APPLICATION OF SYNTHETIC ANALYSIS OF RS，GIS AND GEOLOGY IN THE COPPER AND GOLD ORE-FORMING FORECAST IN YIWU AREA, XINJIANG, CHINA

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Abstract. This paper quantitatively analyzes the relation of geological structure and ore-deposit in Yiwu area, Xinjiang municipality with the synthetic use of remote sensing and geological information. In the study, computer graphics processing and spatial analysis in GIS were synthetically used on the base of linear structure interpreted by remote sensing. At last ore-finding future area was pointed out, which has been practically applied in field and effects are remarkable.
Keywords: *remote sensing; geographical information system; geological structures; ore-forming forecast*

Introduction

Yiwu area is located in the south of collided stylolite which lies along Maqinwula Takezhalei Kelamaili between Siberian plate and Talimu plate and in the north of Haerlike ore-forming zone of lead copper and gold at north-east of Jueluotage islandarc. Tectonics and magmatite developed in this area and NW-SE fault (F1) walked through this area by Talei and Shangmaya, which controls the distributing of copper and gold deposits (Mattern and Schneider, 2000) .

Large scale magmatism involved in arc-volcano has happened during Hualixi-Haixi period in Yiwu area. Areal porphyritic copper ore-forming zone was in accordance with Haerlike volcano-arc and Aqi mountain according to ore-forming space; the deposits in this area were forming during medium and latter stage of Haixi period and were activated, rebuilt and deformed during Himalayan orogenesis according to ore-forming period[6]; The deposits in this area were formed with plate’s diving and belong to ocean shell’s diving or diorite pattern. In conclusion, it was proved that Yiwu area was rich in ore resource from both tectonics and metallization characters, especially for copper (molybdenum) and gold ore (Chen et al., 2012; Wang et al., 2009). Although pre-researchers had much studied the ore-finding rule and ore-finding forecast, it is still groping to quantitatively forecast deposit combined with geographical information system under the base of synthetic analysis of remote sensing and geological information. Based on some previous work (Yang, 1997), the authors quantitatively processed and analyzed the interpreted tectonics and analyzed tectonics pattern by remote sensing through redeveloping exiting data. The perspective ore-forming spots

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were pointed out through using model and non-model ore-precasting and effects are remarkable.

Digital processing of remote sensing image (TM) and information extraction

A remote sensing image is a stereoscopic miniature of natural landscape. It objectively records information on shapes and physical characteristics (tones and colors) of tectonic deformations, both the individual parts and the overall patterns, and is a high quality summary (Blaschke, 2010). It also records some information on concealed structures (Yang and Zhu, 1996). Apart from such information, much information on remotely sensed multispectral images is invisible to the human eyes, such as infrared or microwave images, and much of this information is useful in analysis of geological features out of sight. Using remote sensing images to analyze ore-forming information especially for faint mineralization information not only provides useful data, but also is helpful for combining fracture systems of rocks and tectonic deformation with geological formations very well, so as to achieve conclusions that coincide with objective reality.

Authors did the principal components transformation (KL transform) and correlation analysis to the Landsat TM image (seven bands) in this area and the variance sequence of the seven bands image was worked out (Stock and Watson, 2002). That is to say TM6, TM1, TM5, TM3, TM4, TM2, TM7. According to the result of every band image's statistical analysis, the combination of TM453 (*Fig. 1*) was selected considering that TM6 image is low in resolving power (120m) and TM1 belonging to blue band is insufficient in details and practice proved that the combined image is good in interpretation and can do as the best image for theme image processing and characteristic information extraction. In addition, authors had completed a lot of good theme images (*Fig. 2*) and extracted a great deal of useful tectonics information by using some digital image processing methods such as radiometric enhancement (linear contrast enhancement, histogram equalization, matching histogram normal shap), multispectral transformation of image data, principal components transformation, chroma transform and texture analysis .

