

# Hydrothermal alteration mapping of Siberian gold-ore fields based on satellite spectroscopy data

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**Abstract.** The mapping of the hydrothermal alterations in Urjahskoe and Fedorov-Kedrov gold-ore fields was conducted by applying channel relationship method (band ratio) based on ASTER spectral-zonal satellite image data. It was determined that the calculated mineral indices in ore-bearing structures are zonal. Outer ore-bearing structures revealed increased ferric mineral index values, while inner – high epidote- chlorite- calcite and muscovite- siderite mineral index values. Detected regularities could be used in identifying potential gold-ore bearing areas within identical fields based on remote sensing survey data.

## 1. Introduction

Spectral methods in remote sensing of geological surveying, mineral deposit exploration activities became applicable in the 70s of the last century due to the introduction of multispectral Earth surface photographs. Today, there are numerous operating spectro- radiometers, including not only satellite (ASTER, MODIS, Hyperion, Landsat ALI and others), but also aeronautic (SFASI, MASTER, SEBASS, AVIRIS, Hymap) ones, as well as a significant data archive of space systems.

Based on the technical features of the spectral channel configuration in the radiometer and data accessibility, ASTER data in geological surveying is more optimal in application.

The system characteristics include the following number of channels: 3- visible and near infrared (VNIK); 6- shortwave infrared (SWIR) and 5- thermal infrared (TIR). Spatial resolution is 15m, 30m and 90m, respectively.

The research target is Urjahskoe ore field, located within Sulban deep-fault distribution area in Baikal-Patom upland and Fedorov-Kedrov ore field within Orton-Baliksino district in southern Kuznetsk-Alatau.

North N-W trending Sulban deep fault within Urjahskoe gold-ore field divides the host rocks into two blocks: eastern (significantly metaterrigenous and metacarbonate) and western (predominately metavolcanogenic) [1]. Intrusive rocks as plagiogranite dykes can be found only in the western block of this ore field. Host ore rocks metamorphosed in environments of green schist and amphibolite facies [2], while in affected Sulban deep fault zones these rocks transformed into dynamochists and subjected to metasomatic alteration resulting in beresite-listvenite profile. In these metasomatite zones veined and stringer-porphyry mineralization have been detected. Quartz-carbonate and carbonate veins and veinlets have been revealed in the axial Sulban fault region. Productive gold-sulphide mineralization is confined to pre-selvages in these veins. Stringer-porphyry mineralization is followed by beresitization and carbonizing of host rocks and this, in its turn, is confined to dynamochist



development areas within the Sulban fault. Sulban deep fault is the major ruptured ore field zone. In the north field area it is a single joint branching southward and forming lense-boudin blocks. Here, it is trending S-W, while in the south area - N-E.

Fedorov-Kedrov gold-ore field is located in the south of Orton-Baliksinsk gold-ore area, southern Kuznetsk-Alatau. Structurally, this area is confined to the joint area of deep-medium and vari-oriented structural complexes: N-E joint zone of mesozonal structure and N-W zone of Kuznetsk-Alatau epizonal deep fault. Host, predominately volcanogenic-carbonate, rocks are cross-cut by a dense network of meridional mafic dykes. Ore-bearing Fedorov-Kedrov zone, enclosing Fedorov gold-ore deposit, is located in the S-E edge of the North-East joint being structurally, lenticular and cross-grained in apparent thickness of more than 2km. Several linear areas of intensive N-E trending dynamometamorphism were identified within this area, followed by metasomatic propylitic-listvenite-beresite alterations. Gold mineralization involves structural-morphological veins (Fedorov deposit) and stringer-porphyry mineralization (Kedrov, Zolotoe, Anomalnoe ore occurrences) [3].

## 2. Research methods

Mapping of hydrothermal alterations associated with ore mineralization, including ASTER data, involves band ratio methods, Spectral Angle Mapper, its modifications and constrained energy minimization. Such an approach was applied to identify potential areas of gold-ore, gold-silver, copper-porphyry, copper- molybdenum-porphyry targets [4 – 7]. It should be noted that mapping hydrothermal alterations and identifying potential areas are conducted in conditions of rather favorable exposure.

Investigated area embraces partially forestry and peat zones which restrict the possible application of Spectral Angle Mapper and constrained energy minimization in mapping the hydrothermal alterations. In this case, the basic research method is band ratio.

The designed procedure in processing ASTER satellite images and further interpretation of obtained calculations included:

- 1) image screen preparation;
- 2) calculation of spectrum indexes;
- 3) interpretation of obtained material.

Image screen preparation involves the following: projecting ASTER data to a rectangular cartographic system, atmospheric correction, noise masking, spatial resolution to 30m, recalculation of radiometric resolution of TIR to 8bit/pixel.

