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THE APPLICATION OF REMOTE SENSING TECHNIQUE ON GEOLOGICAL INVESTIGATION OF PLACER DEPOSIT

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ABSTRACT: The practice has proved that it is an economic and effective method to investigate placer gold deposit by using multi–level information sources of remote sensing and multi–variate analysis methods, especially for the area with a sparse population and difficult condition like the Da Hinggan Mountains, China.

The information sources used in our work includes Landsat TM, aerial infrared photography and their mosaic image maps and enlarged photos with different scales. According to statistic data, in the study area the gold–bearing rocks are mainly granite, alaskite, granodiorite and some old metamorphic rocks. On gold–bearing geological structures, the fault zones in the four directions (NE, NNE, NW and EW) are obvious, in which NNE and EW are the most key fault zones. On fluvial geomorphology the flow courses stored placer are in the tributaries of the 4th and 5th levels, especially in straight or slight curve reaches. On the basis of analysis the interpretative signs were set up, and the interpretative work began on a sheet of picture with a single band at first, furtherly, the integral interpretation on color enlargement pictures the extraction and composition work was carried out by means of multicolor digital analyzer, and computer image processing equipment with the VAX 11 / 750 as a host computer so as to draw up the relatively specialized maps of placer deposit and delimit the locations of ore body on the pictures or on the screen. Finally, the satisfatory effect was achieved through a series of comprehensive analyses.

KEY WORDS: remote sensing, Nenjiang River, placer gold deposit, image processing, interpretative signs, perspective effect

The study area is situated in the upper reaches of the Nenjiang River and their tributa-

ries in the Da Hinggan Mountains, belonging to Heilongjiang Province and the Inner Mongolia Autonomous Region of China (Fig. 1), covers an area of about 17,000 sq.km. Dense forest, overgrown weeds and vast swamp in the area bring about extreme difficulties to work and traffic. With regard to data, very few data, such geology, regional survey, geomagnetism etc. even no a large scale topographic map can be used. Therefore, in 1988 Changchun Institute of Geography, Chinese Academy of Sciences decided to investigate and survey placer gold deposit in the study area by means of the remote sensing technique, combining with traditional geologic method. This work has a special significance, especially for the area with a sparse population, difficult work condition.

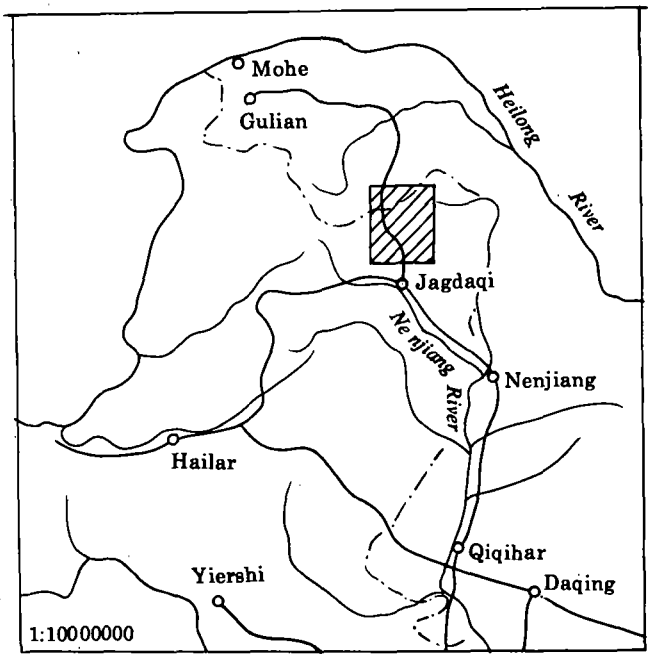


Fig. 1 Location of the study area

I. IMAGE PROCESSING AND INTERPRETATIVE METHOD

1. Remote Sensing Data

The information source used in the work includes two images of the bands 2,3,4,5,6,7 of Landsat TM(April 16, 1988), the 220 scenes of aerial infrared photographs(May 22, 1988), the mosaic image map forscale 1:50,000. In addition, in accordance with work needs we carried out the enlargement of photographs in different scales.

