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A LARGE SCALE FEEDER DYKE ASSOCIATED WITH ARFVEDSONITE DIABASE AND ITS BEARING ON THE BASEMENT OF THE TOKORO BELT, CENTRAL AXIAL ZONE OF HOKKAIDO, JAPAN

by

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(with 3 Tables and 5 Figures)

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Abstract

The Tokoro Belt, a tectonic unit of the Central Axial Zone of Hokkaido, is characterized by the preponderant Jurassic effusive rocks of geosynclinal phase of so-called Hidaka Orogenic Movement. As a large scale feeder dyke consisting of perpendicularly arranged pillows of diabase associated with perlite textured sericite rock has been found there in the Tokoro Belt, mode of occurrence, rock properties and chemistry of the feeder dyke are outlined in this paper.

Mass of arfvedsonite diabase which has not been known in the Central Axial Zone of Hokkaido was discovered closely related to the dyke. From the mode of occurrence of the mass, it is considered that this peculiar rock mass might have been taken up from a basement of the Tokoro Belt.

Introduction

The Tokoro Belt is a tectonic unit occupying the eastern side of the Central Axial Zone of Hokkaido. Geology of the belt is stratigraphically classified into the following three groups in ascending order: the Yubetsu, the Nikoro and the Saroma Groups. The Nikoro Group is mainly composed of well pillowed or massive diabase lavas associated with thin chert layers and diabase tuffs of upper Jurassic System, while the Yubetsu and the Saroma Groups consist of merely clastic sediments as shale and sandstone.

So-called green rocks of the Central Axial Zone of Hokkaido predominate at the Kamuikotan Tectonic Belt occupying the western side of the axial zone and at the Tokoro Belt in question (Fig. 1). These two belts run parallel to each other. The geologic features characterized by the restricted distribution of the green rocks at both sides of the Central Axial Zone of Hokkaido has been interpreted as follows: i.e. The sea bottom of the Hidaka geosyncline of Trias to Jurassic periods might have been sunk at the western and eastern margins of the basin in pre-accumulating phase of the Yezo Group, Cretaceous time. Thus it has been interpreted that the sub-aqueous volcanic activities were activated in the preceding two belts. In other words, the basaltic magma ascended at both margins of the Hidaka geosynclinal basin in late Jurassic period and this magmatism yielded the formation of green rocks of the Kamuikotan and the Tokoro Belts (Minato et al. 1965).

The manner of tectonic movement of the Kamuikotan Belt and the Tokoro Belt in the successive orogenic phase, however, might have become to be distinguishable: i.e. The orogenic movement made the former "compression zone" and the latter "tentional zone"

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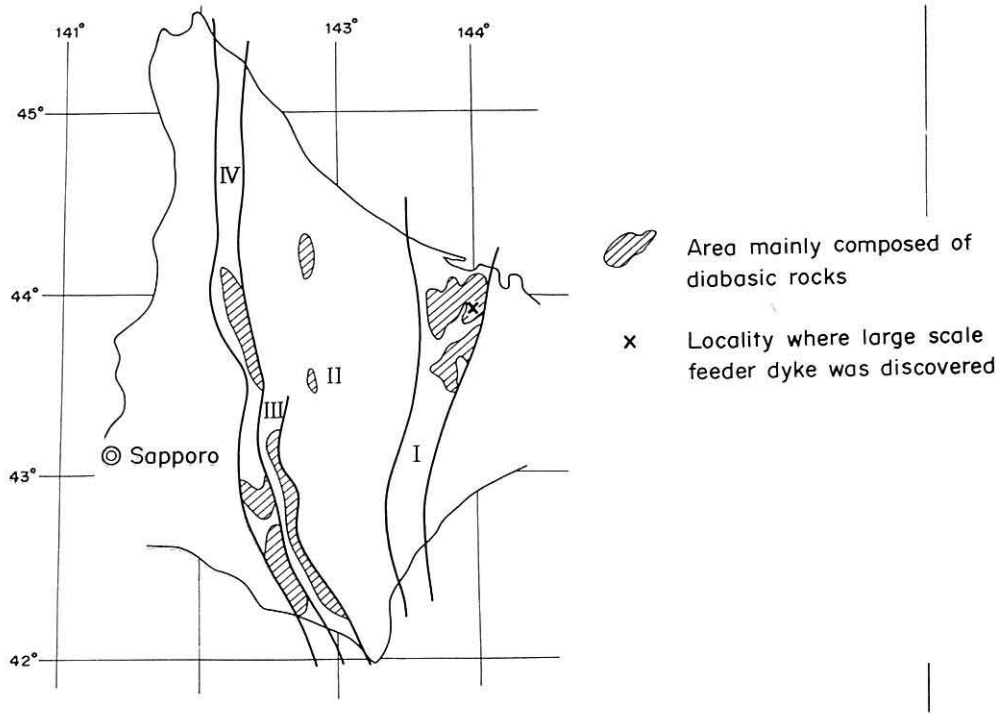

