Fractal Feature of Western Fracture Zone in Xikuangshan Antimony Mine and its Geological Significance

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Abstract: In Xikuangshan antimony ore-field, the western fracture zone is a composite of major fault, F75, and its secondary faults, such as F71, F72 and F73 etc. On plane, the fracture zone scatters from southwest to northeast, and concentrates from upper to deeper level on profile. All ore-bodies exist in the carbonate of footwall of the major fault or that of the footwall of its secondary faults. From 480 m and 320 m to 120 m level, the fractal dimensional number of the fault system decreases from 1.482 2 and 1.448 6 to 1.339 2, which indicates the form of fracture zone becoming more simple at deeper level. And in five subranges, the III and IV subranges are the known area, and the I, II and V subranges are unknown. The fractal studies of the western fracture zone in these subranges show that the fractal dimensional numbers of the I and II, being 1.201 5 and 1.278 0, respectively, are smaller than that of the III and IV, being 1.475 9 and 1.576 9, respectively; and that of the V, being 1.573 2, keeps with that of the III, IV subranges. So mineralization is not well in I and II subranges, and V subrange is the best to benefit mineralization.

Key words: fractal; fractal dimension; fracture zone; Xikuangshan antimony mine

1 Geological Feature of the Western Fracture Zone

Xikuangshan antimony mine, lying in central section of Hunan province of China, is a famous antimony deposit, which is made up of four sub-deposits: Feishuiyan, Tongjiayuan, Laokuangshan and Wuhua deposits. The ore vein lies in Devonian carbonate, and is controlled obviously by the structure, in which the major view is "anticline adds a sword", that is, the "anticline" is Xikuangshan anticlinorium, and the "sword" is the western fracture zone, which affects not only the distribution and scale of sub-deposits in ore-area, but also the form and occurrence of ore-body[1,4,5].

1.1 Geometric feature

The western fracture zone, located in the west of Xikuangshan anticlinorium, consists of many different scale and period faults that connect, coincide and incise each other (see Fig. 1). The zone is represented by F75, under which some secondary faults develop, such as F71, F73 and F72 etc., which are NE-striking, NW-dip and 40-60° dipping angle. Its upper part is steeper and lower part is placid. The major fault, F75, and its secondary faults form a "Y" shape on appearance, and across the whole ore-field. Seen from plane or section figures, the fracture zone is like a root. On plane, the fracture zone scatters from southwest to northeast, contracts into “a handle of broom” in the southwest; and concentrates from upper to deep.
level on profile (see Fig. 2).

Fig. 1 Distribution of the western fracture zone in Xikuangshan

1—fault and number; 2—antcline and number; 3—sub-range and number: ①Laomaotang anticline; ②Baiyunyan anticline; ③Chenjiachong anticline; ④Laozhuangshan anticline; ⑤Feishuiyuan anticline; ⑥Guangchangli anticline; ⑦Yuemushan anticline

Fig. 2 Distribution of the western fracture zone in three-dimensional space

1.2 Zonal feature

Oberved in field, the western fracture zone has obvious zonal feature, which is formed by tectonic activation of several times (see Fig. 3). Early tensile fracture planes, such as $f_1$, often filled with carbonate and breccia rocks, lie near the upper wall of the fault. Usually, their plane surfaces are coarse and discontinuous, near the plane, carbonate breccia zone often develops. Sub-early tensile compressional planes, such as $f_2$, lie near footwall of the fault, in which many schistose and lenticular zones can often be seen. Most of these plane surfaces appear fluctuant. The planes are often silification, so their surfaces are not clear. And the later compressional planes, such as $f_3$, with folded breccia zone lie in the center of fault, and their surfaces are smooth.

1—silicon limestone; 2—schistose zone; 3—lenticular zone; 4—folded breccia zone; 5—carbon breccia zone

Fig. 3 Profile sketch of fault $F_{75}$

1.3 Ore-controlling feature

The western fracture zone, one segment of the Taorjiang-Chengdu deep and large fault, is the important ore-controlling structure in this mine. The reason is as follows:

1) Major and minor faults control the distribution and scale of four sulr deposits, that is, Feishuiyuan, Tongjiayuan, Laozhuangshan and Wuhua deposits.

2) All ore-bodies exist in carbonate of the footwall of the major fault, such as $F_{75}$, or that of the footwall and upwall of its secondary faults.

3) Near the fracture zone, ore-body has larger scale and higher grade. On the contrary, it will become thin and disappear gradually far away from the zone.

4) The zone is a passing way of ore fluid, in which and wallrock, near the zone, ore with high antimony exists, and at local segment, stibnite is found, too.

2 Fractal Feature of the Western Fracture Zone

The fracture structure with self-similarity can be described quantitatively by fractal dimensional number. Using the fractal dimensional number, the spatial distribution, complicated degree and relationship with mineralization of fracture, can be expressed. Now many methods have been applied in calculating fractal dimensional number. In this paper, the fractal dimensional number of the western fracture zone is calculated by box-counting method, that is, applying square box with a certain length (r) to cover the studied area, counting the box number ($N_r$) that contains fault, then setting up straight line equation by the least square method:

$$\log N_r = a + b \log r \quad (1)$$

where, $N_r$ is the box number that contains fault; $r$ is the length of square box; $a$, $b$ are constant numbers; the slope $b$ of Eq. 1 is fractal dimensional number that will satisfy the following equation$^{(1)}$:}
where, $D$ is the fractal dimensional number; $C$ is constant number.

2.1 Fractal feature on different level planes

Fractal dimensional numbers of the western fracture zone on three planes of 480 m, 320 m and 120 m level, represented by $A$, $B$ and $C$, respectively (see Fig. 2), are calculated by five kinds of boxes with 160 m, 320 m, 480 m, 640 m and 1280 m in length, respectively. The results are shown in Table 1.

