THE CHARACTERISTICS OF GEOLOGICAL GENERAL FIELD OF VOLCANIC BELT IN LANCANG RIFT VALLEY AND ITS SINGNIFICANCE FOR EXPLORATION[①]

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ABSTRACT

Based on the theory of dissipative structures and moving character-parameters of elements, this paper examines the characteristics of the geological general field of volcanic belt in the Lancang rift valley, west Yunnan, China. with an open system and lower pressure environment, the volcanic belt is characterized by a large scale continuously graduating dissipative structure and three orders of concentrated minerogenetic material fields, and by the energy fields that influence the time and space structure of material fields. The research shows that the third order minerogenetic material fields which surround volcanic eruptive centers and have hydrothermal superposition and reconstruction after the magma stage possess favorable prognosis targets for copper polymetal.

Key Words: rift valley, volcanic belt, geological general field , copper polymetal prognosis.

1 GEOLOGICAL STRUCTURE BACKGROUND

Located in Lancang-Mengnian region of west Yunnan Lancang rift valley extends for one hundred km from Heihe fault of Northern to Burma of Southern, and connects with Changning-Gengma rift valley. It shows a graben shape along the S—N strike. Both sides of the rift valley developed metamorphic rocks of Simon and Lancang group during the Proterozoic era. The rift valley accumulated thick sediments during the mid-upper Palaeozoic era. Among them three stratra successions can be classified: clasolite and silicolite of Devonian and Carboniferous period on the bottom; volcanic rocks of the Eliu group of lower series of Carboniferous period in the middle; and carbonatite and silicotite of the mid-upper series of Carboniferous, Permian and Jurassic period in the upper stratum. The whole thickness of the three strata successions reach 15,000 m, In the strata volcanic rock occupies about 320 km^2 with the greatest thickness of 1,500 m, It consists of volcanic clasolite (including volcanic tuff; breccia and agglomerate) and basalt that belongs to continent marginal rift valley type[1].

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There are three zones and one branch in the volcanic belt with west zone develops best. The famous Laochang Pb–Ag–Cu ore deposit is located in the north end of west zone . The other fifteen mineralized points distributed mainly in west zone. The principal metallogenetic elements are Cu, Pb, Zn, Au, Sb, etc. (Fig.1).

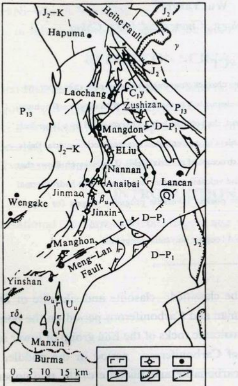

Fig.1 Geological Map of Lancang Region

1–Quaternary; 2–Jurassic–Cretaceous; 3–Devonian–Permian; 4–Volcanic rocks of Eliu group of lower Carboniferous; 5–Metamorphic rocks of upper Proterozoic; 6~ 9–Basic–ultrabasic vein rocks; 10–Granodiorite; 11–Granite; 12–Quartz vein; 13–Volcanic rocks; 14–Volcanic vent; 15–Mineralized point; 16–Fault; 17–Stratigraphic boundary; 18–National boundary

2 THE CHARACTERISTICS OF THE GEOLOGICAL GENERAL FIELD

Prigogine, the originator of famous theory of dissipativre structure, pointed out that in disequilibrium conditions far from an equilibrium area, a kind of stable orderly dissipative structure might appear[2,3]. Since then this theory has been applied in many fields including geology. many orderly structures in geology are self-organized phenomenons of microscopic system because of diffusing-moving and chemical reactions of materials and energies under disequilibrium conditions. In the volcanic belt of Lancang rift valley locate in Lancang-Mengnian region of west Yunnan, there exists a large scale continuously graduating dissipative structures and three orders of gradually concentrating minerogenetic material fields. This kind of structure is a new time-space one formed due to a strong decrease of temperature and pressure when magma erupts to the surface in an open system and due to the differences of moving character-parameters of elements.

