STRATIGRAPHY AND RADIOACTIVITY OF THE ROCKS IN THE SETAMAI-SAKARI DISTRICT, KITAKAMI MOUNTAINS, NORTHEAST HONSHU, JAPAN

by

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(with 5 Tables, 12 Text-figures and 1 plate)

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Introduction

The Setamai-Sakari District, Kitakami mountains, N.E. Honshu, previously mapped by MINATO, CHOI, KUMANO and others consists of Palaeozoic and Mesozoic formations of Silurian to Lower Cretaceous age, gneissic, granitic and dyke rocks of different ages.

This paper examines the radioactivity of the rocks in this area after the method of the three authors (DOI, ITO and TABUCHI) who have previously examined the radioactive properties of Tertiary sediments in many fields in Japan.

Method

The intensity of γ ray was measured by car borne radioactivity measuring and recording instrument made by Japan Radiation and Medical Electronics, Inc. mounted on a jeep. The apparatus is composed of two parts: scintillator (cylindrical fluorescent crystal = NaI (T1), 5 inches in diameter and 5 inches in length) and a photomultiplier. The measurements are automatically recorded on a paper, in this survey, a system of 10mm paper feed for 50m measuring are used. Then the radioactivity of rocks are recorded continuously on recording paper as 0–100,000 counts/min. In some cases a handy scintillation survey meter (TCS-121, made by the Nippon-Musen-Irigaku-Kenkyusho) was also used for checking the outcrops. In this paper, radioactivities are shown as counts per minuit (cpm) measured by the car borne instrument.

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Geologic setting

Stratigraphy and sedimentary facies

The area studied is situated in the Kitakami mountains, N.E. Honshu (Fig. 1). Structurally, the southern Kitakami mountain is distinguished from the northern Kitakami mountain, by Palaeozoic-Mesozoic sediments of shallower facies as indicated by relatively thin deposits, comparatively rich in fossils, while the reverse is true of the northern Kitakami mountain. The boundary between these two structural units is defined by ultrabasic rocks of Cretaceous age, that are exposed as a N.W. to S.E. striking belt.

Stratigraphic columns of the area are given in Table 1.

Pre-Silurian-Silurian

The rocks of the Tsubonosawa gneiss is well exposed at the upper course of the Tsubonosawa Creek. The gneiss is intruded by the Higami granodiorite of *c* type. Although a stratigraphic relationship between this gneiss and the lowest fossiliferous formation of this area which is of Silurian age, is unknown, it may be older than the Silurian from petrographic aspect and probably belonging to the Precambrian.

The Silurian Formation is mainly composed of limestone and slate.

The Devonian

The Takainari Series, about 50m in thickness is exclusively composed of radiolarian bearing reddish and greenish cherts intercalated with thin sandstone layers. The Ohno Series (some 390m thick), is chiefly composed of keratophyre tuff, lesser amounts of slate and fossiliferous limestones; the Nakazato Series (at least 750m thick), is mainly composed of black slate and basic tuff occupying both the lowest and uppermost horizons; a small amount of keratophyre tuff is found in the lower part. The upper part of the Nakazato series is locally fossiliferous, in which trilobites, brachiopods and corals including *Calceola* sp. are found.

The Upper Middle Devonian and and Upper Devonian Formations seem to have been eroded in this area prior to the deposition of the Lower Carboniferous sediments.

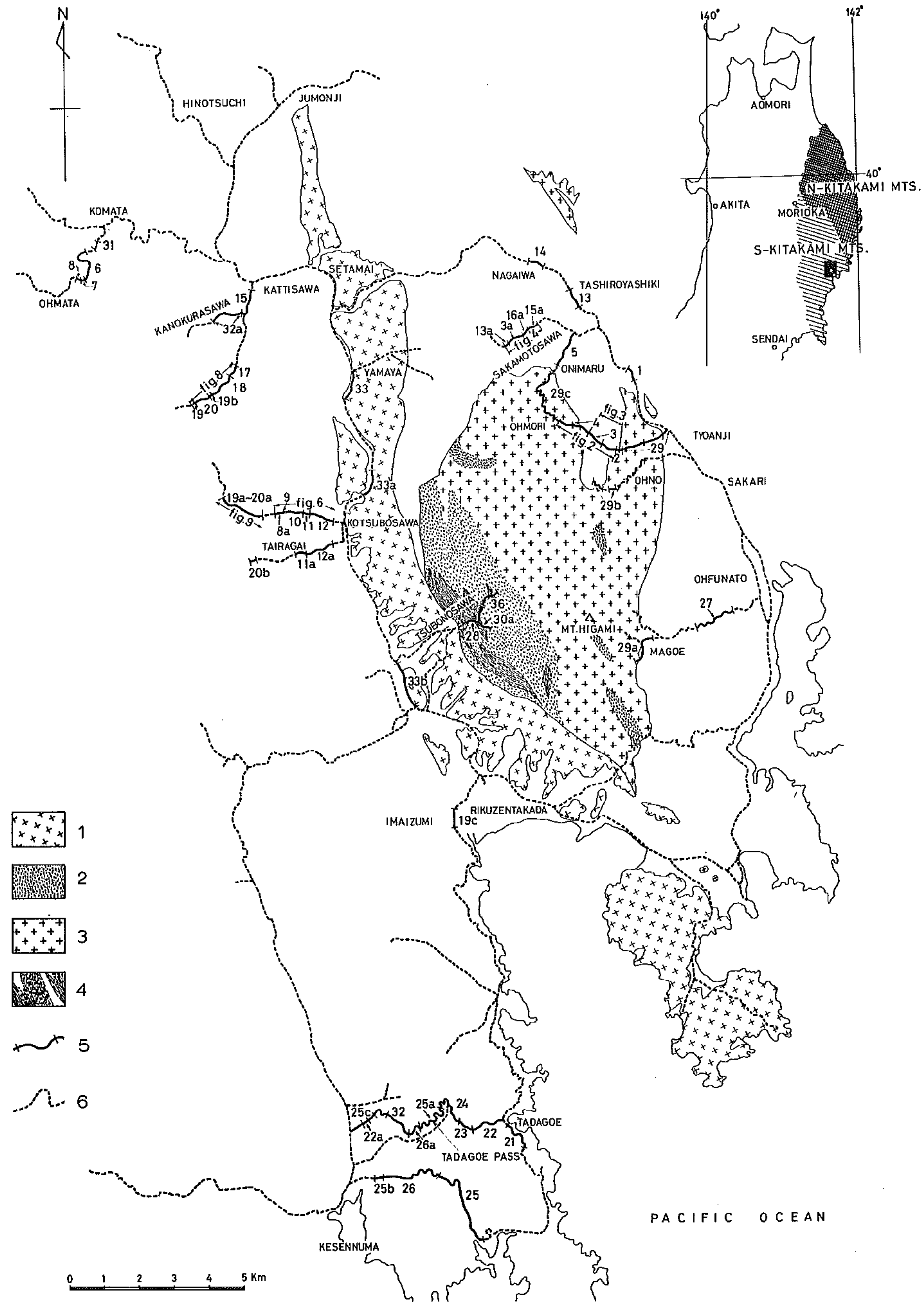

Fig. 1 Surveyed area (Setamai-Sakari District).
1: Takekoma granodiorite, 2: Higami granite of Type c, 3: Higami granite of Type a and Type b, 4: Tsubonosawa gneiss (after S. Ho), 5: Route for measurement of radioactivity which is reported in this paper, and 6: Route for measurement of radioactivity.

Table 1

	Geologic formations					Surface Geologic Constituents				
	Numeral correspond to that of the table 5	Major division	-III~XI Lithologic groups	Subdivision	Western	Central to Western	Central	Central to Eastern	Eastern
Lower Cretaceous	33	Takekoma granite							
	32	Dyke rocks		Porphyrite					
	31			Diabase					
	27	Ofunato group							
Middle to Upper Jurassic	26	Shishiori group		Kogoshioformation					
	25			Mone formation					
	24	Karakuwa group		Tsunakizaka formation					
	23			Kosaba formation					
L. Jurassic									
Upper Triassic	30	Higami granite c type							
Lower Triassic	22	Inai group							
U. Permian	21	Toyoma series							
Middle Permian	20.19.18	Kanokura series		Iwaizaki stage					
	17		XI	Kattisawa stage					
Lower Permian	16	Sakamotosawa series	X	Kabayama stage					
			IX						
	15		VIII	Kawauchi stage					
Upper Carboniferous									
Middle Carboniferous	14	Nagaiwa series	VII				(?)		
U. Visèan	13	Onimaru series	VI						
Lower Carboniferous	12	Ohdaira series	V	Kozubo stage					
	11		IV	Maide stage					
	10		III						
	9	Arisu series	II	Jumonji stage					
	8		I						
	7		-I	Hinozuchi stage					
	6	Hikoroichi ser.	-II	Ohmata stage					
	5		-III	Ikawa stage					
Upper Devonian	29	Higami granite a,b type							
Lower to Middle Devonian	4	Nakazato series							
	3	Ohno series							
	2	Takainari series							
Silurian	1	Kawauchi series							
Pre-Silurian	28	Tsubonosawa gneiss							

Geologie formations in the Setamai – Sakari District, Kitakami mountains, Northeast Honshu, Japan.
black: Surface geologic constituents.

