Vol. 6 №. 1 TRANSACTIONS OF NFsoc Mar. 1996

SUPERPOSING-REWORKING METALLOGENESIS OF JINNINGIAN MAFIC VOLCANIC-INTRUSION COMPLEX IN DONGCHUAN COPPERFIELD①

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ABSTRACT Mafic "intrusive rocks", distributed greatly within Dongchuan strata-bound copperfield and really comprising volcanic, subvolcanic and volcano plutonic rocks, should be termed as volcanic-intrusive complex (VIC). Geology and geochemistry of Jinningian VIC and its relation to Cu ores reaffirm that VIC play an important role in mineralizations, which are not only vein bonanzas deduced from coose beds, but also new orebodies occurred within VIC. Bonanzas of superposing-reworking type and orebodies of magmatic liquation-differentiation type in the depth are suggested to be found in the largely developing VIC area.

Key words volcanic-intrusive complex Jinningian period superposing-reworking Dongchuan Copperfield

1 INTRODUCTION

In Dongchuan Copperfield, Yunnan, China, the typical Proterozoic strata-bound deposit, there are large quantities of mafic "intrusive rocks". All of Cu deposits discovered in Proterozoic Kunyang Group were widely believed to ones formed by hydrothermal replacement along beds associated with Jinningian magmatism before 1960's[1,2]. Afterwards sedimentary-structural reworking metallogenic theory was proposed in view of Cu ores in stratiform and distribution along beds, generally eliminated the superposing-reworking metallogenesis resulted from late magmatism[3,4,5]. Mafic rocks sometimes destroyed the continuity of stratiform ores. Horsetail-shaped ores were not generated by hydrothermal replacement indeed. However, special Cu-enriching orebodies hosted in either sedimentary or volcanic formations are located exactly in the largely developing mafic dike area. Based on the detailed research since 1991, the authors have found that the mafic "intrusive rocks" really consist of intrusive (volcanic-plutonic), subvolcanic and a few volcanic rocks, being suggested to term as the volcanic-intrusive complex (VIC)[6]. Magmatism resulted in the emplacement of VIC destroyed occasionally pre-existed stratiform ores, but played building role for ores in the much more cases. In special case, even VIC itself is one ore body. Therefore, magmatic hydrothermal theory should not be eliminated overall, on the contary must be reappraised.

2 FEATURES OF VIC

2.1 *Distribution*

VIC crops out mainly along Yinming-Shijiangjun, Tangdan-Baixila and Xintang-Shamuqing-Tuobuka structural zones, emplaced in Yinming Formation (YF), Luoxue Formation (LF), Heishan Formation (HF),

① One part of the National"Eight-Five"Key Science and Technology Program(85-901-04-04);
Received Jan. 13, 1995, accepted May 29, 1995

Qinglongshan Formation (QF) and Dayunpan Formation (DF) from lower to upper of Kunyang Group. Dikes in VIC have variable scale, larger dikes are Shuixiegou dike of Tangdan Mine in length of 4.5 km and width of 100 m, Xintang dike in length of 2 km and width of 5 ~ 10 m, and Mianshan dike of Yinming Mine in length of 2 km and width of 3 ~ 5 m. Small dike swarms commonly compound a larger dike down to the depths. "Laoxinshan rock body", "Baixila rock body" and "Shamuqing rock body" are typical VIC consisting of volcanic, subvolcanic and volcanically plutonic lithofacies.

Frequently, VIC can be in an explosive pipe structure, in whose center or depth exist gabbrodiabase, diorite or quartz albitite dikes, in surrounding are volcanic breccias, shattered rocks and lavas (Fig. 1).

