# Appendix 11

# Geology

# of the

# I60 area

1. Locality

The locality of the I60 area is as follows;

Northwestern corner; UTM_EW 530513, UTM_NS 7345741

Southwestern corner; UTM_EW 530418, UTM_NS 7301454

Northeastern corner; UTM_EW 561027, UTM_NS 7345643

Southeastern corner; UTM_EW 560837, UTM_NS 7301355

2. Topography

The topography of the I60 area is almost flat except for the ridge located in the northeastern area. This ridge continues from the I59 area and reflects the fold (See Geology of the I59 area).

3. Satellite image

The Landsat image of the I60 area with composite color, Red = Band 3, Green = Band 2, Blue = Band 1, is shown in Figure 2. The red and black lines on the image are geological structure and lineament traced on the image, respectively. Several folds are visible. The fold in the northeastern area continues from the I59 area. Another fold is located in the southwestern area. In the southern center and southeastern of the area, there are ring structures suggesting sheath folds.

4. Geological survey

Table 1 indicates classification of the rock samples used in the field. The number of the outcrops observed is 309. Figure 3 shows locality of the outcrops, lithology, strike direction and dipping on the topographical image. The colors of the points indicate lithology displayed in the Table 1.

The garnet-bearing gneiss and the pelitic gneiss are predominant in the eastern part and western part of the northern 1/3 of the I60 area, respectively. In the southern part of their distributional area, the magnetite-bearing gneiss is observed. The granitic gneiss, the carbonate rock, the gneiss, the quartzite and migmatite are included in the amphibole-bearing gneiss in the southern 2/3 area.

Photos 1 to 3 show the outcrop of the migmatite located southern Manakompy. The greenish and brownish parts and white part are pyroxenite and meta-gabbro, and granitic gneiss. They are irregular shaped and show complicated mixture indicating

deformation. Carbonate rock is rarely observed. Photo 4 to 6 also demonstrates migmatite outcrop located near Bekily. The gneiss and granitic gneiss have very complicated relationships. The granitic gneiss in the migmatite is formed by the partial melting during the high temperature metamorphism. The migmatite is originated form the mixture between the melt (neosome) and the gneiss (paleosome).

One of the geological characteristics of the I60 area is mixture between the pyroxenite and the carbonate rock (Photos 7 and 8). This kind of assemblage is common in the phlogopite mine, Ampandrandava in the J60 area. The mechanism to form this assemblage and texture is unclear.

In the southern part of the all 8 areas (I60 and J60 areas) the dikes of the volcanic rocks, basalt, andesite and rhyolite are described in the old 1/100,000 scale maps. The direction of the dikes is WNW-ESE. The age of the dikes is middle Cretaceous. Photo 9 shows the example of the dike, aphyric basalt, cutting the host gneiss with high angle.

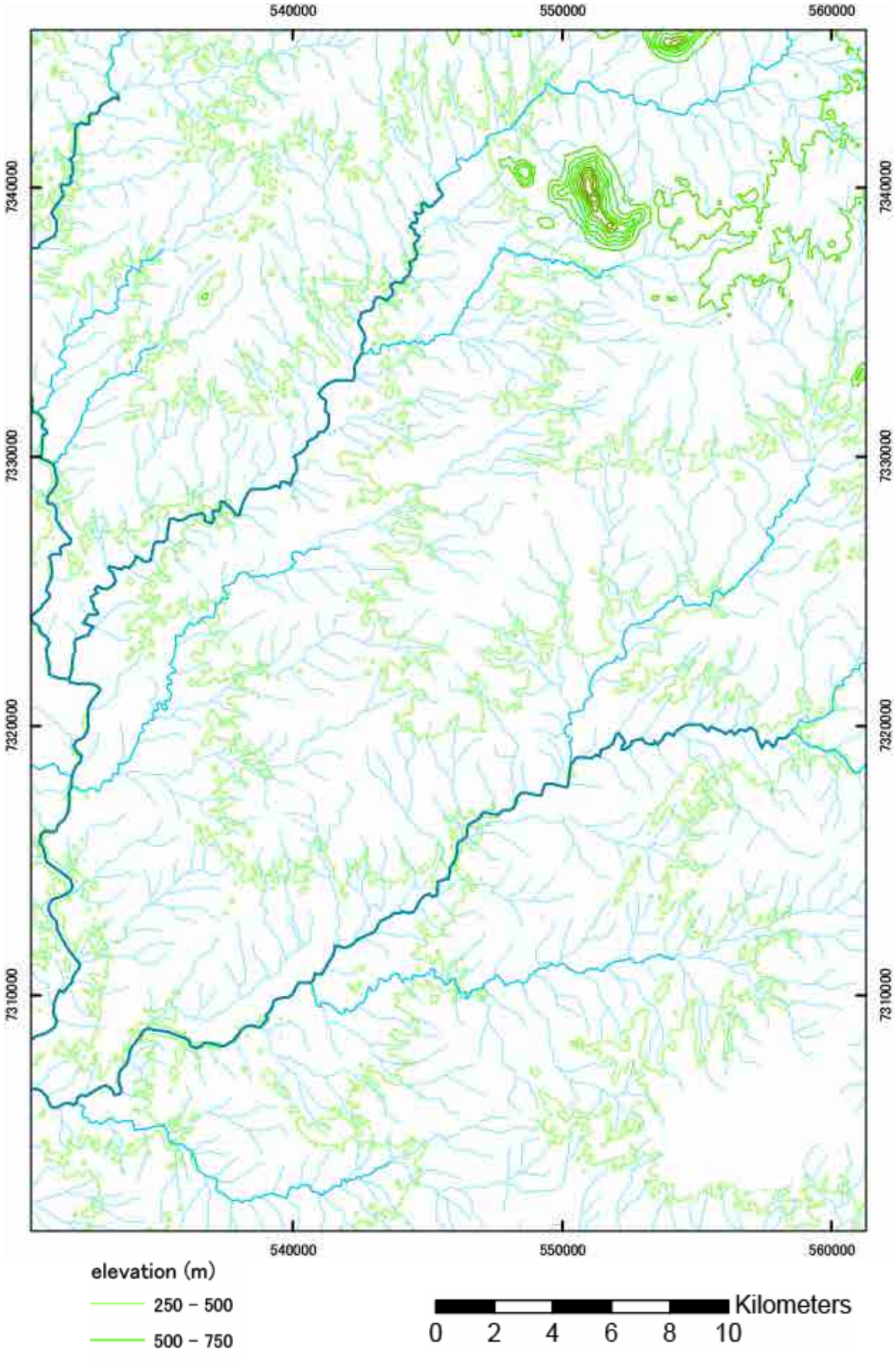


Figure 1. Topographical map of the I60 area


Figure 2. Landsat image of the I60 area

Table 1. Classification of the rocks

| ID | Rock Name | Color | Abb. | Propotion of Qtz & Fld | Metamorphic mineral | Foliation | Origin | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1 | Quartzite | | Qtz | Qtz | Grt, Bt, Sil, Crd… | clear | Sedimentary rocks | |
| 2 | Psammitic Gneiss | | Psm | Qtz > Fld | Grt, Bt, Sil, Crd… | clear | Sedimentary rocks | |
| 3 | Pelitic Gneiss | | Plt | Qtz = Fld, Qtz < Fld | Grt, Bt, Sil, Crd… | clear | Sedimentary rocks | |
| 4 | Garnet-bearing Gneiss | | GrtGn | Qtz = Fld, Qtz < Fld | mainly Grt | clear | Sedimentary rocks | |
| 5 | Magnetite-bearing Gneiss | | MagGn | Qtz = Fld, Qtz < Fld | mainly Mag | clear | Sedimentary rocks | |
| 6 | Amphibolite-bearing Gneiss | | AmpGn | Qtz = Fld, Qtz < Fld | mainly Amp | clear | Sedimentary rocks | |
| 7 | Gneiss | | Gn | Qtz = Fld, Qtz < Fld | mainly Bt | clear | Sedimentary rocks | |
| 8 | Granite | | Gr | | Bt (small amount) | not clear | Igneous rocks | Granitic Texture preserved |
| 9 | Granitic Gneiss | | GrGn | | Bt (small amount) | clear | Igneous rocks | Granitic Texture preserved |
| 10 | Augen Gneiss | | AugGn | Fld Megacryst | | clear | Igneous rocks | Granitic Texture preserved |
| 11 | Syenite | | Sy | Kfd, Amp (Qtz) | | not clear | Igneous rocks | |
| 27 | Micro Granite | | McGr | | | | | |
| 12 | Charnockite | | Chk | Opx | | | Igneous rocks | Opx-bearing granitic rock |
| 13 | Pegmatite*3 | | Peg | Large Grain Size | | | Igneous rocks | Dikes or Lens or Layer*4 |
| 14 | Pyroxenite | | Px | Pyroxene (diopside) | | | Igneous rocks | ultramafic composition |
| 15 | Amphibolite | | Amp | Amphibole | | | Igneous rocks / Metamorphic rocks | mafic (basaltic) composition |
| 16 | Gabbro | | Ga | Pyroxene (augite, Opx), Plagioclase | | | Igneous rocks | mafic (basaltic) composition |
| 17 | Diorite | | Di | Amphibole, Pyroxene, Fld | | | Igneous rocks | andesitic composition |
| 18 | Migmatite | | Mgm | Mixture of irregular shaped gneiss *5 and felsic rock network. Available on the outcrop only. Tsy misy "migmatite rock sample" | | | | |
| 19 | Mylonite | | My | strongly deformed | | | sometime unknown | |
| 20 | Basalt | | Ba | | | | volcanic rocks | mafic |
| 21 | Andesite | | An | | | | volcanic rocks | intermediate |
| 22 | Rhyolite | | Rh | | | | volcanic rocks | felsic |
| 23 | Carbonate | | Car | Marble, Limestone | | | | |
| 24 | Calcsilicate | | Cls | carbonate-silicate | | | | |
| 25 | Carbonate-Pyroxenite | | Car-Px | | | | | |
| 26 | Laterite | | | | | | | |
| 28 | River Sediment | | | | | | | |

*1 : Describe the amount & the order of amount
*2 : Indicating the amount of clay mineral in the original rocks
*3 : If misy Pegmatite in the outcrop, describe with host. Ex) Pelitic Gneiss with Pegmatite Dikes, Granitic Gneiss with Pegmatite Lens,,,
*4 : Dike cuts the host folication, Lens and Layer are parallel to the host foliation.
*5 : Possibly all kinds of gneiss

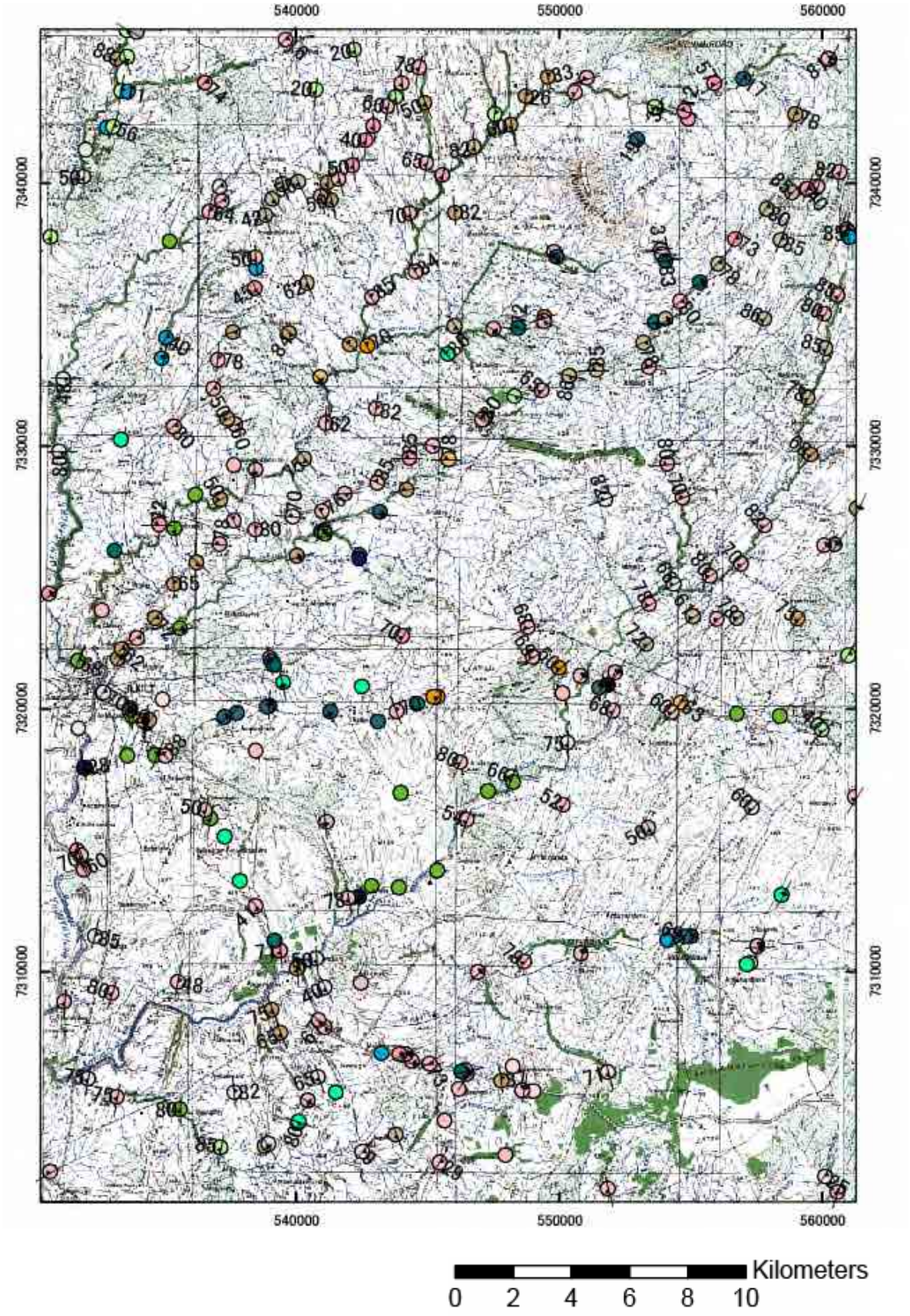


Figure 3. Locality of the outcrops

Photo 1. Migmatite outcrop southern Manakompy

Photo 2. Migmatite comprising meta-gabbro and granitic gneiss

Photo 3. Pyroxenite strongly deformed

Photo 4. Migmatite outcrop near Bekily

Photo 5. Close-up of the migmatite

Photo 6. Close-up of the migmatite

Photo 7. Mixture between pyroxenite and carbonate rock

Photo 8. Close-up

Photo 9. Basaltic dike cutting the host gneiss with high angle

5. Geological survey for the all 8 areas

The information about geological and geological structure around the I60 is necessary for the geological mapping. The satellite image with natural color and geological structure traced on the image for the all 8 areas are shown in the Figure 4. The red and black lines are geological structure and lineament, respectively. Figure 5 is geological map for the all 8 areas created in this study. The legend and lithology are indicated in the Figure 6. Figure 7 is simple inspection about geological structure. Open and closed dots indicate dip angle less than 50 degree and more than 50 degree, respectively. The major axes of the diamonds displays strike direction and their color means dipping direction like this. In the eastern part of the study area, west-dipping is abundant. This is eastern opening anticline structure. In the center, low-angle east-dipping prevails. In the boundary zone between center and western parts, there is west-dipping and western opened syncline structure. The study area is divided into two domains, Androyen and Anosyen. These domains are split up into subdomains.

