Application of Fractal Theory to the Jiangyong Lead-Zinc Deposit in Southern China

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Abstract
Nanling area has superior metallogenic conditions in southern China and it is an important source of nonferrous and rare metal mineral resources in China. Nanling area can be divided into three sections: east, middle and west. The Jiangyong Pb-Zn deposit is one of the representative deposits of the Pb-Zn polymetallic ore zone in the middle section of Nanling area. Using the fractal theory in mathematics, this paper studied the fractal dimension characteristics of lead and zinc grade of the deposit. It suggested that the grade distribution of lead and zinc has self-similarity, and the relative size of fractional fractal dimension D can be used to quantitatively determine the distribution characteristics of ore grade. The results of the study will serve useful purposes for prospecting and economic evaluation of the similar ore deposits.

Key words: Fractal Theory, Lead-Zinc Grade, Ore Deposit

1. INTRODUCTION
Nanling area has superior metallogenic conditions in southern China and it is an important mineral lands reserve in China. It is characterized by a large concentration of ore deposits, a large concentration of mineralization, a concentrated distribution of reserves and a complete deposit types. Nanling region can be divided into 3 sections in the space, where the quartz vein type tungsten ore and the uranium ore in the eastern section, the tin-lead-zinc ore in the western section, and the tungsten, tin, molybdenum, bismuth in the middle section (Chen et al., 1995; Mao et al., 2007; Ma, 2008; Wang et al., 2014a, Zhang et al., 2014). The Jiangyong Pb-Zn deposit is one of the representative deposits of the Pb-Zn polymetallic ore zone in the middle section of Nanling area. Although the geological characteristics (Zhang,1986; Yang,2012), rock features and mineralization (Tan, 1983; Wei et al., 2007; Quan et al., 2013), and metallogenic structures (Wang et al., 2000) of the mine have been studied. The lead and zinc grade distribution characteristics of the target mine remains unsettled. Therefore, the purpose of this paper is to study the fractal dimension of Pb-Zn grade in Jiangyong lead-zinc deposit with the "fractal theory" created by mathematician Mandelbrot, which can provide valuable quantitative parameters for ore prospecting and economic evaluation.

2. GEOLOGICAL SETTING
The Jiangyong Pb-Zn deposit is located at the northern margin of the middle section of Nanling area. Its tectonic position is located at the collapsing site of Yangtze plate and Cathaysian plate, which is an important lead-zinc deposit in southern Hunan. The Tongshanling Pb-Zn-Cu deposit is located in the northeast of the mining area, and the Yanshanian Tong shanling granodiorite rocks are exposed on the southern side (Figure 1).

The strata are divided into two tectonic layers, namely the Upper Paleozoic tectonic layer and the Mesozoic tectonic layer, which are unconformably in contact. The lower tectonic layer is composed of the Lower Carboniferous Shidengzi Formation (C1sh), Ceshui Formation (C1c) and Zimen Qiao Formation (C1z). The karst stratum of Shidengzi Formation is medium-thick limestone and chert-limestone, while Ceshui Formation and Zimen Qiao Formation are mainly marl, shale and dolomitic limestone.

Upper tectonic layer is Lower Jurassic (J1), which is mainly consist of conglomerate and siltstone, unconformable overlying on Ceshui Formation. The main folds in the region are nearly SN trending, and anticline is broad and syncline is closed. The mine area is located in the west wing of the broad Dayuanling anticline. The regional main faults are mainly SN and EW trending. Mine fault is divided into two groups of NE and NWW trending. The Tong shanling stocks are EW trending, and the three small stocks are intruded along the EW trending to the basement fault and underplate by the way of blowing bubbles. The lithofacies zonation is concentric belt, and the more is inward, the era is new (206 Team of Hunan Province Nonferrous Metal Geology Survey Bureau, 1985).
3. ORE DEPOSIT GEOLOGY

The target deposit is mainly formed in the sulfide stage, followed by the quartz sulfide stage. It consists of karst type orebodies and faulted orebodies (Wang et al., 2000). \( \text{III}-1 \) and \( \text{III}-1 \) karst-type orebodies developed in the middle-thick limestone of the Lower Carboniferous Shidengzi Formation in contact with the granodiorite from the Yanshanian copper-mountain ridge. \( \text{I} \) fault-type orebody developed in the contact zone with the tensile fracture structure (Figure 2).
Vividly, orebodies is like a "blanket" spreading in the dustpan-shaped contact zone surface, while the II, III karst is like a "pillar" oblique standing on the "blanket" above the two about 200m elevation connection. A group of karst is composed of two galleries and the corridor between 320m and 400m in the upper (400 ~ 500m) and lower (200 ~ 320m elevation). The previous study suggested that before the occurrence of mineralization, the coarse-grained calcite is filled with most of the karst structure and fracture structure. After the occurrence of mineralization, a structural tectonics occurred on the bottom of contact zone, resulting in a pyrite mineralization superimposed on the ore body. Ore-forming fluids were diffused into the karst structure by contact zone fractures (Wang et al., 2000). Metal minerals are mainly galena, sphalerite, pyrrhotite, chalcopyrite, silver copper, deep red silver mine, times for the scheelite, arsenopyrite, gluconite, while gangue minerals are iron calcite, Quartz, dolomite, sub-diopside, muscovite, chlorite, garnet and so on. In the vicinity of ore-bearing faults and veins and vein-like ore bodies, they are accompanied by alteration signs such as iron calcite, silification, dolomitization and pyrite mineralization.