2.2 *Petrology and Petrochemistry*

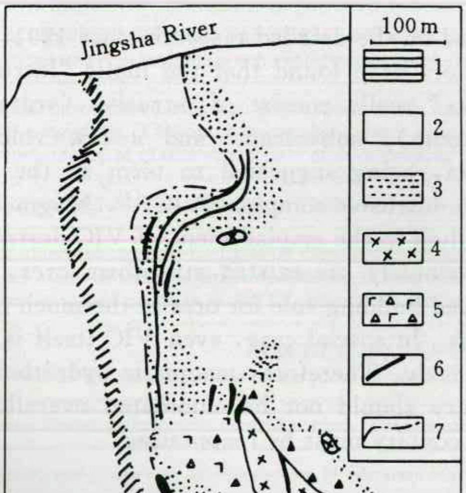

Fig. 1 An explosive pipe structure and Cu Mineralizations in Renzhanshi

1—carboneceous slate, QF; 2—dolomite, QF;
3—silicified and marblized dolomite;
4—gabbrodiabase;
5—volcanic breccia and lava; 6—Cu ore

Rocks making up VIC are gabbro, diabase, dolerite, basalt porphyrite, pyroclast, diorite, quartz albitite, etc. Subvolcanic and volcanic lithofacies have hyaline texture, amygdules and vesicles filled with quartz, carbonate, biotite and chlorite. Rock-froming minerals are chiefly plagioclass, albite, pyroxene, amphibole and uralite, with subordinate biotite epidote, chlorite, muscovite, apatite, leucoxene, sphene and sulfide.

Petrochemically, VIC are mostly mafic with SiO_2 of 44% ~ 54%, fewly felsic with SiO_2 of 60% ~ 65%. However difference between occurrences and lithologies, all of VIC are chemically high in titanium (TiO_2 of 1.6% ~ 3%, max. 5% ~ 9%) and alkaline (K_2O and Na_2O of 3.5% ~ 6%). Quartz albitite has content of K_2O and Na_2O of 7% ~ 8%. Above features imply that VIC in the whole copperfield is derived from the same magmatic reservior, and characterized by the continent rift igneous rocks.

2.3 *Age*

In the copperfield, VIC is emplaced in from YF to DF, In many locations such as Yinming Mine exist shattered beds of YF and LF cemented by mafic material and Cu-bearing sulfides, and explosive breccia veins (Fig. 2).

In Renzhanshi the explosive pipe cut through dolomite beds of QF. Sm-Nd isochron dating on quartz albitite is 927.1 ± 28 Ma in level 2 922 of Luoxue Mine[7], K-Ar dating on Shuixiegou mafic dike is 1 028 Ma. These geological facts and isotopic data reveal that all of VIC were emplaced in the roughly same age, i. e., Jinningian Period. Rb-Sr isochron age of Xinchun granitic batholith about 15 km east to the copperfield is 960 Ma, which also demonstrates that the strong and extensive magmatism happened during Jinningian period.

3 DISCUSSION ON METALLOGENESIS

3.1 *Metallogenic Evidences*

(1) Intruded in YF and LF in Run 2, Baixila Mine, gabbrodiabase has a massive Cu-Fe bonanza which is in finger shape in the plan (i. e. , palm orebody), and is in lense shape in the cross section. Ore minerals are magmatite, hematite, chalcopyrite, bornite and pyrite.

(2) Altered gabbro, diabase, dolerite and alkaline basalt in the all copperfield, are more or less disseminated in chalcopyritization, bornitization and pyritization. In the weathering front is often seen eye-catching malachitization. In the particular case the altered mafic rocks have Cu mineralizations up to the edge grade (more than 0. 3%).

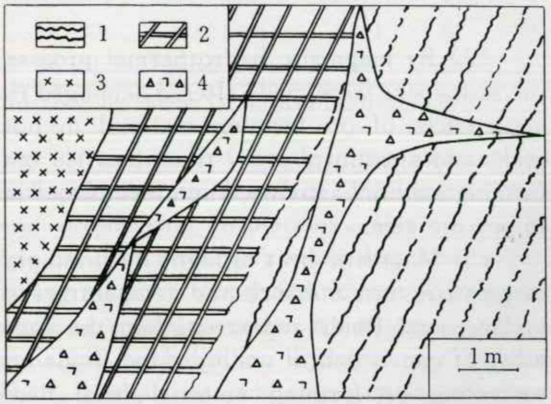

Fig. 2 Explosive breccia vein and basalt porphyrite in LF (tail channel in Yinming Mine)

1—dolomite with wave algae;
2—algal dolomite;
3—basalt porphyrite;
4—explosive breccia

(3) Cryptoexplosive subvolcanic pipe is commonly the best locus for Cu mineralizations, espicially bonanzas such as No. 3 and No. 4 orebodies in Baixila Mine , up to 20% of Cu grade. All of rocks are disseminated in bornite, chalcopyrite, forgerite and pyrite as well asminor fuchsite, cobaltite and nicklocobaltite.

