Cu_2CO_3(OH)_2$)



Hydrothermal activity, Secondary enrichment effect were confirmed.

SAMPLE PICTURE(BORING CORE)

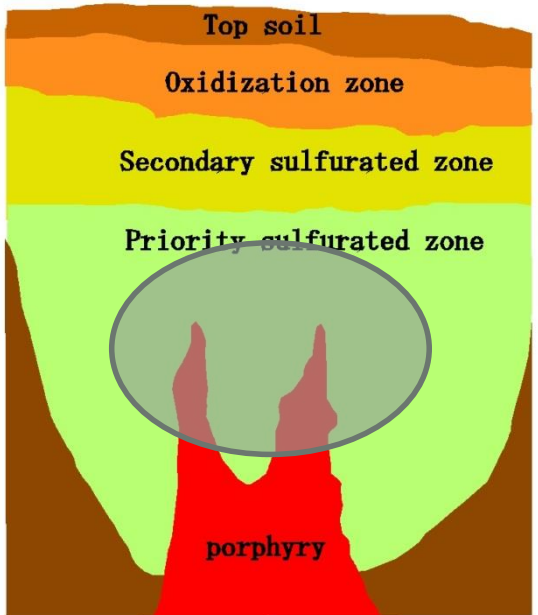
Boring core :SMD057

・stock work of quartz

TORITE

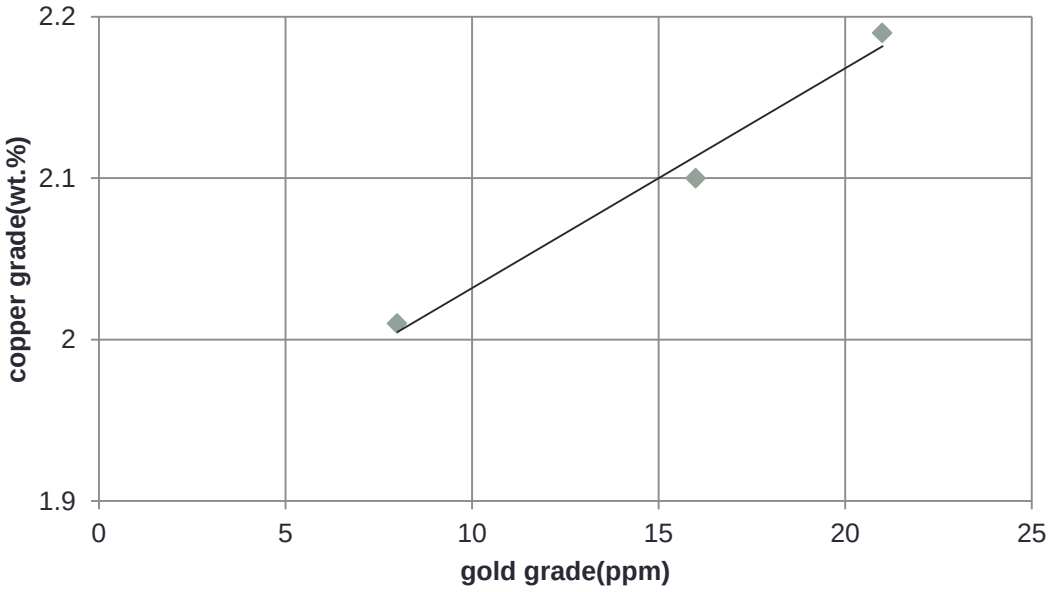
・characteristic of porphyry

Around the 160m depth from surface, boundary of primary sulfide zone and intrusive rock are estimated.



