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ABASHIRI TECTONIC LINE
— with special reference to the tectonic significance of the southwestern margin of the Kurile Arc —

by

Gaku Kimura

(with 10 text-figures and 1 table)

Abstract

It has been considered that the Kurile Arc "collided" with the Northeastern Japan Arc or Central Hokkaido. (Kaizuka, 1972, 1976; Fujii and Sogabe, 1978). Fujii and Sogabe (1978) recognized a N-S trending suture fault zone in eastern Hokkaido. The author revealed the detailed movement picture of the fault zone on the basis of structural analysis of the fault and adjacent deformation, and called the fault zone the Abashiri Tectonic Line. The Abashiri Tectonic Line is estimated to be connected with the Kitami-Yamato Thrust in the Okhotsk Sea and the Kushiro submarine canyon in the Pacific, and traverses the trench-arc system at the southwestern margin of the Kurile Arc.

The Abashiri Tectonic Line is divided into two segments; the N-S trending northern segment and the NE-SW to N-S trending southern segment. The northern segment is truncated by the southern segment in the Hombetsuzawa area, where the latter segment bends its direction from NE-SW to N-S toward south.

The Abashiri Tectonic Line was formed through the tectonic process of the following two stages. First stage: A notable left-lateral strike-slip movement along the tectonic line occurred in Late Miocene time. This movement picture was revealed by analysis of echelon folding along the northern segment of the tectonic line. This movement, however, has been inactive since Pliocene time, inferred from the evidence that the Pliocene strata overlie the segment.

Second stage: A right reverse displacement along the NE-SW trending southern segment and a reverse displacement along the N-S trending southern segment occurred in Pliocene time. The sense of these displacements was studied by the analysis of the deformation along the fault.

The formation of the Abashiri Tectonic Line is considered to be ascribed to the initial northward shift of the Kurile Arc in Late Miocene time and the subsequent westward shift of the Outer Kurile Arc in Pliocene time.

Introduction

Two island arcs, the Kurile and Northeastern Japan (Tohoku) Arcs, are jointed in Hokkaido. Hokkaido is divided into three geologic provinces; Southwestern (northern extension of the Northeastern Japan Arc), Central (Hidaka Orogenic Belt), and Eastern Hokkaido (Kurile Arc) (Hashimoto, 1958; Yoshida, 1978).

Kaizuka (1972, 1976) postulated that the Kurile Arc shifted westward and "collided" with the northeastern Japan Arc in the Central Hokkaido. Fujii and Sogabe (1978) pointed out that the Kurile Arc "collided" with the Central Hokkaido, and recognized a N-S trending fault zone which traverses the eastern Hokkaido. They considered that the fault zone is a major boundary between the two geologic provinces, the Central Hokkaido and Eastern Hokkaido. The fault zone has been called by various names, i.e. the Hombetsuzawa Fault in the Ukotakinupuri area (Inoue and Suzuki, 1962), the Kamiashoro Fault in the Kamiashoro

Contribution from the Department of Geology and Mineralogy, Faculty of Science, Hokkaido University, No. 1707.
area (Mitani et al., 1964), and the Futamata Fault in the Honki area (Yamaguchi and Sawamura, 1965).

Kimura (1979a, 1979b, 1980) studied the deformed structure in the Ashoro and Futamata areas along the fault zone on the basis of analysis of minor faults, minor folds, sandstone dikes, and joint systems. He pointed out that this fault is a left-lateral strike-slip fault in the Futamata area. He estimated that the fault zone is situated at the southwestern margin of the Kurile Arc and is traceable to the sea areas, the Okhotsk Sea and the Pacific. Kimura (1979b) called this suture fault zone the Abashiri Tectonic Line.

The Abashiri Tectonic Line is divided into two segments; the northern segment and the southern segment as shown in Text-figure 1. The southern segment is identical to the Urahoro Fault (Text-figure 1). The northern segment is truncated by the southern segment near Hombetsuzawa.

In this paper, the strain and movement picture of the Abashiri Tectonic Line in the junction area of two segments, the Hombetsuzawa and Nishoh areas, is discussed together with the tectonic process of collision of the Kurile Arc against the Central Hokkaido.

