4-4 Review of analysis result

4-4-1 Interpretation and analysis

This section outlines the alteration zones for each scene processed. For the details of the 15 scenes used and the image data, see Table II-4-3-1.

The description of each scene focuses on the features of the alteration zones discriminated from six types of processed images.

(1) BGR = 147 (False color image) scenes Fig.II-4-4-1-1

(2) BGR = 4/5, 4/6, 4/7 (Band ratioing composite) scenes Fig.II-4-4-1-2a

(3) BGR = 4/5, 4/6, 4/7 (Band ratioing composite) scenes Fig.II-4-4-1-2b

(4) BGR = Ser, Kao, Aln (Alteration mineral identification image) scenes Fig.II-4-4-1-3

(5) BGR = Ser, Geo, Aln (Alteration mineral identification image) scenes Fig.II-4-4-1-4

(6) BGR = Chl, Ser, Aln+Kao (Alteration mineral identification image) scenes Fig.II-4-4-1-5

(7) BGR = Qtz, Hem, Geo (Alteration mineral identification image) scenes Fig.II-4-4-1-6

(8) Alteration zone outlined by ASTER and Landsat TM Fig.II-4-4-1-7

(9) SiO2 contents Fig.II-4-4-1-8

(10) Landsat TM false color image (BGR=145) Fig.II-4-4-1-9

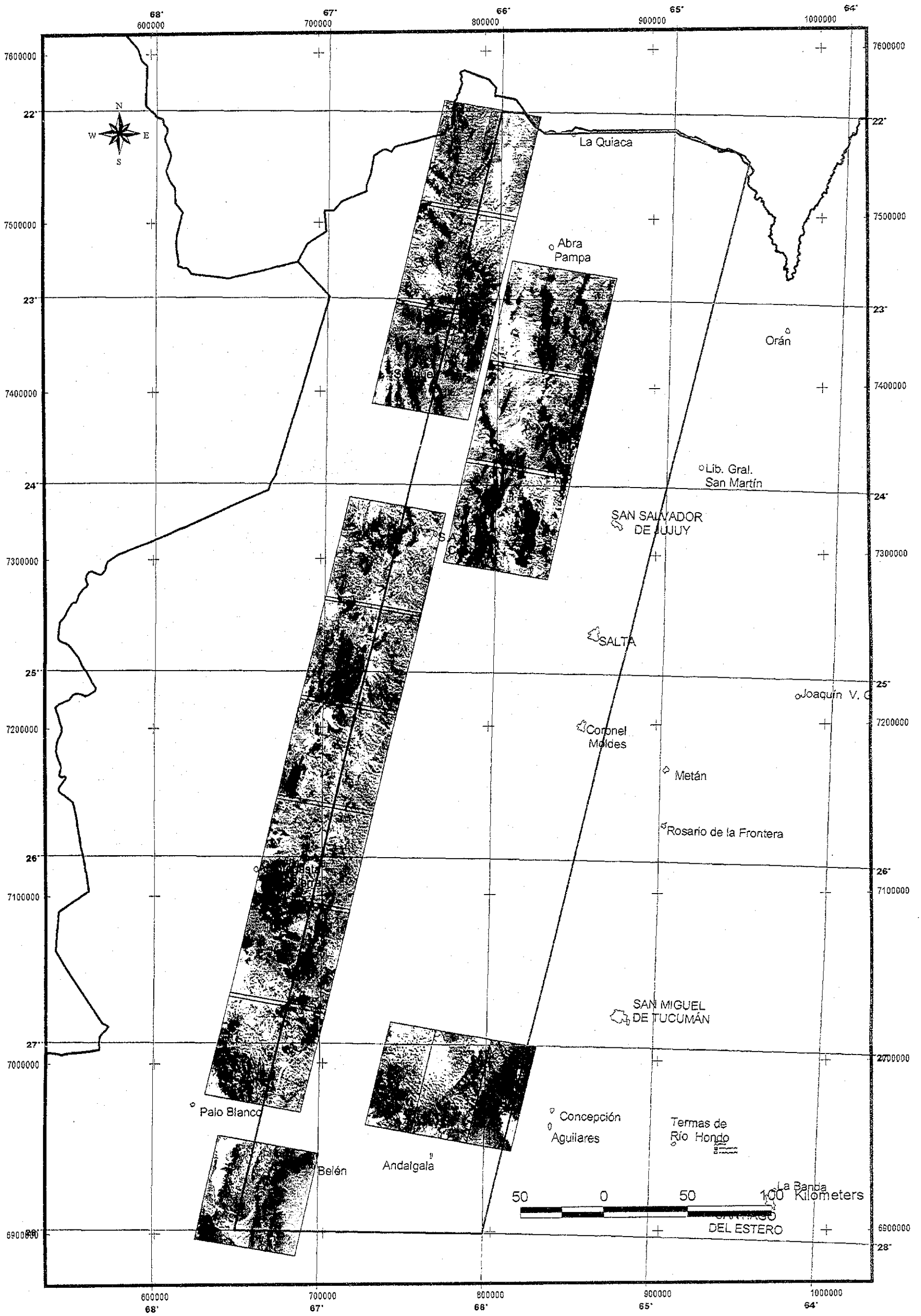


Fig.II-4-4-1-1 BGR=147 (False color image)

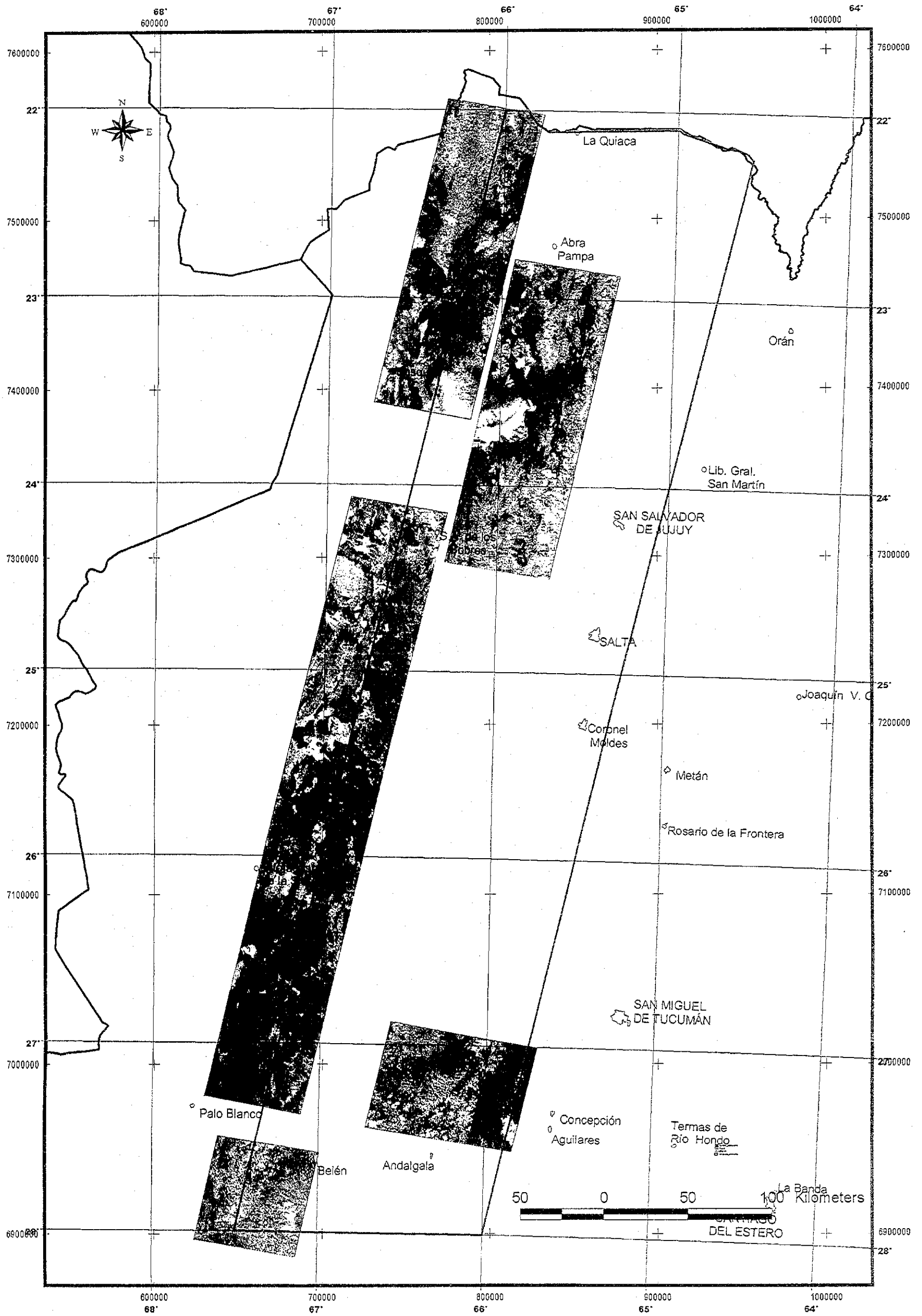


Fig.II-4-4-1-2a BGR=4/5,4/6,4/7 (Ratio image1)

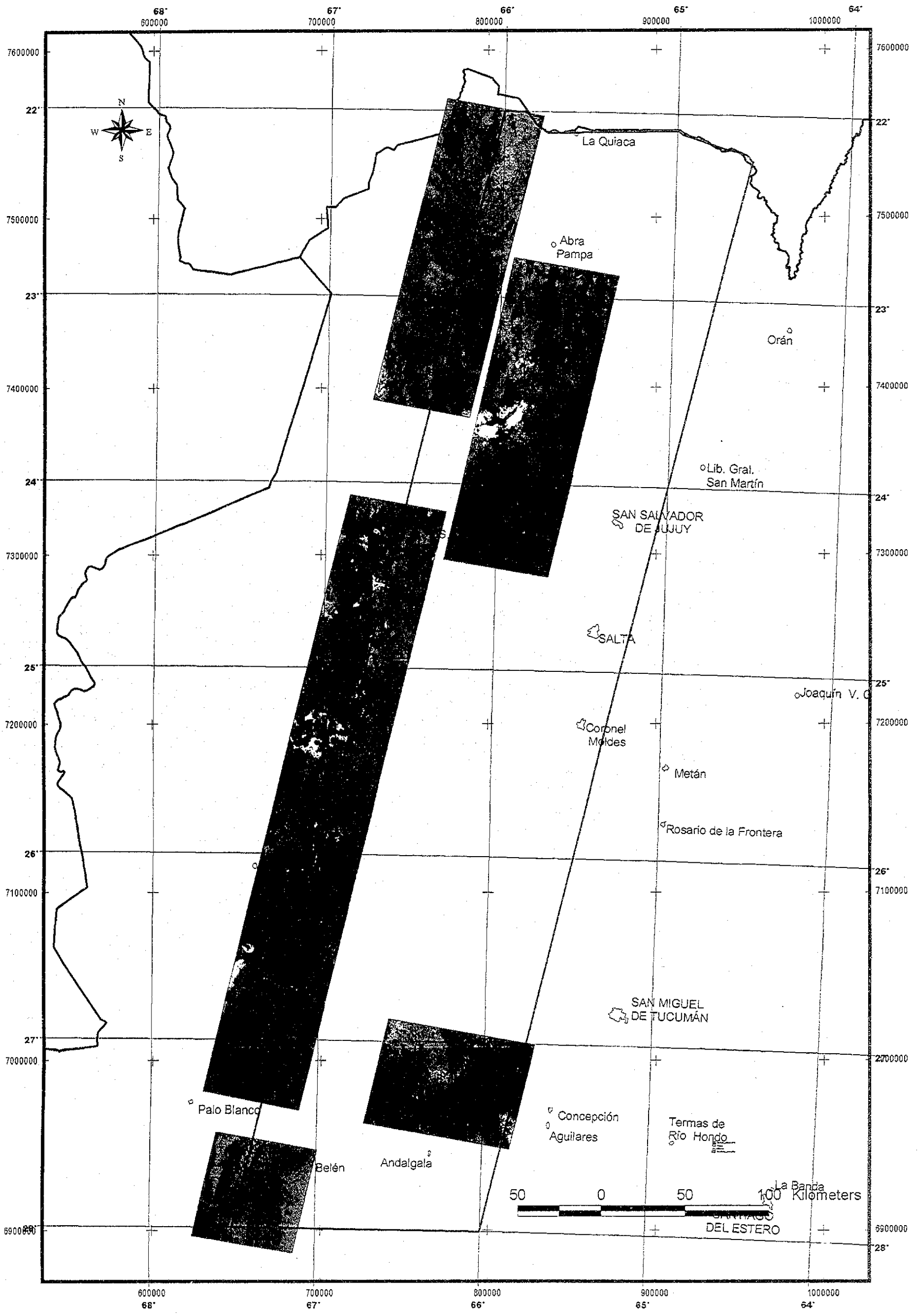


Fig.II-4-4-1-2b BGR=4/5,4/6,4/7 (Ratio_ image2)

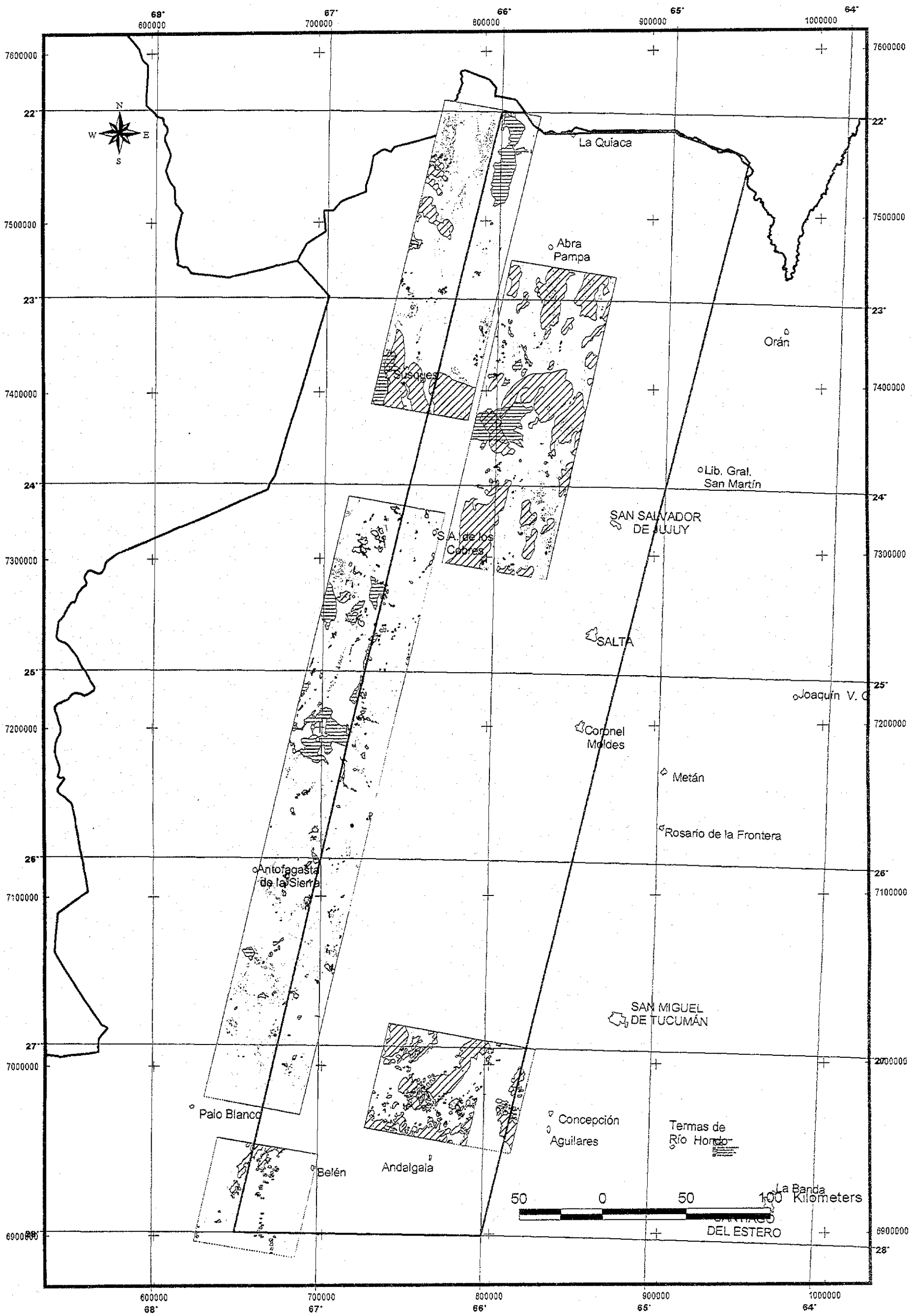


Fig.II-4-4-1-3 BGR= Ser,Kao, Aln (mineral identification)

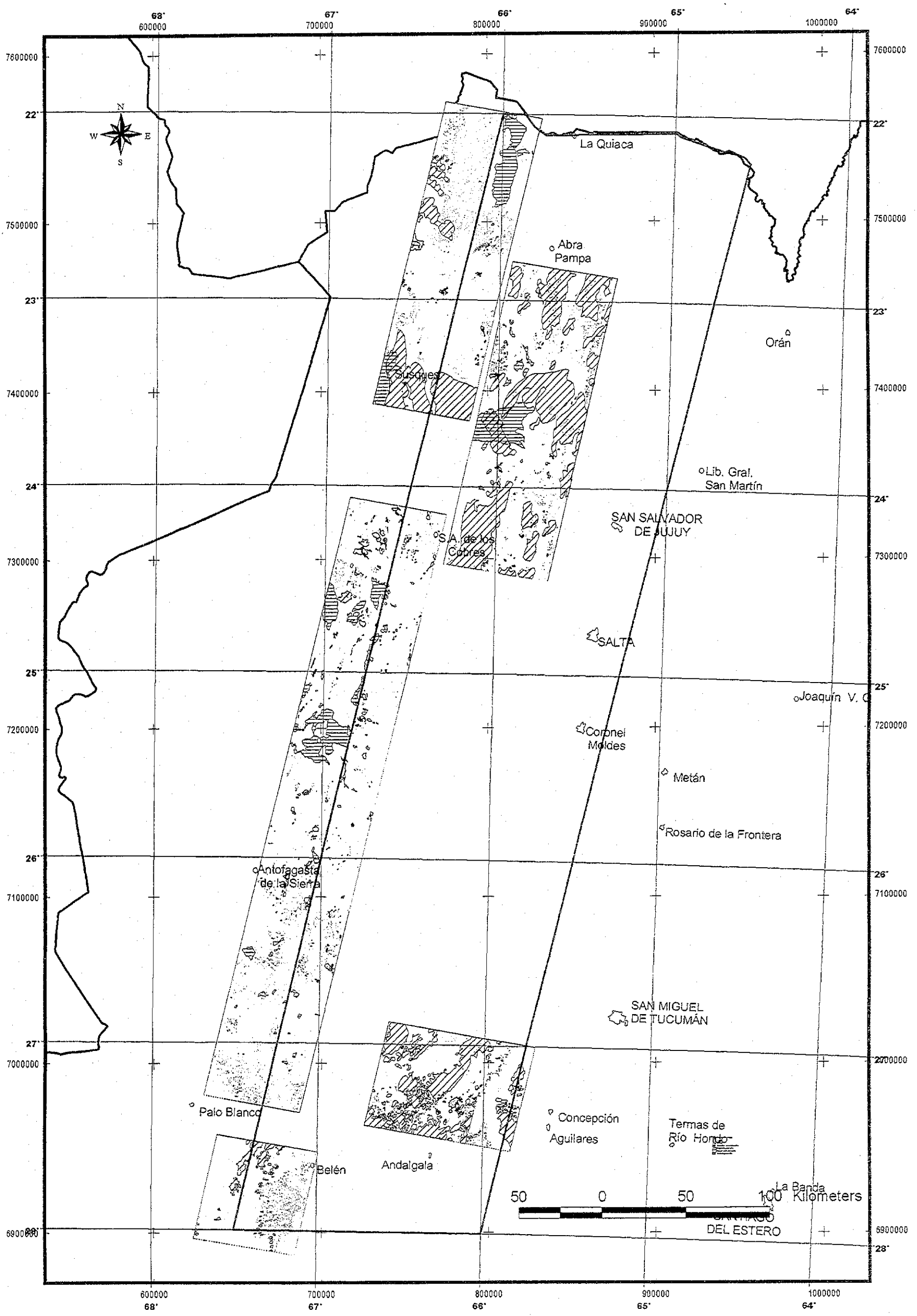


Fig.II-4-4-1-4 BGR= Ser,Goe, Aln (mineral identification)