<table>
<thead>
<tr>
<th>Plane</th>
<th>Marked value</th>
<th>$D$</th>
<th>$R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>113  54  31  21  8</td>
<td>1.482 0</td>
<td>0.997 7</td>
</tr>
<tr>
<td>B</td>
<td>104  34  22  14  7</td>
<td>1.448 6</td>
<td>0.985 7</td>
</tr>
<tr>
<td>C</td>
<td>100  46  26  20  6</td>
<td>1.339 2</td>
<td>0.994 3</td>
</tr>
</tbody>
</table>

It can be seen from Table 1 that the difference of fractal dimensional numbers between $A$ and $B$ plane, which are $D_A = 1.482 2$, $D_B = 1.448 6$, respectively, is little. And the fractal dimensional number of $C$ plane, $D_C = 1.339 2$, is smaller than that of $A$ and $B$. It shows that developing degree of fault on $A$ and $B$ planes is more complicated and better than that on $C$ plane. From $A$ to $B$ plane, fault extends steadily, but to the deep $(C$ plane), it develops relatively poor. Inferred from the above, the form of fracture zone will become simpler at the deeper level, and the reason is probably that rock in the deep is ductile, and brittle fault is difficult to be formed. At the same time, Fig. 4 and correlation coefficient $(R)$ (Table 1) show that the fracture system has better self-similarity on different planes.

![Fig. 4](image.png)

Fig. 4  $\log N_r$-$\log r$ curves of fracture zone on planes with different level

2.2 Fractal feature in different sub-ranges

In order to study the relationship between fractal dimensional number of fracture zone and mineralization, Xikuangshan mine area is divided into five sub-ranges (Fig. 1), in which the III and IV sub-ranges are the areas where some known deposits exist. The III sub-range includes the Laokuangshang and Tongjiaoyuan sub-deposits, and the IV sub-range includes the Feishuiyan and Wuhua sub-deposits. Fractal dimensional numbers of the fault system in different sub-ranges are calculated by five kinds of boxes with 0.5, 1, 1.5, 2 and 4 km in length, respectively. The results are given in Table 2 and Fig. 5. From Fig. 5 and Table 2, it can be seen that the geometric distribution of the western fracture system is a fractal with better self-similarity in statistics. The fractal dimensional numbers in the III and IV sub-ranges are 1.475 9 and 1.576 9 respectively, which are consistent with that in the whole ore-field, which is 1.5716. In the I, II and V sub-ranges that are unknown, the fractal dimensional numbers in the I and II sub-ranges, being 1.201 5 and 1.278 0 respectively, are comparatively small. It indicates that faults in the two sub-ranges are simpler than that in the III and IV sub-ranges. The fractal dimensional number in V sub-range is 1.5712, and keeps with that of the III, IV sub-ranges and the whole ore-field, which shows that fault develops better and tectonic activation is stronger in the V sub-range.

In Xikuangshan area, the mineralization is closely related to the western fault system. And the better the development of the western fault system, the stronger the mineralization, so the space that metallogenic fluid flows and exists is more, and the ore-body is easily to be formed. Reflecting on fractal, the developing degree of fault is reflected on fractal dimensional number. The higher the fractal dimensional number is, the stronger the mineralization. So in Xikuangshan ore-field, fractal dimensional number of the western fault zone is closely related to mineralization. In the above five sub-ranges, fractal dimensional numbers of the I and II sub-ranges are smaller than that of the known ranges, III and IV sub-ranges, and that of V sub-range is in keeping with the known range. That shows mineralization will not be good in I and II sub-ranges, and V range will be better the mineralization. So the focus on looking for mine in this area should be in V sub-range, including Yue-mashan and Guanchangli anticlines (see Fig. 1).

<table>
<thead>
<tr>
<th>Range</th>
<th>Marked value</th>
<th>$D$</th>
<th>$R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>whole ore-field</td>
<td>161 34 21 12 6</td>
<td>1.571 6</td>
<td>0.984 5</td>
</tr>
<tr>
<td>I</td>
<td>12 7 4 3 1</td>
<td>1.201 5</td>
<td>0.987 5</td>
</tr>
<tr>
<td>II</td>
<td>14 5 4 2 1</td>
<td>1.278 0</td>
<td>0.990 7</td>
</tr>
<tr>
<td>III</td>
<td>23 9 5 4 1</td>
<td>1.475 9</td>
<td>0.993 0</td>
</tr>
<tr>
<td>IV</td>
<td>29 9 5 4 1</td>
<td>1.576 9</td>
<td>0.994 8</td>
</tr>
<tr>
<td>V</td>
<td>11 4 3 1 1</td>
<td>1.571 2</td>
<td>0.989 1</td>
</tr>
</tbody>
</table>
3 Conclusions

1) The western fracture zone is the composite of major fault, F₂₅, and its secondary faults, such as F₂₂, F₇₁, F₃, which have obvious zonal features.

2) The mineralization is closely related to the western fracture system, all ore-bodies exist in the carbonate of footwall of the major fault or that of the footwall and up-wall of its secondary faults.

3) On vertical profile, fractal dimensional number of the western fault system decreases gradually from the upper to deeper level, and has better self-similarity.

4) Among five sub-ranges of ore-field, fractal dimensional numbers of the I and II sub-ranges are smaller than that of the known ranges, III and IV sub-ranges, and that of V sub-range is in keeping with the known range. That shows mineralization is not good in I and II sub-ranges, and V range will be the best to benefit the mineralization.

It should be pointed out that fractal feature of fault structure is only one side in the whole mine, for prospecting better, other synthetical information, such as lithologic, structure and deposit must be considered.

References


