Classification of fault rock

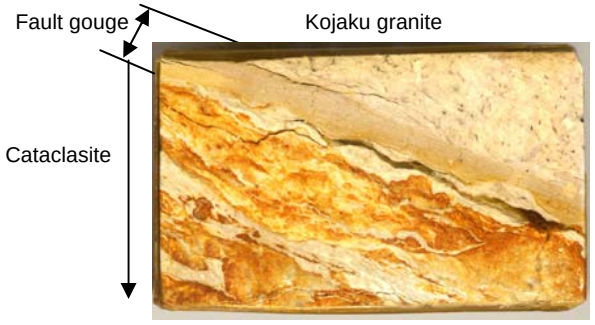
Crushing		Fusion	Recrystallization
Random fabric or foliated			Foliated
Incohesive	Cohesive		
Fault breccia Fault gouge	Protocataclasite Cataclasite Ultracataclasite	Pseudotachylyte	Protomylonite Mylonite Ultramylonite

Grain-size reduction

Boundary values for sub-classification		
Name	Proportion of visible fragments	Grain size of fragment
Fault breccia	>30%	Megabreccia >256 mm Mesobreccia 10-256 mm Microbreccia <10 mm
Fault gouge	<30%	<10 mm in normal
	Proportion of fragments	Grain size of fragment
Protocataclasite Cataclasite Ultracataclasite	>50% 10-50% <10%	<10 mm in normal
	Proportion of porphyroclasts	Grain size of matrix mineral
Protomylonite Mylonite Ultramylonite	Variable depending on the lithology of protolith	>100 μm 20-100 μm <20 μm

Source: Proposed classification of fault rocks (by Takagi & Kobayashi, 1996)

In Kojaku granite that is found in the site, white fault gouge and cataclasite are distributed, while black fault gouge is distributed along dolerite.

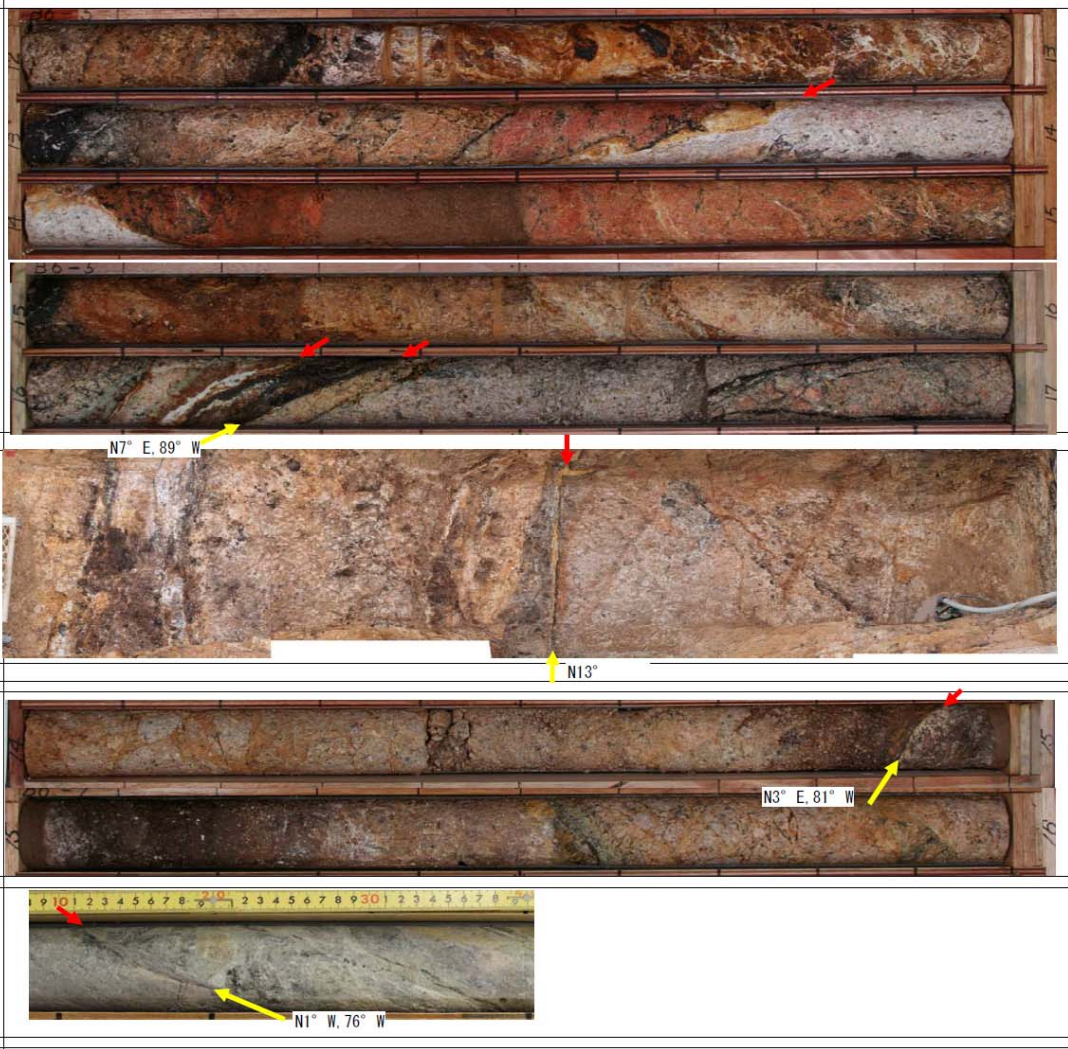


D-1 shatter zone catalog (1/2)

shatter zone No.	Confirmation hole	shatter zone range: Hanging wall depth (m)	shatter zone range: Foot wall depth (m)	Crushing width (cm)	Property (from hanging wall side)	Color tone: Fault gouge	Color tone: Cataclasite	Strike *Magnetic north	Dip	Displacement sense: Vertical	Displacement sense: Horizontal
D-1	B6-5	12.28	16.35	172	Fault gouge and cataclasite	Yellowish-white, gray-brown	Gray-brown, ash gay, orange, reddish brown, light gray green	N7E	89W	—	—
	[illegible]	—	—	100	Fault gouge and cataclasite	Gray-brown	Brown-yellow, ash gay, light reddish brown, dark brown	N13E ※	67W	Normal fault	Right-lateral slip
	B6-1	14.76	15.58	63	Fault gouge and cataclasite	Brown, Yellowish-white	dark brown, dull-orange	N3E	81W	—	—
	B14-2	109.16	109.46	8	Cataclasite occurred between fault gouges	Bright gray green	Ash gray, bright gray green	N1W	76W	Normal fault	Right-lateral slip

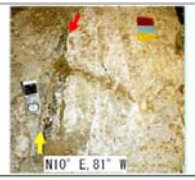
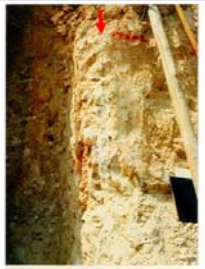
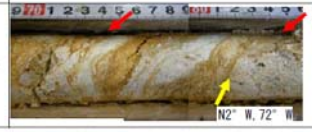
Photos of core and polished section

: Fault gouge : Measurement place for strike and dip



D-1 shatter zones consist of cataclasite and fault gouge, run roughly in a direction of N-S, are high-angle westerly dip.

D-1 shatter zone catalog (2/2)

shatter zone No.	Confirmation hole	shatter zone range: Hanging wall depth (m)	shatter zone range: Foot wall depth (m)	Crushing width (cm)	Property (from hanging wall side)	Color tone: Fault gouge	Color tone: Cataclasite	Strike * Magnetic north	Dip	Displacement sense: Vertical	Displacement sense: Horizontal	Photos of core and polished section
D-1	H-6a (test tunnel)	–	–	10～120	Fault gouge and cataclasite	light gray green, brown-green	Ash gay, light brownish -yellow, yellowish-white	N10E	81W	–	–	
	H-6 (bottom surface of Unit 2)	–	–	–	Fault gouge and cataclasite	Yellowish-white, slight -brownish -yellow	Light brown, yellowish-white	N10E ～5W	75～80W	–	–	 shatter zone H-6  shatter zone H-6a closeup
	No.14	86.12	87.03	51	Cataclasite occurred between fault gouges	Ash gay, grayish brown -yellow	Light white-pink, gray	N20E	81W	–	–	
	②-1	49.21	51.10	80	Stripe texture of fault gouge and cataclasite	Ash gray, orange	Yellowish-white, light brown, light pinkish-gray	–	–	Normal fault	Right-lateral slip	  Unable to measure strike and dip
	No.2	149.71	149.84	8.0	Fault gouge	Ash gray, brown	Brownish-yellow, ash gray	N2W	72W	–	–	
	outcrop	–	–	50.0	Fault gouge and cataclasite	Dark gray	Light yellowish-white, light pinkish-gray, brown, ash gray, brownish-yellow	N16E	73W	Normal fault	Right-lateral slip	

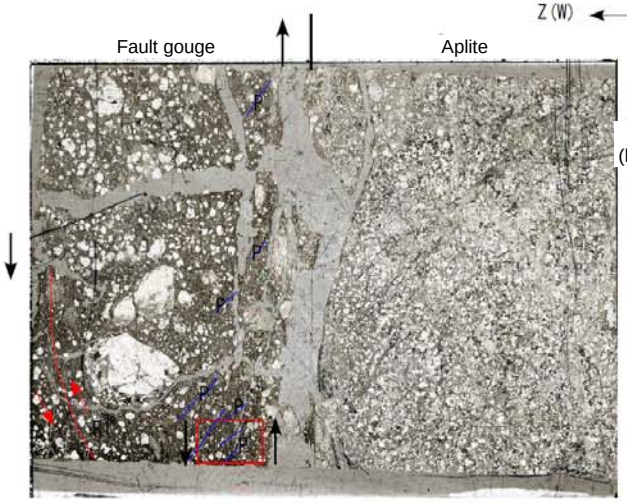
Photos of core and polished section : Fault gouge : Measurement place for strike and dip

D-1 shatter zones consist of cataclasite and fault gouge, run roughly in a direction of N-S, are high-angle westerly dip.