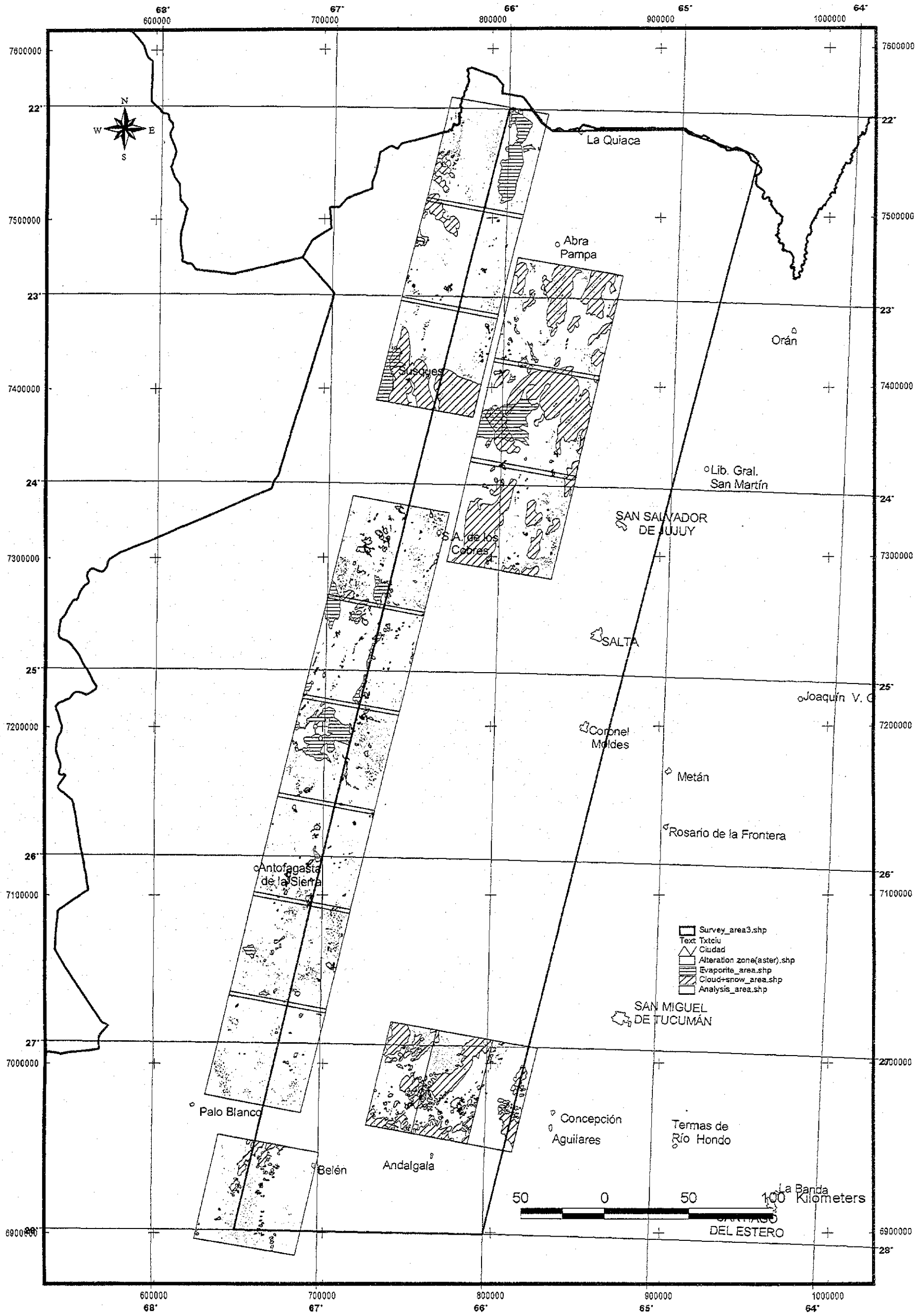


Fig.II-4-4-1-5 BGR= Chl, Ser, Aln+Kao (mineral identification)

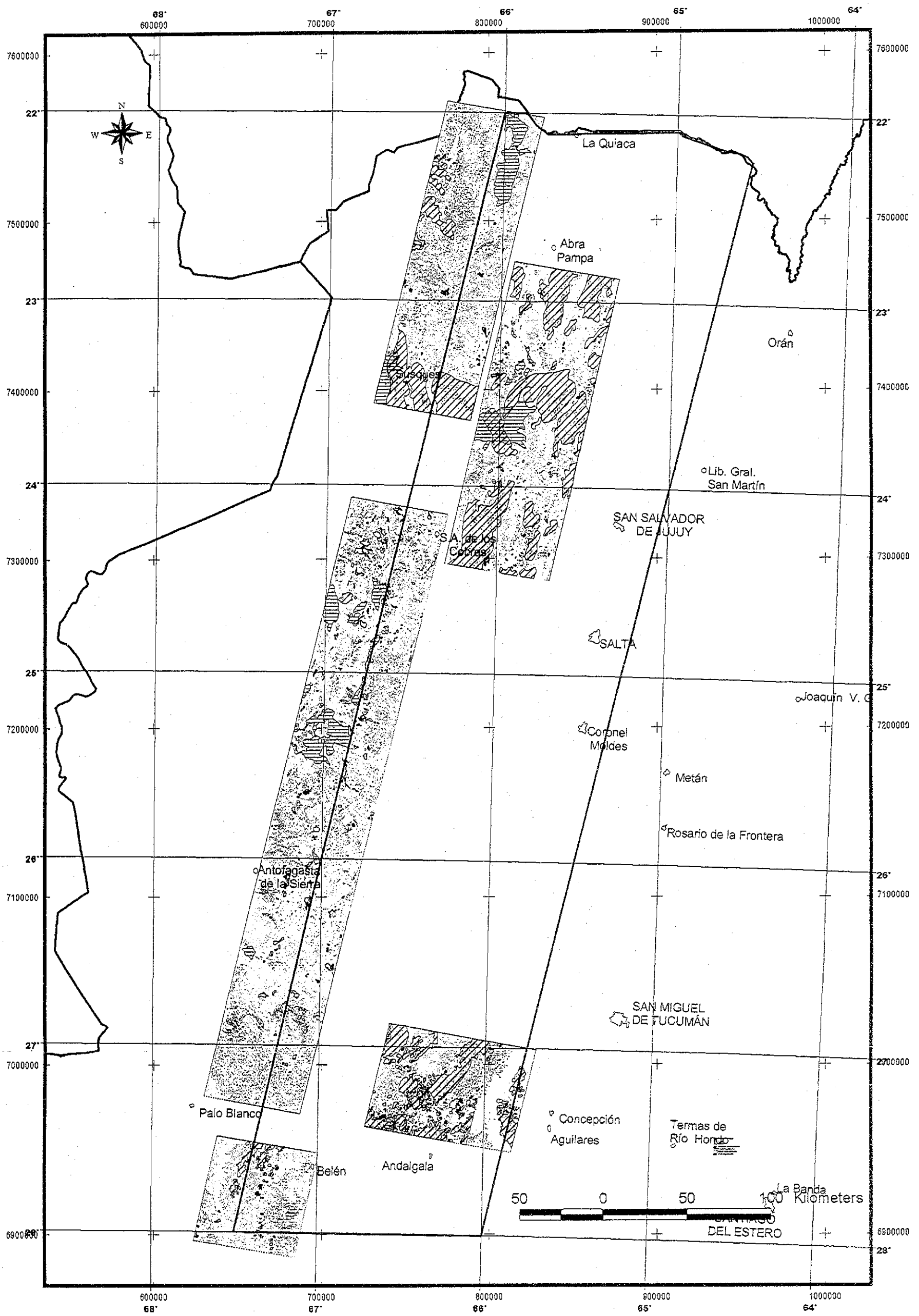


Fig.II-4-4-1-6 BGR= Qtz,Hem,Geo (mineral identification)

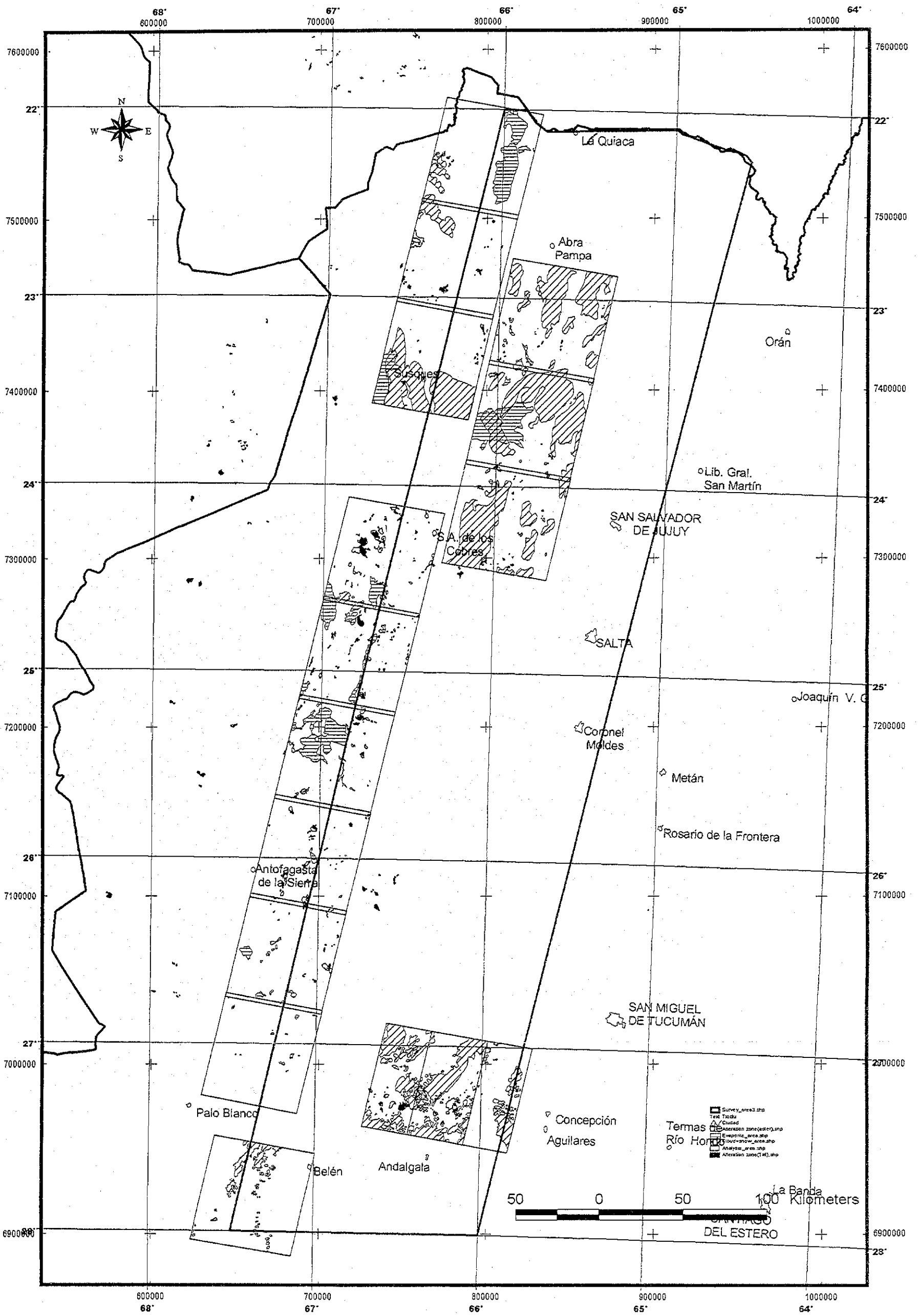


Fig.II-4-4-1-7 Alteration zone outlined by ASTER and Landsat TM

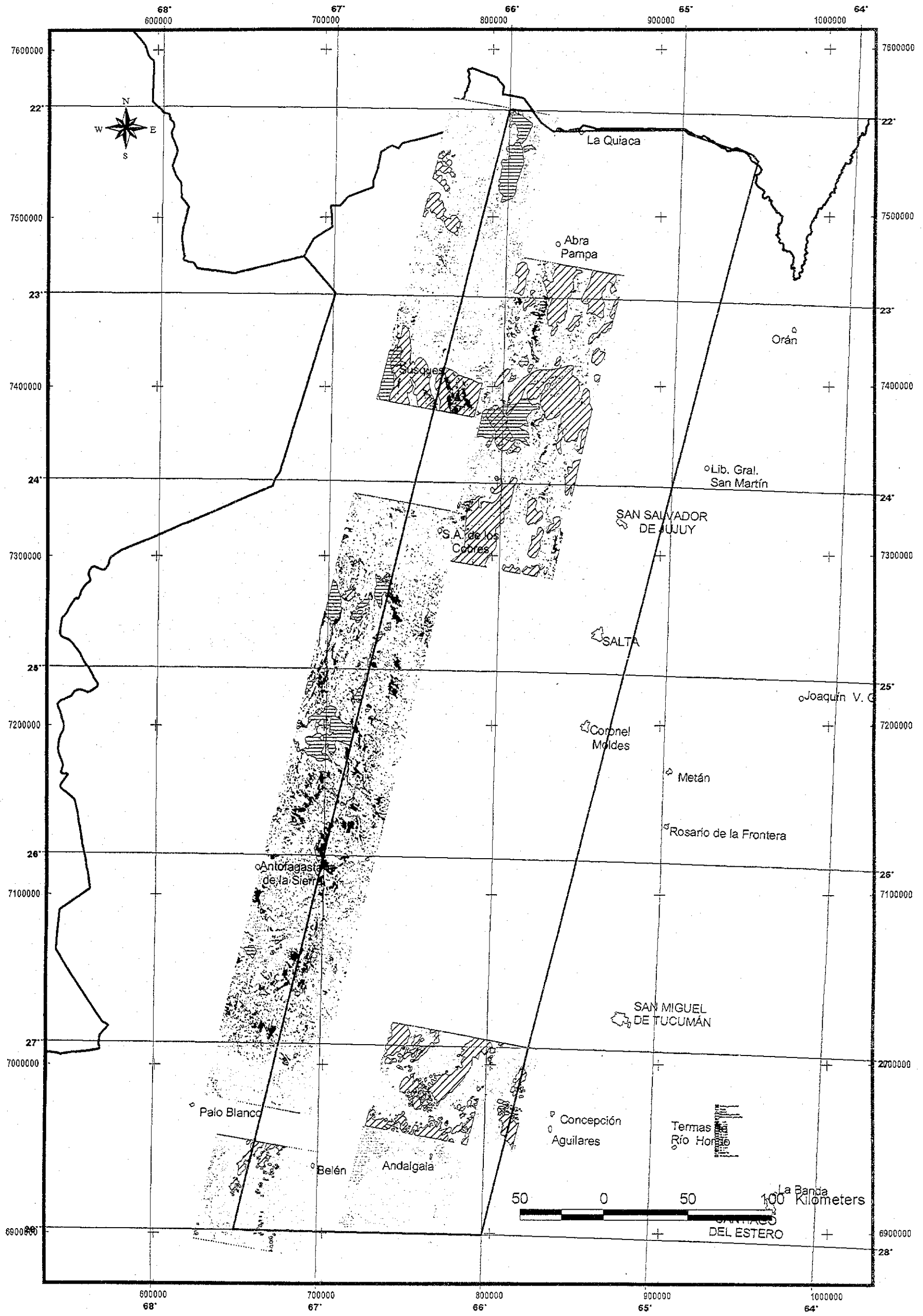


Fig.II-4-4-1-8 SiO2 contents

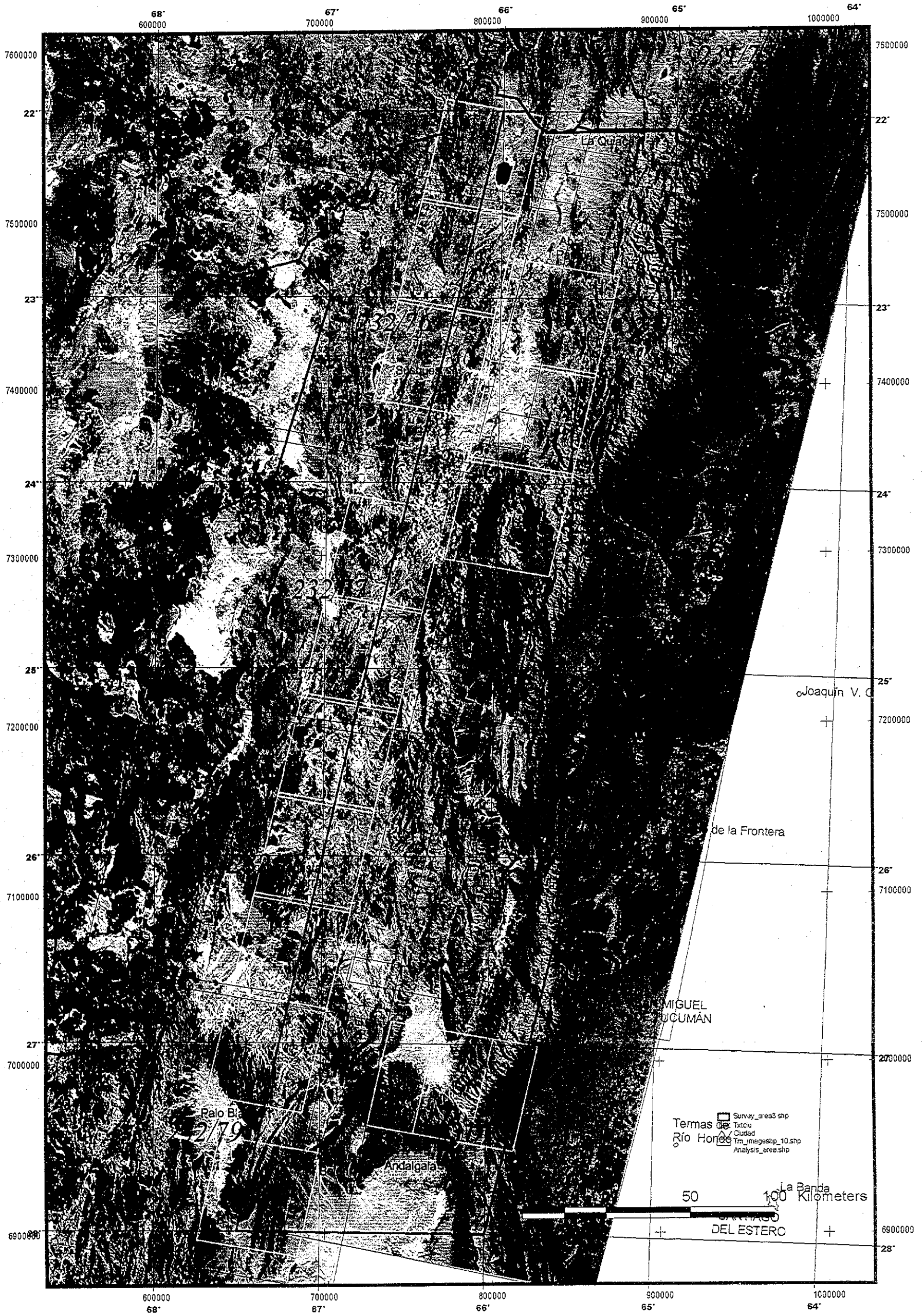


Fig.II-4-4-1-9 Landsat TM false color image (BGR=145)

4-4-2 Result of interpretation

In this section describes alteration mapping for each ASTER scene. Since there is not enough space in the section, the image of false color(BGR=147) is shown for each scene explanation. In the description of each scene, the following codes are used to represent alteration minerals:

Aln for Alunite

Kao for Kao

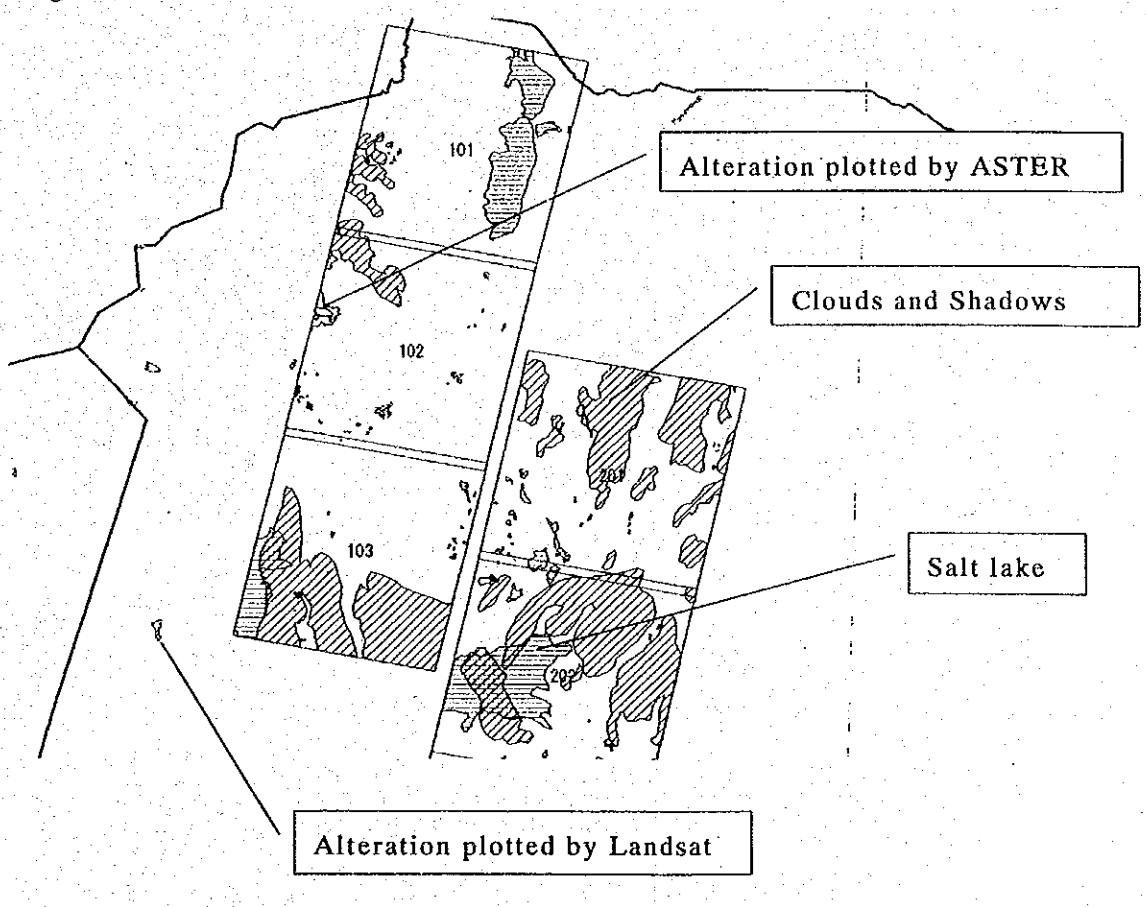
Ser for Sericite

Geo for Geothite

Hem for Hematite

Chl for Chlorite

(Legend of each scene)



