Comparative Study of Gacun and Youre Silver–Lead–Zinc–Copper Deposits in Sichuan, SW China, and their Mineralization Significance

DANG Yuan¹, CHEN Maohong²*, FU Bin³ and XUE Zhiqiang⁴

¹ School of Earth Science and Resources, China University of Geosciences, Beijing 100083, China
² MLR Key Laboratory of Metallogeny and Mineral Assessment, Institute of Mineral Resources, CAGS, Beijing 100037, China
³ Research School of Earth Sciences, The Australian National University, Canberra, ACT 2601, Australia
⁴ NO.1 Institute of Geological and Mineral Resources Survey of Henan, Luoyang 471000, China

Abstract: The large Gacun silver–lead–zinc–copper deposit in Sichuan Province is one of the largest volcanogenic massive sulfide (VMS) deposits in China. The deposit consists of western and central ore bodies, which form a vein–stockwork mineralization system corresponding to hydrothermal channels, and eastern ore bodies, which form an exhalative chemical sedimentary system derived from a brine pool in a submarine basin. The Youre lead–zinc deposit, which is currently under exploration and lies adjacent to the southern part of the Gacun deposit, is characterized by intense silification and vein–stockwork structures and consists of massive silicified rhyolitic volcanics, banded rhyolitic tuff, and phyllitic sericite tuff. From a comparison of their ore-bearing horizons, the Gacun and Youre deposits have a continuous and stable hanging wall (calcareous slate and overlying andesite) and foot wall (rhyolite–dacite breccia and agglomerate), and the lithologic sequence includes lower intermediate to felsic rocks and upper felsic rocks. Thus, the Youre deposit, which comprises relatively thinly layered low–grade ore, is regarded as forming a southward extension of the Gacun deposit. A further comparison of the structures of the ore-bearing belts between the two deposits suggests that the Youre ore bodies are similar to the western ore bodies of the Gacun deposit. Moreover, the characteristics of fluid inclusions and stable isotopes in the Youre deposit are also similar to those of the western ore bodies of the Gacun deposit. Genetic models of the deposits are proposed for the Gacun–Youre ore district, and massive concealed ore bodies may occur in the Youre deposit at depths that are similar to those of the eastern ore bodies of the Gacun deposit.

Key words: ore-bearing horizon, structure of ore-bearing belt, VMS deposit, Gacun–Youre ore district

1 Introduction

Volcanogenic massive sulfide (VMS) deposits are strata-bound accumulations of sulfide minerals that precipitated at or near the sea floor in spatial, temporal, and genetic association with contemporaneous volcanism (Franklin et al., 1981, 2001; Barrie and Hannington, 1999; Large et al., 2001). VMS deposits are major sources of zinc, copper, lead, silver, and gold, and significant sources of cobalt, tin, selenium, manganese, cadmium, indium, bismuth, tellurium, gallium and germanium (Singer, 1995; Song et al., 1997; Kerrich et al., 2000; Peng Runmin and Zhai Yusheng, 2004; Xu Yonghang et al., 2009; Zhang Jing et al., 2009; Zheng Yuanchuan et al., 2011; Shanks and Thurston, 2012; Wang Gongwen et al., 2014; Xu Jiuhua et al., 2014, 2016; Yang et al., 2014; Men Yei et al., 2014; Zhang Hui et al. 2015; Tornos et al., 2015; Ye Huishou et al., 2016; Yang et al., 2017).

The large Gacun silver–lead–zinc–copper deposit (with ore reserves of 1570 Mt, Cu 0.40%, Pb 3.24%, Zn 5.27%, Ag 84.78 g/t; unpublished data) in Sichuan Province, southwestern China, is one of the largest VMS deposits in China. It was discovered in 1973, and mining started in 2006. The Gacun deposit includes western ore bodies (lower), central ore bodies (middle), and eastern ore bodies (upper), which constitute an integrated VMS metallogenic system. Both the western and the central ore
bodies are vein–stockwork mineralization systems with hydrothermal channels. The eastern ore bodies form an exhalative chemical sedimentary system derived from a brine pool in a submarine basin. All three ore bodies have the ‘trinity’ characteristics of host volcanic rocks + sulfide ore bodies + exhalative chemical sedimentary rocks (Ye Qingtong, 1991; Xu Mingji et al., 1993; Hou Liwei, 1994; Hou Zengqian, 2001a) and a bilayer structure with lower tubular and upper stratiform components (Eldridge et al., 1983; Lydon, 1984, 1988; Humphris et al., 1995; Large et al., 2001; Franklin et al., 2005). Among the three ore bodies, massive black ores in the eastern ore bodies are the highest in grade (Ag 145.54 g/t; Pb 4.05%; Zn 6.51%; Cu 0.74%; unpublished data).

The Youre deposit is adjacent to the Gacun deposit to the south. A group of ore bodies with a length of about 1100 m in the Youre deposit has been determined by drilling. These ore bodies are interlayered with rhyolitic volcaniclastic rocks. The ores have vein–stockwork structures, as well as banded and massive structures. However, massive black ores are not seen in the Youre deposit. This led Cao Xinzhi et al. (2009; unpublished) to suggest that the Gacun and Youre deposits have different ore-bearing horizons.

In order to confirm whether or not the Youre and Gacun deposits share the same ore–bearing horizon, and whether or not the silver–copper–lead–zinc mineralization in the Youre deposit is similar to that in the eastern ore bodies of the Gacun deposit, this paper conducts a detailed comparative study of the ore-bearing horizons, structures of the ore-bearing belts, and compositions and stable isotopes of the ore-forming fluids of the Gacun and Youre deposits. Thus, we attempt to establish genetic models of the Gacun and Youre deposits and to pinpoint the ore-bearing horizon and possible black ores in the Youre deposit that are similar to the eastern ore bodies of the Gacun deposit.

2 Geological Setting

The Gacun and Youre deposits are both located in the western Yidun island arc in the Songpan–Ganzi geosyncline fold system along the eastern margin of the Tethys–Himalayan tectonic domain (Ren Jishun et al., 1980; Huang Qijing and Li Chunyu, 1981; Fu Deming and Xu Mingji, 1996; Hou Zengqian et al., 2003; Lin Li et al., 2011; Lai Anqi et al., 2016).

