Activity Evaluation of Fukaya Fault Zone Based on a Study of a Subordinate Fault

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Keywords: Fukaya fault, subordinate fault, fluvial terrace, recurrence interval

1. Introduction

According to data published by the Headquarters for Earthquake Research Promotion (2005), about 25 km long Fukaya fault belongs to the middle part of a fault zone extending NW-SE direction and bounding NW Kanto Plain. Its estimated average displacement rate is 0.2-0.4 mm/1000 years and its latest activity was about 2,500 yBP within the last 6,200 years (Fig. 1). The amount of displacement per single earthquake event is 5 to 6 mm with average time interval of events 13,000 to 30,000 years. Also it is estimated that Kanto Plain NW marginal fault was active as a single unit in the past.

During construction work of Rissho University Energy Center a new cross section of sediments corresponding to the Konan II terrace (and covering soil layer) (Arai *et al.*, 2002) was created (Fig. 2, Fig. 3). At the beginning we anticipated to see new sediments belonging to the ones later than Konan I (and covering soil layer) as we believed that gently sloping cliff between Konan I and Konan II terrace was formed by river erosion (Fig. 4). The lithology of the sediments, however, closely resembled to the one belonging to Konan I terrace (On-Pm1: 100ka; Machida and Arai, 2003). Especially, yellow-green pumiceous bed visible

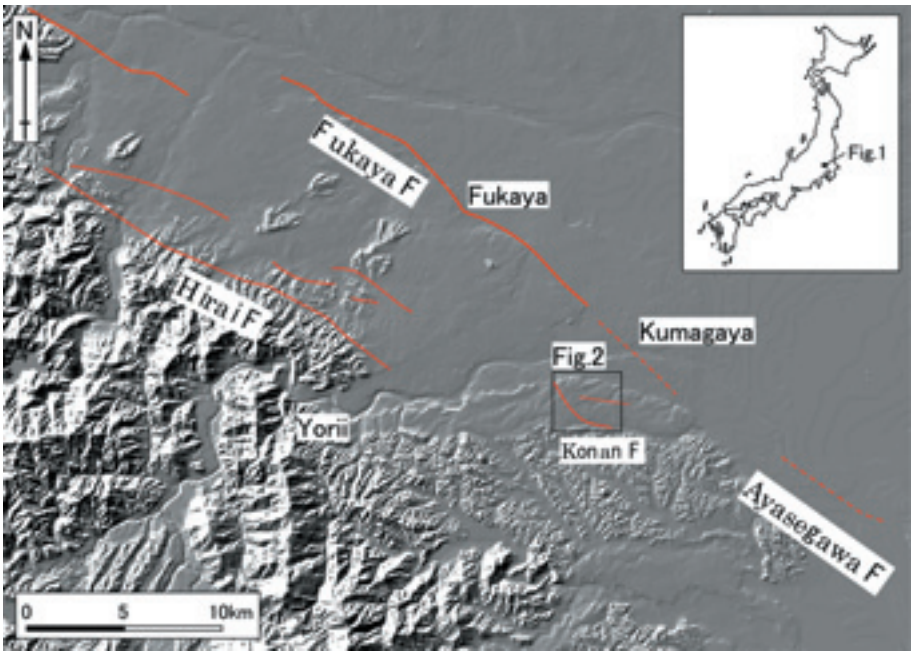

Fig. 1

Distribution of active faults around Kumagaya [modified from The Headquarters for Earthquake Research Promotion (2005)]. Fukaya F : Fukaya fault, Hirai F : Hirai fault, Konan F : Konan fault, Ayasegawa F : Ayasegawa fault.