2.1 *The Moving Character-Parameters of Elements And Their Component Classifications*

The principal character-parameters of elements that influence movement and diffusion of materials are ion radius R(Å), ralative specific volume V (radius / atomic weight) and specific enthalpy h° (the minus quantity of ion generating heat). According to deduction for Degroot diffusive equation[4], the elements with a larger radius will trend to the space of lower pressure, while those with smaller radius will trend to the space of higher pressure in action of pressure field; however material movement on viscous fluid depends not only upon the specific volume but also the viscocity of medium. The larger the viscosity of the medium (such as magma differentiation), the easier the heavy components with smaller V trend to lower pressure space. When the viscosity of the medium is smaller (such as hydrothermal liquid) the components with smaller V will trend to higher pressure space. In the action of the temperature field , the components with a lower h° will trend to a lower temperature space in a continuous system.

A diagram concerning character- parameters $R-V-h^\circ$ (See Fig.2) shows that three kinds of components can be obviously classified from the principal diagenetic and minerogenetic elements of the volcanic belt. The first kind belongs to the petrogenetic elements component, including Si,Al, Ca, Mg, K, Na, Be, etc., Its V and h° are larger so it will trend to the higher pressure space in process of magmatic differentiation; The second kind, including Cr, Ni, V, Ti, Co, Fe, etc., belongs to the component of minerogenetic elements, its R is medium size while V and h° are smaller than those of the first kind, so it will be trended to lower pressure space in the process of magmatic differentiation. The third kind, including Au, Ag, Cu, Pb, Zn, Cd, Ga, Ge, As, Sb, Bi, Hg, etc, also belongs to the components of minerogenetic elements. But its V is smaller than that of the first and second kinds, and it is strong chalcophile, so it often forms various complex sulfur-compound and concentrates in hydrothermal liquids, and then trends to the higher pressure space of the volcanic dome and erupts to the surface along with volcanic gas and liquid.

2.2 *The Characteristics of Material Fields in Volcanic Belt*

2.2.1 The Time Structural Characteristics of Material Fields

Its can be described from two aspects:

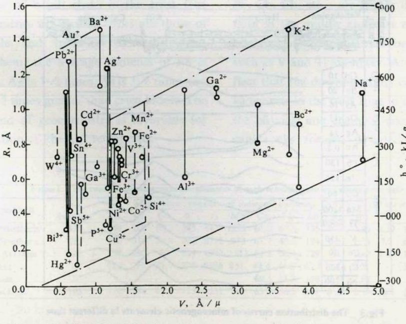

Fig.2 Diagram showing the classification of element-components by their moving character-parameters

1. The time structural characteristics of diagenetic and minerogenetic materials of the volcanic belt are closely connected with tectogenesis and magma activity as well as sedimentation in this region. The rift valley began to extend and downpunch from Devonian, and correspondingly developed clasolite and silicolite formation. In the early carboniferous period the boundary faults of rift valley developed deeply into upper mantle. In lower pressure condition heavy materials rose up and then basic volcanic rocks erupted along faults. In the extending and downpunching environment of the rift valley, the minerogenetic elements of trending lower pressure, such as Co, Ni, Cr, V, Ti, Mn, etc. , began to differentiate , move , and form a basic uprake; while the diagenetic elements of trending higher pressure and temperature, such as Ca, Mg, Al, Si, K, Na, etc. lagged behind so that the magma differentiated toward mid-basic and alkaline-basic property, and then concentrated in some stress-focussing parts and exploded as volcanic center type. Correspondingly many chalcophile minerogenetic elements of trending higher pressure were brought out with volcanic gas and hydrothermal liquid such as Pb, Ag, Cu, Zn, As, and the others. They deposited synchronously with volcanic clastic constituents and formed the principal original-bed. In the mid-late Carbiniferous and early Permian period the rift valley downpunched relatively quietly. But volcanic exhalation sometimes occurred and again brought out a part of the minerogenetic elements such as Pb, Ag, As, and so on. They deposited synchronously with a covering strata materials and formed a

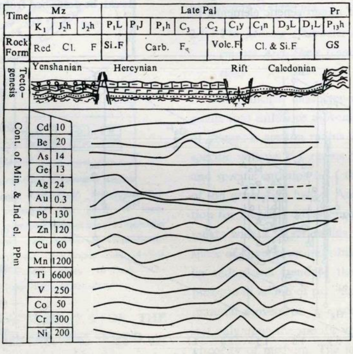

Fig.3 The distribution curves of minerogenetic elements in different time and formation and corresponding tectonic movement in material field of Lancang rift valley.