Fig. 1 Four geotectonic belts in the Central Axial Zone of Hokkaido. The area occupied by oblique lines is composed of diabase of late Jurassic period.
I: Tokoro Belt II: Hidaka Belt III: Western Hidaka Belt IV: Kamuikotan Belt

respectively. It is true that serpentinite and schistose rocks predominate in the Kamuikotan Belt whereas the Tokoro Belt lacks the preceding rock species. Thus these two belts have been geotectonically distinguished owing to the contrasting geologic features.

"Where is the vent related to the formation of pillow lava in the Tokoro Belt?" This question is much attractive for the present authors, and they made endeavor to look for the vent. For this purpose, it should be necessory to check the distribution of diabase tuff layer and the grain-size of the consisting materials. It is reasonable that coarse-grained heavy pyroclastic materials should be more predominant around the vent.

As the results of the investigations for the object, coarse-grained diabase tuff layers were found at the vicinity of Hiyoshi, near the Kokuriki Mine, and at the middle stream of the Ketobetsu River, southwestern area of the Nikoro-cho. As pointed out already by Teraoka *et al.* (1973), the Mesozoic strata of this area form an asymmetrical synclinolium plunging to the north, the axial plane of which dips to the west. Preponderant diabase lavas have been yielded at the both sides of the synclinal axis. The geologic position of the preceding coarse-grained diabase tuff layers of western and eastern wings of the synclinal axis can be stratigraphically correlated as the same horizon of the Nikoro Group.

Thus it was considered that the vent may be existed at the wings of the synclinal axis. As expected, the present authors found a vertically arranged pillowed diabase that seems to

be large scale feeder dyke at the eastern wing of the synclinal axis.

In this paper, the modes of occurrence, petrography and chemistry of the large scale feeder dyke are described. Besides, the implication to the mass of arfvedsonite diabase, perhaps taken up by the dyke is added.

Mode of occurrence of the large-scale feeder dyke

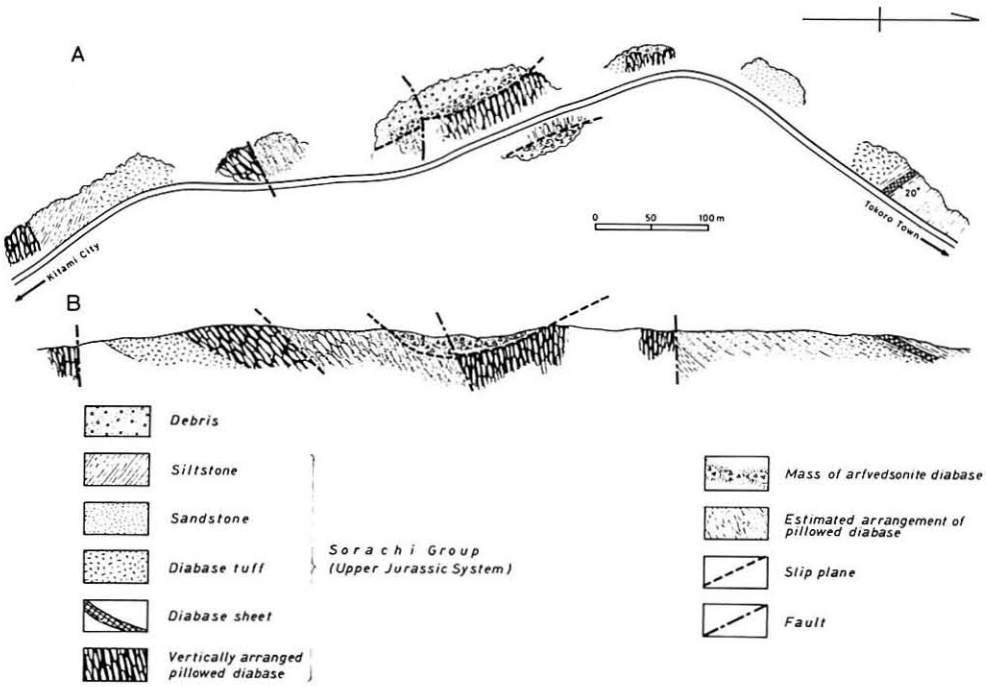

Fig. 2 Geologic sketch and schematic profile showing the modes of occurrence of the large scale feeder dyke and mass of arfvedsonite diabase.
A: Geologic sketch B: Schematic profile