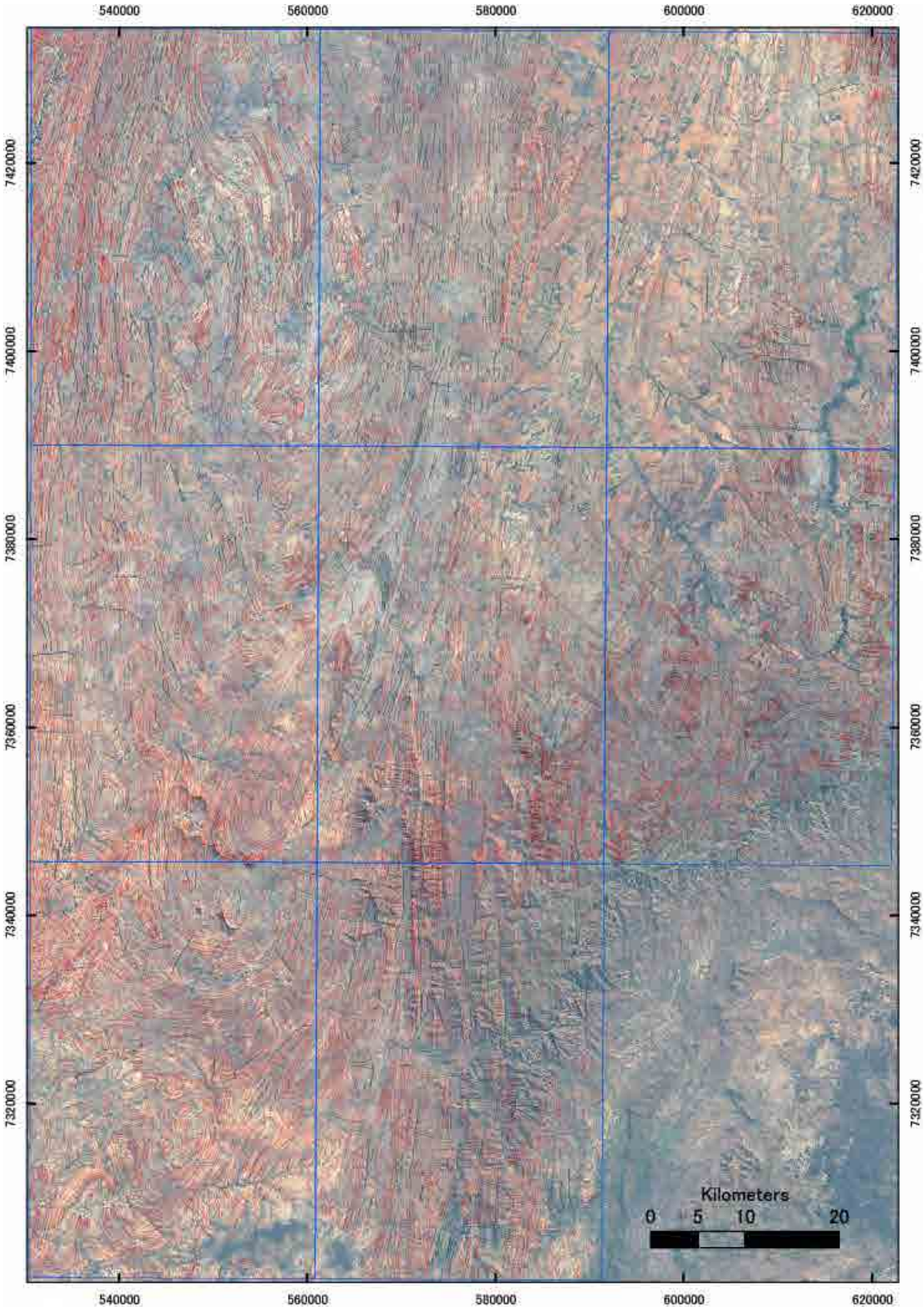


Figure 4. Landsat image with true color for the all 8 areas

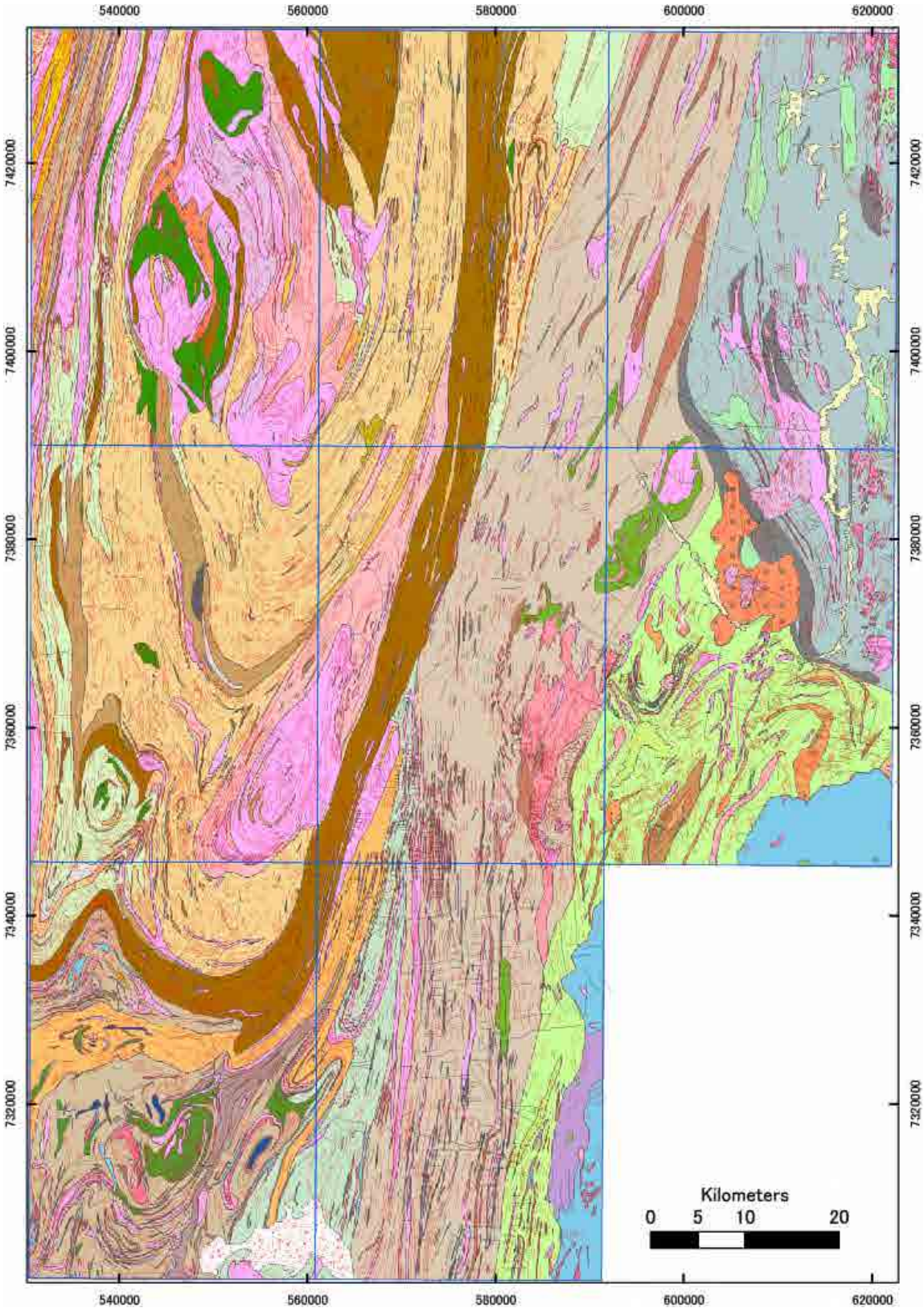


Figure 5. Geological map for the all 8 areas

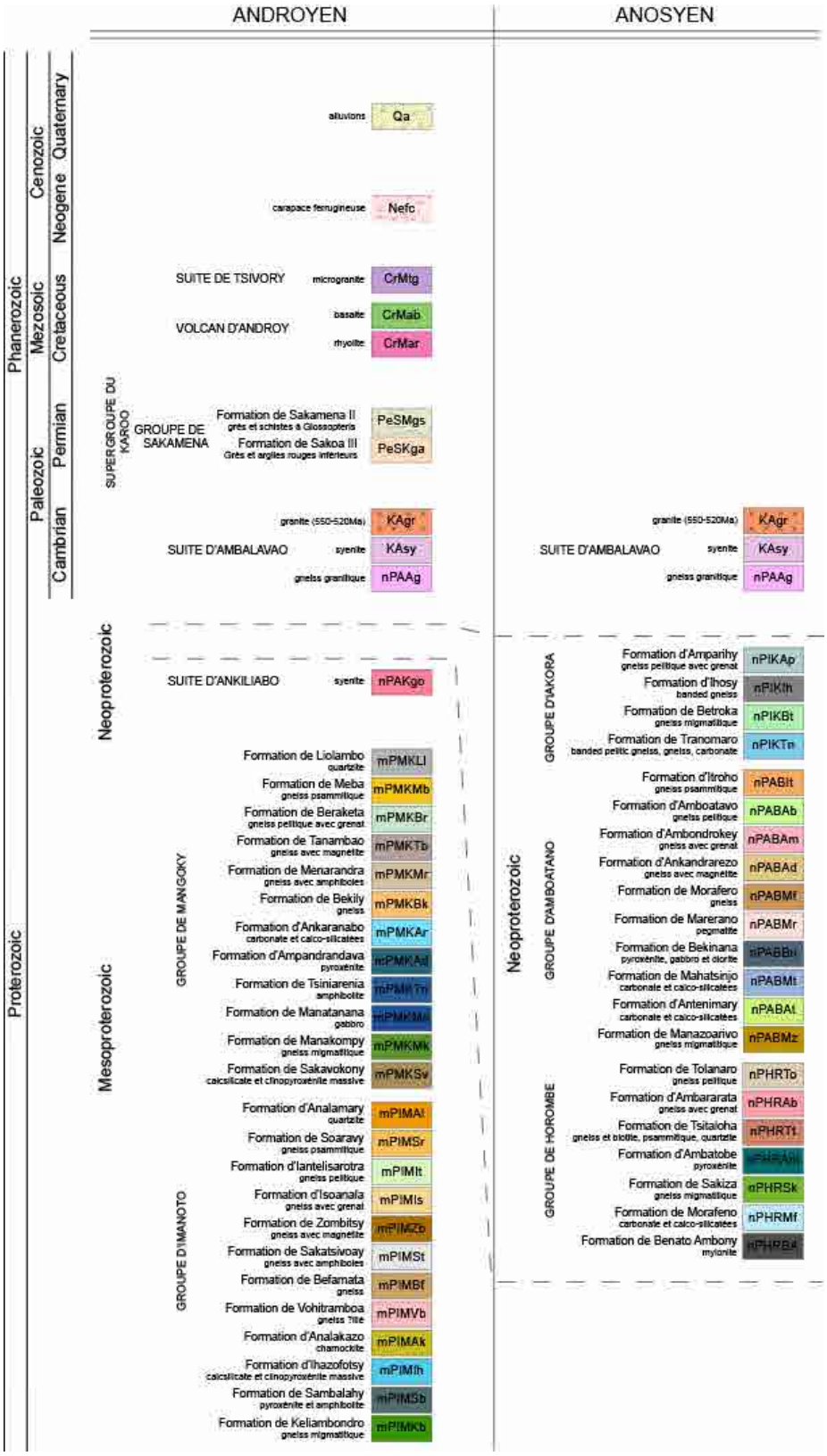


Figure 6. Legend for the geological map

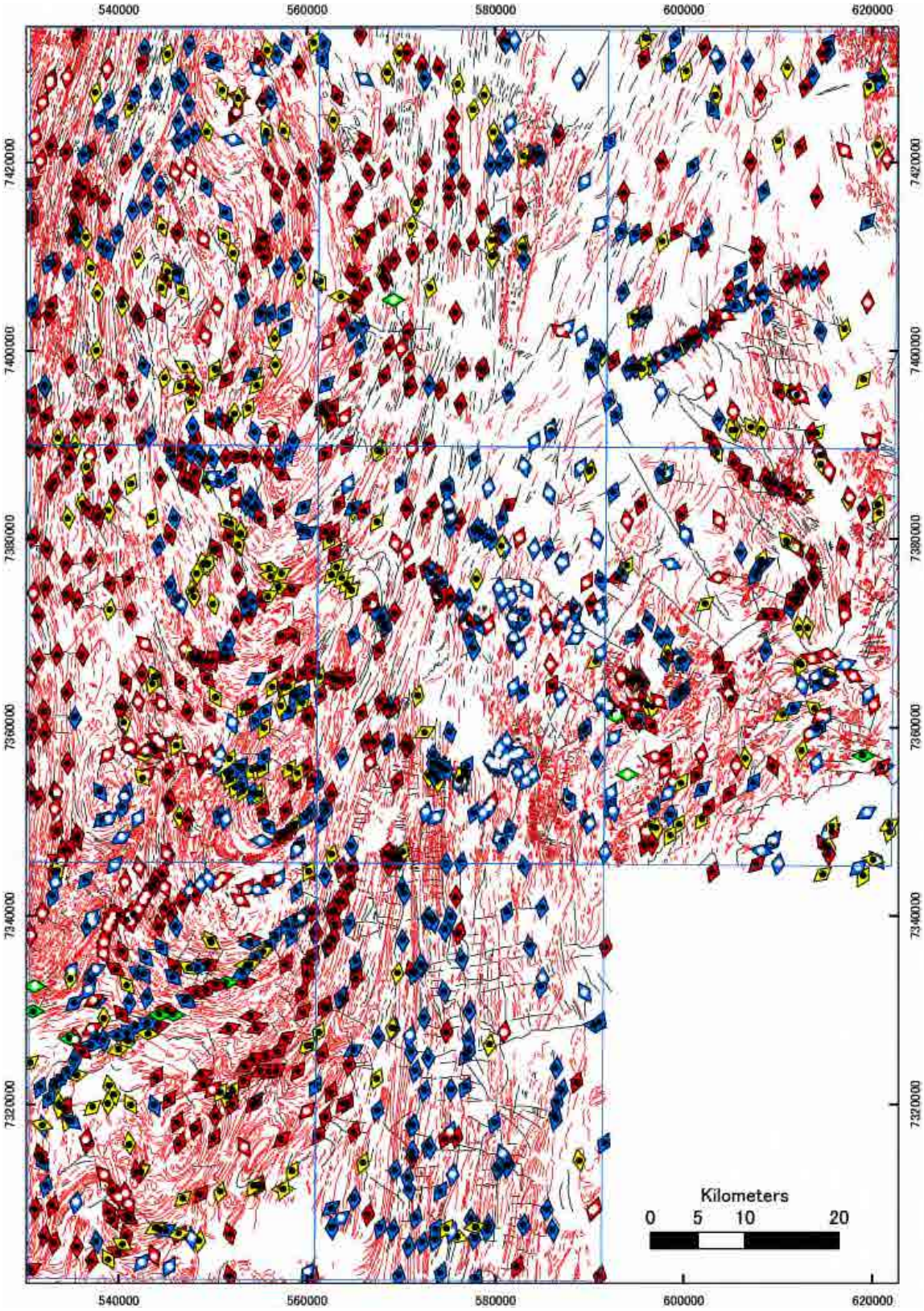


Figure 7. Geological structure for the all 8 areas

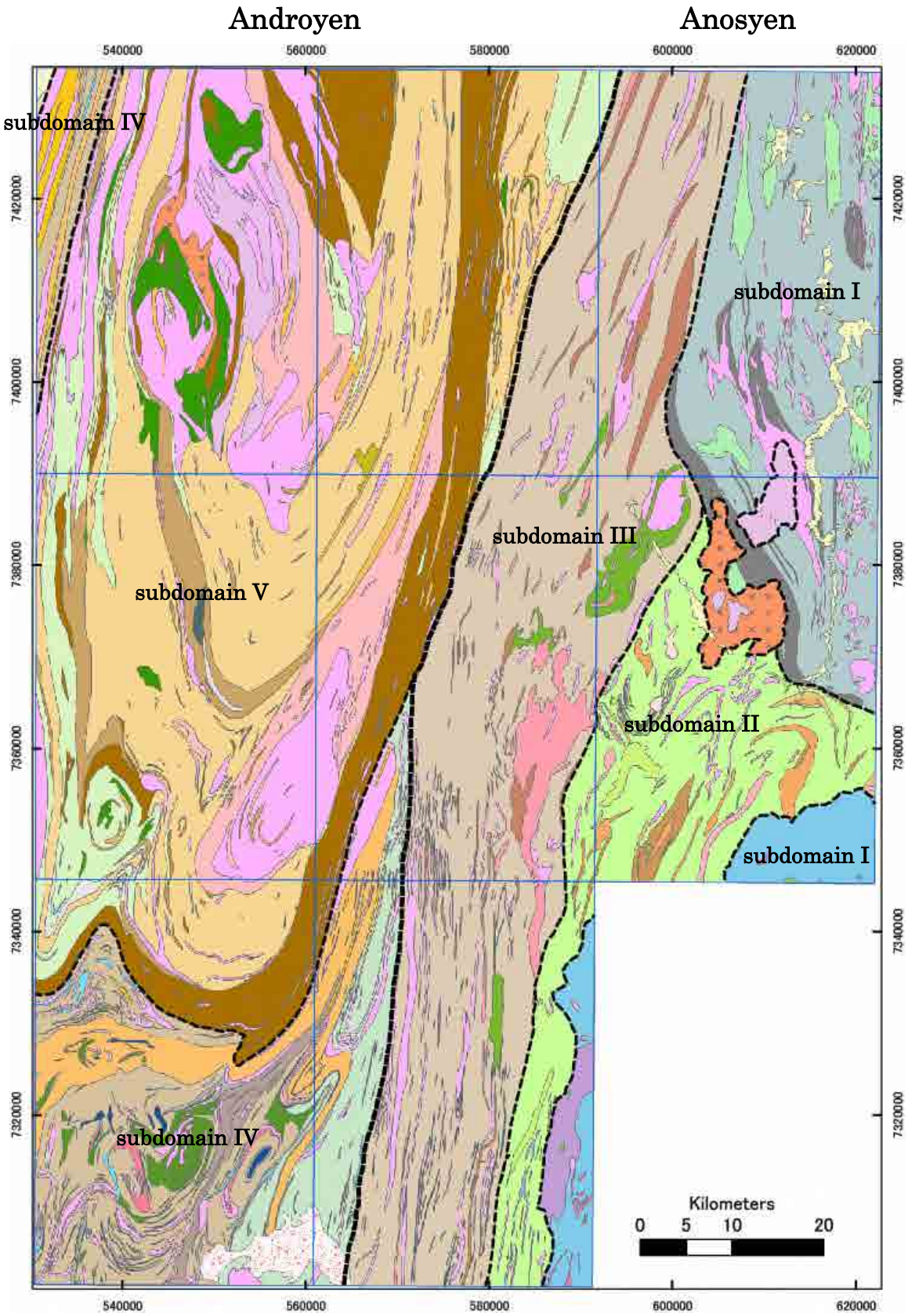


Figure 8. Geological domains and subdomains for the all 8 areas

6. Geology of the I60 area

Figure 9 shows geological map and profile of the I60 area. Legend and lithology are displayed in the Figure 10. The whole area of the I60 belongs to the Androyen domain. The northern 1/3 and the southern 2/3 are involved in the subdomain V and subdomain IV, respectively. The strike direction and dip angle measured on the outcrop in each subdomain are projected on the Schmidt's net (Figures 11 and 12).

In the northern area the distributional area of the garnet-bearing gneiss and the pelitic gneiss continue from the I59 area demonstrating folding structure clearly visible on the satellite image (Figure 2). Their southern end is bordered by the magnetite-bearing gneiss.

In the southern area granitic gneiss, carbonate rock, meta-gabbro, quartzite and migmatite are commonly included in the amphibole-bearing gneiss and gneiss as layers. Their structure exhibit relatively small-scale and complicated fold which is obvious on the satellite image (Figures 2 and 9). The ring structures manifested by the satellite image are sheath folds comprised by syenite and migmatite.

