Mimic active faults – the Quaternary deformations by bedrock expansion

Shuichi HASHIMOTO (1), Tadashi MIWA(2), Yuji TORIGOE(2),
Masanori NIIYAMA(3) and Kunio TAKANO(3)

(1) Tohoku Electric Power Co., Inc., Japan
E-mail:hashimoto.shuichi.sp@tohoku-epco.co.jp
(2) Tohoku Electric Power Co., Inc., Japan,
(3) Dia Consultants co., Ltd., Japan

Abstract

It is important to evaluate seismogenic active faults in order to proper seismic design for nuclear facilities. We should carefully perform geological surveys and judge the fault activity from the viewpoint of earthquake generation, because it is often difficult to distinguish seismic from nonseismic deformation features. We are liable to interpret "the Quaternary deformations along to the geologic fault planes" as the evidence of active faults. In case of the Higashidori Nuclear Power Plant site, there are several sets of characteristic deformations in the late Quaternary terrace deposit (younger than 120ka) covering the weathered Miocene bedrock with some geologic faults. Careful geological surveys clarify that these deformation features are not consistent in the continuity. For clear example, the shear planes of some faults often disappear in the dip direction and strike direction. Furthermore, these features have no accumulation in the late Quaternary. These facts indicate that these deformation features occurred in shallow bedrock which has been suffered from weathering or deterioration. Therefore, they should not be generated by tectonic or seismogenic. Another physicochemical analysis indicates that these features are often better explained by the volumetric expansion of the weathered or deteriorated bedrock.

Keywords: active fault, non-tectonic features, Quaternary deformation, volumetric expansion

1. Introduction

It is very important to consider and evaluate the fault activities in order to assure the seismic design for the electric facilities, particularly nuclear power plants.

Detailed geological surveys were performed in the site of Higashidori Nuclear Power Plant (NPP).

2. Outline of the study area

Higashidori NPP site is located on the Pacific Ocean side of the Shimokita Peninsula, northeast end of Tohoku District, Northeast Japan (Fig. 1). The site covers the area 3.5 km long from north to south and 1 km wide from west to east. The study area is in contact with the Shimokita mountainous area to the west and is facing the Pacific Ocean to the east.

The study area is underlain by Early to Middle Miocene sedimentary and pyroclastic rocks covered with several Late Pleistocene terrace deposits.

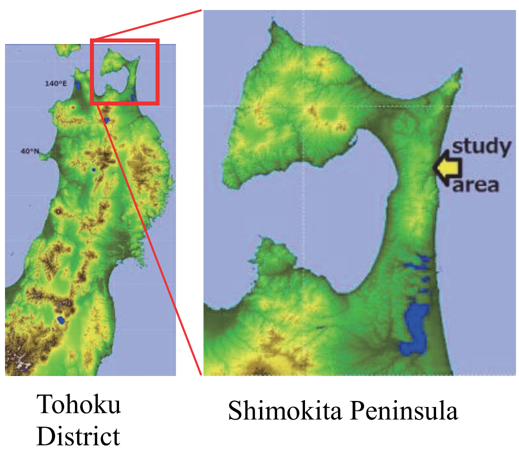

Fig. 1 Location map of the study area

3. Geomorphology

Geomorphologic surface studies about altitude, distribution pattern, clearness, index tephras, etc. show that the on-site terrace are divided mainly into M_1, M_1', M_2, and L_1 surface, which are compared with MIS5e, 5e, 5c and 5a, respectively (Fig.2).

The results also indicate that lineaments or tectonic landform suggesting fault activity are not observed.

4. Regional geology

4.1 Neogene

Neogene basement rocks have no outcrops in the site because they are widely overlain by Pleistocene terrace deposits. So, the basement geology has been studied in detail by drilling, tunneling and trenching method as a result of nuclear energy assessment.

The Neogene geological map and the location of geological surveys are shown in Fig.3. The Neogene of the study area is divided into the Sarugamori, Tomari and Gamanosawa Formations in ascending stratigraphic order.

The Sarugamori Formation is the lowest formation and crops out the north of the site. This formation is composed of mudstone, sandstone, conglomerate and pumiceous tuff.

The Tomari Formation, mainly conformably overlies the Sarugamori Formations, is widely distributed in the site. It is composed of andesite lava, tuff breccia, lapilli tuff and tuff. Tuff breccia rarely contains silicified wood (fossil trunk). K-Ar age of the lava indicate 13-15 Ma (Watanabe et al., 1993).