The Yidun island arc formed in oceanic crust basement in the Xiangcheng region as a result of local expansion in the Late Carnian, i.e., during the Late Triassic period. The main part of the island arc formed at the terminal of the Carnian. The Yidun island arc became a young intracontinental orogenic belt accompanied by the closure of the Paleo-Tethys Ocean. Four discrete fault-controlled island arc rift basins then developed along the rift belt of the Yidun island arc: from north to south, these are named Zengke, Changtai, Xiangcheng, and Zhongdian. Most VMS deposits and prospects in the Yidun island arc belt developed in clusters in these intra-arc rift basins (e.g., Ye Qingtong, 1991; Hou Liwei et al., 1994; Fig. 1). The northern Changtai part of the Yidun island arc underwent extrusive uplift and expansion to form a fault depression. Thus, different subordinate tectonic units developed from east to west within the Changtai island arc rift basin, namely, a volcanic arc (outer arc), an inter-arc rift, a remnant arc (inner arc), and a back-arc basin. The Changtai inter-arc rift basin, which is characterized by a bimodal volcanic suite and abyssal sedimentary rocks, is tectonically similar to the back-arc Okinawa Trough (Letouzey and Kimura, 1986) and the Miocene back-arc sequence in northwestern Japan (Cathles et al., 1983).

An intense arc–continent collision in the Rhaetian stage of the Late Triassic resulted in the intrusion of syn-collision granites in the outer-arc plutonic belt. Intracontinental convergence reflects the termination of the evolution of the Yidun island arc (Hou Liwei et al., 1994).

The main regional structures include closed anticlines, synclinal folds, and faults. Both the fold axes and the faults are N–S trending. The main fault is the Ganzi–Litang deep fault. The Yidun island arc is an economically important part of the Sanjiang metallogenic belt with significant nonferrous and precious metal resources (e.g., Hou Liwei et al., 1994; Liu Xuelong et al., 2015; Gong Xuejing et al., 2017; Yin Minghui et al., 2017).

3 Deposit Geology

3.1 Strata

The main strata that outcrop in the Gacun–Youre ore district are the Tumugou Formation of the Upper Triassic, which is monoclinal and characterized by a steep westward dip and overturning (Fig. 2). The characteristics of each stratum unit from west to east are briefly summarized in Table 1.

3.2 Ore-bearing rocks

The ore bodies of the Gacun deposit are hosted within the upper felsic calc-alkali volcanics of a bimodal volcanic suite that belongs to the upper unit of the second member of the Tumugou Formation, which are conformably covered by dolomitic limestone and slate (Fig. 2). The ore-bearing rock series have the ‘trinity’ characteristics of host volcanic rocks + sulfide ore bodies + exhalative chemical
sedimentary rocks. The bimodal volcanic suite consists of lower mafic volcanics that belong to a tholeiite series and upper felsic volcanics of calc-alkali volcanic series. The mafic volcanics are mainly basalts and basaltic dacites. The felsic volcanic rocks consist of dacite, rhyolitic dacite, rhyolitic lavas, and volcaniclastic rocks. The exhalitive chemical sedimentary rocks coexisting close proximity with, and are interbedded with, the massive sulfide ore bodies. Baritic rocks constitute the main exhalites, whereas the other components comprise silicalite and jasperite. The main chemical sedimentary rocks are limestone and dolostone, which are commonly interbedded with calcium carbonaceous slate.

The ore bodies of the Youre deposit are hosted within rhyolitic volcaniclastic rocks that belong to the second part of the upper unit of the second member of the Tumugou Formation. The main ore-bearing rock series are a set of rhyolitic volcaniclastic rocks, of which the top and bottom parts both consist of gray-black calcium carbonaceous slate and limestone.
3.3 Ore bodies

3.3.1 Gacun deposit

On the basis of differences in mineralization and spatial distribution between the ore bodies, the Gacun deposit can be divided into three parts, i.e., western ore bodies (lower), central ore bodies (middle), and eastern ore bodies (upper) (Fig. 3). The characteristics of the ore bodies in the Gacun deposit are briefly presented here.

The western ore bodies, which have widths of 60–90 m, are developed in rhyolitic volcaniclastic rocks. The main
The gangue minerals are mainly quartz and sericite with chalcopyrite, tetrahedrite and pyrrhotite also abundant. and sphalerite are the dominant ore minerals and ores are veined, banded, and brecciated. Pyrite, galena, stratoid and lenticular forms. The main structures of the ore bodies, which mainly consist of silver–lead–zinc–copper stratiform and stratoid distribution. The main alterations are carbonatation and hyalophane. The main alterations include carbonatation and hyalophane. Quartz veins are neither developed nor mineralized. The Gacun deposit has a representative bilayer structure with lower tubular and upper stratiform components, of which the lower tubular component comprises stringer–stockwork ore bodies that constitute the western (lower) and central ore bodies, whereas the upper stratiform component comprises massive ore bodies that form by the eastern (upper) ore bodies. These three ore bodies represent an entire VMS metallogenic system, i.e., the western and central ore bodies are vein–stockwork mineralization systems with hydrothermal channels, whereas the eastern ore bodies form an exhalative chemical sedimentary system derived from a brine pool in a submarine basin. These three ore bodies have the ‘trinity’ characteristics of host volcanic rocks + sulfide ore bodies + exhalative chemical sedimentary rocks.

### 3.3.2 Youre deposit

The ore bodies of the Youre deposit, which have lengths of 1100m and widths of 100–250 m, dip westward and parallel to volcaniclastic rocks and are characterized by low-grade lead–zinc mineralization. The ore structures from Line 19 to 31 in the north are mainly stringer–stockwork. The main alterations include silicification, yellow-green magnesium-rich muscovitization, and sericitization. Large quartz veins are well developed and some are 5–8 m wide. The lower part from Line 39 to S5 in the south occurs as typical massive structures. The local structures are brecciated, banded, and disseminated. Pyrite is the major ore mineral in the massive ores, whereas the other components are galena and sphalerite. The massive pyrites have a ring-shaped structure that is similar to an exhalative vent. The
Fig. 3. Geological plan view at a level of 4100m of the Gacun and Youre deposits (modified from No.403 Geological Party, Sichuan Bureau of Geology and Mineral Resources, 1993; Sichuan Xinyuan Limited Liability Company, 2010; unpublished).
components (Dang Yuan et al., 2013) comprising lower tubular and upper stratiform bodies to form a typical bilayer structure, i.e., a structure or funnel-shaped and combined with the upper bedded ore original three-dimensional shape of the lower and middle bedded ore bodies. Structural restoration shows that the lenticle shapes and became oriented parallel to the upper rocks, were transformed into tight folds, rootless folds and stringer–stockwork ore bodies, which were originally within the formation. As a result, the lower and middle generally underwent deformation due to ductile shear. Besides, rhyolitic volcanic rocks with low competence folding and overturning of the strata in the deposit.