Carboniferous

The successive Lower Carboniferous Hikoroichi, Arisu and Ohdaira Series, total 2500m in thickness, and are largely composed of black slate and basic-intermediate tuff. Fossiliferous beds are found in many horizons of these formations, and they may be correlatable with the Tournaisian, as a whole.

The lowest part of the Hikoroichi Series is represented by conglomerate of variable thickness, which rests unconformably on the Nakazato Series. The Arisu Series has conformably on the Hikoroichi Series, and the Ohdaira Series conformably covers the Arisu Series.

The Onimaru Series is about 300m thick, and is composed of limestone, calcareous slate, and black slate, all of which are very fossiliferous; possibly Upper Viséan in age. The Onimaru series unconformably overlies the underlying formations, and it directly rests on the Hikoroichi Series in the eastern and western part of the area dealt with this paper, although it lies on the Ohdaira Series over most of the central part of the area.

The Nagaiwa Series is about 700m in thickness, and consists of thick limestones, with or without chert nodules, and thin tuffs. Fossils are rare. Nevertheless, this Series may be correlatable with the Namurian to lower Middle Carboniferous (=*Profusulinella* zone) on the basis of foraminifera and coral fauna. The boundary between the Onimaru and the Nagaiwa Series is probably a disconformity but is not well exposed. An upper part of the Middle Carboniferous and the Upper Carboniferous deposits are lacking in the Sakari-Setamai Districts. This is probably the result of erosion prior to the deposition of Permian sediments.

The Permain

The Lower Permain Sakamotosawa Series, transgressively overlies the underlying Carboniferous formations. The series consists of a basal conglomerate which directly lies on the Nagaiwa Series in the western part of the areas; it rests on the Onimaru Series or older rocks in the central part of the area. In the western part, it directly covers the Hikoroichi Series, where the entire Arisu, Ohdaira, Onimaru and Nagaiwa Series have been eroded before the early Permian transgression. The lower part of the Sakamotosawa Series (Kawaguchi stage) is mainly composed of conglomerate, sandstone, slate, a lesser amounts of tuff, graphite beds etc., while the upper part chiefly consists of limestone.

The Kawaguchi Stage is characterized by the presence of *Pseudoschwagerina,* while the overlying Kabayama Stage, which is composed of

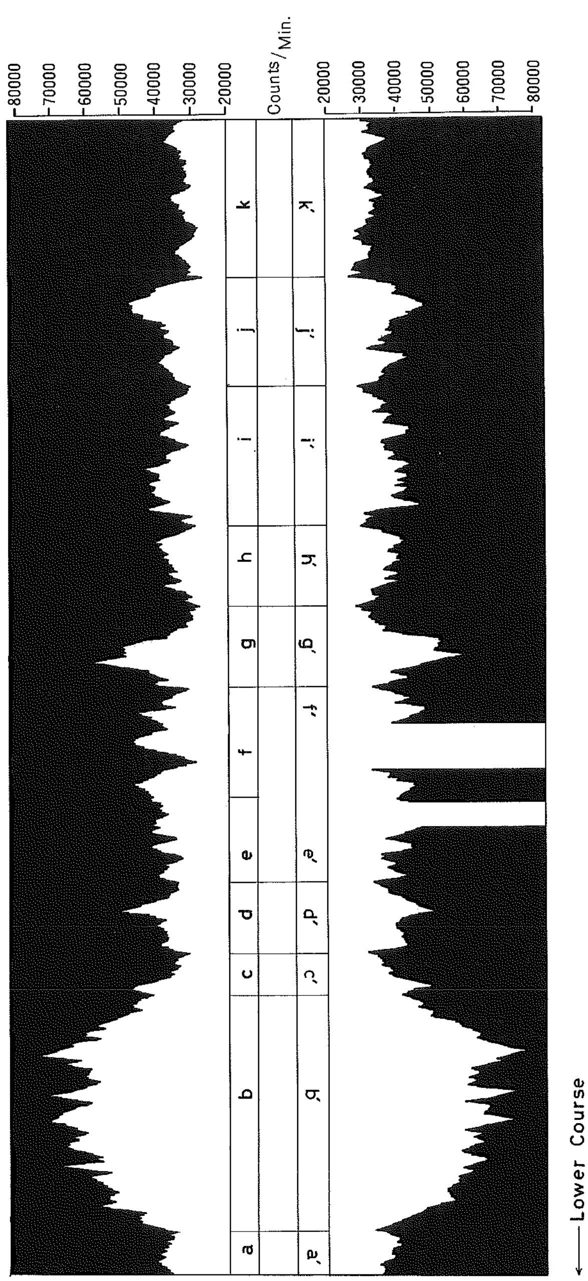

Fig. 2 Recording of radioactivity along the route between Tyoanji and Ohmori. a → k: result of measurement from the Tyoanji (lower course) to Ohmori, while k' → a': from ohmori to Tyoanji. In order to check the reappearance of recording of radioactivity the same route was purposely measured twice. Black in the radioactivity profile in (a' – k') means interuption which was not recorded by mistake. see Fig. 3.

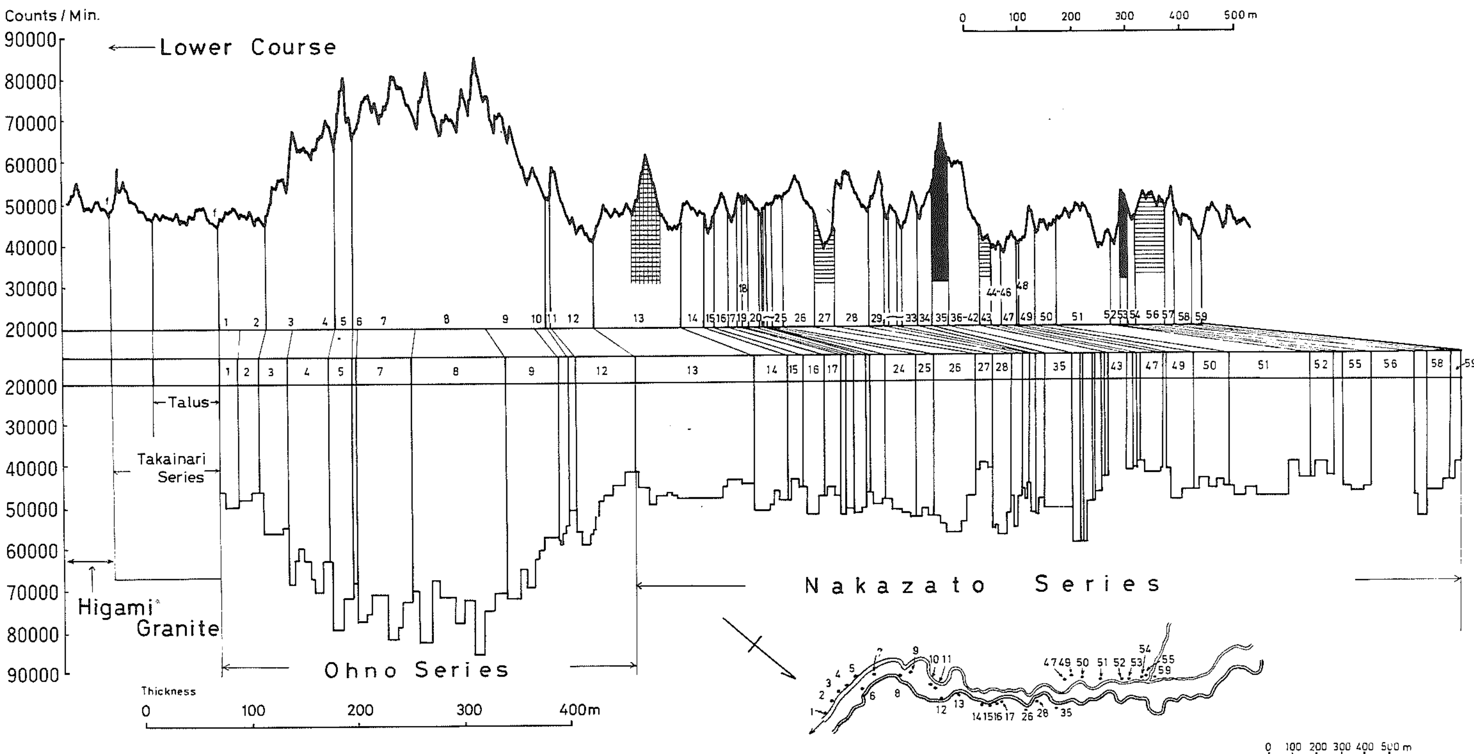

Fig. 3 Radioactivity profile the Ohno and the Nakazato Series along the route between Tyoanji and Ohno. (see Fig. 1, and compare with Table 2 and 3). Numbers in this figure correspons that of the Tables 2 and 3.