There exist many cliffs along the road between the Kitami City and the Tokoro Town. In the cliffs, peculiar rocks consisting of well pillowed diabase associated perlite textured sericite rock are found. The modes of occurrence of the rock is shown in Figs. 2 and 3. At the outcrop, it is estimated that the total width of the peculiar rock attains to more than 100 m. The structure of the rock is noteworthy, i.e. the pillows of diabase are arranged in perpendicular rather than horizontal trending with E-W direction. The longitudinal diameter of a unit lenticular pillow generally attains to 2 – 3 m and it shows 1 m thick.

Grayish brown coloured foliated rock consisting mainly of sericite is associated with the pillowed diabase, i.e. a unit pillow of diabase is occluded by the foliated sericite rock. In other words, this sericite rock fills the boundaries between unit pillows as shown in Fig. 3.

As given in Fig. 2, the perpendicular structure caused by the arrangement of lenticular

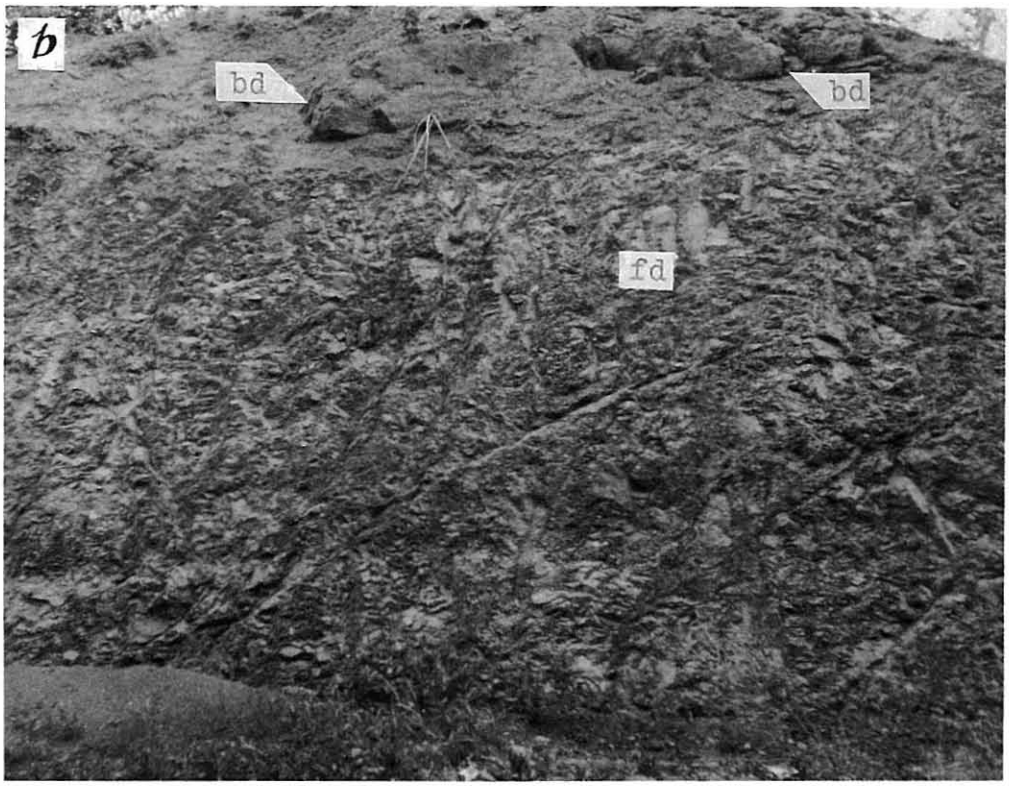

Fig. 3 Photographs showing the modes of occurrence of the feeder dyke and the mass of arfvedsonite diabase.

(a) Photograph showing the mode of occurrence of the large scale feeder dyke of pillowed diabase. Dark coloured part enclosing unit pillow is composed mainly of sericite.