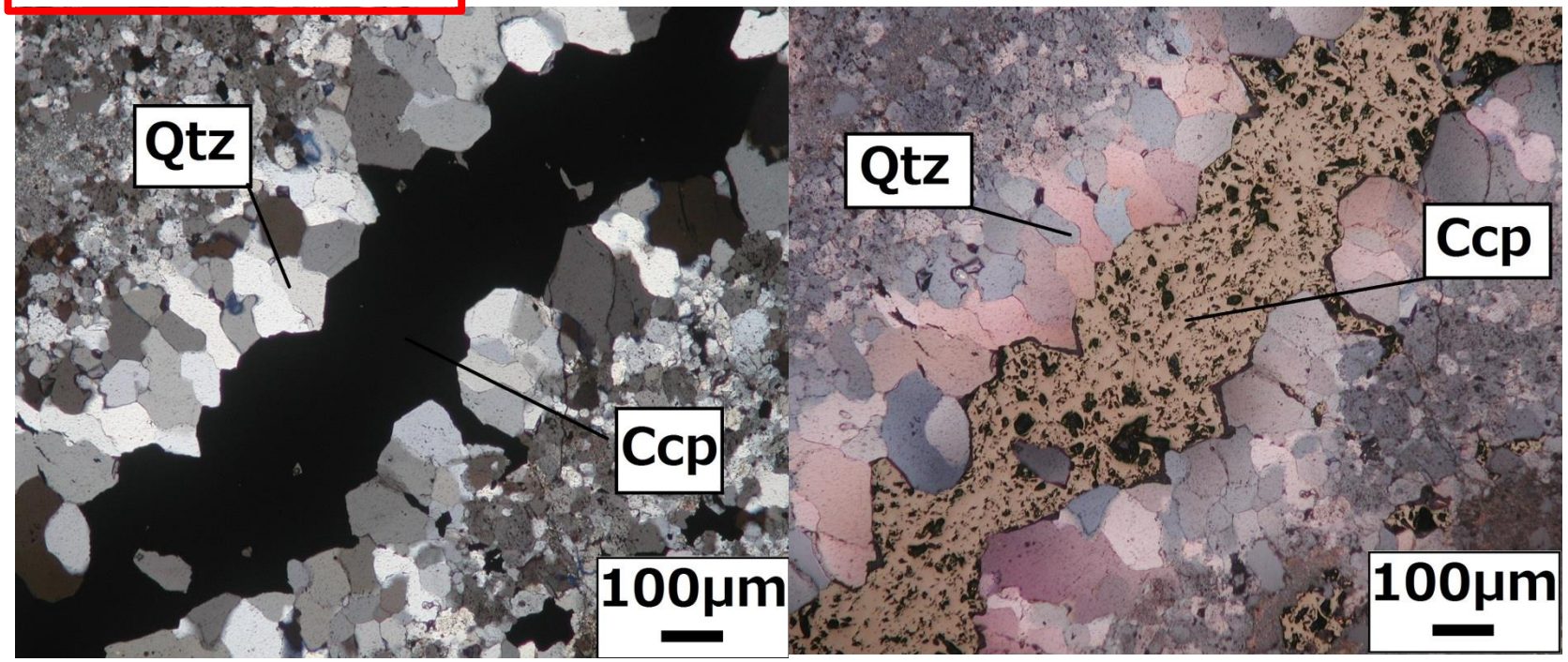
XRF ANALYSIS

Sample No.		SMD057												
		27.20M	54.40M	78.50M	86.50M	102.00M	135.50M	150.00M	165.20M	176.00M	183.00M	194.00M	204.70M	240.00M
SiO_2	wt%	81.3	54.79	87.28	75.71	91.35	68.62	78.63	78.18	87.65	80.91	64.86	64.08	67.52
TiO_2	wt%	0.79	0.8	0.08	0.2	0.06	0.37	0.23	0.28	0.22	0.16	0.39	0.47	0.52
Al_2O_3	wt%	0.61	25.46	4.04	7.13	0.84	15.49	12.06	9.82	7.78	7.51	16.75	16.15	11.43
FeO	wt%	15.49	7.3	2.33	4.91	2.75	5.86	1.82	2.95	0.72	3.59	6.01	5.85	4.06
MnO	wt%	0.01	0.05	0	0	0.01	0.03	0	0	0	0	0.01	0.05	0.04
MgO	wt%	0.17	2.4	0.36	0.52	0.2	3.28	0.33	0.3	0.15	0.55	3.20	3.22	3.22
CaO	wt%	0.03	0.59	0.04	0.06	0.01	0.29	0.11	0.07	0.04	0.1	0.13	2.24	3.10
Na_2O	wt%	0	0.31	0.04	0.01	0.04	0.22	0.15	0.77	0.02	0.17	3.62	3.86	0.54
K_2O	wt%	0.01	2.99	0.87	1.15	0.13	1.37	1.64	1.5	0.04	1.33	1.89	0.91	2.17
P_2O_5	wt%	0.03	0.2	0.04	0.08	0.02	0.04	0.14	0.09	0.12	0.09	0.04	0.23	0.10
Au	ppm	n.d.	n.d.	21	n.d.	8	n.d.	n.d.	16	n.d.	n.d.	n.d.	n.d.	n.d.
Ag	ppm	7	3	17	6	10	14	6	n.d.	n.d.	6	4	4	7
Cu	wt%	0.0228	0.3619	2.1871	1.2872	2.0070	0.9180	0.7076	2.1006	0.0198	0.9963	0.4492	0.2328	0.3399
Pb	ppm	114	96	180	194	97	79	518	300	432	47	27	79	78
Zn	ppm	n.d.	219	29	3									
As	ppm	432	96	47	401									
Sb	ppm	12	9	5	9									
Hg	ppm	2	n.d.	2	n.d.									
Ba	ppm	19	291	298	410									
Rb	ppm	1	83	17	29									
Y	ppm	5	20	6	26									
Sr	ppm	14	31	97	267									
Co	ppm	n.d.	9	2	12									
Nb	ppm	5	5	1	4									
V	ppm	100	169	13	49									
W	ppm	37	49	n.d.	39									
Zr	ppm	115	96	11	31									
Mo	ppm	6	5	12	21									
Cd	ppm	5	2	4	2									
Cl	ppm	1	76	236	108									
LOI	wt%	1.38	4.55	1.00	5.53									