limestones together with a subordinate amount of slate and sandstone is represented by the presence of *Pseudofusulina.*

The Sakamotosawa Series, especially the rocks of the Kawaguchi Stage is different between the eastern and western part of the area, both in thickness and/or lithologic facies. In the east, it is less than 100m in thickness, and is composed of slate intercalated with thin graphite beds, and has a conglomeratic base, while it is over 300m thick in the central and western part of the area, and is composed of greenish feldsparthic sandstone, slate, calcareous slate, tuff, and lenticular graphite beds.

The Middle Permian Kanokura Series rests unconformably on the Sakamotosawa Series. The lower half of this series, from 160 to 200m in thickness, is named the Kattisawa Stage, it's base being defined by conglomerate of variable thickness. The basal conglomerate grades upwards into sandstone with interbedded slate.

The sandstone and slate is very fossiliferous, especially in brachiopods and the averant form of fusulinid: *Monodiexodina.*

The upper half of the Kanokura Series is areally variable both in lighologic facies and thickness. Therefore it is difficult to establish a stratigraphical sequence.

Although it is quite sure that the sandstone and slate belonging to the Kattisawa Stage, a thick sequence of limestone containing *Lepidolina* fauna overlies the sandstone and slate in the upper course of the Kattisawa River and Kanokura Creek located in the central part of the area. South of Kanokura, in the vicinity of Yahagi village, the slate is intercalated with thin limestone bands containing *Lepidolina* and is overlain by thick bedded conglomerate containing grantic pebbles (=conglomerate of the Usuginu type). In many areas of the southern Kitakami mountain, a thick granitic conglomerate is locally intercalated with limestone containing *Lepidolina* fauna. Accordingly the *Lepidolina* bearing formation of the surveyed area probably represents two different rock facies: limestone and conglomerate.

It is also possible that formation composed of alternation of conglomerate and black slate represents the *Lepidolina* zone as a transitional facies between limestone and conglomerate facies, since such a formation is really developed in the area between the limestone complexes with *Lepidolina* and thick conglomerate above mentioned. In addition, *Lepidolina* is rarely found from the calcareous matrix of thin conglomerate alternating with black slate. There is still such a case as thick slate formation intercalating with very thin limestone in which *Lepidolina* is found.

The Upper Permain Toyoma Series, about 400, in thickness, is represented by black slate containing rare fossils, with thin conglomeratic sandstone at it's base.

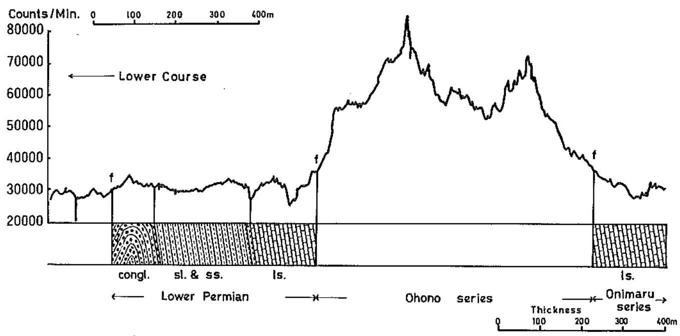

Fig. 4 Radioactivity profile measured along the upper course of Sakamotosawa River. f: fault, conglo: conglomerate, sl & ss.: slate and sandstone, ls: limestone

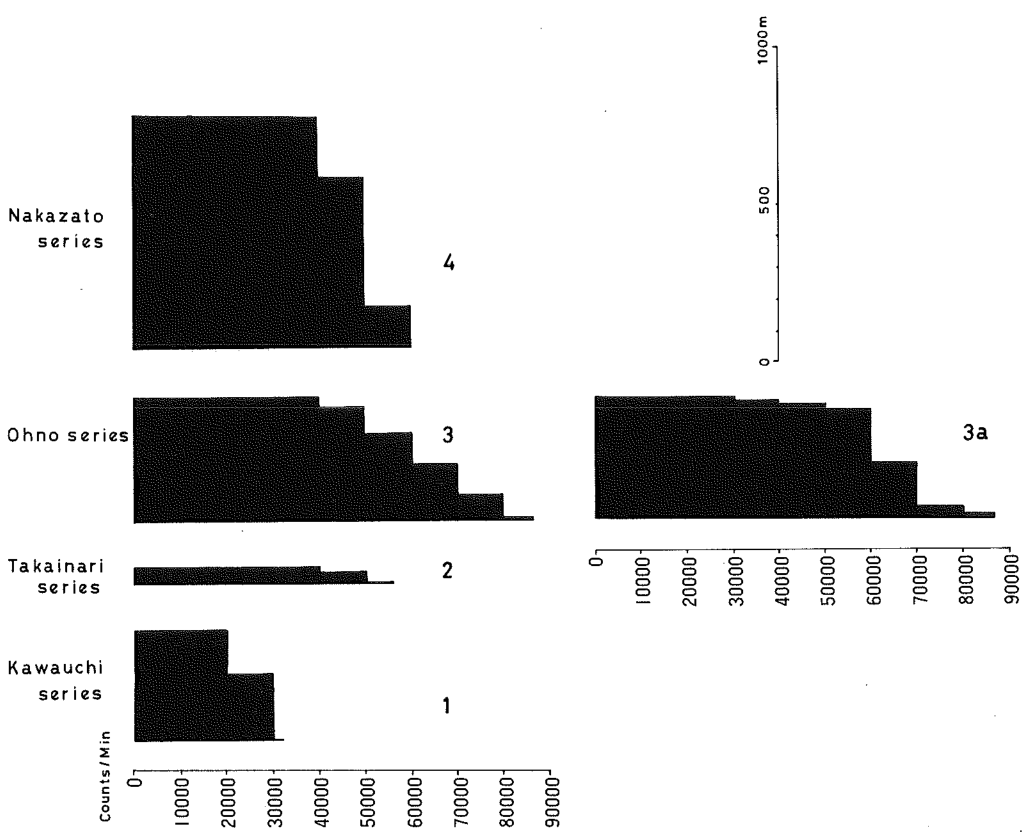

Fig. 5 Averaging of radioactivity in the rocks of the Kawauchi, Takainari, Ohno and Nakazato Series.

Triassic

The Lower Triassic Inai Group outcrops in the central-southern part of the area as a sequence of some 1000m, mainly composed of marine slate, with conglomerate and sandstone in the lower part. The basal conglomerate rests unconformably on the intensely folded Toyoma slate in a few localities in the central southern part of the area. The Middle and Upper Triassic Formations are absent in this area, and the Jurassic Karakuwa Group unconformably overlies the Inai Group.

Jurassic

The Middle – Upper Jurassic (partly Lower) rocks are divided into two Formations; the Kosaba Formation and Tsunakizaka Formation in ascending order. The former is about 230m thick and is composed of conglomerate and sandstone, while the latter is about 450m thick and composed of slate and sandstone. The base of the Kosaba Formation has been correlated to the Aalenian by molluscan fauna.

The Upper Jurassic Shishiori Group transgressively overlies the Karakuwa Group. The lower part of the Shishiori Group, the Mone Formation, is about 450m thick, and is chiefly composed of sandstone and lesser amounts of shale and coal bearing shale, with conglomerate at its base. The facies are in part marine and mostly non-marine.