(b) Photograph showing the relation between the arfvedsonite diabase and the large scale feeder dyke. bd: arfvedsonite diabase fd: feeder dyke (pillowed diabase)

pillowed diabase seemingly becomes in turn to be horizontal at the south of the cliff though the gradational change is not observable due to the lack of continuous exposure. From the general geologic aspects, however, the present authors confirmed that this peculiar diabase is a kind of feeder dyke related to the formation of wide spread pillow lavas in the Tokoro Belt.

Siltstone intercalated with tuffaceous sandstone containing coarse fragments of diabase is observed around the preceding pillowed feeder dyke. The strata of siltstone dipping gently to NE is intruded by the pillowed diabase disconcordantly. At the top of the cliff, some blocks of diabase overhanging with the above-stated feeder dyke is observed. The overhanging mass of diabase is unique as to the rock properties, i.e. this rock is composed of arfvedsonite and albite taking subophitic texture under the microscope. This unique rock species has been already known as xenolithic patches occluded by pillow lavas in the Hokko mining district, northern part of the Tokoro Belt (Bamba 1962). The manner of occurrence of the overhanging diabase and the underlain one is given in Figs. 2 and 3. From the preceding features, the arfvedsonite diabase, overhanging block, may belong to a mass taken up from the deeply lying strata, perhaps a basement of the Tokoro Belt.

Petrography of the quartz bearing diabase, main constituent of the feeder dyke

Rock properties of the preceding rock, quartz bearing pillowed diabase filling a vent, is compact and no chilled margin is observed. Minor joint or cleavage crossing the longitudinal direction of a lenticular pillow is observed. The colour of the rock at exposure is grayish green. So-called differentiated vein of diabase is not observed in it. Microscopically, it belongs to variolitic textured diabase. The variole consists of albite and clinopyroxene aggregated taking acicular form. The colour of the clinopyroxene is brown that seems to be titaniferous augite and the c-axis of the clinopyroxene crystal is perpendicular to the elongation of the acicula. Actinolite frequently replaces the clinopyroxene. The area among the aciculas composed of clinopyroxene is filled by albite and fine-grained quartz. The dimmension of above-noted variole is more or less 0.5 mm.

Considerable amount of clots or amygdaloids which consist of quartz are observed in the diabase. The mode of occurrence of the quartz is given in Fig. 4-(1) and the manner of aggregation of the mineral in an amygdaloid is shown in Fig. 4-(2). Small amount of sphene and apatite are attendant as accessory minerals of the rock.

Rock properties of podiform sericite rock enclosing the pillow of diabase

Podiform sericite rock, 10 – 20 cm thick, shows dark grayish brown in colour and is loose being foliated at the exposure. Microscopically, perilite texture is prevalent as given in Fig. 4-(3) and (4). The perlite texture is formed by the presence of ring, 0.02 mm thick, consisting of fibrous sericite. The fibri-form sericites elongate taking perpendicular to the curvature of the ring. This ring is tentatively called "Sericite Ring" by the present authors. A unit sericite ring shows 0.02 mm thick but rhythmic band of double or triple layers of sericite ring is observed as shown in Fig. 4-(3) and (4). Inside of the sericite ring is composed