THIN SECTION OBSERBATION

SMD057—78.50M—

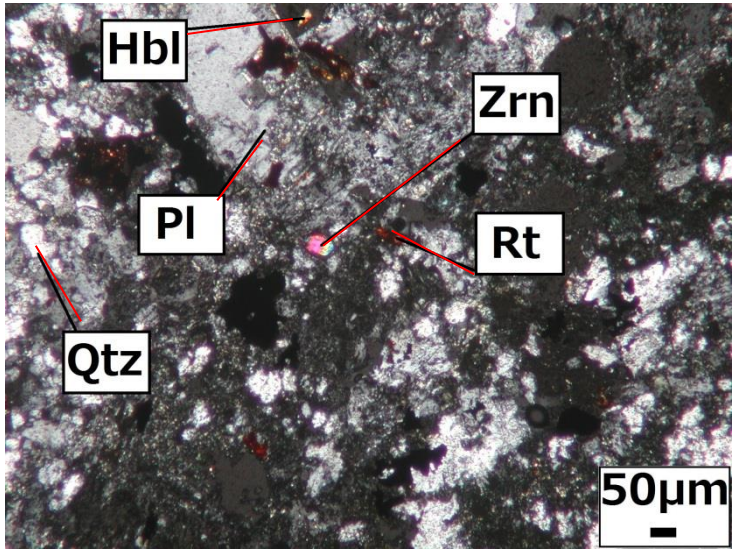


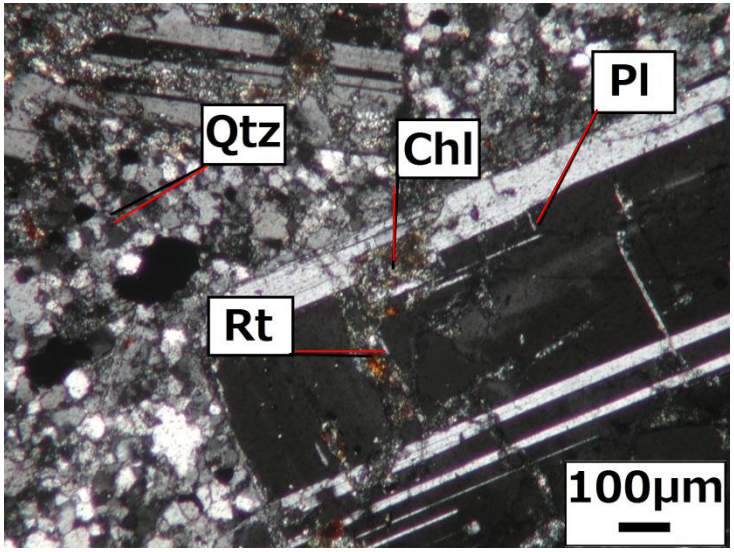
Quartz vein and chalcopyrite-pyrite vein（left：crossed nicols, right：open nicol)

After quartz vein developed, chalcopyrite-pyrite vein fill the gap of quartz vein.
At least, hydrothermal activity was happened two times.