Yanshanian orogeny during the stage of collision between the deposit underwent extensive reformation in the 3.4 Ore district structure

After the formation of the Gacun deposit in the Triassic, the deposit underwent extensive reformation in the Yanshanian orogeny during the stage of collision between the arc and the continent, which resulted in the vertical folding and overturning of the strata in the deposit. Besides, rhyolitic volcanic rocks with low competence generally underwent deformation due to ductile shear within the formation. As a result, the lower and middle stringer and stockwork ore bodies, which were originally vertically bedded ore bodies and exhalative sedimentary rocks, were transformed into tight folds, rootless folds and lenticle shapes and became oriented parallel to the upper bedded ore bodies. Structural restoration shows that the original three-dimensional shape of the lower and middle vein and stockwork ore bodies was unconformably tubular or funnel-shaped and combined with the upper bedded ore bodies to form a typical bilayer structure; i.e., a structure comprising lower tubular and upper stratiform components (Dang Yuan et al., 2013). Ancient VMS deposits commonly occurred near plate margins in extensional basins that were inverted and strongly deformed during subsequent orogenesis (Allen et al., 2002; Mao Jingwen et al., 2014). Consequently, many ancient massive sulfide deposits are strongly deformed and their primary textures could be altered (Tornos et al., 2015).

4 Ore-bearing Horizons of the Gacun and Youre Deposits

At least five lithostratigraphic types, namely, bimodal–mafic, mafic, pelitic–mafic, bimodal–felsic, and siliciclastic–felsic types, can be determined in VMS deposits worldwide (Barrie and Hannington, 1999; Franklin et al., 2005). According to the classification by Franklin et al. (2005), the Gacun deposit should be classified as the bimodal–felsic lithostratigraphic type. The main structure of the known ore bodies is vein–stockwork in the Youre deposit; these ore bodies are bed-hosted within rhyolitic volcaniclastic rocks, but massive pyrite ores can also be found locally. Therefore, the key issues of whether or not the Gacun and Youre deposits share the same ore-bearing horizon and whether massive high-grade silver–copper–lead–zinc ores exist in the Youre deposit have been discussed for a long time. In order to solve these problems, a detailed comparison of the ore-bearing horizons between the Gacun and Youre deposits is made below. This comparison focuses on thickness, lithologic associations, characteristics of lithofacies and their spatial variation, and features of alteration and mineralization zoning. Finally, a histogram has been created that compares the structures of the ore-bearing horizons in the Gacun–Youre ore district (Fig. 4).

The dacite-rhyolite breccia agglomerate that belongs to the second part of the upper unit of the second member of the Tumugou Formation and the andesite that developed in the third member of the Tumugou Formation are hypothesized to be the lower and upper boundaries, respectively (Fig. 4). The ore-bearing horizons of the Gacun–Youre ore district can be divided into nine volcanic extrusive units. The Gacun River section in the Gacun deposit and drill sections from Line 39 in the Youre deposit are taken as examples and are summarized in Table 2.

To the east of unit IX of the Gacun deposit are rocks marking the beginning of another eruptive cycle, of which the lower part is massive grayish-green andesite and the upper part is andesite breccia. To the east of unit IX of the Youre deposit are also found rocks marking the beginning of another eruptive cycle, of which the lithologies are the same as those of the Gacun deposit.

The vertical variation characteristics show that the lithology of the ore-bearing horizons of the Gacun deposit changed from intermediate-felsic to felsic and the grain size of rocks changed from coarse to fine from the bottom to the top: the bottom consists of breccia and agglomerate, the lower part comprises dacite and rhyolitic dacite, the middle part is rhyolite, the upper part comprises breccia tuff, tuff, and sedimentary tuff, and the top consists of calcium carbonaceous slate.

The horizontal variation characteristics of the ore-bearing horizons in the Gacun–Youre ore district indicate that the top and bottom boundaries along the extent of the ore-bearing horizons are defined; all the bottom boundaries consist of rhyolite-dacite breccia and agglomerate, whereas all the top boundaries comprise calcium slate and overlying andesite.
Fig. 4. Histogram comparing the structures of ore-bearing horizons in the Gacun and Youre deposits.
The structures, mineralization zoning, and alteration zoning in the Gacun and Youre deposits were investigated (Xue Zhijiang et al., 2014; Fig. 6), and the characteristics are summarized in Table 3.

5 Structures of Ore-bearing Belts

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5.1 Gacun deposit

According to their structures and combined relationships with exhalative chemical sedimentary rocks, the massive sulfide ore bodies in the eastern ore bodies of the Gacun deposit can be further classified into five exhalative sedimentary units, which are described in Table 3 (Hou Zengqian et al., 2001a; Fig. 7). The microstructural units of the eastern ore bodies are composed of low-temperature hydrothermal deposition products and sulfide ore beds (black ores), which are characterized by barite and silicalite. The cyclic arrangement of these units indicates that the vertical accumulation of the ores occurred via the chemical precipitation and mechanical accumulation of the contents of a brine pool. Therefore, the sulfide and sulfate microstructural units of the massive ore bodies in the eastern ore bodies are the products of the periodic accumulation of hydrothermal fluids in a brine pool, which are episodically discharged, and the chemical precipitation and mechanical accumulation of metal sulfides.

The structural pattern of the western ore bodies, with thick massive silicified rhyolite and vein mineralization, is completely different from that of the eastern ore bodies.
The bottom part comprises dark grey rhyolitic dacitic tuffaceous breccia. The lower part is dark grey intensely pyritized silicified dacite (Fig. 8e). Banded and disseminated pyrite is the dominant sulfide. The breccia contains numerous white quartz veins with a width of 0.5–6 cm. It grades into less highly silicified and pyrite-rich dacite upward, and the dacite breccia is partially cemented by pyrite (Fig. 8f). The upper part is pyrite-bearing rhyolitic dacitic tuffaceous lava. The top comprises sericite tuff with well-developed cleavage. Cu–Zn–Pb mineralization is rare in this unit. The well-developed brecciated structure implies that this unit represents a hydrothermal channel or near-caldera facies.

The lower part is massive sericitized and pyritized dacite, and some quartz and Zn-Pb ore stringers are visible (Fig. 8k). The upper part is phyllicitic sericite tuff. The underlying part of this unit is yellow-green magnesium-bearing muscovitized banded rhyolitic tuff.