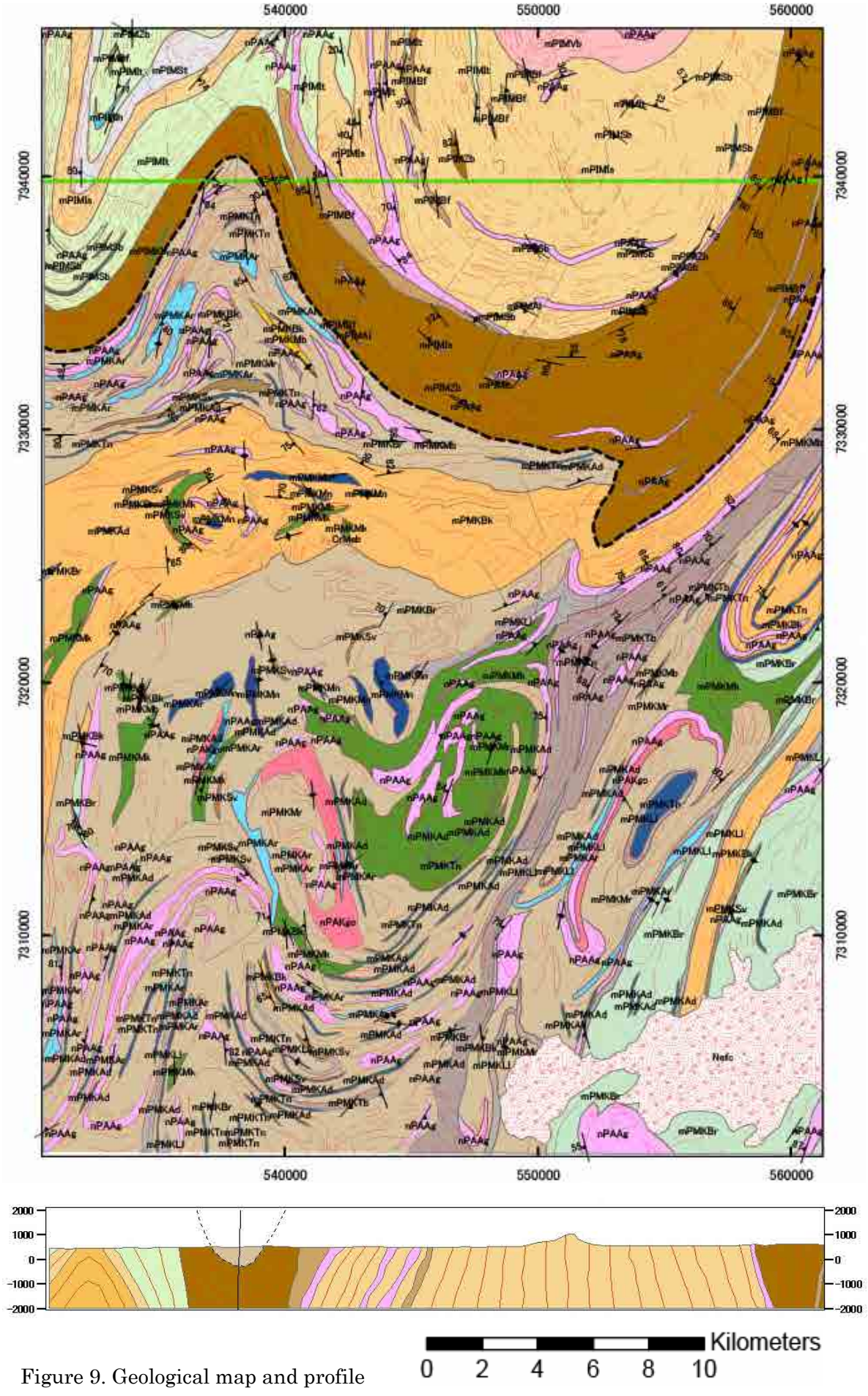


Figure 9. Geological map and profile

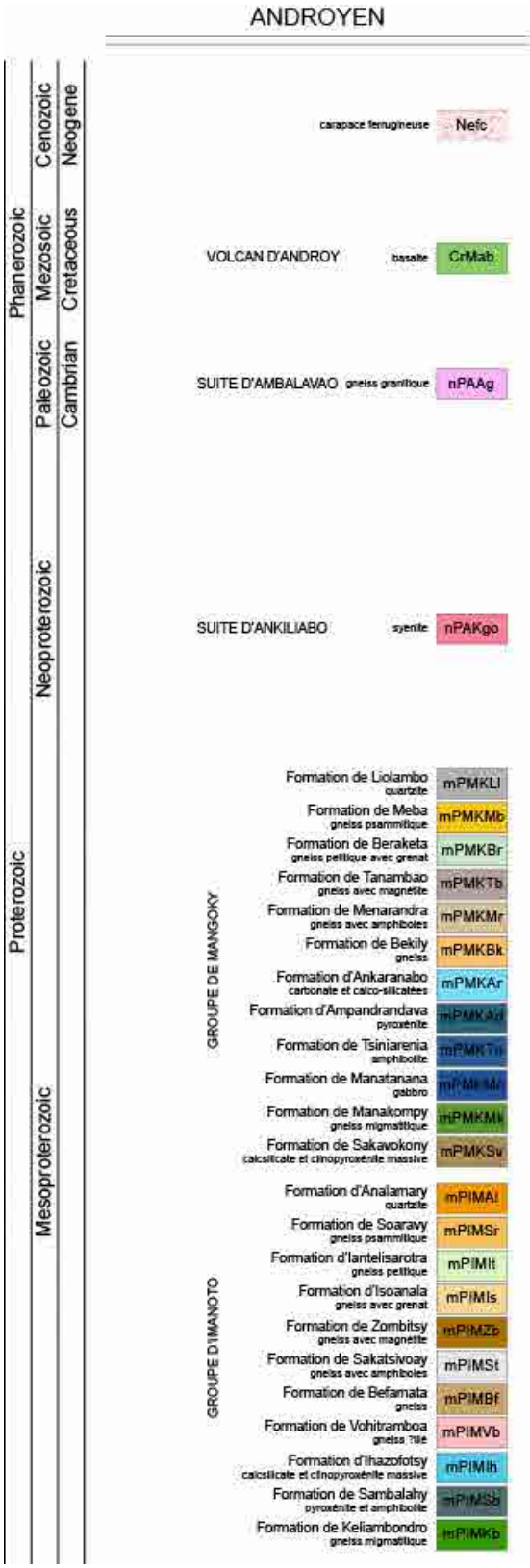


Figure 10. Legend and lithology

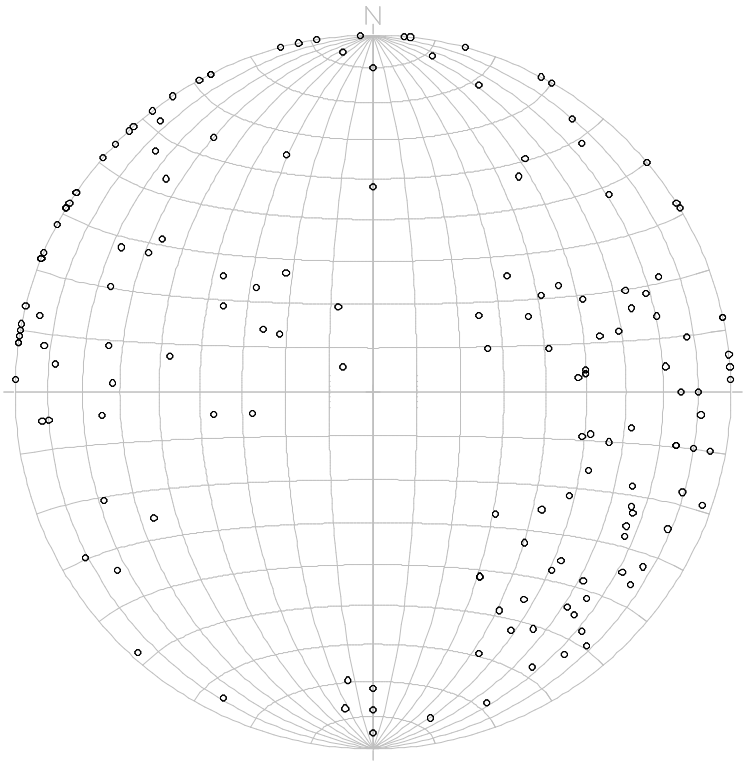


Figure 11. Schmidt's net projection of the strike direction and dip angle observed on the outcrops in the subdomain IV. Lower hemisphere projection.

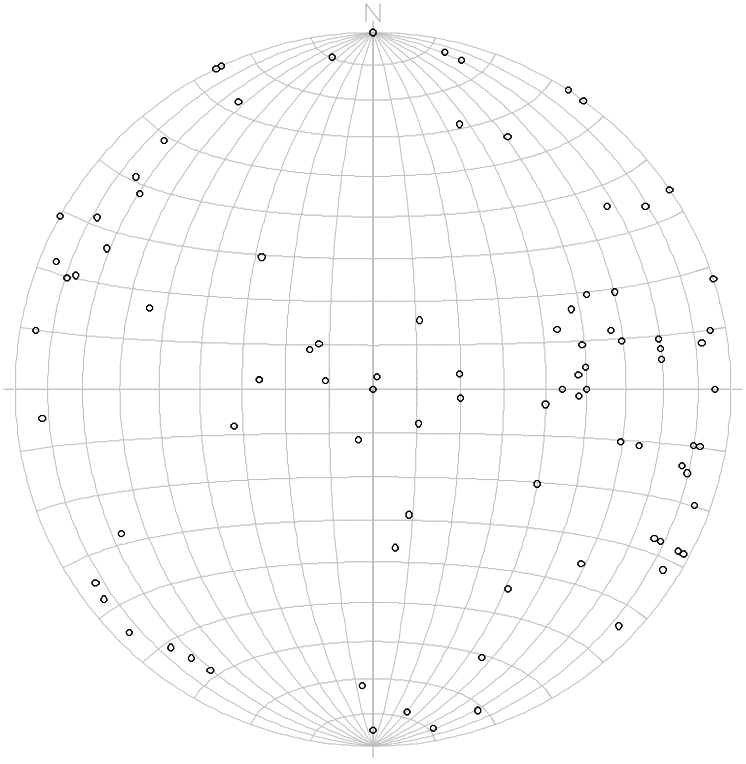


Figure 12. Schmidt's net projection of the strike direction and dip angle observed on the outcrops in the subdomain V. Lower hemisphere projection.

Appendix 12

Geology

of the

J58 area

1. Locality

The locality of the J58 area is as follows;

Northwestern corner; UTM_EW 561399, UTM_NS 7434213

Southwestern corner; UTM_EW 561215, UTM_NS 7389930

Northeastern corner; UTM_EW 592100, UTM_NS 7434055

Southeastern corner; UTM_EW 591823, UTM_NS 7389769

2. Topography

The topography of the J58 area is shown in the Figure 1. Although the topography is approximately flat, the altitude simply decreases from east (around 750 m above the sea level) to the west (around 650 m above the sea level) as displayed the westward river flow. In the eastern area, there are small-scale ridges with relative elevation around 100m. The direction of the ridges is NNE-SSW.

3. Satellite image

The Landsat image with true color, Red = Band 3, Green = Band 2, Blue = Band 1, is shown in Figure 2. The red and black lines on the image are geological structure and lineament traced on the image, respectively. The geological structure directed NNE-SSW is dominant in the eastern area. The ridges mentioned above are clearly visible on the satellite image as white lines. The folds in the western area open westward.

4. Geological survey

Table 1 indicates classification of the rock samples used in the field. The number of the outcrops observed is 158. Figure 3 shows locality of the outcrops, lithology, strike direction and dipping on the topographical image. The colors of the points indicate lithology displayed in the Table 1.

The outcrops of the pelitic gneiss are distributed in the eastern area where geological structure with NNE-SSW direction is abundant. Quartzite is observed on the ridges displayed as white lines on the satellite image. In the central to western area magnetite-bearing gneiss and garnet-bearing gneiss exist. The western end of this area contains metaigneous rocks such as augen gneiss and syenite.

Gneisses in the all 8 areas commonly include coarse-grained quartz and

feldspar. The portion including coarse-grained quartz and feldspar shows lenticular or irregular shape. Photos 1 to 3 exhibit the example of the pelitic gneiss. The coarse-grained parts included in the pelitic gneiss appear granitic gneiss. With the considerations of the high temperature metamorphism in the southern Madagascar, it is highly possible that these coarse-grained parts are originated from the melt formed by partial melting of the gneisses.

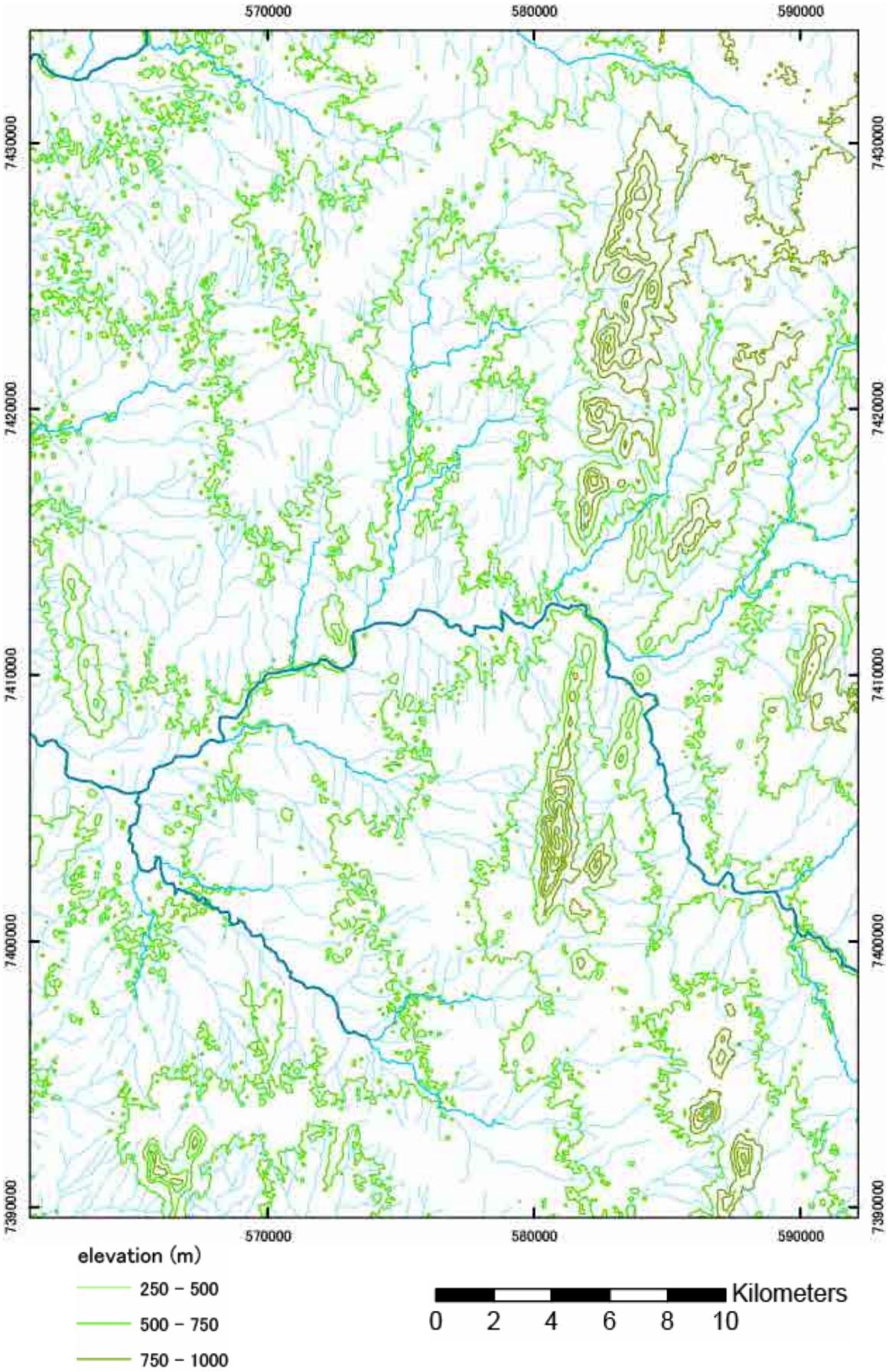


Figure 1. Topographical map of the J58 area


Figure 2. Landsat image of the J58 area

Table 1. Classification of the rocks

| ID | Rock Name | Color | Abb. | Propotion of Qtz & Fld | Metamorphic mineral | Foliation | Origin | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1 | Quartzite | | Qtz | Qtz | Grt, Bt, Sil, Crd… | clear | Sedimentary rocks | |
| 2 | Psammitic Gneiss | | Psm | Qtz > Fld | Grt, Bt, Sil, Crd… | clear | Sedimentary rocks | |
| 3 | Pelitic Gneiss | | Plt | Qtz = Fld, Qtz < Fld | Grt, Bt, Sil, Crd… | clear | Sedimentary rocks | |
| 4 | Garnet-bearing Gneiss | | GrtGn | Qtz = Fld, Qtz < Fld | mainly Grt | clear | Sedimentary rocks | |
| 5 | Magnetite-bearing Gneiss | | MagGn | Qtz = Fld, Qtz < Fld | mainly Mag | clear | Sedimentary rocks | |
| 6 | Amphibolite-bearing Gneiss | | AmpGn | Qtz = Fld, Qtz < Fld | mainly Amp | clear | Sedimentary rocks | |
| 7 | Gneiss | | Gn | Qtz = Fld, Qtz < Fld | mainly Bt | clear | Sedimentary rocks | |
| 8 | Granite | | Gr | | Bt (small amount) | not clear | Igneous rocks | Granitic Texture preserved |
| 9 | Granitic Gneiss | | GrGn | | Bt (small amount) | clear | Igneous rocks | Granitic Texture preserved |
| 10 | Augen Gneiss | | AugGn | Fld Megacryst | | clear | Igneous rocks | Granitic Texture preserved |
| 11 | Syenite | | Sy | Kfd, Amp (Qtz) | | not clear | Igneous rocks | |
| 27 | Micro Granite | | McGr | | | | | |
| 12 | Charnockite | | Chk | Opx | | | Igneous rocks | Opx-bearing granitic rock |
| 13 | Pegmatite[*3] | | Peg | Large Grain Size | | | Igneous rocks | Dikes or Lens or Layer[*4] |
| 14 | Pyroxenite | | Px | Pyroxene (diopside) | | | Igneous rocks | ultramafic composition |
| 15 | Amphibolite | | Amp | Amphibole | | | Igneous rocks / Metamorphic rocks | mafic (basaltic) composition |
| 16 | Gabbro | | Ga | Pyroxene (augite, Opx), Plagioclase | | | Igneous rocks | mafic (basaltic) composition |
| 17 | Diorite | | Di | Amphibole, Pyroxene, Fld | | | Igneous rocks | andesitic composition |
| 18 | Migmatite | | Mgm | Mixture of irregular shaped gneiss [*5] and felsic rock network. Available on the outcrop only. Tsy misy "migmatite rock sample" | | | | |
| 19 | Mylonite | | My | strongly deformed | | | sometime unknown | |
| 20 | Basalt | | Ba | | | | volcanic rocks | mafic |
| 21 | Andesite | | An | | | | volcanic rocks | intermediate |
| 22 | Rhyolite | | Rh | | | | volcanic rocks | felsic |
| 23 | Carbonate | | Car | Marble, Limestone | | | | |
| 24 | Calcsilicate | | Cls | carbonate-silicate | | | | |
| 25 | Carbonate-Pyroxenite | | Car-Px | | | | | |
| 26 | Laterite | | | | | | | |
| 28 | River Sediment | | | | | | | |

