Analysis of Geochemical Characteristics Prospecting Prospects of Nickel Polymetallic Ore in Langmuri Dulan County of Qinghai

Liu Zhihua, Chen Jianlin, Zhang Dexiang, Li Yulu
Qinghai First Institute of Geological Exploration, 810600, China

Keywords: Dulan, Qinghai, Langmuri nickel polymetal, Geochemical characteristics, Prospecting prospects

Abstract: The Langmuri Nickel Polymetallic Ore is located in the eastern part of the East Kunlun metallogenic belt (East Kunlun Central Orogenic Belt) in Qinghai Province, lying in the Berkalik-Xiangride Indosinian polymetallic metallogenic belt. The stratum of Baishahe Formation is widely exposed in the area, and the structural characteristics of the area are very prominent, showing obvious multi-phase characteristics, which seriously affects the production and distribution direction of the strata in the area. There are obvious magmatic rocks in the area, including not only basic magmatic rocks but also ultrabasic magmatic rocks. For example, syenogranite and monzonitic granite are widely developed in this area, and they are the main occurrence of the main ore bodies in this area. These nickel mineralization clues indicate that the eastern section of East Kunlun also has the potential to find nickel polymetallic deposits.

1. Introduction

Due to the distribution pattern of sedimentary construction and magmatic activity in the East Kunlun metallogenic belt, the geotectonic structure of this area is clamped between the Qimantage-Dulan suture zone and the East Kunlun middle suture zone. The geological structure is complex in the area: tectonic faults are distributed in the northwest-northwest direction; magmatic rocks occupy most of the space with the Variscan-Indosinian intermediate-acid intrusive rocks, forming the Kunlun Northern magmatic arc zone; the strata are composed of the Late Archaean-Paleoproterozoic Xiaomiao Formation.[1, 2] Two ultra-basic rock bodies, namely Σ1 and Σ2, have been found in the area, and one nickel polymetallic ore body (M1) is circled in the Σ1 ultra-basic rock body, which has great prospecting potential.

2. Regional Geological Features

2.1 Stratum

The regional outcropping strata include the Early Proterozoic Baishahe Formation (Pt1b), which is mainly outcropped in the central and southern regions. It is generally distributed in a northwest-west-near-east-west direction. This is a set of advanced metamorphic rock series, which constitutes the crystalline base of the Qaidam ancient land. Due to the influence of multiple magmatic activities in the later, only a small amount of this formation remains, which is widely exposed in the northern part of the mapsheet. The Early Carboniferous Halaguole Formation (C1hl) is mainly distributed in the southwestern part of the regional mapsheet. It is a set of sedimentary formations with greywacke and slate interbedding. Its sedimentary thickness is greater than 650m, and it is in parallel and integrated contact with the Upper Carboniferous strata. The Elashan Formation (T3e) is distributed in a small amount in the north-eastern corner of the mapsheet and is composed of acidic or intermediate-acid volcanic rocks. The lower part of it contains clastic rocks and coal lines, and some areas are dominated by clastic rocks. Volcanic rocks gradually transition from neutral to acidic and from bottom to top. The Nagengkangche large silver bed produced in the northeast corner of the pre-investigation area is present in this set of strata; and the Quaternary (Q)
was also found in this area.

2.2 Construction

This area is located on the north side of the central Kunlun fault zone and belongs to the ocean-continent subduction zone (Early Paleozoic). Thrust nappe faults are widely developed in the area and have very prominent structural mixing characteristics. Prominent fault structures developed in this area, mainly compressive or compressive torsion fracture, and they constitute the backbone structure.

2.3 Magmatic Rocks

This area belongs to the East Kunlun magma arc belt, which is the east edge of the magma arc (multi-cycle). The formation and development of the Kunnan Ocean and the ancient Kunzhong Ocean are very closely related to the granite (multiple periods and types) in the region. Intrusive rocks are very well developed in this area, mainly in the variscan and Indosinian periods. At the same time, the granodiorite formed in the late Caledonian period is less developed in this region[3].