**Text-fig. 1.** Structural map of eastern Hokkaido showing the location of the Abashiri Tectonic Line. A-B: northern segment, C-D: southern segment (Urahoro Fault).

**Geologic setting in the Hombetsuzawa and Nishoh area**

Summary of the stratigraphy

Table 1 shows the geologic system in the Hombetsuzawa and Nishoh areas.
Table 1. Stratigraphic sequence in the Hombetsuzawa and Nishoh areas.

Shohtoshibetsu Formation

This formation is exposed in a limited area along the Abashiri Tectonic Line in the Hombetsuzawa area, and mainly composed of slate, chert, and basic tuff. The formation is correlated with the Jurassic Nikoro Group (Yamada et al., 1953).

Nemuro Group

This group is well exposed to the southeast of the Urarahoro Fault, and mainly composed of sandstone, mudstone, and their alternating beds. The group was deposited during the age from Campanian to Danian (Yoshida, 1967).

Ombetsu Group

This group crops out in an area along the Urarahoro Fault. The group is assigned to the Oligocene, and lithologically divided into the following two formations in ascending order.

(1) Charo Formation: This is mainly made up of sandstone in lower half and mudstone with a large number of nodules in upper half. The basal conglomerate unconformably overlies the Shohtoshibetsu Formation, as observed at several points along the Hombetsuzawa.

(2) Nuibetsu Formation: This is mainly composed of shale, black sandstone, and their
Kawakami Group

The Kawakami Group is widely distributed in these areas. This group has been regarded as sediments deposited from Early to Middle Miocene (Mizuno et al., 1969). The group is lithologically divided into the following three formations in ascending order.

1) Hombetsuzawa Formation: This formation is made up almost entirely of shale and conglomerate. Several thin beds of conglomerate are observed at Ikeshomanaizawa. The relation between this formation and the underlying Nuibetsu Formation is recognized as a parallel unconformity.

2) Nishoh Formation: This formation is composed mainly of massive siltstone accompanied with several tuff beds in the upper horizon. The formation is correlative with the Morawan Formation in the northeast of the Hombetsuzawa area (Inoue and Suzuki, 1962).

3) Kiroro Formation: This formation is made up of massive sandstone in the lower half and mudstone in the upper half.

Hombetsu Formation

The Hombetsu Formation is exposed in the northwestern part of the Hombetsuzawa area, and mainly is composed of conglomerate and tuff bed. The thick basal conglomerate unconformably overlies the older strata. The formation is considered to be the lower Pliocene (Mitani et al., 1959).

Mode of occurrence of the fault systems in the Hombetsuzawa area

The sedimentary rocks in this area are cut by many faults (Text-figure 2a). These faults are classified into two systems, i.e. N-S and NE-SW fault systems. The N-S fault system underlies the Pliocene Hombetsu Formation, and is cut by the Urahoro Fault. Extension of the N-S fault system into the Nemuro Group is not recognized. Folds in this area are mostly minor with a half-wavelength of several ten meters.

NE-SW Fault System

1) Morawanzawa (Text-figure 2, Loc.1): A shear zone of the Urahoro Fault is observed at Loc. 1 (Text-figure 3c). The Nemuro Group thrusts up on the Nishoh Formation inclined reversely. The fault plane dips 60° SE. Many striations can be observed on the fault plane, being obliquely about 45° to the dip direction (Text-figure 3d). The shear zone mainly composed of a fault gouge of a few ten meters thick with a fault breccia zone of several meters thick. Bedding slip is observed in the Nishoh Formation of the foot-wall block of the fault.

2) Temmakuzawa (Loc. 2): At Loc. 2, the shear zone of the Urahoro Fault does not crop out, but a deformation near the fault can be observed (Text-figure 3a). The Nishoh Formation of the foot-wall block of the Urahoro Fault is inclined reversely and associated with many minor reverse faults. The stress field deduced from the minor faults is a lateral compression oblique to the strike of the Urahoro Fault (Text-figure 3d).
Text-fig. 3. a) Deformation in the footwall block of the Urahoro Fault at Temmakuzawa (Loc. 2). b) Stress field deduced from the minor faults. \((\sigma_1): \text{maximum compressional principal stress axis}) c) Mode of occurrence of the shear zone of the Urahoro Fault (Loc. 1). d) Stereogram of the fault plane and striations on the plane. (all projections to upper hemisphere)