The upper half of the Shishiori Group, the Kogoshio Formation, is about 350m in thickness and is chiefly composed of sandstones intercalated with coal bearing shale. The rocks represent shallow water estuary to brackish facies.

Cretaceous

The Lower Cretaceous Ofunato Group ranges from 1600 – 2500m in thickness, and consists of conglomerate, sandstone, slate or shale, with interbedded tuff and lava. The rocks are partly terrestrial but mostly marine in facies. The Ofunato Group unconformably overlies the Toyoma Series, and is covered by Pleistocene deposits.

Igneous rocks

Porphyrite dykes with gold bearing quartz veins and the Takekoma grano-diorite intrude the Palaeozoic and Mesozoic rocks. The porphyrite dykes are older than the granodioilite as they have been metamorphosed in the

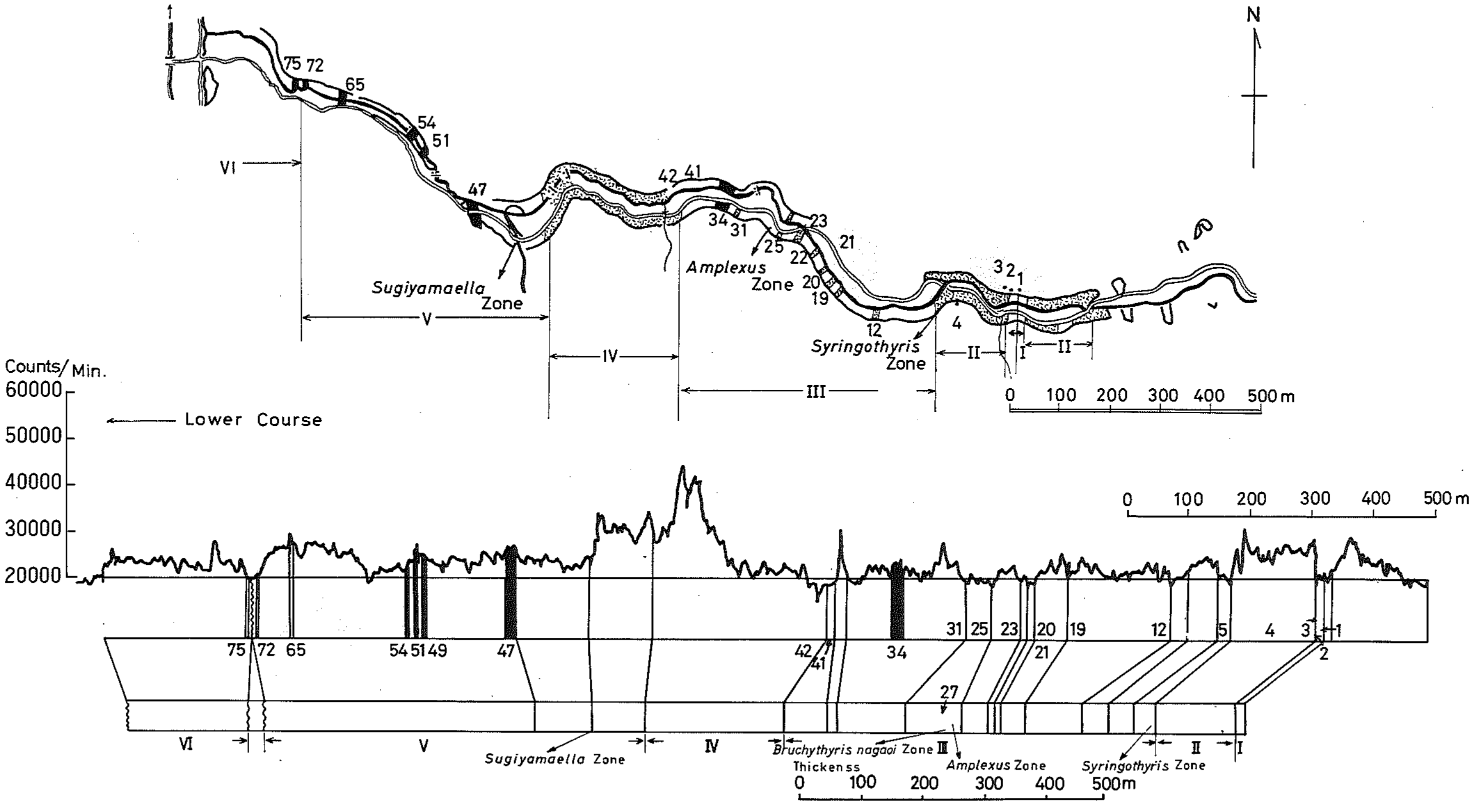

Fig. 6 Radioactivity profile of the Lower Carboniferous (ranging from the upper part of the Group I to the Group VI), measured along the lower course of the Kozubo River. Numbers in the figure correspond that of the Table 4.

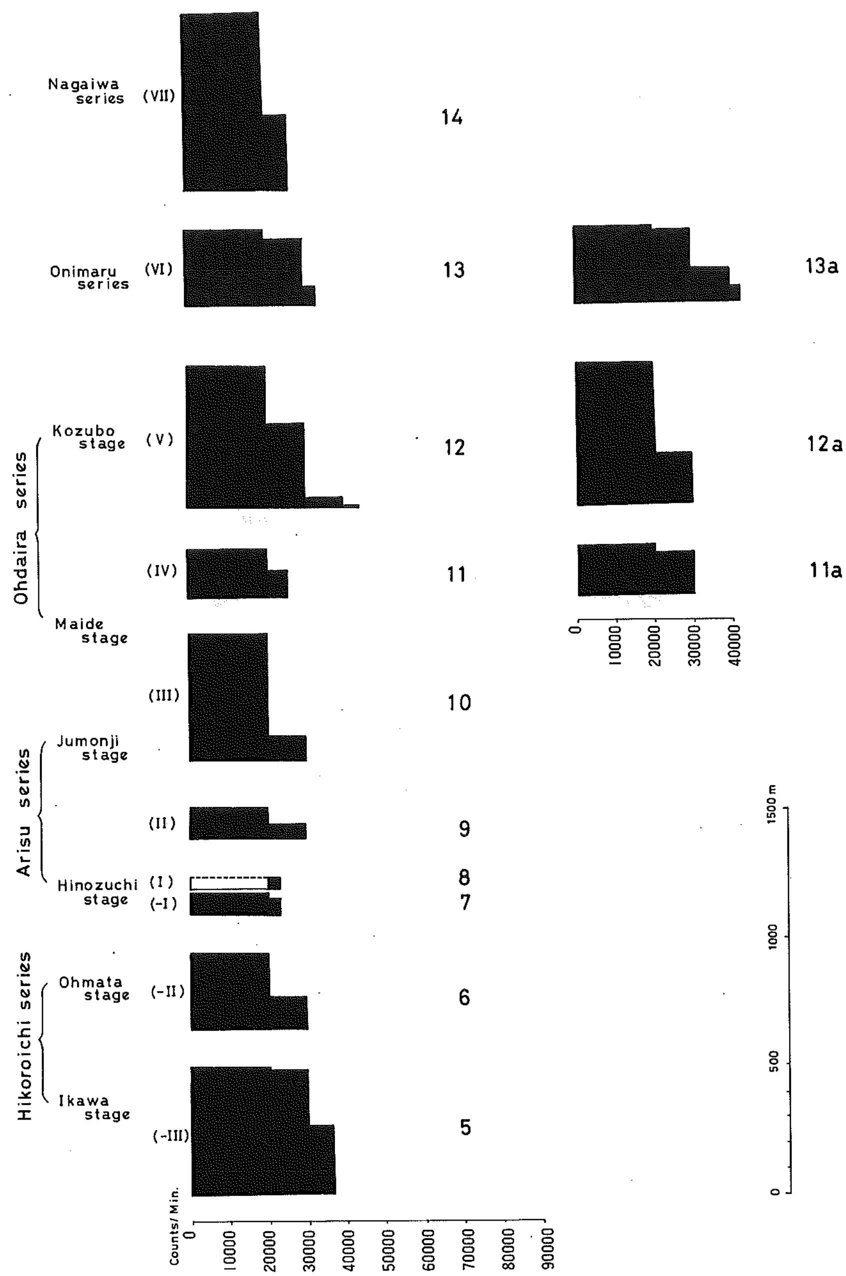

Fig. 7 Averaging of the radioactivity of the Lower Carboniferous Formations.

contact aureole of the granodiorite. The K-Ar age of the granodiorite is about 112 my. (KAWANO and UEDA, 1965; SHIBATA, 1973).