The color–infrared aerial remote sensing photographs were taken in spring, the size 23 × 23 cm. Landsat TM was mainly used to know the large–scale geological structure in the

area. The orbit number of theTM film used especially is 120 / 24 and 120 / 25. Selecting spring temporal was to avoid the season of snow coverage in winter and luxuriant vegetation in spring.

2. Image Processing

The optical image processing system we adopted is a well–automated color enlarger called DEVERE, enlarging image up to 20 times with clear picture and less distortion. In the Da Hinggan Mountains area, the satellite images are generally enlarged to 1:200,000, part of them are amplified to 1:75,000 and the color infrared films are enlarged to 1:10,000, partly even 1:2,000. The TM composite images with 3 / B, 5 / G and 7 / R are used to place emphasis on the boundary of geomorphologic information.

The film is the type 180, made in China. Because of gradual halo effect of lens in taking picture, the imbalanced density in films might emerge, forming the state that half of a film has thicker density and the other half has thinner density, the differentiation in density of the two halves can be up to several times. In order to achieve the color balance in a sheet of picture, we adopted the method to intermittently shut off light so as to reduce the differentiation of the film density and eliminate the color fault in a sheet of picture. In enlarging and printing other photographs, the same processing method should be used.

The TM and color infrared films, after enlarged, can be directly applied for interpretation. Foe some important area, they may be scanned by CCD camera and transferred into the digital image, then further processed by the computer or the color image analyzer with the method of data transformation to obtain the interpretative picture as ideal as possible.

In the Xaio Hinggan Mountains, TM tape information were input to the image system which takes VAX 11 / 750 as host computer (Fig. 2), after a series of enhancement and extraction processing, some information such as fluvial geomorphology and linear structural features was projected.

3. Interpretative Method

At first, the interpretative work was carried out on a sheet of picture with a single band, further the integral interpretation on color synthetic picture and mosaic image. For some important areas, the digital analyzer and computer image processing equipment. At last, we can draw up the relative specialized map of placer deposit on enlarged pictures, analyze the mineralization conditions and delimit the location of the ore body as well as design construction plan. After the image has been interpreted on screen, the larger scale film can be output as possible, the processed and enlarged into photograph, it is directly used for the field investigation and thematic interpretation. For a specific demand, the computer and the multicolored image analyzer can be used separately to stretch and classify on the purpose of work. For example, according to the foreign materials and the results obtained in the practical work in our country, the radiated values of geophysics are related to ch6 / ch5 and ch7 / ch4. The ideal effect on the rocky difference can be obtained from the composite image by setting ch6 / ch5 with blue, ch7 / ch4 with green, ch5 / ch4 with red.