THIN SECTION OBSERVATION AND XRD RESULT

SMD057—204.70M—



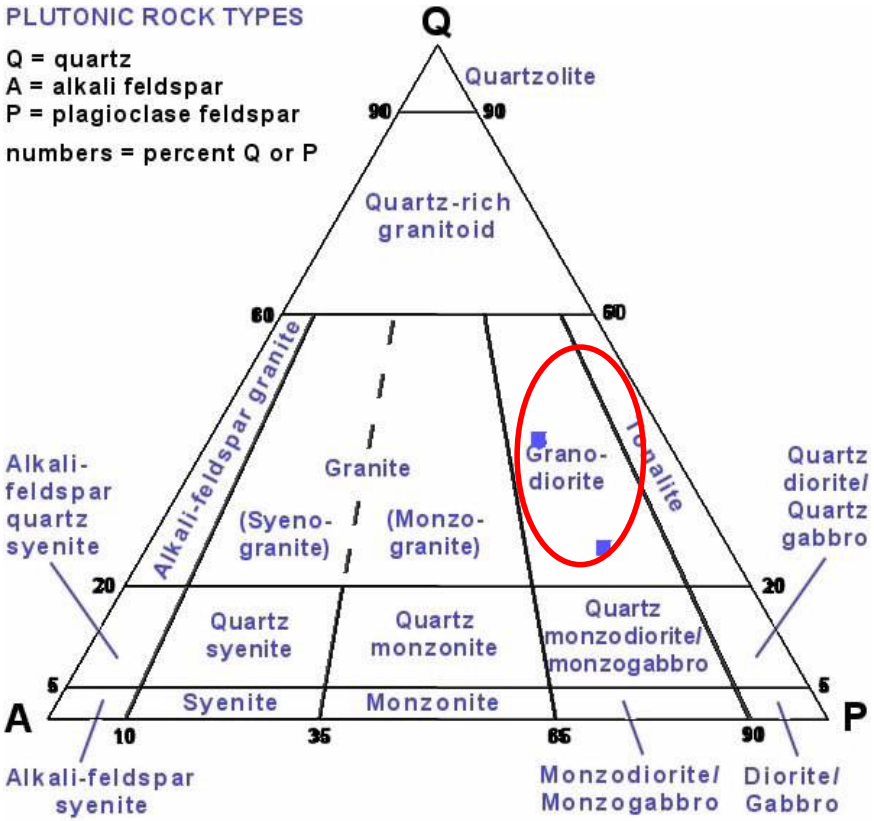


Hbl : hornblende **Rt :rutile**
Pl : plagioclase **Qtz : quartz**
Chl : chalorite **Zrn : zircon**

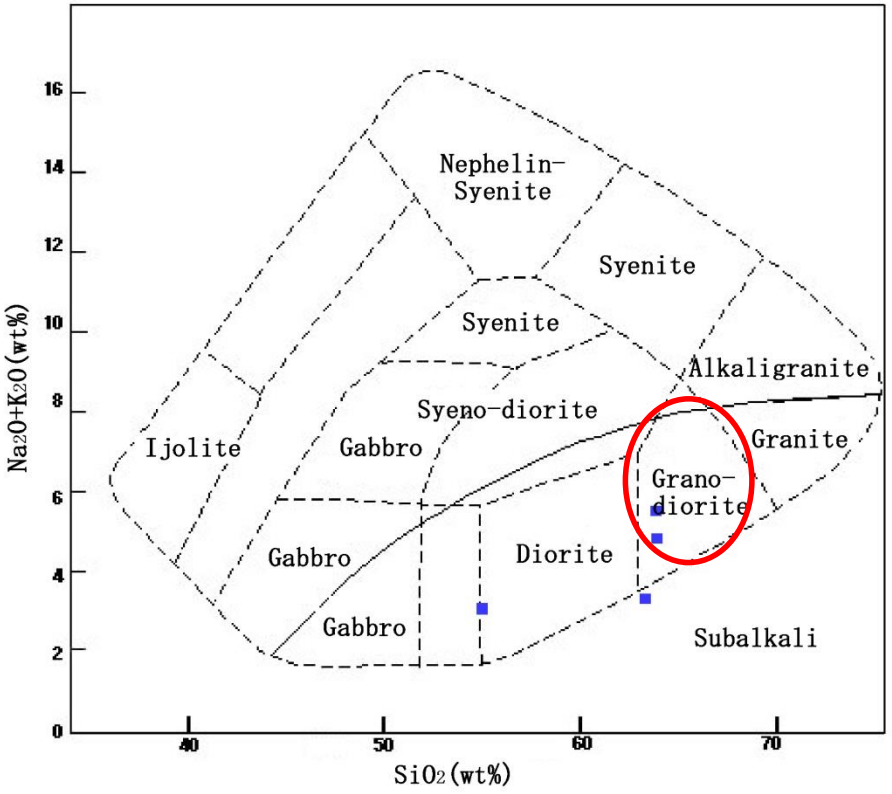
・By thin section observation and XRD analysis, hornblende, plagioclase, chalorite, illite and pyrophyllite were confirmed as rock-forming minerals.