*1 : Describe the amount & the order of amount
*2 : Indicating the amount of clay mineral in the original rocks
*3 : If misy Pegmatite in the outcrop, describe with host. Ex) Pelitic Gneiss with Pegmatite Dikes, Granitic Gneiss with Pegmatite Lens,,,
*4 : Dike cuts the host folication, Lens and Layer are parallel to the host foliation.
*5 : Possibly all kinds of gneiss

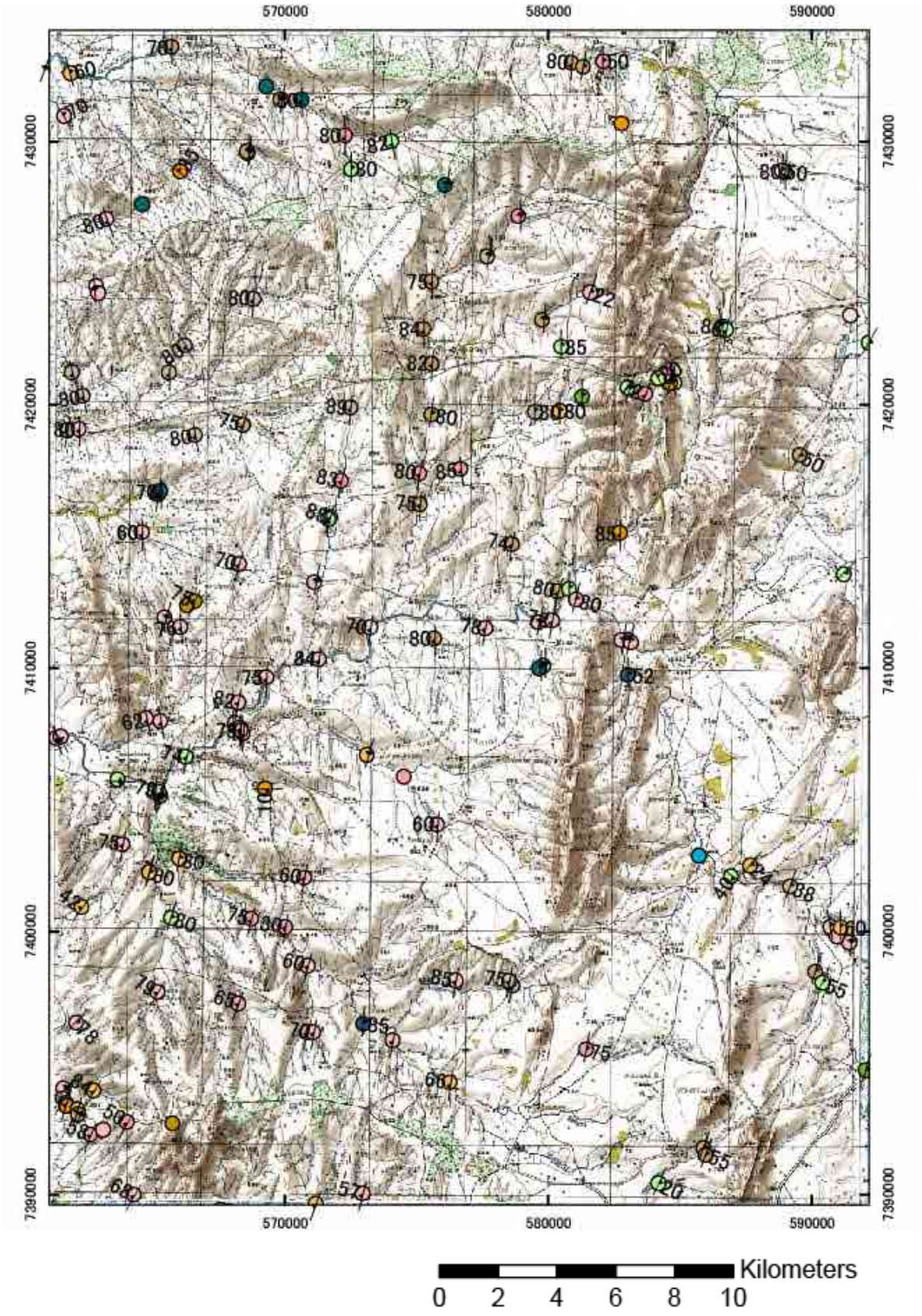


Figure 3. Locality of the outcrops

Photo 1. Pelitic gneiss deformed and including coarse-grained quartz and feldspar

Photo 2. Pelitic gneiss deformed and including coarse-grained quartz and feldspar

Photo 3. Pelitic gneiss deformed and including coarse-grained quartz and feldspar

5. Geological survey for the all 8 areas

The information about geological and geological structure around the J58 is necessary for the geological mapping. The satellite image with natural color and geological structure traced on the image for the all 8 areas are shown in the Figure 4. The red and black lines are geological structure and lineament, respectively. Figure 5 is geological map for the all 8 areas created in this study. The legend and lithology are indicated in the Figure 6. Figure 7 is simple inspection about geological structure. Open and closed dots indicate dip angle less than 50 degree and more than 50 degree, respectively. The major axes of the diamonds displays strike direction and their color means dipping direction like this. In the eastern part of the study area, west-dipping is abundant. This is eastern opening anticline structure. In the center, low-angle east-dipping prevails. In the boundary zone between center and western parts, there is west-dipping and western opened syncline structure. The study area is divided into two domains, Androyen and Anosyen. These domains are split up into subdomains.