Some ultrabasic rocks are distributed in the pre-surveyed area. The output mainly presents a belt-like characteristic, and the distribution characteristic is the same as that of the fault structure. Peridotite is its main lithological feature. The variscan intermediate-acid rock masses are widely developed in this area, and the Caledonian, Indosinian and Yanshanian intermediate-acid intrusions are also distributed.

3. Geochemical Characteristics

Since 2014, a 1:25,000 river sediment survey has been carried out in the census area, and a total of 10 comprehensive anomalies dominated by Cu, Ni, and Co have been circled, of which 7 are Co anomalies and 3 are Ni anomalies, of which the larger ones are the HS\textsuperscript{70}_{Ni2} abnormality, HS\textsuperscript{71}_{Ni3}, HS\textsuperscript{73}_{Ni2} abnormalities and HS\textsuperscript{75}_{Co} abnormality.

3.1 HS\textsuperscript{70}_{Ni2} Abnormality

The anomaly area is located in the northern part of the pre-surveyed area and is a comprehensive multi-metal anomaly mainly composed of Ni, Cu and Co. It is composed of elements such as Ni, Cu, Co, Au, etc., with good fit. The anomaly is generally in a long strip of northwest direction, with a length of about 1.5km, a width of about 500m, and an area of about 0.7km\textsuperscript{2}. The concentrated center is obvious. The anomaly scale of Ni is relatively large, and that of other elements is relatively small. In this anomaly area, the Ni anomaly spreads in a long strip in the northwest direction, and the peak value of Ni58 is 1462.2×10\textsuperscript{-6}, with an inner zone concentration center. The Cu anomaly is distributed in a long strip in the northwest direction, and the peak value of Cu77 is 538.1×10\textsuperscript{-6}, with an inner zone concentration center. Co anomalies are scattered along the northwest direction in short strips, and the peak value of Co69 is 148×10\textsuperscript{-6}, with an inner zone concentration center. Co anomalies are scattered along the northwest direction in short strips, and the peak value of Au88 is 9.37×10\textsuperscript{-9}, with a middle zone concentration center. The outliers of other elements are low and the anomaly scale is small. The anomaly parameters and characteristics are shown in Table 1.

The gray biotite plagioclase gneiss, mixed rock, granulite and mixed gneiss of the Baishahe Formation are the main exposed rock types in the area. Granite and diorite dikes are developed in the stratum, and ultrabase rock masses can be seen locally.

The structure is relatively developed in the anomaly area, which is mainly manifested as a north-east-trending fault. In this abnormal fault, the parameters of Ni, Cu, Co and Au show good geochemical mineralization characteristics. The anomaly peak is relatively high, and all element fit well. It is inferred that there are ultrabasic dykes and tectonic alteration zones in the anomaly area, which have directivity for finding Ni, Cu, Co, Au and other deposits in this area.
Table 1 Characteristics of Various Element Parameters of Hs\(^{70}\)_Ni\(^2\) Comprehensive Anomaly

<table>
<thead>
<tr>
<th>No.</th>
<th>Points</th>
<th>Anomaly threshold</th>
<th>Mean-squared deviation</th>
<th>Peak (10(^{-6}))</th>
<th>Contrast value</th>
<th>Mean (10(^{-6}))</th>
<th>Area (Km(^2))</th>
<th>Coefficient of variation (Cr)</th>
<th>Anomaly scale</th>
<th>Concentration zoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ni58</td>
<td>10</td>
<td>50</td>
<td>493.17</td>
<td>1462.2</td>
<td>6.30</td>
<td>314.92</td>
<td>0.49</td>
<td>1.57</td>
<td>3.09</td>
<td>Inner, middle and outer</td>
</tr>
<tr>
<td>Au88</td>
<td>2</td>
<td>3</td>
<td>0.90</td>
<td>9.37</td>
<td>2.91</td>
<td>8.74</td>
<td>0.06</td>
<td>0.10</td>
<td>0.17</td>
<td>Middle and outer zones</td>
</tr>
<tr>
<td>Cu77</td>
<td>5</td>
<td>50</td>
<td>207.37</td>
<td>538.1</td>
<td>3.84</td>
<td>191.90</td>
<td>0.22</td>
<td>1.08</td>
<td>0.84</td>
<td>Inner, middle and outer zones</td>
</tr>
<tr>
<td>Co68</td>
<td>2</td>
<td>20</td>
<td>2.19</td>
<td>23.4</td>
<td>1.09</td>
<td>21.85</td>
<td>0.06</td>
<td>0.10</td>
<td>0.07</td>
<td>Outer zone</td>
</tr>
<tr>
<td>Co69</td>
<td>2</td>
<td>20</td>
<td>17.54</td>
<td>148</td>
<td>6.78</td>
<td>135.60</td>
<td>0.08</td>
<td>0.13</td>
<td>0.54</td>
<td>Inner, middle and outer zones</td>
</tr>
<tr>
<td>Bi40</td>
<td>1</td>
<td>1</td>
<td>/</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.09</td>
<td>/</td>
<td>0.06</td>
<td>Outer zone</td>
</tr>
</tbody>
</table>