[Displacement sense of shatter zone] Results of observation of thin section collected from B-14-2 hole (vertical components)

B14-2 hole YZ direction

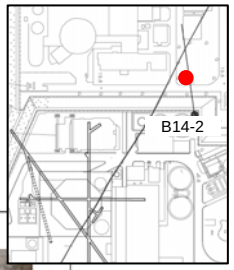
10cm



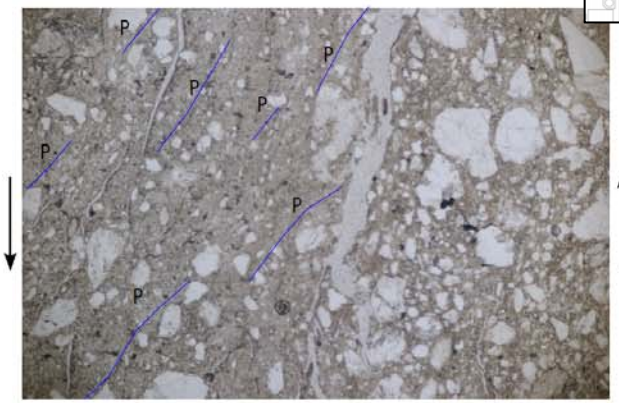
Parallel nicols

Crossed nicols

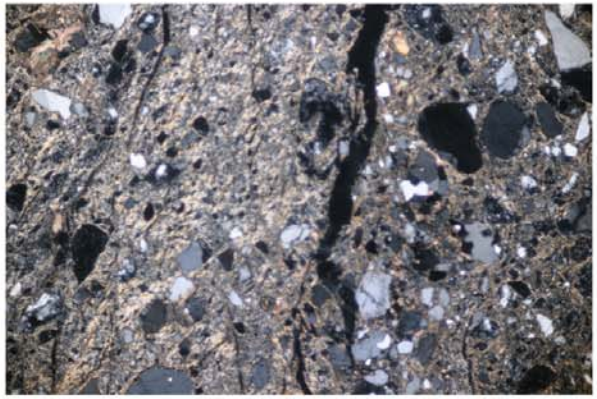
1cm



Area within red frame is enlarged



Parallel nicols



Crossed nicols

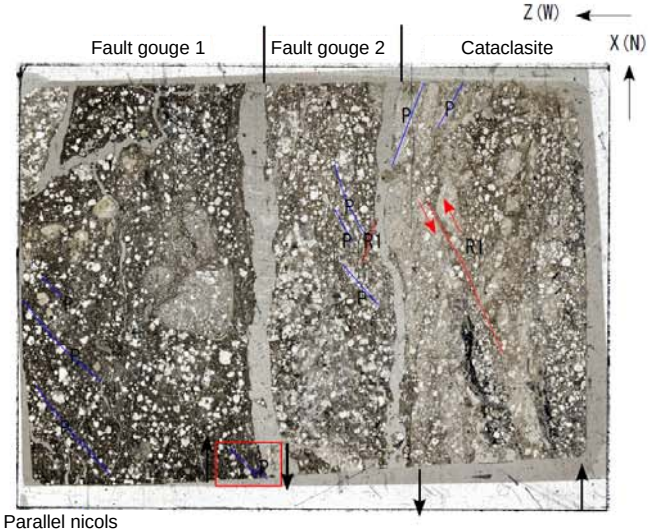
1mm

- Fault gouge (last slip)
  Consists of the brown-gray matrix of fine grain, as well as quartz, feldspar, cataclasite fragment and calcite that are semi-circular gravels or sub-angular gravels with diameters of 0.1 to 5 mm. The matrix contains lots of clay minerals and calcite. The displacement sense of normal fault can be recognized from R1 and P.
- Aplite
  Contains fine grains of quartz, potassium feldspar, plagioclase, biotite, muscovite and calcite.

[Displacement sense of shatter zone] Results of observation of thin section collected from B-14-2 hole (horizontal components)

B14-2 hole XZ direction

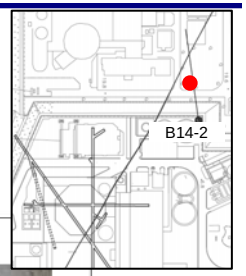
10cm



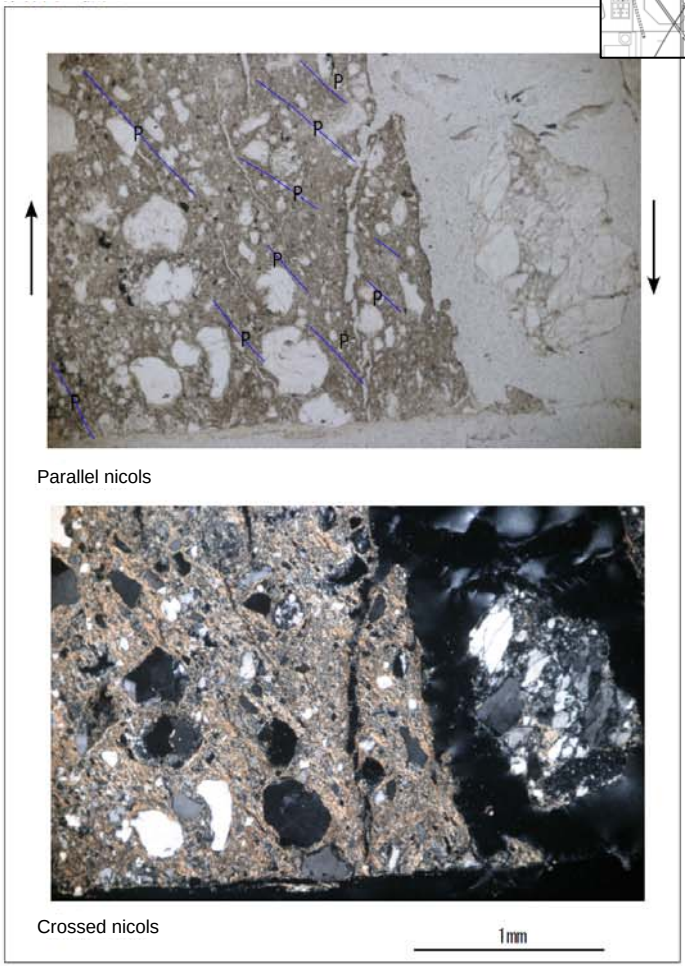
Parallel nicols

Crossed nicols

1cm



Area within red frame is enlarged



Parallel nicols

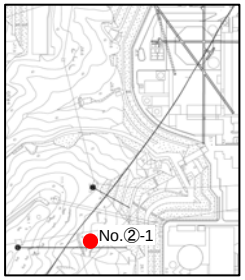
Crossed nicols

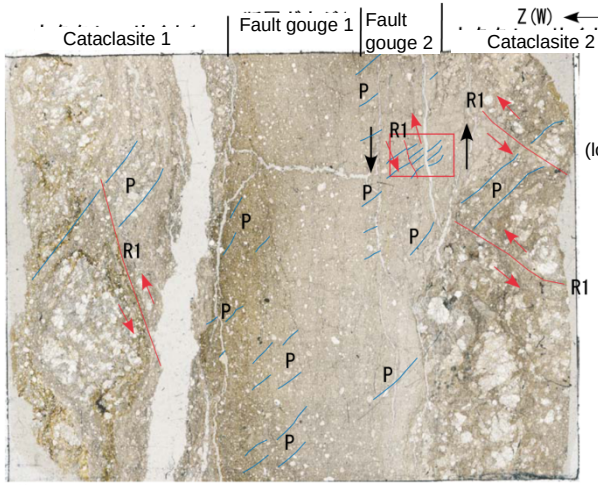
1mm

- Fault gouge 1 (last slip)
  Consists of the brown-gray matrix of fine grain, as well as quartz, feldspar, cataclasite fragment and calcite that are semi-circular gravels or sub-angular gravels with diameters of 0.1 to 5 mm. The matrix contains lots of clay minerals and calcite. The displacement sense of right-lateral slip can be recognized from P.
- Fault gouge 2
  Consists of the brown-gray matrix of fine grain, as well as quartz, feldspar, cataclasite fragment and calcite that are semi-circular gravels or sub-angular gravels with diameters of 0.1 to 10 mm. Ratio of fragments is higher than in fault gouge 1. The matrix contains lots of clay minerals and calcite. The displacement sense of right-lateral slip can be recognized from R1 and P.
- Cataclasite
  Consists of the gray-white matrix of fine grain, as well as cataclasite fragments, quartz, feldspar and calcite fragments that are sub-angular gravels with diameters of 0.1 to 2 mm. The matrix contains less clay minerals.

[Sense of displacement of shatter zone] Results of observation of thin section collected from No. ②-1 hole (vertical components)