The middle part is gray banded rhyolitic tuff, part of which appears enriched in galena and sphalerite. The lower part is gray banded rhyolitic tuff, and vein–stockwork Zn–Pb ores are developed. The upper part is pyritized tuff, in which quartz stringers are well developed. The top comprises light gray sericite tuff with well-developed stockwork veins of quartz and Zn–Pb. The characteristics mentioned above suggest that the massive ore bodies have a typical exhalative sedimentary genesis, but this unit lacks exhalative sedimentary rocks represented by barite and silicicite.

The lower part is light green intensely silicified mineralized rhyolite. Because of the intense silicification, the rock displays a massive structure (Fig. 8l). Quartz and Zn-Pb ore stringers are well developed with a width of 0.5–2 cm (Fig. 8m). Sphalerite and galena are abundant and massive. Their lower parthas banded structure, and the middle part is interbedded with silicified rhyolitic tuff.

The lower part is massive layer of pyrite ore, which forms typical yellow ores (Fig. 8n). Other metal minerals include galena, sphalerite, and chalcopyrite; chalcopyrite is observably more common than at the top. The phenomenon whereby chalcopyrite–tetrahedrite–galena–sphalerite exhibits a circular distribution around geodes of quartz–calcite (Fig. 8l) is common, which is similar to the characteristics of a mature chimney structure. The upper part is light grey silicified mineralized tuff, which grades upward into dense silicified and banded ores. The top comprises light gray sericite tuff with well-developed stockwork veins of quartz and Zn–Pb. The characteristics mentioned above suggest that the massive ore bodies have a typical exhalative sedimentary genesis, but this unit lacks exhalative sedimentary rocks represented by barite and silicicite.

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The lower part is a massive layer of pyrite ore, which forms typical yellow ores. The phenomenon whereby chalcopyrite–tetrahedrite–galena–sphalerite exhibits a circular distribution around geodes of quartz–calcite can also be observed. The upper part is light grayish-green intensely silicified chloritized pyritized tuff, in which quartz stringers are well developed. The top comprises dark gray phyllicitic sericite tuff, in which there are abundant vein–stockwork quartz and numerous Zn–Pb veins (Fig. 8j). Sphalerite and pyrite are the dominant metal minerals in the veins. The massive sulfide ore beds change from laminated, strated, and graded bedding to massive ore beds that host barite breccia. The baritic rocks are mainly gray or black and massive. Their lower part has banded structure, and the middle part is interbedded with silicified rhyolitic tuff.

The bottom comprises small amounts of gray silicified mineralized banded rhyolitic tuff. Veins of Zn–Pb ores are well developed. The lower part is a 5m-thick massive layer of pyrite ore, which forms typical yellow ores (Fig. 8o). Other metal minerals include galena, sphalerite, and chalcopyrite; chalcopyrite is observably more common than at the top. The phenomenon whereby chalcopyrite–tetrahedrite–galena–sphalerite exhibits a circular distribution around geodes of quartz–calcite (Fig. 8l) is common, which is similar to the characteristics of a mature chimney structure. The upper part is light grey silicified mineralized tuff, which grades upward into dense silicified and banded ores. The top comprises light gray sericite tuff with well-developed stockwork veins of quartz and Zn–Pb. The characteristics mentioned above suggest that the massive ore bodies have a typical exhalative sedimentary genesis, but this unit lacks exhalative sedimentary rocks represented by barite and silicicite.

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Fig. 6. Detailed structural comparison of ore bodies in the Gacun and Youre deposits (after Xue Zhiqiang et al., 2014).
According to the combined relationships and textural structure of massive silicified mineralized rhyolite, banded rhyolite, and phyllitic sericite tuff, the western ore bodies can be divided into four exhalative sedimentary units. Here taking Line 11 at a Level of 4100 m as an example (Fig. 6), a description of these four exhalative sedimentary units is given in Table 3. The four exhalative sedimentary units described in Table 3 represent four major eruptive cycles. In each unit, massive intensely silicified mineralized (disseminated and vein) rhyolite is overlain by banded rhyolitic tuff with weak silicification, abundant large veins, and stringers and phyllitic sericite tuff with little or no silicification and mineralization. The exhalative sedimentary units represent hydrothermal channels of the hydrothermal exhalative metallogenic system. Therefore, the shape of each unit appears tubular in three-dimensional space and lenticular in plane view; this phenomenon could only be observed between Line 10 and Line 12 in the north and from Line 7 to 11 in the south.

5.2 Youre deposit
There are two major types of ore bodies in the Youre deposit (Table 3 and Fig. 6): massive ore bodies and veined ore bodies. The former occur between Lines 39/39A and Line 55 in the south, and the latter occur from Line 19 to Lines 31/31B.

Massive ore bodies: On the whole, the ore-bearing horizon consists of four microstructural units, in which the microstructure is characterized by silicified volcanics + massive ore bodies + stockwork mineralized sericite tuff. The phenomenon where by silicified volcanics occur at the bottom of the structural unit and breccias are cemented by sulfides indicates a hydrothermal channel or near-caldera facies. The middle part is mainly massive yellow ores; the lower and upper parts both contain disseminated and banded ores. This part should represent a sedimentary mound near the volcanic vent. The occurrence of sericite tuff at the top of each unit corresponding to the terminal stage of exhalative processes. This structural style is different from that of massive ore bodies + exhalative chemical sedimentary rocks found in the eastern ore bodies of the Gacun deposit.

Veined ore bodies: The structure of the ore-bearing horizon at ZK1901 is similar to that of the western ore bodies in the Gacun deposit, in that lower massive silicified rhyolitic volcanics and upper phyllitic sericite tuff are present in several repeating cycles. The ore bodies hosted within the lower massive silicified rhyolitic volcanics, which have a typical vein–stringer structure, represent hydrothermal channels in the hydrothermal exhalative system.

6 Discussion

6.1 Ore-bearing horizon
A comparison of the Youre and Gacun deposits shows that they are located in the same ore-bearing horizon (Fig. 4). Representative features of the two ore deposits are described in detail here.

All the bottom strata of the ore-bearing horizon consist of rhyolite-dacite breccia and agglomerate, which represent near-crater eruptive facies. Owing to the central eruption of intermediate to felsic rocks, rhyolite-dacite breccia and agglomerate would undergo a phase transition to breccia and lava, but the bottom margin of an eruptive cycle could be estimated by the boundary between breccia and agglomerate.

The lower part (including units II–V) of the ore-bearing horizon is mainly a set of coarse-grained rhyolite-dacite lavas and volcaniclastic rocks (breccia and tuff), which represent early intermediate to felsic magmatic activity in the eruptive cycle.