The Gamanosawa Formation unconformably overlies the Tomari Formation and is restricted in distribution by major faults. Elongated shape bodies from north to south of this formation lie in NNE trending fault contact with the Tomari Formation. The Gamanosawa Formation is composed of conglomerate, sandstone, mudstone and tuff. The diatom age indicates 9.9-14.9 Ma (NPD 5C-4A zone).

4.2 Quaternary

The Middle Pleistocene terrace deposits unconformably cover the Neogene basements and widely distributed in the study area.

These terrace deposits consist mostly of gravel and marine sand and are overlain by loam. These terrace deposits contain some intercalated index tephras, such as Toya (112-115ka), Aso-4 (85-90ka), To-Rd (80ka) and so on. These terrace deposits are divided into M1, M1', M2 and L1 terrace based on above mentioned index tephras and the altitude of their planes.

5. Geological structure

The structure of Miocene strata in the study area is characterized by several NNE-SSW trending major faults (Fig.3). Although gently dipping to eastward generally, the Miocene strata are faulted by above mentioned NNE trending normal faults. The throw of these major faults are estimated up to several hundred meters in maximum. It is considered that these structures were formed during the late Miocene tectonics of WNW trending tension stress field as known in Northeast (Tohoku) Japan.

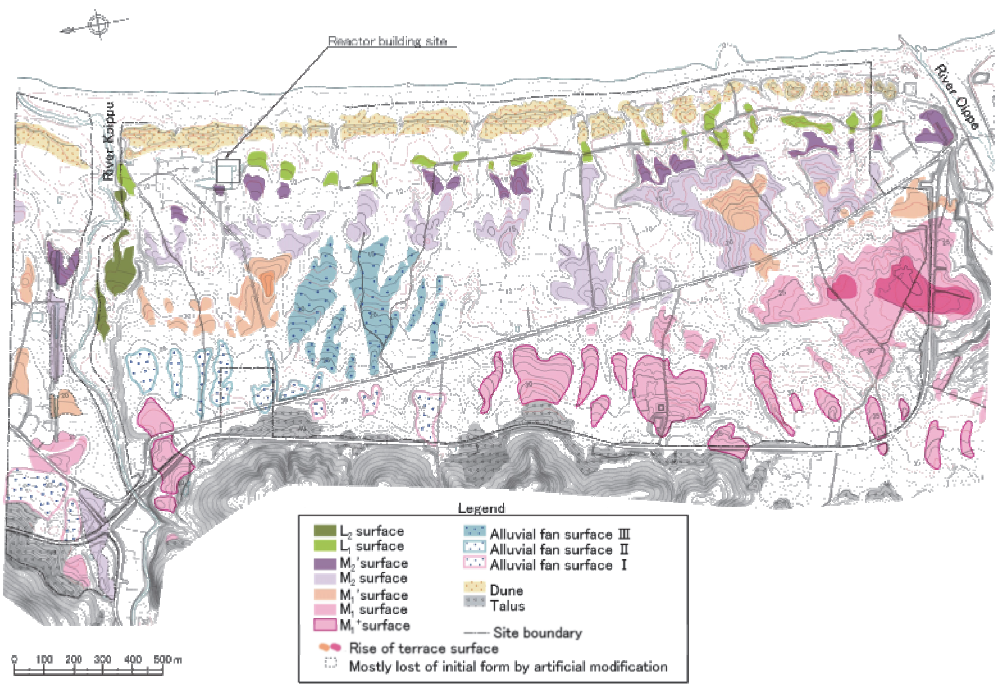

Fig. 2 Geomorphic surface map in the study area

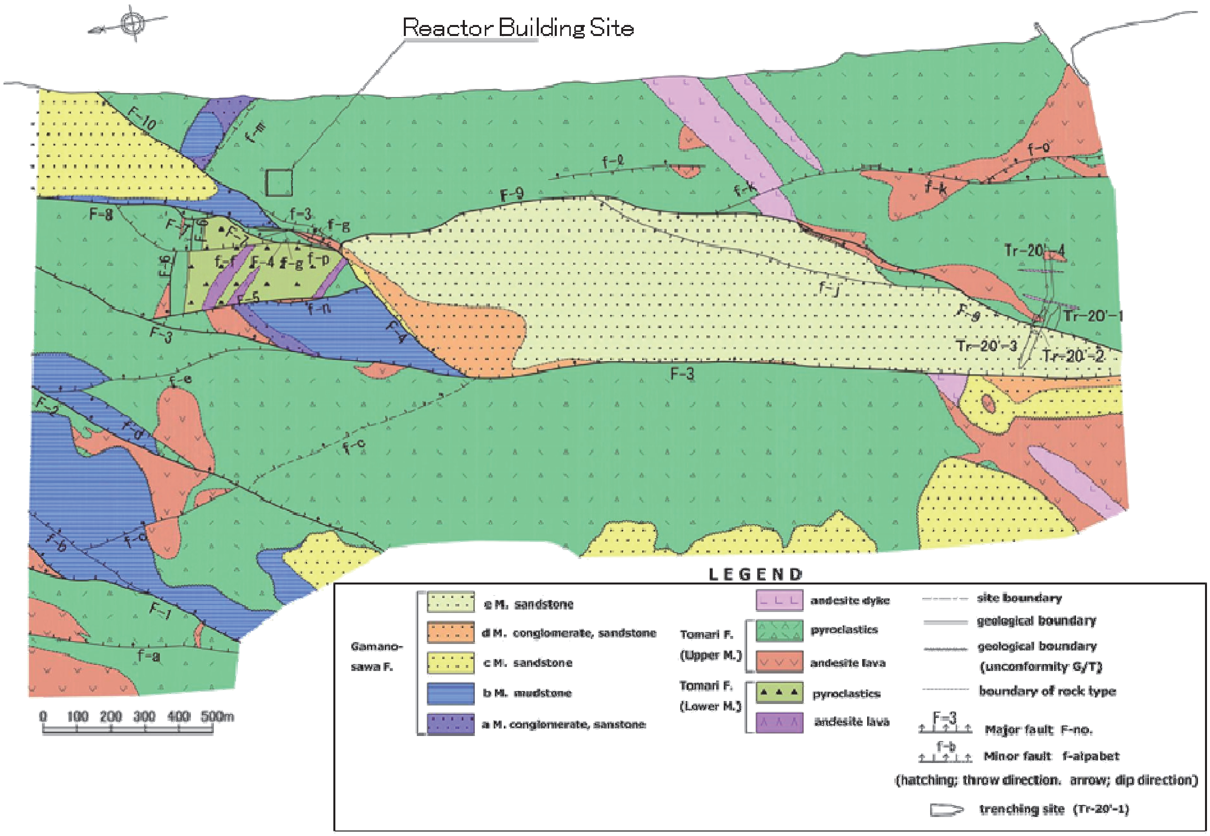

Fig. 3 Geological sketch map of the study area

6. Quaternary deformations

A wide variety of the Quaternary deformations occur in the study area. They are often observed at the surface of weathered basements. "The Quaternary deformations" can be divided into three types. The characteristics of each deformation are as follows;

Type 1: small displacement or step along fault plane