No. ②-1 hole YZ direction

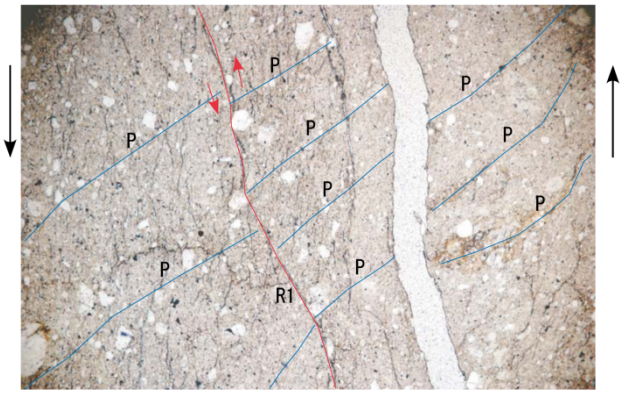




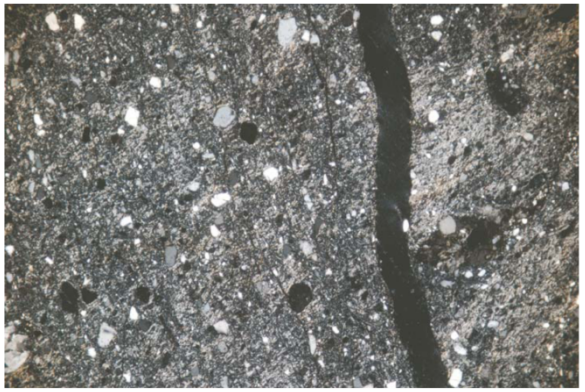
Parallel nicols

Crossed nicols

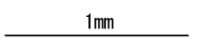
Area within red frame is enlarged



Parallel nicols



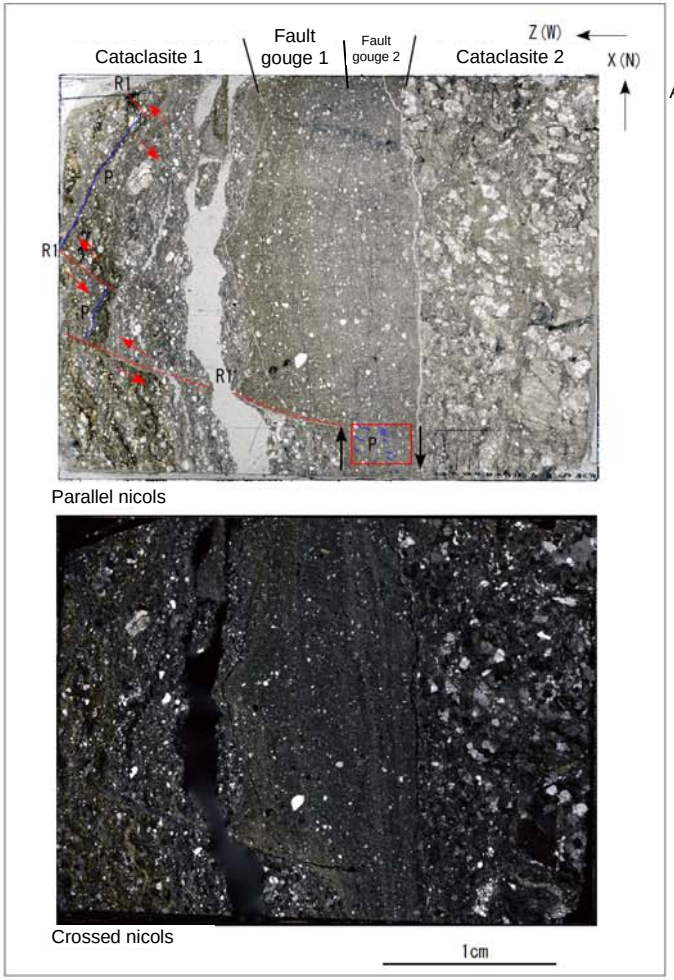
Crossed nicols



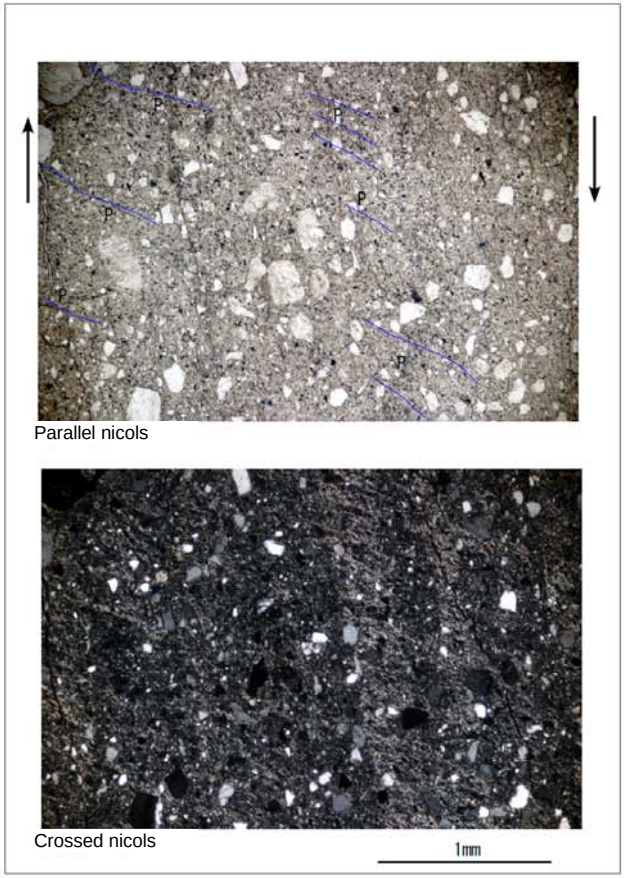
- Cataclasite 1
  Consists of the gray-white matrix of fine grain, as well as granite fragments, quartz and feldspar fragments that are sub-angular gravels with diameters of 0.1 to 9 mm. Contains lots of clay minerals in stripes. The displacement sense of normal fault can be recognized from P and its cut-off of R1.
- Fault gouge 1
  Consists of the brown-gray matrix of fine grain, as well as quartz and feldspar fragments that are sub-angular or semi-circular gravels with diameters of 0.1 to 0.5 mm. Contains lots of clay minerals. The displacement sense of normal fault can be recognized from P. There are some unclear areas.
- Fault gouge 2 (last slip)
  Consists of the brown-gray matrix of fine grain, as well as quartz and feldspar fragments that are semi-circular or sub-angular gravels with diameters of 0.1 to 0.5 mm. Contains lots of clay minerals. In the matrix, clay minerals in stripes are seen. The displacement sense of normal fault can be recognized from P and R1.
- Cataclasite 2
  Consists of the gray-white matrix of fine grain, as well as granite fragments, quartz and feldspar fragments that are sub-angular gravels with diameters of 1 to 10 mm. Contains less clay minerals. The displacement sense of normal fault can be recognized from P and R1.

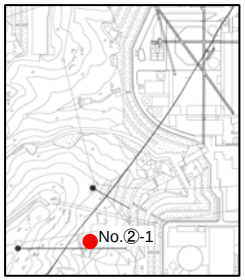
[Sense of displacement of shatter zone] Results of observation of thin section collected from No. ②-1 hole (horizontal components)

No. ②-1 hole XZ direction



Area within red frame is enlarged

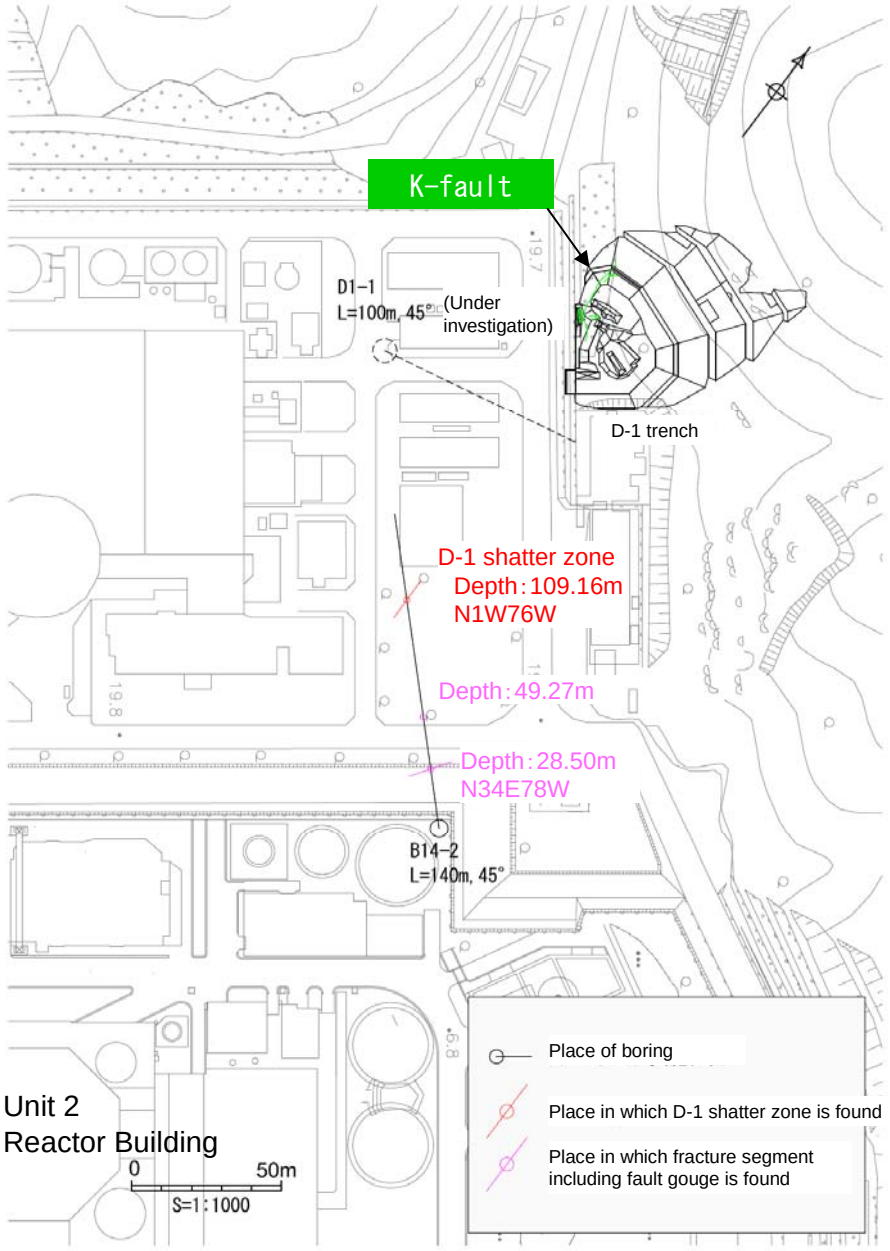




- Cataclasite 1
  Consists of the gray-white matrix of fine grain, as well as granite fragments, quartz and feldspar fragments that are sub-angular gravels with diameters of 0.1 to 2 mm. Contains lots of clay minerals in stripes. The displacement sense of left-lateral slip can be recognized from P and its cut-off of R1.
- Fault gouge 1
  Consists of the brown-gray matrix of fine grain, as well as quartz and feldspar fragments that are sub-angular or semi-circular gravels with diameters of 0.1 to 1 mm. Contains lots of clay minerals. The displacement sense of left-lateral slip can be recognized from R1.
- Fault gouge 2 (last slip)
  Consists of the brown-gray matrix of fine grain, as well as quartz and feldspar fragments that are semi-circular or sub-angular gravels with diameters of 0.1 to 0.3 mm. Contains lots of clay minerals. In the matrix, clay minerals in stripes are seen. The displacement sense of right-lateral slip can be recognized from P.
- Cataclasite 2
  Consists of the gray-white matrix of fine grain, as well as granite fragments, quartz and feldspar fragments that are sub-angular gravels with diameters of 1 to 10 mm. Contains less clay minerals.

Discussion about K-fault's extension to the southward

Newly obtained data after February 5, 2013



- Three fracture segments with fault gouge have been confirmed at B14-2 drilling, that cross the line between Unit 2 reactor building and K-fault.
- Displacement sense of the last slip has normal fault sense at each fracture segments.

- K-fault, that has reverse fault sense, does not extend to the southward from at least B14-2 drilling place.

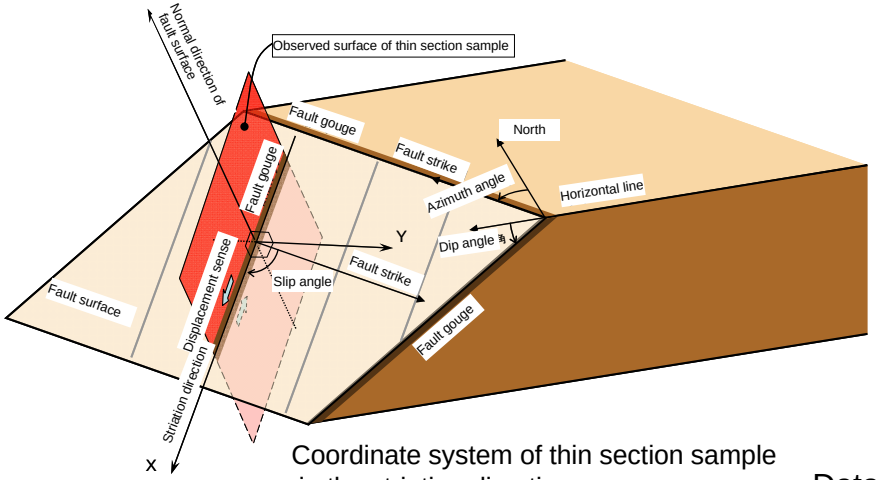
※To enhance the data, drilling at D1-1 is undergoing.