・Groundmass and phenocryst were confirmed, so this one is porphyry.

CLASSIFICATION OF INTRUSIVE ROCK



(after Steckeisen, 1978)

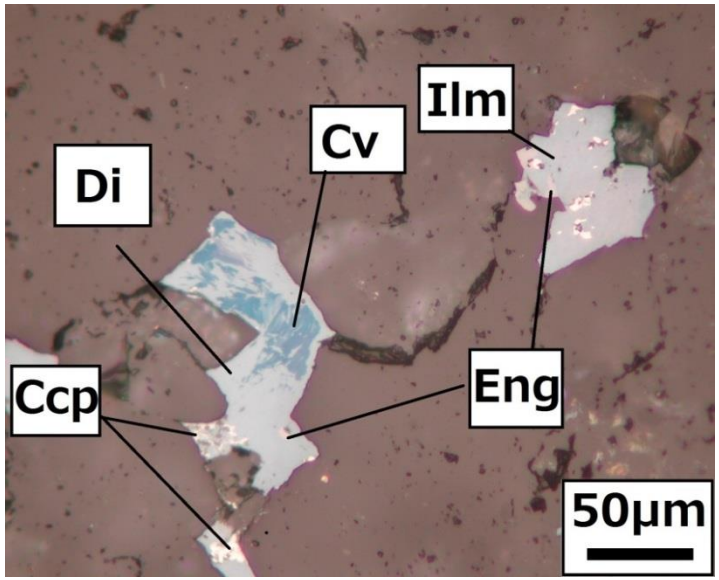


(after Cox et al., 1979, adapted by Wilson,1989)