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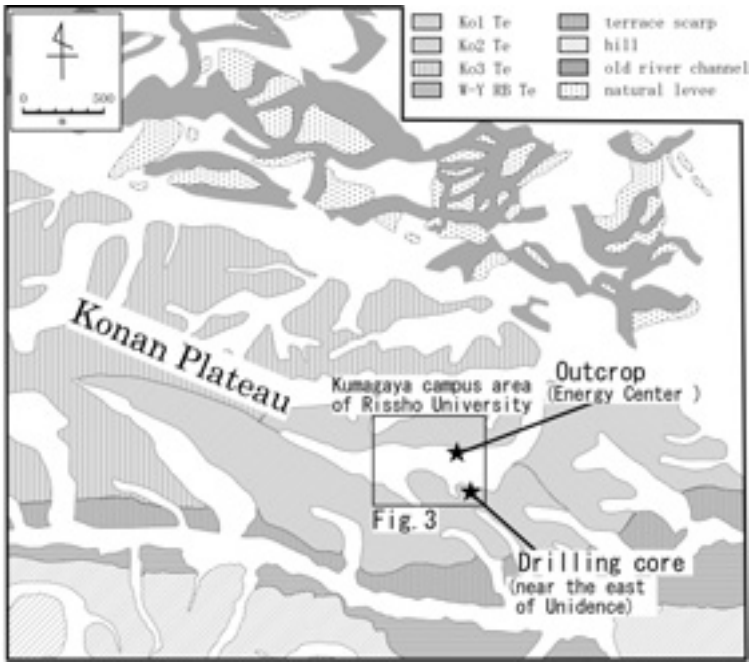

Fig. 2

Geomorphological map around the Kumagaya Campus of Rissho University [modified from Arai et al. (2002)]. Ko1 Te : Konan 1 Terrace, Ko2 Te : Konan 2 Terrace, Ko3 Te : Konan 3 Terrace, W-Y RB Te : Wada-Yoshino river right bank Terrace.

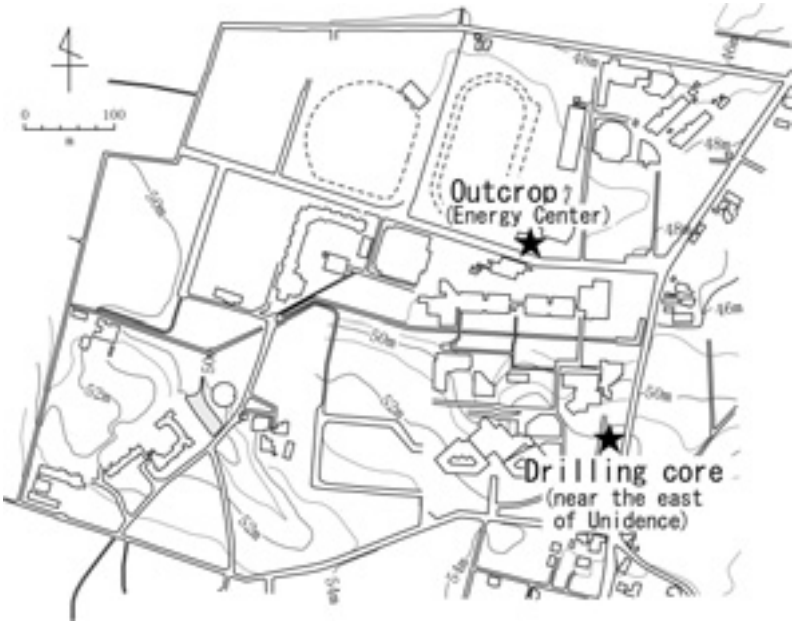

Fig. 3

Campus map of the Kumagaya Campus of Rissho University [modified from Arai et al. (2002)].

to unaided eyes (first discovered by Kikuchi, one of the authors) intercalated with grayish white silt in the middle of the sediments was identified to be Ontake I Ash based on lithology and stratigraphic position. If so, the cliff between Konan I and Konan II terrace is not created by erosion but fault movement. To prove that this cliff is a fault scarp, mineralogical analysis including refractivity measurements of pumice, air photo analysis and topographic survey of the cliff have been carried out.