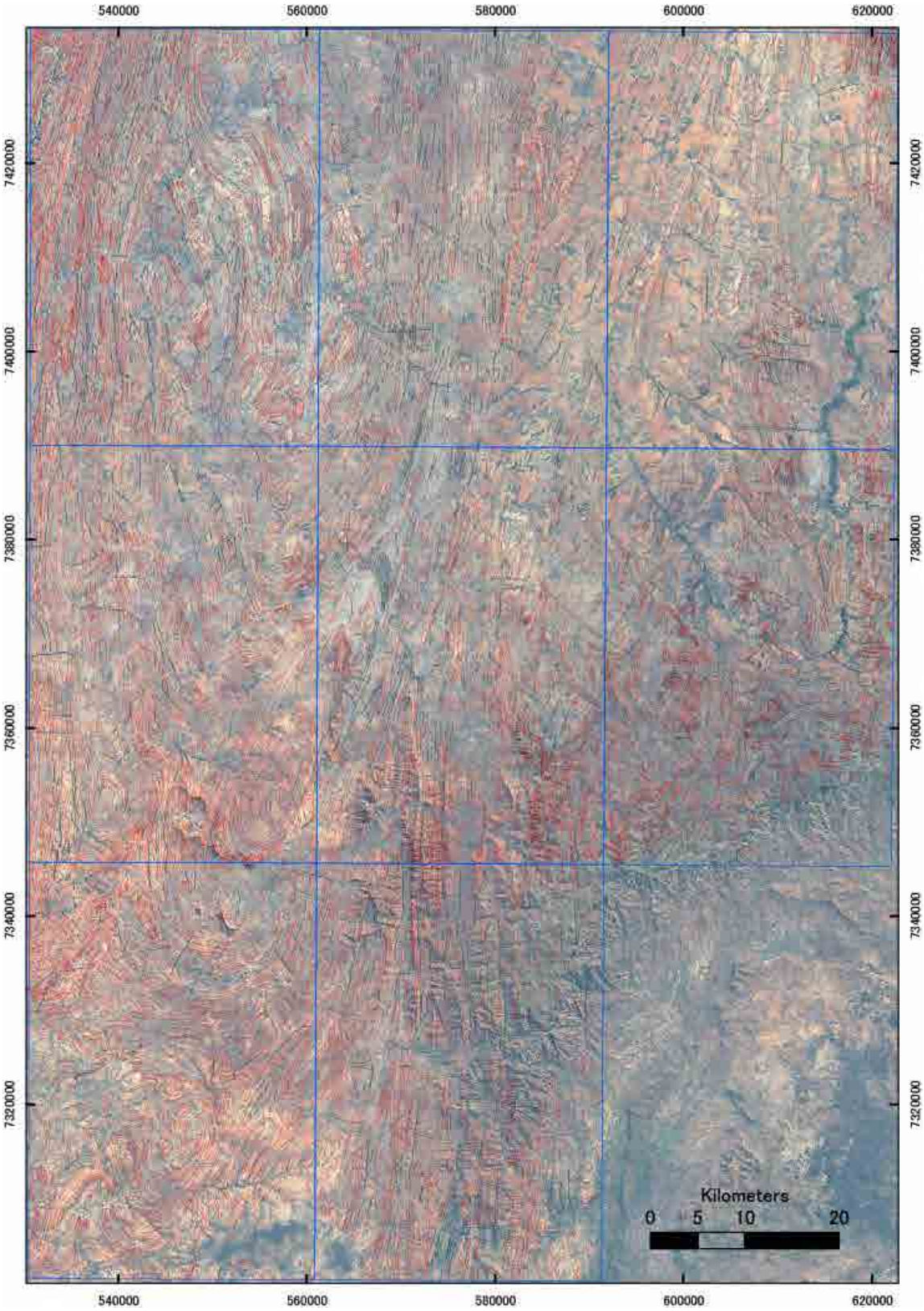


Figure 4. Landsat image with true color for the all 8 areas

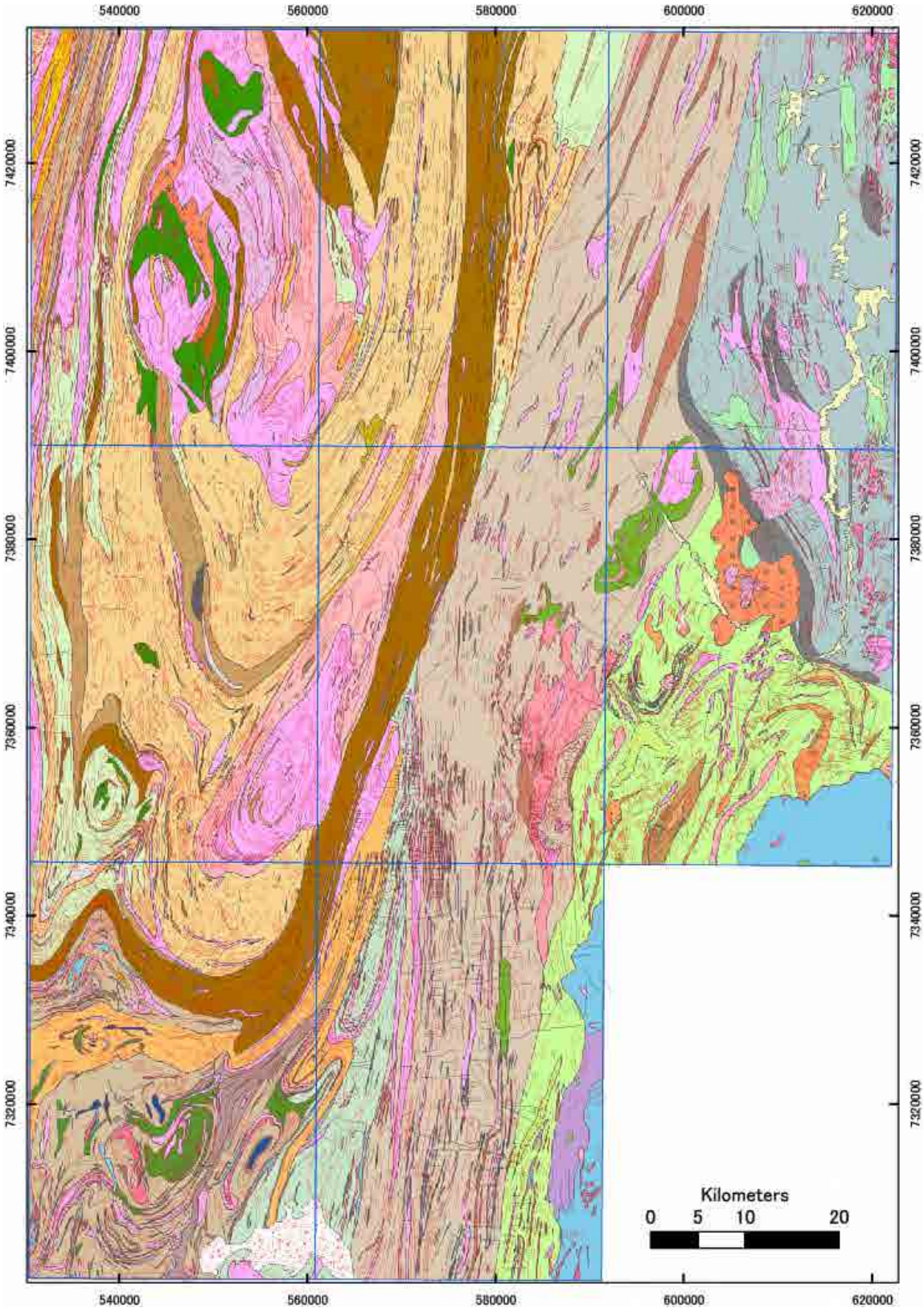


Figure 5. Geological map for the all 8 areas

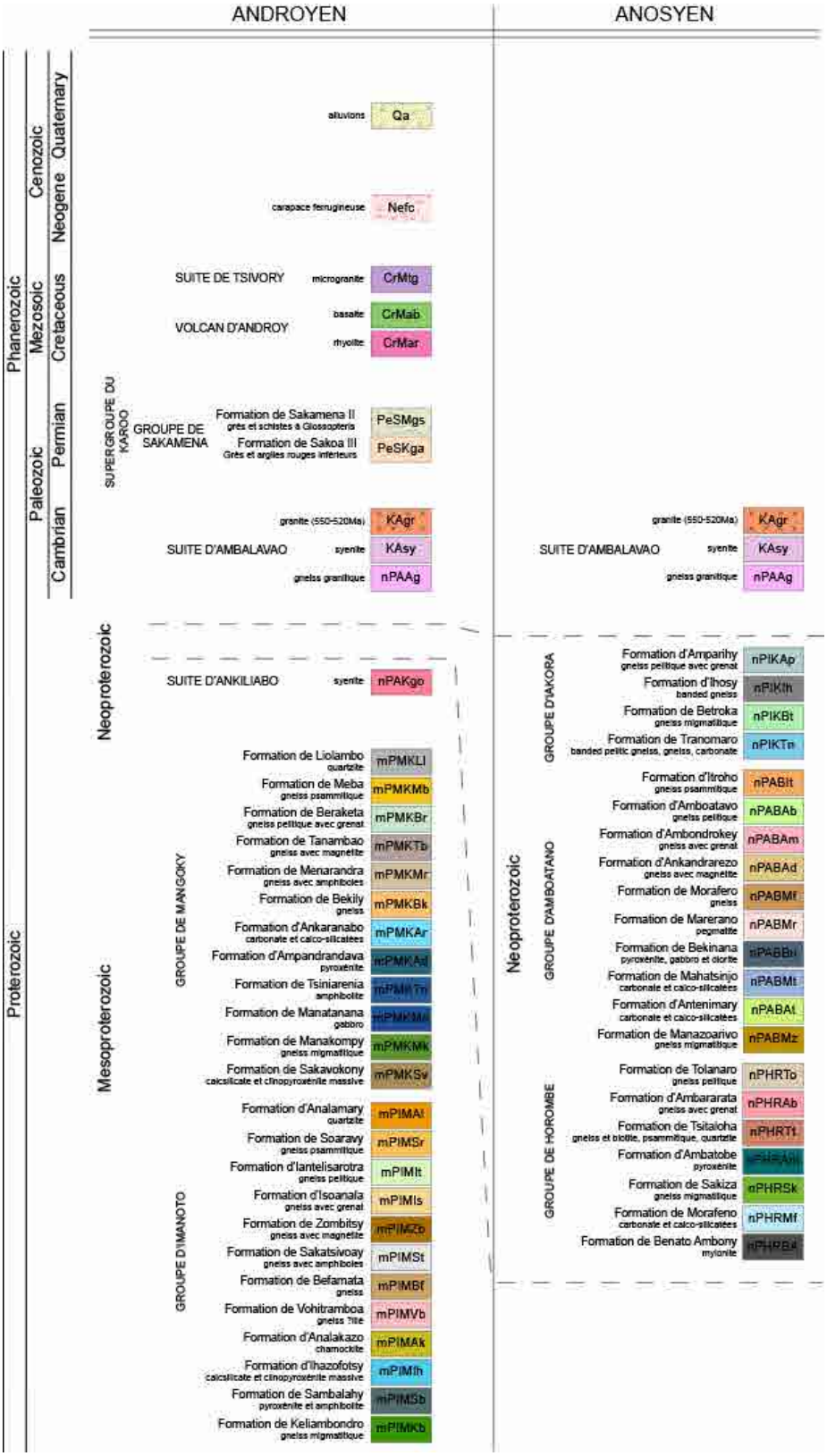


Figure 6. Legend for the geological map

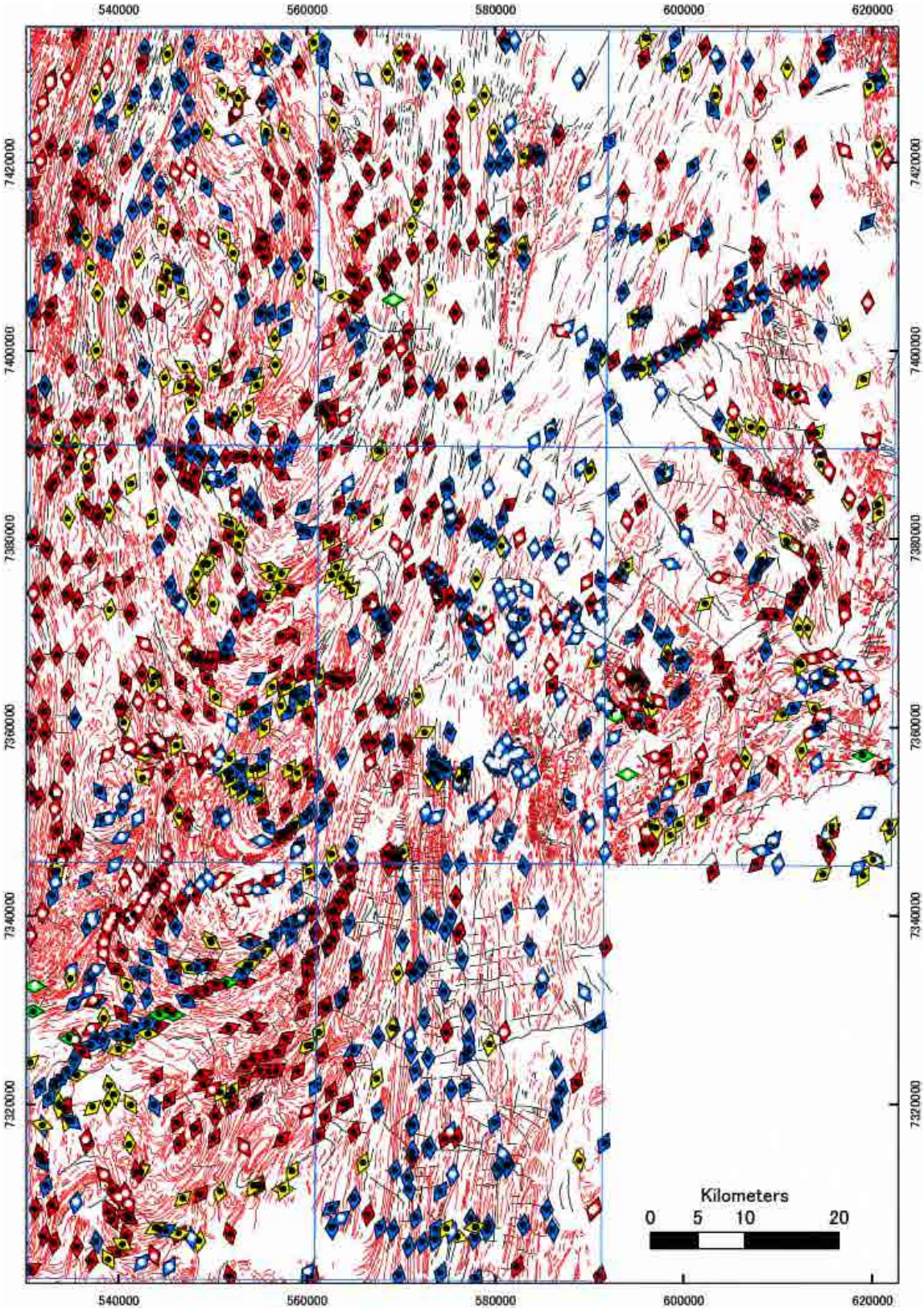


Figure 7. Geological structure for the all 8 areas

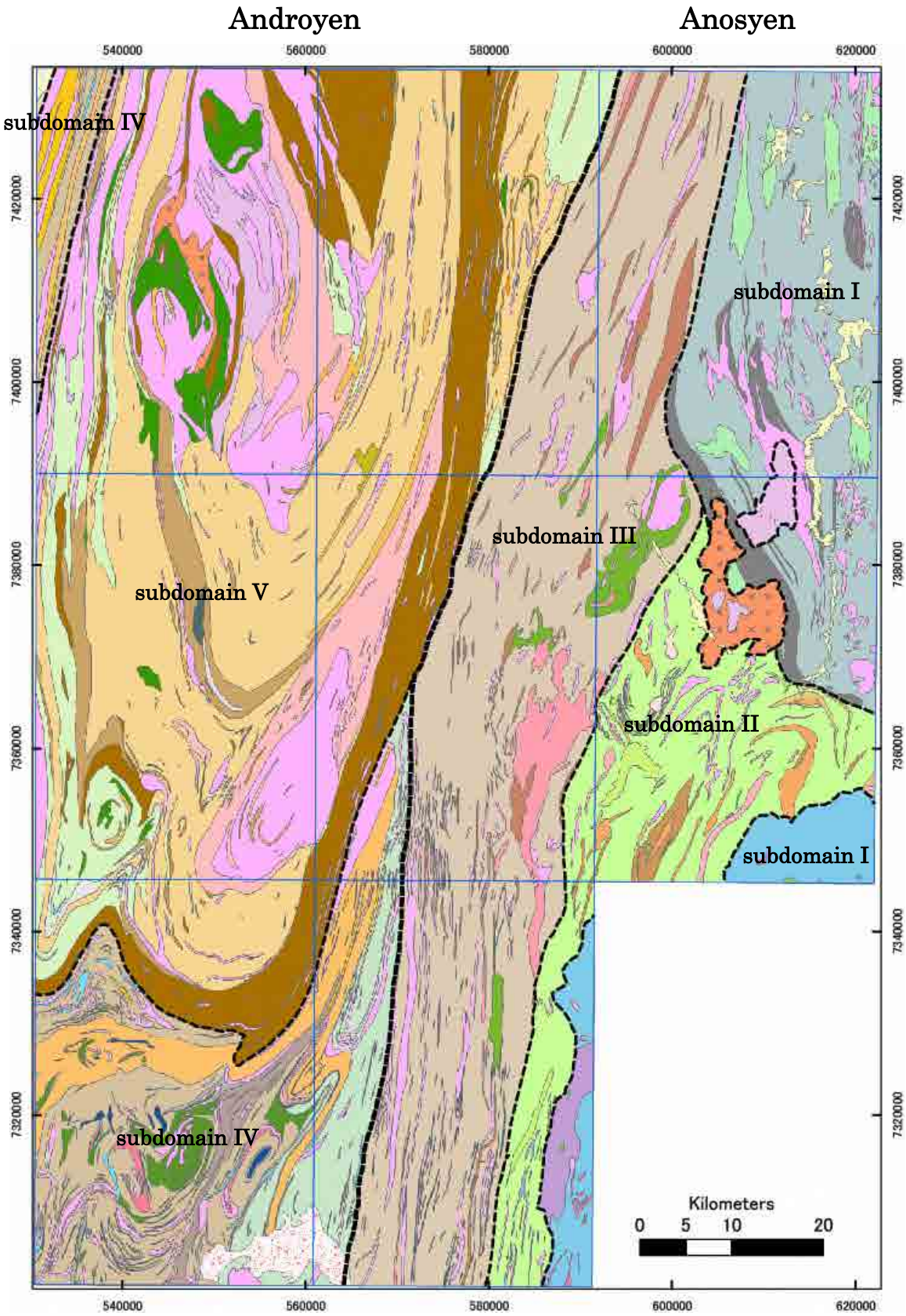


Figure 8. Geological domains and subdomains for the all 8 areas

6. Geology of the J58 area

Figure 9 shows geological map and profile of the J58 area. Legend and lithology are displayed in the Figure 10. The J58 area belongs to the Androyen domain except for the southeastern area included in the Anosyen domain. The J58 area of the Androyen and Anosyen domains correspond to subdomains V and III, respectively. The geological structures observed on the outcrops in the subdomains III and V are projected on the Schmidt's nets (Figures 11 and 12). The low and eastward dipping is dominant in the subdomain III. On the other hand, major structure in the subdomain V demonstrates NS to NNE-SSW strike and high angle west dipping.

The pelitic gneiss is broadly distributed in the subdomain III. In the subdomain V, garnet-bearing gneiss, magnetite-bearing gneiss, augen gneiss, granitic gneiss and syenite constitute a fold opening westward. The small ridges displayed as white lines on the satellite image consist of the quartzite.

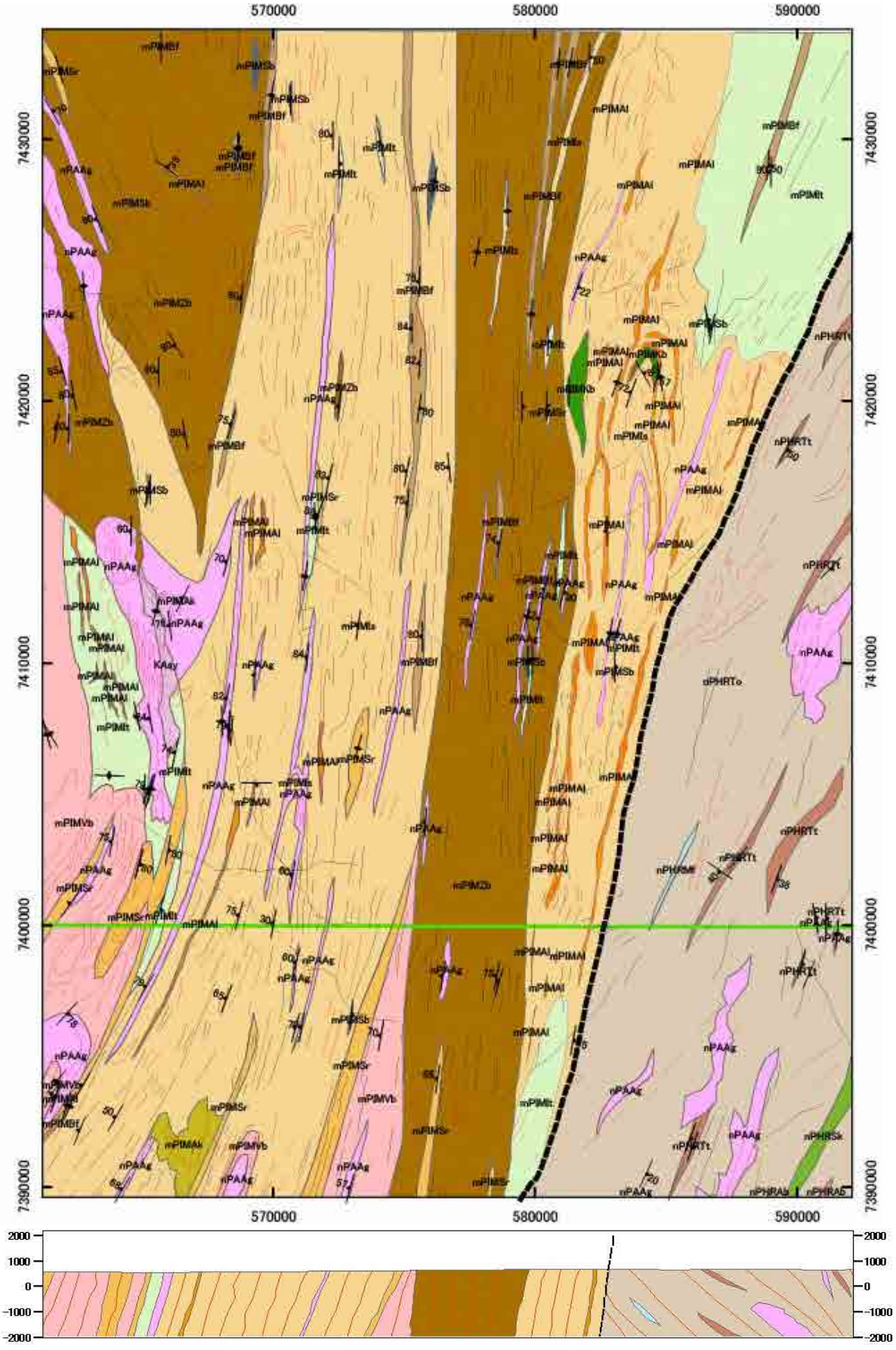


Figure 9. Geological map and profile

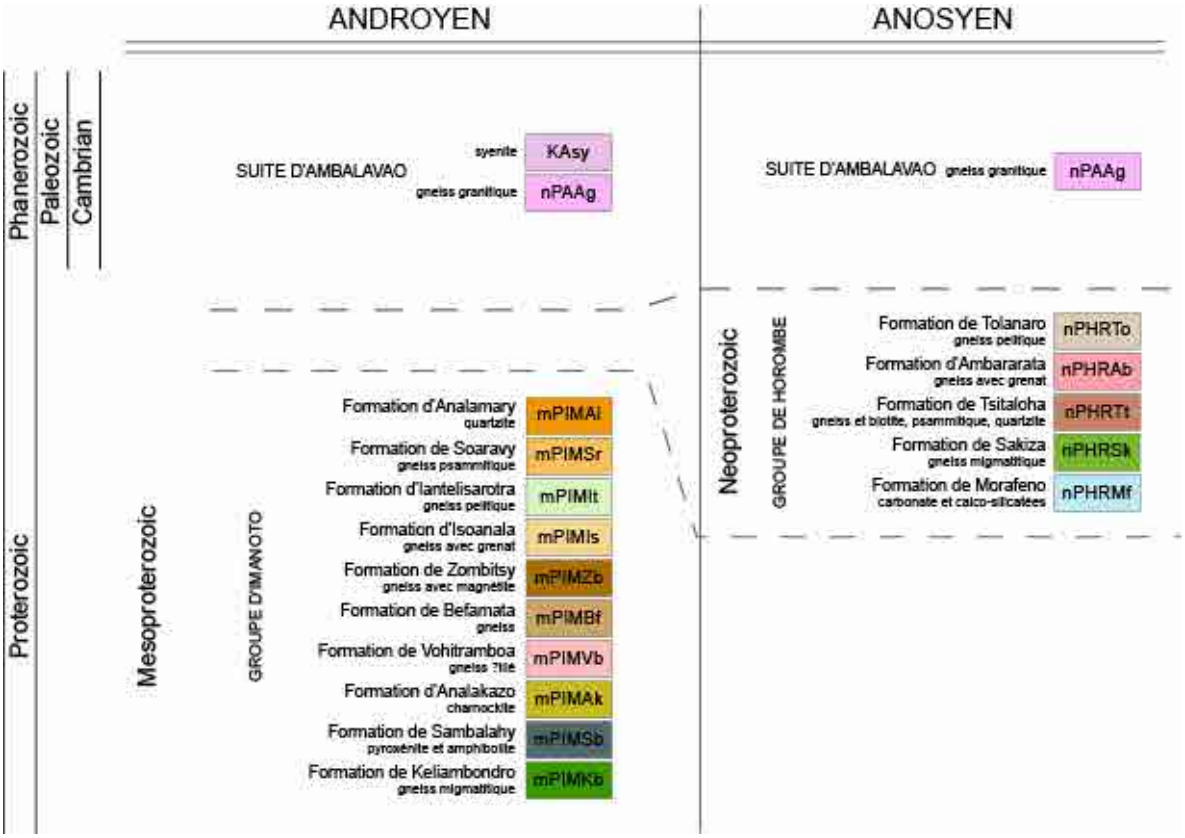


Figure 10. Legend and lithology

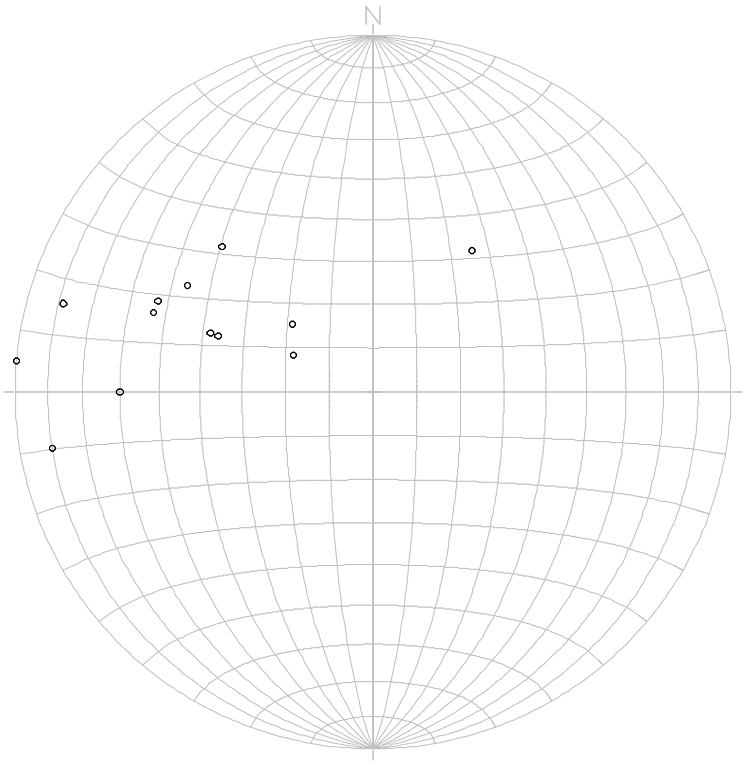


Figure 11. Schmidt's net projection of the strike direction and dip angle observed on the outcrops in the subdomain III. Lower hemisphere projection.

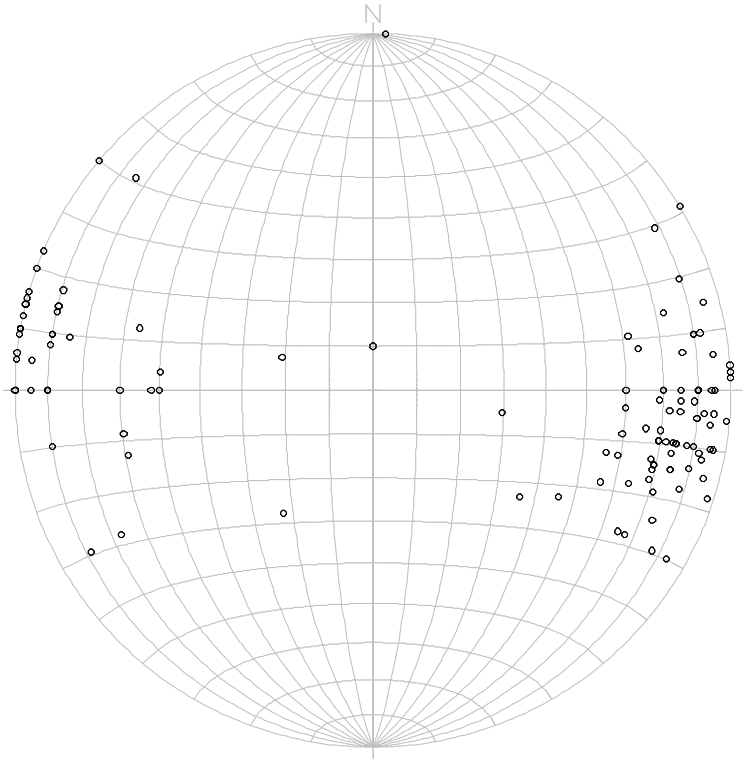


Figure 12. Schmidt's net projection of the strike direction and dip angle observed on the outcrops in the subdomain V. Lower hemisphere projection.

