STRIKE-SLIP FAULT (NAYOROGAWA FAULT) IN NORTHERN HOKKAIDO

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Abstract In the northern Hidaka Belt of Hokkaido, a large N-S trending strike-slip fault, "Nayorogawa Fault", is found. Along the fault, such deformed structures as mappable folds, minor folds, asymmetrically deformed lenses and minor shear planes with strike-slip displacement are observed. On the basis of these deformed structures, two successive phases of movement along the Nayorogawa Fault are discriminated. The earlier is sinistral strike-slip faulting and the later is dextral strike-slip movement along the fault. The earlier movement seems to have occurred before the Miocene. This earlier sinistral movement is considered to have been related to the oblique subduction of the oceanic plate beneath the Eurasian Plate during the Cretaceous Period. The later dextral faulting may have occurred since the Miocene, using the pre-existing fault plane.

Introduction

Recently, N-S trending strike-slip movements along Hokkaido and Sakhalin have been discussed (KIMURA *et al.*, 1983; KIMURA & HOYANAGI, 1983; KIMURA, 1985; KIMURA & TAMAKI, in press; JOLIVET & MIYASHITA, 1985; WATANABE, 1986). The strike-slip movement within the Hidaka metamorphic belt was revealed by TOYOSHIMA (1983), and JOLIVET & MIYASHITA (1985). The existence of strike-slip faulting in northern Hokkaido was suggested by KIMURA *et al.* (1983), while the faults had not been observed. The authors found a large strike-slip fault in northern Hokkaido and recognized two phases of faulting: 1) earlier N-S trending sinistral strike-slip faulting, and 2) later N-S trending dextral strike-slip faulting. It is described and their tectonic significance are discussed in this paper.

Geologic setting

The studied area is located in the central part of northern Hokkaido (Fig. 1), and is dominated by Mesozoic sedimentary rocks, which are intruded by the Miocene Ichinohashi Granite (Fig. 2). These rocks are unconformably overlain by the Neogene Ichinohashi Conglomerate. The Mesozoic and Tertiary rocks are cut by a large N-S trending fault (NAKAMURA *et al.*, 1980). The authors call it the Nayorogawa Fault in this paper (Fig. 2).

The Mesozoic rocks are composed mainly of black shale and phyllite intercalating fine sandstone. On the western side of the Nayorogawa Fault, the rocks strike NE-SW and gently dip NW or SE, making gentle folds with NE-SW trending axes arranged en echelon along the fault, while they strike N-S and dip steeply east or west on the eastern side of the fault (Fig. 2).

The Ichinohashi Granite crops out in the northern part of the mapped area (Fig. 2). Its K-Ar ages are reported to be 18.6 ± 0.6 and 18.4 ± 0.6 Ma (SHIBATA & ISHIHARA, 1981).

The Ichinohashi Conglomerate occurs along the western contact of the Nayorogawa Fault

Received January 24, 1986. Accepted October 20, 1986.

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Fig. 1 Index map showing the location of the studied area and tectonic division of the Mesozoic system in Hokkaido.

R·K : Rebun-Kabato Belt, I·T : Ishikari-Teshio Belt, K : Kamuikotan Belt, S : Sorachi Belt, H : Hidaka Belt, H M : Hidaka metamorphic belt, Y·N : Yubetsu-Nakanogawa Belt, T : Tokoro Belt, N : Nemuro Belt (modified from KIMURA (1985)).

Fig. 2 Geological map along the Naylorogawa Fault. The mapped area is shown in Fig. 4.

(Fig. 2). It consists mainly of cobbles and boulders of granite, slate and sandstone with matrix of mudstone or sandstone. The grains included are highly angular and poorly sorted. The basal part of the conglomerate is composed dominantly of granitic clasts. The conglomerate is considered to be Miocene in age because it includes granitic clasts derived from the Ichinohashi Granite of 18Ma and is correlated lithologically with the Middle Miocene Kamishiyubetsu Formation, whose age is well documented by microfossils (WATANABE & IWATA, 1985).

Mode of occurrence of the Naylorogawa Fault

Sinistral strike-slip movement of the first phase

The mappable folds with NE-SW trending axes which involve the Mesozoic rocks are arranged en echelon along the Naylorogawa Fault (Fig. 2), ultimately converging into it (Fig. 3). The arrangement and convergent patterns suggest drag of strata due to the sinistral strike-slip movement along the fault.

Minor folds within the Mesozoic rocks just along the Naylorogawa Fault represent two stages of folding. The first is characterized by asymmetric inclined fold (F1). Most of them show easterly vergent asymmetry. The

Fig. 3. Route map along the Nayorogawa Fault.
The mapped area is shown in Fig. 4.

second is characterized by vertical fold (F2)*. Superimposition of these folds is observed

* Definition of fold based on orientation of axial plane and hinge line is referred to TURNER & WEISS (1963) and HOBBS *et al.* (1976).