Diabase dykes, less numerous rhyolitic dykes, and small gabbroic masse intrude the Palaeozoic formations but their stratigraphic position is unknown.

The Higami granite may be divided into at least three types: *a*, *b* and *c*, on the basis of mineral content and texture. Type *a* is a coarse grained biotite-hornblende granite, with a hornblende K-Ar age of 351 ±12 –355 ±13 my. (SHIBATA, 1973). The biotite-hornblende granite outcrops mainly in the eastern part of the Higami granitic body, although it is also locally found in the central part.

Type *b* is mainly distributed in the central part of the Higami granite body, and is a fine grained leucocratic granite. Rook type *a* and Type *b* are gradually transitional into one another.

Type *c* is a gneissic granite and intrudes the Tsubonosawa gneiss.

It is noteworthy that the Type *c* granite is dated at 114 – 115 my. (Shibata , 1973), and is metamorphosed by the Takekoma granodiorite whose K-Ar age is about 112 my. Therefore, Type c is possibly older than the K-Ar age.

Radioactivity of rocks

The Upper Silurian Kawauchi Series

The sediments of the Kawauchi Series are thin, about 300 m in total thickness, and composed of partly metamorphosed linestone and slate. Fossils are mainly found in limestone and include stromatoporoid, tabulata, rugosa and brachiopods.

Because of inaccessability of most outcrops only parts of the Silurian rocks could be measured. A section along the road found some 900 m southeast of Sekiya railway station along which well bedded (partly conglomeratic) limestone is intermittently exposed for about 600 m.

The rocks show more than 20000 cpm., mostly reaching 30000 cpm., and a small number show a little in excess of 30000 cpm. (Figs. 1 and 5).

The Devonian

The Takainari Series

The reddish and greenish chert of the Takainari Series is exposed along the road between Tyoanji and Ohmori (Fig. 1 and Fig. 3) where they usually show more than 40000 cpm. The chert is intruded by stock like bodies of granite, probably belonging to the Higami granodiorite (Type a).

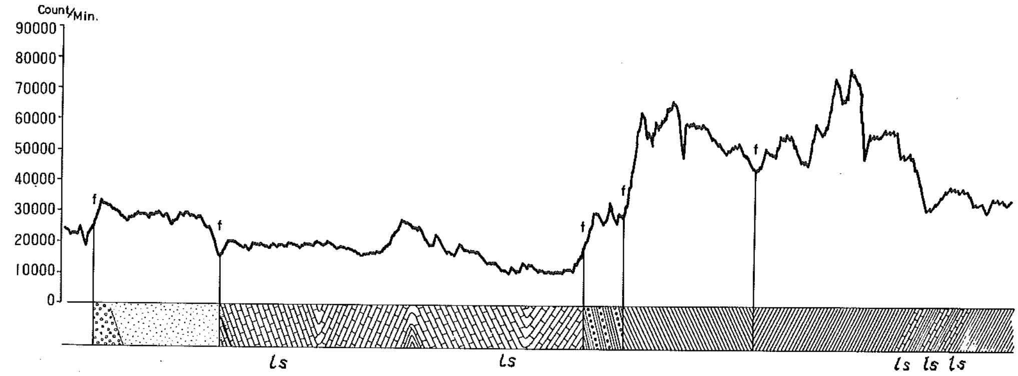

Fig. 8 Radioactivity profile along the upper course of the Kattisawa River. The left section (white circle: conglomerate, dotts: sandstone) is the Kattisawa Stage. The middle section (ls: limestone) is the Iwaizaki Stage with *Lepidolina* fauna, hattched lines and conglomerate in alternation is also the member of the Iwaizaki Stage. The right side section shows slate and alternation of slate and thin limestones with *Lepidolina* fauna, including *Lepidolina minatoi.* The high radioactivity shows the horizon immeadiately above the limestones with *Lepidolina minatoi.*

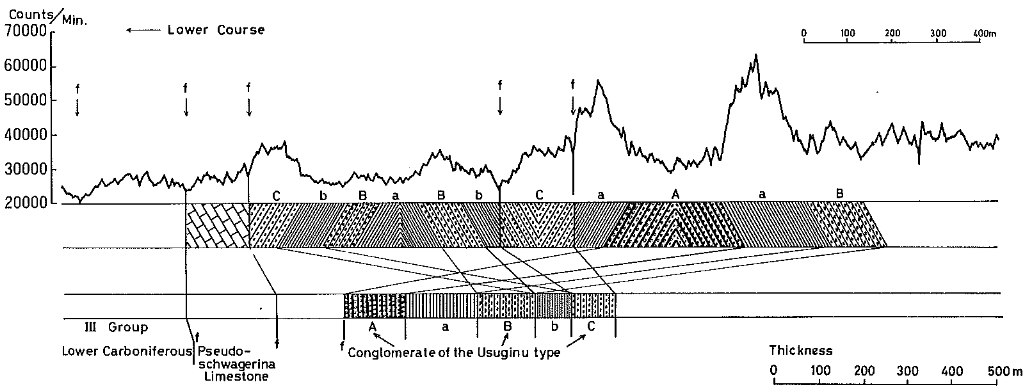

Fig. 9 Radioactivity profile along the upper course of the Kozubo River.

The Ohno Series

The Ohno Series is well exposed along the same road as the preceding Series (Fig. 3). It is in fault contacted with the Takainari Series, but nearly an entire sequence is exposed from the fault up to the basal part of the Nakazato Series.

The radioactivity of the Ohno Series are generally higher than 50000 cpm., some reaches about 80000 cpm. Radioactivity among the layers of keratophyre tuff are high, although some individual layers (Members 1, 3, 10 and part of 12 in Table 2) have comparatively low counts. At Ohno, the type locality of the Ohno Series, Members 1 and 3 are also weak in radioactivity. It is significant that the slate (Member 4 in Table 2) has a radioactivity as high as most of the keratophyre tuff.

Table 2 Stratigraphic sequence of the Ohno Series in descending order.

		thickness in meters
12	keratophyre tuff	55.0
11	black slate	6.8
10	keratophyre tuff	7.5
9	keratophyre tuff	50.5
8	keratophyre tuff	89.0
7	dark bluish slate	52.3
6	keratophyre tuff intercalted by purplish slate	2.7
5	keratophyre tuff and bluish slate	21.8
4	black slate	40.0
3	keratophyre tuff	29.0
2	limestone	20.0
1	keratophyre tuff	15.0

Table 3 Stratigraphic sequence of the Nakazato Series in descending order.

		thickness in meters
59	diabasic tuff	10.0
58	sandstone	22.0
57	slate	10.0
56		40.0
55	slate	20.0
54	sandstone	3.0
53	(dyke)	7.5
52	slate	19.0
51	sandstone	79.2
50	slate	32.0
49	slate	24.5
48	slate	2.0
47	slate	27.5

46	keratophyre tuff	1.5
45	slate	2.8
44	keratophyre tuff	7.5
43		15.0
42	slate	3.0
41	keratophyre tuff	2.0
40	slate	4.6
39	keratophyre tuff	1.8
38	slate	10.0
37	keratophyre tuff	1.2
36	keratophyre tuff	7.0
35	(dyke)	14.0
34	slate	6.5
33.	keratophyre tuff	5.6
32	slate	2.0
31	keratophyre tuff	1.0
30	slate	1.8
29	keratophyre tuff	7.5
28	keratophyre tuff	19.0
27		16.0
26	slate	35.0
25	keratophyre tuff	18.0
24	slate	27.4
23	keratophyre tuff	11.5
22	slate	1.5
21	keratophyre tuff	2.0
20	slate	12.6
19	keratophyre tuff	7.5
18	slate	6.5
17	keratophyre tuff	15.0
16	slate	20.0
15	keratophyre tuff	14.0
14	slate	34.0
13	diabasic tuff	113.0

An outlier of intensely faulted and folded Ohno Series sediments, some 670 m of exposture, occurs in the upper part of the Sakamotosawa River (Fig. 4). Although the stratigraphical sequence cannot be established the rocks (mainly keratophyre tuff) have radioactivity as high as 60000 to 80000 cpm. In the vicinity of Sekiya station, the good expostures are found in a river section. The rocks in this section, which could be measured invariably gave over 70000 cpm. At the type locality, keratophyre and slate intercalated with limestone, which may represent the lower horizon of this Series, have low radioactivity of 50000 cpm., but the rocks in the higher horizons generally exceed 70000 cpm.