Displacement sense of fracture segment with fault gouge at B14-2

Place	Name of shatter zone	Depth (m)	Strike and dip	Striation direction	Displacement sense (Observation on striation direction of thin section)
B14-2	—	28.50	N34E78W	50S	Normal fault, left-lateral slip
	—	49.27	N44E80SE ※1	75S ※1	Normal fault ※1
	D-1	109.16	N1W76W	–	Normal fault, right-lateral slip※2

※1: Fault surface is assumed to be high-angle dip like K-fault, because it was impossible to measure strike and dip by bore-hole TV

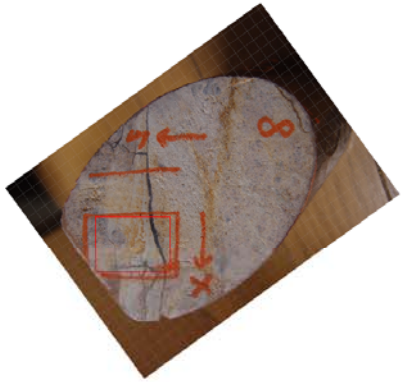
※2: Thin section samples are made in the lateral and horizontal direction.

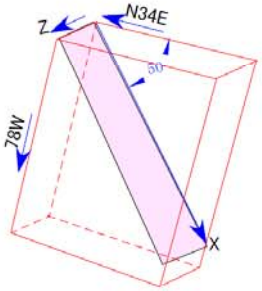


Coordinate system of thin section sample in the striation direction

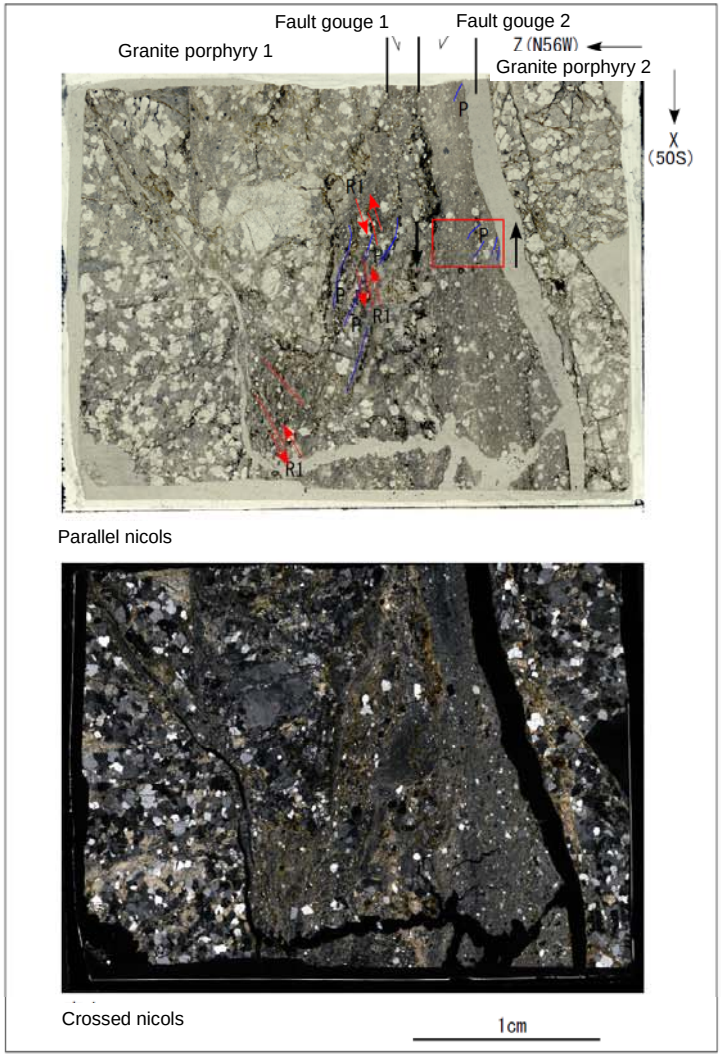
[Displacement sense of shatter zone]
Observation of thin section of B14-2 depth 28.50m (middle-angle southerly dips components)

Newly obtained data after February 5, 2013

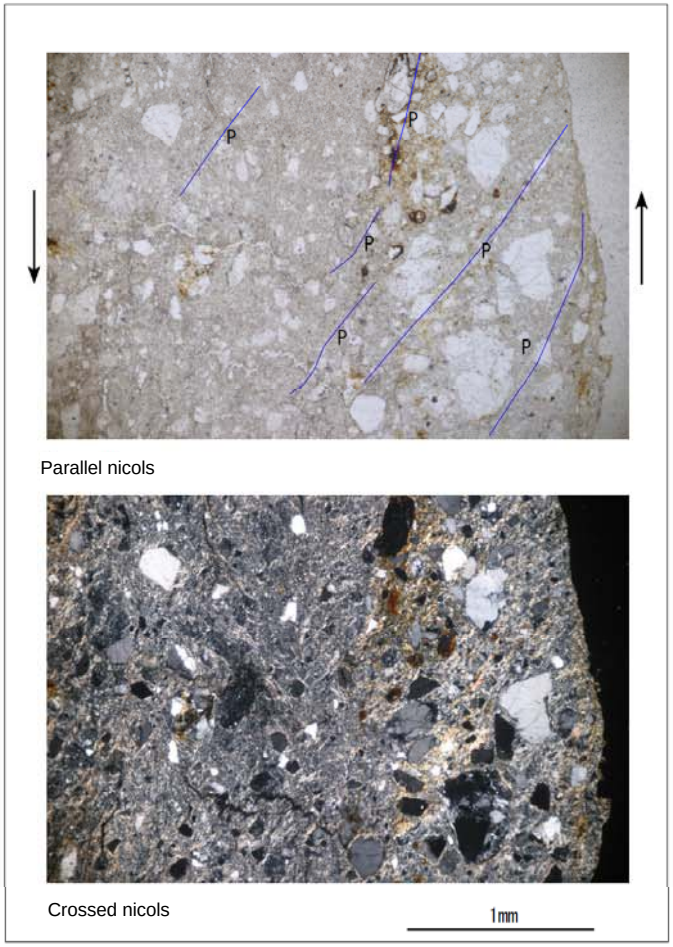




10cm



Area within red frame is enlarged

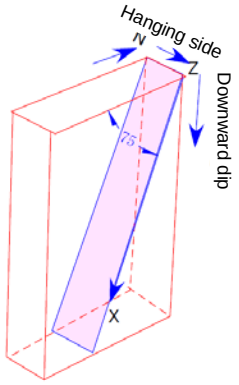


・Granite porphyry 1
Consist of quarts, potassium feldspar, plagioclase and muscorite with alternation.
・Fault gouge 1
Consists of the brown-gray matrix of fine grain, as well as quartz, feldspar and cataclasite fragments and that are semi-circular or sub-angular gravels with diameters of 0.02 to 3 mm. The matrix contains lots of clay minerals. The displacement sense of westerly dip (normal fault) and left-lateral slip can be recognized from R1 and P.
・Fault gouge 2 (last slip)
Consists of the brown-gray matrix of fine grain, as well as quartz, feldspar, granite porphyry and cataclasite fragments and that are semi-circular or sub-angular gravels with diameters of 0.01 to 1 mm. The matrix contains lots of clay minerals. The displacement sense of westerly dip (normal fault) and left-lateral slip can be recognized from P.
・Granite porphyry 2
Consist of quarts, potassium feldspar, plagioclase and muscorite with alternation.

B14-2_28.50m_8-1_XZ方向

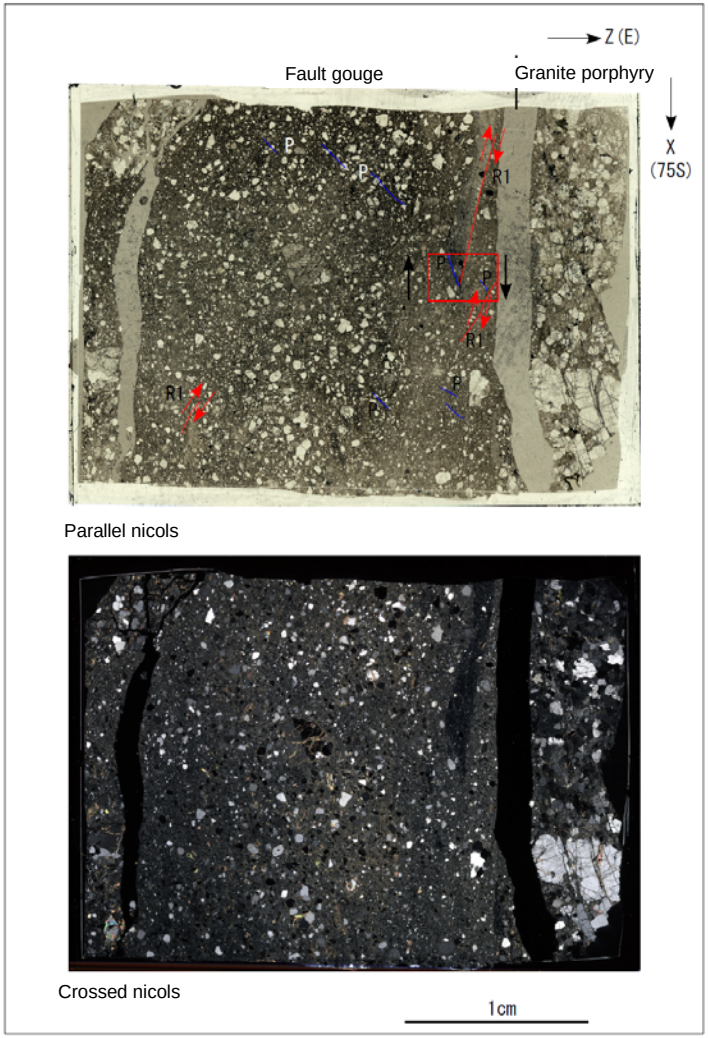
[Displacement sense of shatter zone]
Observation of thin section of B14-2 depth 49.27m (high-angle southerly dips components)

Newly obtained data after February 5, 2013

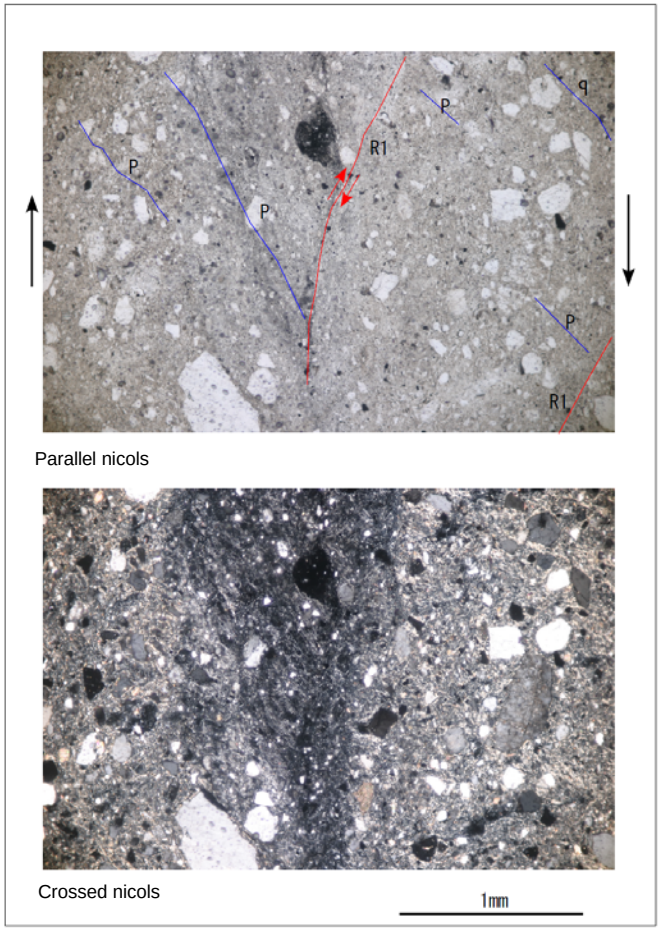


※)Fault surface is assumed to be high-angle dip like K-fault, because it was impossible to measure strike and dip by bore-hole TV

10cm



Area within red frame is enlarged

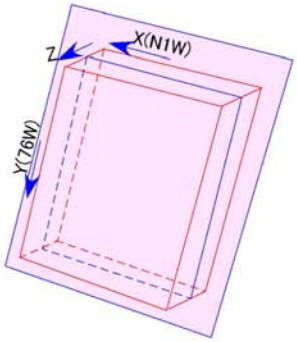


・Fault gouge (last slip)
Consists of the brown matrix of fine grain, as well as quartz, feldspar, cataclasite and granite porphyry fragments and that are semi-circular or sub-angular gravels with diameters of 0.02 mm to 5mm. The matrix contains lots of clay minerals and calcite. The displacement sense of easterly dip (normal fault) and right-lateral slip can be recognized from R1 and P.