Note: The unit of Au and Ag is 10\(^{-9}\); the unit of other elements is 10\(^{-6}\).

3.2 Hs\(^{71}\)_Ni\(^3\) Abnormality

This anomaly area is located in the west part of the pre-surveyed area and is a comprehensive multi-metal anomaly mainly composed of Ni, Cu and Co. It is composed of elements such as Ni, Cu, Co, Au, etc., with good fit. The anomaly is generally in a long strip northwest direction, with an area of about 0.51 km\(^2\) and an obvious concentration center. The scale of Ni anomaly is large, and the scale of other element anomalies is small. Among them, the Ni anomaly spreads in a long northwest direction. The anomaly peak of Ni59 is 495.2×10\(^{-6}\), with a concentrated center of inner zone. The Co element anomaly spreads northwest in a strip shape. The anomaly peak value of Co105 is 81.5×10\(^{-6}\). The anomaly parameters and characteristics are shown in Table 2, and Figure 1 shows the anomaly analysis.

Table 2 Characteristics of Various Element Parameters of Hs\(^{71}\)_Ni\(^3\) Comprehensive Anomaly

<table>
<thead>
<tr>
<th>No.</th>
<th>Points</th>
<th>Anomaly threshold</th>
<th>Mean-squared deviation</th>
<th>Peak (10(^{-6}))</th>
<th>Contrast value</th>
<th>Mean (10(^{-6}))</th>
<th>Area (Km(^2))</th>
<th>Coefficient of variation (Cr)</th>
<th>Anomaly scale</th>
<th>Concentration zoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ni59</td>
<td>8</td>
<td>50</td>
<td>170.62</td>
<td>495.2</td>
<td>4.04</td>
<td>201.93</td>
<td>0.32</td>
<td>0.84</td>
<td>1.30</td>
<td>Inner, middle and outer</td>
</tr>
<tr>
<td>Cu96</td>
<td>2</td>
<td>50</td>
<td>7.00</td>
<td>95.4</td>
<td>1.81</td>
<td>90.45</td>
<td>0.10</td>
<td>0.08</td>
<td>0.18</td>
<td>Outer zone</td>
</tr>
<tr>
<td>Co70</td>
<td>2</td>
<td>20</td>
<td>2.19</td>
<td>24.1</td>
<td>1.13</td>
<td>22.55</td>
<td>0.02</td>
<td>0.10</td>
<td>0.02</td>
<td>Outer zone</td>
</tr>
<tr>
<td>Co105</td>
<td>3</td>
<td>20</td>
<td>29.96</td>
<td>81.5</td>
<td>2.90</td>
<td>57.90</td>
<td>0.13</td>
<td>0.52</td>
<td>0.38</td>
<td>Inner, middle and outer</td>
</tr>
<tr>
<td>Au96</td>
<td>1</td>
<td>3</td>
<td>/</td>
<td>3.33</td>
<td>1.11</td>
<td>3.33</td>
<td>0.02</td>
<td>/</td>
<td>0.02</td>
<td>Outer zone</td>
</tr>
</tbody>
</table>

Note: The unit of Au and Ag is 10\(^{-9}\); the unit of other elements is 10\(^{-6}\).