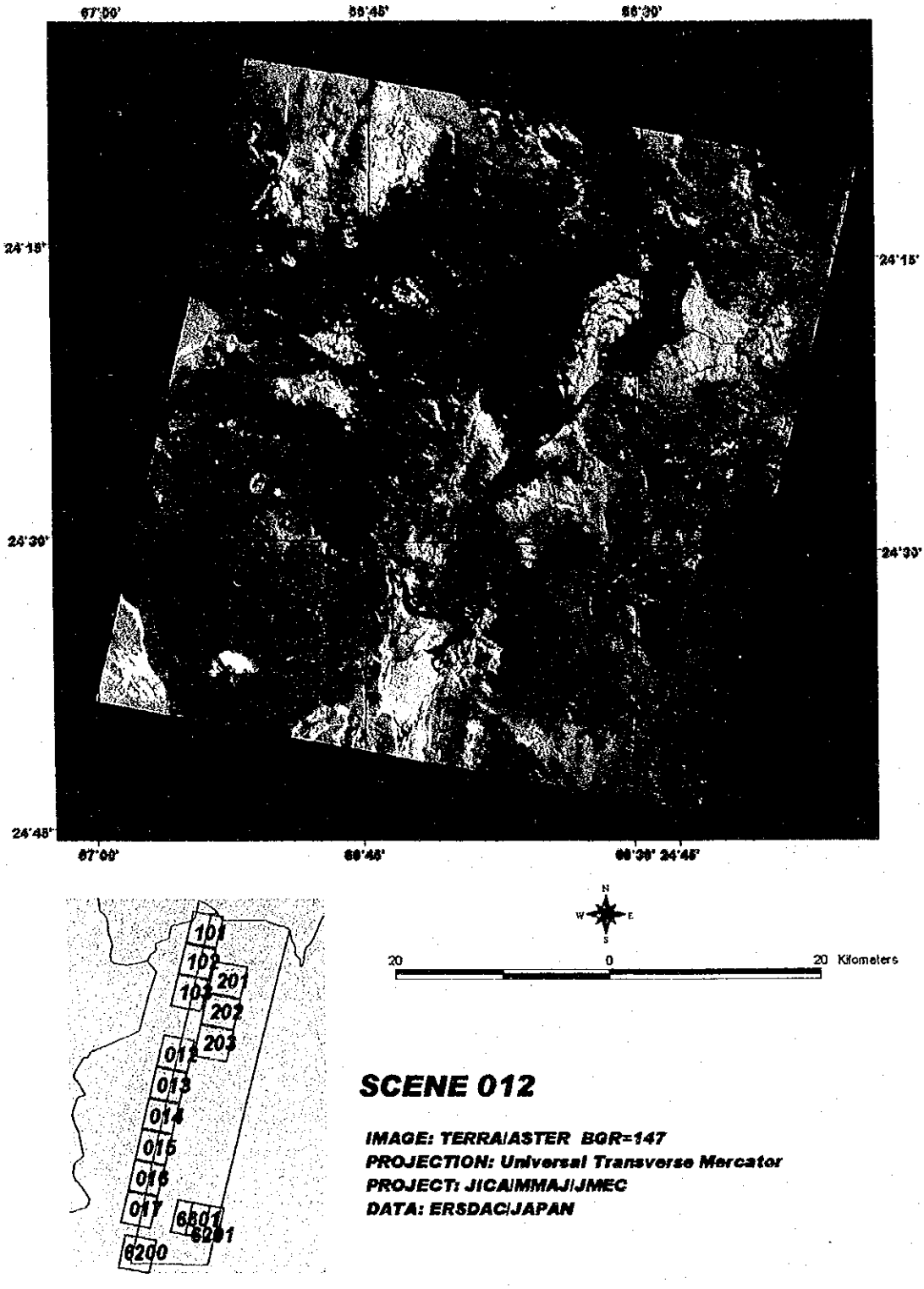
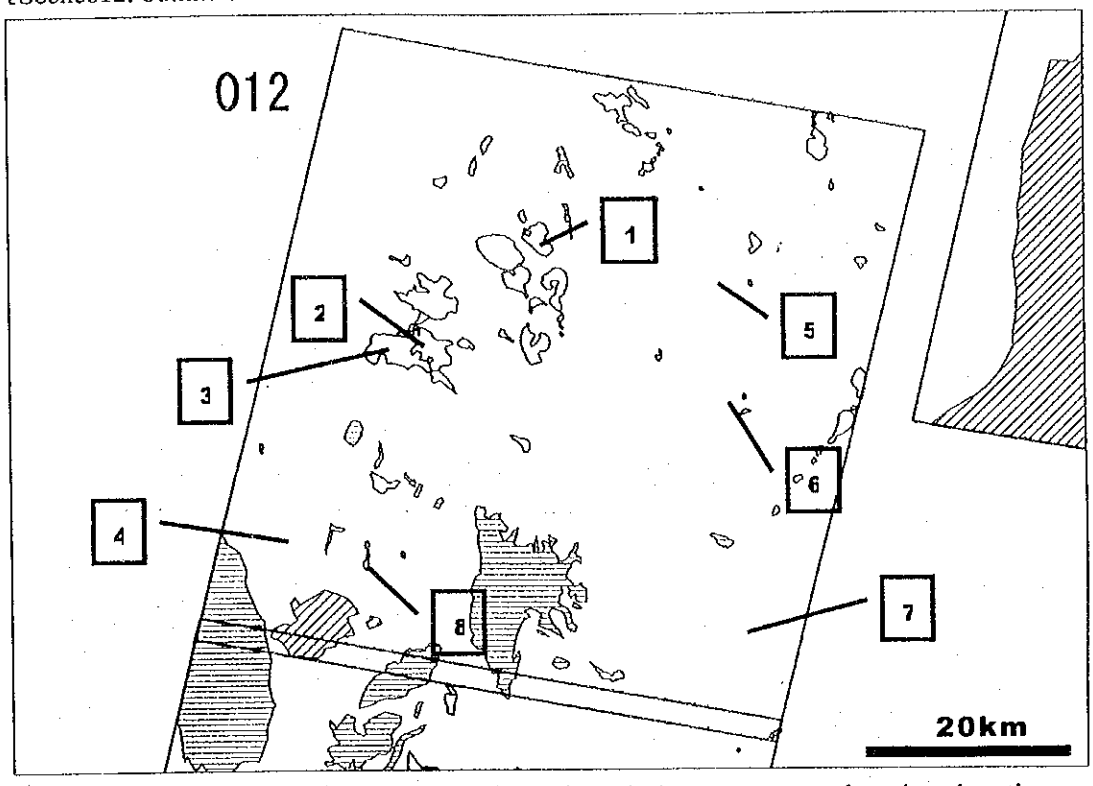


Fig.II-4-4-4-1 False color image of scene 012(BGR=147)

[Scene012: outline of alteration]



In this scene, many areas are discriminated that are assumed to be alteration zones, including Incachule mineral showing and Organullo mineral showing where a survey was conducted for ground truth.

1: Mostly made up of Al only, especially in talus.

2: Kao+Aln is dominant. Geo is not frequently observed. Pb-Zn deposits exist in the north.

3: Ser alteration is dominant with a small amount of Aln, which may possibly be the alteration of Ser-Qtz type.

4: Although this is not an alteration zone, Chl, Ser and Geo are dominant. Since this is an Ordovician sedimentary rock area, this may be an effect of diagenesis alteration.

5: An area where volcanic rocks in the Miocene are distributed and where Geo+Qtz is dominant. Incachule mineral showing are located in the neighborhood.

6: The combination of Geo + Ser + Chl and possibly a weak alteration zone. Mainly made up of Ordovician granite, but the distribution configuration and the geological boundary do not agree. There are Organullo mineral showing in the east.

7: Hem is dominant.

8: There are Kao-rich alteration zones in Ordovician sedimentary rocks.

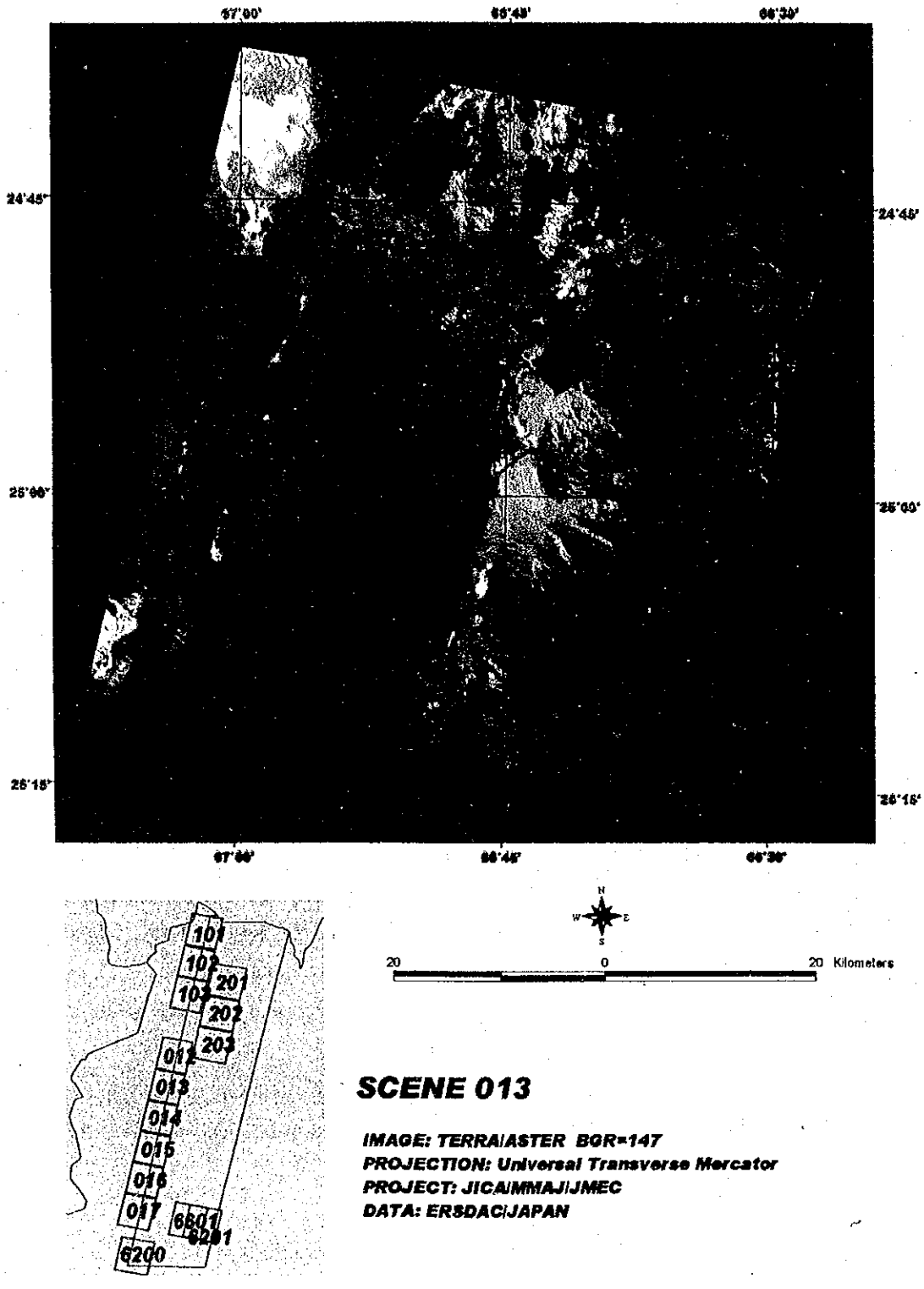
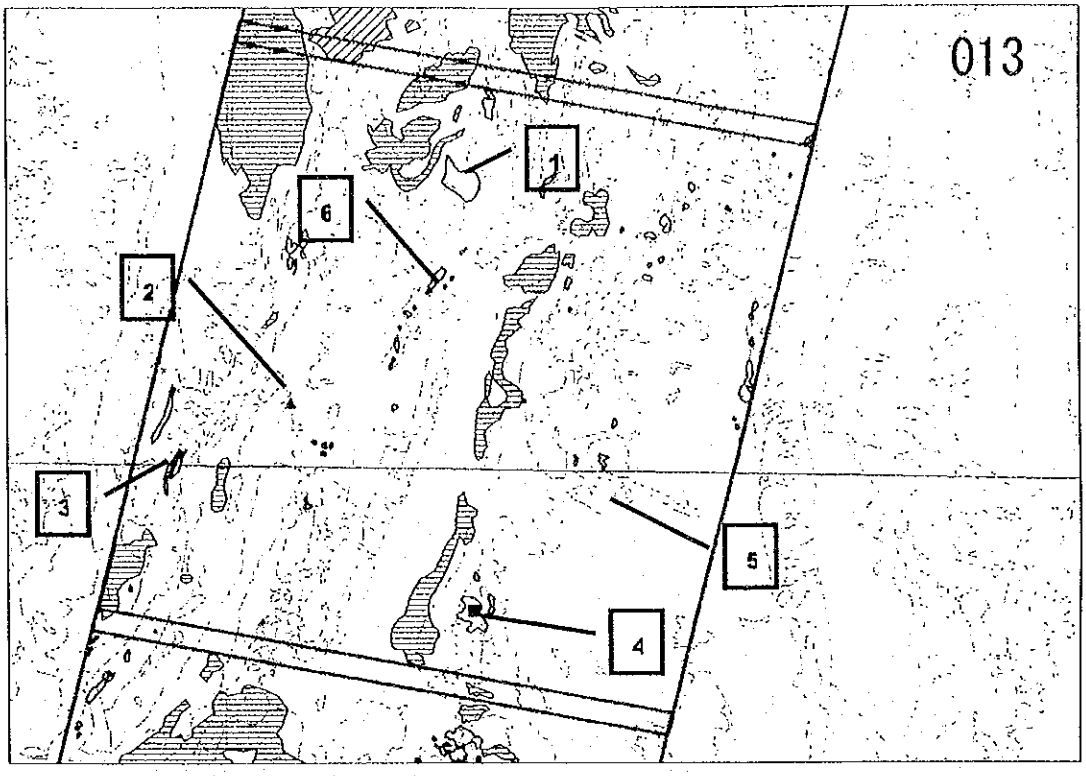


Fig.II-4-4-4-2 False color image of scene 013(BGR=147)

[Scene013: outline of alteration]



In this scene, many alteration zones are discriminated that run in the direction of NE-SW~NNE-SSW. A ground truth survey was conducted on the Vicuna Muerta, Centenario and Inca Viejo mineral showing.

1: A Kao-rich alteration zone with a small deposit of Geo.

2: In spite of the presence of Pb-Zn deposits, no alteration zones are detected.

3: Although a long, narrow Aln-Kao distribution was detected in the Cambrian or Ordovician sedimentary rocks, it is not clearly defined.

4: There is a Cu deposit (Inca Viejo), which is surrounded by an Aln-Kao alteration.

5: The ring structure of Vicuna Muerta. Only a small alteration zone exists inside the ring structure, and both Ser and Chl are weak inside the ring structure. However, Geo is detected along the ring structure.

6: Centenario mineral showing.

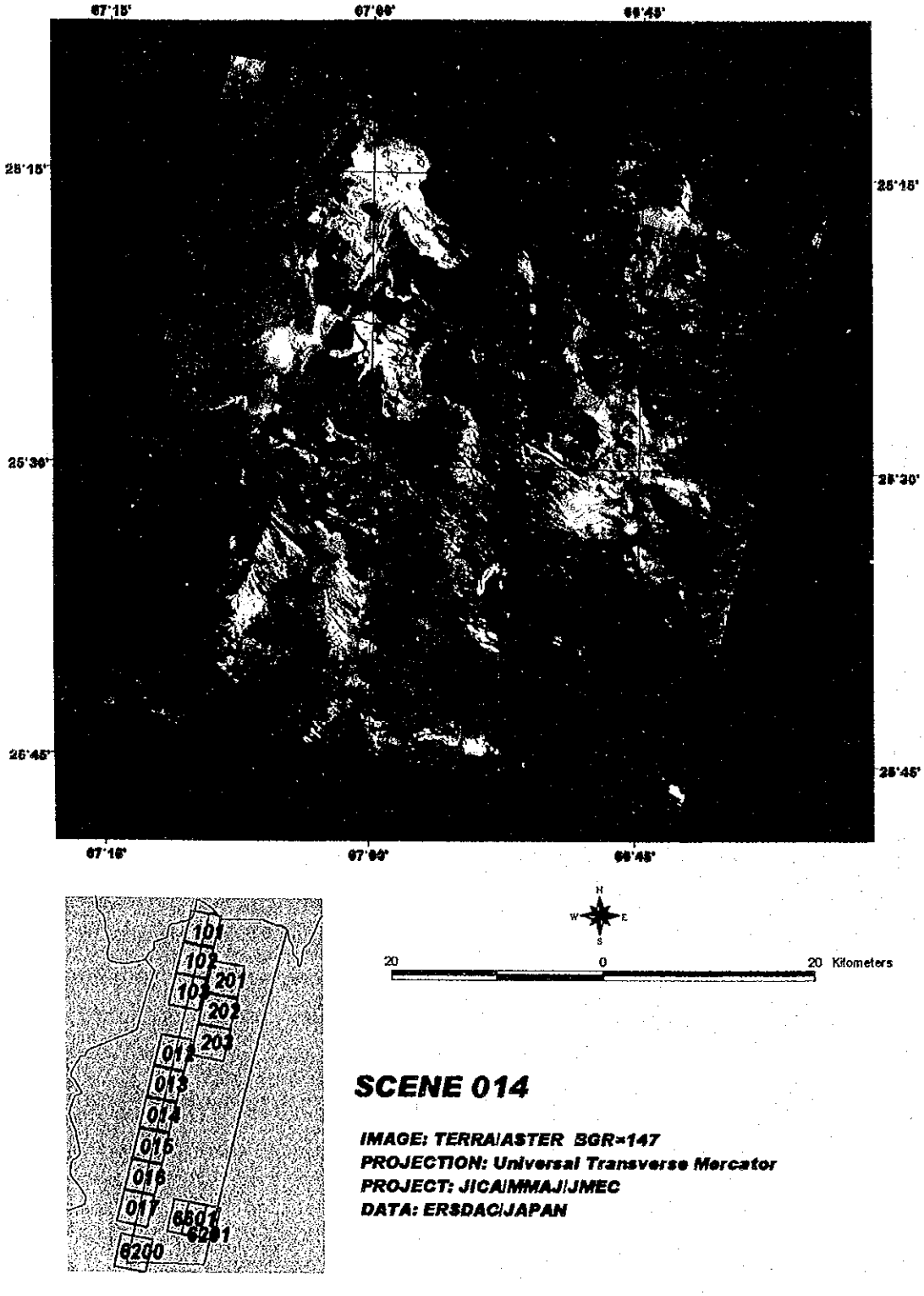
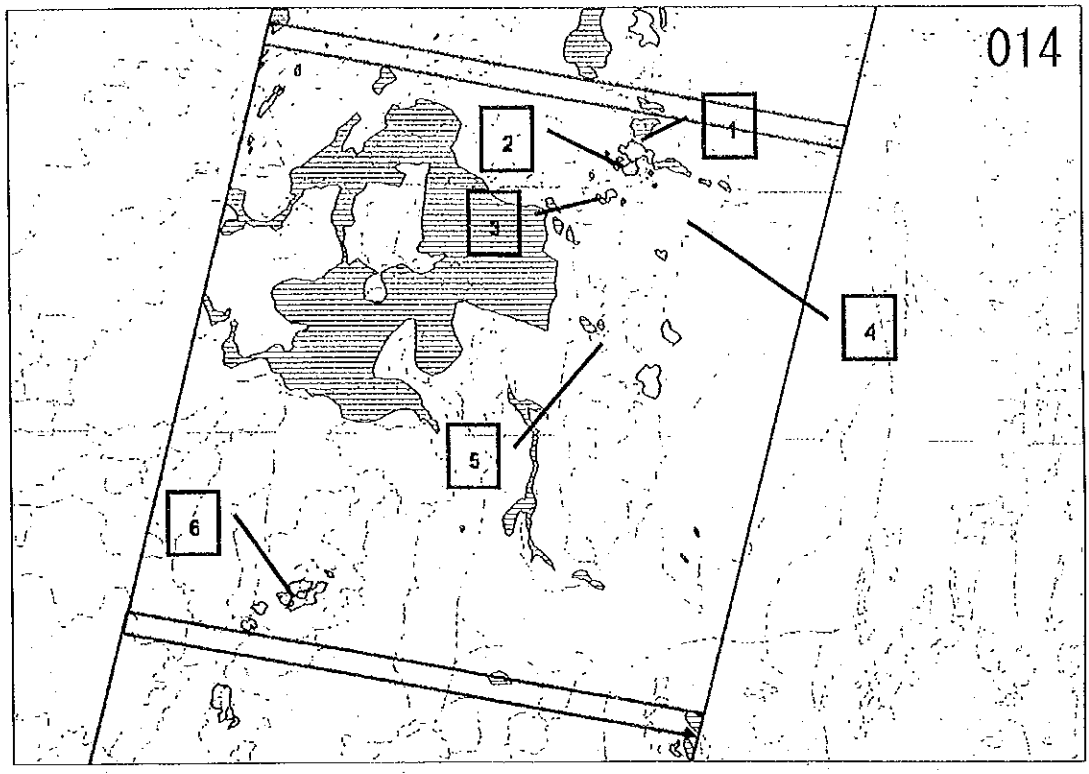


Fig.II-4-4-4-3 False color image of scene 014(BGR=147)

[Scene014: outline of alteration]



This scene includes the Diablillos mineral showings where a ground truth survey was conducted.