(3) Kamiinaushi (Loc. 3): Fault UF-a (Text-figure 2a) and deformation around the fault are observed at Kamiinaushi (Text-figure 4). The Fault UF-a is a thrust fault dipping about 40° SE. The hanging-wall block of the fault is composed of mudstone of the Charo Formation. A number of micro-faults are developed in the foot-wall block (Text-figure 4b). These micro-faults have a component of right-lateral strike-slip (Text-figure 4b, d). The strike of the micro-faults is oblique to that of the Fault UF-a. Micro-drag folds are formed in the base of the hanging-wall block (Text-figure 4b). The axial plane of these folds are oblique to the strike of the Fault UF-a. Gentle folds with a half-wavelength of several ten meters are also developed in the foot-wall block. The direction of axial trace of the folds is about 30° oblique to the strike of the Fault UF-a. Moreover, a conjugate set of the strike-slip faults is recognized (Text-figure 4a, c). Horizontal striations are also observed on the plane of the strike-slip fault (Text-figure 4c).

(4) Urahorogawa (Loc. 4): Three NE-SW reverse faults (Faults UF-c, UF-d, and UF-e in Text-figure 2a) converge to the Urahoro Fault at Urarogawa. The Fault UF-c is a thrust inclined SE. Micro-drag folds are observed in the base of the hanging-wall block of the fault (Loc. 4, Text-figure 5a, b). The axial plane of the drag folds is oblique to the strike of the Fault UF-c.

\textit{N-S Fault System}

The N-S fault system is mainly observed along the rivers of Hombetsuzawa and
Text-fig. 4. The Fault UF-a at Kamiinaushi (Loc. 3).

a) Route map near the Fault UF-a. b) Occurrence of the Fault UF-a. c) Streogram of the Fault UF-a and the conjugate set of minor strike-slip faults. d) Streogram of micro-faults along the Fault UF-a. e) Streogram of the axial plane of micro-drag folds in the hanging-wall block of the Fault UF-a. (all projections to upper hemisphere)

Urahorgawa.

(1) Fault H-a: The shear zone of the Fault H-a is exposed across the both rivers. At Loc. 5 in Urahorgawa, a mudstone bed of the Nishoh Formation thrusts up on a sandstone bed of the Kiroro Formation. The fault plane dips 50° E. Many minor reverse faults are observed in the foot-wall block (Text-figure 5c, e). At Loc. 6 in Hombetsuzawa, the fault plane dips 70° E, and the fault gouge is about 10 cm thick. Horizontal striations are clearly observed on the fault plane (Text-figure 5f).

(2) Fault H-b: A shear zone and associated deformation of the Fault H-b are observed at Loc. 7 in Hombetsuzawa (Text-figure 6). The fault gouge is about 30 cm thick. The striations on the fault plane are oblique to the horizontal line. Minor left-lateral strike-slip faults are also developed along the fault. Folds with a wavelength of a few ten meters are observed along the fault. The axial traces of these folds are oblique to the strike of the Fault H-b and cut by the same fault. Displacement of the axis attains about 150 m left-laterally along the fault.

(3) Fault H-c: The Fault H-c is observed at Loc. 8 in Hombetsuzawa, where the fault plane dips about 70° E. The fault gouge is 20 cm thick.

(4) Fault H-d: This fault is observed at Kannozawa (Loc. 9). Minor folds with a flexural slip and minor reverse faults are formed along the fault (Text-figure 7). The axis of the fold
Text-fig. 5. a) Route map along the Fault UF-c (Loc. 4). b) Mode of occurrence of the hanging-wall block. c) Occurrence of the Fault H-a at Loc. 5. d) Streogram of the axial planes of the drag folds and minor reverse faults. e) Streogram of the Fault H-a and minor faults in the foot-wall block at Loc. 5. f) Streogram of the fault plane and striations on the plane at Loc. 6. (all projections to upper hemisphere)

trends northeastward, being oblique to the strike of the Fault H-d.

Urahoro Fault in the Nishoh area.