# Appendix 13

# Geology

# of the

# J59 area

1. Locality

The locality of the J59 area is as follows;

Northwestern corner; UTM_EW 561215, UTM_NS 7389930

Southwestern corner; UTM_EW 561027, UTM_NS 7345643

Northeastern corner; UTM_EW 591823, UTM_NS 7389769

Southeastern corner; UTM_EW 591543, UTM_NS 7345481

2. Topography

Figure 1 indicates the topography of the J59 area. In this area, three mountain ridges are distributed. First, the altitude of the mountain ridges with NNE-SSW direction is around 1000 m above the see level and around 350m of the relative elevation in the southeastern area. Second mountain ridges with NE-SW direction, 1400 m above the sea level, are distributed in the western area. Third ranges with NS direction, 1200 m above the sea level are located between first and second ranges.

3. Satellite image

The Landsat image with true color, Red = Band 3, Green = Band 2, Blue = Band 1, is shown in Figure 2. The directions of the geological structure correspond to that of the mountain ridges.

4. Geological survey

Table 1 indicates classification of the rock samples used in the field. The number of the outcrops observed is 307. Figure 3 shows locality of the outcrops, lithology, strike direction and dipping on the topographical image. The colors of the points indicate lithology displayed in the Table 1.

The outcrops of the augen gneiss and granitic gneiss are abundant around the mountain range with NNE-SSW in the western area. On the outcrops they are strongly deformed with the direction parallel to that of the mountain range. Garnet-bearing gneiss is observed on the northwestern side of the mountain range. Garnet-bearing gneiss, pelitic gneiss and psammitic gneiss are confirmed in and around the mountain range in the southeastern area. In the mountain ridges with NS direction in the southern center of the area pelitic gneiss, granitic gneiss and mylonite are distributed. They are strongly deformed with the same direction as the mountain range, NS.

Photo 1 shows the pelitic gneiss with heterogeneous texture. Although pelitic gneiss includes coarse-grained feldspar, their genetic relationship is unknown. Photo 2 is a quartzite layer included in the pelitic gneiss. This quartzite lacks feldspar, is dark in color and contains magnetite and garnet (Photo 3). Photo 4 to 6 display the variation of the pelitic gneiss. The pelitic gneiss of Photo 4 composes quartz, feldspar, garnet, biotite and magnetite and exhibits sinistral shear. The pelitic gneiss sometimes includes sillimanite which shows needle shape and transparent and often concentrates (Photo 5). Photo 6 is an example of the pelitic gneiss containing the cordierite layer. The color of the cordierite is dark violet and transparent.

Photo 7 displays the mountain ridges with NNE-SSW direction in the western area. The augen gneiss which constitutes this mountain range is variously deformed (Photos 8 to 10). The direction of their foliation is parallel to that of the mountain ridges.

The primary rockslide rarely occurs. The locality of the rockslide (Photo 11) is around 10 km west of Isoanala. The joint is not clear but rock falls down along the joint. The rock is the pelitic gneiss including garnet and biotite (Photo 12).

The pegmatite vein and layer are very common in not only the J59 area but also all 8 areas. Photo 13 is an example of the pegmatite with apatite.

The deformation structure observed on the outcrops is various. Photo 14 is an example of the boudins.

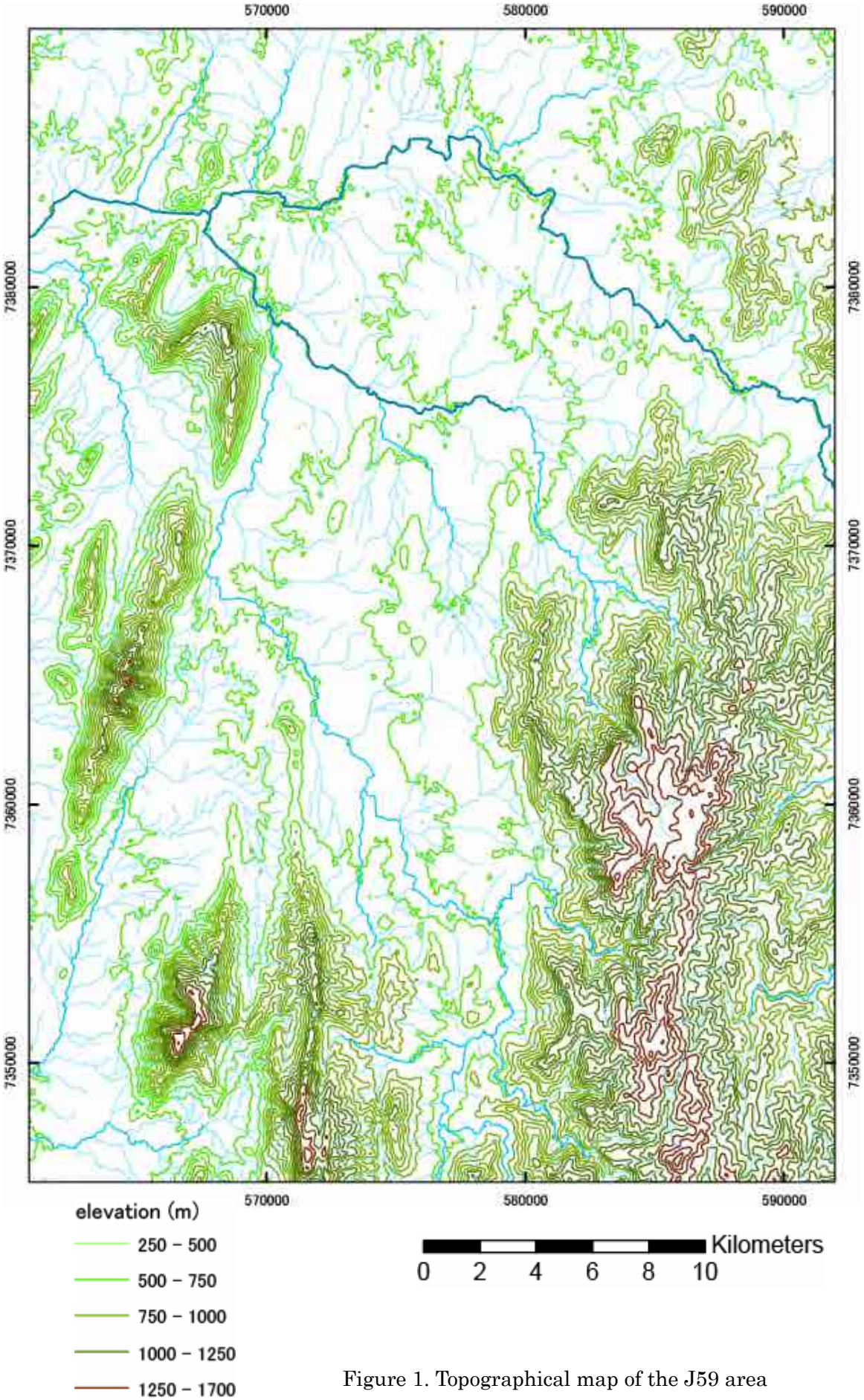


Figure 1. Topographical map of the J59 area

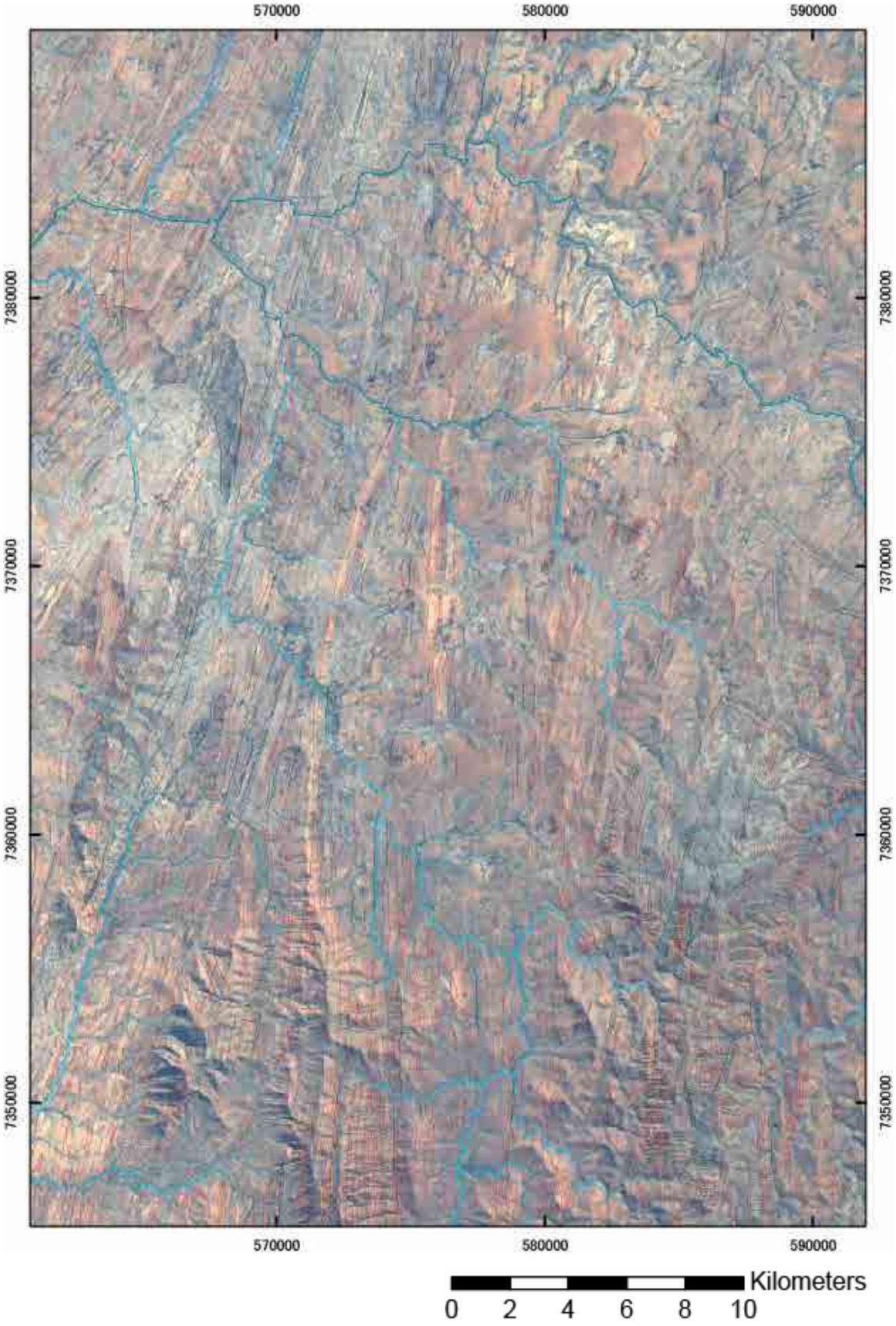


Figure 2. Landsat image of the J59 area

Table 1. Classification of the rocks

| ID | Rock Name | Color | Abb. | Propotion of Qtz & Fld | Metamorphic mineral | Foliation | Origin | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1 | Quartzite | | Qtz | Qtz | Grt, Bt, Sil, Crd… | clear | Sedimentary rocks | |
| 2 | Psammitic Gneiss | | Psm | Qtz > Fld | Grt, Bt, Sil, Crd… | clear | Sedimentary rocks | |
| 3 | Pelitic Gneiss | | Plt | Qtz = Fld, Qtz < Fld | Grt, Bt, Sil, Crd… | clear | Sedimentary rocks | |
| 4 | Garnet-bearing Gneiss | | GrtGn | Qtz = Fld, Qtz < Fld | mainly Grt | clear | Sedimentary rocks | |
| 5 | Magnetite-bearing Gneiss | | MagGn | Qtz = Fld, Qtz < Fld | mainly Mag | clear | Sedimentary rocks | |
| 6 | Amphibolite-bearing Gneiss | | AmpGn | Qtz = Fld, Qtz < Fld | mainly Amp | clear | Sedimentary rocks | |
| 7 | Gneiss | | Gn | Qtz = Fld, Qtz < Fld | mainly Bt | clear | Sedimentary rocks | |
| 8 | Granite | | Gr | | Bt (small amount) | not clear | Igneous rocks | Granitic Texture preserved |
| 9 | Granitic Gneiss | | GrGn | | Bt (small amount) | clear | Igneous rocks | Granitic Texture preserved |
| 10 | Augen Gneiss | | AugGn | Fld Megacryst | | clear | Igneous rocks | Granitic Texture preserved |
| 11 | Syenite | | Sy | Kfd, Amp (Qtz) | | not clear | Igneous rocks | |
| 27 | Micro Granite | | McGr | | | | | |
| 12 | Charnockite | | Chk | Opx | | | Igneous rocks | Opx-bearing granitic rock |
| 13 | Pegmatite*3 | | Peg | Large Grain Size | | | Igneous rocks | Dikes or Lens or Layer*4 |
| 14 | Pyroxenite | | Px | Pyroxene (diopside) | | | Igneous rocks | ultramafic composition |
| 15 | Amphibolite | | Amp | Amphibole | | | Igneous rocks / Metamorphic rocks | mafic (basaltic) composition |
| 16 | Gabbro | | Ga | Pyroxene (augite, Opx), Plagioclase | | | Igneous rocks | mafic (basaltic) composition |
| 17 | Diorite | | Di | Amphibole, Pyroxene, Fld | | | Igneous rocks | andesitic composition |
| 18 | Migmatite | | Mgm | Mixture of irregular shaped gneiss *5 and felsic rock network. Available on the outcrop only. Tsy misy "migmatite rock sample" | | | | |
| 19 | Mylonite | | My | strongly deformed | | | sometime unknown | |
| 20 | Basalt | | Ba | | | | volcanic rocks | mafic |
| 21 | Andesite | | An | | | | volcanic rocks | intermediate |
| 22 | Rhyolite | | Rh | | | | volcanic rocks | felsic |
| 23 | Carbonate | | Car | Marble, Limestone | | | | |
| 24 | Calcsilicate | | Cls | carbonate-silicate | | | | |
| 25 | Carbonate-Pyroxenite | | Car-Px | | | | | |
| 26 | Laterite | | | | | | | |
| 28 | River Sediment | | | | | | | |

*1 : Describe the amount & the order of amount
*2 : Indicating the amount of clay mineral in the original rocks
*3 : If misy Pegmatite in the outcrop, describe with host. Ex) Pelitic Gneiss with Pegmatite Dikes, Granitic Gneiss with Pegmatite Lens,,,
*4 : Dike cuts the host folication, Lens and Layer are parallel to the host foliation.
*5 : Possibly all kinds of gneiss

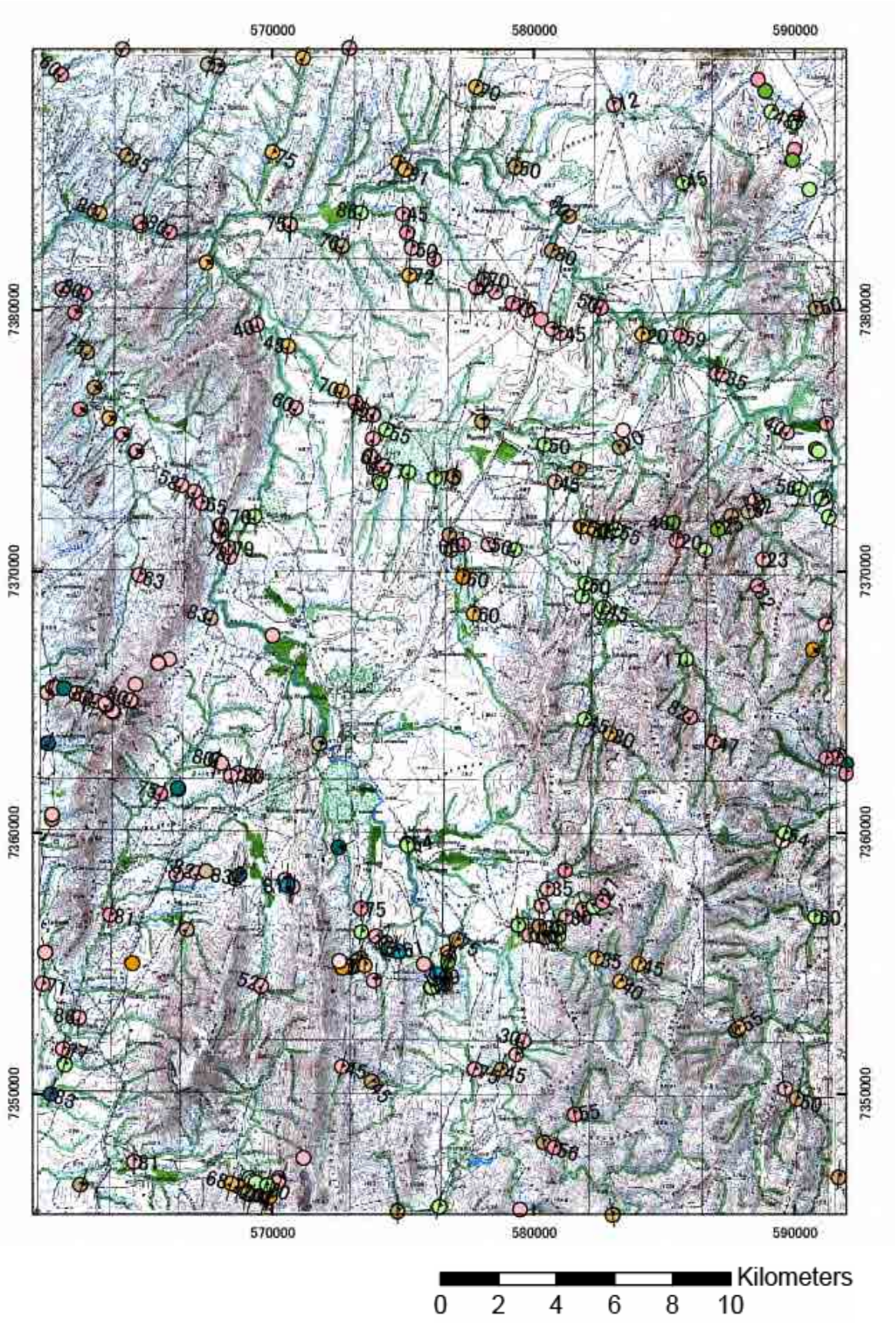


Figure 3. Locality of the outcrops

Photo 1. Pelitic gneiss with heterogeneous texture

Photo 2. Quartzite layer included in pelitic gneiss

Photo 3. Close-up of the quartzite with garnet and magnetite

Photo 4. Pelitic gneiss including coarse-grained garnet

Photo 5. Pelitic gneiss including sillimanite concentrate

Photo 6. Pelitic gneiss including cordierite layer

Photo 7. Mountain range with NNE-SSW direction, comprising augen gneiss

Photo 8. Augen gneiss heterogeneously deformed

Photo 9. Augen gneiss strongly deformed

Photo 10. Augen gneiss not deformed

Photo 11. Primary rockslide

Photo 12. Close-up. Pelitic gneiss

Photo 13. Pegmatite vein including apatite

Photo 14. Boudins

5. Geological survey for the all 8 areas

The information about geological and geological structure around the J59 is necessary for the geological mapping. The satellite image with natural color and geological structure traced on the image for the all 8 areas are shown in the Figure 4. The red and black lines are geological structure and lineament, respectively. Figure 5 is geological map for the all 8 areas created in this study. The legend and lithology are indicated in the Figure 6. Figure 7 is simple inspection about geological structure. Open and closed dots indicate dip angle less than 50 degree and more than 50 degree, respectively. The major axes of the diamonds displays strike direction and their color means dipping direction like this. In the eastern part of the study area, west-dipping is abundant. This is eastern opening anticline structure. In the center, low-angle east-dipping prevails. In the boundary zone between center and western parts, there is west-dipping and western opened syncline structure. The study area is divided into two domains, Androyen and Anosyen. These domains are split up into subdomains.