1: Diablillos mineral showing. The alteration zone in the north is Kao-rich and accompanied with Geo.

2: The alteration zones in the south are Aln and Kao deposits, but have only a small deposit of Geo.

3: Aln-Geo alteration zones. To the south of the alteration zones is the Condor Yaku exploration area. Weak alteration zones comprising Ser-Chl and Geo extend to the east of the alteration zones.

4: Hem-rich. In this area, Cambrian or Precambrian sedimentary rocks or Paleozoic granite are distributed.

5: Geo+Ser is distributed. It shows a dark color in band ratioing composites and an ocher color in false color images. Because it has no conspicuous distinction from the surroundings, there is a good possibility that this is not an alteration zone.

6: An alteration zone practically comprising Ser and Geo. While the combination is the same as No. 5 above, in all probability this area may be an alteration zone because it shows a rather bright blue color in band ratioing composites. It shows a green color in false color images.

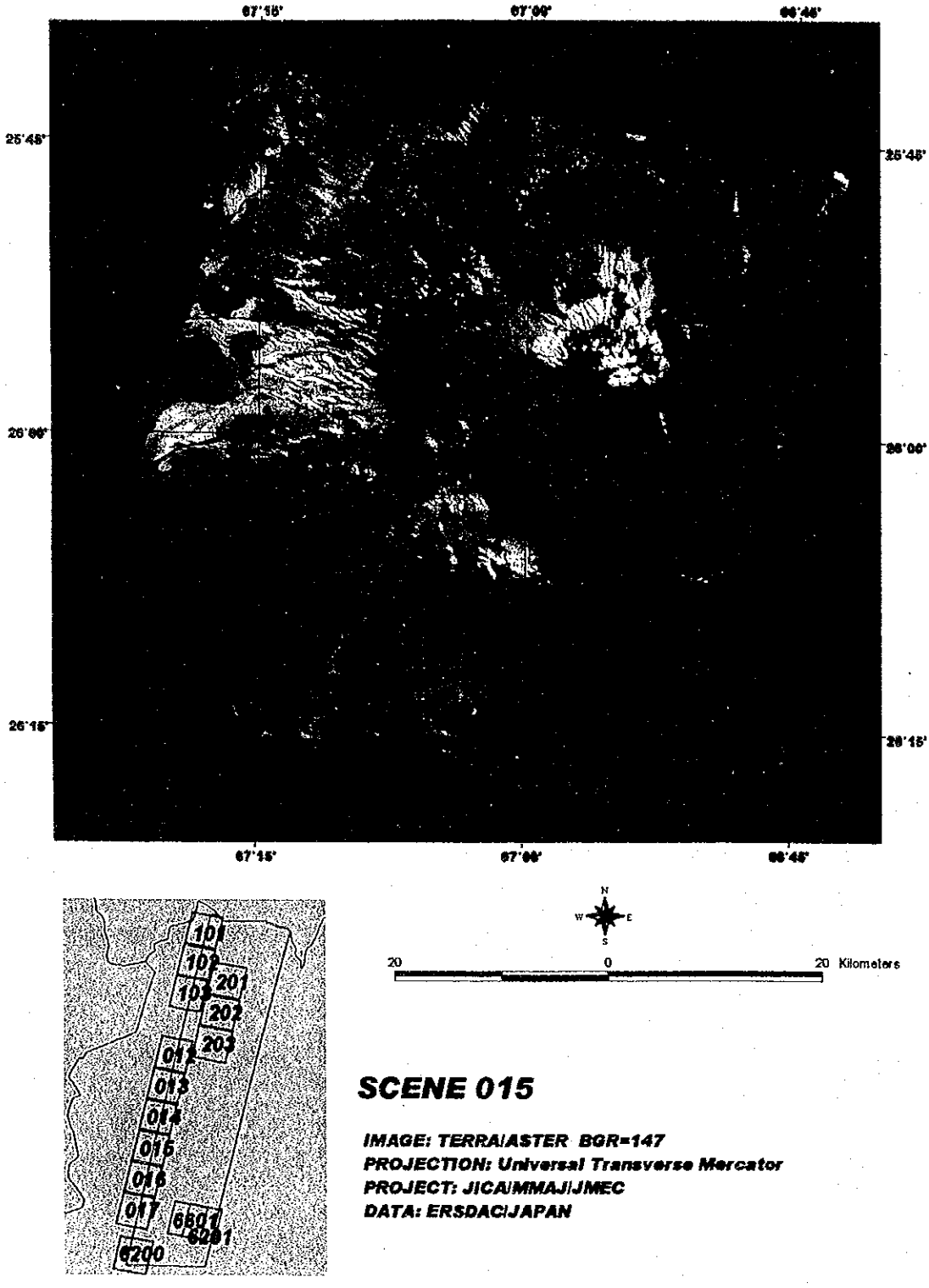
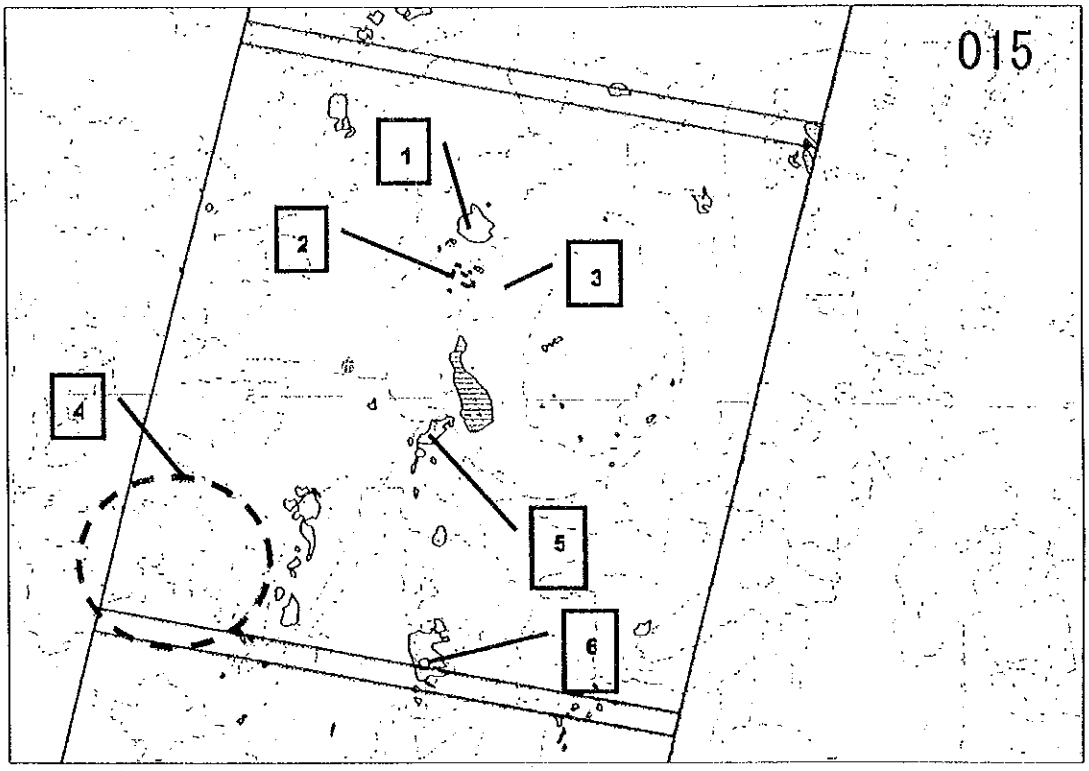


Fig.II-4-4-4-4 False color image of scene 015(BGR=147)

[Scene015: outline of alteration]



This scene is the range where giant "Galan caldera" lakes are present from the center of the scene to its northeast, and where many alteration zones are discriminated. Of these, alteration zone No.6 and the Laguna del Salitre mineral showing located about 16 km to its east were surveyed for ground truth.

1: Alteration zone of Kao with a small bit of Aln, Ser and Geo. This is the alteration zone located at the northwestern edge of the Galan caldera lakes.

2: Exposed rocks of Aln, Aln+Kao and Kao are distributed, and Aln is accumulated in the lower reaches.

3: This is probably an Aln talus but there is no exposure of Aln in the upper reaches. However, if the talus flowed from alteration zone No. 2, the distribution of Aln in alteration zone No. 2 is too small. In addition, because of the presence of wadis between No. 2 and No. 3, it is hardly conceivable that the talus came from No. 2. Perhaps vegetation might have some relationship. It is developed in a white color in the band ratioing composites and in a gray color in the false color images.

4: Aln+Ser is distributed widely here, developing a strange reddish color in band ratioing composites. This is the area where Quaternary and Tertiary volcanic rocks and Ordovician sedimentary rocks are distributed. The area is shown in a black color in the false color images. As to the reason why alteration minerals were detected by mineral identification, there is a good

possibility that, because of the extremely low luminance value, noise was identified as alteration minerals.

5: An alteration zone where Aln, Kao and Ser are distributed. Especially, Kao is present in a number of small rocks. Ser is distributed over a wide range. Geo is also present.

6: An alteration zone of Lagna Grande. The center is made up of Kao, and the surroundings are made up of Ser alteration over a wide range.

7: The northeast edge of Galan caldera lake and distributed with long, narrow deposits of Ser+Chl. This area shows a bright white color in the band ratioing composites and a dark green color in the false color images, resulting in a possibility of a weak alteration zone. Because the geology is Precambrian metamorphic rocks, there is a fair possibility that Sericite-Schist was identified.

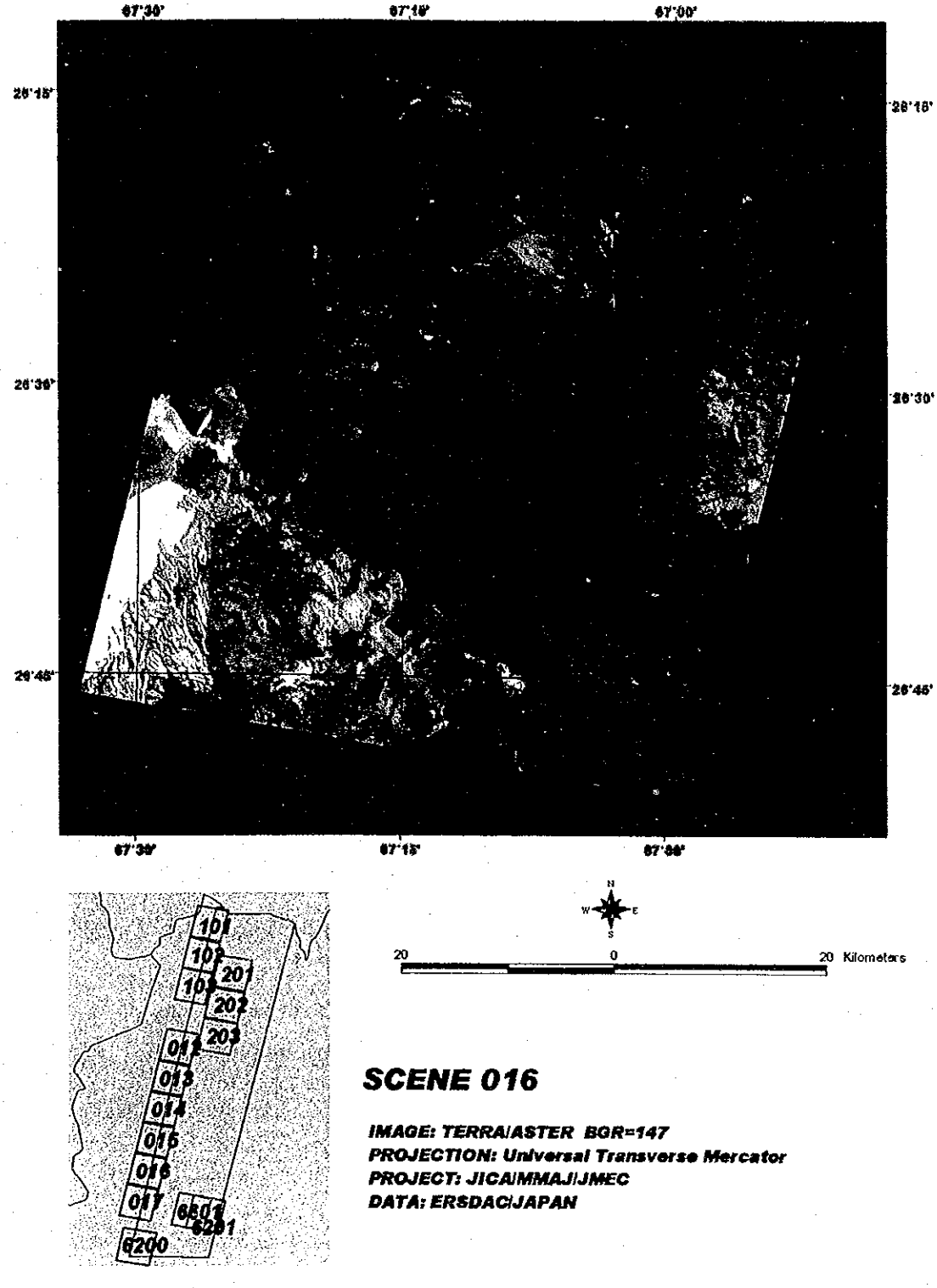
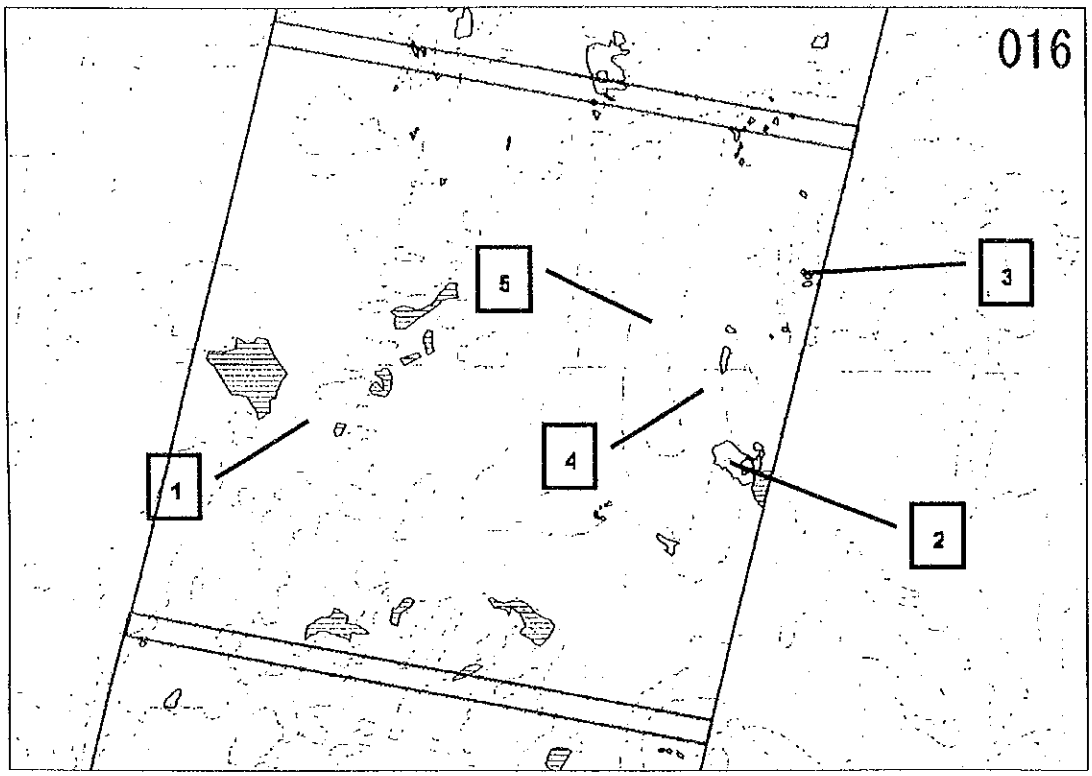


Fig.II-4-4-4-5 False color image of scene 016(BGR=147)

[Scene016: outline of alteration]



In this scene, a ground truth survey was conducted on the Lagna Grande alteration zone shown in No. 2.

1: Deposits of Ser are distributed in a long, narrow strip in the direction of WNW-ESE. This is considered as materials of salt lake sedimentation carried by the westerly wind. This is not an alteration zone.

2: An alteration zone of Lagna Blanca. This is an alteration zone comprising Aln-Kao and Ser. In this area, Geo is dominant.

3: An alteration zone comprising Aln-Kao and Ser. Geo is dominant in this area. A lot of small alteration zones are distributed.

4: This is an area where Geo is considerably weathered. The wall rock is Ordovician granite.

