GEOLOGICAL INDICATORS ASSOCIATED WITH PALEOEARTHQUAKES: FOCUSING ON THE GEOMORPHOLOGICAL EVIDENCES

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ABSTRACT

In this study, I have categorized the evidences into two groups; geomorphological evidences (macro-scale) related with surficial expressions and stratigraphic evidences (micro-scale) which is obtained from trench studies. This study is focusing on the geomorphological evidences to find the location of fault, to prove the existence of large earthquakes or not in the past from the geological point of view. Geomorphological evidences which are obtained from aerial photography and geological field excursion have been done for Tachikawa Fault, Itoigawa-Shizuoka Tectonic Line Active Fault System, and Sekiya Fault to test the reliability of geomorphological features indicating fault on the surface. Some of the evidences which are topographic altitude differences between both sides of the fault, displaced landforms, drainage patterns cut and displaced by main fault, geological unit differences, and lineament analysis have been investigated by using the aerial photographs for study areas. Other evidences which are used to check the reliability of data coming from aerial photography study, detailed geological unit description to find the deformation pattern produced by fault and to determine the exact location of fault, and preparation of geological map to define the boundary of units have been obtained by geological field excursion. For three study areas, firstly aerial photography study has been done to get the general idea about areas. Secondly, field excursion has been carried out to control the data from aerial photos and to obtain new evidences by using the geological evidences. Also, to examine the recent surficial expressions, Iwate-Miyagi Earthquake area is selected and geomorphological study has been carried out to discuss the critical situation for paleoseismology.

Keywords: Paleoseismology, Paleoearthquakes, Geomorpgological evidences.

1. INTRODUCTION

Paleoseismology an interdisciplinary science between Geology and Seismology is purely geological exploration for paleoearthquakes. Paleoseismology is the study of prehistoric and historic earthquakes (Solonenko, 1973; Wallace, 1981) especially their location, timing and size (McCalpin, 1996) mainly by using the field investigations. It is deeply concerning with the identification of active faulting, amount of slip rate, rupture length, repeated time, and slip per event and assessment of magnitude of future events. The main reasons to understand the paleoearthquakes are activation of the same fault with similar behavior and the latest earthquake on the fault which are critical to judge the hazard coming from that fault (Schwartz and Coppersmith, 1984). Although it is very difficult to get information about past events implying pre-historical or historical events, paleoseismological investigations have proven all around the world to be very effective device for assessing the seismogenic potential of any given fault.

The main purpose of this study is to clearly document the relationship between geomorphological and structural behavior of the geological units to be exposed to destructive earthquakes in the past. This study is supposed to give clear explanation about geomorphological evidences to investigate the large earthquakes happened in the historical and pre-historical time.

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2. METHODOLOGY

The first and significant method in paleoseismology is aerial photography interpretation. Totally, 193 aerial photos (Tachikawa Fault (98), Itoigawa-Shizuoka Tectonic Line Active Fault System (45), and Sekiya Fault (50)) have been examined. By using the aerial photos, all topographic features presenting in the study areas are carefully described and then some critical places which have sharp vertical changes on the slope, drainage displacements and displaced landforms have been signed to visit later during field study. Therefore, lineament maps have been drawn. Second method used to define geomorphological evidences is field excursion. After examining the aerial photographs, I selected some critical places which have strong evidences like sharp changes in altitude, slope and also some clear lineaments which are possible to accurate location of fault. Before visiting these areas, I prepared general geological map of the study areas by using the aerial photos. It should be prepared very detail but time is not enough to do so. After the step, I visited and tried to observe the fault plane.

In this study, I divided into two groups of indicators; the geomorphological (macro scale) and stratigraphical indicators (micro scale). The main part of this thesis is geomorphological indicators from the three examples in Japan. But stratigraphic indicators have been explained briefly.

3. STRATIGRAPHIC INDICATORS (MICRO SCALE EVIDENCES)

Stratigraphic indicators to define the paleoearthquakes are also very effective to get the actual ages of units and events. Geomorphological and stratigraphical evidences are used to describe different part of events. For example, geomorphological evidences are used to find the location of faults and all information included by surficial expression. On the other hand, stratigraphic clues can give fault plane itself by means of trenching study. For stratigraphic evidences, trenching study is an influential application.

In trenching studies, these laws are the key to define the past events or any abnormal situation. The relationship between sedimentary structures must be examined carefully. Before constructing the faulting history of any trench site, the characteristics of sedimentary units, and deformation features must be recorded in detail. In some cases, we cannot observe the fault because of lack of permanent clue. In this case, the deformation patterns of units become very important.

The classification of stratigraphic indicators can be very difficult in complex structural events. They can be divided into on fault, off fault, direct and indirect evidences according to their probability percentages for past event (Allen, 1986; Toda, 1998). These authors described some features used to identify individual paleoearthquakes obtained from trench survey under this classification. In this study, I explained all situations and divided into four groups; faulting related, depositional patterns, strong shaking and borehole and coring evidences.

In next part of the report, I have explained my study geomorphological approaches for three main faults in Japan.