carbonatite formation that contained Pb and Ag etc . This is the subordinate minerogenetic original-bed of this region. From the late Permian to the Cretacous period the rift valley was sealed and extended once again. Since its descending depth was not so great as before there were no deep original materials rising up, and only large thick red clasolite formation developed in the rift valley during the Jurassic-Cretaceous period. It is Yanshanian movement that made the rift valley compress and seal again, accompanied by intrusion of neutral-acid magma and superposition and reconstruction of minerogenetic activity, see Fig.3.

2. The density of minerogenetic materials. Comparing the strata of each period, it can be seen from Table 1 that the contents of minerogenetic elements trending to lower pressure in the formation of C_{1y} basic volcanic rocks are higher than those in the strata of other period. Howerer they only close to the abundance of basalt rocks in the crust. The richer elements in volcanic rocks are those of chalcophile and trending higher pressure. Among them, the average contents of Pb is 5–8 times, Ag is 1–2 times, As is 3–4 times and Cd is 6–15 times greater than crust-basalt. The background of geochemistry is favorable for the formation of Pb–Ag ore deposits.

2.2.2 The Space Structural Characteristics of Material Field.

1. The first order minerogenetic material field is the geological-geochemical background field with a continuously graduating dissipative structure in the region. It formed the principal minerogenetic original-bed. But it is not uniform and a certain difference exist in rock types and the contents of minerogenetic elements, which can be seen from Table 1 and through the comparsion of three volcanic zones from west to east and from north to south respectively:

West-East comparison shows the volcanic rock in west zone developed better. Its thickness is larger and contains more lava . In volcanic clasolite, there are more breccia and agglomerate. In mid-east zones the principal volcanic rocks are tuff and sediment-tuff, and they developed imperfectly and discontinously. It can be seen from Table 1 that the contents of chalcophile minerogenetic elements such as Ni, Co, Cu, etc. , are higher in the west zone than in the middle and east zones, while the contents of lithophile minerogenetic elements such as V and Ti are lower. All these above reflect that the downpunching center of the rift valley was in the west zone in that period, and the physical and chemical condition that volcanic rocks formed deviated more reductive

Table 1 The contents of minerogenetic elements of each volcanic zone in Lancang rift valley

Volcanić belt		No. Samples	Main minerogenetic and indicator elements (Au: ppb; the others:ppm)														
			Ni	Cr	Co	V	Ti	Mn	Cu	Pb	Zn	Ag	Au	As	Be	Ge	Cd
West Zone	Northern	327	159	268	50.2	245	3977	1258	61.3	67.6	135	0.14	2.25	6.37	19.8	1.0	3.98
	Southern	293	198	314	51.0	222	6712	973	61.7	43.2	124	0.07	1.34	7.8	6.74	0.98	2.65
	Average	620	178	290	50	234	4992	1123	61.5	56.1	129	0.11	1.82	7.04	13.7	0.99	3.35
Mid–Zone		14	92.6	279	39.7	276	9366	851	44.4	44.5	82.4	0.18	1.98		2.96	1.0	1.14
East–Zone		27							60.5	33.7	198	0.18	2.05				
Arkarbai Dist.		193	120	180	43.9	215	6231	794	65.5	53.8	144	0.21	2.19	16.3	2.98	6.27	2.53

environment. Especially the contents of chalcophile minerogenetic elements which trend to higher pressure, such as Cu, Pb, Zn, Cd, etc. , and diagenetic element Be which related to volcanic exhalation are higher. These characteristics show that the minerogenetic condition of copper polymetal deposits of volcanic type in the west zone is better than in the mid-east zones.