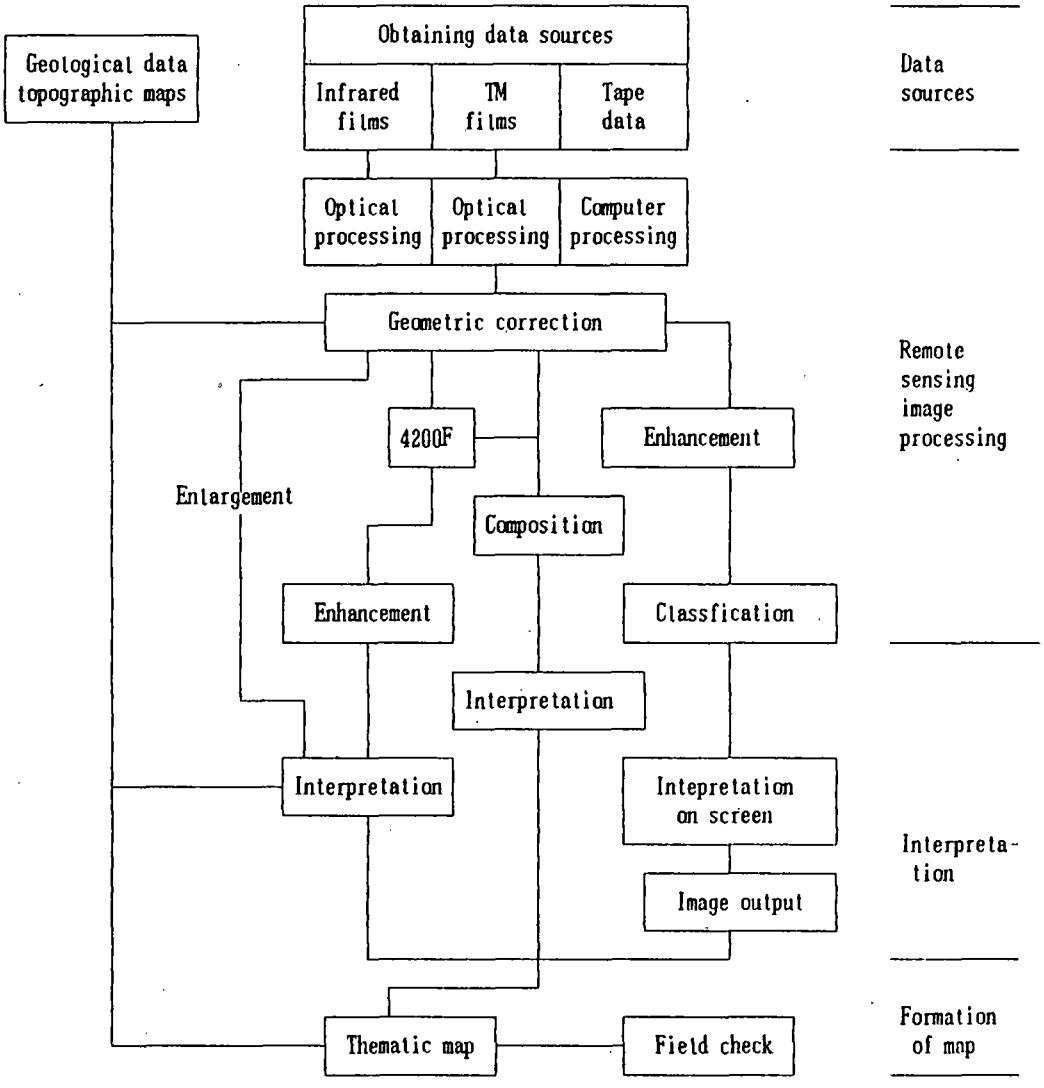


Fig. 2 Remote sensing data processing and flow chart of work

II. THE PRIMARY GEOLOGICAL BACKGROUND AND INTERPRETATIVE SIGNS IN THE STUDY AREA

On the tectonic system, the study area lies in the northeastern end of the Mid–Asia–Mongolia–Hinggan Mountains Geosyncline Fold Zone, belonging to geosyncline fold zone of the Variscian Movement. The zone consists of a series of old rise massif such as Erguna rise, Weileger rise, Xingkailing rise, Jiamusi rise etc. Basically all

study sites are in the fringes of these rises. The oldest stratum in the study area are crystalline schist genesis, migmatite of the Xinghua Group and Xingkailing Group of the Proterozoic Era. Here the stratum of the Lower Palaeozoic Era is not developed. The stratum of the Mesolithic Era mainly are mid–acidic volcano rocks and the stratum of the Cenozoic Era mainly are fluvial and lacustrine deposits.

The intrusive rock bodies in the area can be divided into four cycles. The chief rocks in the Proterozoic Era are basic and ultrabasic intrusive rocks such as peridotite, diabase, granite migmatite. The rocks of the Caledonian Movement are anorthose granite, granodiorite with mid–coarse grain structure. The intrusive rocks in the Variscian period such as alaskite, anorthose granite distribute extensively in the Da Hinggan Mountains area where are main material course of gold–bearing. The intrusive rocks in the Yanshan Movement is not developed and distributes some odd pieces of the area.