In short, the radioactivity of the Ohno Series, some 390 m in total thickness, ranges from 50000 to 80000 cpm.

The Nakazato Series

Good exposures of rocks of the Nakazato Series crop out along the road between Tyoanji and Ohmori. The Nakazato Series rests conformably on the Ohno Series and the base is defined by brecciated or agglomeratic basic tuff, over 110 m in thickness. Numbers 13 to 59 in Fig. 3 correspond to the lithological units of this formation and are given in Table 3. Numbers 35 and 53 represent porphyrite dykes. The mass effect of outcrops on both sides of the road on the radioactivity of the rocks is clearly shown by member 31 (Fig. 3 represented as crossed lines).

In general, the radioactivity of keratophyre tuff of the Nakazato Series (Members 28, 29, 36-42 in Fig. 3 and Table 3) give higher counts than the other rock units, although the counts are not as high as similar tuffs belonging to the Ohno Series. Basaltic tuff has a low radioactivity. Sandstone and slate fluctuant in radioactivity, but usually show less than 50000 cpm., and rarely reach 60000 cpm.

The Carboniferous

Carboniferous deposits are divisible into ten groups of major lithological facies which enumerated in descending order (Table 1). As time stratigraphical units, they are divided into the Hikoroichi, Arisu, Ohdaira, Onimaru and Nagaiwa Series. Of them, the Hikoroichi Series is divided into the Ikawa Stage (Group-III), and the Ohmata Stage (Group-II).

The Hikoroichi Series

The Ikawa Stage

Although this statge is widely distributed in many parts of the surveyed area, it is not easily accessible by car, because of the bad condition of the roads. The rocks of the Ikawa Stage are 500 m thick. The base is defined by conglomerate, overlain by alternation of the beds of slate and tuff. In the lower course of the Sakamotosawa River exposures of the Ikawa Stage give radioactive counts of between 28000 and 35000 cpm. Near the junction of the Sakamotosawa River and a Creek flowing from Onimaru, the upper to middle part of the Ikawa Stage is well exposed, and gives of 35000 cpm as maximum (Fig. 7). In other localities, such as Ohmata, Hinozuchi and Kashiwari, the radioactivity of the rocks could not be measured because of poor exposture.

The Ohmata Stage

In the western part of the area, the rocks of the Ohmata Stage are well exposed between Komata and Ohmata. The base of the Stage is defined by porphyrite tuff, which is overlain by slate, 300 m in thickness. The tuff has low radioactivity, and over 20000 cpm., were measured in some parts. The slate gives less than 30000 cpm. (Fig. 7).

The Arisu Series

The Hinozuchi Stage

The lower half of the Arisu Series is represented by the Hinozuchi Stage, which consists of two major lithologic units; Group-I, 40 m~180 m thick, consists of porphyrite tuff, Group I, some 220 m in thickness, consists of slate. Nearly the entire exposed sequence of Group-I was measured and was about 20000 cpm. Group I could only partly measured, because of a fault contact with the Permian Sakamotosawa Series near Ohmata. The rocks measured gave around 20000 cpm., (7 and 8 in Fig. 7). The upper part of the Ohmata Stage is exposed along the upper course of the Kozubo River (Fig. 1), where little over 20000 cpm., were recorded.

The Jumonji Stage

The Jumonji Stage is represented by Group II and the lower half of Group III. Group II chiefly consists of basic tuff, about 120 m thick (Fig. 6). Radioactivity of the rocks was measured along the Kozubo river and averaged around 30000 cpm. The upper limit of the Jumonji Stage is difficult to lithologically define, since Group II is mainly composed of a monotonous sequence of black slate with thin intercalations of basic tuff. In the section exposed along the Kozubo river, the middle part contains a thin impure limestone in the black slate containing *Brachythyrina nagaoi* MINATO and *Amplexus nipponensis* OISHI et MINATO. These fossils are regarded as representing the uppermost part of the Jumonji Stage. Thus the upper half of stage is estimated to be about 245 m in thickness. Radioactivity of the upper stage was 25000 cpm., or less, partly over the counts were measured along the Kozubo river. Intercalated beds of basic tuff have much lower, generally about 20000 cpm.

Table 4 Stratigraphic sequence of the Lower Carboniferous observable along the lower course of the Kozubo River.

(After Minato, 1944)

	Group VI (over 200 m)	
80.	Sachaloidal limestone	20 m
79.	.... Unexposed and intrusion of dyke	125.0 m
78.	Sachaloidal limestone	18.0 m
77.	Diopside rock	20.0 m
76.	Sachaloidal limestone	10.0 m
75.	.... Intrusion of dyke	7.0 m
74.	Banded limestone	ca. 4.0 m
	.... Clino-unconformity	
	Group V (about 560 m)	
73.	Alternation of coaly shale and calcareous sandstone	2.5 m
72.	.... Intrusion of dyke	20.5 m
71.	Chiastolite hornfels	4.0 m
70.	Biotite hornfels	1.5 m
69.	Chiastolite hornfels	12.0 m
68.	Hornfels	10.0 m
67.	Sandstone	20.0 m
66.	Chiastolite hornfels	ca. 5.0 m
65.	.... Intrusion of dyke	ca. 8.0 m
64.	Chiastolite hornfels	ca. 9.0 m
63.	Fine-grained sandstone	15.0 m
62.	Alternation of impure limestone and banded fine-grained calcareous sandstone	15.0 m
61.	Fine-grained calcareous andstone	48.0 m
60.	Banded sandstone	30.0 m
59.	Banded fine-grained calcareous sandstone	24.0 m
58.	Fine-grained sandstone	4.0 m
57.	Banded fine-grained calcareous sandstone	12.0 m
56.	Chert	1.0 m
55.	Banded fine-grained calcareous sandstone	6.0 m
54.	.... Intrusion of dyke	36.0 m
53.	Crystalline limestone	8.0 m
52.	Hornfels	6.0 m
51.	.... Intrusion of dyke	17.0 m
51.	Sandstone with limestone lenses	8.0 m
49.	.... Intrusion of dyke and unexposed	15.0 m
48.	Banded fine-grained sandstone	50.0 m
47.	.... Intrusion of dyke	10.0 m
46.	Alternation of fine- and coarse-grained schalstein	165.0 m
	Group IV (about 230 m)	
45.	Massive schalstein	190.0 m

44. Brecciated schalstein .... 7.0 m
43. .... Unexposed .... 32.0 m
42. Schalstein and brecciated schalstein .... 8.0 m

Group III (about 510 m)

41. Radioralian chert.................... 5.0 m
40. Black slate .... 22.0 m
39. Alternation of slate and coarse-grained sandstone .... 6.5 m
38. Black slate .... 21.0 m
37. Fine-grained sandstone .... 2.0 m
36. Black slate .... 13.0 m
35. Biotite hornfels .... 5.0 m
34. .... Intrusion of dyke .... 19.0 m
33. Black slate .... 7.0 m
32. Black slate .... 9.0 m
31. Schalstein .... 3.0 m
30. Black slate .... 9.0 m
29. Alternation of coarse- and fine-grained sandstone .... 3.0 m
28. Black slate .... 12.0 m
27. Alternation of black calcareous slate and sandy schalstein .... 30.0 m
26. Black slate .... 27.0 m
25. Schalstein .... 10.0 m
24. Black slate .... 30.0 m
23. Schalstein .... 10.0 m
22. Black slate .... 12.0 m
21. Schalstein .... 5.0 m
20. Black slate .... 38.5 m
19. Schalstein .... 1.2 m
18. Black slate .... 16.0 m
17. Sandstone .... 4.0 m
16. Black slate .... 45.0 m
15. Sandstone .... 4.0 m
14. Black slate .... 10.0 m
13. Calcareous slate .... 5.0 m
12. Schalstein .... 12.0 m
11. Thin alternation of slate and tuff .... ca. 15.0 m
10. Alternation of fine- and coarse-grained tuffaceous sandstone
.... ca. 25.0 m
9. Black slate .... ca. 10.0 m
8. Alternation of coarse- and fine-grained tuffaceous sandstone
.... ca. 25.0 m
7. Chert .... ca. 10.0 m
6. Alternation of coarse-grained tuffaceous sandstone and slate
.... ca. 15.0 m
5. Tuff intercalting with impure limestone .... ca. 15.0 m

Group II (about 135 m)

4. Massive schalstein .... 135.0 m

Group I (35 m+)

3. Greenish sandstone.. 1.5 m
2. Sandstone.. 5.0 m
1. Black slate.. 30.0 m

In the Arisu series, the upper course of the Hinozuchi and Nashirozawa creeks near Jumonji, where they typically measured low radioactivity less than 25000 cpm.