The Urahoro Fault bends its direction from NE-SW to N-S to the south of the Urahorogawa. At the Kawaruppugawa, a N-S trending fault is observed in the Nishoh Formation (Text-figure 8a). In the footwall block, minor thrusts are found (Text-figure 8b) and their strikes are mostly parallel to that of the main fault.

In the Nishoh area, the Urahoro Fault does not appear, but its associated deformation can be observed in the foot-wall block (Text-figure 8c, d). An isoclinal fold and imbricated thrusts were formed by the fault movement.
Text-fig. 6. a) Route map near the Fault H-b. b) Striations on the plane of the Fault H-b (Loc. 7, upper hemisphere).

Text-fig. 7. Occurrence of the Fault H-d at Loc. 9.
   a) Route map along the Kannozawa river. b) Flexural slip fold near the Fault H-d.
Movement picture of the Abashiri Tectonic Line

Movement picture of the fault systems in the Hombetsuzawa and Nishoh areas.

The mode of occurrence of the fault systems leads to the following consideration with respect to their movement picture.

**NE-SW Fault System**

Judging from the above-mentioned occurrence of the fault systems and experimental results of simple shear (Tchalenko, 1970; Wilcox et al., 1973), it can be pointed out that the dislocation along the NE-SW fault system has both components of reverse dip-slip and right-lateral strike-slip. The right-lateral strike-slip component along the NE-SW fault system may explain the following features which are recorded near the fault.

1. Striation on the fault plane is oblique to the strike of the plane (Loc. 1).
2. Right-handed echelon fold is developed along the NE-SW fault system (Locs. 3 and 4).
3. Axial planes of drag folds in the base of the hanging-wall block are oblique to the strike of the fault (Locs. 3 and 4).
4. The $\sigma_1$ of the stress field deduced from the minor faults in the footwall block is nearly horizontal and oblique to the strike of the main fault (Locs. 2, 3, and 4).
5. Left-handed echelon fault of the Riedel Shear type is formed along the main fault (Loc. 3).
N-S trending Urahoro Fault in the Nishoh area is estimated a pure reverse fault based on the fold and faults in the foot-wall block. The amount of displacement along the Urahoro Fault can not be estimated because no offset marker has been observed.

**N-S Fault System**

The N-S faults incline to east at Locs. 5 and 8 (Faults H-a and H-c) and are vertical at Locs. 7 and 10 (Faults H-b and H-d). Although the inclination of fault plane of the N-S fault system is variable, all of the fault is considered to have a left-lateral strike-slip component along the N-S fault system, as inferred from the following deformed structure found near the fault.

1) Horizontal striations developed on the plane of the Faults H-a, H-b, and H-c Faults (Locs. 6, 7, and 8).
2) Left-handed echelon fold along the Faults H-b and H-d.
3) Right-handed echelon faults of Riedel Shear type along the Fault H-d.
4) The horizontal displacement along the Fault H-b attains about 150 m left-laterally.
5) The $\sigma_1$ of the stress field deduced from the minor faults in the footwall block of the Fault H-a is nearly horizontal and oblique to the strike of the Fault H-a.

Age of the formation of fault systems and tectonic stress field in the Hombetsuzawa and Nishoh areas.

**Age of the formation of the fault systems**

The age of the formation of the fault systems in the Hombetsuzawa area can be estimated from different patterns of deformation between overlying and underlying strata of the unconformity. In this area, three unconformities are recognized; an unconformity between the Ombetsu Group and the Shohtoshibetsu Formation, a parallel unconformity between the Kawakami Group and the Ombetsu Group, and an unconformity between the Hombetsu Formation and the Kawakami Group, in ascending order.

The unconformity between the Kawakami Group and the Hombetsu Formation was formed by intense tectonic movement. The Middle Miocene Kawakami Group is intensively disturbed, while the Hombetsu Formation is slightly deformed. The Pliocene Hombetsu Formation is not cut by the faults such as Faults H-a, H-b, H-c, and H-d. These facts indicate that the N-S fault system in the Hombetsuzawa area was formed during the Late Miocene time and inactive in Pliocene time.

On the other hand, the Urahoro Fault was generated after the formation of the N-S fault system. The Pliocene Hombetsu Formation at Kawaruppu (Text-figure 8a) is deformed by thrusting of the Urahoro Fault. Therefore, the activity of the Urahoro Fault is considered to have been occurred in Pliocene time.