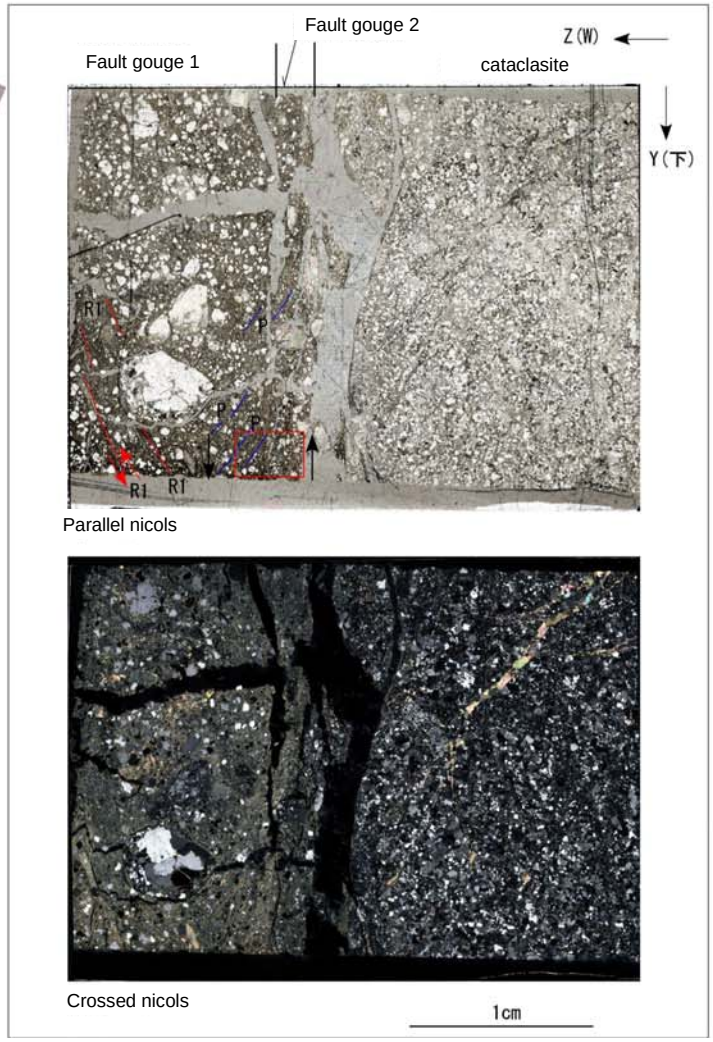
・Granite porphyry
Consist of quarts, potassium feldspar, plagioclase and biotite

B14-2_49.27m_10-1_XZ方向

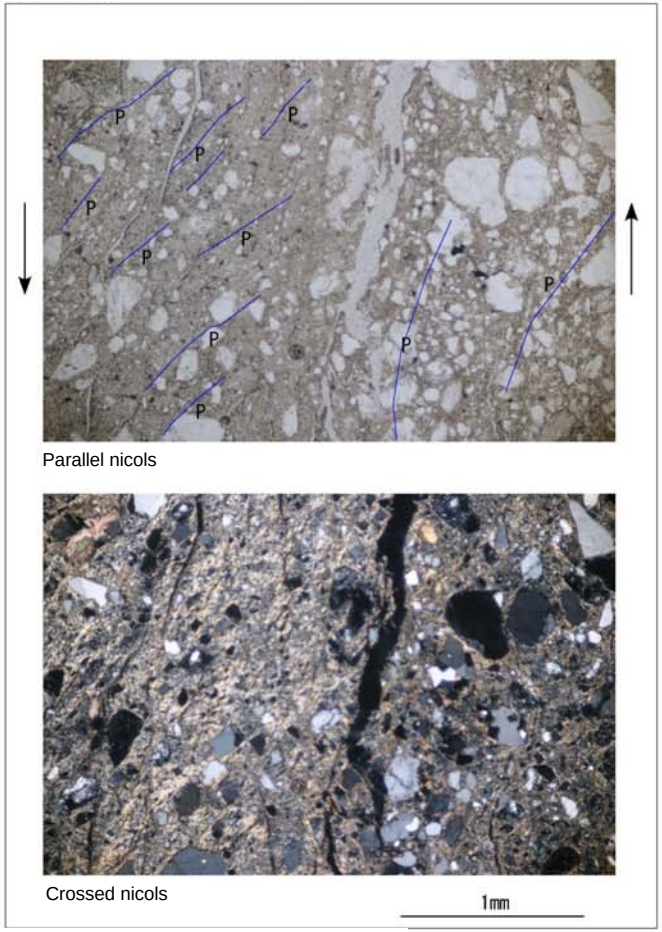
[Displacement sense of shatter zone]
Observation of thin section of B14-2 depth 109.16m (vertical components)



10cm



Area within red frame is enlarged



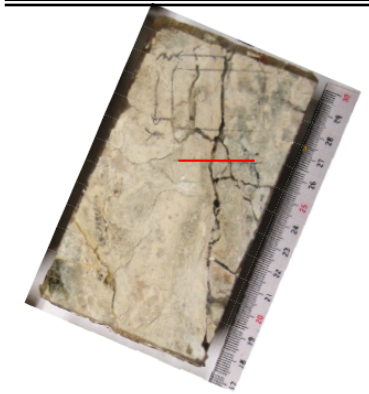
・Fault gouge 1
Consists of the brown matrix of fine grain, as well as quartz, feldspar, granite porphyry and cataclasite fragments and that are semi-circular or sub-angular gravels with diameters of 0.02 mm to 5mm. The matrix contains lots of clay minerals and calcite. The displacement sense of normal fault can be recognized from R1 and P.

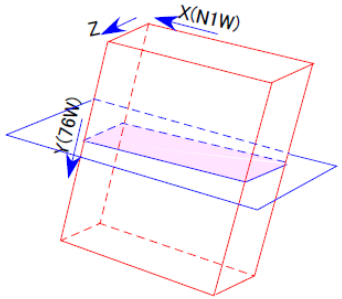
・Fault gouge 2
Consists of the brown matrix of fine grain, as well as quartz, feldspar, cataclasite fragments and that are semi-circular or sub-angular gravels with diameters of 0.02 mm to 1mm. The matrix contains lots of clay minerals. The displacement sense of normal fault can be recognized from P.

・Cataclasite
Consists of the gray matrix of fine grain, as well as quartz, feldspar, aplite and cataclasite fragments and that are sub-angular or semi-circular gravels with diameters of 0.1mm to 1mm. The matrix doesn't contain much clay minerals. Calcite vein can be recognized.

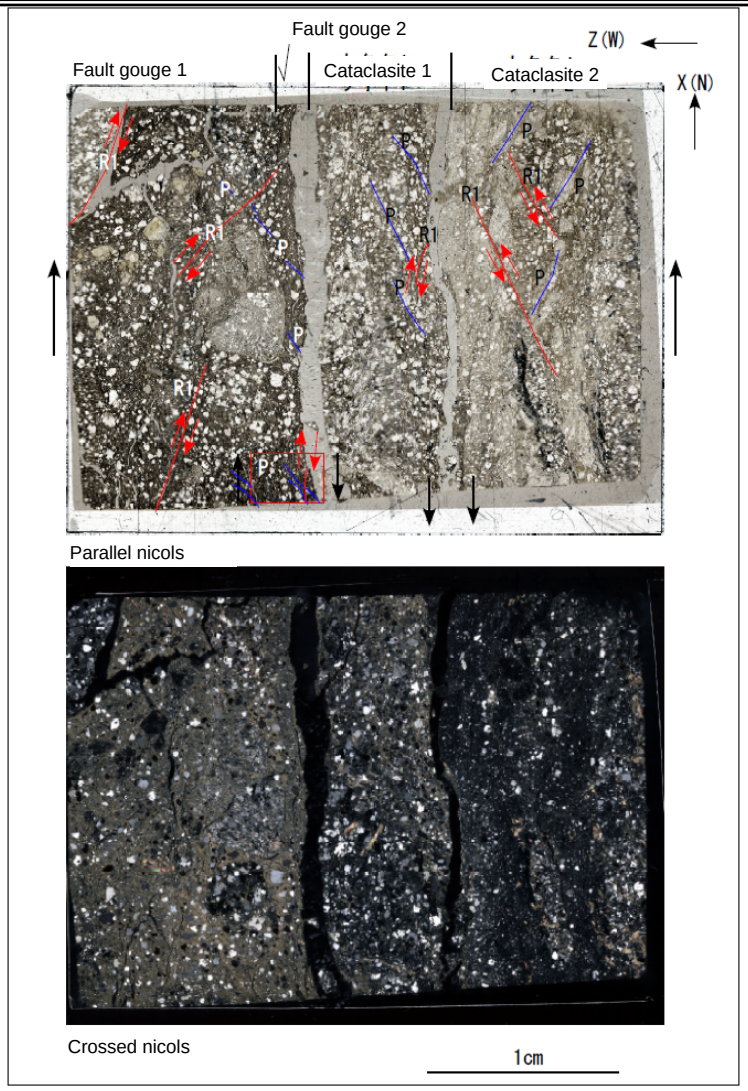
D-1 B14-2 109.16m_2_YZ方向

[Displacement sense of shatter zone]
Observation of thin section of B14-2 depth 109.16m (horizontal components)