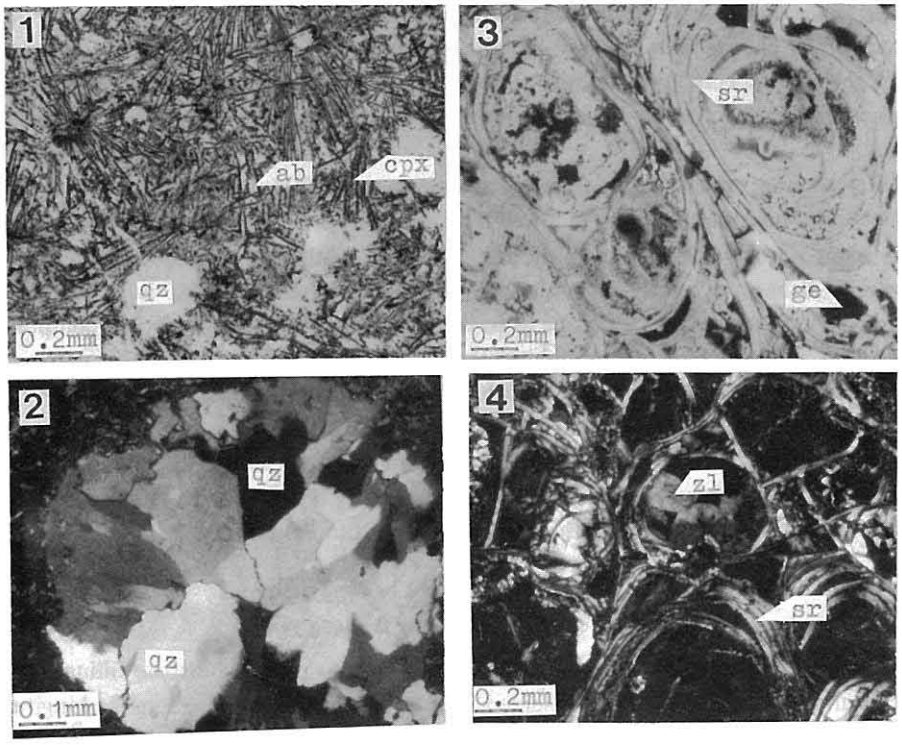

Fig. 4 Photomicrographs illustrating the pillowed diabase of the large scale feeder dyke and the associated sericite rock.

1. Variolitic textured diabase. ab: albite cpx: acicula consisting of clinopyroxene qz: quartz
2. Manner of aggregation of quartz in diabase. Equicrystalline quartz mosaic in which some crystals show partial development of crystal faces. This texture indicates that the quartz might have been formed from the excess silica.
3. Perlite textured sericite rock enclosing the unit pillow of diabase (parallel nicols). sr: sericite-ring ge: goethite
4. Ditto (crossed nicols). zl: zeolite sr: sericite ring

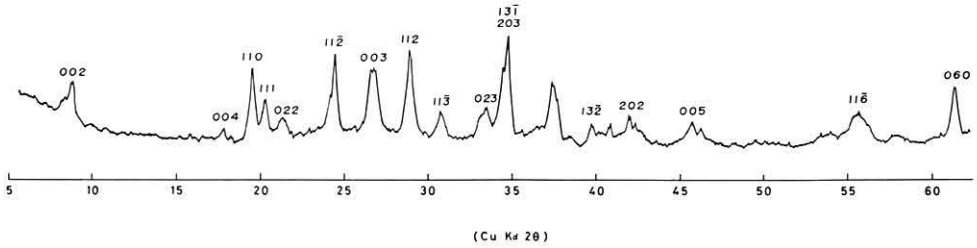

Fig. 5 X-Ray powder diffraction pattern of the perlite textured rock mainly consisting of mica clay mineral.

of aggregates of zeolite, sericite and some other clay minerals. Sometimes quartz is recognized.

There is no way to separate the minerals from this peculiar textured rock, then the examination by X-Ray powder diffraction method was carried out for the whole of the rock in order to determine the main mineral components. The result obtained is given in Fig. 5. The reflection indicating the presence of sericite* predominates. Thus it is confirmed that the main mineral component of the rock is sericite.

Goethite, reddish brown in colour, scatters in the rocks. The peculiar colour of the rock is considered to be attributed to the presence of this mineral.

Chemical composition of the quartz bearing diabase and associated sericite rock

Table 1 Chemical composition of the large scale feeder dyke and related rock from Tokoro district, eastern Hokkaido

	(1)	(2)
SiO_2	70.44	49.88
TiO_2	0.64	0.79
Al_2O_3	13.83	16.73
Fe_2O_3	1.55	7.88
FeO	1.32	5.04
MnO	0.07	0.14
MgO	0.46	3.53
CaO	1.12	0.39
Na_2O	6.60	0.13
K_2O	2.90	7.91
P_2O_5	0.24	0.22
$H_2O(+)$ $H_2O(-)$	1.09	6.77
Total	100.26	99.41

(1): pillowed diabase (2): sericite rock
(analyst: S. Miyashita)

As given in Table 1, the chemical composition of the diabase in question is unique. Abundant SiO_2 and alkalis are detected as compared with the other pillow lavas spread over the Tokoro Belt. The podiform sericite rock associated with the preceding rock is characterized by the richness of potassium, H_2O and silica and poorness of Al_2O_3 as compared with the modal chemical composition of sericite. If some of silicon are replaced by aluminium, the chemistry of the rock becomes to be approximate value to that of sericite. The texture of the rock and its bulk chemical composition indicate that the rock might have been originated from siltstone or mudstone accumulated in geosynclinal phase.