The upper part (unit VIII) of the ore-bearing horizon is mainly a set of fine-grained rhyolitic lavas and volcaniclastic rocks, including typical banded rhyolitic tuff and rhyolite, which represent felsic magmatic activity in the eruptive cycle. The upper part mainly consists of banded rhyolitic tuff and well-developed stringer–stockwork lead–zinc ore bodies. Rhyolite breccia and tuff are more abundant in this unit in the Youre deposit than in the Gacun deposit. The stringer–stockwork lead–zinc ore bodies in the Youre deposit are also high-grade with abundant pyrite. This ore-bearing horizon is equivalent to the central ore bodies of the Gacun deposit.

All the top boundaries of the ore-bearing horizon contain calcium carbonaceous slate and overlying andesites, which are typical marker beds. From the Gacun deposit to the Youre deposit the lithologies are steady and continuous. The steady appearance of carbonaceous slate (unit IX) represents a period of intermittent eruptions. The appearance of andesite, which is considered to be a marker bed, represents the beginning of another eruptive cycle. Moreover, there are thermally altered faded borders and condensation horizons at the boundary between carbonaceous slate and andesite in both the Gacun deposit and the Youre deposit, which indicate a normal sedimentary–volcanic contact relationship.

The Youre ore bodies (unit VI) are located at the lithologic transition interface between lower rhyolite–dacite volcanics and upper rhyolitic volcanics of the ore-bearing horizon, which is an obvious marker bed for the position of the ore-bearing horizon, i.e., the ore bodies are located at the bottom of the upper horizon, whereas thick rhyolitic volcanics cover the ore bodies. The western ore
bodies of the Gacun deposit (unit VI) display the same horizon characteristics as the Youre deposit.

The eastern ore bodies of the Gacun deposit (unit VIII) are located at the lithologic transition interface between the top of the upper rhyolitic volcanics and calcium carbonaceous slate, which is also an obvious marker bed of the position of the horizon. Although cycles of massive ore bodies and exhalative sedimentary rocks gradually grade into banded ore bodies interlayered with rhyolitic tuff, the thickness of the top volcanic rocks is commonly less than several meters. Owing to the southward lateral trend of the brine pool, the unit VIII cycle gradually pinches out.

The four former features mentioned above indicate that the Gacun and Youre deposits have continuous steady top and bottom marker beds and characteristic vertical lithologic variations from lower intermediate–felsic to upper felsic rocks. Therefore, we suggest that the Youre deposit is a natural southward extension of the Gacun deposit and both deposits are located in the same ore-bearing horizon. The two latter features indicate that the ore bodies are located at the different lithologic interfaces. The ore bodies in the west of the Gacun deposit and the Youre deposit occur at the lithologic transition interface between intermediate–felsic and felsic rocks, whereas the eastern ore bodies of the Gacun deposit occur at the interface between volcanic and sedimentary rocks. Different lithologic transition interfaces contain various types of ore bodies. Owing to the deficiency of ore bodies at the lithologic transition interface (unit VIII cycle) between volcanic and sedimentary rocks in the Youre deposit, we speculate that massive ore bodies that are similar to the eastern ore bodies of the Gacun deposit are concealed at depth.

### 6.2 Comparison of structures of ore-bearing belts between the Gacun and Youre deposits

The analysis of the structures of the ore-bearing belts in all drill sections from the Youre deposit (Fig. 6) suggests that massive ore bodies and vein–stockwork ore bodies are both present in the Youre deposit. The following is a comparison of the characteristics of the structures of the ore-bearing belts of the Youre and Gacun deposits:

1. **Comparison of massive ore bodies**

   - **Cyclic structure**: a typical exhalative sedimentary unit of the eastern ore bodies of the Gacun deposit is composed of massive ore bodies and exhalative sedimentary rocks (barite and silicalite) that are well developed on an outcrop–deposit scale.

   - **Mineral composition**: the massive ore bodies of the eastern ore bodies of the Gacun deposit are typical black ores, in which sphalerite is the dominant sulfide and other sulfides are abundant galena, tetrahedrite, and chalcopyrite, which compose the industrially important silver–copper–lead–zinc ore bodies. The massive ore bodies of the Youre deposit are typical yellow ores, in which pyrite (70%–80%) is the dominant sulfide and the...
other sulfides are sphalerite, galena, and small amounts of chalcopyrite and tetrahedrite. Thus, the massive ore bodies of the Youre deposit form low-grade lead–zinc ore bodies.

Position in ore-bearing horizon: the eastern ore bodies of the Gacun deposit are located at the interface between rhyolitic volcanics and sedimentary rocks, over which lie sedimentary rocks, i.e., sedimentary tuff with a thickness of less than 2–3 m. The Youre ore bodies are located at the interface between intermediate–felsic to felsic volcanics, over which lie banded rhyolitic tuff and rhyolite with a thickness of 70–130 m.

The characteristics mentioned above suggest that there are significant differences between the massive ore bodies of the Youre deposit and the massive ore bodies of the eastern ore bodies of the Gacun deposit. The presence of silicified volcanics and breccias cemented by abundant pyrite at the bottom of the Youre ore-bearing belt indicates the existence of a near-exhalative vent facies. Therefore, the massive ore bodies of the Youre deposit probably represent mounds accumulated in the early stages of an exhalative metallogenic system.

(2) Comparison of vein–stockwork ore bodies

Cyclic structure: the western Gacun ore bodies and Youre ore bodies are both composed of lower massive silicified rhyolitic volcanics and upper banded rhyolitic tuff and phyllicitic sericite tuff. More banded rhyolitic tuff is present in Gacun; however, amounts of breccia tuff and phyllicitic sericite tuff increase gradually southward toward Youre.

Alteration: The deposits are characterized by intense silicification. Yellow-green magnesium-bearing muscovite is well developed in large quartz veins and on both sides of the ore bodies. Large quartz veins, stringers, and stockwork are well developed.

Mineralization: sphalerite is the dominant sulfide in both the Gacun deposit and the Youre deposit. Pyrite, galena, chalcopyrite, and tetrahedrite are also present.

Position in ore-bearing horizon: the Youre ore bodies and western Gacun ore bodies are both located at the interface between intermediate–felsic to felsic volcanics, over which lie thick banded rhyolitic tuff and rhyolite.

The characteristics mentioned above suggest that the veined ore bodies of the Youre deposit are similar to those in the western ore bodies of the Gacun deposit. Unit IV of the Youre ore bodies is similar to the lower part of the middle ore bodies of the Gacun deposit, which represents their beginning.