South-North comparison appears the volcanic rocks in south part of the west zone deviate to basic and ultrabasic property. They are characterized by greater thickness and more lava with pillow structure. In some places Komatite was discovered such as in Mengnian county, while in north part of the west zone there are alkali-neutral rocks. In Laochang ore field appears ignimbrite. The contents of Pb, Zn, Ag, Au, Cd, Mn, etc. and Be are higher than those in south part, while the contents of Ni, Ti, Co, etc. are lower in north and those of Cr and V are nearly the same in both part (Table 1). The principal factor analysis shows that the main components of the minerogenetic elements are Pb–Ag–Cu–Zn in the north part, and Co–Ni–Cu–Au in the south part. These characteristics imply that the developing depth of the rift valley and the emplacing depth of see water in the north were shallower than that in south part. On the other hand, the volcanic explosion in north part is stronger, correspondingly the condition of forming volcanic exhalation-sediment Pb–Ag–Cu deposits is more favorable in the north than that in the south.

2. The second order minerogenetic material field means a geological-geochemical background-abnormal field of minerogenetic materials, which is distributed around a volcanic center and forms the ore field. According to the geological survey of 1 / 50,000 scale, eight volcanic eruptive centers have been discovered in Lancang, Mangdon, Eliu, Ahaibai, Jinmao, Jinxin, Manghong in the west zone, and Zushizan in the east zone (Fig.1). Besides the known ore field, Akarbai district which surrounds the Ahaibai volcanic center is the first order prognostic one this time. The result of the geological survey of 1 / 10,000 scale shows that minerogenetic materials of ore field trend to further differentiating and concentrating on the basis of the first order material field in this region:

(1) The rock types: Some neutral and neutral-basic deviating alklai rocks appear in the ore field. In the volcanic center near Laochang and Akarbai districts there are andesite,andesite basalt and andesite-tuff and lava etc.

(2) Minerogenetic materials: In ore field around volcanic center, there are a lot of chalcophile minerogenetic elements and natural metals which trend to higher pressure, Their contents are higher in the second order minerogenetic material field. Also there are some chalcophile minerogenetic elements which trend to lower pressure such as Cr, Ni, Co, V, etc., but their contents are lower than those in the first order minerogenetic material field (Table 1).

(3) Most of the mineralized points and lithogeochemical abnormals are distributed around the volcanic centers. In the west zone of the volcanic belt, nearly thirty lithogeochemical abnormals or component anomalies of Cu,Pb, Zn, Ag, Au,Co, Ni, As etc. elements surround seven volcanic centers. Most anomalies are distributed in the strata of the anchi-volcanic center face. Recently drilling holes have passed through a pyrity bed

8 m in thickness, possessing higer contents of Cu, Pb, Ag, Sn, in the shallow of the anchi-volcanic center face of Akarbai minerolized point.

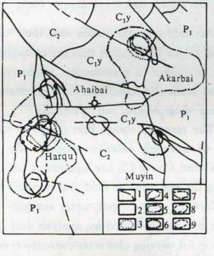

Fig.4 The second order minerogenetic material field and lithogeochemical anomolies around the volcanic vent in Akarbai district

P_1–permiam; C_2–mid-upper Carbaniferous; C_{1y}–volcanic rocks of Eliu group of lower Car- baniferous; 1–Faults; 2–volcanic vent; 3–Cu, Pb, Zn, Ag, Au, As, Sn, lithogeochemical anomolies

3. The third order minerogenetic material field is a geological-geochemical abnormal field of minerogenetic materials . It forms on the basis of the second order minerogenetic material field on which the volcanic materials are superposed and reconstructed by the minerogenetic materials provided by magma hydrothermal or mobilized from volcanic rocks by an intrusive body. In Laochang district, it has been proved by drilling hole that a granite-porphyry intrudes into the volcanic dome. There is a copper-containing pyrity bed 80 m thick above the contact zone. Up again in C_{1y} volcanic rocks and in the faults and fractures of C_{2+3} limestones the stratoid and vein Pb–Ag ore bodies are distributed. The genesis of ore deposit belongs to a polygenetic compound ore deposit of marine volcanic synchronous deposit-exhalating hydrothermal type superposed by deuteric hydrothermal liquid.