Fig. 4. Locality map. A set of solid arrows shows the earlier sinistral strike-slip and that of open arrows shows the later dextral strike-slip movement.

at Locs. 1 & 2 (Fig. 4). F1 fold is prevailing not only along the Nayorogawa Fault but also regionally in the Mesozoic rocks in northern Hokkaido (KIMURA, 1985).

On the other hand, the subsequent F2 fold is found only near the Nayorogawa Fault, where the F1 folds are refolded by the F2. Most of the F2 folds have vertical axes and show a long limb-short limb asymmetric feature in plan (Fig. 5a). Figs. 5b and 5c exhibit the sense of shear around the axis based on the asymmetric feature. As shown in the figures, sinistral shear is predominant, and axial planes of these folds are almost parallel with the orientation of the Nayoro-

Fig. 5. Axial plane of F2 fold and the sense of shear around axis.

a : A schematic form of F2 fold. b : Plot of axial plane of F2 fold and the sense of shear around its axis observed at Locs. 1 and 2 (Fig. 4) (lower hemisphere). c : The same at Locs. 3 and 4 (Fig. 4).

Fig. 6. Direction of maximum compressive principal stress deduced from conjugate fold.

a : An example of the conjugate fold (Loc. 5). b : Stereographic projection of the conjugate fold (lower hemisphere).

gawa Fault. Consequently, the asymmetric and vertical folding process of F2 stage seems to have been related to the sinistral strike-slip movement along the Naylorogawa Fault.

The gouge zone of the fault is exposed at Loc. 2 shown in Fig. 4. Folds with NNE–SSW trending axial planes and vertical axes are found in the Mesozoic rocks close to the gouge zone (Fig. 7a). The asymmetric feature and obliquity of the fold axes against the fault indicate that the folds were formed by sinistral drag along the fault (Fig. 7b).

At Loc. 5 (Fig. 4), conjugate folds with

vertical axes are developed. Each fold of conjugate set indicates dextral (Z shape) and sinistral (S shape) asymmetric ones. The former is rarely observed and has an open hinge zone, while the latter is predominant and has a tight hinge zone (Fig. 6a). These conjugate folds have the similar character with those in the Franciscan Complex analyzed by RAMBERG & JOHNSON (1976). They experimentally indicated that these folds were developed under simultaneous layer-parallel shortening and shear. Because most axial planes of sinistral asymmetric folds trend N–S and

Fig. 7. The shear zone of the Nayorogawa Fault at Loc. 2 (Fig. 4).

a : A route map around Loc. 2. b : A sketch of F2 fold in the Mesozoic mudstone close to the gouge zone. c : A sketch of the eastern part of the gouge zone. In the consolidated gouge immediately west of the new gouge zone, NE-SW tension gashes are developed. d : A rose diagram showing the trend of tension gashes. e : Occurrence of asymmetric lenses of white siliceous layer.

Fig. 8. The shear zone of the Nayorogawa Fault at Loc. 6 (Fig. 4).

a : A route map around the shear zone. b : A photograph showing newly formed dextral shear planes on the western side of the shear zone. c : A photograph showing dextral strike-slip shears in the shear zone.

those of the dextral one trend NE-SW (Fig. 6b), the stress field deduced from these conjugate set at Loc. 5 has WNW-ESE trending σ_1 . It is consistent with the sinistral strike-slip movement along the Naylorogawa Fault.

Dextral strike-slip movement of the second phase

While the mappable structure shows only the sinistral strike-slip pattern, careful observation reveals subsequent dextral faulting. Though most of the fault gouge observed at Loc. 2 (Fig. 4) are consolidated, that along the eastern margin was revived after the consolidation (Fig. 7c). The new fault gouge is about 5 centimeters thick. Many tension gashes oblique to the elongation of the revived fault are observed in the consolidated zone (Fig. 7c). These gashes mostly trend N40°E and arrange en echelon (Fig. 7d). On the eastern side of the gouge, white siliceous layers are intensively sheared and detached, resulting into formation of many lenses (Fig. 7e). The lenses range in length from several to over ten centimeters. Some lenses have an asymmetric S shape whose eastern top is tailed to the south, while western top to the north. Tension gashes en echelon and asymmetric S-shaped siliceous lenses show a dextral strike-slip movement along the reactivated fault planes. The fault is cut by NE-SW trending minor dextral faults of a further younger stage (Fig. 7c).