From the above comparison, the veined ore bodies from Line 19–31 in the northern Youre deposit are similar to those in the western ore bodies of the Gacun deposit, but in the corresponding position the massive ore bodies appear at Line 39–55. In addition to the veined ore bodies that exist above and below these massive ore bodies, above the massive ore bodies there is also present rhyolite with a thickness of nearly 100 m. Moreover, the massive ores of the Youre deposit mainly contain pyrite, which is also present in Canadian VMS deposits (Galley et al., 2007), but differ from the massive black ores and barite of the eastern ore bodies of the Gacun deposit. The spatial position, cyclic structure, and mineral associations of the massive Youre ore bodies are similar to those of the western ore bodies of the Gacun deposit. Therefore, we consider that the Youre ore bodies (as a single ore-bearing belt) are similar to the western ore bodies of the Gacun deposit.

6.3 Source of ore-forming fluids

Dang Yuan et al. (2014) conducted detailed research into fluid inclusions and found that abundant biphasic aqueous inclusions with low salinity, sometimes with an unidentified solid phase, are present in quartz in massive ores and vein ores from the Gacun and Youre deposits. Microthermometric results show that the fluid temperatures of the western Gacun ore bodies (which range from 203°C to 350°C) are similar to those of the Youre deposit (which range from 183°C to 317°C), and both values are higher than those of the eastern Gacun ore bodies (which range from 153°C to 317°C). The fluid salinities of the western Gacun ore bodies vary from 2.6 to 7.2 wt% sodium chloride equivalent (NaClequiv); those of the Youre deposit range from 2.1 to 6.7 wt% NaClequiv; and those of the eastern Gacun ore bodies vary from 1.1 to 6.5 wt% NaCl equiv. The fluid densities are 0.65–0.90 g/cm³ for the western Gacun ore bodies, 0.73–0.91 g/cm³ for the Youre deposit, and 0.81–0.94 g/cm³ for the eastern Gacun ore bodies. Thus, the characteristics of the ore-forming fluids of the Youre deposit are similar to those of the western ore bodies of the Gacun deposit. The homogenization temperatures of aqueous inclusions from lower vein and stockwork ores are distinctly higher than those of the upper massive ores in Kuroko-type deposits (Urabe and Sato, 1978; Yoshida, 1979). Both the Gacun deposit and the Youre deposit have the same characteristics with respect to homogenization temperatures.

The ore-forming fluids of VMS deposits is approximately comprise a simple sodium chloride–water system, the salinity of which is similar to or slightly higher than that of normal seawater (Ulrich et al., 2002; Zaw et al., 2003). Fluid inclusion data suggest that the salinities of the ore-forming fluids (3–6 wt% NaClequiv) of Kuroko-type deposits are generally equivalent to that of seawater (Ishihara, 1974; Lu Huanzhang et al., 2004), i.e., the salinities of fluid inclusions from massive ores and...
stockwork ores are similar to that of seawater (2–5 wt% NaCl equiv). Moreover, there is evidence that suggests that salinities of deep fluids (5.7–8.4 wt% NaCl equiv) are higher than that of normal seawater (Urase and Sato, 1978). The higher salinities can be attributed to the input of magmatic water (Lu Huanzhang et al., 2004), and previous researchers have proved that a certain amount of magmatic water is introduced into submarine hydrothermal metallogenic systems (Urase and Marumo, 1992; Yang and Scott, 1996; Hou et al., 2001b). The salinities of the Gacun and Youre deposits have the same characteristics as those of Kuroko-type VMS deposits.

The $\delta^{18}$O$_{\text{SMOW}}$ values of quartz from the western Gacun ore bodies vary from 14.7‰ to 16.3‰, whereas these values range from 14.5‰ to 15.5‰ for the Youre deposit and from 14.8‰ to 16.1‰ for the eastern Gacun ore bodies (Dang Yuan et al., 2014). The $\delta^{34}$S$_{\text{CDT}}$ values are $-22.51$‰, from Zhu Weiguang et al., 2001) are similar to those of the eastern ore bodies of the Gacun deposit. Nineteen samples of sulfides from the western ore bodies of the Gacun deposit and the Youre deposit were plotted close to those for magmatic water (Dang Yuan et al., 2014). The above analysis concluded that the source of the ore-forming fluids of the Gacun and Youre deposits comprised seawater mixed with magmatic water. The reason why all the samples have $\delta^D$ values below those of the original magmatic water is attributed to a severe reduction in $\delta^D$ values during the main stage of metallogenesis. Because the bisulfide ions and hydrogen sulfide cause a severe reduction in $\delta^D$ values with respect to water, the addition of even a small amount of hydrogen ions from bisulfide ions and hydrogen sulfide can lead to a severe reduction in $\delta^D$ values in fluid systems (Chen Yanjing and Zhang Li, 2008). The $\delta^{18}$O$_{\text{HDO}}$ values of the western ore bodies of the Gacun deposit and the Youre deposit lie within the range of those of the original magmatic water. However, the $\delta^{18}$O$_{\text{HDO}}$ values of the eastern ore bodies of the Gacun deposit are less than those of the other samples and slightly lower than the range for the original magmatic water, which may have been caused by an increase in the input of seawater as the eastern ore bodies are closer to seafloor.

The data for stable isotopes and fluid inclusions suggest that the hydrogen and oxygen isotope compositions of ore-forming fluids from altered pipes (channels of fluid migration) and massive ores are similar to those of seawater ($\delta^{18}$O $\approx$ 0). However, the $\delta^{18}$O values range from 14.5‰ to 16.3‰ in the Youre and Gacun deposits. The reason for this is that fluids with high $\delta^{18}$O values comprise a mixture of magmatic water and seawater, which causes an increase in $\delta^{18}$O values and a decrease in $\delta^D$ values with respect to seawater. (Huston et al., 2011). Moreover, the reaction of seawater with felsic volcanic rocks with high $\delta^{34}$S values can form fluids with high $\delta^{34}$S values in conditions of high temperatures and a low m$_{\text{water}}$/m$_{\text{rock}}$ ratio (Yu Jinjie et al., 2000).

From the above discussion, we consider that the source of the ore-forming fluids of the Gacun and Youre deposits comprised seawater with addition of magmatic water. The characteristics of fluid inclusions from the main metallogenesis in the Gacun and Youre deposits are similar to those of typical Kuroko-type deposits. The ore-forming fluids of the Youre deposit are similar to those of the western ore bodies of the Gacun deposit but differ from those of the eastern ore bodies of the Gacun deposit.