The Ohdaira Series

The Maide Stage

The Maide stage is represented by the upper half of the Group III, about 265 m thick, which consists mainly of slate, and the Group IV consisting exclusively of basic tuff, 200 m in thickness. Radioactivity of the rocks was measured along the lower course of the Kozubo River (Fig. 6). Rocks representing the lower half of this stage attain nearly 30000 cpm., while those of the upper half mostly exceed 40000 cpm., (10 and 11 of Fig. 7). The higher counts of the rocks in the part of upper half of the stage may be a result of the (mass effect) more extensive exposure.

The Kozubo Stage

The Kozubo State is represented by sandstone, impure limestone and slate. The basal part consists of an alternation of slate and diabasic tuff. The result of measurement of the rocks of this Stage is given in Fig. 6 and Fig. 7. The Ohdaira Series is widely distributed in the central and northern part of the area, and the radioactivity of many exposures were measured (see 11a and 12a in Fig. 7).

The Onimaru Series

Although rocks of the Onimaru Series (=Group VI) are extensively developed in the Seatamai – Sakari District, they are rarely exposed in road. In Fig. 7, the result of measurement along two routes is shown: Northwest of Tashiroyashiki and along the upper course of the Sakamotosawa River (Fig. 1).

Limestone, which is the predominate rock type in the sections measured gives 3 – 40000 cpm., (eg, at the type locality – Onimaru).

The Nagaiwa Series

At the type locality (Nagaiwa), the Nagaiwa Series (Group VII) is largely represented by limestone intercalated with thin beds of porphyrite tuff and nodules. The limestone is partly nodulous; the noduls being mostly composed of chert. The result of measurement of the limestone at the type locality is given in 14 of Fig. 7: 20000 – 30000 cpm.

The radioactivity of the Carboniferous sediments is comparatively low, averaging 25000 cpm. Maximum counts of 45000 cpm., are recorded from the basic tuff of the Kozubo stage.

The Permian

The Sakamotosawa Series

The lower part of this Series is defined by a basal conglomerate, which is overlain by slate with interbedded fine sandstone with or without thin tuff and graphite beds. The rocks are divided into the lower Kawaguchi Stage and the upper Kabayama Stage. The boundary between there two stages is based on the first appearance of *Chalaroschwagerina vulgaris,* since the Kabayama Stage is mainly represented by limestone.

The radioactivity of the rocks is given in Fig. 10, (given in terms of lithologic units Group VIII and Group IX, instead of time stratigraphic units). Maximum of the Group VIII: 30000 cpm., while of the Group IX: a little over 3000 cpm. The Group VIII corresponds to the lower half of the Kawaguchi Stage within which limestone is not represented, while the Group IX corresponds in general to the upper half of the Kawaguchi Stage and the Kabayama Stage, both represented by limestone.

The Kanokura Series

The Kattisawa Stage

The basal conglomerate of the Kanokura Stage unconformably overlies the rocks of the Sakamotosawa Series. The Series is divided into the Kattisawa Stage (=Group XI) and the Iwaizaki Stage. Rocks of the Kanokura Series are mainly composed of slate and sandstone, totalling some 160 m in thickness. They are well exposed along Kanokura Creek and Kattisawa River. Radioactivity along the upper course of the Kattisawa River are shown in Fig. 8 and

17 of Fig. 10.

The Iwaizaki Stage

The upper half of the Kanokura Series, viz. the Iwaizaki Stage has a variable lithology. In some localities, this stage is chiefly composed of a thick sequence of limestone, in others it is composed of both slate or an alternation of slate and limestone, while in other localities it is represented by either, thick conglomerate with granitic pebbles or conglomerate alternating with slate. Rocks of the Iwaizaki Stage are therefore not correlatable by lithology but by the presence of *Lepidolina* fauna.

The limestone exposed along the upper course of the Kattisawa River, has extremly low radioactivity (less than 20000 cpm.) (Fig. 8). In contrast the slate also exposed along the upper course of the Kattisawa River has very high counts of nearly 80000 cpm.

Slate exposed in the upper course of the Kozubo River (Fig. 9), also has a high radioactivity of 63000 cpm. The slate is associated with conglomerate containing granitic pebbles and therefore may be correlatable with a part of the Iwaizaki Stage, although it's precise stratigraphic position is unknown.

Again, in the upper course of the Tairagai River (Fig. 1), slate overlying conglomerate with granitic pebbles, is found, the radioactivity of which exceed 60000 cpm. (20 b of Fig. 10).

The Toyoma Series

Near Tadagoe, along the sea shore (Fig. 1), the Toyoma Series is fairly well exposed. However, the basal part which is composed of conglomerate with some granitic pebbles, could not be measured because of the bad condition of the road. The exposed parts of the section, a total of 200 m thick, consist essentially of black slate; maximum about 50000 cpm. (21 of Fig. 10).

Mesozoic Group

Inai Group

In the south of the area, the Inai Group, Scytian to Anisian in age, is developed. The basal part (=Group Tr 1) is about 200 m thick, begining in conglomerate, which grades upwards into sandstone and slate. The Group Tr 2 overlying the preceding is about 300 m in thickness, it's base is also defined by conglomerate, which is overlain by sandstone and consists of well laminated slate in the middle and upper part. The Group Tr 3 is about 300 m thick, the lower part consists mainly of sandstone, overlain by finely laminated slate, partly intercalated by sandstone in the upper part. The Group Tr 4 is about 300 m in thickness, it's cyclic units of sandstone and slate. The Group Tr 5 and Group Tr 6 are represented by similar lithologic facies as the Group Tr 4.

Rocks of the Groups Tr 2, Tr 3 and Tr 4 are exposed in road cuttings from Tadagoe to the Tadagoe Pass. Results of measurements for radioactivity are given in 22 of Fig. 11: 40000 to 60000 cpm

The Karakuwa Group

This Group, probably Aalenian to Bajocian in age, is divided into the Kosaba and Tsunakizaka Formations; the former is about 230 m thick, and is chiefly composed of sandstone with conglomerate at its base, while the latter is about 450 m thick, and mostly composed of black slate, with sandstone in the uppermost horizon. The rocks were measured along the road between Tadagoe and Tadagoe Pass and the result is given in 23 and 24 of Fig. 11. Maximum counts of the Kosaba formation: 50000 cpm., while that of the Tsunakizaka formation 62000 cpm.

Shishiori Group

The Shishiori Group, Callovian-Kimeridgian in age, consists of two formations: the Mone and Kogoshio Formations. The Mone Formation is about 450 m thick, begining with granitic conglomerate and overlain by arkosic sandstone. The sedimentary facies is predominantly terrestrial, although brackish-marine facies is present. Radioactivity is very high throughout the formation, reaching more than 90000 cpm. in maximum.

The Kogoshio Formation is about 750 m thick, and is mainly composed of arkosic sandstone. The facies is predominantly terrestrial with intercalations of marine to brackish facies in the middle portion. Radioactivity is also very high, averaging 6000 cpm., and recording 90000 cpm. in maximum. Measurement of radioactivity of the Shishiori Group were carried out along the road to the east and west of the Tadagoe Pass. The results are shown in 25, a, b, c and 26, a, b of Fig. 11.