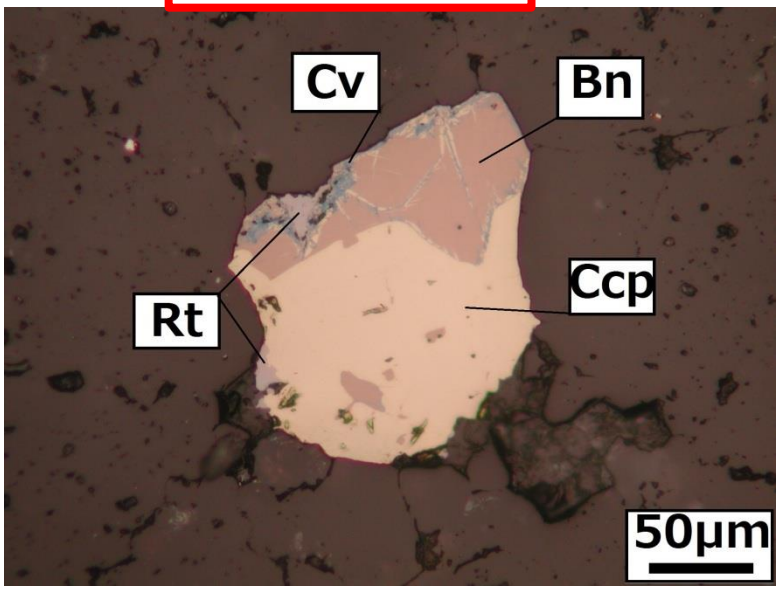
Intrusive rock is Grano-diorite

POLISH SECTION OBSERVATION

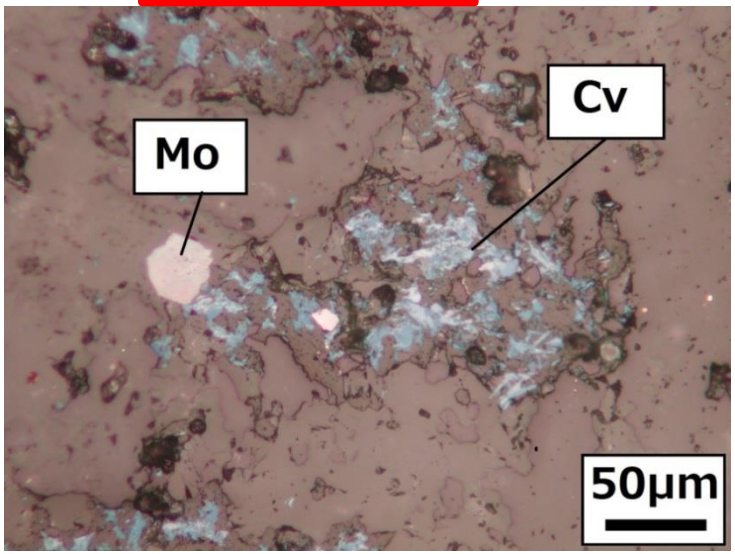
SMD098-45.50M



SMD057-102.00M



SMD098-45.50M

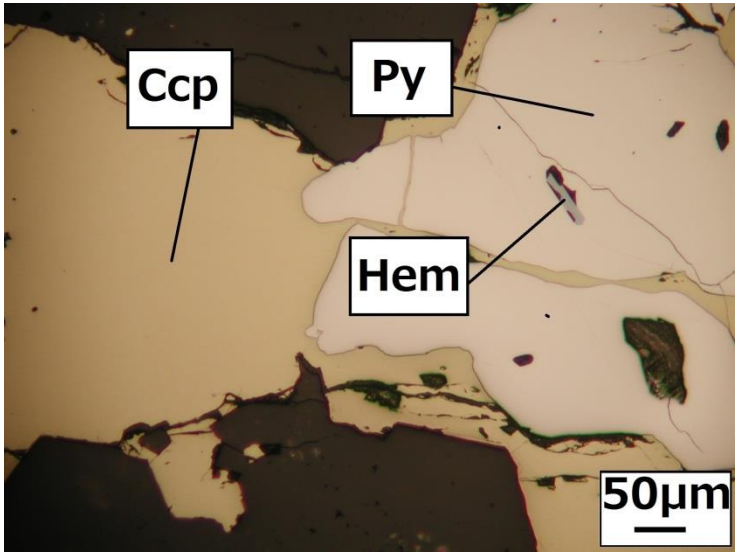


Ccp: chalcopyrite
Di : digenite
Cv : covellite
Rt : rutile
Eng :enargite
Mo :molybdenite
Bn : bornite

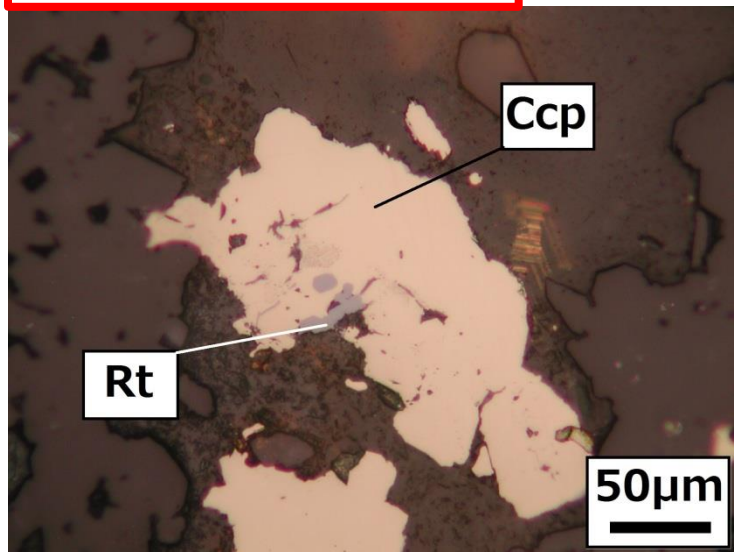
Chalcopyrite, bornite, chalcocite, digenite, enargite, molybdenite, (covellite) that are produced as ore mineral of porphyry copper deposit were confirmed.