5 This is an area where Hem is severely weathered. The wall rock is Miocene volcanic rocks.

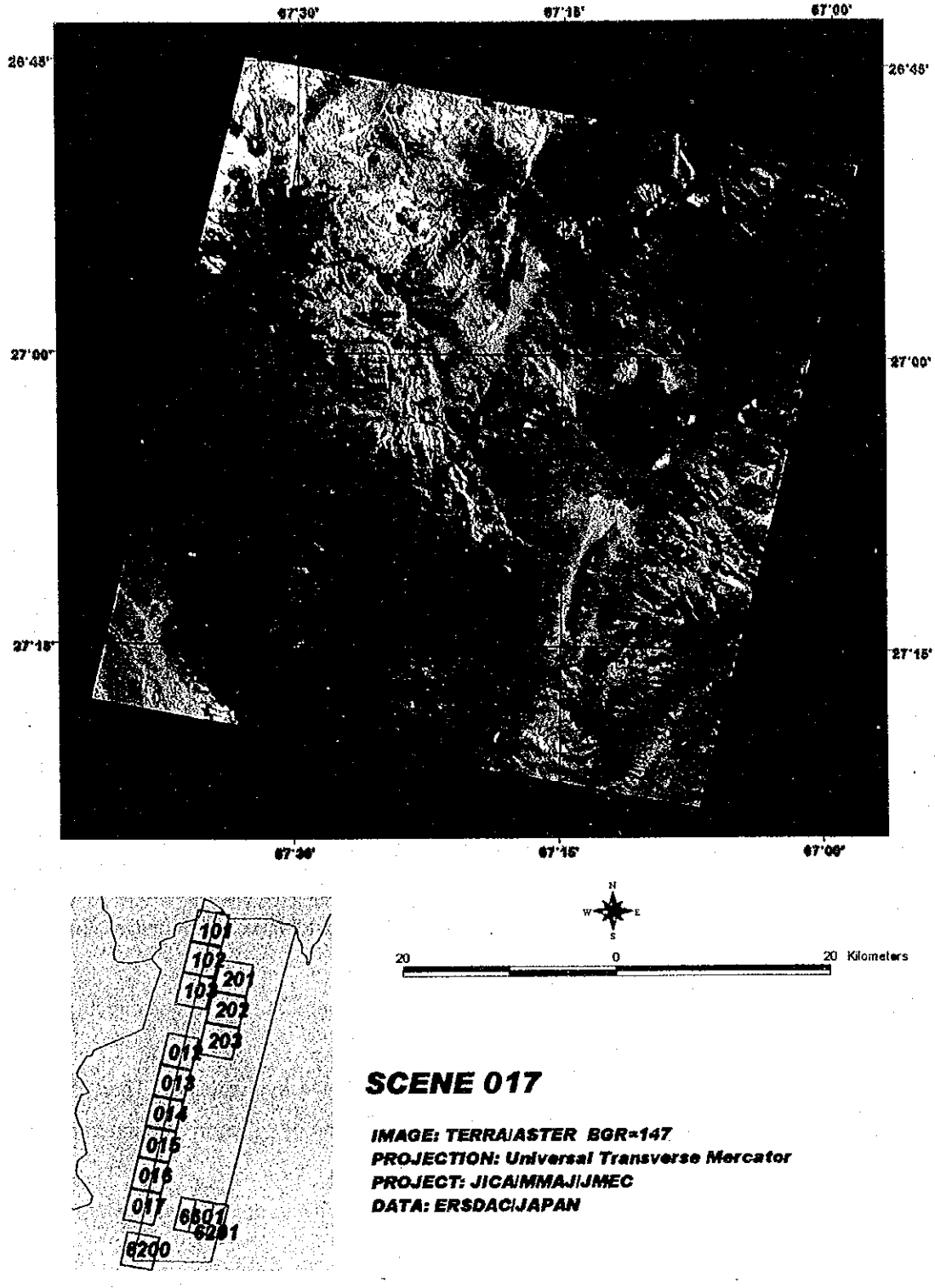
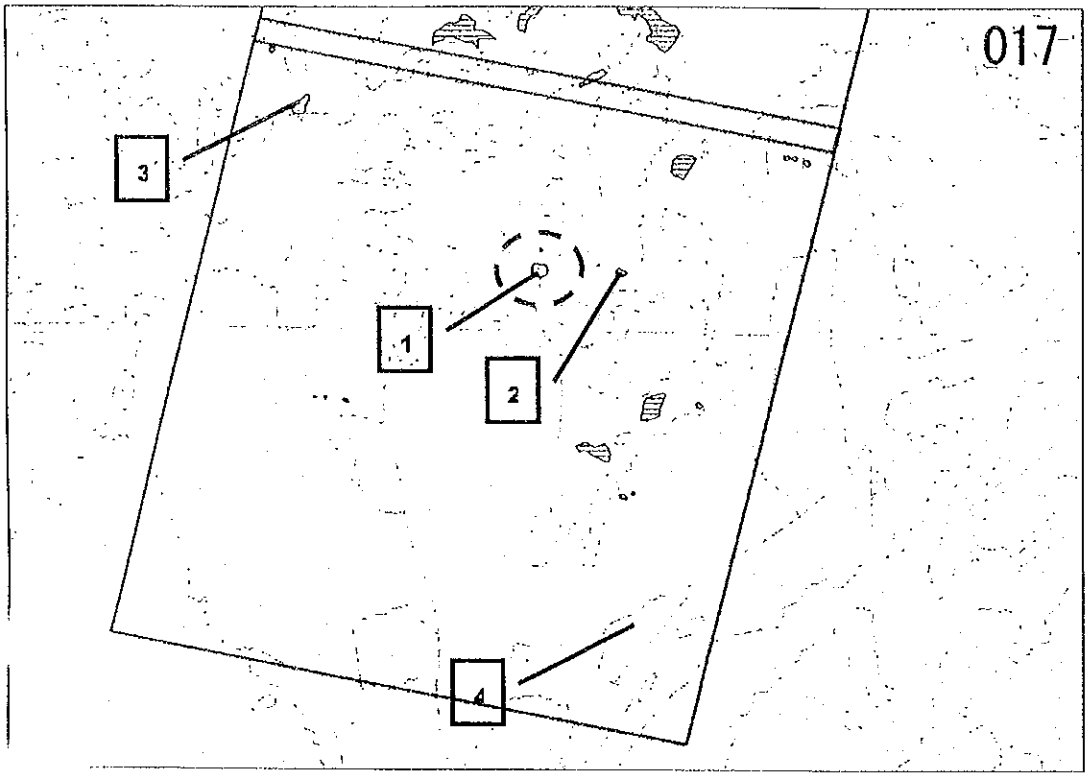


Fig.II-4-4-4-6 False color image of scene 017(BGR=147)

[Scene017: outline of alteration]



1: At the center, there is an alteration zone mainly comprising Kao. Surrounding the center is a wide alteration zone of Ser+Chl accompanied with Geo and also is a local concentration of Ser. The strong alteration zone at the center develops a green color in the false color images and a white color in the band ratioing composites and, hence, can be clearly recognized as an alteration zone. The surrounding Ser shows a slightly greenish color in the false color images, but it is not clear enough for recognition. Its color in the band ratioing composites is bluish white. While it is difficult to grasp weak Ser alteration by means of band ratioing composites and false color images, its recognition is possible by means of mineral identification imaging.

2: A circular alteration zone mainly comprising Kao. No development of Ser is seen in the neighborhood.

3: There is Kao+Aln on top of the mountain, with Ser distributed on the mountainside. There is practically no Geo accompanying. Judging from the topography and the distribution of alteration minerals, there is a fair possibility that the mountain top is a leached cap.

4: Aln+Geo+Ser is distributed in a dotted fashion. High values are distributed on a mountain ridge, there is a good possibility of erroneous judgment due to matching error.

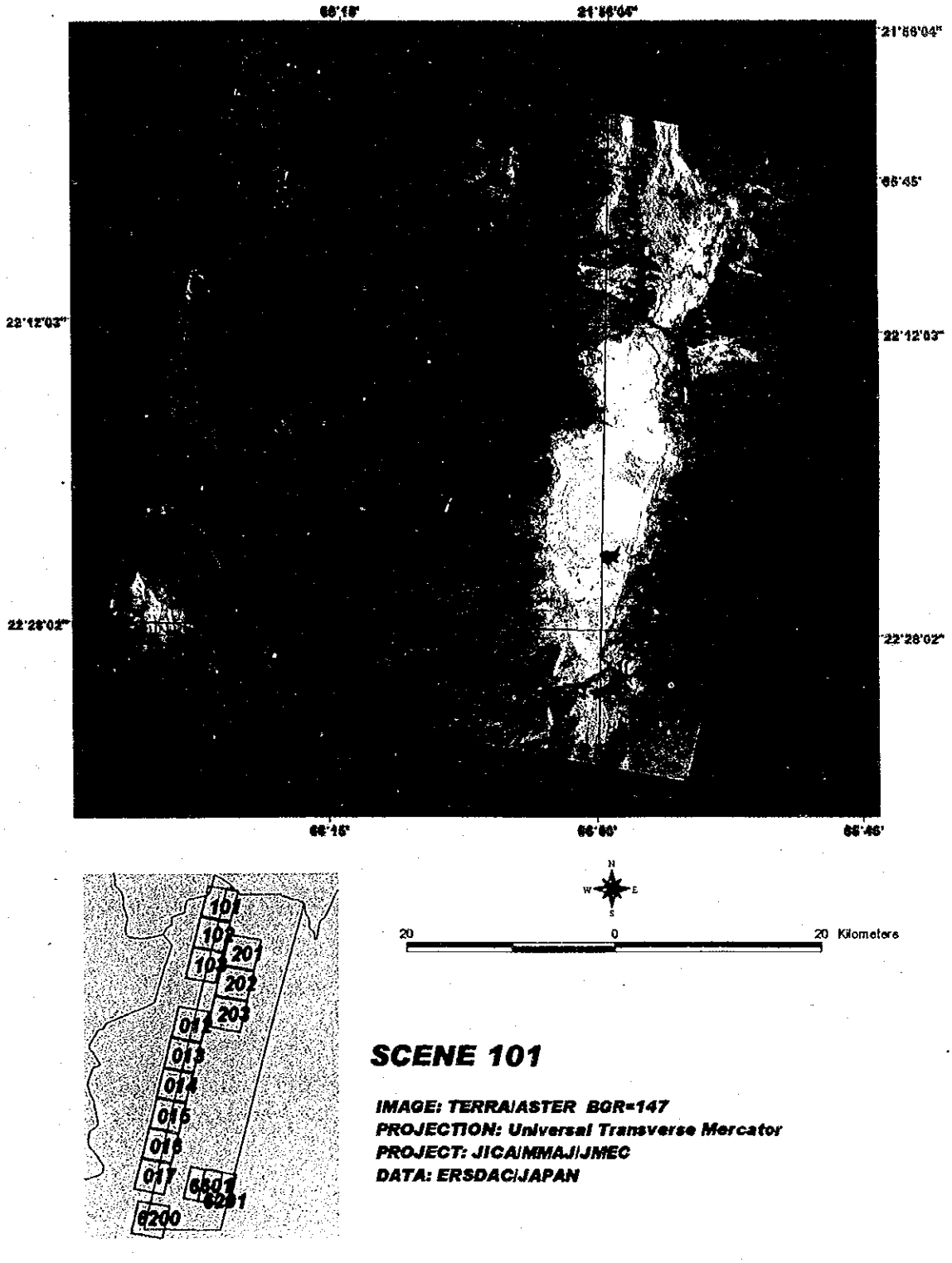
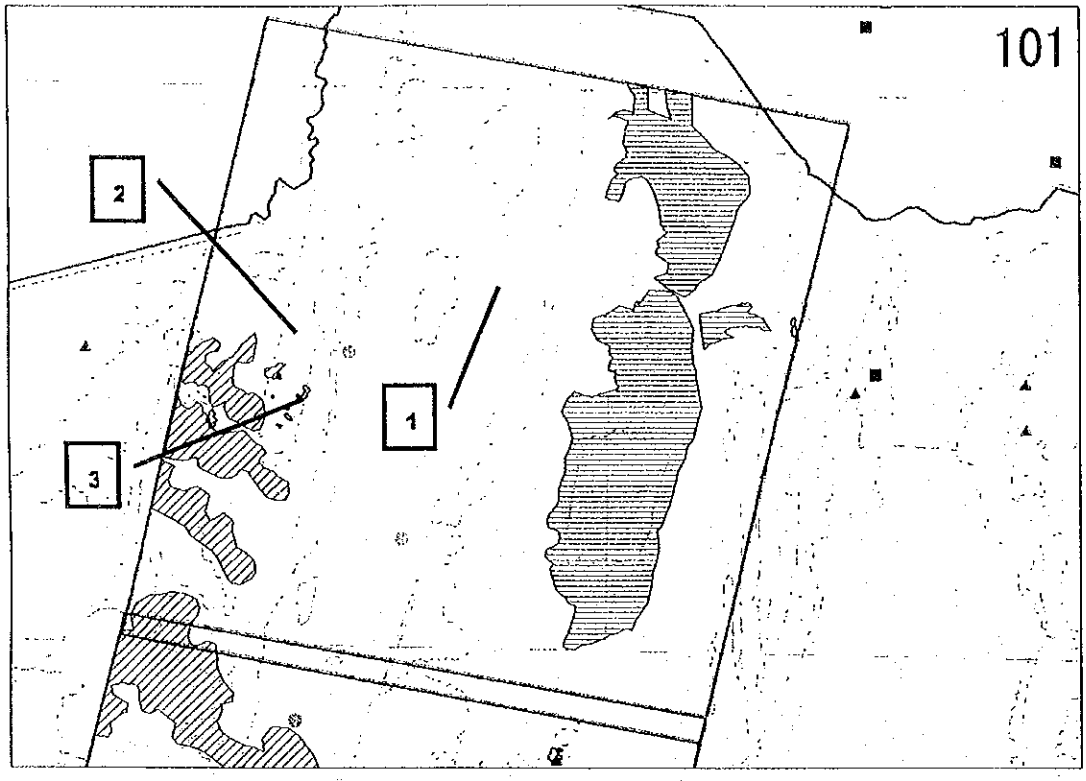


Fig.II-4-4-4-7 False color image of scene 101(BGR=147)

[Scene101: outline of alteration]



This scene is the area located at the northwestern edge of this survey area and bordering Bolivia. It is the place where Ordovician sedimentary rocks and Neogene volcanic rocks are distributed. To the east of this scene are Pumahuasi mineral showing (outside the scene).

1: Ser+Chl is distributed in a long, narrow strip. It develops a brown color in the false color images. Ser and Chl react to Ordovician sedimentary rocks. Perhaps by diagenesis alteration?

2: The same combination as No. 1 above. Its geology also belongs to the same category.

3: Small regions that develop a bluish green color in the false color images are dotted in Ordovician sedimentary rocks. They show a white color in band ratioing composites in two areas in the southwest side. Most probably, they may be alteration zones. They are made up of Aln for the most part, and of Kao in part.

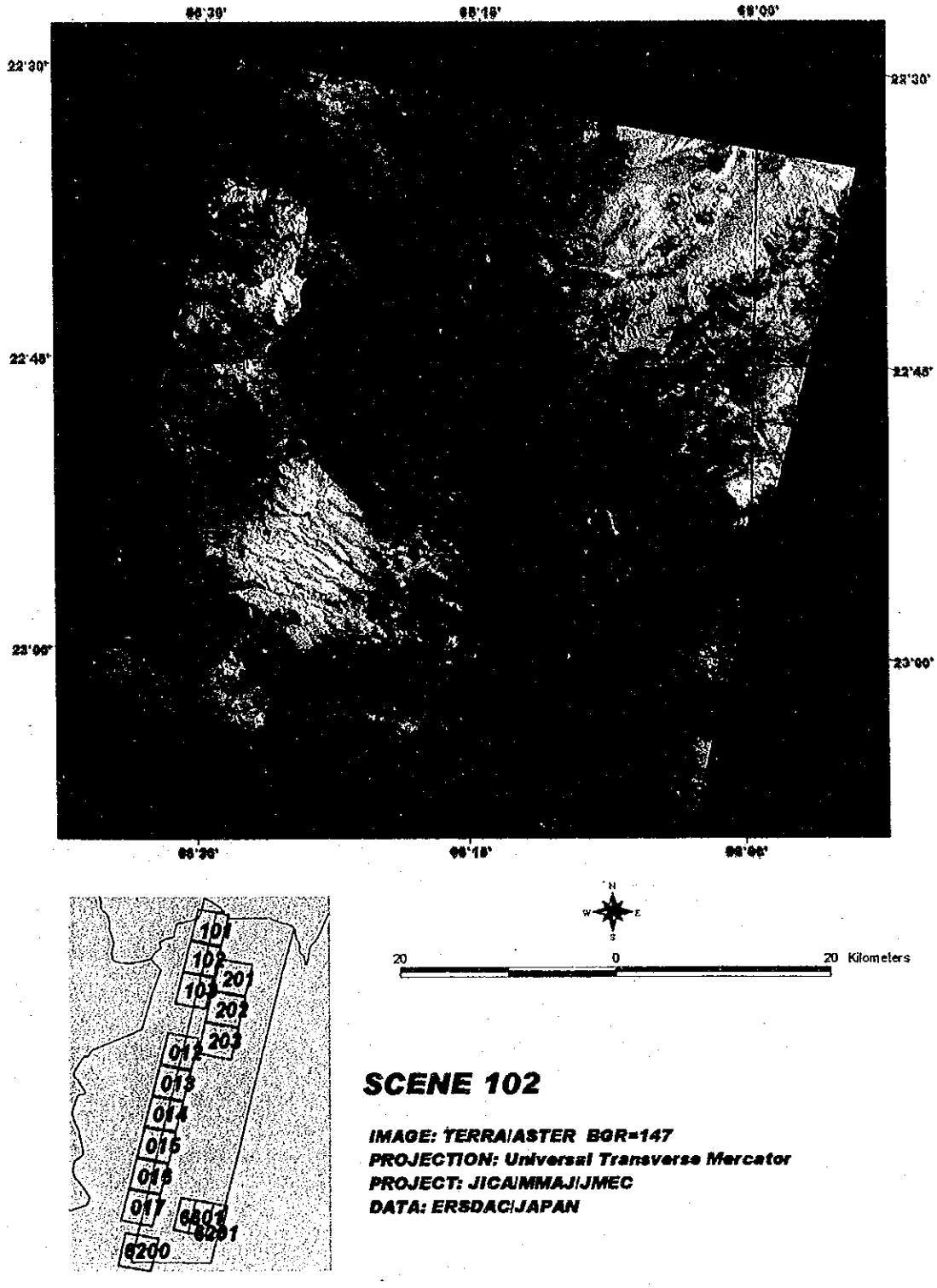
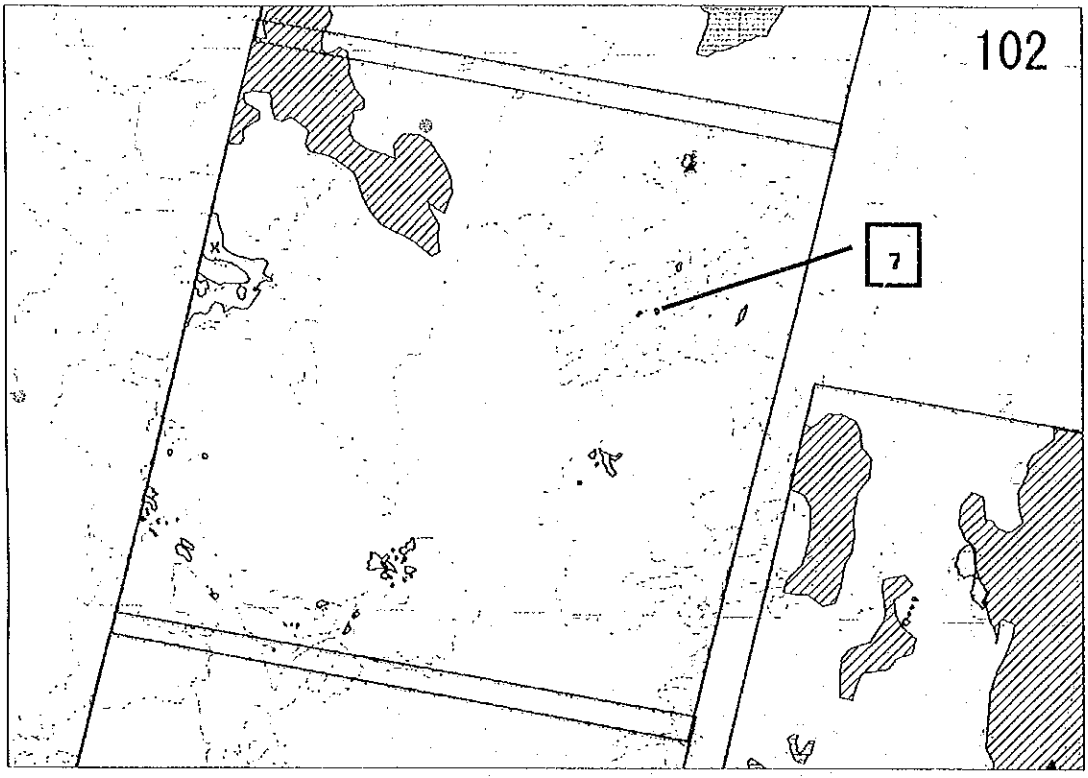


Fig.II-4-4-4-8 False color image of scene 102(BGR=147)

[Scene102: outline of alteration]



This scene covers Rachaite (No. 3), Pan de Azucar (No. 5) and Tupza (No.7) mineral showing where ground truth survey was conducted.

1: Mainly comprises Aln and has Kao at the center (i.e., at the mountain top). This area can be recognized as an alteration zone both in the false color images and the band ratioing composites. This area has accompanying Geo.

2: A Ser+Geo alteration developed around No. 1. Chl exists on the outermost contour. This area has accompanying Geo in the same way as in the case of No. 1. Hem is dominant around this alteration zone.

3: Rachaite alteration zone comprising Aln-Kao-Ser. Halo is small. This area has accompanying Geo+Qtz. The features of the alteration zone are conspicuous both in the band ratioing composites and the false color images. Neighboring to the southwest of this alteration zone, mafic volcanics are distributed that develop a greenish yellow color. The volcanics comprise only Geo+Chl, but no altered minerals are detected. In the meantime, this area has an Aln alteration zone of about 200 m diameter in its inside.

4: A lot of clear alteration zones are distributed on the northwest slope of Miocene volcanic rocks (the volcano). They consist of Aln+Kao or Kao-Ser and have weak Geo.

5: Pan de Azcar mine producing Pb-Zn. It is an alteration zone having Aln+Kao at the center and Ser on the circumference. To its southeast are distributed small taluses comprising Ser. The light

blue streaks running from the center of the alteration zone toward southeast on the false color images indicate mining wastes that have overflowed from mining dumps.