Calculation of band ratio is based on ArcGIS. Thirty different indices were calculated for each area and further evaluated in terms of informativeness (table 1).The interpreted information involved the data of geological structure and areal minerageny.

**Table 1.** Information relationships to map hydrothermal alterations based on ASTER data.

Index	Calculation formula	Reference source
RBD6 (muscovite+siderite+illite+smectite)	(band 5+ band 7)/band 6	[8]
RBD8 (epidote+chlorite+calcite)	(band 7+ band 9)/band 8	[8]
Quartz I	(band11/band 10)/(band 11/band 12)	[9]
“Hematite” (Gossan)	band 4/band 2	[10]
“Ferric” oxides	band 4/band 3	[11]

## 3. Research results and discussion

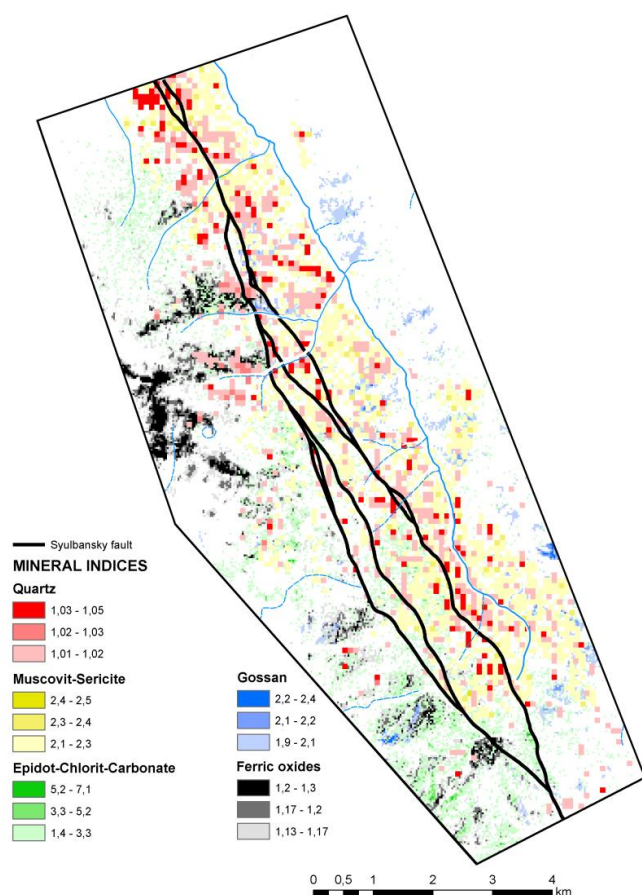
The most informative indices within Urjahskoe gold-ore field are quartz, muscovite-siderite, epidote-chlorite-calcite and ferric.

Increased quartz index value distinctly shows silicification along the developing Sulban deep fault zones revealing a regional ruptured hanging wall block structure. Muscovite- kaolinite index values are also predominately high within Sulban fault zone. However, it should be noted that the increased index values are correlated to the location of metaterrigenous rocks in the eastern ore field block, while in the western metavolcanogenic block the index value is lower. The conjugation domain of high muscovite- siderite index values indicates beresitization areas.

High epidote-chlorite-calcite index values are typical only for the western metavolcanogenic ore field block. In developing Sulban fault zones the high values of this mineral index are observed sporadically in areas of low quartz and muscovite-siderite index values. Accordingly, it is supposed that epidote-chlorite-calcite index values could reveal areas of developing propylitization.

“Hematite” and “Ferric” indices have exactly the same behavior. These indices are minimum in the influence zone of the Sulban fault and progressively increasing outward from the fault. Particularly, “Hematite” index is revealed within the metavolcanogenic environment of the western ore field, while “Ferric” index- in the eastern area within shale metaterrigenous environment.

Based on the obtained consistent spatial attitude values of the above-described mineral indices according to ASTER data, a model of metasomatic zoning in Urjahskoe gold-ore field was plotted (figure 1).