The gray biotite plagioclase gneiss, mixed rock, granulite and mixed gneiss of the Baishahe Formation are the main exposed rock types in the area. According to the anomaly interpretation of geophysical and magnetic method, there is a certain scale of ultrabasic rock intrusion.

The ultrabasic rock mass delineated in this anomaly area is believed to be the same one as the ultrabasic rock mass found in the east side of the HS\(^{73}\) abnormality. In the later period, the rock mass morphology was displaced due to the influence of the north-east trending fault structure. In this anomaly area, the parameters of Ni and Co elements show good geochemical mineralization characteristics. The anomaly peak value is relatively high, and the compatibility of each element is good, indicating that it is a good target area for prospecting Ni and Co minerals.
3.3 $\text{Hs}^{75}_{\text{Co}}$ Abnormality

This anomaly is located in the south part of the pre-surveyed area and is a comprehensive abnormality dominated by Co and Ni. The anomaly is generally elongated and distributed in a nearly east-west direction, with an area of about 0.56 km² and an obvious concentration center. The Ni anomaly is large in scale and spread in the north-east direction. The anomaly peak of Ni93 is $481.7 \times 10^{-6}$, with an inner zone concentration center, and an anomaly area of 0.14 km². The anomaly peak of Ni110 is $65.9 \times 10^{-6}$, with a concentrated center of inner zone. The anomaly parameters and characteristics are shown in Table 3.

Table 3 Characteristics of Various Element Parameters of $\text{Hs}^{75}_{\text{Co}}$ Comprehensive Anomaly

<table>
<thead>
<tr>
<th>No.</th>
<th>Points</th>
<th>Anomaly threshold</th>
<th>Mean-square deviation</th>
<th>Peak ($10^{-6}$)</th>
<th>Contrast value ($10^{-6}$)</th>
<th>Mean ($10^{-6}$)</th>
<th>Area (Km²)</th>
<th>Coefficient of variation (Cr)</th>
<th>Anomaly scale</th>
<th>Concentration zoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co110</td>
<td>4</td>
<td>20</td>
<td>20.06</td>
<td>65.9</td>
<td>1.96</td>
<td>39.23</td>
<td>0.19</td>
<td>0.51</td>
<td>0.37</td>
<td>Middle and outer zones</td>
</tr>
<tr>
<td>Ni93</td>
<td>6</td>
<td>50</td>
<td>172.69</td>
<td>481.7</td>
<td>3.19</td>
<td>159.33</td>
<td>0.14</td>
<td>1.08</td>
<td>0.46</td>
<td>Inner, middle and outer</td>
</tr>
<tr>
<td>Ag162</td>
<td>3</td>
<td>140</td>
<td>30.45</td>
<td>206</td>
<td>1.28</td>
<td>179.00</td>
<td>0.05</td>
<td>0.17</td>
<td>0.06</td>
<td>Outer zone</td>
</tr>
</tbody>
</table>

Note: The unit of Au and Ag is $10^{-9}$; the unit of other elements is $10^{-6}$.

The exposed rocks in the anomaly area are mainly the biotite plagioclase gneiss of the Baishahe Formation. The interpretation with the 1:10,000 magnetic profile shows that there are obvious positive and negative anomalies in the east part of the anomaly, which means that there may be underlying ultrabasic rock masses. In this anomaly area, the parameters of Ni and Co elements show good geochemical mineralization characteristics. The anomaly peak is high, but the elements fit well and the anomaly scale is small. This anomaly is Co abnormality, which has certain indicative significance for Ni and Co ore prospecting.

4. Characteristics of Mineralized Bodies

Basic-ultrabasic rock mass is a preliminary indicator for finding Cu-Ni ore, so it is particularly important to understand the spatial distribution and mineralization of rock masses. There are two ultrabasic rock bodies ($\Sigma 1$ and $\Sigma 2$) of varying sizes in the $\text{Hs}^{73}_{\text{Co}}$ abnormality in this area.