POLISH SECTION OBSERVATION

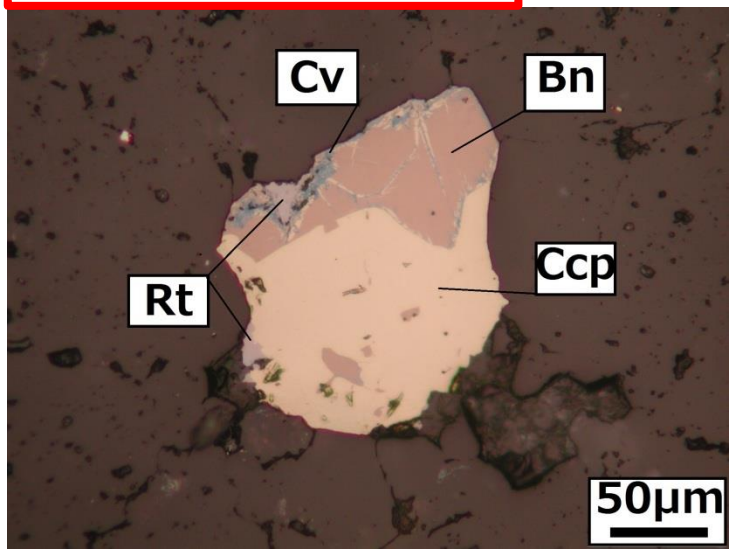
SMD057—78.50M—



SMD057—102.00M—



SMD057—165.00M—



Ccp: chalcopyrite **Py : pyrite**
Hem:hematite **Rt :rutile**
Cv : covellite **Bn : bornite**

From three samples, gold mineralization were confirmed by XRD.
Gold was mineralized with high grade copper.

RESULT OF MICROSCOPY

Sample No.	Sample Name		chalcopyrite	covellite	bornite	digenite	enargite	pyrite	ilmenite	hematite	molybdenite	rutile	zirocon
YM20120909-05	SMD057	78.50M	+++	TR.	TR.	TR.		+					
YM20120909-08		102.00M	+++	TR.	TR.	TR.		+				TR.	
YM20120909-10		135.50M	+++		+			+				TR.	
YM20120909-11		150.00M	++	TR.	TR.			+++	TR.				TR.
YM20120909-12		165.20M	+++	TR.	TR.	TR.							
YM20120909-13		176.00M	+									TR.	TR.
YM20120909-14		183.00M	+++					+++		+		+	+
YM20120909-15		194.00M	++		TR.				++	+		TR.	
YM20120909-16		204.70M	+						++	++		++	+
YM20120909-19	SMD098	45.50M	++	++							TR.	TR.	
YM20120909-23		176.20M										++	