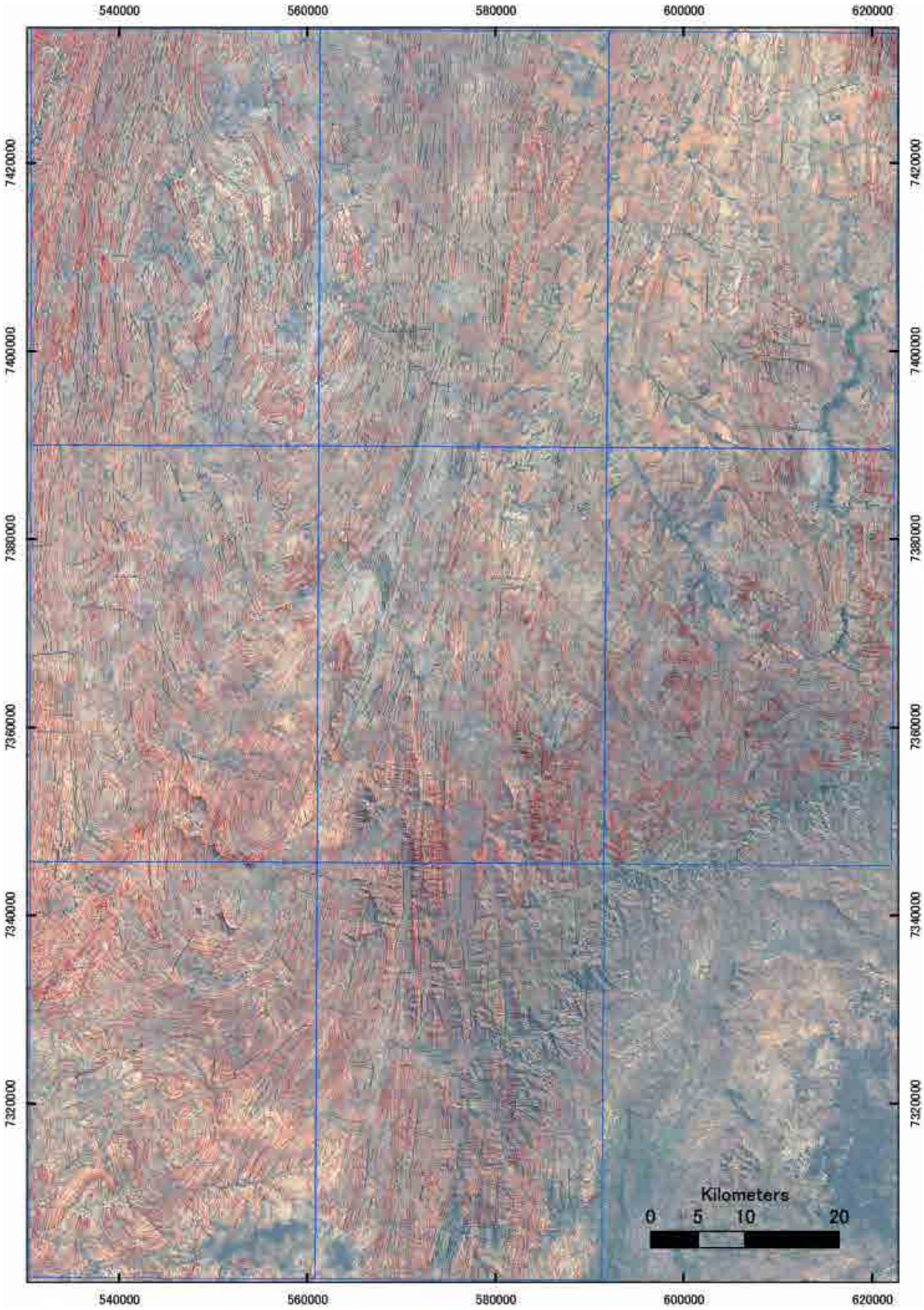


Figure 4. Landsat image with true color for the all 8 areas

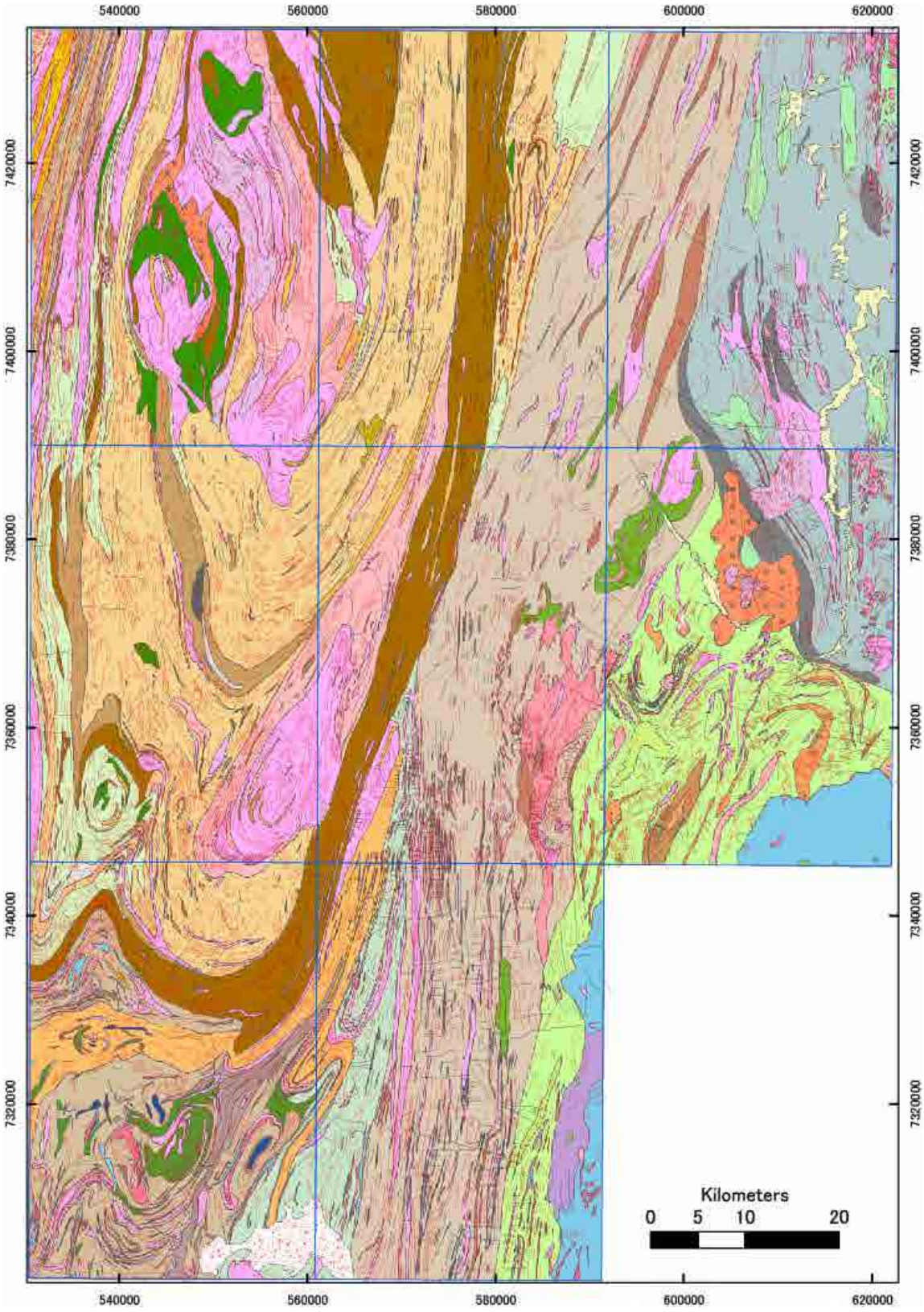


Figure 5. Geological map for the all 8 areas

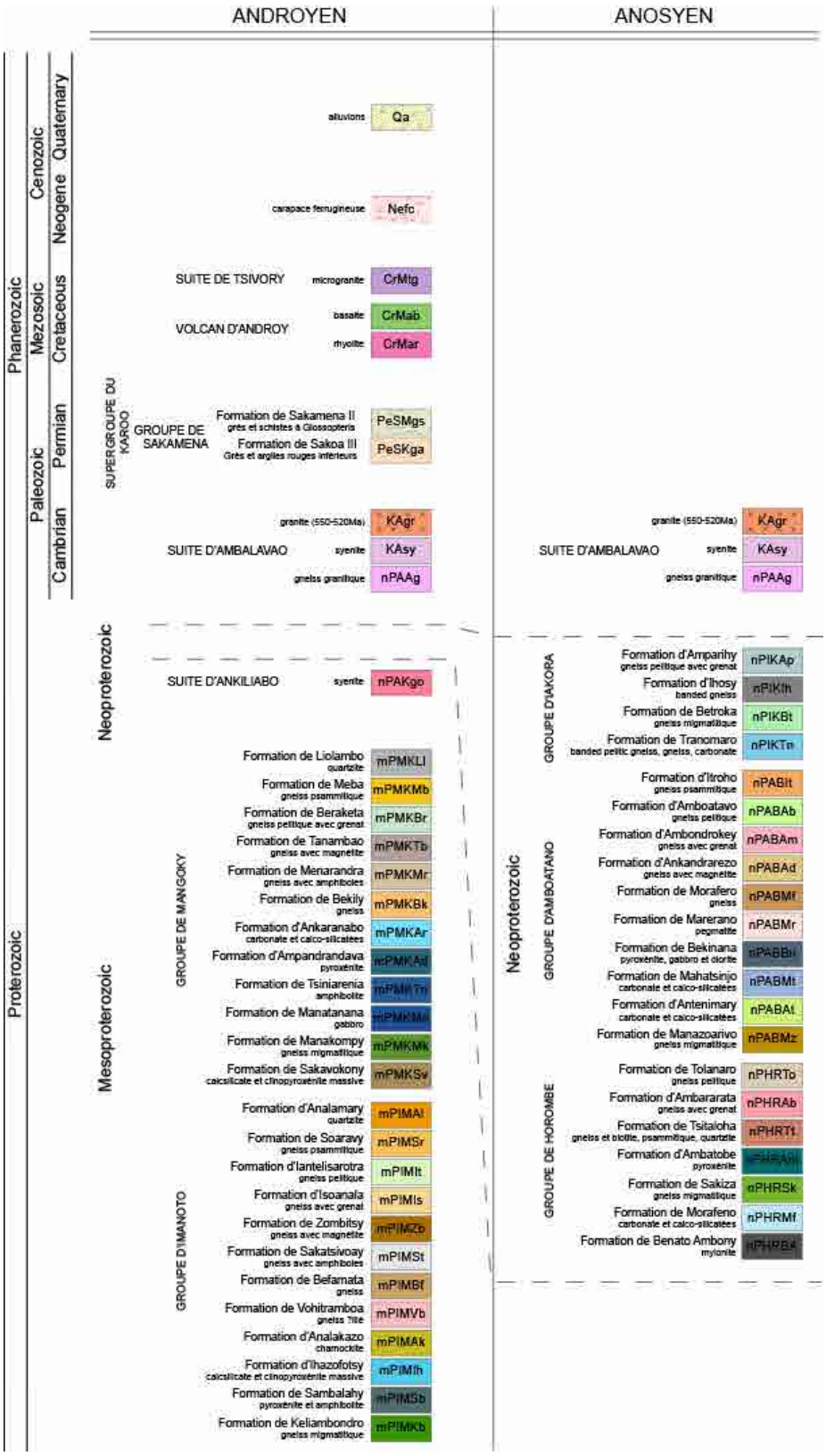


Figure 6. Legend for the geological map

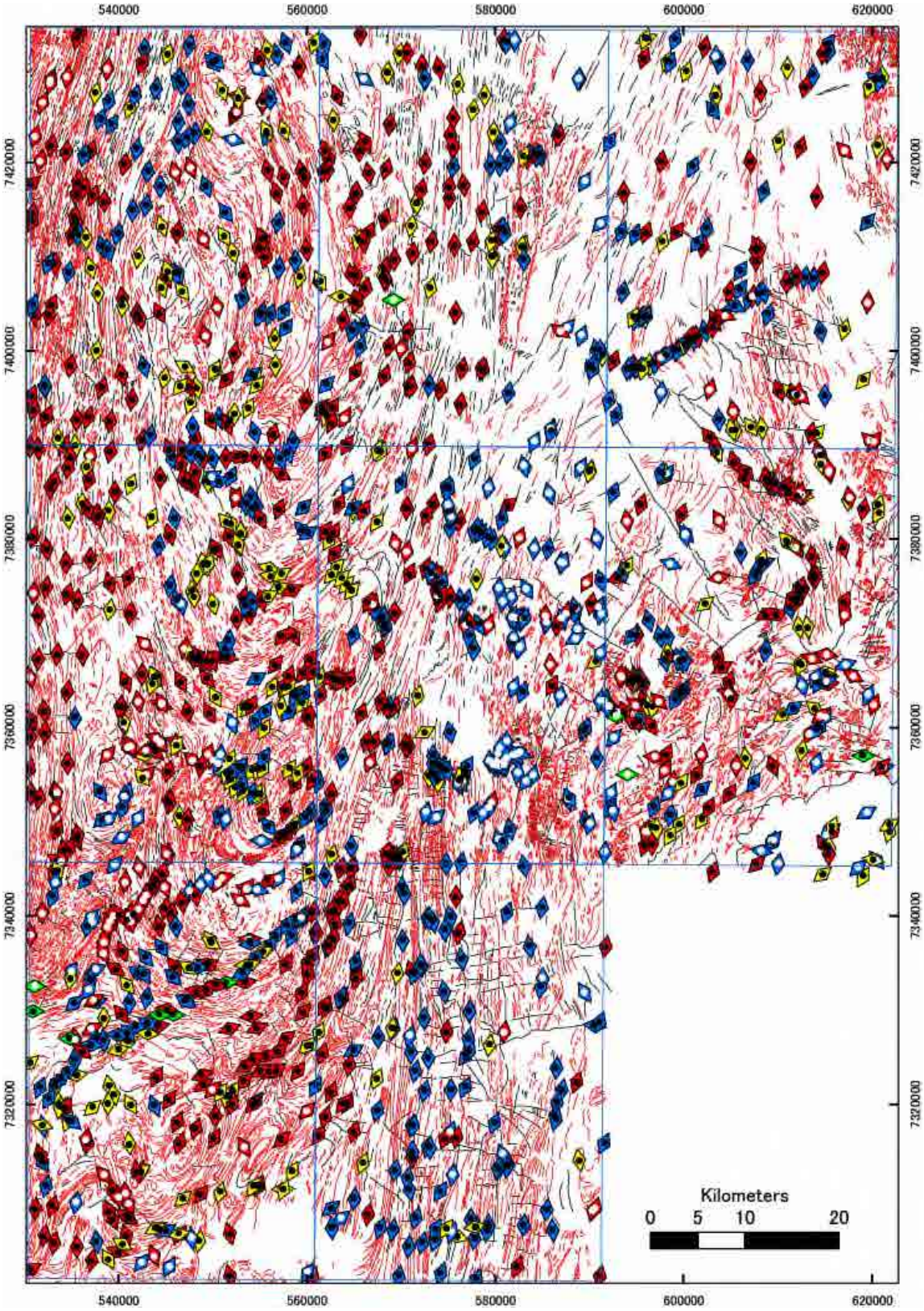


Figure 7. Geological structure for the all 8 areas

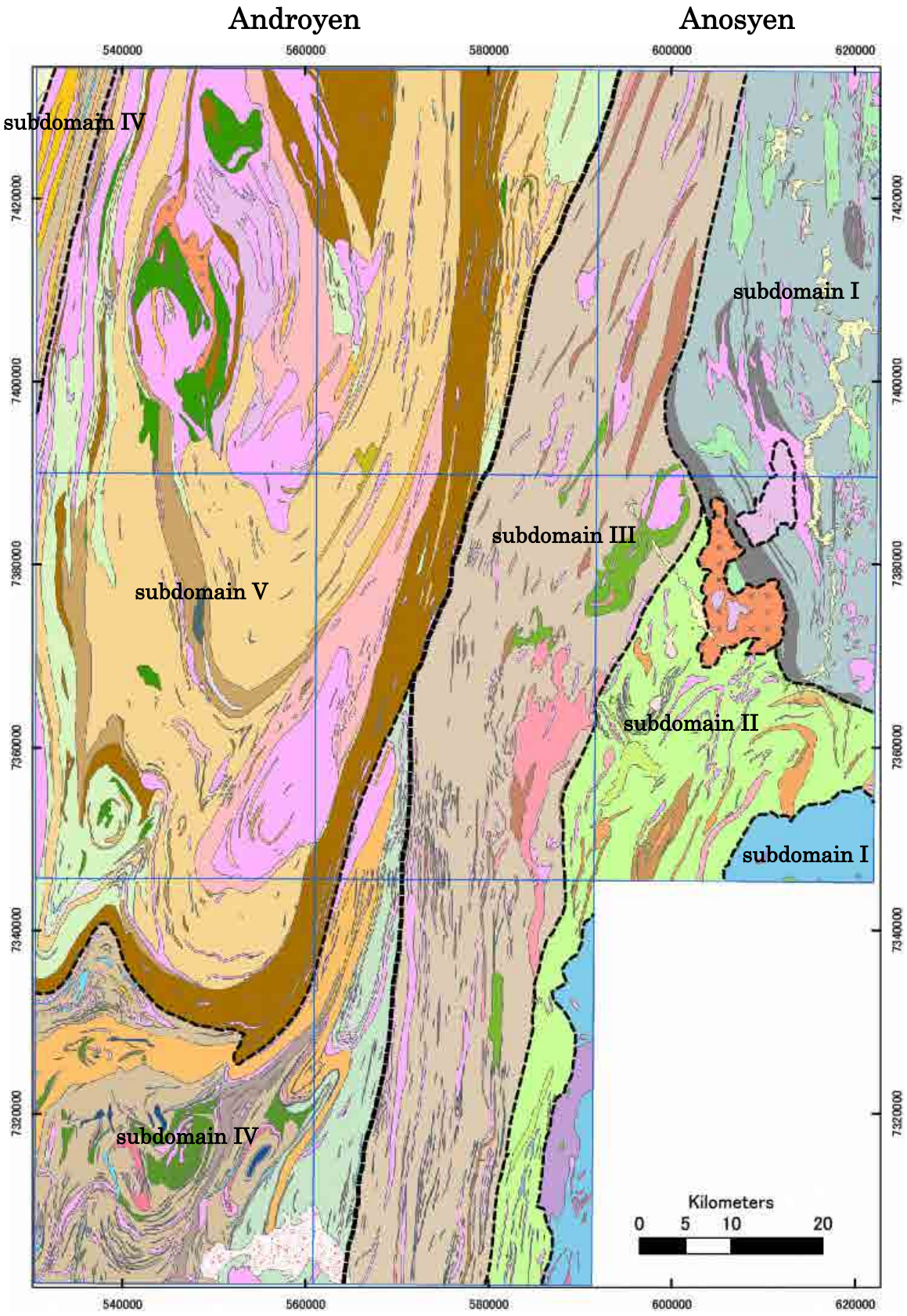


Figure 8. Geological domains and subdomains for the all 8 areas

6. Geology of the J59 area

Figure 9 shows geological map and profile of the J59 area. Legend and lithology are displayed in the Figure 10. The western 1/3 and eastern 1/3 of the J59 area belong to the Androyen and Anosyen domains, respectively. The Androyen domain of the J59 area is divided into subdomains IV and V. The Anosyen domain of the J59 area consists of subdomains I and II. These subdomain distributions correspond to that of the mountain ridges in the J59 area.

Gneiss, psammitic gneiss and pelitic gneiss including quartzite are broadly distributed in the subdomain III. Subdomain IV consists of pelitic gneiss and gneiss. Many layers of the granitic gneiss exist in the boundary zone between subdomains III and IV. These layers