The interpretative signs of the primary geological bodies in the area are shown in Table 1.

The primary structure in the area can be summarized the four directions, i.e., EW, SN,NE and NW. The judge and interpretation of fault structure mainly are in accordance with the following signs and geological phenomena.

1) Jigsaw–like of geological body or structural line occur.

2) River shows linearity or in broken line form or the flow cource changes at right angle.

3) Fault cliff or fault facet.

4) The boundary of geomorphologic unit is in straight line and clear.

5) The boundary of vegetation extent is straight line.

6) Others.

The property of fault can be judged according to the following characteristics:

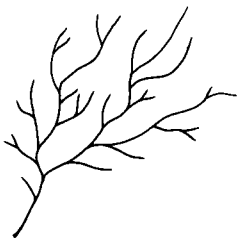
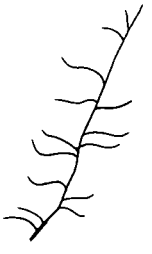
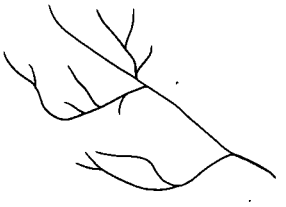
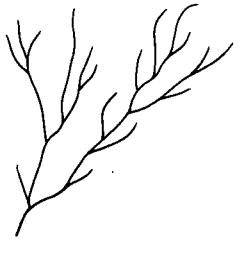
Pressure fault: Extension of fault is longer and displays in straight line, accompanying with narrow, longer and parallel ridge–like hill and belt–like depression. Tension faults generally distributes along valley and gully, being wider and no longer extend. Sometimes the faults shows saw–like and jigsaw–like form. The twist fault often combines with pressure and tension fault.

The drainage net pattern is relative to rock property and structure in the study area, the main drainage type is shown in Table 2. The rivers in the area have mountainous characteristics, the comprehensive fluvial geomorphologic profile is shown in Fig. 3.

Table 1 The interpretation model of primary geological body in the Da Hinggan Mountains

Geologic-al body	Topography	Drainage	Color tone	Land use	Example (place)
Granite	Massive and rounded, domelike hills, little change of relative height, having softly rounded tops of the hill and steeper side slopes.The weathered debris and large boulders with rounded shapes accumulated in the drainage courses and depression	Medium dendritic drainage pattern, intersection of tri-butaries occur at right angles or may be slightly acute upstream, gullies show U-shaped pattern in the cross section	Light tone,fracture zones are dark tone, infrared image is light purple to brown,clear boun-daries to other geologic bodies	Generally forest covered, secondary forests, shrub	Sidaogou, Wudaogou, Nanyang River
Alaskite	Ditto	Ditto	Light tone,on infrared image it is purple, but it has smaller size and rough surface	Ditto	Ergun River
Volcanic fragmant	Sharp ridge of hill deeper dissected topography, side-slopes are steeper and hill tops do not occur at equal elevations	Mid to fine dendritic dleainage pattern or ribbed pattern,fewer tributaries, intersection of tributaries occur at small angles. narow valley, V-shaped cross section	Grey,rough surface.image on infrared picture is orange-yellow color	Natural forests, grassland, swamp	Rivers of Yilihuli Moun-tains
Schist, gneiss	Rounded top of hill, steep side slopes, often developed deep residual soil, overall topography is in smooth, undulating hill	Rectangular, mid-fine dendritic drainage pattern, having longer deeper and parallel gullies, cross section of river is various	Light tone, some-times having black banded image alternating with white band	Natural and secondary trees	
Migmatite	Hill landform, less dissection, no clear creast line	Dendritic drainage pattern, well-developed gullies, the heads of river source appear in petal form.	Light tone, color varies with rock element, it is light red on the infrared image	Mixed wood, shrub	Yilihuli Mountains
Fluvial sediment body	River bed, flood land,terrace		Light yellow, yellow-green	Meadow	

Table 2 The drainage patterns of main river systems in the region of the Da Hinggan Mountain