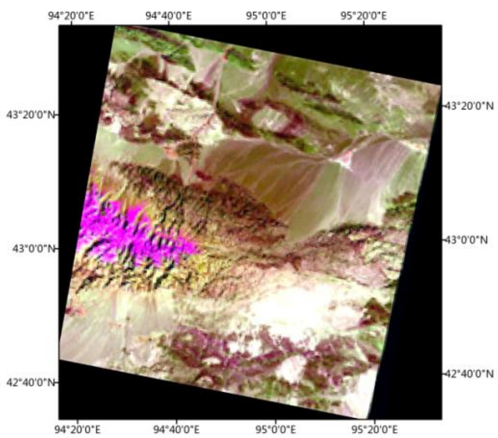

Figure 1.*TM453 color combined image in Yiwu*

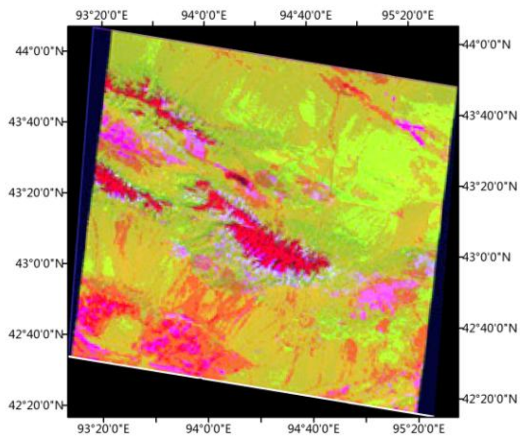

Figure 2. *TM color combined images of the first three principal components in Yiwu*

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Linear tectonics information extraction

The tectonics is very complex and rich in fault in this area. Linear tectonics always reflect the trace of faults enrichment, which are not only the channels of mine liquid's activation and transportation but also the important factor of ore latter rebuild and ore-forming elements reenrichment and have the inherent control to the forming and distribution of deposits (Han and Wang, 2008; Yang and Zhu, 1997).

According to the scale size and continuity of the faults in image, the control degree of the faults to magma activity and sediment and pre-researchers' study results, author classified the faults to three classes:

(1) main linear tectonics: these tectonics are always great areal faults which distinctly control magma activity, sediment and the progress of tectonics movement. They are distinct narrowband-shape, large scale, extending far, fine continuity and distinct in interpretation character. They are depicted as following: ① F1 linear tectonics: it begins from Tianshan mountain in the west of the area, extends to south-east-east, bypasses Talei Shangmaya and ends at three kilometre south of Xiamaya. As a whole it extends east-west and likes "S" shape on plane. On remote sensing image, it is distinctly different in physiognomy and hue beside the fault which controls the distributing of the stratum and sub-fault on both sides. In the west, lots of large mountains lie in the south of the fault otherwise plain lies in the north (*Fig. 3*). ② F2 fault: it comes from the west-south of the area, extends to east-north and transects the F1 fault group. It is the fifth subgroup and sixth subgroup stratum of Devonian System Dananhu group in the north of the fault and the forth subgroup in the south. On the remote sensing image it takes on distinct concave physiognomy and the rivers always bend at the fault. The distribution of stratum and magmatic intrusion were controled by this fault (*Fig. 3*). ③ F3 fault: This fault, 20 km long, begins from Xiaopu town in the west-south of the area and extends east-north to F1 linear tectonic belt. It is different in tone on the both sides of the fault. It is yellow biotite granite in the west and brown the forth and the fifth subgroup stratum of Devonian System Dananhu group. The part of intersection of F1 F2 and F3 fault see *Fig. 3*. ④ F4 fault: This fault lies in north of this area and is 48 km long in the area. It begins from the west of the area and extends to east bypassing Yiwu city. On the remote sensing image it is the boundary of mountainous area and plain and the tone is distinct different between two sides. It is the first subgroup stratum of Yamansu group Carboniferous System and Quaternary System stratum in the south.