**Tectonic stress field from Late Miocene to Pliocene time in the Hombetsuzawa and Nishoh areas.**

The geologic structure in these areas was formed by the tectonic movements of the following two stages.
First stage: Formation of the N-S fault system and associated folds.
Second stage: Formation of the Urahoro Fault and associated faults and folds.

The movements of the two stages seem to have successively occurred from Late Miocene to Pliocene time as discussed above. The stress field which produced these faults can be deduced from the deformation along the faults. It is inferred that the N-S fault system was formed by a NW-SE lateral compression, whereas the Urahoro Fault and associated faults by an E-W lateral compression. Then, in the first stage, the left-lateral strike-slip faults were formed by the NW-SE compression and the NE-SW reverse fault and N-S reverse fault (Urahoro Fault) were successively formed by the E-W compression. It should be noted that the maximum compressional principal stress axis \((\sigma_1)\) of the stress field of the above two stages is slightly different in direction.

Summary of the movement picture of the Abashiri Tectonic Line

On the basis of analysis of joint systems and folds, Kimura (1980) investigated the mechanism of formation of echelon folds along the Abashiri Tectonic Line in the Futamata area. He concluded that the tectonic line is a left-lateral strike-slip fault which was formed during Late Miocene time. The sense of displacement of the tectonic line in the Futamata area is consistent with that of the N-S fault system in the Hombetsuzawa area. Consequently, the northern segment of the tectonic line is regarded as a left-lateral strike-slip fault. The northern segment was probably formed during Late Miocene time as already mentioned above.

Kimura (1980) also suggested that the tectonic stress field on the eastern side of the tectonic line was a lateral compression trending NW-SE in the Late Miocene time. On the contrary, the tectonic stress field in Middle Miocene time seems to be a lateral extension. To the north of the Hombetsuzawa area, the tectonic line was probably situated at the western margin of the sedimentary basin of the Kawakami Group during Middle Miocene time. The tectonic stress field on the eastern side of the tectonic line, is considered to have been a vertical compression with lateral extension (Kimura, 1979a). These facts indicate that the tectonic stress field markedly changed from Middle Miocene to Late Miocene time.

The Urahoro Fault was formed by an E-W lateral compression just after the formation of the northern segment of the tectonic line. The movement picture of the Urahoro Fault can be analogical to that in the Kushiro coal field. Mabuchi (1962) showed that the Kushiro coal field was deformed by an E-W lateral compressional force during Late Miocene and Pliocene time, and that a right-lateral strike-slip fault trending NE-SW (e.g. Yuubetsu Fault in Text-figure 1) was formed by the force. The lateral component of the displacement of the Urahoro Fault is similar to that of the Yuubetsu Fault in their sense. These facts suggest that the stress field caused the Urahoro Fault prevailed over the Kushiro coal field from Late Miocene to Pliocene time.

Discussion

Structural pattern in the eastern Hokkaido and its adjacent area.

Text-figure 9 shows the folds and faults which were formed since Miocene time in the
Eastern Hokkaido and its adjacent area. The following characteristics are noticed from the figure. On the eastern side of the Abashiri Tectonic Line, the structure is characterized by NE-SW axial traces of fold and NE-SW faults. The axial traces of the fold are arranged en echélon along the tectonic line. On the other hand, on the western side of the tectonic line, the axial traces of fold are mostly aligned from NW-SE to N-S in the northern part and NNW-SSE in the southern part. Moreover, the N-S faults are predominant and the NE-SW faults superimpose on the N-S faults.

Sakurai et al. (1975) showed that the Pacific Ocean south of the eastern Hokkaido is structurally divided into two parts by the Kushiro submarine canyon. On the east side of the canyon, axial traces of fold arrange predominantly in ENE-WSW direction, whereas on the west, NNW-SSE arrangement is predominant. Sakurai et al. (1975) also showed that the Kushiro submarine canyon continues nearly perpendicularly to the Kurile-Kamchatka Trench. Sato (1962) and Sakurai et al. (1975) considered that the canyon was formed by a tectonic movement since Late Miocene. Honza (1979) regarded that the canyon is one of the boundaries of the structural units in the fore-arc region.