4. METHOD

Fractal theory was founded by the mathematician Mandelbrot (Mandelbrot, 1977). It is based on the fractal dimension, self-similarity, statistical self-similarity and power function as a tool to study the complex phenomenon of non-characteristic length, very irregular and highly segmented and self-similarity. Quantitative description of this self-similarity of the parameters is known as the "fractal dimension", which is abbreviated as "fractal dimension" and denoted by D. The formula for calculating the fractal dimension D is: D = log(N(r)) / logr (Shen, Shen, 1993). Where r is the metal grade, N(r) is the number of samples whose metal grade is greater than r, and D is the fractal dimension. By changing the value of r to vote on the double logarithmic coordinate line, if the investment point is distributed on a straight line, it shows that the metal grade distribution has self-similarity, which means it is a fractal structure. Calculate the fractal dimension D value of lead and zinc grade data from Geological Department of Jiangyong lead-zinc mine, and sampling interval is about 1m. For comparison purposes, 15 r values were chosen for each group of grades, with r values of N × (rmax - rmin) / 15. Where (rmax - rmin) is the difference between the maximum and minimum values of Pb and Zn, and N is an integer value of 1 to 15.

5. RESULTS

Computer graphics results are showing in Figure 3, and D values and correlation coefficients are listing in Table 1.

<table>
<thead>
<tr>
<th>Orebody number</th>
<th>Orebody type</th>
<th>Number of samples</th>
<th>Metallogenic structure</th>
<th>Pb grade</th>
<th>D</th>
<th>R</th>
<th>D</th>
<th>Zn grade</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>II-1</td>
<td>Karst type</td>
<td>144</td>
<td>Karst</td>
<td>1.643</td>
<td>-0.977</td>
<td>1.561</td>
<td>-0.959</td>
<td></td>
<td></td>
</tr>
<tr>
<td>III-1</td>
<td>Karst type</td>
<td>153</td>
<td>Karst</td>
<td>1.571</td>
<td>-0.962</td>
<td>1.428</td>
<td>-0.951</td>
<td></td>
<td></td>
</tr>
<tr>
<td>①</td>
<td>Contact of fracture type</td>
<td>128</td>
<td>Fracture</td>
<td>1.456</td>
<td>-0.988</td>
<td>1.871</td>
<td>-0.969</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: R represents the correlation between Log(N(r)) and Logr

Figure 3 Relation map between Log r and Log(N(r))
6. DISCUSSION

There is no significant difference in the fractal dimension of Pb and Zn grade distribution in the II-1, III-1 karst structure. The fractal dimension D of Zn grade in the same karst structure is slightly smaller than that of Pb grade. The fractal dimension D of the Pb and Zn grades in the karst tectonics is slightly smaller than the corresponding fractal dimension values of the Pb and Zn grades in the karst structure. However, the fractal dimension of Pb and Zn is slightly different from that of Pb in the fracture zone. On the contrary, the fractal dimension D of Pb is smaller than that of Zn. According to the formula of D value, the smaller the value of D, the greater the variance of metal grade among the samples, the worse the degree of homogeneity of grade spatial distribution, the more likely the samples with higher average grade to concentrate in the local area Large, but scattered and small scale; the other hand, D value of the larger, the difference between the metal grade of the smaller samples, i.e the better the uniformity of the ore body in the average grade of the sample in the relative concentration of local sections tend to Small, suggesting that the possibility of a rich ore body is smaller, if found rich ore body, the smaller scale. The value of the fractal dimension D of Pb and Zn is in good agreement with the actual distribution of Pb and Zn grade in known orebodies. Therefore, it is possible to quantitatively determine the distribution characteristics of the grade of the ore body by using the relative size of the grade fractal dimension D value, thus providing valuable quantitative parameters for ore prospecting and ore deposit economic evaluation.

According to Cheng et al. (1994), the fractal dimension D of Pb grade in the Fankou Pb-Zn deposit is between 2.483 and 13.885, and the D value of Zn grade is between 2. 519 and 3 816 rooms. The D value of Pb grade of Jiangyong Pb-Zn deposit is between 1.456 and 1.643, and the D value of Zn grade is between 1. 428-1.871. The fractal dimension values of Pb and Zn in the two deposits are different. The main reason may be: the genesis of the deposit is the decisive factor influencing the value of D value. The Fankou Pb-Zn deposit has both sedimentary-type ore bodies formed by early jet-flow and reconstructed ore bodies formed by late-stage tectonism (Lai, 1988). On the one hand, the distribution of the metal grade of the deposit formed by the jet flow is relatively uniform, which determines the overall D value is large. On the other hand, the late tectonic transformation caused the transformation of the type of the orebodies and resulted in different types of ore bodies Between the Pb, Z grade of fractal dimension D values are quite different. The Pb and Zn grade of the Jiangyong lead-zinc deposit is not only the whole D value is small, but also the fractal dimension of the Pb and Zn grades of the ore body is different. The value difference is also small. The types of permafrost structures, spatial structure patterns and spatial positions may have a certain influence on D value. Because of these factors on the ore-bearing fluid migration and precipitation process have some impact, and thus indirectly affect the size of D value. The difference of Pb and Zn grade fractal dimension of karst type II-1, III-1 and contact zone faulted orebodies may be mainly caused by the above reasons, but the effect is limited. Therefore, the D value of the grade distribution can be used as a quantitative parameter to determine the genetic type of the deposit.

Although most of the points generally distributed in a straight line, but there are 3-5 points there is a large deviation. This may be due to unreasonable sampling methods leading to inadequate sample sampling in certain intervals or the presence of scale segments in these intervals.

7. CONCLUSIONS

The results show that the grade distribution of lead and zinc is self-similar, and the value of grade D is mainly affected by genetic type and ore-forming structure type, and the relative size of lead-zinc grade of Jiangyong deposit, which may be used to quantitatively determine the distribution characteristics of ore bodies and provide valuable quantitative parameters for ore prospecting and ore deposit economic evaluation.

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REFERENCES