### 6.4 Source of ore-forming materials

Sulfur isotope data obtained by Dang Yuan et al. (2014) are summarized below. Eleven $\delta^{34}$S$_{\text{CDT}}$ values recorded for sulfides from western ore bodies of the Gacun deposit range from $-6.2$‰ to $0.7$‰. The values of $\delta^{34}$S$_{\text{CDT}}$ vary between $-4.5$‰ and $-1.3$‰ for 17 samples from the eastern ore bodies of the Gacun deposit. Nineteen samples of sulfides from the Youre deposit have $\delta^{34}$S$_{\text{CDT}}$ values that vary from $-6.2$‰ to $+0.1$‰. The $\delta^{34}$S$_{\text{CDT}}$ values of the Youre deposit are close to those of the western ore bodies of the Gacun deposit. The average $\delta^{34}$S$_{\text{CDT}}$ value (47 sulfide samples, with a mean $\delta^{34}$S$_{\text{CDT}}$ value of $-2.59$‰) is similar to that of a mantle source (Hoeft, 1997), which may suggest that the sulfur in the ore-forming fluids of the Gacun and Youre deposits originated from magma. The $\delta^{34}$S$_{\text{CDT}}$ values for barite ($+11.7$‰ to $+22.51$‰, from Zhu Weiguang et al., 2001) are similar to those for Triassic seawater sulfate ($+12$‰ to $+17$‰) (Claypool et al., 1980), which suggests that the sulfur in barite is derived from contemporaneous seawater at the location of the hydrothermal eruption. Therefore, we consider that most sulfur in the Gacun and Youre deposits is derived from hypomagma, whereas part of the sulfur is derived from sulfate in seawater.

### 6.5 Mineralization processes and genetic models

In the Late Triassic, submarine eruptive activity took place in the fault-bounded basins of the Yidun island arc belt. Mineralization of the Gacun and Youre deposits occurred during the period of bimodal volcanic activity, i.e., the terminal stage of rhyolitic volcanic activity in the Gacun cycle in the Late Triassic. Ore-forming fluid
comprising a mixture of magmatic water and infiltrated heated seawater, which carried ore-forming materials such as metals, sulfur, etc., were propelled by the lower asthenolith (which acted as a heat source), ascended and circulated through the fractures in volcanic vents or volcanic edifices. As the ore-forming fluids ascended, they exchanged materials with the wall rocks and mixed with seawater, which caused changes in fluid pressure, temperature, salinity, and redox properties. Sulfides such as pyrite, galena, sphalerite, etc., were deposited and formed vein–stockwork ore bodies by hydrothermal filling metasomatism in the western ore bodies of the Gacun deposit and the Youre deposit. As the fluids continued to ascend, they mixed with more seawater, which caused the fluid pressure, temperature, salinity, and redox properties to continue to change, and the formation of ores also continued. Sulfides such as galena, sphalerite, chalcopyrite, tetrahedrite, pyrite, etc., were deposited in the eastern ore bodies of the Gacun deposit. The ore-bearing volcanic hydrothermal solution broke through the cap rocks and erupted onto the seafloor, which cemented part of the volcanic breccia and then formed bedded ore bodies near the crater. Part of the ore-bearing hydrothermal fluid was deposited and formed bedded ore bodies on the top and both sides of the brecciated ore bodies. The other part mixed with seawater in the basin and formed a metallogenic brine pool. The ore-forming materials were deposited and formed massive sulfide ore bodies under specific physical and chemical conditions.

The Gacun deposit has a similar structural style and genetic model to a typical VMS deposit, i.e., a bilayer structure comprising a lower vein ore body and an upper stratiform ore body (Sato, 1972; Sangster and Scott, 1976; Urabe and Sato, 1978; Ohmoto et al., 1983; Goldfarb et al., 1983; Campbell et al., 1984; Lydon, 1988; Huston and Large, 1989; Rona and Scott, 1993; Humphris et al., 1995). However, according to field observations, the orientation of lower vein and stockwork ore bodies of in the bilayer structure is not nearly perpendicular to the bedded ore bodies and exhalative sedimentary rocks but is nearly parallel instead. This phenomenon cannot be interpreted by a typical model of VMS deposits.

In order to explain this phenomenon, Hou Zengqian et al. (2001a) proposed a model of mineralization zoning that comprises a sheeted ore zone and strata-bound stockwork ore bodies. They proposed that the ore bodies that developed in the rhyolitic volcanics are strata-bound stockwork ore bodies, which are oriented parallel to the overlying massive ore bodies. Besides, they are conformable or paraconformable and lack structures with lower tubular and upper stratiform components. However, we maintain that tectonic reformation after the formation of the deposit had an important influence on the deposit (Dang Yuan et al., 2013). After its formation, the Gacun deposit underwent an intense arc–continent collision during the Yanshanian orogeny, which made the strata fold, and the strata in the ore district became vertical and overturned. Moreover, intense intra-formation ductile shear and structural transpositions developed in the ore-bearing rhyolitic volcanic series. Vein and stockwork ore bodies that were sub-perpendicular to bedded ore bodies and exhalative sedimentary rocks were transformed into lenticular structures and were oriented nearly parallel to the bedded ore bodies.

According to the structural restoration, the original orientation of the bedding vein–stockwork ore bodies should be perpendicular to the bedded ore bodies. The Gacun deposit has the characteristics of a bilayer structure, i.e., lower tubular and upper stratiform components. The original geometrical morphology of the lower vein–stockwork ore bodies was tubular and funnel-shaped, and these were unconformable to the overlying stratiform or massive sulfide ore bodies. A correct interpretation of the style of mineralization in a particular deposit or district has profound implications for models for the exploration of VMS deposits (Tornos et al., 2015). The description of the deposit geology shows that the Gacun deposit consists of lower vein ore bodies, middle stockwork ore bodies, and upper massive ore bodies. These characteristics suggest that the Gacun deposit has the essential characteristics of a typical VMS deposit: the lower tubular and funnel-shaped pipes of hydrothermally altered rock represent hydrothermal channels of the hydrothermal exhalative metallogenic system, and the upper multiple massive sulfide ore bodies and exhalative sedimentary rocks represent periodic chemical deposits and olistostomes from a brine pool.