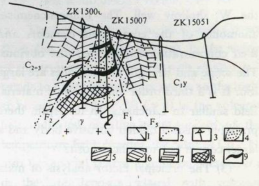

Fig.5 The model of mineralizing and element zoning of No. 150 profile in Laochang ore deposit

C_{1y}–Volcanic rocks of Eliu group of lower Carboniferous; C_{2+3}–Limestone and dolomite of mid-upper Carboniferous; r–Granite; 1–Faults; 2–The boundary of strata; 3–Drilling hole; 4–7–Sn-Cu-Pb-Zn lithogeochemical anomolies; 8–Copper ore body; 9– Pb-Ag ore body

The third order minerogenetic material field has the following characteristics:

(1) The higher pressure-trending minerogenetic elements concentrate further than in the second ore field, The strength and scope of the lithogeochemical anomolies of the minerogenetic and indicator elements enlarge, the horizontal and vertical zonings of those develop better, and the concentration centers are more obvious. For example in Laochang district, the composite series of the lithogeochemical anomolies from upper to lower is Cd–Pb–Hg–Zn–Mn–Ni–Co–W–Sn–As–Bi–Cu. The first seven elements are the zoning series of Pb–Ag ore deposit, and the latter five elements are the zoning series of copper ore

deposit.

(2) Some minerogenetic elements which trend toward higher temperature and higher pressure, such as Sn–Bi–W which obviously related to magma hydrothermal liquid are superposed in former minerogenetic materials (Fig. 5). In Akarbai, felsic veins appear on the surface. The content of tin is very high in the W_1 shollow well. The lithogeochemical anomolies of the component elements and their concentration centers are more obvious. The scope and strength of anomolies are large too. It is a third order minerogenetic material field similar to Laochang. In its depth, there probably exists a hidden intrusive body and a larger copper polymetallic deposit.

(3) The principal factor analysis of main minerogenetic and indicator elements in volcanic rocks of Akarbai ore field shows that (Table 2) about 60% of minerogenetic materials (As, Ag, Pb, Cu, etc.) is provided by minerogenetic orginal bed of volcanic rocks; 20% –30% comes from those superposed by deuteric hydrothermal. An intrusive body can not only provide heat energy that made the minerogenetic materials of original bed mobilize and move to a favorable space of ore-formation structure, but also made the new minerogenetic materials superposed in the former ore deposit. So copper polymetal deposits with large scale should occur in the third order minerogenetic material fields and locate in the volcanic domes with hidden granitoid and favorable ore-bearing structures.

2.3 *The Characteristics of Energy Field*

According to the ratios and their variation of a pair of elements that are strongly relative or similar in geochemical property, the special formative condition and geochemical process of ore deposit can be reflected[5].

The research shows that the ratio variation of intensely relative elements Zn and Cd,Ni and Co or Cu are significant for indicating the temperature field and pressure field for forming copper polymetal deposit. The cause can be illustrated by analysis and comparison for moving character-parameters of element pairs (Table 3).

2.3.1 The Ratio of Zn / Cd

According to the principle delineated by Goldschmidt, Cd is more sensitive than Zn to temperature rising. In the temperature field, along with heat diffusion the Cd with smaller h° will trend to the lower temperature space, while Zn with larger h° trends to the higher temperature space . The result is the higher

Table 2 The Principal Factor Analysis of Volcanic Rocks in Akarbai District

strata	Lithology	F1 (Volcanic exhalation)		F2(Magma hydrothermal)		F3(Basic lava differenciation)	
		Prin. comp.	Var. distr.	Prin. Comp.	Var. distr.	Prin.Comp.	Var. distr.
C_{1y}	volcanic tuff, breccia, basalt, Andesite	Ge, As, Ag, Pb, Mn, Cu	56. 07%	As, Ag, Pb, Cu, Au, Cd	20. 28%	Co, Ni, Cr, Au	11. 90%

Table 3 The moving character–parameters of relative elements in volcanic rocks

Moving Character Parameter	Zn^{2+}	Cd^{2+}	Cu^{2+}	Co^{2+}	Ni^{2+}
Ion Radius R(A)	0 · 83	0 · 92	0 · 81	0 · 83	0 · 77
Specific Volume V	1 · 28	0 · 82	1 · 27	1 · 41	1 · 31
Specific Enthalpy h°	153 · 4	75 · 9	–65 · 7	58 · 2	54 · 0
Ion Potential π	2 · 41	2 · 17	2 · 47	2 · 41	2 · 60

ratio halo of Zn / Cd in the volcanic belt indicated the positive point-source of the temperature field. On the other hand, the difference between the V of Zn and Cd is also larger, In the pressure field and in the volcanic gas and hydrothermal liquid, because the medium viscosity is smaller the Zn with larger V trends to the lower pressure space, while the Cd with smaller V trends to the higher pressure space.