2. Summary of topography and geology

Konan Plateau (Fig. 2) is a plateau on the right

Fig. 4
A new cross section of sediments at the Rissho University Energy Center

bank (south side) of Arakawa River and belongs to the southern part of an old river fan created by Arakawa River. Konan Plateau is underlain by over 15 m thick gravel layer. The gravel layer is overlain by about 3 m thick gray clay and in turn overlain by less than 2 m Kanto Loam. The gray clay is intercalated with yellow-green and white pumice beds. Among the pumice beds, yellow-green one contains biotite and zircon, and because of this it is interpreted to belong to Ontake I Ash (Yanagida *et al.*, 1982).

3. Descriptions of drill core and results of refractive index measurements

The sequence of drill core consists of four layers in descending order: cultivation soil, Kuroboku soil, brown loam (eolian), and clay (water-laid) (Fig. 5a). The soft and light-weight black-brown to dark brown cultivation soil is down to 50 cm. At 50 to 80 cm depths is a transition layer from Kuroboku soil to brown loam containing pale brown humus. From 85 to 225 cm is a massive eolian loam showing no layering mixed with brown to dark brown materials and considered to belong to the so-called Kanto Loam. In addition, at 120 cm depth, a white layer probably volcanic ash is observed (this is not clearly visible in the photo of the core, Fig. 3a). The lower part of the brown loam between 230 and 240 cm depths shows dull yellowish brown color probably suggesting transition from eolian to water-laid deposition. From the depths 245 cm and below consists of water-laid clay containing rounded pebbles 5 mm in size (Nakamura *et al.*, 2005). Nakamura *et al.* (2005) also found and described several volcanic ash beds including those of AT and K-Tz in the soil covering Konan I surface near Rissho University Unidence, and estimated the timing of emergence above the sea of Konan I surface to be after K-Tz fall and before Aso-4, that is, about 90,000 yBP:.

On the other hand, lithofacies of sediments observed on the outcrop is: from the top to be: artificial piled-up soil, brown eolian loam, and water-laid clay (Fig. 5b). From the ground surface to the depth of 70 cm is artificially piled-up soil for laying water pipe. Kuroboku soil and upper part of brown loam beds seen in the drill core are not recognized. Instead, about 50 cm thick chocolate-colored loam is recognized. It is underlain by silt bed about 2 m thick. Within this silt bed at depths 170 cm is yellow-green pumice bed and at 300 cm depth is medium-grained sand layer about 15 cm thick. As described before, the

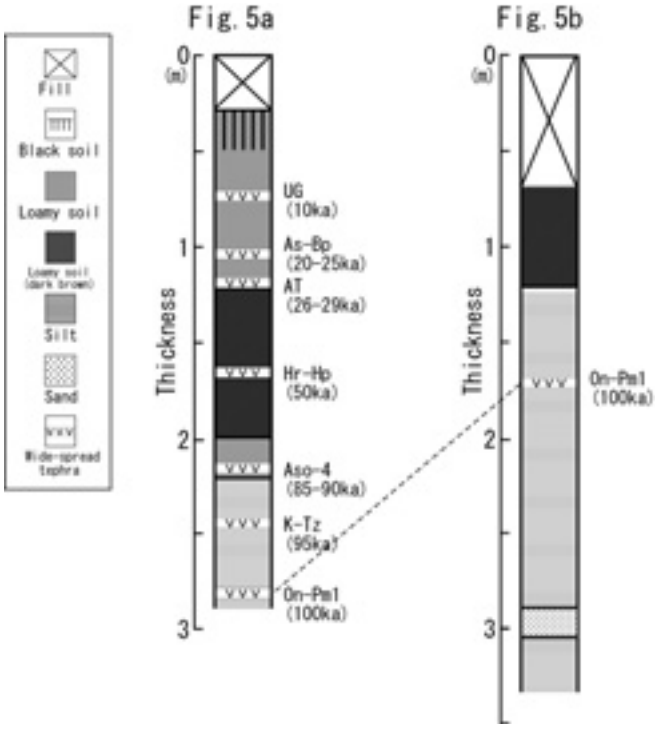

Fig. 5

Columnar sections of the drilling core (near the east of Unidence : Fig. 5a) and Outcrop ((Energy Center : Fig. 5b). Locations are shown in Fig. 3.

pumice bed occurring at 170 cm depth is correlated to Ontake I Ash bed (On-Pm1; 100,000 yBP) because it occurs within lower silt bed of chocolate-colored loam (identified to be Musashino Loam bed referring on previous studies), its color is yellow-green, and includes biotite.