With respect to the model of the Gacun deposit, at a level of on 4100m (Fig. 3) near the northern Line 12 and southern Lines 7–11 the western ore bodies contain thick high-grade ore bodies, large quartz veins, muscovitization, and silicification. Therefore, the western ore bodies can be classified as tubular and funnel-shaped pipes of altered rock, which represents hydrothermal channels of the hydrothermal exhalative metallogenic system. Between Line 10 and Line 7 the western ore bodies are not developed, but the eastern ore bodies are thick and high-grade with multiple layers of exhalative sedimentary rocks such as barite and silicilute. Therefore, the eastern ore bodies can be classified as a brine pool that is located between hydrothermal channels (Sato, 1972; McDougall, 1984; Solomon et al., 1990). Since the brine pool model was first applied to ore formation processes by Sato
(1972), it has been applied to various VMS deposits (McDougall, 1984; Ohmoto, 1986; Turner and Campbell, 1987; Solomon and Quesada, 2003; Solomon et al., 2004), including Mattagami (Costa et al., 1983), the Bathurst Mining Camp (Solomon, 2007), and several deposits in the Iberian Pyrite Belt (Tornos et al., 1997, 2002; Tornos, 2006; Inverno et al., 2008). Stanton (1972) suggested that ancient chemical sediments accumulated in depressions both near and far from vent sites. Therefore, we propose a two-channel deposit model for the Gacun deposit (Fig. 9).

Regarding the model of the Youre deposit, massive ores exist in the southern part of the Youre deposit, but it pinches out sharply northward. The structural style of the Youre deposit is yellow ores + rhyolitic volcanics, but it lacks exhalative sedimentary rocks such as barite and silicalite. Therefore, there is no typical structure of massive sulfide ore bodies + rhyolitic volcanics + exhalative sedimentary rocks, because the accumulation of massive ore bodies, which form in the hydrothermal channels of a hydrothermal exhalative metallogenic system, was impossible. In addition, brecciated structures cemented by pyrite, weakly mineralized quartz veins, and intense silicification are seen in the bottom volcanics of the massive ores of the Youre deposit. Although the volcanics are not thick, they still represent hydrothermal channels of the hydrothermal exhalative metallogenic system. Moreover, the massive pyrites have a ring-shaped structure that is similar to that of an exhalative vent. The exterior of the ring-shaped structure consists of pyrite and its interior comprises galena–sphalerite–tetrahedrite. The core of the structure consists of quartz and calcite. Distinct zonation of mineral associations is observed from the exterior to the interior. Therefore, only parts of the Youre deposit have a small bilayer structure of which the lower part contains vein–stockwork ore bodies and the upper part contains massive ore bodies. Because this structure is not thick and is characterized by yellow ores and a lack of exhalative sedimentary rocks such as barite and silicalite, it may represent another small individual VMS deposit from the early stage of the exhalative metallogenic system. There are still rhyolitic volcanics with a thickness of 70–130 m with vein–stockwork lead–zinc and quartz veins (such as ZK3904) on top of the massive Youre ore bodies (Fig. 6), which are similar to the central ore bodies of the Gacun deposit and represent hydrothermal channels of the hydrothermal exhalative metallogenic system. Therefore, we can infer that at the
transition interface between the eastern volcanics and carbonaceous slate there exist concealed ore bodies that are similar to the eastern ore bodies of the Gacun deposit. The Youre ore bodies form a stacked structural pattern with two layers of massive ore bodies (Large, 1992).

The western ore bodies from line 7 to line 31B, which contain large quartz veins, are characterized by intense silicification and yellow-green magnesium-bearing muscovitization and comprise tubular and funnel-shaped pipes of altered rock, which represent hydrothermal channels of the hydrothermal exhalative metallogenic system (Fig. 6). There are typical massive ore bodies of yellow ores from Line 39 to line 55, but a lack of exhalative sedimentary rocks, which represent sediments from the early stages of the brine pool in the sag basin and form the lower bedded ore bodies of the stacked structural pattern. On top of massive pyrites, there are thick rhyolitic volcanics and vein–stockwork lead–zinc and quartz veins, which represent hydrothermal channels of the hydrothermal exhalative metallogenic system of the upper VMS deposit. There should also exist concealed ore bodies of black ores that are similar to those of the eastern ore bodies of the Gacun deposit, which should form the upper bedded ore bodies of the stacked structural pattern (Fig. 9).

7 Prospecting

The comparison of the structures of the ore-bearing belt and research into the models of the deposits indicate that the known ore bodies of the Youre deposit are similar to the western ore bodies of the Gacun deposit. We can infer that concealed ore bodies that are similar to the eastern ore bodies of the Gacun deposit exist to the eastern of the known Youre ore bodies. Therefore, the target of prospecting in the Youre deposits comprises massive concealed silver–copper–lead–zinc ore bodies characterized by a combination of black ores and barite.

According to the model of the VMS deposit and the geological features of the Gacun deposit, the black ores in the Youre deposit may be located at the lithologic transition interface between the eastern banded rhyolitic volcanics and calcium carbonaceous slate.

As the vein ore bodies of the Youre deposit from the northern Lines 19–31 are highly similar to the western ore bodies of the Gacun deposit, which represent hydrothermal channels of the hydrothermal exhalative metallogenic system, to the east of the northern Lines 19–31 brine pool deposits are therefore more likely to exist, and there is a possibility of finding massive black ores. Nevertheless, the southern Lines 39–55 in the Youre deposit contain massive yellow ores, which suggests that the metallogenic environment had changed and was different from that of the Gacun deposit. Therefore, further prospecting at Lines 39–55 should be based on the results of prospecting at Lines 19–31.

8 Conclusions

(1) A detailed comparison of their ore-bearing horizons suggests that the Gacun and Youre deposits are quite similar and share top and bottom marker beds, and their vertical lithology changes from lower intermediate–felsic rocks to upper felsic rocks. Therefore, we suggest that the Gacun and Youre deposits have the same ore-bearing horizon and the ore system of the Youre deposit is a southern extension of the Gacun deposit.

(2) The structures of the ore-bearing belts suggest that the Youre deposit consists of massive silicified rhyolitic volcanics, banded rhyolitic tuff, and phylilitic sericite tuff. The Youre deposit is characterized by intense silicification and vein–stockwork structures, and the Youre ore bodies are similar to the western ore bodies of the Gacun deposit: both represent hydrothermal channels of the hydrothermal exhalative system. Some massive yellow ore bodies at Youre have a small bilayer structure, which may represent another small individual VMS deposit from the early stage.
of the exhalative system.

(3) We propose a two-channel deposit model for the Gacun deposit and a stacked structural pattern for the Youre deposit.

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About the first author
DANG Yuan, male; born in 1989 in Sanyuan County, Shanxi Province; PhD student; study in School of Earth Sciences and Resources, China University of Geosciences, Beijing. He is now interested in the study on VMS deposit. Email: dangyuan1120@163.com.