Drainage pattern	Graphic	Characteristics	Remarks
Dendritic drainage pattern	Dendritic 	Tributaries are well-distributed, dendritic pattern and of medium texture. Some heads of river source appears as pincer shape,forming pincer-like drainage pattern.	Developing in the area of uniform rocky element and gentle slopes. Generally, in the later period of geologic history, the tectonics of this area is less, the rock body is very easy weatherred, hill tops are soft rounded, tending to domelike appearance, such as the drainage pattern of the grainite area ect.
Ribbed drainage pattern	Ribbed 	It is a mutation of lattice drainage pattern, the tributaries intersects the main stream at right angles	Developing on sedimentary rocks and volcanic fragmental area such as Tahe River valley ect.
Angular drainage pattern	Angular 	Similar to lattice drainage pattern	Tributaries flow the main river at bigger angle or right angle, such as the Ergun River, Naiaoer River ect.
Parallel drainage pattern	Parallel 	Drainage system of tributaries is parallel	Distributing on a tilted platform surface, controlled by structure. Generally, developing along a group of faults such as Nanyang River ect.

Terrain system	Denudation hill	River bed	Tender flood land	Low flood land	High flood land	Fluvial terrace	Alluvial–diluvial fan	Denudation hill
Geomorpholo gical process	Sheet, rill, gully erosion, wheathering	River action	Scouring, deposition	Periodically flooded	Periodically flooded	Exceptional–ly flooded	Alluvial diluvial	Wheathering some sheetwash
Soil	Deep brown soil	Sand and gravel, alluvial deposits	Sandy gravelly and clayey deposit	Sandy and gravelly alluvial soil	Gravelly and sandy alluivial soil	Well–developed silty alluvial soil	Alluvial–diluvial soil (gravel sand detritus)	Residural soil
Vege–tation	Natural and secondary forests	Water	No	Swamp vege-tation herbosa	Shrub, bush	Secondary forests shrub,grass land	Secondary forests, shrub	Natural and secondary forests

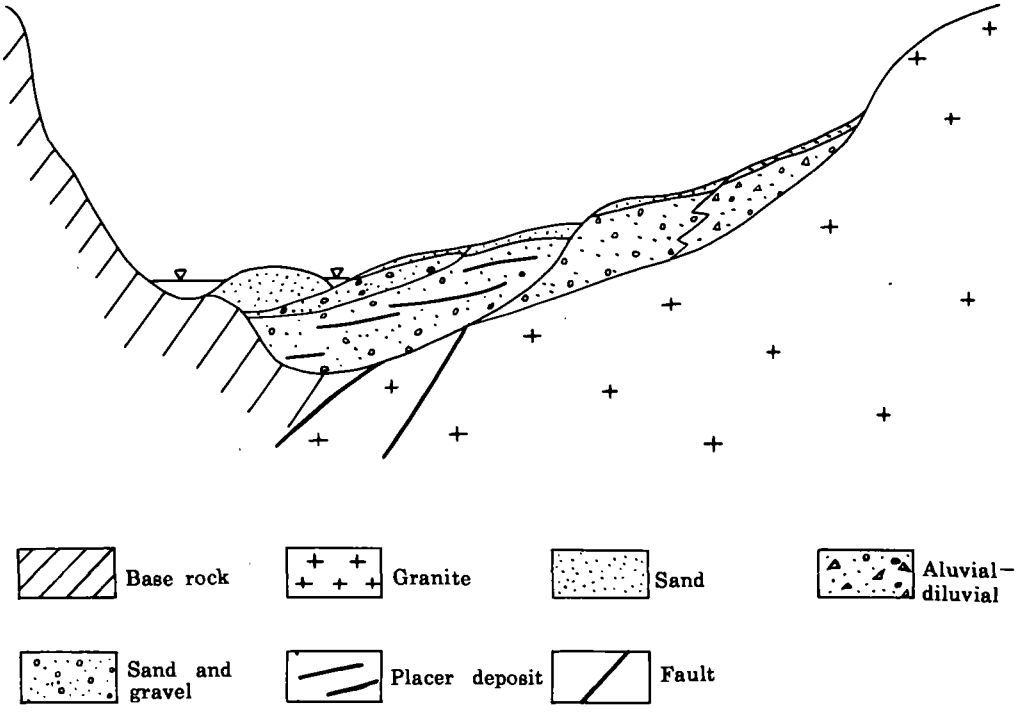


Fig. 3 The comprehensive geomorphologic map of placer gold in the Da Hinggan Mountains