Site and features; in the basement of Quaternary deposits or in the lamina of Quaternary deposits. Size; several centimeters to tens of centimeters

Type 2: convex upward form

Site and features; upside of the weathered bedrock surface and the shape is concordant to the heaving bedrock surface. Size; wave length is several meters, heaving height is several tens of centimeters

Type 3: clay injection into Quaternary deposits

Site and features; upside of major fault zone, the soft clay is originated from shear zone of geologic major fault. Size; tens of centimeters.

7. Example of Quaternary deformation at Trench 20'-1

Examples of the Quaternary deformation and distribution of weathered bedrocks at Trench 20'-1 are shown in Fig. 4.

Minor reverse-like s-19 fault (type 1) is observed at the south wall of the trench. Fault plane trends NNW and dips west in the deeply weathered tuff breccia. Although the hanging wall side of the fault was elevated one meter, displacement is diminishing westward and it dies out in the berm. Although hanging wall side rises asymmetrically only the range of ten meters, there is no difference in the altitude of the basement surface from east to west. On the other hand, when we trace a fault line to the north wall in the strike direction, there become only convex form(type 2). Furthermore, we can observe several convex form of bedrock surface which wave length is ten meters in the same trench wall (Photo.1, Fig.5).

Bedrock around here is highly weathered and turned dark brown color. And strongly deteriorated zone of the bedrock in the hanging wall side of the s-19 fault is rather thicker than in the foot wall side (Fig.4). A number of low dipping sheeting joints are developed in the basements (Fig.5).

Black fine precipitates adhere to their joint planes, and slickensides are often observed on them. These facts indicate the result of rocks friction between joints.