4. AERIAL PHOTOGRAPHY AND FIELD EXCURSION ON STUDY AREAS (JAPAN)

I have explained aerial photography study and geological field excursion on the study areas in Japan. These are Tachikawa Fault, Itoigawa-Shizuoka Tectonic Line Active Fault System, and Sekiya Fault. Former three areas have been selected as an application area of aerial photos and field excursion methods to determine the active faults. Besides, latter one Iwate-Miyagi earthquake area has been selected to discuss the situation in which before large earthquake there is no any surficial expression. It is explained in discussion part in detail.

The reason to choose three main areas for application is that in paleoseismology there are many geomorphological indicators and it is not possible to describe many of them in only one place. To get many evidences and define them clearly, we have chosen three areas. These study areas have been explained separately.

4.1. Tachikawa Fault

First of all, I have examined 98 aerial photos totally. I have prepared two maps including lineament and drainage pattern map to define the critical area to visit during field excursion. These two maps are very important to find the location of fault. In lineament map, big vertical differences cannot be detected. For Tachikawa fault, drainage map is not useful to define the location of map. There is not any clear deformation or lateral displacement on the map.

After aerial photograph study, we have visited the place and checked the lineaments seen on the aerial photos. There are some clear displacement along highway and agricultural field (Figure 1). In this figure, black arrows are showing the part of fault which has been affected by human activity and white arrow is showing the actual displacement on the fault.

For Tachikawa fault, the data obtained from the aerial photography study to define the location of the fault has not satisfied. Without field study, it can be difficult to define the exact place of fault.

Figure 1. Location of Tachikawa fault.

4.2. Itoigawa-Shizuoka Tectonic Line (ISTL)

45 aerial photographs have been examined to obtain 3-dimensional view to identify topographical expressions. The most important part of the study for this fault, topographic altitude differences between both sides of the fault is very high and it has been detected obviously from aerial photos.

ISTL cover very large place on the centre of Honshu Island. We only focused on the central part of it. Figure 2 is showing one of the aerial photography interpretations in this fault. Topographic elevation differences between two sides of the fault and drainage pattern change are very important clues to define the location of fault. Dark color area is showing the mountainous area. After aerial photos study, I defined many place to visit during field excursion. One of the selected areas is shown on Figure 2 in circle. Close up view of the area can bee seen on Figure 3. The exact location of fault has been detected successfully.

After aerial photography study, many places selected during this study have been visited and all of them are the place illustrating the fault clearly. For paleoseismological study, next step should be trench site selection. In this study, because of the time limitation, trenching study cannot be applied.

The most important issue in Figure 3 is that older unit is located on higher elevation and younger unit is located on lower elevation and they have very sharp boundary.

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Figure 2. Aerial photo interpretation of the central part of the ISTL, Shimotsuburai Fault.

Figure 3. The close up view of fault from SSE to NNW on the area signed by circle in Figure 2.

Topographic elevation differences, drainage pattern, and lineaments maps from aerial photography and geological unit boundaries, reverse location of younger and older units obtained from field study are apparently prove the location of fault.

4.3. Sekiya Fault

For this fault, I have looked at 50 aerial photos to prepare lineament map and drainage pattern map. In lineament map, the trace of the fault is signed by large vertical displacement. Western site of the fault is mountainous area and it has steep slopes, but, eastern site of the fault is almost flat-lying area represented by recent alluvial fans. By using the altitude differences and sharp slope changes between two sides of the fault, and lineament pattern, it is very easy to find the location of fault from aerial photos.

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Figure 4. Aerial photograph of tip area from Sekiya fault.

In Figure 4, location of the fault from aerial photos has been shown by white arrows. The area showing in the figure 3 is very big and it is very difficult to walk along the fault. Because of this reason, I selected some places to visit and the situation is the same in ISTL, fault location can be seen easily during the fault excursion.

I have visited not only the places which have big vertical elevation differences but also the small elevation differences on the alluvial deposits to get the idea for further trenching studies.

As a conclusion, surficial expressions elevation and slope change, drainage pattern, lineament maps from aerial photograph studies, field excursion for geological description and evidences and results obtained from past trenching studies are used to get reliable data about fault location. These criteria have been checked for each study areas, and concluded.

5. DISCUSSION AND RECOMMENDATION

Paleoseismology is very important tool to detect the past events by using the geomorphological evidences. For Tachikawa fault, Itoigawa-Shizuoka Tectonic Line (ISTL), and Sekiya fault, many of the geomorphological indicators have been observed and the location of fault has been defined. Yet, it is possible not to observe any geomorphological evidences without any recent large earthquake. Iwate-Miyagi Nairiku Earthquake (13.06.2008) is very good example for such difficulties in case of no surficial expression before large event. According to USGS, the epicentral location of event is 39.122°N, 140.678°E, magnitude is Mw=6.8.

Before occurring the earthquake, there was not any clear indicator about existence of active fault here. That is the reason to select this area as a good example in which geomorphological evidences cannot be seen or used to define the fault location.