show NS strike direction. The magnetite-bearing gneiss is distributed as a wide layer in the eastern edge of the subdomain V. The mountain range in the western area comprises the augen gneiss and granitic gneiss. The garnet-bearing gneiss occupies the northwestern area.

According to the Schmidt's net projections, the structures of NS strike and low eastern dipping, and NNE-SSW strike and high dip angle are prevalent in the subdomain III and subdomains IV and V (Figures 11 to 13).

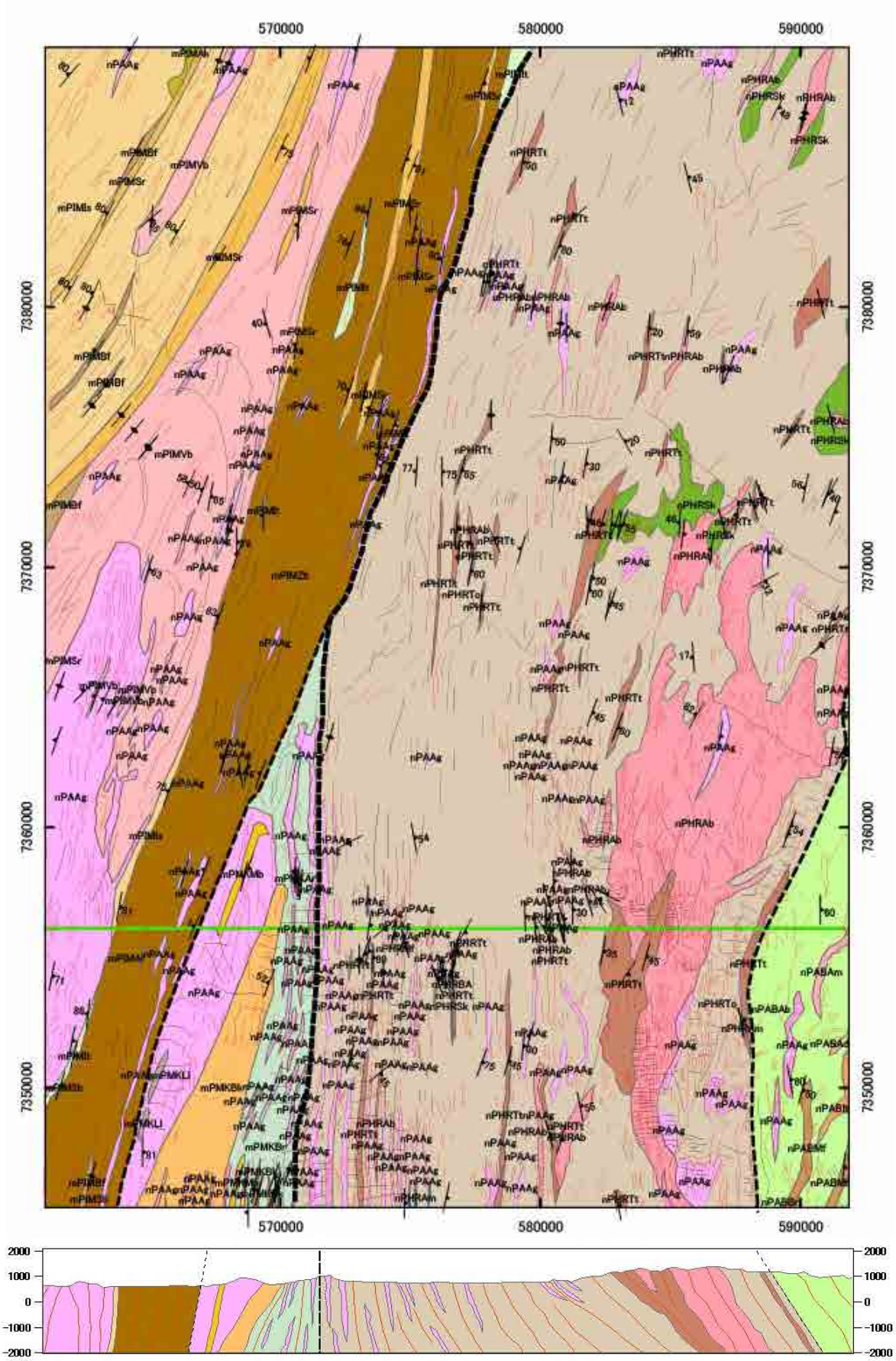


Figure 9. Geological map and profile

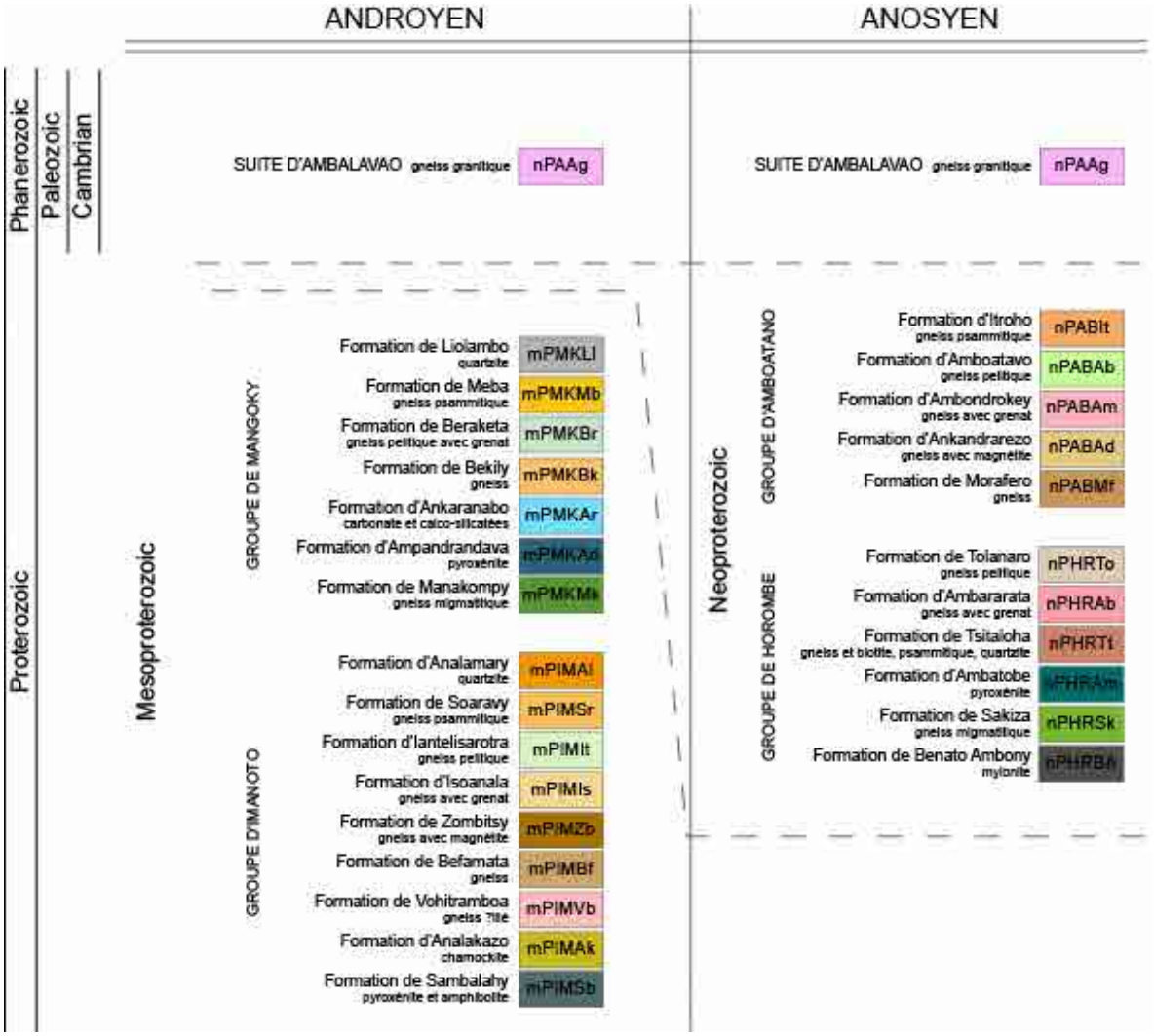


Figure 10. Legend and lithology

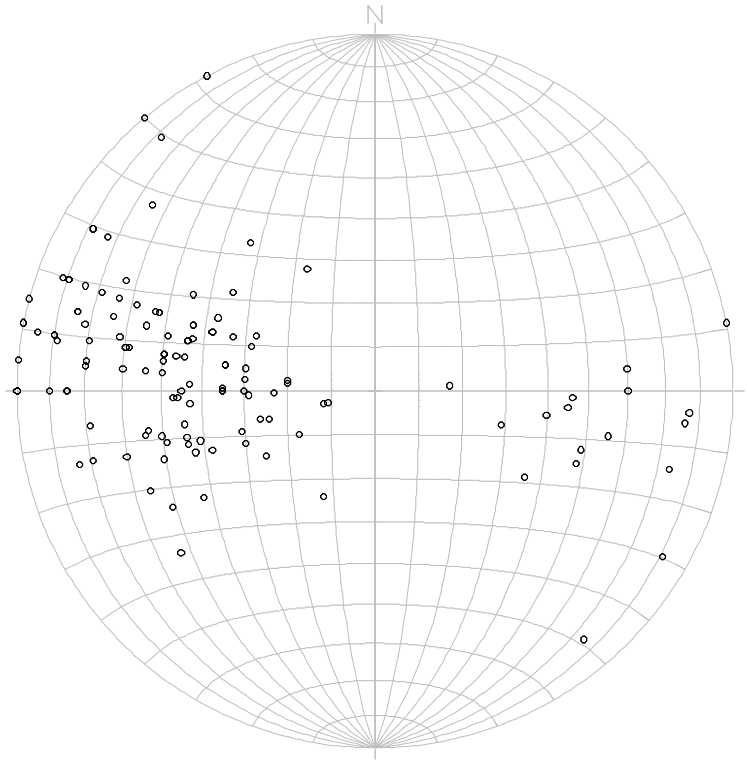


Figure 11. Schmidt's net projection of the strike direction and dip angle observed on the outcrops in the subdomain III. Lower hemisphere projection.

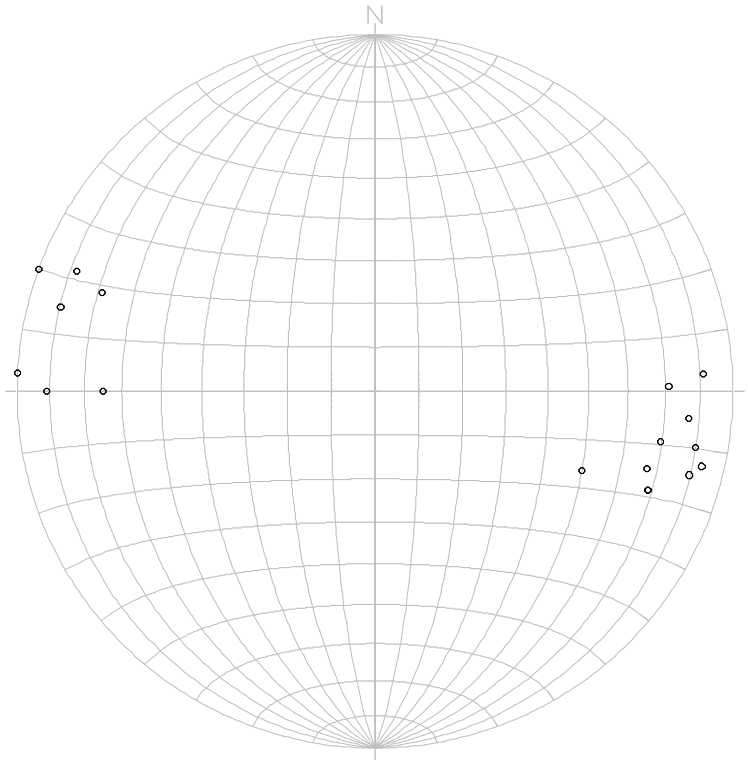


Figure 12. Schmidt's net projection of the strike direction and dip angle observed on the outcrops in the subdomain IV. Lower hemisphere projection.

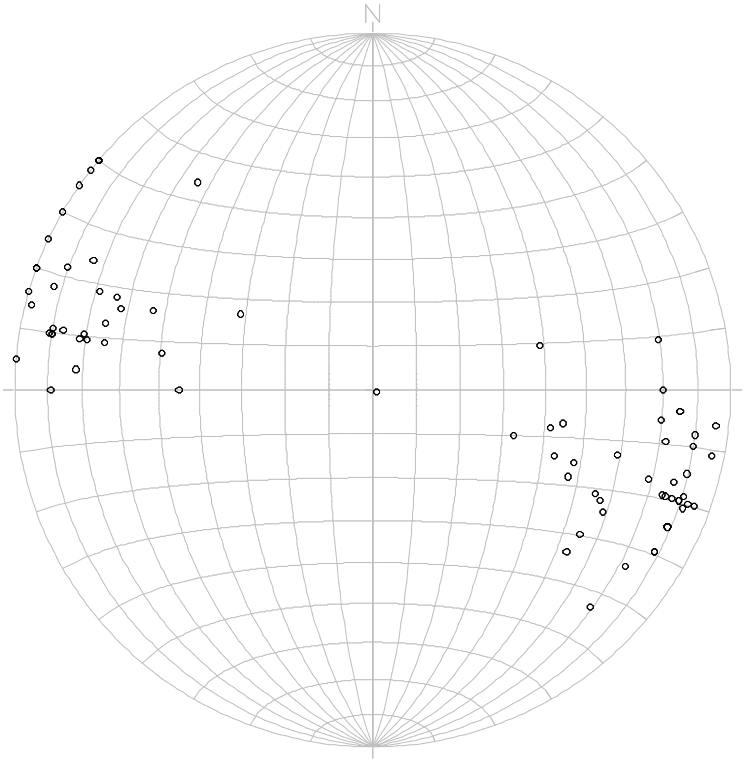


Figure 13. Schmidt's net projection of the strike direction and dip angle observed on the outcrops in the subdomain V. Lower hemisphere projection.