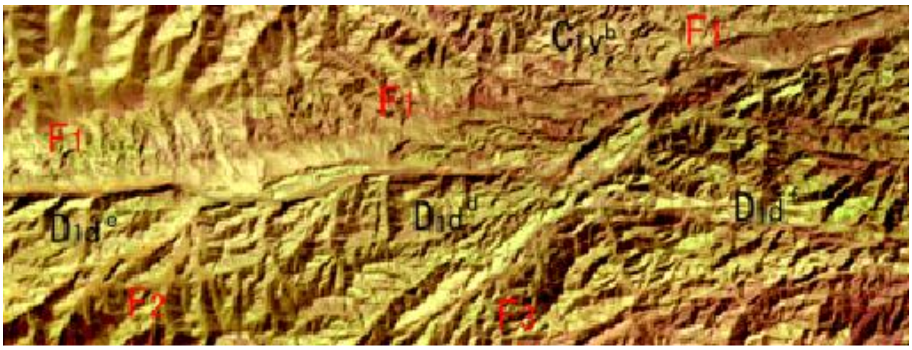

Figure 3. *Landsat TM 453 color combined image at the south of Yiwu；the image at the intersection of the faults F1, F2 and F3 (C_1y^b is the second subgroup stratum of Yamansu group Carboniferous System;D_1d^d, D_1d^e,D_1d^f are separately the forth, the fifth, the sixth subgroup stratum of Devonian System Dananhu group)*

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(2) Generic linear tectonics: These faults are relatively small in scale, relatively distinct in image interpretative characters and little fine in continuity and the control to magma activity, sediment and the progress of tectonics movement is relatively small. In this area there are tens of this class of fault which mainly distribute in the Carboniferous System stratum and magmatic intrusive body in the south of F1 fault belt and north of Yiwu city and extend north-west-south-east and north-east-south-west. The scale is not uniform. Some are 35 km long and some are only 1-2 km long. On the image they take on line shape and linear concave physiognomy, which leads to interceptive stratum and tectonic line (Srinivasa and Jugran, 2003) .

(3) Remotely sensed major joint: They represent a naturally preferred selection of the same group of structural joints in outcrop and mainly lie in the outcrop of rock. On the image they take on dim linear texture and the length is small, but they are orderly in direction and distribution, from which we can deduce the state of terrane’s stress. The remote sensed major joints extend mainly to NE NW and SN in direction. This suggests the main stress was pressing in SN direction, which is consistent with the stress of the areal pull-overlap tectonics (Das et al., 1997).

The quantitative analysis of tectonics

It is characteristic of enrichment of linear tectonics in this area. Because of the closely relation between the linear tectonics and ore-forming, it is not enough for the need of production only to qualitatively analyses. We should quantitatively analyses it for convenience to ore-forecasting. It has some shortcomings for statistical analysis such as density diagram, rectangular chart, rose map, etc presently. In this study, authors built three-dimensional interpretative pattern of remote sensing information and quantitatively extracted lots of useful information, combining image processing and geographical information system through quantitatively processing linear tectonics, measuring the length of linear tectonics per grid in installments. Author showed the result of processing by overlapping two-dimensional and three dimensional plot and provided quantitative base for prospecting deposit, using modern technology of image processing (*Fig. 4*, *Fig. 5*). These figures reflect clearly the spatial distribution of linear tectonics and the characters of remote sensing information. In Yiwu area, the main linear tectonics’ direction of strike is east-west for the most part and NE-SW in the next place. They are mainly at the south of this area. The generic linear tectonics and remotely sensed major joint were distinctly controlled by main linear tectonics and the direction of strike is mainly NE-SW and NW-SE. Where was rich in main linear tectonics the generic linear tectonics and remotely sensed major joint were too. In addition, the authors processed the main linear tectonics in GIS software for convenience to spatially analyse with quantified ore-deposits.

The quantitative analysis of deposits

Because of the lack of data of geophysical and geochemical exploration, authors made the most of provided geological data and drew separately density map of deposits distributing (*Fig. 6*) and quantitatively interpretation pattern map of overlapped deposits and linear tectonics (*Fig. 7*). On these pictures, it is clearly to show the spatial distribution of ore-deposits and the relation of linear tectonics in this area. The distribution of ore-deposits is mainly controlled by main linear tectonics, especially at the intersection between main tectonics, generic linear tectonics and remotely sensed

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major joint. This suggests the main tectonics are possible ore-carried tectonics and generic linear tectonics and remotely sensed major joint nearby are ore-controlled tectonics. In addition, the authors made ore-deposits to vectorial point file under GIS software and calibrated the point file to line file above. The congruence analysis of point to line was doing in the spatial analysis module, then the analysis result was done through single attribute additive statistical analysis to the distance of deposit to linear tectonics (*Fig. 8*). It is surmisable that the 84 percent of ore-deposits in this area are concentrated in the belt whose distance to main tectonics is 122 meters. The controlled distance of main tectonics to ore-deposits was quantitatively analyzed.