6: An alteration zone consisting of Aln+Ser is distributed at the northwest edge of Ordovician sedimentary rocks. This alteration zone develops a green color in the false color images, while a wider region including this alteration zone is displayed by a white color in the band ratioing composites, and its location cannot be determined by band ratioing composites. The area showing a white color in the band ratioing composites is Ser+Geo and Chl+Geo and may be an extremely weak alteration zone or diagenesis alteration. Anyway, it is necessary to check the wall rock.

7: Tupiza mineral showing.

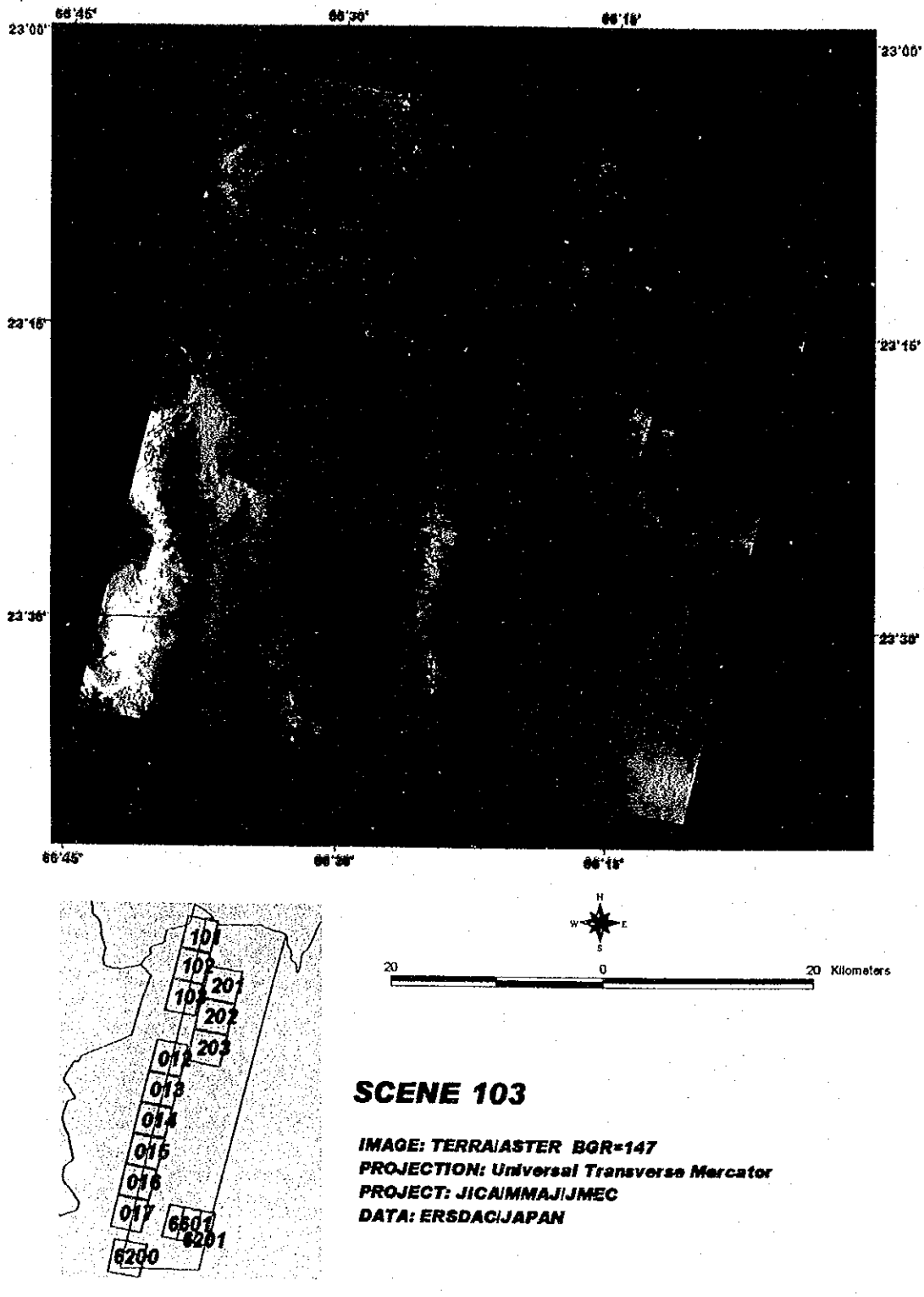
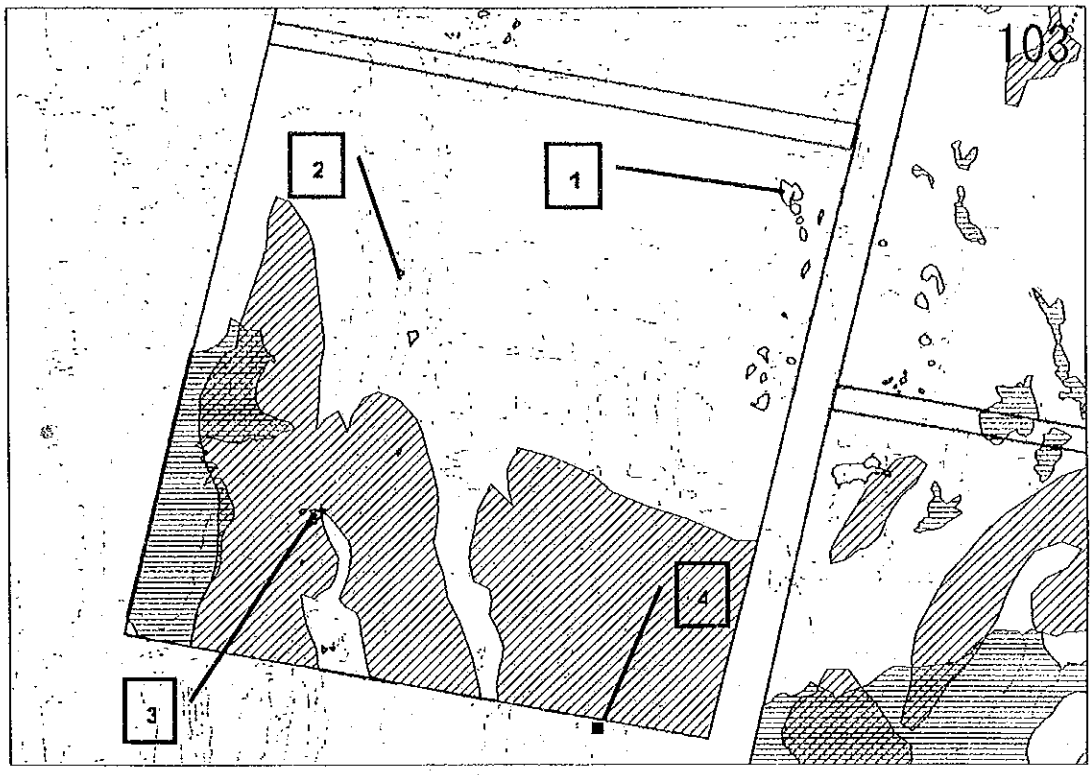


Fig.II-4-4-4-9 False color image of scene 103(BGR=147)

[Scene103: outline of alteration]



1: Many small alteration zones are distributed in Ordovician sedimentary rocks in which Aln is dominant. In addition, the whole of these Ordovician sedimentary rocks alters to Ser+Chl+Geo. These characteristics are also seen in scenes 101 and 102.

2: Two small alteration zones are distributed in Cretaceous to Paleogene sedimentary rocks. This area consists of Aln-Ser on the north side and Kao-Ser on the south side. To the north of the northern alteration zone is distributed a geology that develops a dark green color in the false color images and a bluish gray color in the band ratioing composites. The geological map and the image, however, do not agree on their boundary. Further, it is necessary to make it sure what geology develops this green color.

3: An alteration zone recognized through a thin cloud. There may be an effect from the clouds. This area mainly consists of Ser and accompanying Geo. Chl is distributed in the southern area of this alteration zone but, as it corresponds with the area of thicker clouds, the reliability is low.

4: This is outside the scene, but La Colorada mineral showing are located in this area.

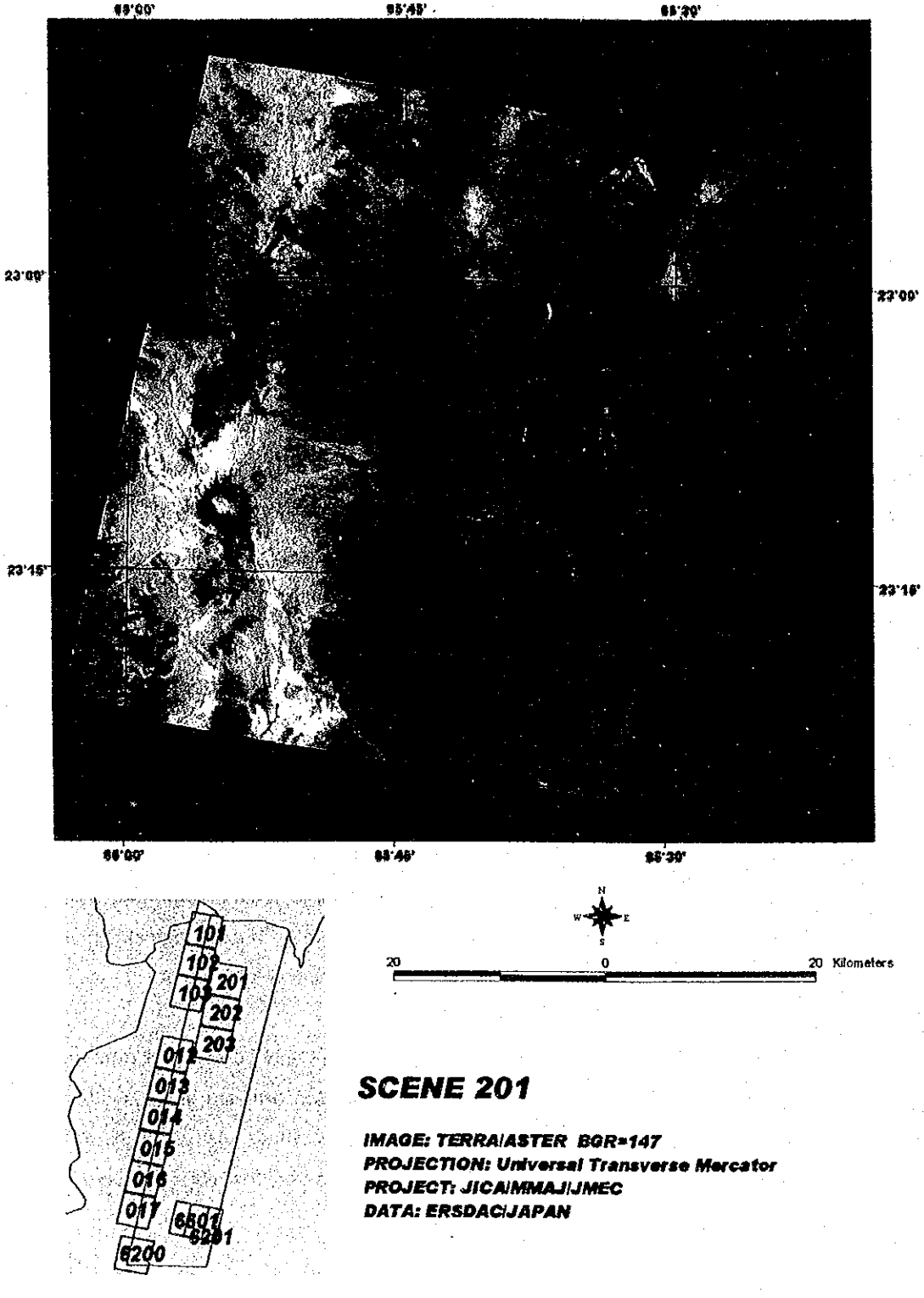
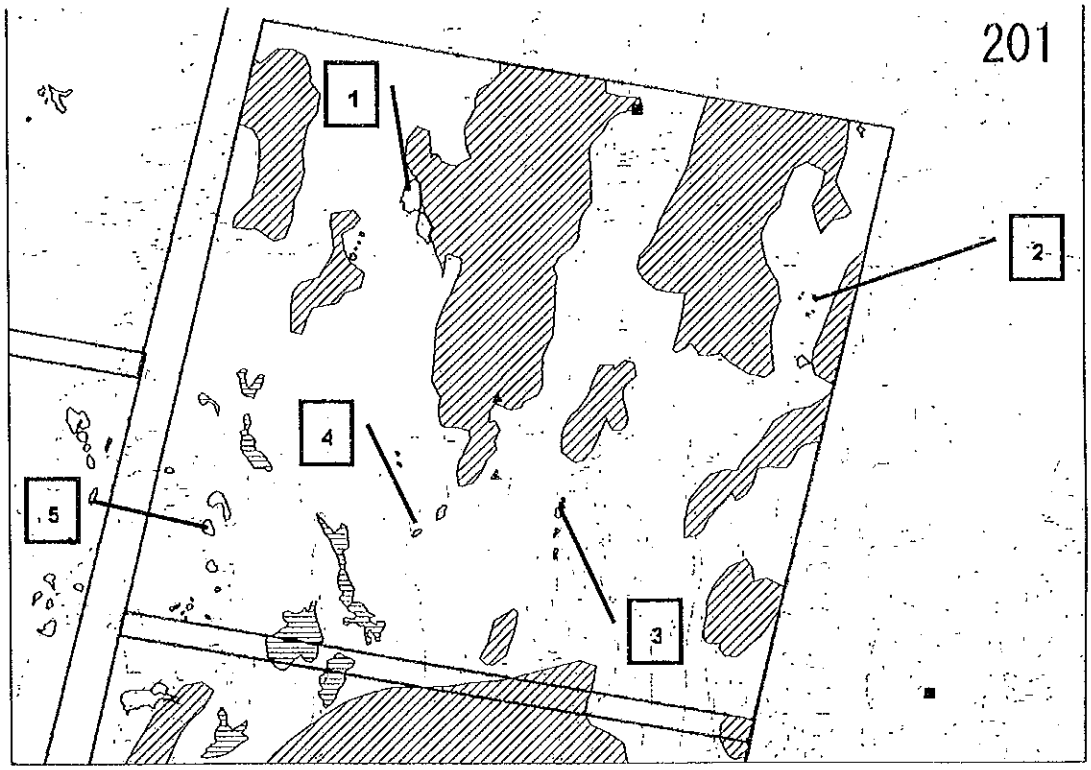


Fig.II-4-4-4-10 False color image of scene 201(BGR=147)

[Scene201: outline of alteration]



In spite of its high degree of cloudiness, this is a scene that includes the important El Aguilar mine of SEDEX type. From the south of the center of the scene to the north rise the Aguilar mountains, of which Ordovician sedimentary rocks are shown in a dark blue color as a dense surface structure and granite in a rather bright green color.

1: An alteration zone comprising Ser+Chl and Geo. Because of its position on the border of the shadow of clouds, the reliability is somewhat low.

2: This area comprises Aln+Ser and accompanying Kao. The wide range including the alteration zone consists of Geo. The wall rock is Ordovician sedimentary rock. Its false color images present a somewhat greenish brown color. Its band ratioing composites are represented by a somewhat bright white color with the Geo+Ser region around the alteration zone developing a bright purple color.

3: Small alteration zones are arranged straight along the south-to-north ridge. This area comprises Aln+Kao and is rich in Geo. The wall rock is Cambrian sedimentary rocks. The false color images develop a dark green color while the band ratioing composites show a bright purple color. A field survey of the northern edge area of these sections revealed the distribution of ortho-quartzite.

4: This area comprises Aln+Kao and Ser, but we cannot say with certainty that this is an alteration zone because Ser is detected over a wide range surrounding this area. Geo is widely dominant and its distribution agrees generally with that of Cretaceous granite. The southeastern side of this area,

which comprises Ordovician sedimentary rocks and has very weak Geo and Hem, makes a clear boundary.

5: A number of alteration zones, large and small, are present in Cambrian granite, which as a whole develops a light green color. Its band ratioing composites show the alteration zone in a bright white color and the other granite in a grayish white color. This area mainly constitutes Ser and accompanying small amount of Aln, and Geo is universally detected.

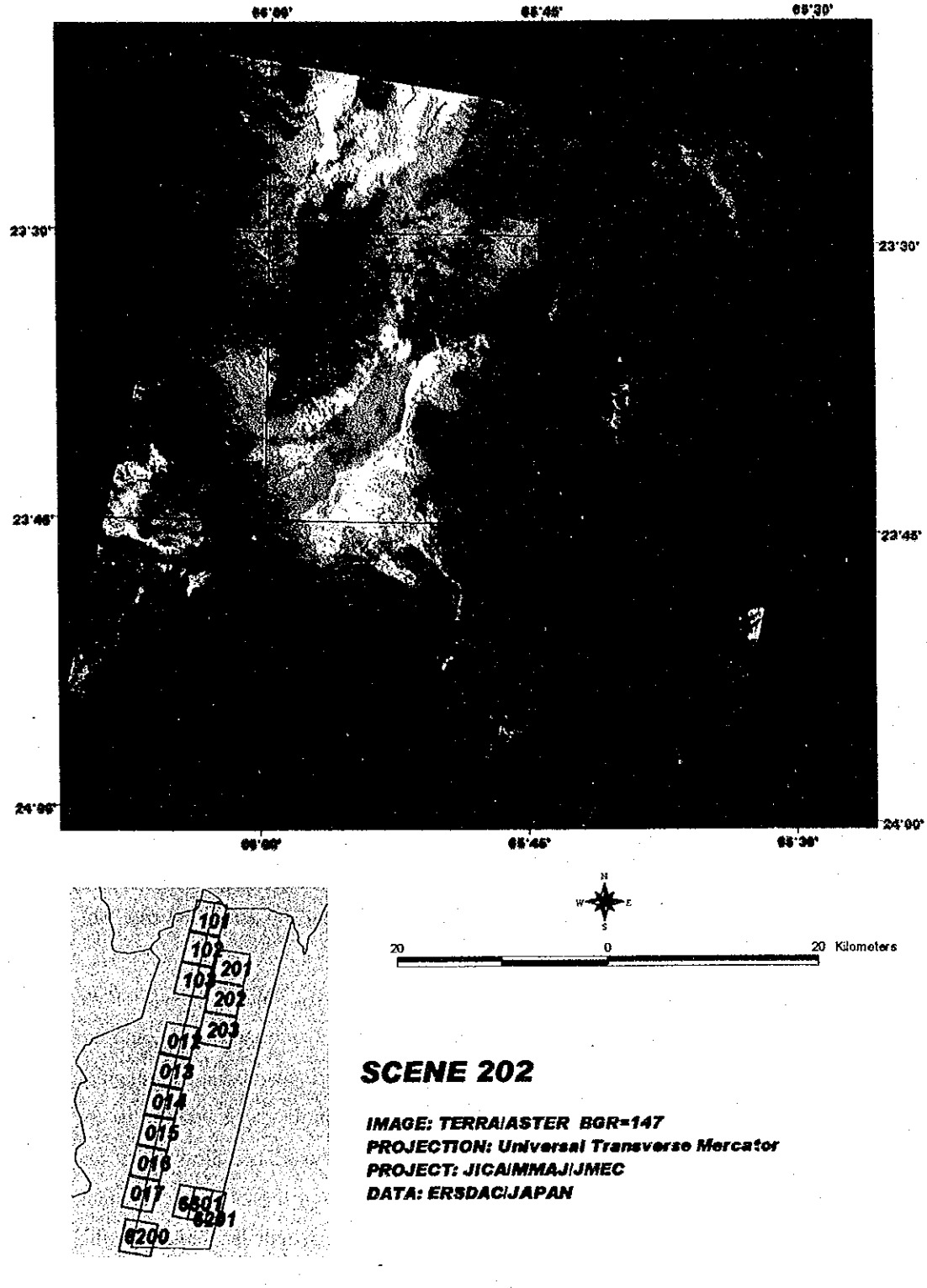
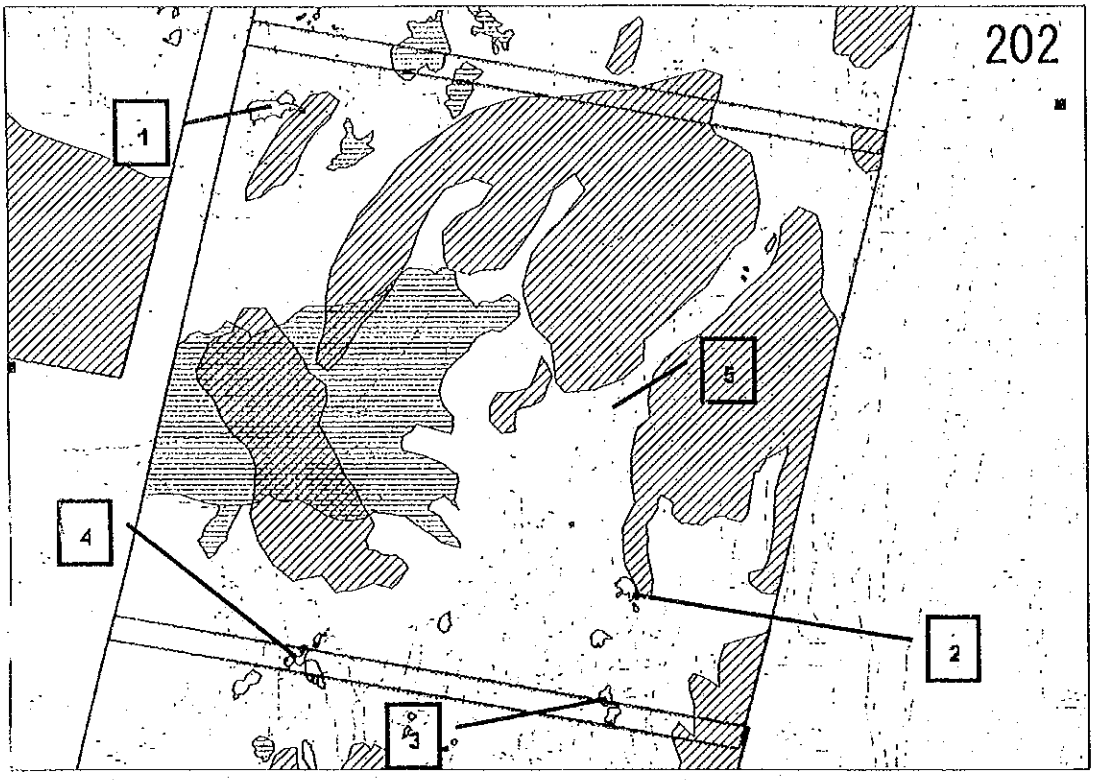


Fig.II-4-4-4-11 False color image of scene 202(BGR=147)

[Scene202: outline of alteration]



1: An alteration zone occupying the north of Ordovician sedimentary rocks. This is strong Ser alteration accompanying Aln and accompanying intense alteration to Geo. The false color composites develop a dark green color while the band ratioing images a white color with a good possibility of being an alteration zone.