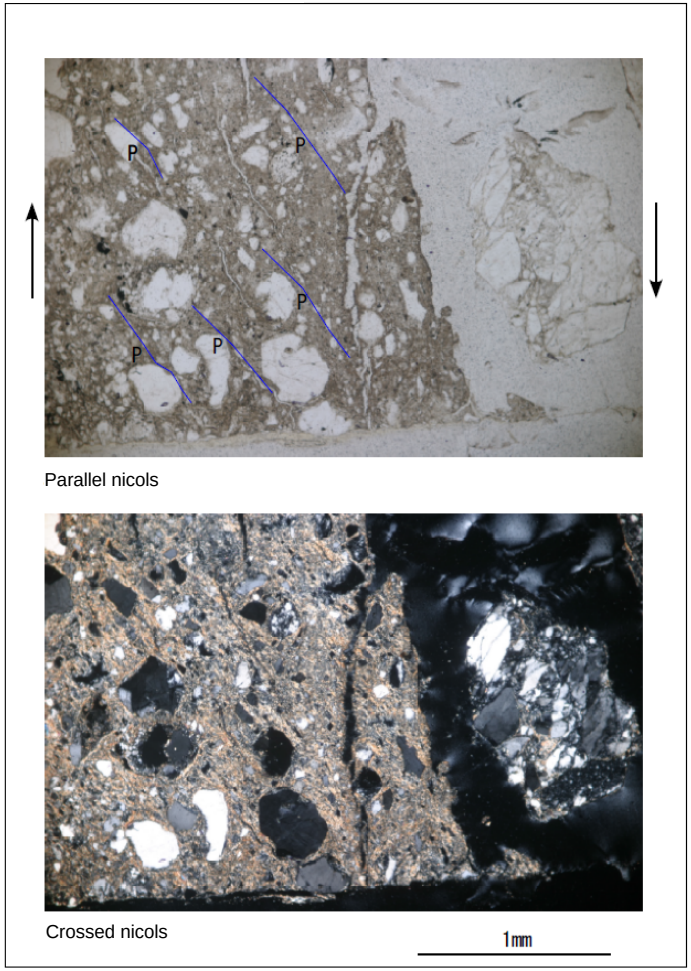




10cm



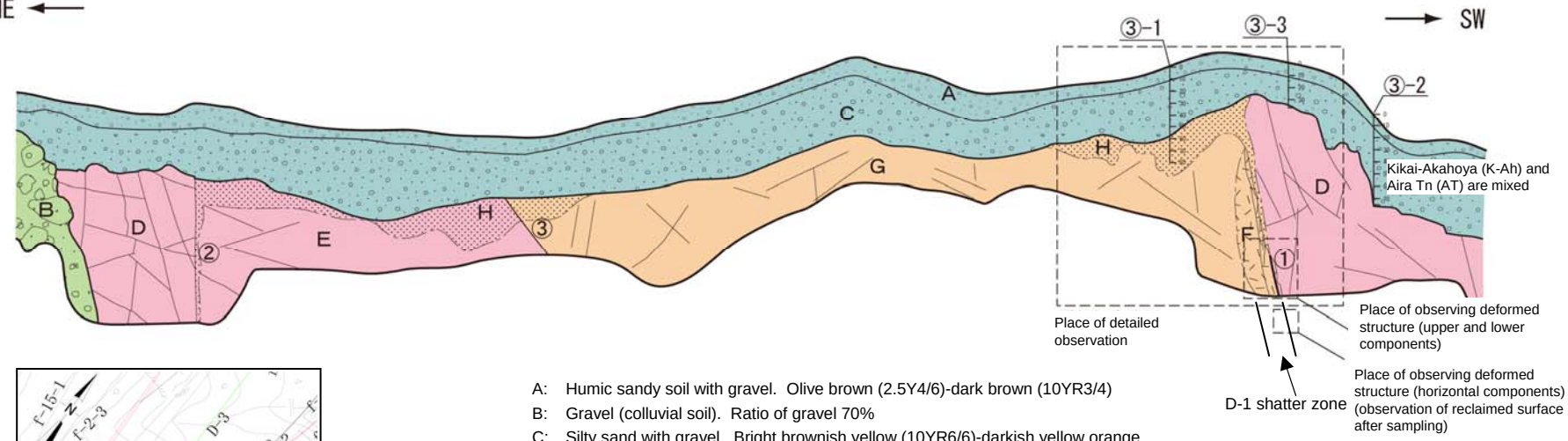
Area within red frame is enlarged

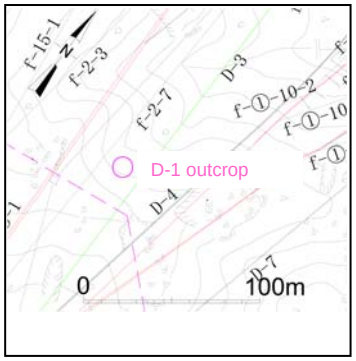


・Fault gouge 1
Consists of the brown matrix of fine grain, as well as quartz, feldspar, aplite and cataclasite fragments and that are semi-circular or sub-angular gravels with diameters of 0.02 mm to 7mm. The matrix contains lots of clay minerals and calcite. The displacement sense of right-lateral slip can be recognized from R1 and P.
・Fault Gauge 2 (last slip)
Consists of the brown matrix of fine grain, as well as quartz, feldspar, cataclasite fragments and that are semi-circular or sub-angular gravels with diameters of 0.02 mm to 1mm. The matrix contains lots of clay minerals. The displacement sense of right-lateral slip can be recognized from R1 and P.
・Cataclasite 1
Consists of the brown-gray matrix of fine grain, as well as quartz, feldspar, aplite and cataclasite and that are sub-angular or semi-circular gravels with diameters of 0.1 mm to 8mm. The matrix contains lots of clay minerals and calcite. The displacement sense of right-lateral slip can be recognized from R1 and P.
・Cataclasite 2
Consists of the brown-gray of fine grain, as well as quartz, feldspar, cataclasite and aplite fragments and that are sub-angular or semi-circular gravels with diameters of 0.1 mm to 8mm. The matrix doesn't contain many clay minerals but it contains lots of calcite. The displacement sense of left-lateral slip can be recognized from R1 and P.

D-1 B14-2 109.16m_2 XZ方向

D-1 outcrop





Map of outcrop location

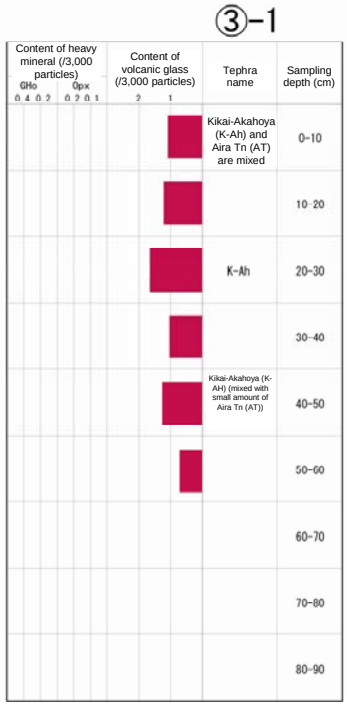
A: Humic sandy soil with gravel. Olive brown (2.5Y4/6)-dark brown (10YR3/4)
B: Gravel (colluvial soil). Ratio of gravel 70%
C: Silty sand with gravel. Bright brownish yellow (10YR6/6)-darkish yellow orange (10YR6/4)
D: Granite porphyry
E: Slightly fractured portion of granite porphyry (subject to alteration)
F: Aplite cataclasite
G: Slightly fractured portion of aplite (subject to alteration)
H: Unclear portion of texture due to strong weathering
① f: N16° E73° W Fault gouge (light brown clay: 2-5 mm wide)
② f: N38° E85° W
③ f: N22° E36° W Boundary between granite porphyry and aplite

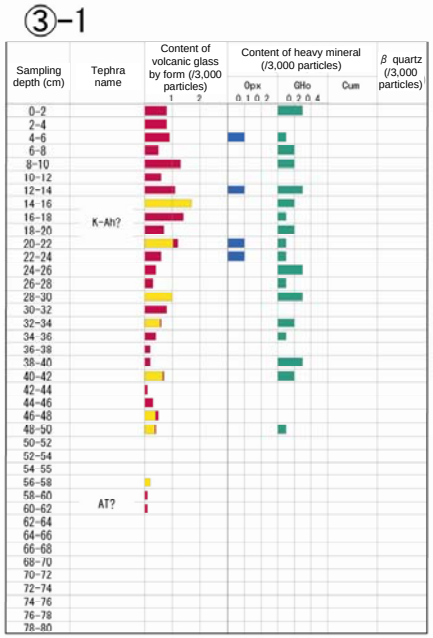
Legend

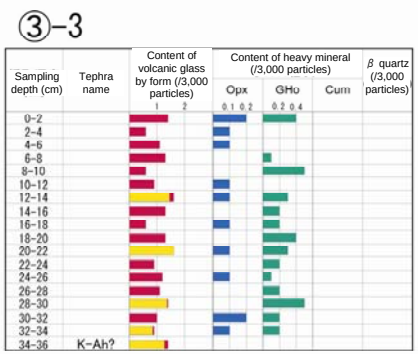
- Talus deposit
- Older fan deposit 2
- Granite porphyry
- Aplite
- Cataclasite
- Unclear portion of structure due to strong weathering
- Place for continual sampling of tephra

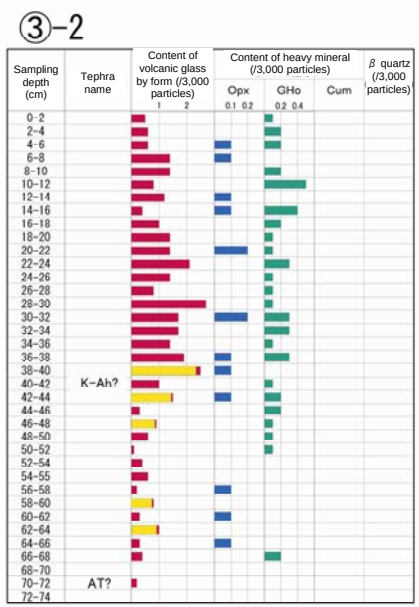
・The shatter zone has not displaced or deformed the stratum, which was deposited after Kikai-Akahoya (K-Ah) (about 7,300 years ago).