(4) Stretching-longer thick pay ores are inseparable with mafic dikes as same as body and shadow, occurring in either upper or lower wall of dikes. The distances between pay ores and dikes are generally not more than 40 m.

(5) Most of pay ores filled in fractures exhibit $\delta^{34}S$ of from +0. 6% to −0. 6%, $\delta^{13}C$ of −0. 528%. δD and $\delta^{18}O$ for ore-forming fluids are projected in the region of magmatic fluids or the transition between magmatic water and formation water. The data support that magmatic material was involved in mineralizations.

3. 2 *Ore-Forming Element Geochemistry*

3. 2. 1 Cu content of VIC

Assay results suggest that VIC have Cu background values of from 212×10^{-6} to 310×10^{-6}, obviously higher than those of Kunyang Group (Table 1). Generally speaking, VIC intruded in ore-bearing beds such as YF, LF and HF contain higher Cu. However, intruded in ore-baring beds such as QF and DF, VIC even have Cu contents as several times to ten times as beds, in whose outer contact zone also exist Cu mineralizations, even Cu ores (Fig. 1). Therefore, high Cu contents of VIC and mineralizations in ore-bearing beds contacted with VIC and within VIC of itself display undoubtedly that Jinnigian magmatism must have provided with ore-froming material for superposing-reworking metallogenesis.

3. 2. 2 Ore-forming element geochemistry in contact zone

Table 1 Cu background contents of Kunyang Group and VIC(10^{-6})

Stratum	Sample number	Cu /10^{-6}	VICS	Sample number	Cu /10^{-6}
YF	31	52	Baixila	8	310
LF	28	189	Shamuqing	4	256
HF	12	45	Laoxinshan	102	78
QF	10	25	Tuobuka	6	250
DF	11	20	Mianshan	4	210

Analysed by Hunan Geological Institute, CNNC.

In both sides of larger-scale dikes contact metamorphic zone are seen commonly in variable widths, such as Shuixiegou dike, its outer contact zone is in width up to 1～5 m, undergone strong hornfelsization, skarnization and marblization, whereas its inner contact zone was saussuritized. From dike center and inner zone to out of dike, Cu contents change form 0.11% and 0.05% to 0.09%. Xintang dike has inner contact zone talcized, tremolitized, biotitized and carbonatized and outer contact zone talcized, tremolitized, marblized and skarnized. An evidenlty deplet halo of Cu exists in the margin of the dike. In the outer contact zone, Cu change greatly in content, either increasing or decreasing, locally concentrating into ore bodies (Fig. 3, Table2). Other trace elements have great changes in content as same as Cu. Above-mentioned facts clarify that material in the contact zone was clearly activitized and transported, on the whole, in inner zone output and depleted, whereas out of dike either decreased or enriched. The material activitized and transported was precipitated in the favorable lithological, structural and geochemical environment,

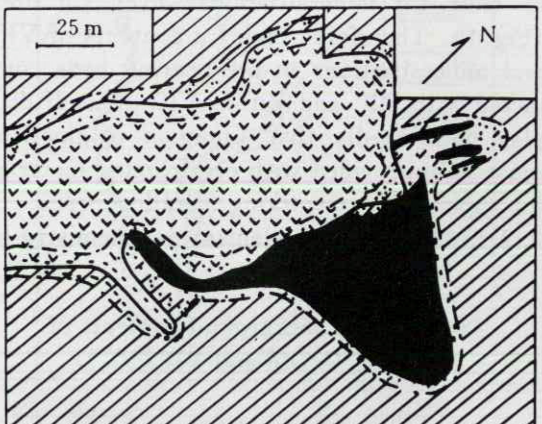

Fig. 3 Contact metamorphic zone of Xintang dike and mineralization

1—pelitic dolomite of upper YF;
2—gabbrodiabase;
3—outer/inner contact metamorphic zone;
4—Cu ore body

commonly in the dolomitic rocks out of dike enriched into pay ores.