The Ohfunato Group

The Lower Cretaceous Ohfunato Group is represented by a thick sequence (some 3500 m) of alternating slate and sandstone with intercalations of tuff and conglomerate. The basal part consists of basic volacnic and pyroclastic

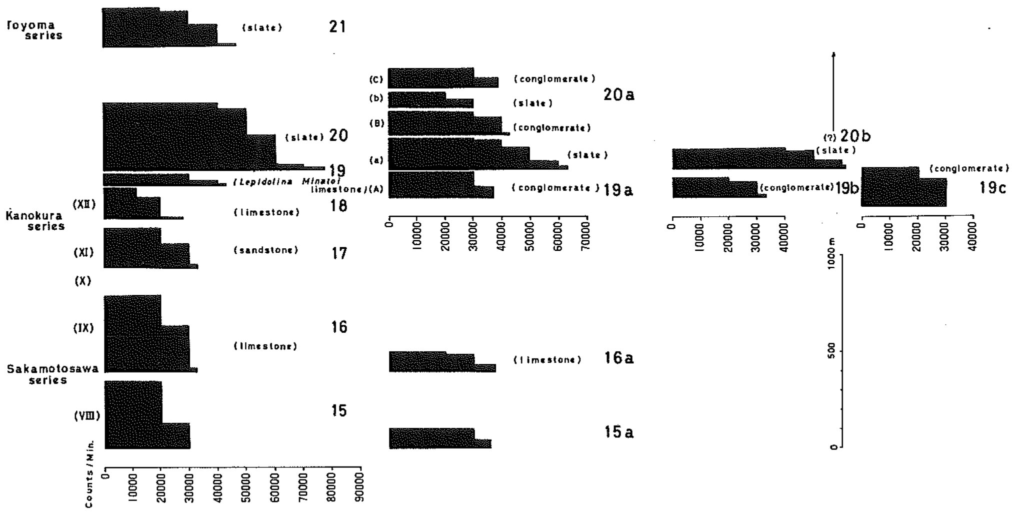

Fig. 10 Averaging of the radioactivity of the Permian formations.

deposits. Radioactivity of the slate -sandstone sequence gave counts ranging 40000 to 50000 cpm., and rarely 60000 to 70000 cpm.

The Tsubonosawa Gneiss

In the upper course of the Tsubonosawa River (Fig. 1), the Tsubonosawa gneiss is well developed, and is intruded by the Higami granite of Type *c*. Radioactivity of the gneiss is usually over 40000 to 50000 cpm., and sometimes exceeding more than 60000 cpm.

The Higami granite

Among the granitic rocks developed in this area, the Higami granite of Type *a* and Type *b* gave very high radioactivity. The maximum reach more than 70000 cpm., althogh 50000 cpm is typical.

In contrast, the Higami granite of Type *c* is low in radioactivity generally recording less than a maximum of 50000 cpm. (Fig. 12).

The Takekoma granodiorite

This is the youngest granitic rock of the area and has a low radioactivity of – typically less than 45000 cpm. (Fig. 12).

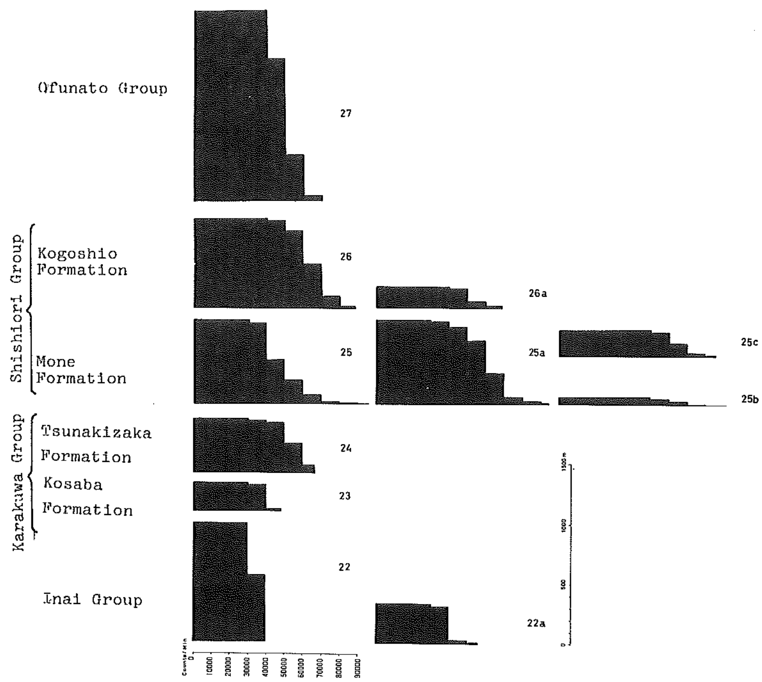

Fig. 11 Averaging of the radioactivity for the Mesozoic formations.

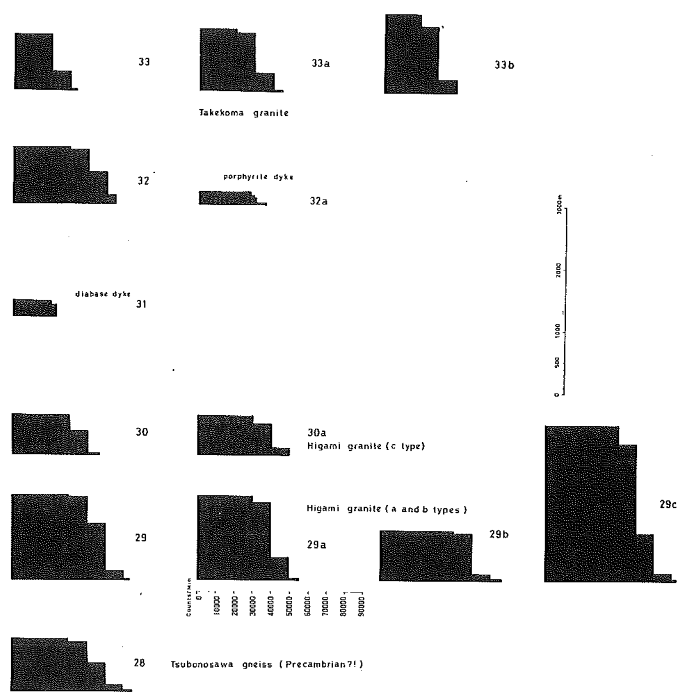

Fig. 12 Averaging of the radioactivity for the granitic, dyke and gneissic rocks.

Diabasic and Porphyrite dykes

Diabasic dykes have very low radioactivity – generally recording around 20000 cpm. In contrast the radioactivity of the porphyrite dykes locally exceed 50000 cpm. (Fig. 12).

Uranium content of some rocks

Analysis for Uranium was carried out at the chemical laboratory attached to the Power Reactor and Nuclear Fuel Development Corporation on certain rock specimen which showed high radioactivity.

The sandstone stratigraphically situated near the top of the Mone Formation, from the Tadagoe and Ishiwari Passes contained 80 ppm U_3O_8 and 200 ppm ThO_2. A specimen of keratophyre from Ohno gave a U_3O_8 content of 5 ppm U_3O_8.

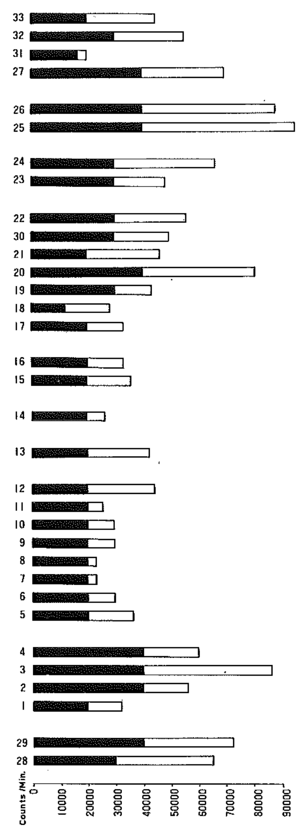

Table 5 The radioactivity for each formation and rock unit. Numbers in the table corresponds that of the Table 1. Black: minimum value, while white: maximum value.

Conclusion

A summary of the radioactivity is given in Table 5. The Lower Devonian Ohno Series (3), the Late Middle Permain slate complex within the Kanokura Series (20), the Upper Jurassic Mone (25) and Kogoshio (26) Formations show very high radioactivity.

The Tsubonosawa gneiss (28), Higami granite of Type *a* and Type *b* (29), and the Lower Cretaceous Ohfunato Group are relatively high in radioactivity, although lower than the rocks above listed.

The Silurian Kawauchi Series (1), the Lower Carboniferous (5-13), the Middle Carboniferous (14), and the Lower Permian formations (15-16), are generally low in radioactivity.

With the exceptions of the Lower Devonian Ohno Series the geologically younger formations ranging from the Middle Permain Kanokura Series up to the Lower Cretaceous Ohfunato Group, have high radioactivity in comparison to the older formations in the Setamai – Sakari Districts.

It is concluded that, the concentration of radioactive elements in the sediments has progressively increased from Silurian to Lower Cretaceous times.

The reverse is true of the granitic rocks with the older granites having higher radioactivity.

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Plate 1 Surveying in the road between Tyoanji and Ohno. The instrument is mounted on the front jeep.