In this study, minerals contained in the pumice bed are identified with polarizing microscope and refractive indices of volcanic glass and hornblende are measured to help identify if the bed is correlated to Ontake I. Under the microscope, volcanic glass (pumice), feldspar, hornblende, orthopyroxene, biotite, and zircon are identified. The assemblage closely resembles to that of On-Pm1 reported by Machida and Arai (2003). Refractive index of glass is n=1.5011-1.5027 (mean 1.5021) while that of hornblende n_2=1.6845-1.6864 (mean 1.6854). Those are close to the values reported by Machida and Arai (2003) for On-Pm1. Therefore it is safe to conclude that the pumice bed observed on the outcrop is correlated to On-Pm1.

4. Description of topography due to fault activities around Kumagaya campus of Rissho University

As lithofacies and ages of constituting sediments of Konan I and Konan II surfaces are found to be identical, cliff between Konan I and Konan II surfaces seems to be created not by erosion but displacement with fault movement. As a means to prove this possibility, topographic details with stereographic viewing of air photos are carried out. At the place shown in Fig. 3, topographic flexure with uplifted south side is confirmed (Fig. 6). The flexure seems to have formed through several earthquake events since about hundred thousand years in the past. Topographic cross section obtained with total station method revealed about 3.7 m vertical displacement at ground surface level while about 3.2 m at On-Pm1 horizon (Fig. 7). Here the reason why the displacement is larger for the ground surface than that for On-Pm1 seems to be on the fact that the surface soil on the footwall was somewhat removed when building and playground were constructed.

Distribution of active faults around Kumagaya is

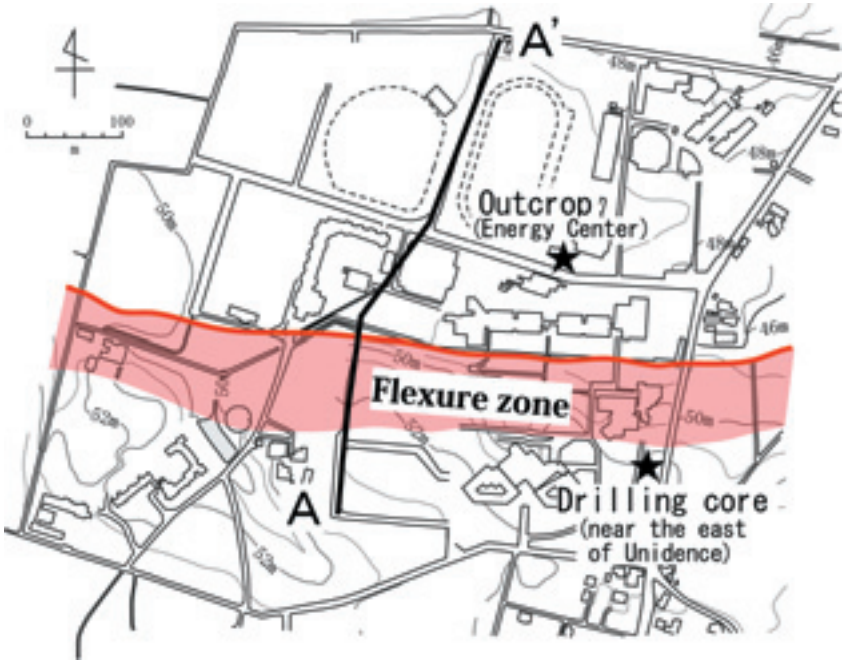

Fig. 6

Campus map and active faults around the Kumagaya Campus of Rissho University.