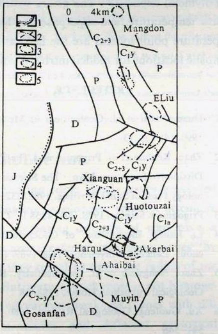

Fig.6 Distribution of halos of higher Zn / Cd, Cu / Ni and Co / Ni ratio in the middle part of Lancang volcanic belt.

L–Jurassic; P–permian; C_{2+3}–Mid-upper Carboniferous; C_{1Y}–Volcanic rocks of lower Carboniferous; D–Devonian; 1–plane of unconformity; 2–faults; 3~5–Higher ratio-halo of Zn / Cd, Cu Ni and Co / Ni

So the higher ratio halo of Zn / Cd in volcanic belt also indicated the negative point-source of the pressure field. The isolines enclosed by high ratio of Zn / Cd (> 300) in the middle part of Lancang volcanic belt showed four positive point-sources of the temperature field respectively in Eliu Jinmao (Gosanfan), Akarbai and Huotouzai. The first two places coincide with the locations of volcanic centers investigated this time, the latter two places are probably relative with hidden intrusive bodies.

2.3.2 The Ratio of Cu / Ni and Co / Ni

The ion radius of Cu, Ni,N and Co are close, but their h° are different. In the action of the temperature field, Cu with smaller h° trends to lower temperature space, so the higher ratio halo of Cu / Ni (> 8) in the volcanic belt indicated negative point-sources of the temperature field. Besides, the ratio of Co / Ni also has special genetic significance, especially in the ore deposits related with volcanic sedimentation, Cobalt is very high[6]. So higher ratio halos of Cu / Ni and Co / Ni (>8) indicated the locations of volcanic basin and the moving direction of volcanic materials. Especially in Akarbai, the higher ratio halos of Zn / Cd, Cu / Ni and Co / Ni superposed together. That means the positive and the negetive point-sources of the temperature field superposed together, that is, the volcanic basin with a lower temperature field superposed by a higher temperature point-source. This is an important information for prognosticating the hidden intrusive body.

3 CONCLUSION

(1) The Lancang volcanic belt forms in the open system of the rift valley. In the lower pressure environment, basic magma and heavier materials rise up. Along with the procession of effusion-explosion-sedimentation of the volcanic activity, the diagenetic and the

minerogenetic materials gradually differentiate and diffuse to form a large scale of continuously graduating dissipative structure and three order minerogenetic material fields.

(2) The principal energy fields that influence the time-space structure of the material field are the temperature field and the pressure field. In the action of the energy field , the chalcophile minerogenetic elements which trend to higher pressure, move toward the volcanic center and erupt out with volcanic exhalation and hydrothermal liquid, while the chalcophile and lithophile minerogenetic elements which trend to lower temperature, move toward the volcanic basin. The ratio isolines of relative elements indicate the places of volcanic domes or basins and the directions of movement of minerogenetic materials.

(3) The comparison of material fields of the volcanic belt from west to east and from north to south indicates the difference of the formative environment of the rift valley: The dowmpunching depth of the rift valley is larger in the west zone, especially in south part of the west zone. However the volcanic explosion is stronger and effusion is weaker in the north part than in the south part of the west zone. So the north part provide more minerogenetic materials of Pb, Ag,As, Cd, ect. and more favorable conditions for forming the Cu–Pb–Ag deposits related with volcanic–exhalation and hydrothermal superpostion and reconstruction.

(4) The third order minerogenetic material fields that surround volcanic eruptive centers and have hydrothermal superpostion and reconstruction action after the magma stage are favorable explorative objects for copper polymetal deposits; The places with original low temperature field superposed by high temperature point-sources are the favorable prognostic locations for hidden intrusive bodies.

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