2: The center of the alteration zone comprises Aln+Kao with the surroundings dominated by Ser. This area is accompanied by Geo. A similar alteration zone is distributed in its northwest side. Aln+Kao is located at topographically high levels and may be represented by a leached cap. The wall rock is Cambrian or Precambrian sedimentary rocks.

3: The north side comprises Aln>Kao while the south side is Kao>Aln, and both sides have accompanying Ser. The center of the north side shows strong alteration to Geo intensively, and the south side is somewhat weaker than that. The wall rock is Cambrian or Precambrian sedimentary rocks. To the east of the south side is another alteration zone of a similar scale, which is not accompanied by Aln, Kao and comprises Ser+Chl and Geo. Because these alteration zones are closely located to each other, their comparison may be of interest. Further, the false color images present only part of the northern alteration zone in a dark green color, and the band ratioing composites show the two southern alteration zones in a somewhat bright bluish white color.

4: This area consists of Aln+Ser and has weak Geo. Its false color images do not present a green color, and its band ratioing composites show a somewhat bright pink color. The wall rock is Cambrian or Precambrian sedimentary rocks.

5: Tusca mineral showing. A ground truth survey was conduced here.

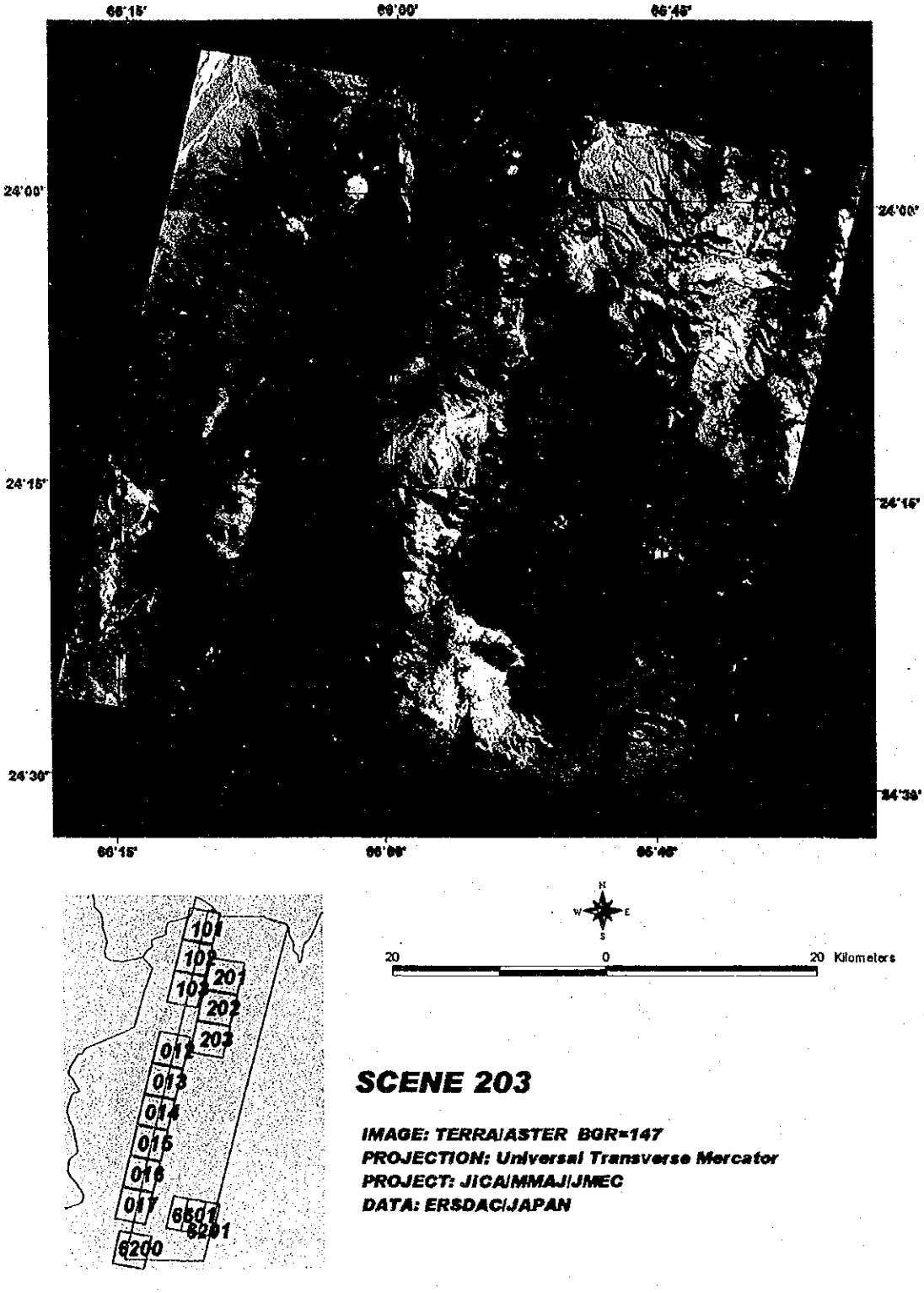
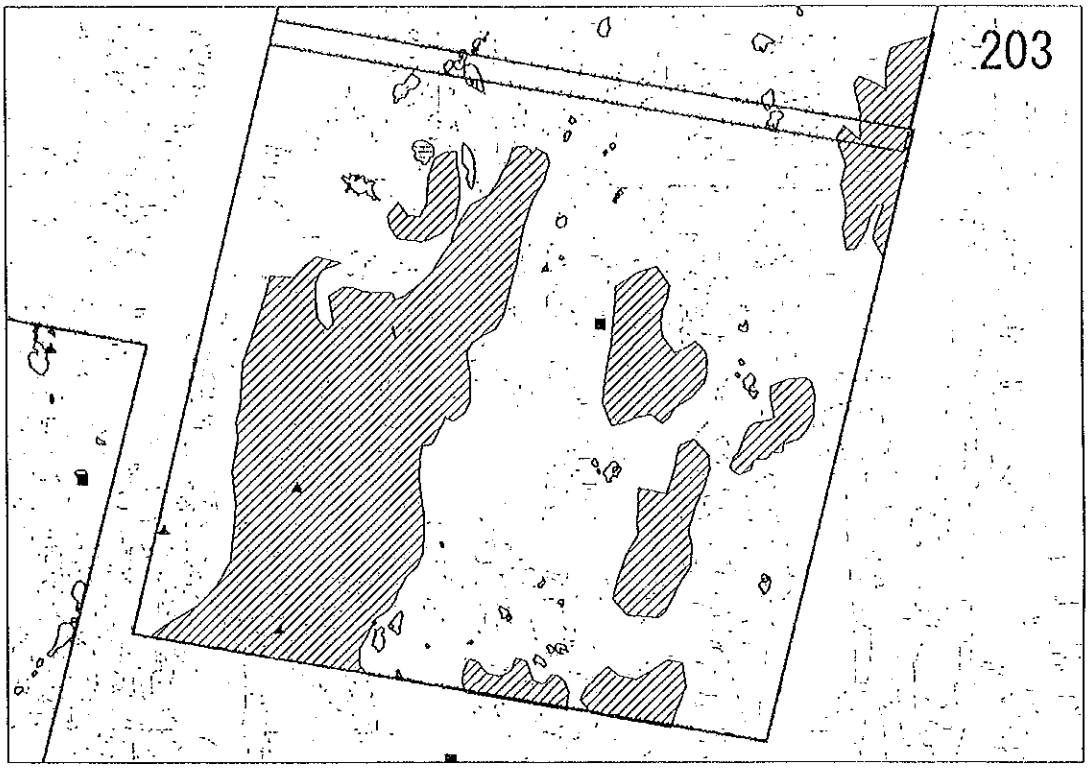


Fig.II-4-4-4-12 False color image of scene 203(BGR=147)

[Scene203: outline of alteration]



This scene covers Pancho Arias mineral showing where a ground truth survey was conducted.

1: In this area, Aln is dominant, accompanied by Kao. Ser is dominant on the outskirts of the alteration zone. The whole area of alteration zone is accompanied by Geo, in contrast to the surrounding Hem. The wall rock is Miocene volcanic rocks. The elevation is extremely high.

2: This area consists of Aln+Ser and accompanies Geo with Geo showing much higher value in the north. The wall rock is Miocene sedimentary rocks, which develop a green color in the false color images but do not develop a white color so bright in band ratioing composites.

3: The north side has dominant Kao and the south side dominant Aln. Ser is widely distributed around the alteration zone. This area is subject to the intensive alteration to Geo. The wall rock is Cambrian sedimentary rocks, which develop no colors characteristic of an alteration zone in either the band ratioing composites or the false color images; hence, its distinction is difficult.

4: Pancho Arias mineral showing. This area is a clearly discernible alteration zone in both the band ratioing composites and the false color images. It is rich in Kao and accompanied by Ser. Geo gossan is distinct. The wall rock is Ordovician granite. Except for the alteration zone, oxide minerals are found only in a small quantity in contrast to Geo of an alteration zone.

5: This area mainly comprises Kao and is accompanied by Ser. Geo is much less in comparison with No. 4. The wall rock is Cambrian and Ordovician granite.

6: The alteration zone is Aln+Kao at the center with the most part consisting of Ser. This area has distinct Geo gossan. The wall rock is Ordovician granite. The granite outside the alteration zone has low iron oxide mineral content.

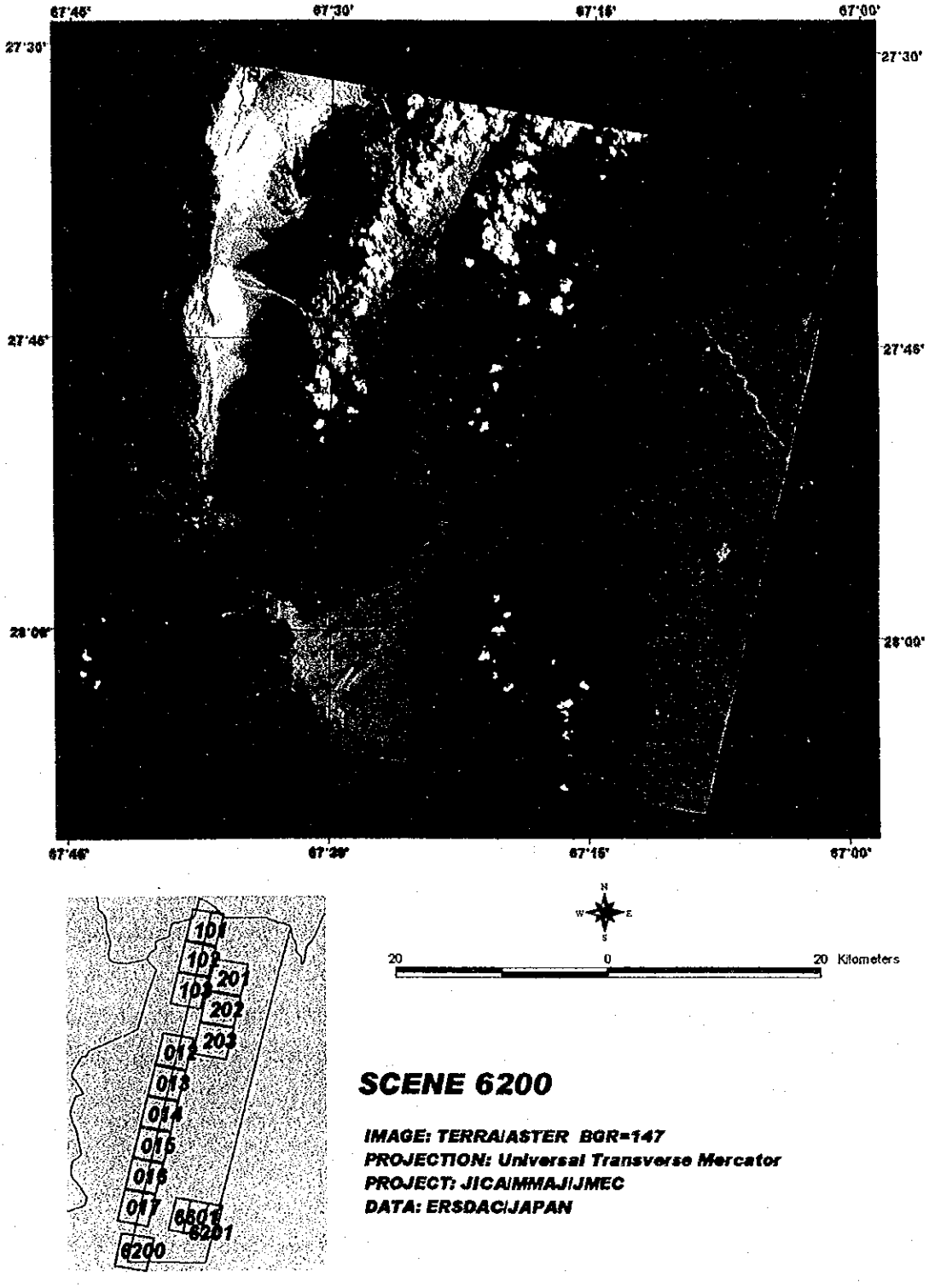
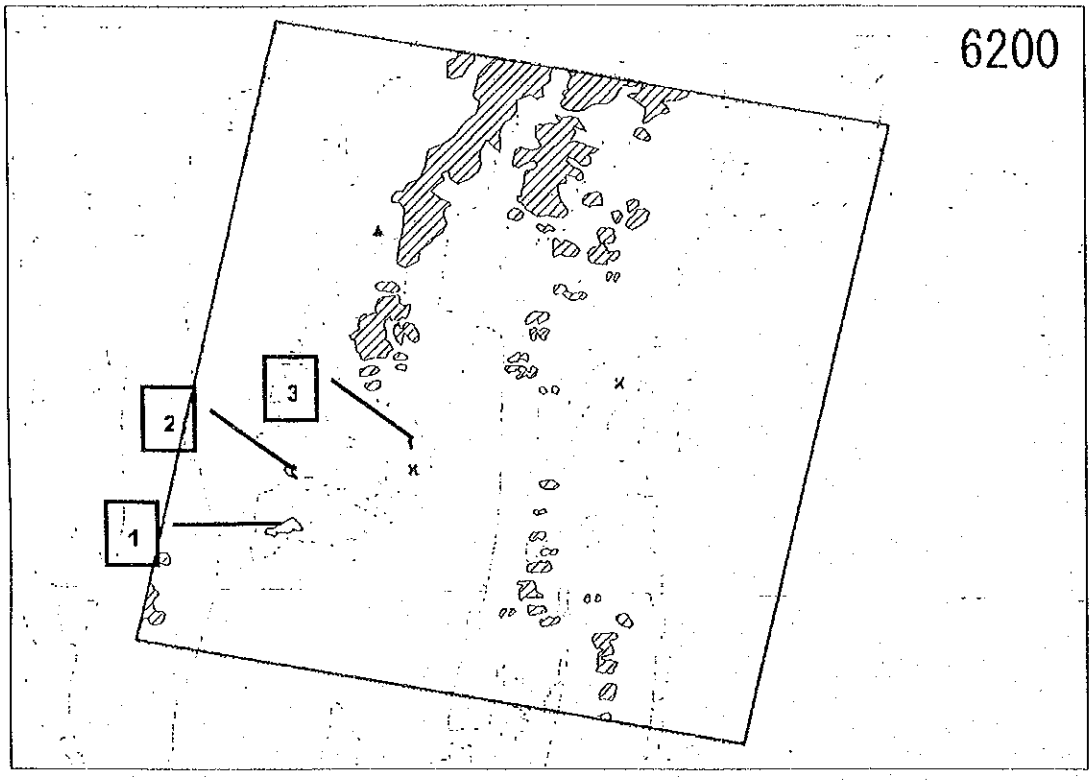


Fig.II-4-4-4-13 False color image of scene 6200(BGR=147)

[Scene6200: outline of alteration]



This scene is the southwestern edge of the survey area. Only a small number of alteration zones were discriminated. This scene has no places where a ground truth survey was conducted.

1: This area consists mainly of Ser and is accompanied by a small bit of Kao. Geo is not so much, and the surroundings are made up of Hem. The wall rock is Paleozoic Ordovician granite rocks.

2: This area consists of Aln+Ser and is accompanied by weak gossan (Geo). The wall rock is Ordovician granite the same as No. 1.

3: Aln+Ser? This area is small in size and gives no distinct features. Also, no clear distribution of iron oxide minerals is given. It develops a gray color in the false color images and a yellowish brown color in the band ratioing composites without giving any distinct features of an alteration zone. There is a Sn-W deposit to the south of this area, but no corresponding alteration zone is observed. The wall rock is Ordovician granite.