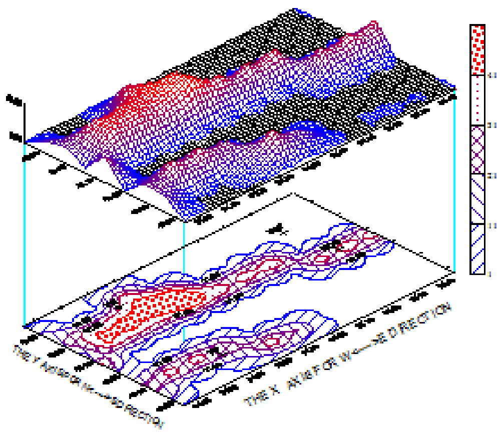

Figure 4. *Quantitatively interpretative pattern map of main tectonics in Yiwu (the upper is quantitative distributing plan of main tectonics, the higher the denser; the lower is the contour map of its tectonics distributing. (X axis is longitude and Y axis is latitude) placename: KTNY-Kuotuogayi，XP-Xiaopu，YW-Yiwu，XMY-Xiamaya)*

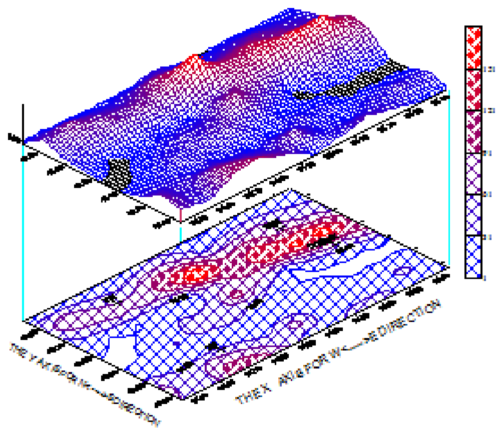

Figure 5. *Quantitatively interpretative pattern map of generic linear tectonics and remotely sensed major joint in Yiwu (the upper is quantitative distributing plan of generic linear tectonics and remotely sensed major joint , the higher the denser; the lower is the contour map of its distributing. (X axis is longitude and Y axis is latitude) placename is the same with Figure 4.)*

The synthetic analysis of remote sensing and geology and the application of ore-forming forecast

Yiwu is located in the islandarc belt between Siberian plate and Talimu plate and controlled by Kelamaili- Maqinwula collided stylolite and sub-class linear tectonics. It was controlled locally by generic linear tectonics. A series of ore-deposits are distributing along the generic linear tectonics and a large scale ore-forming belt comes into being. It’s characters are as follows:

(1) From the distributing of known ore-deposits, a majority of ore-deposits were distributing in the stratum of the forth sub-group Dananhu group of Devonian System (D_2d^d), a small quantity of ore-deposits were distributing in the stratum of the first sub-group Yamansu group of Carboniferous System ($C1y^a$). They were all controlled by the intruded granitic porphyry and diorite porphyrite. This showed the magmatic special attribute of ore-forming and lithofacies condition of the stratum.

(2) A majority of ore-deposits were distributing along the faults belt, especially for main linear tectonics and intersection. From overlapping quantitative analysis pattern picture of ore-deposits and linear tectonics, it was shown that the main tectonics are

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possible ore-carried tectonics and generic linear tectonics and remotely sensed major joint nearby are ore-controlled tectonics.