3.3 *Superposing-Reworking Metallogenesis*

The superposing-reworking metallogenesis triggered by Jinningian magmatism is chiefly in following three respects.

(1) Directly provided with ore-forming material and formed ores by the magmatic liquation, differentiation and exhalation, e.g., palm orebody of Baixila Mine, and orebodies of explosive pipe type and Yanzhiyan type. Ores are characterized by high contents of Ti, Co, Ni, Cr and V as well as titanomagnetite, fuchsite, folgerite, cobaltite and nicklocobaltite.

(2) By magmatic hydrothermal process, the host rocks were made altered, changed the occurrences of ore-forming material in host rocks and stratiform ores, thus impelled ore-forming material activitized and reemplaced into pay ore veins.

(3) Magmatic heat brought by Jinningian magmatism can enhance the temperature of underground fluids and strengthen the capability of convection of underground fluids and extracting ore-forming material from mafic rocks and ore-bearing strata. Moreover, emplacement structures (explosive pipe and new fissures) produced by magmatism are favorable for underground fluids to circulate and extract ore-forming material and provide with spaces hosting ores.

4 SUMMARY

With the development and evolution of Kunyang Proterozoic Rift, stratiform ores were successively formed in YF (Xikuangshan type), LF (Dongchuan type) and HF (Taoyuan type). During the closure of the rift, strong mafic-dominante magmatism formed many Jinningian VIC enriching alkaline and titatium along Tandan-Baixila, Xintang-Shamuqing and Yinming-Shijiangjun structural zones. Because Jinningian magma

Table 2 Trace element contents in the contact zone of Xintang dike(10^{-6})

Sample	Rock	Ti	V	Cr	Mn	Co	Ni	Cu	Pb	Zn	Sr	Ba
DC420	outer zone	3 610	86	65	2 817	32	40	5.1	109	64	170	2 473
DC421	outer zone	3 692	86	62	3 457	28	40	11	113	63	263	1 210
DC422	inner zone	3 857	112	82	1 942	27	40	10	107	96	115	319
DC423	diabase	4 156	186	67	4 236	46	62	10	100	189	228	96
DC424	gabbro	>10 000	274	125	1 288	46	45	92	86	177	162	551
DC425	quartz vein	3 688	176	46	919	23	36	18	36	115	5.8	88
DC426	gabbro	>10 000	452	53	1 849	52	30	170	87	184	131	406
DC427	gabbro	>10 000	361	72	1580	47	29	1 067	88	174	252	396
DC428	diabase	>10 000	268	121	1 763	47	34	130	64	133	27	475
DC428-1	inner zone	3 637	104	71	4 210	46	34	26	100	76	579	215
DC429	outer zone	3 665	96	71	3 410	28	42	12	80	74	378	2 050
DC429-1	outer zone	3 117	69	76	5 154	41	54	56	97	135	1 014	346
DC430	outer zone	3 461	97	74	4 370	33	48	19	92	77	779	155
DC431	upper YF	740	56	30	6 510	18	13	75	76	80	89	345

Analysed by Hunan Geological Institute, CNNC.

was derived from Cu-rich upper mantle, and suffered contamination of continental crust and ore-bearing formations, Jinningian VIC has Cu content largely more than host rocks, laying material foundation for superposing-reworking metallogenesis. By magmatic differentiation, exhalation, hydrothermal process heat, flow process and emplacement structure activity, Jiningian magmatism formed pay ores of liquation-differentiation, superimposition and transformation types, making up a metallogenic series of superimposition and transformation.

According to above research, it is suggested to focus on prospecting for pay ores of superimposition-transformation type in ore-bearing strata in the special development of Jinningian VIC. In view of geological and geochemical data and occurrences of palm orebody and minerals of Cr, Co , Ni and V, it is concluded that in the depths of VIC may exist Cu-Ni mineralizations at large-scale. This should be devoted much attention by the department concerned.

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(Edited by He Xuefeng)