D-1 outcrop (result of tephra analysis)

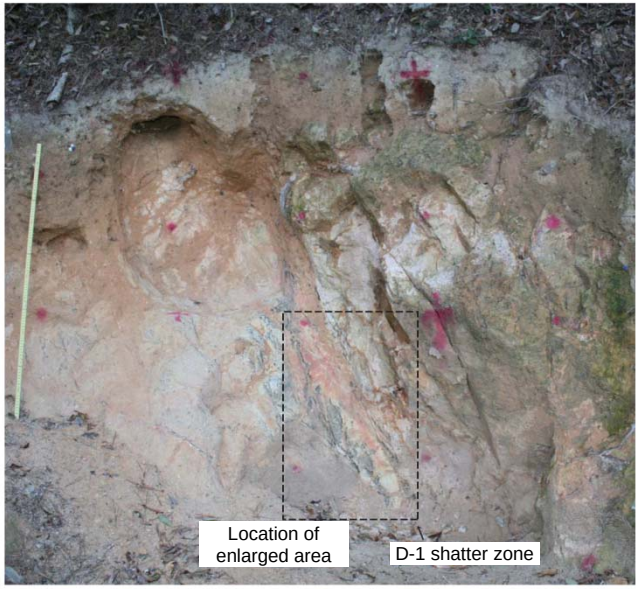


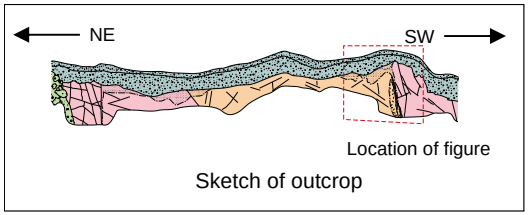






Detailed observation of D-1 outcrop





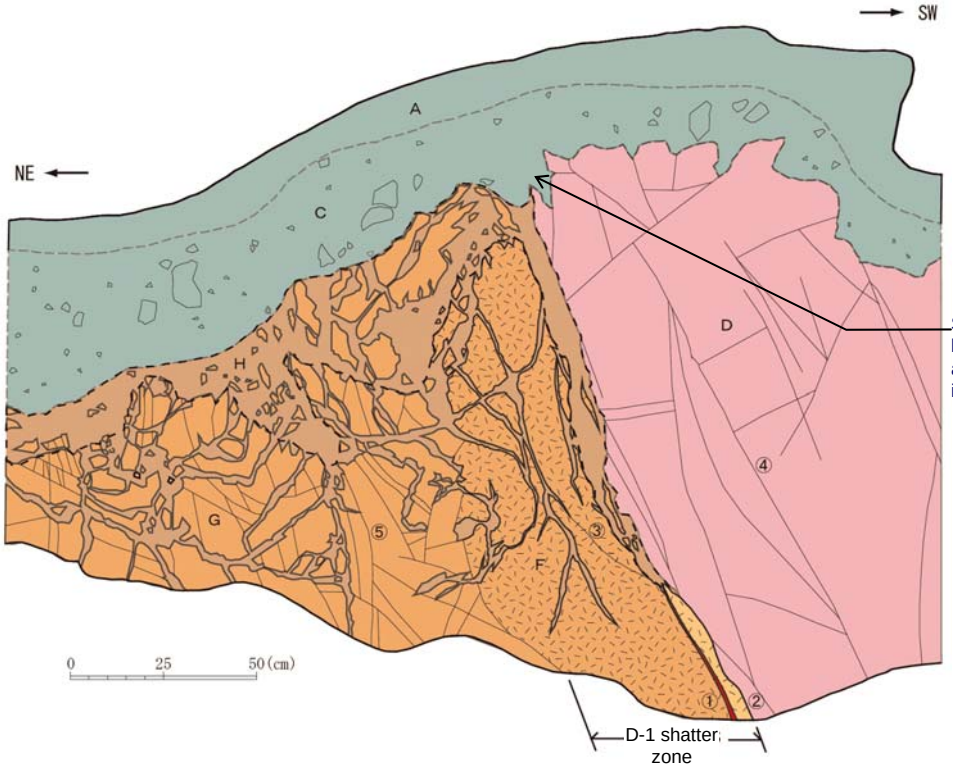
- Texture of gouge of the shatter zone is unclear, due to weathering in the upper part of rock mass.

Legend

- Talus deposit
- Aplite
- Granite porphyry
- Cataclasite
- Unclear portion of structure due to strong weathering

A: Humic silty sand. Brownish yellow (10YR5/2)
C: Silty sand with gravel. Darkish yellow orange (10YR6/4). Ratio of gravel: 10%
D: Granite porphyry. Slight yellow orange (7.5YR8/3)
F: Aplite cataclasite
G: Aplite (weathered and soft). Slight yellow orange (10YR8/4)
H: Aplite (highly weathered portion) sandy silt. Slight yellow orange (10YR8/4)-orange (7.5YR7/6)

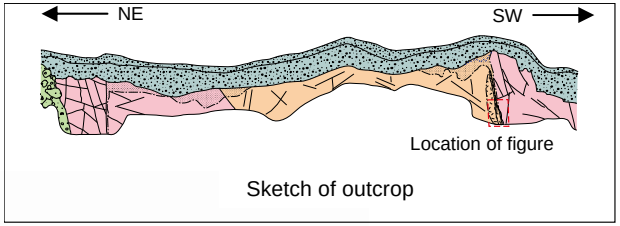
① f: N28° E57° W Fault gouge (light brown clay: 2-5 mm wide)
② f: N26° E66° W Fault gouge (light brown clay: 0-1 mm wide)
③ j: N6° E63° W Manganese adhered
④ j: N27° E66° W
⑤ j: N28° E65° W Manganese adhered



Some portions are lost due to erosion, and an overlying layer inroads.

D-1 outcrop (observation of deformed structure) (vertical components)

- In the sense of vertical displacement of cataclasite, reverse fault components with going up in the west and going down in the east are recognized.



Sketch of outcrop

Result of observation of deformed structure 2

Sketch of wall surface

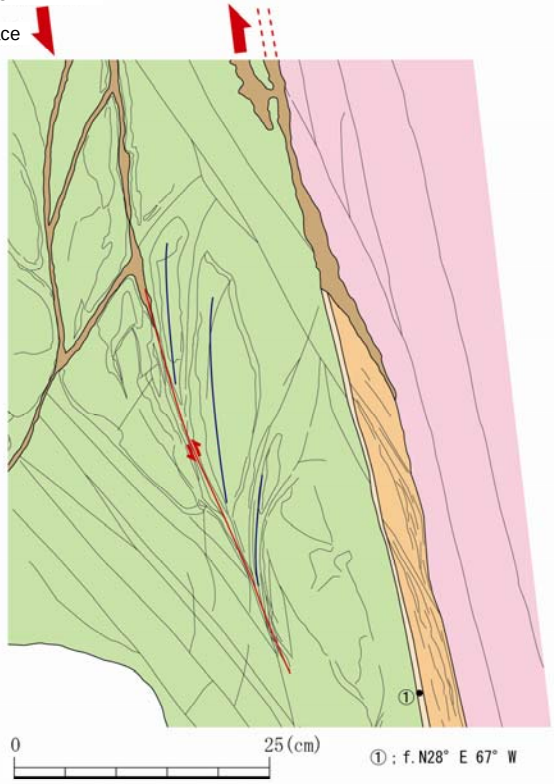
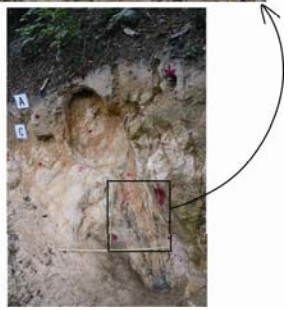


Photo of wall surface



Clay (brown clay (inflow))

Fractured portion of clay (light brown gouge)

Fractured portion of sandy breccia (foliated cataclasite)

Fractured portion of sandy breccia (sandy-brecciated cataclasite)

Slightly deformed-nondeformed granite porphyry

P Shear

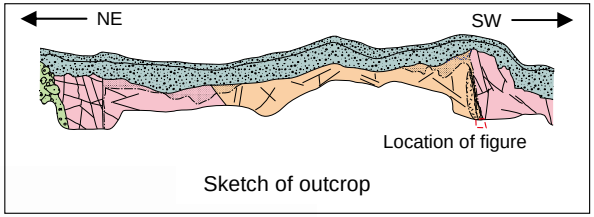
R1 Shear

f. N16° E84° W

Strike and dip in shatter zone (declination uncorrected)

D-1 outcrop (observation of deformed structure) (horizontal components)

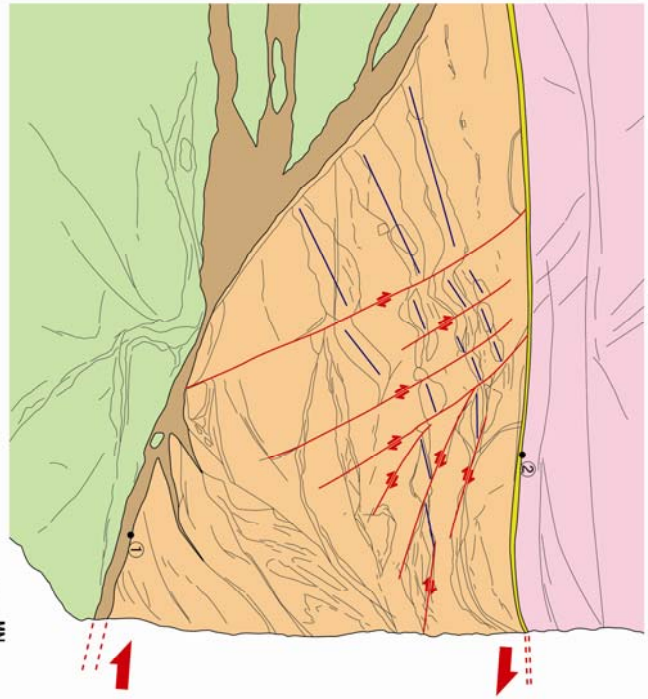
- The sense of horizontal displacement in cataclasite incorporates a component of right-lateral slip.



Sketch of outcrop

Result of observation of deformed structure 1

Sketch of wall surface



①；f. N32° E 75° NW
②；f. N20° E 58° W

Photo of batholith

Clay (brown clay (inflow))
Fractured portion of clay (light brown gouge)
Fractured portion of sandy breccia (foliated cataclasite)
Fractured portion of sandy breccia (sandy-brecciated cataclasite)
Slightly deformed-nondeformed granite porphyry
P Shear
R1 Shear
f. N16° E84° W
Strike and dip in shatter zone (declination uncorrected)

[Displacement sense of shatter zone] Location of collecting thin section from D-1 outcrop