After one month, we visited the place to examine the surface rupture and surficial expression occurred after event. We walked along the central part of the surface rupture and observed the displacement very clearly. Surface rupture cut and displaced many rice fields. The amount of vertical offset is around 20 cm.

Vertical displacement range is 20-55 cm which I measured around this part of the fault. These displacements are located on rice fields so before that earthquake, the detection of fault and existence of active fault are very difficult because of the flat rice fields. During this trip, I also observed many landslides because of strong shaking. But these are not useful to define the exact location of fault.

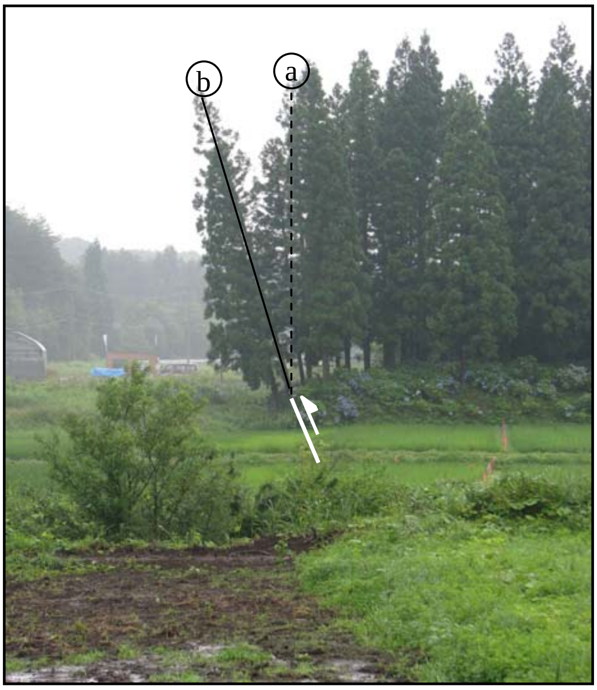

Figure 5. Deformation of pine trees and vertical displacement on the fault.

In Figure 5, I measured max displacement 55cm. As you see the pine tree and vertical displacement, location of fault is very clear. The letters a and b are showing the position of pine trees before and after the earthquake, respectively. Location and the displacement of fault are signed by white line and arrow in the figure. This point is the clearest location of fault even before the earthquake. Small amount of displacement and lack of indicators in other parts of the fault are the reason that this place was not evaluated as an active fault location. It means that if there was not any earthquake here, the existence of active fault could not be detected. This situation is one of the important limitations of paleoseismology. If you do not have or very little surficial expression which cannot be realized during aerial photography or field survey study, it is very difficult to judge the location of fault even the existence of fault.

In such situation, there is only way to detect the existence of fault in any place that is historical documents if the nation has.

6. CONCLUSIONS

In this study, Tachikawa fault, Itoigawa-Shizuoka Tectonic Line Active Fault System, and Sekiya fault located inland part of the Japan have been studied carefully. Aerial photography study and detailed field excursion study carried out for these areas. Additionally, Iwate-Miyagi earthquake has been examined as a difficult case for paleosesimological application. For Tachikawa fault, 98 pieces of aerial photos have been examined. Because of the small slip amount of fault, a clear vertical displacement has not been observed. After preparing the lineament, drainage map and topographic altitude differences, I checked them in the field. During the field study, the fault location can be seen with minor amount of displacement same with the results coming from aerial photos. The reason for the small amount of displacement is that this place has a dense construction and fault trace on the surface destroyed by them, but, still there is a flexural surface rupture in some parts. Combination of aerial photography results and field excursion study, the existence of fault and past event which has been produced by this fault have been detected. For central part of the Itoigawa-Shizuoka Tectonic Line Active Fault System, 45 aerial photos are examined. This part of the fault is strike-slip with thrust component. Because of the thrusting, topographic altitude differences between two sides of the fault very clear. Drainage pattern is signing the location of fault properly without any doubt. Therefore, lineament map of the aerial photos is also showing the same location of fault getting from other indicators. During field study, triangular facets, river offsets, sharp boundary between two different units and their order (older is upper, younger is lower elevation) are clearly indicating the existence of fault and past earthquake here. For Sekiya fault, 50 aerial photos have been studied. This fault has thrust character dominantly. That is why I observed a very large vertical displacement between up-thrown and down-thrown blocks of the fault. Depending on this feature, lineament map of the area is obviously indicating the location and existence of fault.

Lineaments, and drainage maps, altitude differences on both sides of the faults, geological unit description and boundary between them have been defined to check closely during the aerial photography and field excursion. Aerial photography study is the first step to look the field as a general point of view. Geological field study is the second step to confess the information coming from aerial photographs. In addition, by using the geomorphological evidences, I only described the existence of fault and past large events. I cannot say anything about how many earthquakes occurred in the past and their times. For these things, trenching study is needed. Furthermore, detailed geological mapping is very important for next step which is trenching. For want of time, trench study could not be applied in this study. One of the most important data obtained from trenching investigation is the stratigraphical indicators for paleoearthquakes. Besides, I have summarized the information about necessary tasks and useful Stratigraphical Indicators for my studies in future.

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