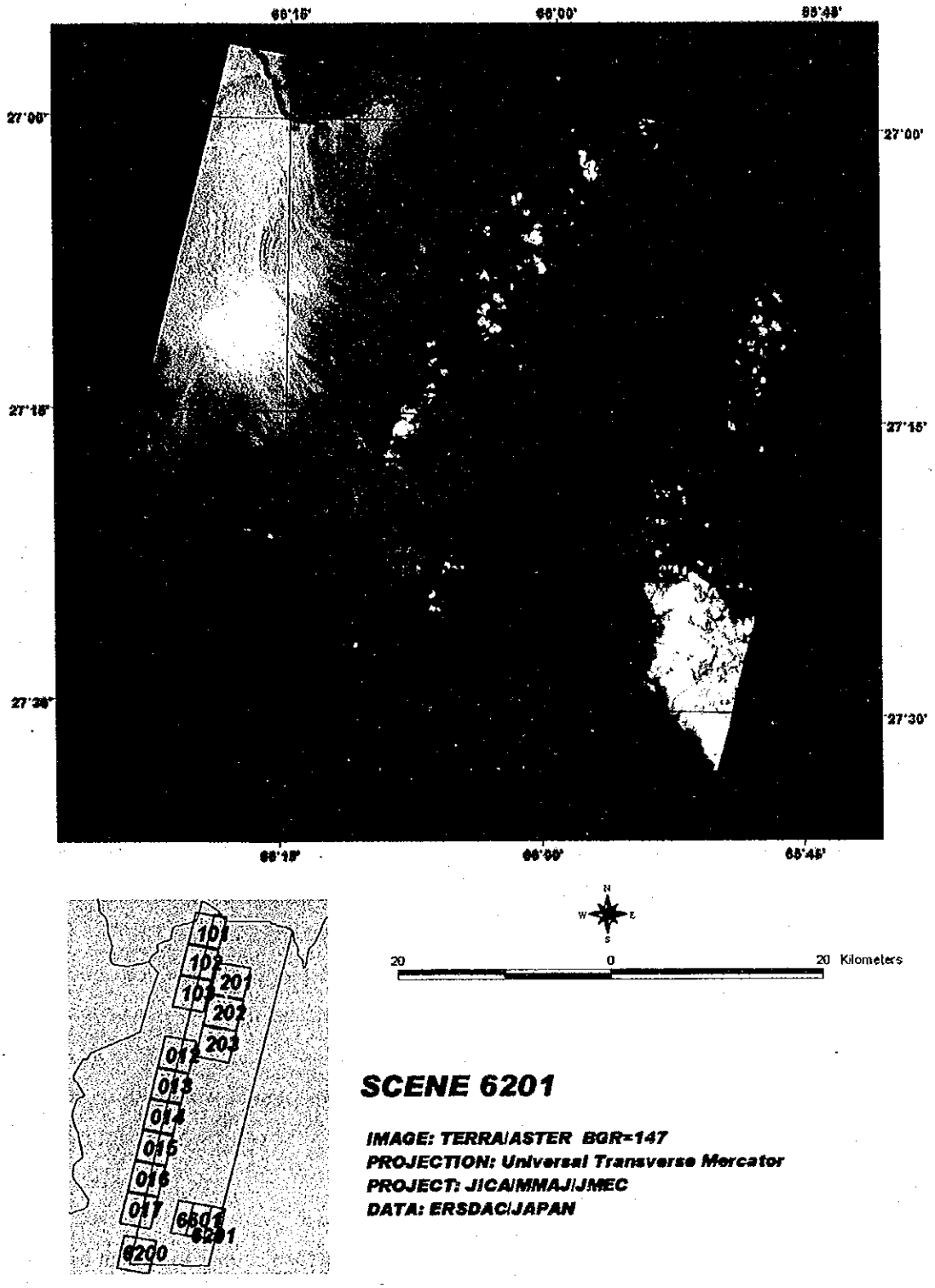
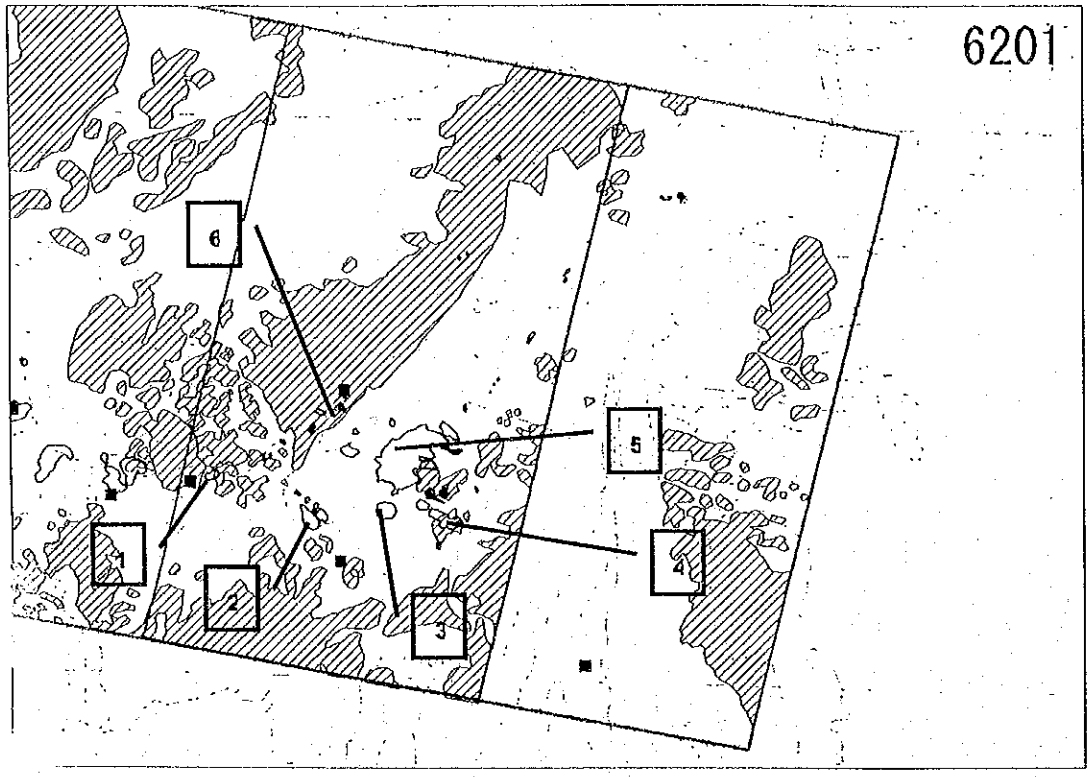


Fig.II-4-4-4-14 False color image of scene 6201 (BGR=147)

[Scene6201: outline of alteration]



This scene is located to the east of the scene which includes Bajo de la Alumbrera mine (partially overlapped). This is the scene in which a number of major deposits, such as Agua Rica and Firo Colorado mineral showing and Capillitas mine, are distributed.

1: In this area, Aln+Kao+Ser is distributed, but the center of the alteration zone is not clearly discernible. It lacks Hem and Geo. As the alteration zone is located near the borderline between the basic volcanic rocks of the Miocene and the granite of the Paleozoic, it is unknown to which of these ages the zone belongs.

2: Agua Rica porphyry copper deposit. This is an alteration zone covered with vegetation. It mainly consists of Aln. The alteration zone is more clearly seen on the image of the neighboring scene 6601. The wall rock is Cambrian or Precambrian schist rocks.

3: Firo Colorado mineral showing. This has an evident ring structure consisting of Aln and Kao. It has a weak Ser alteration on its outside. Although Geo is descernible in the part of Aln+Kao, its volume is small.

4: This area mainly comprises Ser and is accompanied by Aln and Geo. Kao is not observed. Surrounding the alteration zone, Hem is dominant. The center of the alteration zone is located at its southeastern end. The wall rock is Cambrian or Precambrian schist rocks.

5: A large alteration zone of Ser, partially accompanied by Aln. The whole area shows alteration to Geo in contrast to the surrounding Hem. It develops a gray color in the false color images to show

no alteration zone features. On the other hand, it shows a bright white color in the band ratioing composites. The wall rock is Cambrian or Precambrian schist rocks. As the alteration zone borderline can be considered as the geological borderline, there is a possibility that the geological map is wrong. Since the elevation is not less than 5,000 m above sea level, confirmation is quite difficult. The nearby part shown in a dark brown color on the false color images looks like a pendant roof of granite rocks.

6: Small alteration zones are distributed along the base of the mountain. Many of them are small alteration zones of Aln+Ser, slightly accompanied by Geo. They cannot be distinguished by the false color images or the band ratioing composites. A field survey revealed them to be white clay of fault-scrap.

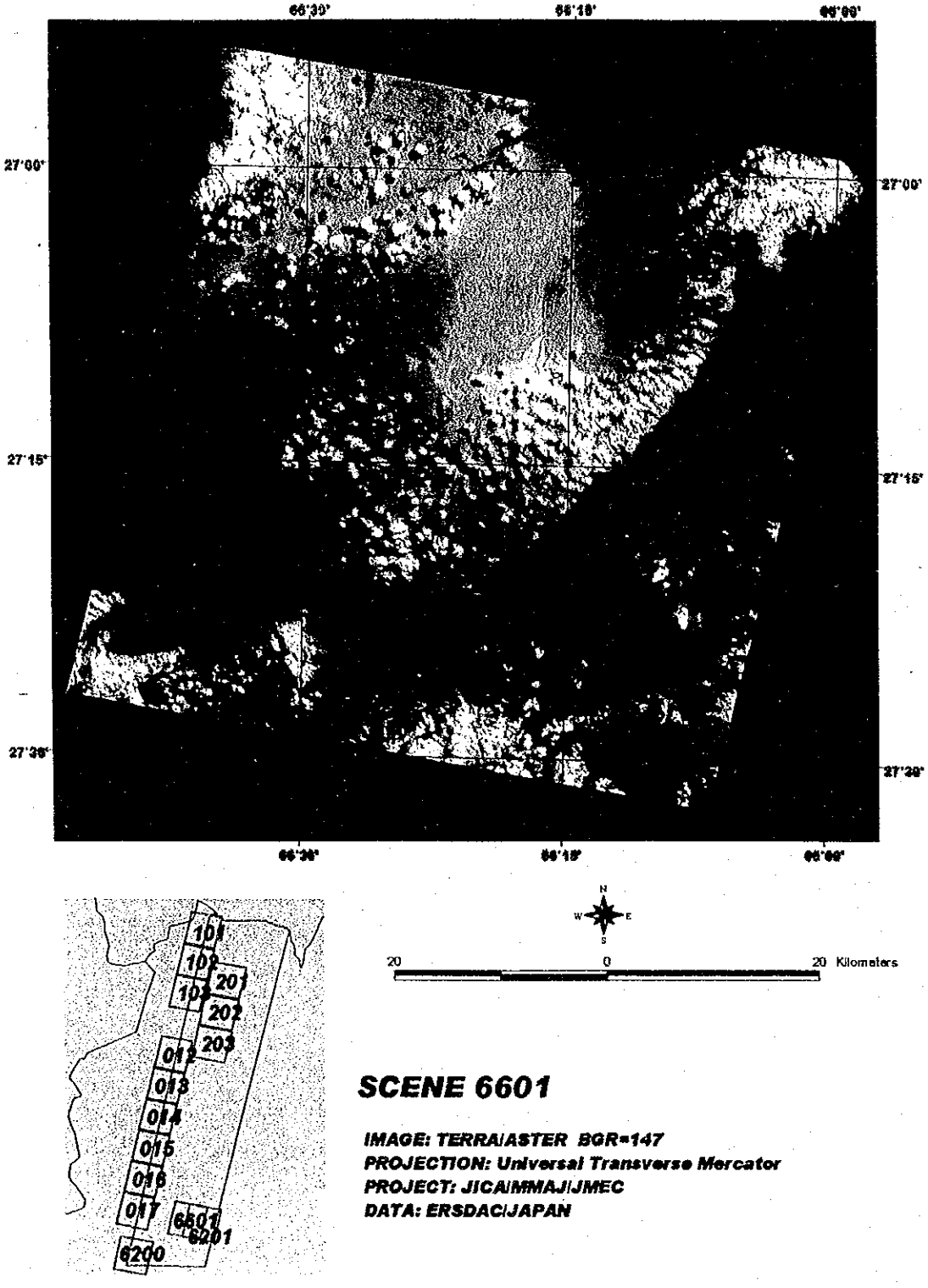
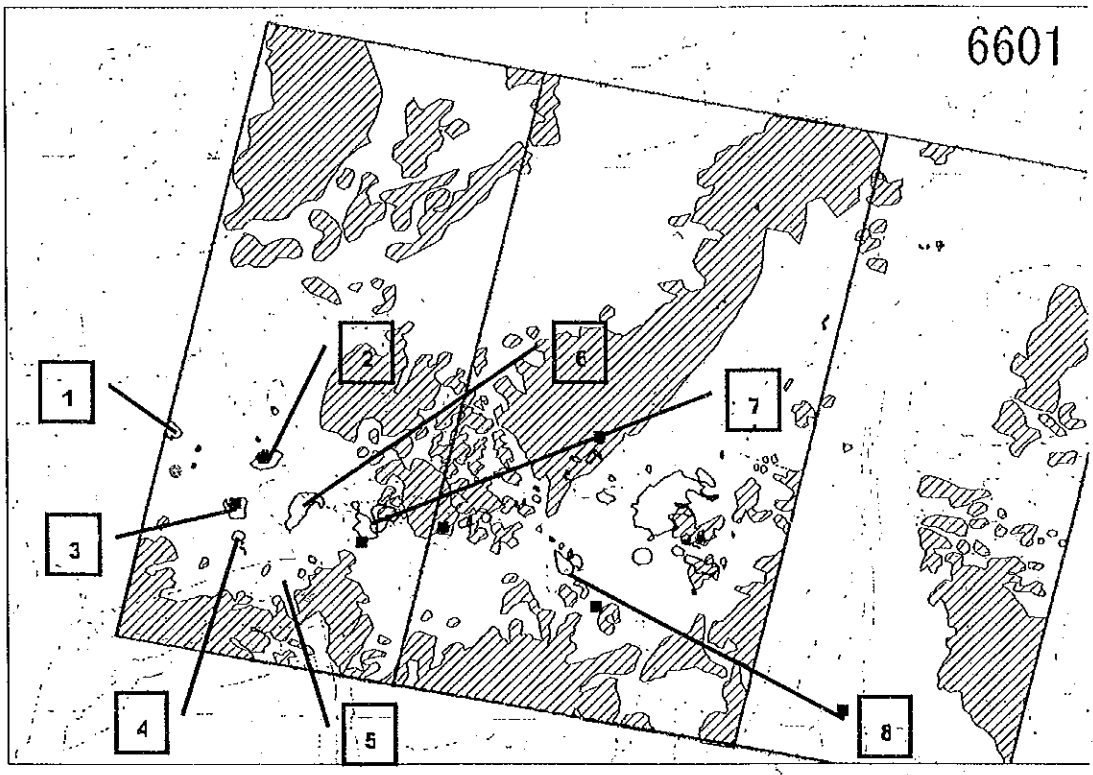


Fig.II-4-4-4-15 False color image of scene 6601(BGR=147)

[Scene6601: outline of alteration]



This scene is the scene which covers Bajo de la Alumbrera mine and partially overlaps the previous scene 6201. It is a scene containing many important mines, places of mineral showing and alteration zones, including Bajo de la Alumbrera mine.

1: Agua Tapada mineral showing, comprising Kao and Ser and accompanied by distinct Geo gossan. A weak alteration zone in which Ser is seen exists also to the southeast of the mineral showing. The wall rock is Miocene basic volcanic rocks.

2: El Durazno mineral showing. This is an alteration zone located to the north of the mine and consisting of Kao and Ser. There is a Cu deposit located at the center of the alteration zone. Geo gossan accompanies. Kao thickening is locally observed. The alteration zone consisting of Ser develops a brown color in the false color images, making it difficult to recognize as an alteration zone, but it shows a white color in the band ratioing composites. The wall rock is the same as No. 1.

3: Alumbrera mine, now in operation. The pit periphery has dominant Kao and is shaped in a ring that is accompnied by Aln. This configuration suggests the possible presence of a leached cap. The inside of the pit consists of Ser, and Aln or Kao are not detected. In the northeast of the mine is a dumping place, where Aln, Kao and Ser are distributed. In addition, as the pit and the dumping place are of fresh rock, neither Geo nor Hem is detected. The above facts show that iron oxide minerals are identified.

4: An alteration zone in the south of the mine. This mainly consists of Ser with a little thickening of Kao. There is clear Geo gossan accompanying. Further, weak Chl is detected in the neighborhood of the alteration zone.

5: Though this is not an alteration zone, very strong Geo is distributed on the same border as the geological border. The geology is Cambrian sedimentary rocks.

6: Alteration zones are distributed on the western slope of the mountain. Strip-like-thickening of Kao is are observed on the mountain hill. Geo gossan is observed, but Geo itself is more often detected on the eastern side of the mountain. According to some local mining engineers, it might be due to dust cover caused by dust from Alumbrera mine. (There is a good possibility of mine dust accumulating on the western slope of the mountain because of the presence of large mine dumps to the west of this place and a constant and strong northwesterly wind blowing over this area.)

7: In this area, Aln is dominant with small Kao thickening existing at the eastern end. On the whole, Ser accompanies. Geo gossan also accompanies. The wall rock is Miocene basic volcanic rocks. Cerro Atajo mine (Cu) is adjacent to the alteration zone.

8: Agua Rica mineral showing. This is the alteration zone in the vegetation which is covered by scene 6201. It comprises Aln+Ser with Kao thickening existing on the northeast side. This is judged as weak Geo gossan, but since vegetation strongly affects Bands 2 and 3, reliability is low regarding the result of iron oxide mineral identification.

4-5 Discussion

In this survey, the image analysis was carried out using 15 scenes of the ASTER image. For regions the ASTER image of which had not been obtained, mosaic images of 10 scenes taken by the LANDSAT TM (hereinafter the "TM") were used, which were prepared in the regional survey for mineral resources(Southern Andes, Argentine) 1997.

Fig. II-4-4-1-7 shows the results of the above-mentioned analysis. As analysis of the wide range is made by the TM, many alteration zones (places shown in blue) have been discriminated in the zone toward the west side of this survey area. However, in comparison within the analysis range of the ASTER, more alteration zones (shown in red) were discriminated by ASTER image taken this time. This is because, although only the false color image and the band ratioing composite are used for discrimination of alteration zones in the case of the TM, a very small difference of spectra was identified with the iso-grain model used in addition to these images in the case of ASTER. Particularly, the superiority of the ASTER is that resolution of the spectrum is high, and it is possible to effectively use such spectrum pattern matching as the iso-grain model. Although spatial resolution of the TM is 30 m per pixel and that of the ASTER is 15 m on visible images, as the short-wavelength infrared band is combined in the extraction of alteration zones, resolution of the visible image of ASTER reaches 30 m. As long as a short wavelength is used, there is no difference between the TM and the ASTER.

In the field survey of this fiscal year, we verified alteration zones discriminated from the ASTER data. As a result, many places discriminated as an alteration zone were the known deposits and the known places of mineral showing, and alteration could be confirmed at almost all points. The effectiveness of the ASTER was confirmed with these results. On the other hand, it can be said that there are few epithermal deposits accompanied by alteration zones and few known deposits and places of mineral showing of the porphyry type which could not be discriminated by the ASTER. However, areas that are altered but have much muscovite in fault clay and granite rocks were discriminated as an alteration zone. These areas should be discriminated as a matter of course from the viewpoint of capacity to discriminate alteration zones, and the sensor is not defective in its performance. However, the alteration is not accompanied by mineral showing. In the future analysis, a subject will be verifying whether it is possible to distinguish between alteration accompanied by mineral showing and alteration without mineral showing and verifying alteration zones that have not confirmed on the site.

From distribution of alteration zones discriminated by the ASTER, many alteration zones could be discriminated in the row on the image on the west side of the survey range, particularly centering around Scenes 012, 013, 014 and 015. Discriminated alteration zones exist in 462 places of 15 scenes.

There are few alteration zones discriminated on the east side of the survey area because vegetation is thick. However, as shown by an example of El Pago (scene 6201), Tucman State, important places of mineral showing were discriminated from thick vegetation by the ASTER. It was found that the influence of vegetation could be removed well with relatively thin vegetation, as shown by an example of Agua Rica.

In the ASTER analysis of this year, a DEM was prepared and its usability was examined. A birds-eye view was prepared from the ASTER image with the DEM used. In the investigation from ground surface, it is difficult to recognize large-scale lineaments and ring structure even if the topography can be observed from an elevated spot. The preparation of a birds-eye view with the DEM used enables grasping the three-dimensional distribution of large-scale structure, alteration zone and lithofacies. In this analysis, this view was effective particularly for grasping distribution of ring structures and alteration zones.

In this analysis, examination was further made regarding usability of thermal infrared data. Concretely, a map of estimated SiO2 contents (Fig. II-4-4-1-8) was prepared from thermal infrared data, and comparison was made on the site. As a result, the tendency was observed that places which were presumed to have a large amount of silica were places where sand accumulated, such as sandhills and talus cone, in other words, such a place as a Quaternary layer, and that, on the other hand, the content of silica was not very high in acidic rocks such as granite rocks whose content of silica should be high. However, estimated silica content varies according to lithofacies as in the vicinity of Galan caldera shown on scene 015, clearly indicating the difference is lithofacial distribution. As a whole, although a difference in the silica content according to the difference in lithofacies is observed, it seems that the silica content held by the rock is not accurately shown. For this, as mentioned in the section of analysis, it is necessary to correct elevation with the DEM used. Therefore, we would like to make detailed examination in the next year rather than this time.

4-6 Summary

This analysis targeting the dry area with bare rocks aimed at identification of alteration minerals in the alteration zone accompanying deposits by the use of actual data obtained by the ASTER, which enables satellite data to be effectively used for exploration of metal deposits.

Prior to the analysis, the following pre-processing was carried out:

- Registration between bands to correct divergence of pixels that occurs inside and among telescopes.
- Pseudo reflection conversion using the pseudo reflection conversion factor (the Ministry of Economy and Industry, 2001).
- Removal of reflectance spectra of plants using the SAVI (soil adjust vegetation index).

For identification and semi-quantitative analysis of alteration minerals, the iso-grain model, for which consideration was given to reflection and absorption among mineral particles, was used. In this analysis, nine kinds of minerals observed widely were selected. A database of spectral reflection where these minerals were mixed was prepared by the use of the iso-grain model, and mineral identification and semi-quantitative analysis of minerals on the ground surface were carried out. Mineral mapping was then executed.

In addition, a DEM was prepared from data of the stereoscopic image of five successive scenes without clouds. Spatial resolution of the prepared DEM was determined to be 30 m. At the same time, orthorectified images at a spatial resolution of 30 m were prepared for each of VNIR and SWIR data, and a satellite birds-eye view was also prepared.

Furthermore, atmospheric correction and separation of temperature and emissivity were carried out for data of thermal bands, which are one of the characteristics of the ASTER. Mapping of SiO2 contents was carried out by the use of the conversion expression proposed in the METI (2000).

In the discrimination of alteration zones by the use of the visible and short-wavelength infrared ranges of the ASTER and the iso-grained model, more alteration zones could be discriminated by far than with the existing analysis with the LANDSAT TM used. As a result of the field verification, it was found that almost all of the known deposits and places of mineral showing had been covered. The future objective is to identify alteration zones accompanied by mineral showing and those without mineral showing, and to verify alteration zones that have not been confirmed.