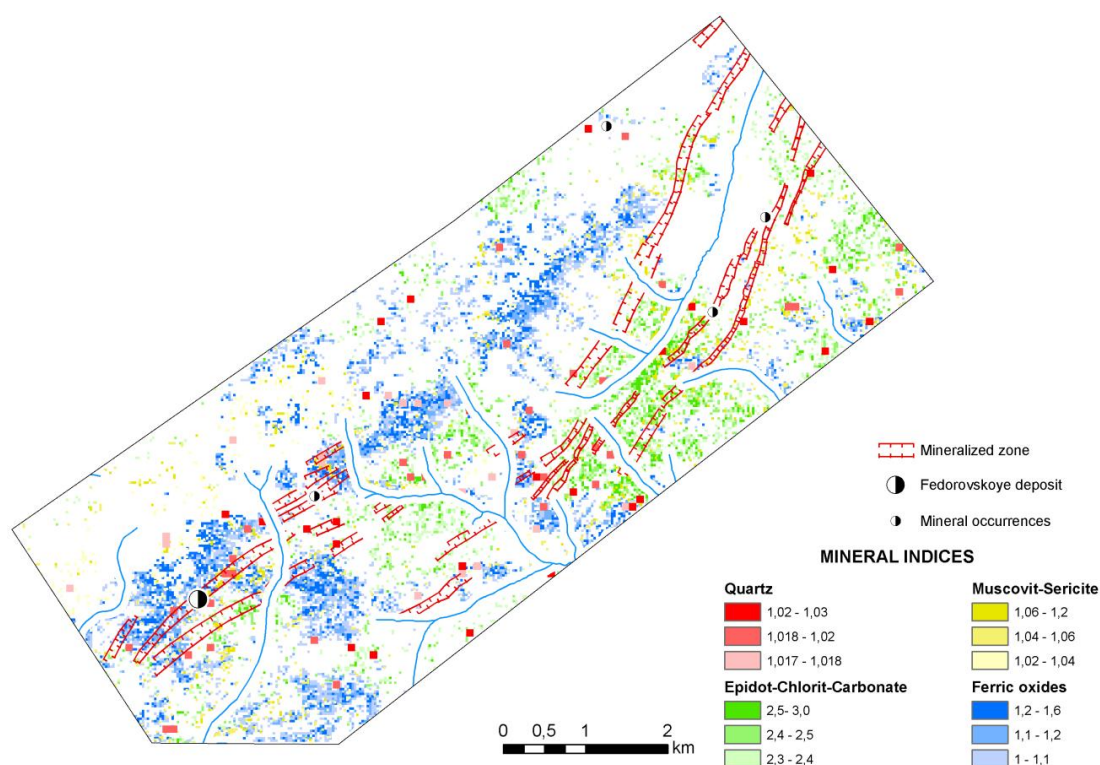
**Figure 1.** Model of metasomatic zoning in Urjahskoe gold-ore field.

The spectral model of metasomatic zoning in Urjahskoe gold-ore field revealed the following: significant inner quartz index zone; first intermediate quartz- muscovite- siderite index zone; second intermediate epidote-chlorite-calcite index zone within the metavolcanogenic thickness; outer “ferric”: in metavolcanogenic thickness – ferric oxide, while in metaterrigenous thickness- hematite index zones.

The most informative indices were those of epidote-chlorite-calcite and ferric oxide within Fedorov-Kedrov gold-ore field. In this case, quartz and muscovite- siderite indices only supplement

the above-described ones and, in some cases, accentuate the inner structure of potential ore-bearing zones.

High “Ferric” oxide index values embrace north-western, south-western and southern potential ore-bearing joints in Fedorov-Kedrov gold-ore field disaggregating its lenticular structure. Conversely, increased epidote-chlorite-calcite index values reveal the inner part of these lenses. In some cases, the increased muscovite- siderite index values reveal the inner part of local joints in potential ore-bearing zones. However, the quartz index within this area does not demonstrate any consistency to gold mineralization. This could be explained by development of crust weathering in the investigated area. Based on the obtained consistent spatial attitude values of the above-described mineral indices, according to ASTER data, a model of metasomatic zoning in Fedorov-Kedrov gold-ore field was plotted (figure 2).



**Figure 2.** Model of metasomatic zoning in Fedorov-Kedrov gold-ore field.

The spectral model of metasomatic zoning in Fedorov-Kedrov gold-ore field revealed the following: inner muscovite- siderite; intermediate epidote-chlorite-calcite and outer ferric oxide index values.

Obtained consistent metasomatic structure areolas in Urjahskoe and Fedorov-Kedrov gold-ore fields closely correlate to the classical metasomatism concept of gold-ore bearing areas, where the inner zones are silicificated, while intermediate zones embrace metasomatites of beresite-listvenite thickness, which, in its turn, are replaced progressively outwards by propylites and propylitized rocks. Ultimately, outer ferric zones correlate to frontal basification zones.

#### 4. Conclusions

- 1) Muscovite- siderite, epidote-chlorite-calcite, hematite (gossan) and ferric oxide mineral indices, calculated from ASTER spectral-zonal satellite image data, consistently reflect characteristic gold-ore fields.

- 2) Designed spectral models distinctly showed several zones: inner with hematite and ferric oxide, intermediate composed of increased epidote-chlorite-calcite and inner with muscovite- siderite mineral indices. Quartz mineral index does not always reflect unambiguous results. This is associated with the ASTER spatial resolution TIR channels (90 meters), landscape environments and specific feature of silicification.
- 3) This consistency could be used in collaboration with other minerogenic data as potential criteria for gold-ore bearing areas.

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