The shear zone of the Naylorogawa Fault is also observed at Loc. 6 (Fig. 4). At this point, Mesozoic mudstone and dolerite are severely sheared (Fig. 8a). On the western side of the sheared zone, the older foliation and siliceous layers of mudstone are cut and dragged by newly formed brittle shear planes of N-S trend. Judging from the displacement of siliceous layers along shear planes, the sense of shear is dextral strike-slip one (Fig. 8b). In the central part of the sheared zone, the foliation is strongly dragged until it becomes almost parallel to the shear planes. Many siliceous mudstone lenses surrounded by sheared mudstone are observed to be dragged by the shear planes and elongated asymmetrically (Fig. 8c). This fact also indicates

Fig. 9. Equal area projection showing poles of shear planes developing in the Ichinohashi Conglomerate at Loc. 7 (lower hemisphere).

that the shear is dextral strike-slip.

The Miocene Ichinohashi Conglomerate which occurs on the western side of the Naylorogawa Fault is also sheared by N-S trending minor faults close to the fault (Fig. 9). Some clasts are cut by minor faults and slightly deformed (Fig. 10). The deformation patterns of the clasts show a dextral strike-slip movement along the minor faults.

It is noteworthy that the deformation structures observed in the Miocene Ichinohashi Conglomerate indicate only dextral strike-slip, whereas those in the Mesozoic rocks show the superposition of two phases of faulting; earlier sinistral and later dextral ones.

Age of faulting

The deformation structures by the later dextral faulting are observed both in the Tertiary and Mesozoic rocks, while the earlier sinistral ones are found only in the Mesozoic rocks. This fact clearly explains that the dextral faulting occurred after the deposition of the Ichinohashi Conglomerate. On the contrary, the sinistral strike-slip movement had

Fig. 10. Plan figures of outcrops showing a mode of occurrence of the sheared Ichinohashi Conglomerate at Loc. 7 (Fig. 4). Sets of arrows show the sense of shear inferred from the deformation of clasts.

been already diminished before the sedimentation of the Ichinohashi Conglomerate. The age of the earlier faulting cannot be determined accurately from the available data.

Tectonic significance of the Naylorogawa Fault

KIMURA (1985) pointed out that Mesozoic rocks in northern Hokkaido are regarded as the Cretaceous accretionary complex associated with the subduction of the oceanic plate under the Eurasian Continent. Judging from deformation features of the prism, he suggested that the Cretaceous subduction was sinistral oblique one. If the earlier sinistral strike-slip movement along the Naylorogawa Fault took place in the Cretaceous, it would be related to the deformation of the accretionary prism caused by the sinistral oblique subduction. Thus the determination of the actual age of the faulting would make a significant contribution to the clarification of the Cretaceous tectonics in Hokkaido.

The dextral shears of the N-S trend after

the deposition of the Ichinohashi Conglomerate reactivated the Naylorogawa Fault which had been already formed. Recently, the dextral strike-slip movement along central Hokkaido has been documented. JOLIVET & MIYASHITA (1985) confirmed the existence of dextral ductile shear in the Hidaka metamorphic belt, which was previously suggested by MIYASHITA (1981), OSANAI *et al.* (1981), KIMURA (1981) and TOYOSHIMA (1983). The dextral strike-slip movement along the Naylorogawa Fault may represent one of these regional tectonics in the central Hokkaido during the Tertiary Period.

Acknowledgements

The authors wish to express their sincere thanks to Profs. M. MATSUI and Y. KATSUI of Hokkaido University and Dr. J. YAJIMA of Geological Survey of Japan for critical reading of manuscript and helpful advice, and to Dr. S. MIYASHITA of Hokkaido University for presentation of his unpublished data and useful suggestions.

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- * In Japanese with English abstract,
** In Japanese.

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(要 旨)

WATANABE, Y. and KIMURA, G., 1987 : Strike-slip fault (Nayorogawa Fault) in northern Hokkaido. *Jour. Geol. Soc. Japan*, 93, 1-10. (渡辺 寧・木村 学, 1987 : 北部北海道の横ずれ断層(名寄川断層). 地質雑, 93, 1-10.)

北海道の北部日高帯において, 南北性横ずれ断層が発見され, 名寄川断層と命名された. この断層沿いには, 白亜紀堆積岩, 18 Ma の一の橋花崗岩, 中期中新世の一の橋礫岩が分布する. これらの岩石中に見られる褶曲の形態, 非対称レンズ, 剪断面に沿う変位, 礫の引きずりなどの変形構造の解析に基づき, 名寄川断層には 2 つの運動が識別された. 最初は左横ずれ運動であり, 2 番目は右横ずれ運動である. 前者の運動に伴う変形は白亜紀堆積岩にのみ見られるのに対し, 後者に伴うものは, 白亜紀堆積岩に加えて, 中新世の一の橋礫岩にも見られる. このことから, 左横ずれ運動は中新世より前に, 右横ずれ運動は中新世以降に起こったと考えられる.