III. THE INTERPRETATION OF GOLD–BEARING ROCKS

Based on the known data of 300 placer ore sites in and close to the study area, the gold–bearing rocks are mainly granite, alaskite, granodiorite and some old metamorphic rocks such as gneiss. Therefore, interpreting and drawing up the outline of the rock body stated above can greatly reduce the search scope. The interpretation for granite rock body, especially mid–coarse grain granite, is easier. Generally the rock is positive feature and ap-

pears as circle or ellipse map–patch on the image. The granite is very easy to weather, there is a soil layer of 30—50cm thick developing on the top of it, on which birch, *larch, Pinus sylvestris,* and mixed wood grow; round top and gentle side slope, wide valley and debris deposit on its bottom, mid–density water net, all of those characteristics are clear on the macroscope. The granite area displays the undulatory landform pattern. These characteristics are also easily recognized on the image of Landsat TM by visualization or mirror stereoscope. The granite body has a comparatively bright tone. Water net spreads out regularly in this area and is darker color. On the pseudo color composite image and the color–infrared image, granite body is a light red and pink, having clear outlines and differentiation from other geologic body. That is because granite itself is a comparatively high thermal source on the ground[1]. Its spectral effectiveness is much more the other rock body.Bare granite body has a light tone, the brightness is 2 levels higher than that of other rock body (Fig. 4).

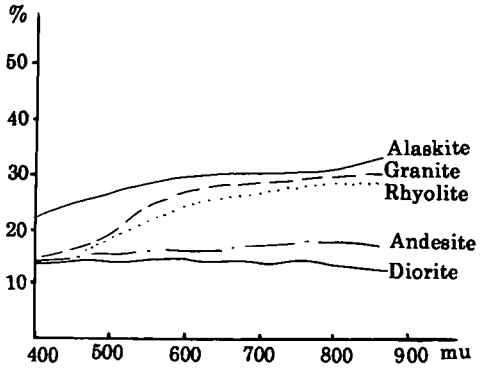


Fig. 4 Spectral curves of rocks in the area

Alaskite is a light tone and granodiorite shows brown color in the standard pseudo color image. You can extract information about various granite body and sketch its range by transformation with image processing device.

In the area, metamorphic rock is mainly composed of schist and gneiss which are essential origin rocks containing gold. They have the geomorphic features of circular hill ridge, steeper slope and thicker remained soil layer, moderate–high drainage density etc. Whole landform looks like smooth undulance, most of the gullies are deeply eroded with intersection of letter "V" and parallel each other. The color–tone appears as grey on MSS 7 image or as dark red on the pseudo color composite image and infrared picture. The loose Quaternary deposit distributes along river valley, it is easy to portray their boundaries according to its geometric shape and yellow–green color on the image. The river deposit is a key accumulated type stored placer gold, those valleys of the rock layers stated above have bright prospects for finding placer.

The mid–acidic volcanic rock of the Mesozoic Era including basalt and rhyolite distribute in the axis part of the Yilihuli Mountain, and extend in NE–WS direction, having the features ofnarrow valley, intersection with V form, dense water net, small confluent angle between tributary and main stream, more gentlehill type, growing swamp on steep slopes of valley. There is a fault between granite intrusive rock and volcanic rock, and the outline is clear. Because of low gold content in volcanic rock, it was ruled out in this study.