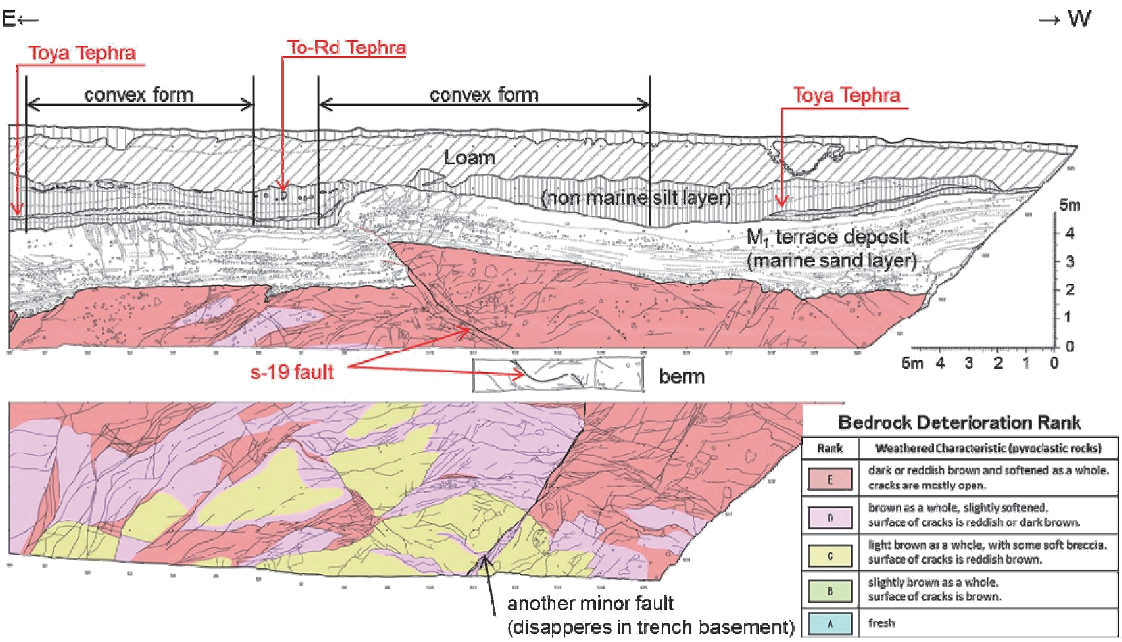

Fig. 4 Bedrock deterioration rank of Trench 20’-1 south wall

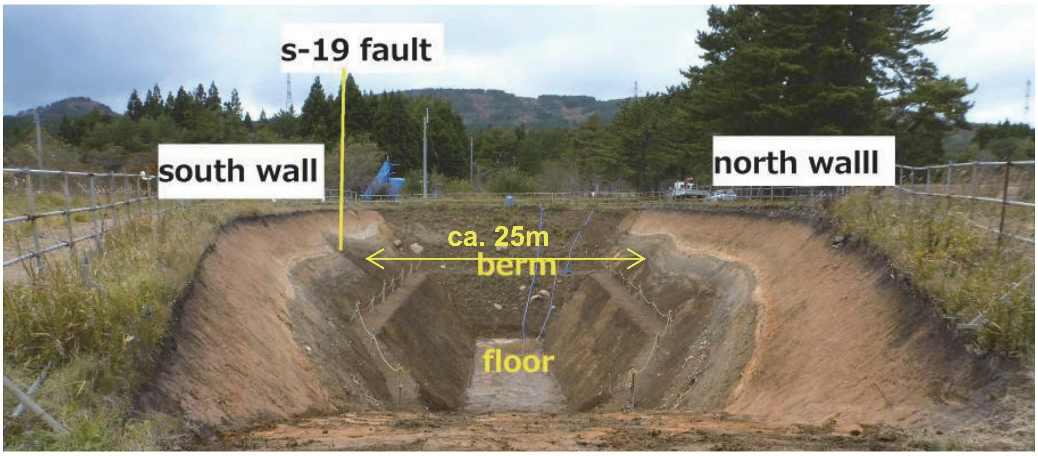

Photo1 Photo of Trench 20’-1(from east to west)