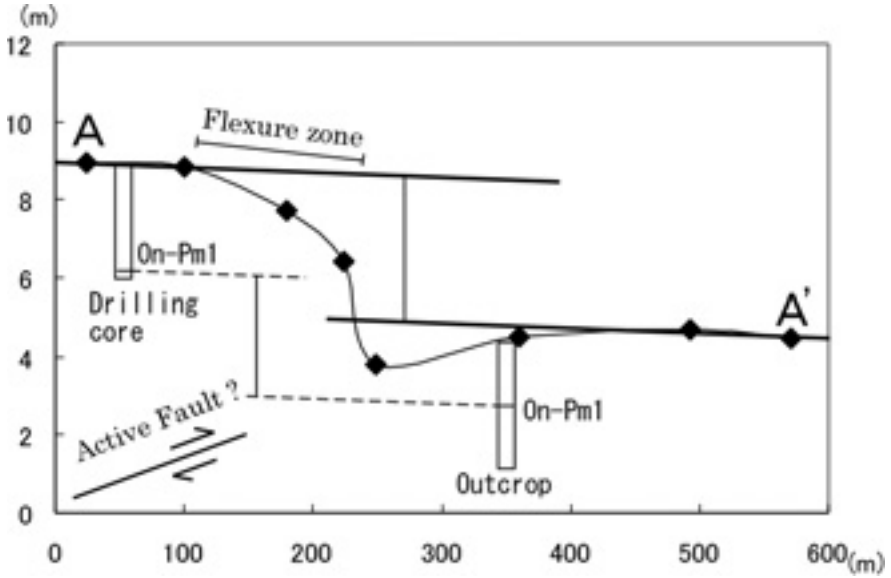

Fig. 7

The Profiles of deformed terraces across the Kumagaya campus area of Rissho University (A-A' line). Location of the profiles are shown in Fig. 6.

shown in Fig. 1. In the map, the position of newly found fault scarp of this study is shown by the letter R. This fault scarp is related to subordinate fault of Konan fault which itself is a subordinate fault of Fukaya fault (Fig. 8: modified from Yamaguchi *et al.*, 2000). Referring to Mizuno *et al.* (2002) and The Headquarters for Earthquake Research Promotion (2005), displacement of Konan fault per single earthquake event is estimated to be 70 cm and total displacement of loam bed (about 30 thousand years or older) to be 2.5 m. The displacement found this time in Rissho University campus is about 3.2 m for the last 100 thousand years. Assuming the displacement per single earthquake event related to Konan fault to be 70 cm or less, the displacement topography corresponds to repeated movements of once for 20