IV. THE GOLD–BEARING STRUCTURE AND INTERPRETATION

A lot of facts proved that the placer deposit is intimately tied to the geological structure in the area, especially fault structure.Statistics tell us that 44% of placer sites in the area of the Da Hinggan Mountains are bound up with the structure in northeasterndirection. The placer sites of 42% are related to the structure in northwestern direction. The wider the zone of the fault break is, the more breakable it is; the more the quantity of placer deposits is,the larger the size is, especially in the cross position of the fault.

There exist the fault zones in four directions: NE, NNE, NNW andEW, in which the faults in both NNE and EW directions are the most obvious(Fig. 5).

Three dark stripes in EW direction can be seen on the pseudo–colorcomposite image of TM, in which the two stripes lie at the both sides of the volcanic rock body and the other is in the south part of the study area. There is a dark thick stripe at the west side of the area, having saw tooth form and extending in NE direction. Those four fault stripes formed the basic structural layout in the area, their occurrence is accompanied with the eruption of volcano and the intrusion of granite body. In fact, the study area was located within the basin embraced by these fault stripes.

The faults of NNW direction are the main structural lines in the study area. Some main rivers, such as the Xiangyang River and the Ergun River developed along with the faults in NNW direction. These faults belong to the pressure property and it spreads long and straight. The facts that the spine hills and the valley rank parallelled and densely, are caused by the extrusion pressure of the tectogenesis. We may see these phenomena in the western side of the Yilihuli Mountains, where the faults in the EW direction were cut off by the faults in the NNW direction at the Xiangyang River, so as to make volcanic rocks occur twisting in the counter clock direction. The color tone got dark and the boundaries blurred. The rock was broken at the cross location of the faults. In some rivers, vertical diversion happened from one fault to another, such as the western tributaries of the Ergun River etc.

The faults in "Huaxia system"(NE direction) and "New Huaxia system" (NNE direction) developed in the northern part of the Yilihuli Mountains and the distributed densely in the study area. They are defined as tension faults, and distribute along with the river valley, but their extension is not longer. The concealed lines with different degree of depth can

be seen on the image.