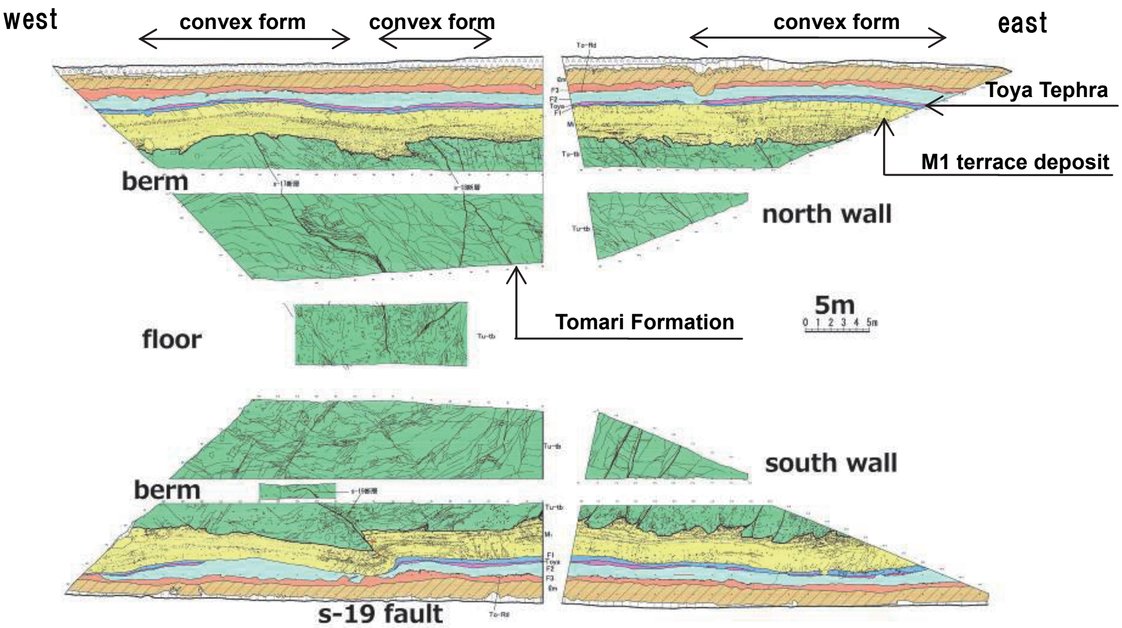

Fig. 5 Layout of Trench 20’-1

8. Discussion

In this example of reverse-like s-19 fault, 1 meter displacement near the bedrock surface along the shear plane is disappeared within a few meters depth. Although very local zone (less than 10m wide) of upheaval around the s-19 fault was formed, there is no vertical separation in whole wall of the trench.

In addition, distribution of weathered bedrocks (Fig. 4) strongly corresponds to “the Quaternary deformations”. Other trenching data show that many convex upward forms with wavelength of ten meters are commonly distributed in weathered bedrocks.

The phenomena of volumetric expansion of rocks during weathering are reported concerning various types of rocks (Chigira and Nakata, 2013). In case of Higashidori site, the measurements of volumetric expansion were carried out for tuff breccia using titanium known as immobile element. The measurement obtained the result of 20 percent expansion at highly weathered part in comparison at fresh part (Torigoe et al., 2013).

From the above-mentioned observations and the measurements, we think these deformations are not formed by tectonic origin at least, but formed by the volumetric change of weathered rocks.

Concerning type 3, “heaving bedrock” phenomena which can form shear planes by slow speed deformation is reported (Noe, et al., 2007).

9. Conclusions

The Quaternary deformations can be divided into three types. The characteristics of each deformation are as follows;

Type 1 (“fault like planes”) mainly exist in weathered rocks and go extinct at shallow depth. It means “rootless”.

Type 2 (convex upward deformation of Quaternary deposits) exist in weathered bedrock beneath it and often accompanied with no faults.

Type 3 (injected clay) often has irregular flow structure in it with no sharp shear planes. These facts indicate that the injection was not coseismic event with high-speed shearing during earthquake.

On the whole, the Quaternary deformations are not consistent in the continuity and orientations, and have no accumulation of displacements respectively.

All of the facts suggest these phenomena occurred in shallow weathered or deteriorated zone and should not be tectonic and seismogenic faults.

Because the research cases are rare, it is not still clear the mechanism of volumetric change of rocks completely. A few issues to be solved are left. We should more discuss a quantification of volumetric change and the timing of heaving for the future.

References

Chigira, M. and Nakata, E. (2013): Volumetric expansion during weathering of various rocks and its geological significance, Abstracts of the 120th annual meeting of the geological Society of Japan, p.151 (in Japanese).

Noe, D. C., Higgins, J. D. and Olsen, H. W. (2007): Steeply Dipping Heaving Bedrock, Colorado: Part 1—Heave Features and Physical Geological Framework, Environmental and Engineering Geoscience, Vol.13, No.4, pp.289-308.

Torigoe, Y., Miwa, T., Nakata,E. and Chigira, M. (2013): The volume expansion of rocks by the weathering, a case study of Higashidori Nuclear power station, Abstracts of the 120th annual meeting of the geological Society of Japan, p.303 (in Japanese).

Watanabe, N., Takimoto, T., Shuto, K. and Itaya, T. (1993): K-Ar ages of the Miocene volcanic rocks from the Tomari area in the Shimokita Peninsula, Northeast Japan arc, J. Min. Petr. Econ. Geol., vol.88, pp.352-358.