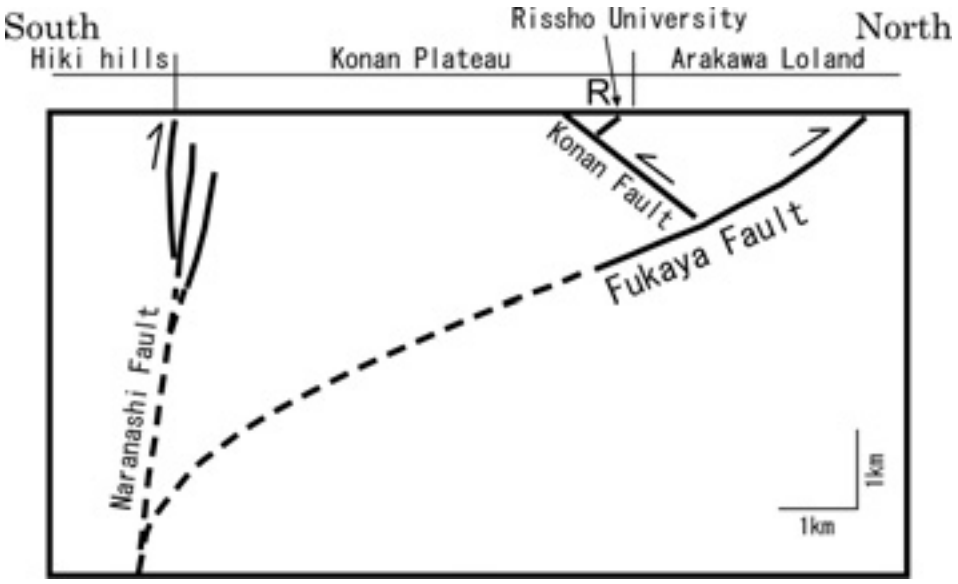

Fig. 8

Underground structure in the Konan Plateau (modified from Yamaguchi et al., 2000). In the map, the position of newly found fault scarp of this study is shown by the letter R. This fault scarp is related to subordinate fault of Konan fault which itself is a subordinate fault of Fukaya fault

thousand years (the earthquake itself is related to the activity of Fukaya fault).

The latest activity of Konan fault, however, seems to have occurred after 6,200 yBP and before 2,500 yBP (The Headquarters for Earthquake Research Promotion, 2005), suggesting that the possibility of recurrence movement of this fault seems to be low. On the other hand, for Kushibiki fault, another subordinate fault of Fukaya fault, recurrence interval of the earthquakes was found to be once for 10 thousand years based on a trenching study (Sugiyama *et al.*, 2009). As recurrence intervals of the earthquakes in several subordinate faults are about 10 thousand years, and that of Fukaya fault is suggested to be less than 10 thousand years.

Lastly this study suggests that a cliff created by fault movement misidentified to be erosion cliff (or vice versa) may possibly be common in the world. Misidentification of the origin of surface cliff could lead to erroneous interpretation of topo- and geo-history of the area. We' d like to draw attention to this fact.

5. Conclusions

In this study the following conclusions are reached.

1. A study of newly created outcrop with construction work of Rissho University Energy Center revealed existence of On-Pm1 pumice in sediments constituting Konan II surface (Arai *et al.*, 2002). This fact indicates that the cliff between Konan I and Konan II is not an erosinal one as has been assumed in the past, but the one created by fault movement.
2. Stereographic examination of air photos of Rissho University campus area confirmed a topographic flexure (about3.2m) with south side uplifted.
3. The flexure is interpreted to have formed by several earthquakes since about 100 thousand years. Assuming displacement of 70 cm or less at Konan fault per single earthquake, the displacement topography found in Rissho University Kumagaya campus suggests displacements repeatedly occurring at a rate of once for every 20 thousand years or so.

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Abstract:

An active fault, which displaced Konan terrace surface about 3.2 m about 100 thousand years ago, was newly discovered within the Kumagaya campus area of Rissho University. This fault is interpreted to be a subordinate fault of Konan fault, which itself is a subordinate fault of Fukaya fault, and is estimated to have repeated its displacement movements once in about 20 thousand years considering evidence on earthquake activities of Konan fault. The cliff formed by displacement by the fault has been interpreted to be an erosion cliff. This suggests that such misidentification of movement cliff as erosion cliff or vice versa may exist in other cases in the world including Japan.

Keywords: Fukaya fault, subordinate fault, fluvial terrace, recurrence interval

副次断層の調査に基づく深谷断層の活動性評価

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要　旨：

立正大学熊谷キャンパス内にて、約100,000年前に形成された江南面を約3.2m 変位させる活断層を新たに確認した。この活断層は深谷断層の副次断層である江南断層のさらに副次的な断層であると解釈され、江南断層におけるこれまでの地震活動を考慮すると約20,000年に１回程度の割合で断層変位を繰り返してきた計算となる。今回新たに発見した江南面の変動崖は従来の研究においては浸食崖であると解釈されており、日本はもとより世界中においても変動崖が浸食崖と誤認されているケース、もしくはその逆（変動崖→浸食崖）の事例が少なからずあるであろうことを示唆できた。

キーワード：深谷断層、副次断層、河成段丘、地震の再来間隔