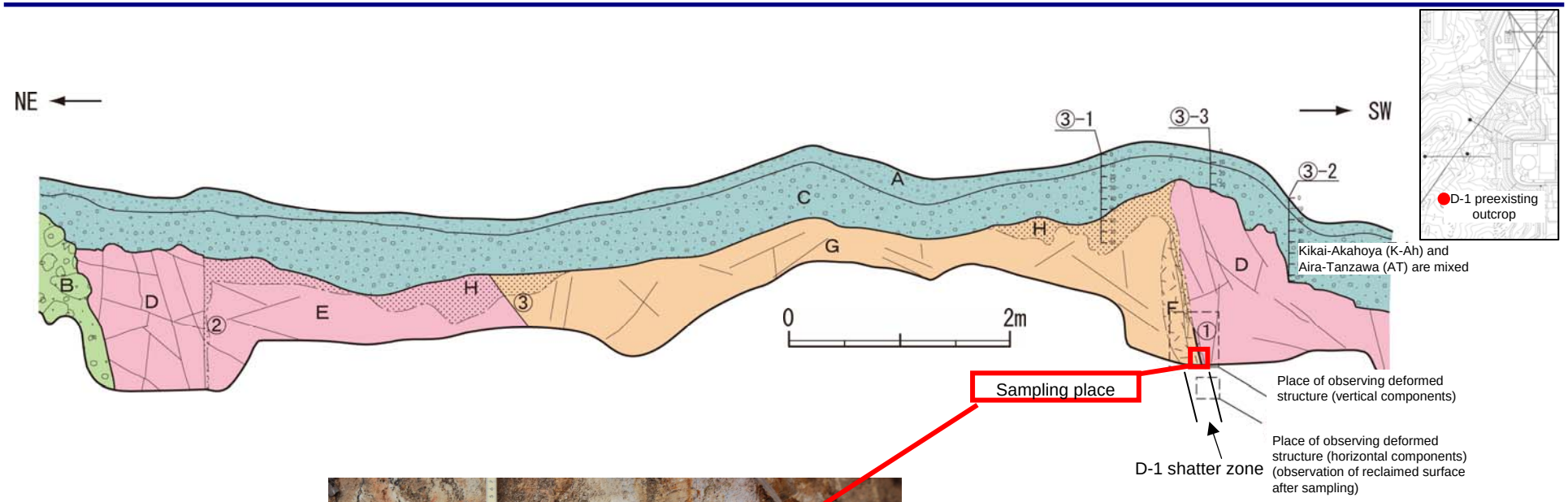
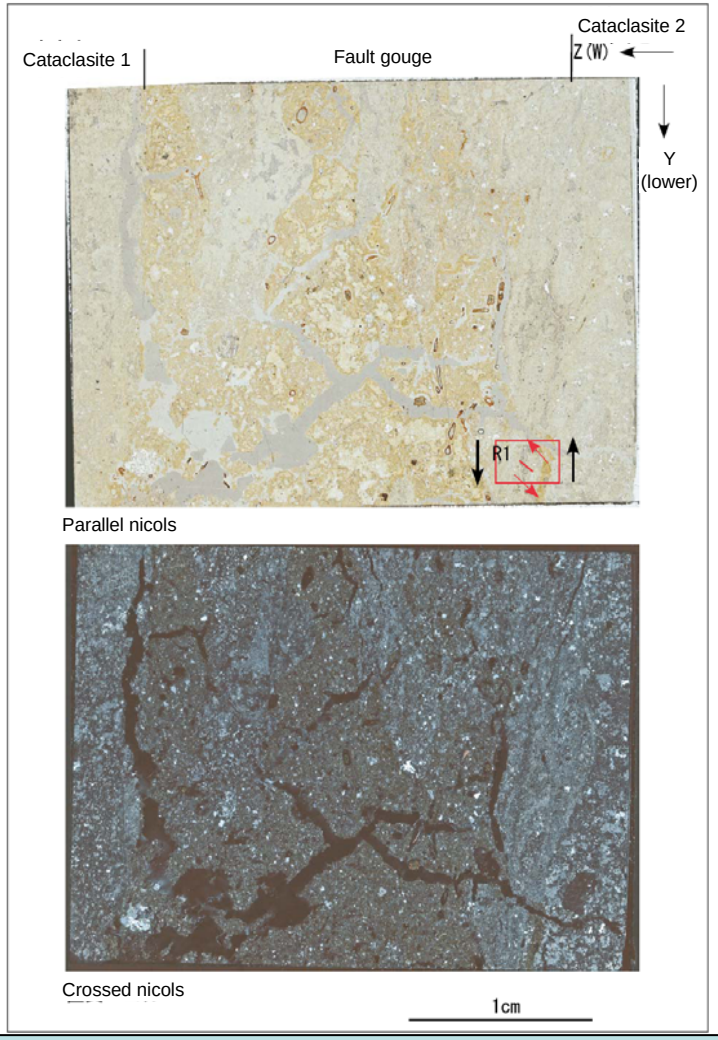


Photo of sampling place

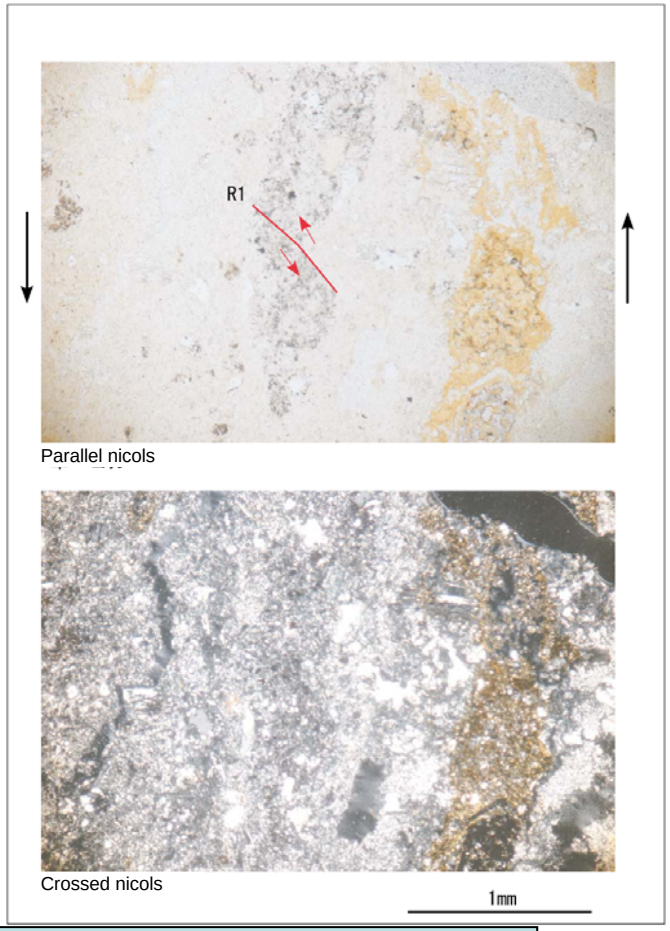
Legend

- Talus deposit
- Older fan deposit 2
- Granite porphyry
- Aplite
- Cataclasite
- Unclear portion of structure due to strong weathering
- Place for continual sampling of tephra

[Sense of displacement of shatter zone] Observation results of thin section from D-1 outcrop (vertical components)

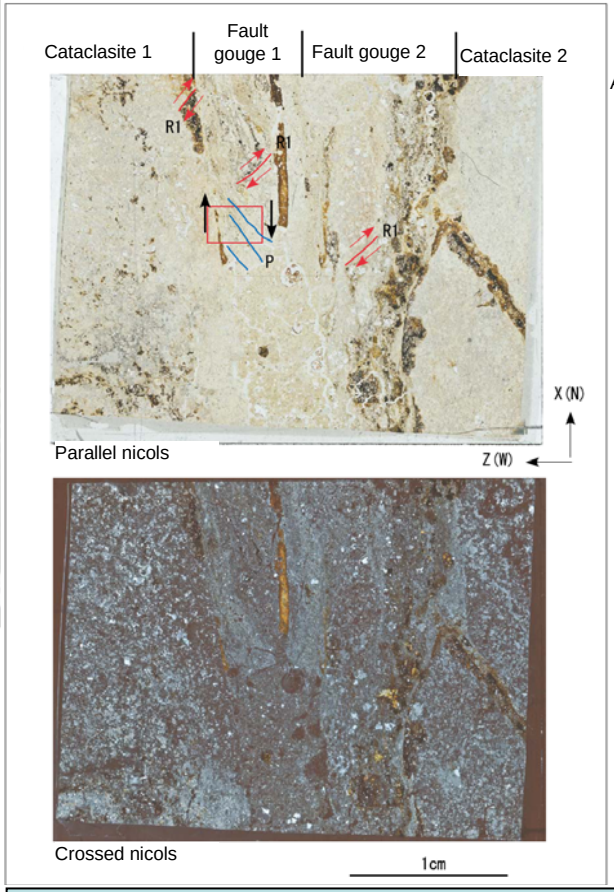


Area within red frame is enlarged

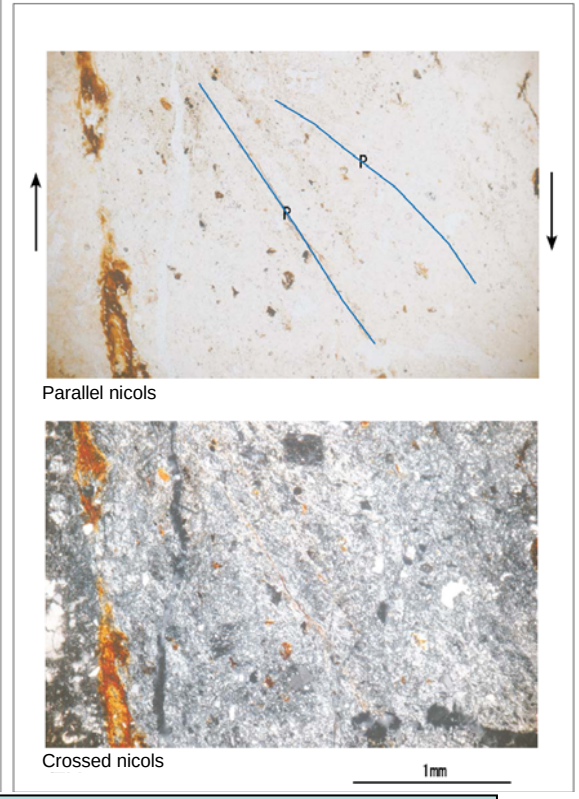


- Cataclasite 1
  Consists of the gray-white matrix of fine grain, as well as granite fragments, quartz, feldspar and cataclasite fragments that are sub-angular gravels with diameters of 0.1 to 2 mm. Contains less clay minerals.
- Fault gouge (last slip)
  Consists of the brown-gray matrix of fine grain, as well as quartz, feldspar and cataclasite fragments that are sub-angular or semi-circular gravels with diameters of 0.1 to 1 mm. Contains lots of clay minerals. The sense of displacement of normal fault can be recognized from R1.
- Cataclasite 2
  Consists of the gray-white matrix of fine grain, as well as granite fragments, quartz and feldspar fragments that are sub-angular gravels with diameters of 0.1 to 2 mm. Contains less clay minerals.

[Sense of displacement of shatter zone] Observation results of thin section from D-1 outcrop (horizontal components)



Area within red frame is enlarged



- Cataclasite 1
  Consists of the gray-white matrix of fine grain, as well as granite porphyry fragments, quartz and feldspar fragments that are sub-angular gravels with diameters of 0.1 to 2 mm. Contains less clay minerals.
- Fault gouge 1 (last slip)
  Consists of the brown-gray matrix of fine grain, as well as quartz, feldspar and cataclasite fragments that are sub-angular or semi-circular gravels with diameters of 0.1 to 1 mm. Contains lots of clay minerals. The displacement sense of right-lateral slip can be recognized from R1 and P.
- Fault gouge 2
  Consists of the brown-gray matrix of fine grain, as well as quartz, feldspar and cataclasite fragments that are sub-angular or semi-circular gravels with diameters of 0.1 to 2 mm. Ratio of fragments is higher than in fault gouge 1. Contains lots of clay minerals. The displacement sense of right-lateral slip can be recognized from R1.
- Cataclasite 2
  Consists of the gray-white matrix of fine grain, as well as granite porphyry fragments, quartz and feldspar fragments that are sub-angular gravels with diameters of 0.1 to 2 mm.