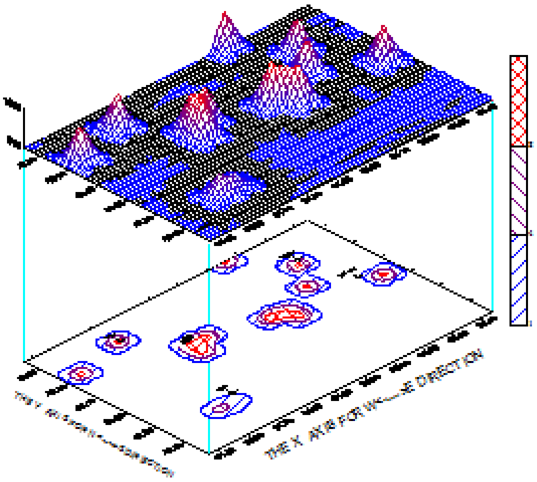

Figure 6. *Density map of deposits distributing X axis is longitude and Y axis is latitude placename: KTNY-Kuotuogayi，XP-Xiaopu，YW-Yiwu，XMY-Xiamaya*

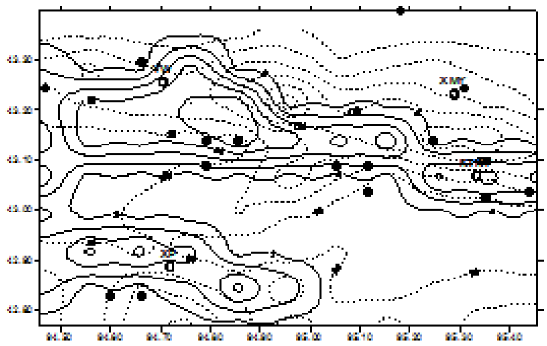

Figure 7. *Quantitative interpretation pattern map of overlapped deposits (black points) and linear tectonics. Solid line is the contour of main tectonics and dot line is the contour of generic linear tectonics and remotely sensed major joint， black points are found ore-deposits, hollow points represent place address.（X axis is longitude and Y axis is latitude）*

placename is the same with Figure 6.

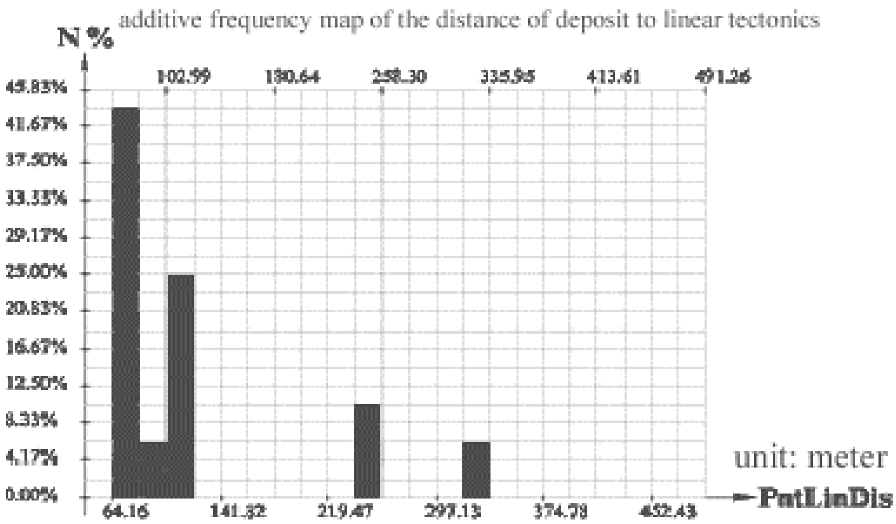

Figure 8. *Single attribute additive statistical analysis map of the distance of deposit to linear tectonics in Yiwu. (Horizontal axis is the distance of deposit to linear tectonics and vertical axis is distributing frequency，the picture quantitatively analyzes the controlled distance of main tectonics to ore-deposits)*

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Conclusion and discussion

Combining the spatial distributing of generic linear tectonics and remotely sensed major joint and the distributing characters of stratum and magmatic rock, through the “BUFFER” analysis to main tectonics under GIS software (the “buffer” radius is 122 meters analyzed above), the perspective area of ore-forming was pointed out by applying the theory of model ore-forecast and non-model ore-forecast. That is the arc belt of Xiaopu, Talei, Kuotuogayi and Xiamaya along the main tectonics of this area in addition to the belt beside of F4 fault. After the examination in field, Xiaopu porphyry copper deposit, Xiamaya breaking ecliptic gold deposit and Talei gold deposit of quartzitic vein were found.

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