Primary sulfide zone

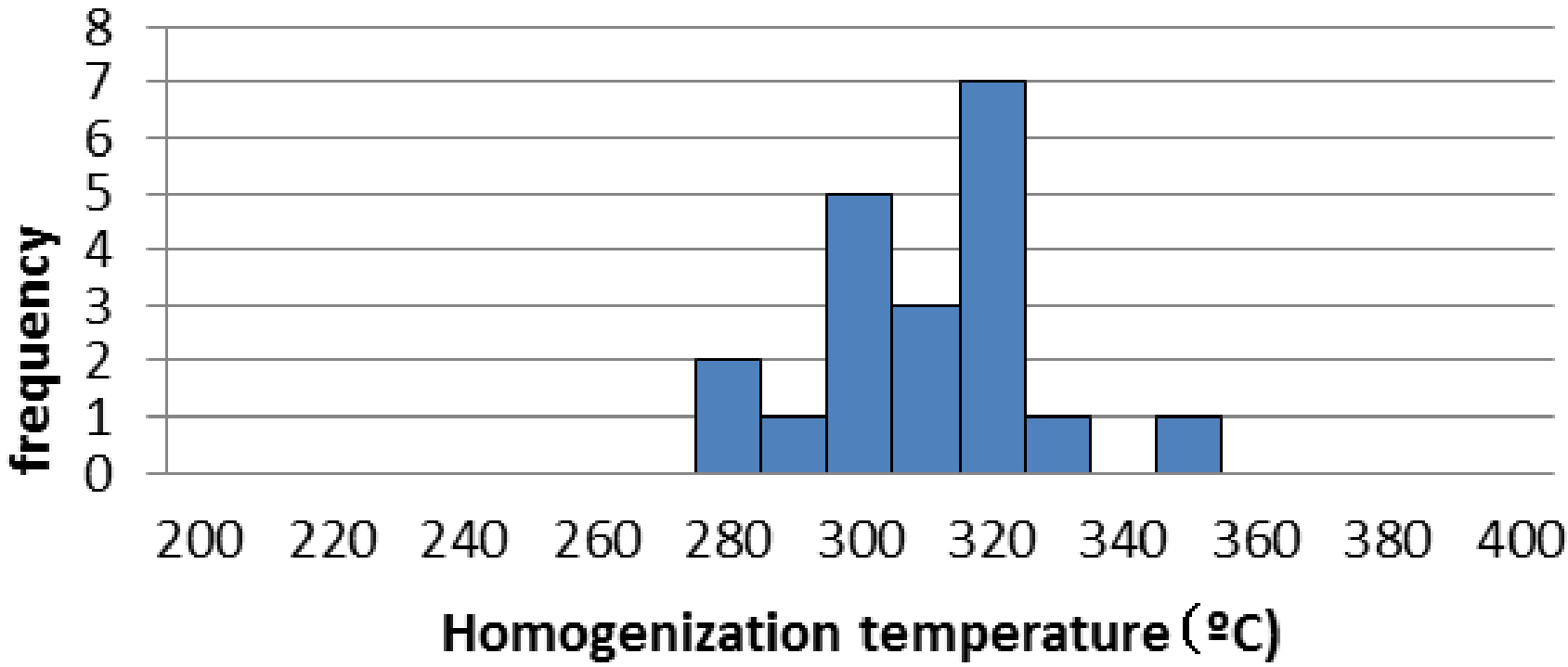
Intrusive rock

Primary sulfide zone

Intrusive rock

+++>++>+ quantity of extend TR.=trace

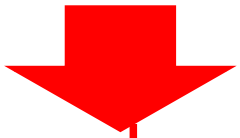
FLUID INCLUSION



The temperature of vein formation in Sungi Mak is **282-350ºC(Mode value:320ºC)**, salinity is **2.4-17.8wt%.**

CONCLUSION

- Intrusive rock is grano-diorite porphyry.
- Characteristic ore of porphyry copper deposit was confirmed.
- Hydrothermal activity was happened at least two times, and gold was mineralized with high grade copper
- Maximum copper grade is 2.1%, and average copper grade is 0.98%. When the combination of chalcopyrite, covellite, bornite, digenite, enargite and pyrite were seen, gold mineralization (8-21ppm) was confirmed.
- The temperature of vein formation in Sungai Mak is 282-350ºC(Mode value:320ºC), salinity is 2.4-17.8wt%.



Sungai Mak is porphyry copper deposit.


Thank you for your kind listening.

Sample No.	Sample Name		chalcopyrite	covellite	bornite	digenite	enargite	pyrite	ilmenite	hematite	molybdenite	rutile	zirocon
YM20120909-05	SMD057	78.50M	+++	TR.	TR.	TR.		+					
YM20120909-08		102.00M	+++	TR.	TR.	TR.		+				TR.	
YM20120909-10		135.50M	+++		+				+			TR.	
YM20120909-11		150.00M	++	TR.	TR.			+++	TR.				TR.
YM20120909-12		165.20M	+++	TR.	TR.	TR.							
YM20120909-13		176.00M	+									TR.	TR.
YM20120909-14		183.00M	+++					+++		+		+	+
YM20120909-15		194.00M	++		TR.				++	+		TR.	
YM20120909-16		204.70M	+						++	++		++	+
YM20120909-19	SMD098	45.50M	++	++		+	++				TR.	TR.	
YM20120909-23		176.20M										++	