* This mineral corresponds to mica clay mineral (1M Type) after T. Sudo (1974)

Arfvedsonite, an essential rock forming mineral of the up-heaved diabase mass

The up-heaved diabase mass, perhaps being taken up by the feeder dyke is composed of peculiar amphibole and plagioclase and shows typical subophitic texture. This amphibole, 0.2 – 0.3 mm in size, is characterized by strong pleochroism from deep green to brown, i.e. X=blueish green, Y=brown, Z=greenish yellow. Zoning structure is observable in some individual crystals of the amphibole. The margin is frequently more pale in colour.

The core and margin of an amphibole were chemically analysed by EPMA. The results obtained are given in Table 2. It is noteworthy that TiO_2, Al_2O_3, MgO and CaO decrease to the margin, and Na_2O, SiO_2 increase to the margin. From the chemical composition of the margin of the amphibole, chemical formula of the mineral was calculated as given in Table 3.

Table 2 Chemical composition of arfvedsonite from the Tokoro Belt, Hokkaido

	(1)	(2)
SiO_2	47.87	49.94
TiO_2	2.67	0.10
Al_2O_3	0.72	0.29
FeO	33.81	35.36
MnO	1.03	1.30
MgO	0.51	0.12
CaO	3.16	1.31
Na_2O	6.20	7.54
K_2O	1.02	1.21
H_2O*	1.84	1.84
Total	98.83	99.01

(1): core of arfvedsonite (2): margin of arfvedsonite (analyst: T. Watanabe)

* H_2O was calculated based on mineral formula of OH = 2.

Table 3 Chemical formula of arfvedsonite from the Tokoro Belt, Hokkaido

Si	7.994	8.000
Al	0.006	
Al	0.048	5.001
Ti	0.013	
Fe^{III}	0.897	
Fe^{II}	3.839	
Mn	0.176	
Mg	0.028	
Ca	0.225	2.815
Na	2.342	
K	0.248	
OH		2.000

This formula was calculated based on 0 = 23

Based on some optical properties and the chemistry of the mineral, this amphibole nearly corresponds to arfvedsonite.

Discussion

Modes of occurrence of the feeder dyke, consisting of numerous units of pillowed diabase arranged perpendicularly, and associated peculiar podiform sericite rock were roughly described in this paper. Besides, rock mass of arfvedsonite diabase, overhanging with the feeder dyke, perhaps up-heaved block from the basement of the Tokoro Belt, has been introduced.

Based on the geologic and petrographic features, the present authors came to a conclusion on a process related to the formation of the feeder dyke.

The origin of the amygdaloidal quartz appeared in the diabase of the feeder dyke is

considered that the excess silica for the formation of diabase might have been added after the consolidation of the diabase, because the variolitic texture, peculiar to the diabase, is observable whereas its chemistry does not correspond to the diabase. The origin of the abundant silica replaced the diabase seems to be related to the contamination process of unconsolidated muddy sediments perhaps existed around the vent where diabase intruded. The contamination of muddy sediments resulted addition of quartz into the diabase and removal of silica from the sediments.

The pillow structure of the diabase might have been formed in early stage of the intrusion due to the abundant water in unconsolidated mud of geosynclinal phase. On the other hand, the wet mud was partially heated by the magma. Thus the hydromagmatic eruption might have been caused at the vent and it resulted to form the sericite rock taking perlite texture.

Richness of potassium of the sericite rock indicates that the starting material of this altered rock must belong to the mud accumulated in the Hidaka geosyncline. It would seem that the basement of the geosynclinal sea or initially formed materials at the sea bottom were composed of alkaline or sub-alkaline green rocks containing the arfvedsonite diabase. Under such an environments, the basaltic magma ascended through a vent available. During the ascending process of the magma, basement rock near by the vent was partially broken and the fragments of arfvedsonite diabase were caught in the ascending magma.

Based on such an assumption, it is possible to interprete the origin of the arfvedsonite diabase and many other characteristic features related to the feeder dyke.

The pillowed diabase dipping gently to the north as given in Fig. 2 is variolitic textured one in which quartz is not observable. Thus this diabase may belong to the common pillow lava in the Tokoro Belt. The underlain diabase tuff is hyaloclastic. The above-stated features are not contradictory to the preceding assumptions.

The arfvedsonite diabase frequently contains some fragmentary patches of a kind of pyroxenite which has not been known in the Jurassic formations of the Tokoro Belt. These evidences support the view of present authors.

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It is authors' pleasure to dedicate this paper to Prof. Masao Minato on the occasion of his retirement from the Hokkaido University.

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