The search for Cu-Ni ore in this area is very closely related to basic and ultrabasic rock masses. Therefore, it is very important to fully understand the distribution characteristics and their mineralization of rock masses $^{[4, 5]}$. There are two ultrabasic rock bodies of different sizes in the $\text{Hs}^{73}$ abnormality.

4.1 $\Sigma 1$ Ultrabasic Rock Mass

The distribution of the rock mass is mainly north-west, with a length of about 30-100m exposed on the surface area. The anomaly is delineated by the 1:10,000 magnetic method, and the deep part
is about 3Km long and 400-600m wide. A 36-84m-wide polymetallic anomaly zone is encircled in
the ultrabasic rock body, initially controlled by three geochemical profiles. The anomalous area of
the profile was exposed by trenching methods, and a NiCuCO ore body was found in this area,
labeled M1. Altered peridotite is the main lithological feature of the ore body. Malachite and
limonite alteration features are prominent, and pentlandite is widely developed. From these, it can
be inferred that nickel sulfide is the main mineralization type of the ore.

M1 ore body: it is controlled by Σ1TC01 exploratory trench and 16YP1 and 16YP2 profiles; the
length is about 500m and the width is 3-7.5m. The Cu-Ni mineralized zone in this area is about 20
meters wide, where the ore bodies are distributed. The grade characteristics of Ni in this zone reach
0.13-0.17%, and the average grades of Ni and Cu in the M1 ore body are 0.29% and 0.30%
respectively. Cu-Ni rich ore bodies have a width of about 3 meters distributed on the hanging wall,
and the average grades of Cu and Ni reach 0.40% and 0.36% respectively. In accordance with the
characteristic that a large number of ore bodies are produced in the Cu-Ni mineralized zone, it is
believed that the ore bodies show the characteristics of continuous expansion in the deep position.

Controlled by the profile to the west, there is an ore body about 3m wide. According to the
analysis of block samples in this area, the grade of Ni is 0.32-0.54%, the grade of Cu is 0.3-0.55%,
and the grade of Co is 0.017-0.044%. The westward ore body presents the characteristic of stable
output and at the same time it has superior mineral-bearing properties. Engineering control is
relatively low in this area.

4.2 Σ2 Ultrabasic Rock Mass

Σ2 ultrabasic rock mass is distributed in the westward direction of HS73 comprehensive anomaly,
and the distribution is nearly east-west. The 20-30m width is controlled currently, and the length is
about 150m. Peridotite is its main ultrabasic rock. The ferritization is very prominent on the rocks,
and the pentlandite is star-shaped. It is found through sample collection and analysis that the grade
of Ni is 0.39% and the grade of Co is 0.018%.

5. Prospecting Prospects

There are 10 1:25,000 comprehensive geochemical anomalies in the area that have been circled
in the area. They have very good element fit and obvious characteristics of element combination.
These areas present very superior geological conditions. Migmatite and the Baishahe Formation
(Jinshuikou Group) which is composed of biotite plagioclase gneiss (grey) and mixed gneiss and
granulite are the main lithological features of this area. There is a large amount of pentlandite
distributed in this ultrabasic rock body, and the prominent ones include chalcopyrite, pyrite,
ilmenite and pyrrhotite.

Due to the insufficient deep research work in these areas, the basic information of the current ore
body is not completely clear. The drilling site is on the near surface area of the rock mass.
Combined with the current superior geological conditions, nickel polymetallic ore can be found in
its shallow and deep positions and has a certain scale. Therefore, the area has good prospecting potential.

6. Conclusion

The ore is located in favorable conditions in terms of regional stratum, structure and magmatic rock, which provides an extremely favorable foundation for mineralization in the region. This is extremely beneficial to the search for nickel polymetallic deposits. The existing analysis showed that the superior mineralization conditions are extremely favorable for the search for nickel ore in the area. The intersection of the faults in the area is distributed with very prominent ultra-basic rock masses. The geological characteristics and the types of mineralization and alterations in the area show that the shallow and deep areas have great mineralization potential. Therefore, it is needed to strengthen the research work in this area to seek a greater breakthrough in prospecting.

References