The difference in tectonic pattern between both east and west sides of the Kushiro submarine canyon is similar to that of the Abashiri Tectonic Line. Accordingly, the Abashiri Tectonic Line possibly extends to the Kushiro submarine canyon though it is obscured by younger sediments at their connection.

The geologic structure of the southwestern Okhotsk sea has been studied in recent years (Honzu ed., 1979; Yamamoto, 1979; Tamaki et al., 1979). Tamaki et al., (1979) reported a reverse fault with N-S trend along the western margin of the Kitami-Yamato Bank (Kitami-Yamato Thrust). The fault is located just on the northern extension of the Abashiri Tectonic Line. To the west of the Kitami-Yamato Thrust, a sedimentary basin extending N-S was found by Yamamoto (1979) and Tamaki et al. (1979). The tectonic pattern of the faults and folds in this area is similar to that of the land.

The eastern Hokkaido and its surrounding sea areas are divided into two structural units by the Abashiri Tectonic Line and its extension, which traverses the present trench-arc system at the southwestern margin of the Kurile Arc.

“Collision” of the Kurile Arc with the Central Hokkaido

The Abashiri Tectonic Line was formed by earlier NW-SE and later E-W lateral compression from Late Miocene to Pliocene time. In Middle Miocene time, however, the stress field in the area along the Abashiri Tectonic Line was lateral extension. Then, it is concluded that the stress field was changed from extension to compression at about Late Miocene time. This event may suggest that the “collision” of the Kurile Arc with the Central Hokkaido took place at about Late Miocene time.

The northern segment of the tectonic line was formed by NW-SE lateral compression in Late Miocene time prior to the formation of the southern segment, and has been inactive in Pliocene time. In the Kushiro coal field east of the southern segment, right-lateral strike-slip faults (e.g. Yuubetsu Fault) were also formed in Pliocene time. The tectonic process of the “collision” can be restored as following two stages. In Late Miocene time, the “collision” started by the northward shift of the crustal block of the Kurile Arc along the Abashiri
Subsequently, in Pliocene time, the direction of the shift of the Kurile Arc changed from north to westward (Text-figure 10), and "collision" was concentrated along the southern segment. The Abashiri Tectonic Line was bent as a result of the later "collision".

The movement of the crustal block in later stage may be interpreted in terms of the Kaizuka's model. Kaizuka (1972, 1976, 1980) suggested that the "collision" occurred by westward shift of the Outer Kurile Arc ("Outer Kurile Bar") which was caused by oblique subduction of the Pacific Plate. He considered that the "mid-arc fault" with right-lateral strike-slip exists along the volcanic front and divides the inner and outer arcs. According to him, the right-lateral strike-slip displacement along the "mid-arc fault" and the echelon ridge of the Greater Kurile are attributed to a horizontal shift of the "Outer Kurile Bar". NE-SW trending faults with right-lateral strike-slip component might be regarded as the "mid-arc fault", but they do not extend toward northeast along the boundary between the inner and outer arcs. He extended the "mid-arc fault" to the west beyond the Abashiri Tectonic Line, but no fault which might be equivalent to the "mid-arc fault" has been found on the western side of the tectonic line. These faults are limited only near the Abashiri Tectonic Line. Consequently, the "mid-arc fault" along the boundary between the inner and outer arcs does not geologically recognized. Fujii and Sogabe (1978) also proposed the collision of the Kurile Arc with the Central Hokkaido. They recognized a N-S trending fault zone, which is nearly identical to the Abashiri Tectonic Line, as the "collision" line and discussed the stress field of the southern part of the fault zone on the basis of the structural analysis of the faults in the Kushiro coal field. They estimated the stress field around the Urahoro Fault and Yuubetsu Fault to be NW-SE lateral compression. The stress field, however, is strictly E-W lateral compression as above mentioned.

Why the "collision" of the Kurile Arc with the Central Hokkaido started in Late
Miocene time? It seems to be related to the generation of the Kurile Basin. The change of the stress field from extension to compression in Late Miocene time may suggest that the Kurile Basin ceased from developing.

The westward shift of the Kurile Arc may be interpreted by the Kaizuka’s model as above mentioned. Absence of the “mid-arc fault” in this area, however, might suggest that the rigidity of the crust gradually increase from the inner arc to the outer arc.

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