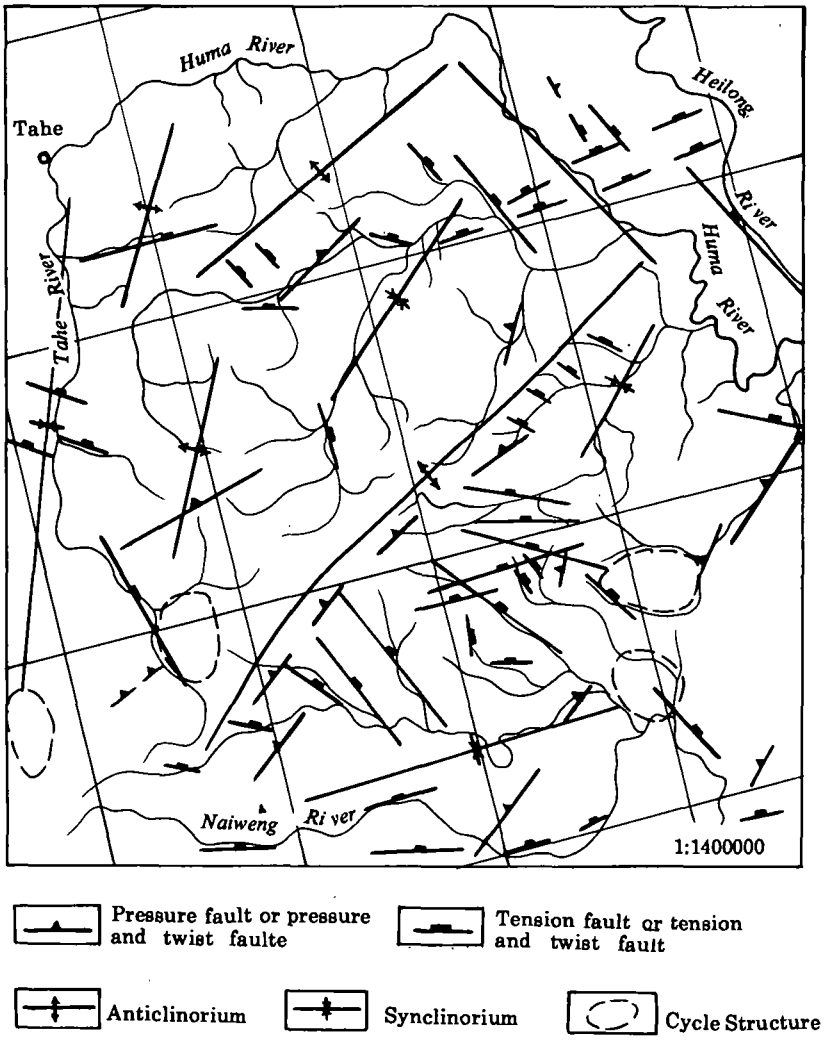


Fig. 5 The structure interpretation of the Da Hinggan Mountains

For a circle structure, the intrusion of magma rock happened, which was represented by a light color—circle, and the shape is approximately a circle or ellipse. More clear circle structure in this area shows alaskite body, its long axis extents in NW direction, its east, west and north sides were cut off by the faults. So far, we have found several placer traces near the fault lines. Therefore, the alaskite body and the fault around is also our major working area in recent years.

V. THE PLACER DEPOSIT AND FLUVIAL GEOMORPHOLOGIC INTERPRETATION

According to the statistical data, the flow courses stored placer are in tributaries of the fourth and the fifth levels, so does the study area. In these rivers the transportation and storage placers have the following regularities.

1) Straight or slight curve river reach is the favorable site for accumulation of placer. The reason is that the flow of water is concentrated and stronger. Otherwise, a wide water surface of river, tscattered flowing course and meandering development or shifting reaches are not beneficial to concentration and sorting of placer.

2) The following places are favorable for placer accumulation: sudden change place of flow velocity, suddenly turning place of flow direction, obstructed place of flow, sudden descent place of gradient of river bottom[1].

3) In general, the flood land of the upper reaches of the Nenjiang River can be divided into two types, higher flood land and lower flood land. And the lower flood land can also be divided into three subtypes; they are old, new and tender patterns, according to forming time and surface height of lower flood land. The old flood land surface is higher, where grows dense vegetation such as woods, overgrown weeds, marsh plant etc. It represents as greendish—red in the color infrared image. The tender flood land formed in this year or recent years, the height of the surface is low, and the shape often changes when flood comes, a little vegetation grows here, the color is fresh green in the infrared image. In ordinary case, the old flood land has higher content of gold than new and tender flood land in the area, and its range is bigger and more stable than the other two patterns. Various types and subtypes of flood land are easy to be distinguished on the standard pseudo color composite image and infrared image on the basis of color—tone and their geometric form locations.

4) The river catchment area, the drainage basin shape, the landform conditions of erosion and transportation decide Quaternary accumulation quantity and content of placer gold. Bigger catchment area and drainage basin with palm shape are favorable conditions for placer concentration.

5) The most directive mark for prospecting placer is to look for traces of mining gold of predecessors. Up to now, a greater part ofplacer gold ore in the area has been sought with this method. Therefore, important problem is to find and recognize the traces on infrared and Landsat images. During the past two years, we found this residual at tens sites by image analyses, among which two sites have not been found before. These residuals or traces distribute on side or two sides along stream, forming a line of sand and gravel banks or more. Certainly, prospecting placer is a comprehensive work, we should be reference to various regional geologic condition and its representation on the image etc.

VI. CONCLUSION

Generally, even existing thermal information of remote sensing, and surface information and perspective effect of image, but these information are mainly superficial, especially surface information covered by dense vegetation in the Da Hinggan Mountains in the work, we select suitable temporal and bands with strong transmissivity. At the same time, we researched relations between vegetation coverage and landform, rock, fault and digging trace, for example, birch woods in valley bottom close to the trace. By comprehensively analyzing rock, structure, coverage, color—tone, map patches etc. we can achieve satisfactory effect.

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