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Late Mesozoic Crustal Movements in the Hida Plateau, Central Honshu, Japan*

By

Masatora KAWAI**

Abstract

In the Hida Plateau region, the Hida gneiss complex on the north side and the Paleozoic system of the Yamaguchi facies on the south side constitute the autochthonous basement. The Tetori basin was formed on the southern margin of the Hida complex, and into this basin were supplied the materials from the north. Thus, the Jurassic Kuzuryu group was deposited first, followed by the mainly Lower Cretaceous Itoshiro group. Afterwards, the Upper Cretaceous Omodani rhyolites were thickly accumulated on the level denudation surface, preceded by the deposition of the Asuwa group in the small depressions which had come into existence in the early period of accumulation of the Omodani rhyolites.

Since Middle Jurassic the crustal movements proceeded intermittently, and culminated during the period from Mid- to Latest Cretaceous. Deformations, accompanied by intense thrusting, took place along with the severe volcanic activities of acid and intermediate rocks which is followed by the intrusion of Early Tertiary granites.

The main thrust faults can be classified into two groups; the Ura-Nippon thrust system extending on the north to northeast side, and the Omote-Nippon system which trends on south to southeast side. The thrust sheets of the former are composed of the Hida complex, whereas those of the latter consists of the Paleozoic system of the Para-Akiyoshi facies, which comprises Silurian, Devonian, Carboniferous and various Permian sediments. The main thrust faults were completed in Latest Cretaceous.

Introduction and Acknowledgements

Since 1953 the writer has occupied himself with the compilation of 1: 50,000 geological maps of Arashimadake, Higashimozumi, Neo, Kyogatake and Hida Furukawa in the Hida Plateau. At the same time he has surveyed the geology of the above-mentioned areas and the vicinities.

The present paper summarizes the geology of the Late Mesozoic system of the surveyed areas.

In preparing this report, the writer was rendered with immeasurable guidance

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** Geological Survey of Japan.

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Outline of Geology

The Hida Plateau region is geologically made up of the pre-Jurassic basement including the older plutonics, the Jurassic and Cretaceous Tetori super-group, the Upper Cretaceous Asuwa group and Omodani rhyolites, the Paleogene younger plutonics, and the overlying Neogene and younger beds. The region is marked with groups of thrust faults, called the Omote-Nippon and Ura-Nippon thrust systems, by which the basement was thrust upon the Late Mesozoic system.

The geological system of the region is summarized in Table 1. Fig. 1 is an index map of the Hida Plateau. Fig. 2 is a compiled geological map of this region, and Fig. 3 is a geological map of the southwestern area.

I. Basement

The pre-Jurassic basement consists of the Hida complex, and the less- or non-metamorphosed Paleozoic rocks. The latter is lithologically divided into the Yamaguchi facies and the Para-Akiyoshi facies.

A. Hida complex

In this region various gneisses are exposed accompanied by crystalline limestone. They are generally called the Hida gneiss. Some authors (e.g. H. FUJIMOTO, 1953) considers the age of the Hida gneiss as the pre-Silurian or pre-Cambrian but others (e.g. T. KOBAYASHI, 1941) as the metamorphosed Paleozoic. Older plutonics, consisting of rocks of varied lithology, ranging from gabbro, through diorite to granite, occur in close association with the Hida gneiss. Among these rocks, the Funatsu granodiorite of the latest intrusion is regarded to as representing the Late Permian or Triassic plutonism, because it contains the rocks of the Permian Moribu formation as xenoliths in the vicinity of Hongo. In this paper the Hida gneiss and the older plutonics are grouped as the Hida complex, as their interrelation and distribution throughout the region are not thoroughly discriminated.

The Hida complex is the major autochthonous basement on which the Late Mesozoic formations were deposited, but in places it occurs as thrust sheets which were pushed upon the Late Mesozoic system.

B. Paleozoic system of Yamaguchi facies

Teiichi KOBAYASHI (1941) named the Paleozoic system predominantly composed of sandstone and clayslate the Yamaguchi facies and the one consisting of limestone accompanied by other rocks the Para-Akiyoshi facies. For convenience' sake his facies-classification is taken in the present paper.

Tabl 1. Classification of rocks and their successions in the Hida Plateau, Central Honshu, Japan.

GEOLOGICAL AGE		STRATIGRAPHY		IGNEOUS ACT. AND CRUSTAL MOV.	
CENOZOIC	QUATERNARY	RECENT	Alluvium	Younger Andesites	Andesites (Dacite)
		PLEISTOCENE	Terrace deposits	Older Andesites	Andesites
	TERTIARY		Ushigadani formation		
		NEOGENE	Hokuriku group	Iwaine volcanics	Andesite
				Nirehara formation	
MESOZOIC	CRETACEOUS	PALEOGENE		Nishitani rhyolite	Rhyolite
		NEOCRETACEOUS	Onodani rhyolites		Porphyrites Granites Diorites M-Diorite-- M-Gabbro
	PALEOCRETACEOUS		Asuwa group		Rhyolite Andesite
			Myogadani formation		(Andesite)
			Akaiwa formation	F	Regression
			Oguchi formation	(Inkstone group?)	(Felsite--QF) (Rhyolite)
	JURASSIC	UPPER JURASSIC	Shimoanama formation	F	Transgression Regression Transgression
		MIDDLE JURASSIC	Arashimadani formation		
		LOWER JURASSIC			(Quartz Porphyry?)
	TRIASSIC				
				F?	(Older plutonism (Gr.-D.-Gab.)(Ultra basic r.?)
PALEOZOIC	PERMIAN	Mino group	Samondake formation	Echizen group & its eq.	Basic rock
		(Moribu form.)	Neo formation	F	
	CARBONIFEROUS			Ashidani form. & its eq.	Basic rock
		Shimozaisho group		(Crystalline schists)	
	DEVONIAN			(Takaharagawa group)	
SILURIAN				F	
				Kamianama gr. & its eq.	(Basic rock?)
PRE-SILURIAN		Hida gneiss			Basic rock

The Paleozoic system of the Yamaguchi facies constitutes a part of the autochthonous basement of the Late Mesozoic system.

Shimozaisho group. The Shimozaisho group is distributed in Itoshiro in the upper reaches of the Kuzuryu River. It consists of limestone, clayslate, sandstone and schalstein. Owing to the discovery of *Carninia* and *Fusulina*? by K. KONISHI (1954), existence of Moscovian (?) beds has become evident.

Mino group and its equivalents. The Paleozoic beds of uncertain ages widely distributed in the southwestern area are called Mino group. The lower limit of the group has not been determined as yet. The lower part of the group is the Neo formation, 2,500 to 3,000 m thick, consisting chiefly of clayslate, and is conformably overlain by the Samondake formation. The Samondake formation is divided, in ascending order, into the transitional Okawara alternation member (about 500 m thick),

the Uosakatoge sandstone member (about 1,000 m thick), the Kuzawa clayslate member (350 to 420 m thick, occasionally accompanied by about 100 m thick schalstein), and the Semaridani sandstone member (more than 700 m thick). In the eastern area the beds consisting of sandstone and clayslate are sporadically exposed and are called the Moribu formation. This formation is thought to be an equivalent of the Mino group. T. NOZAWA and H. ISOMI (1957) collected Middle Permian fossils from the beds (Nakahata and Junigatake formations) which correspond to the Moribu formation.

C. Paleozoic system of Para-Akiyoshi facies

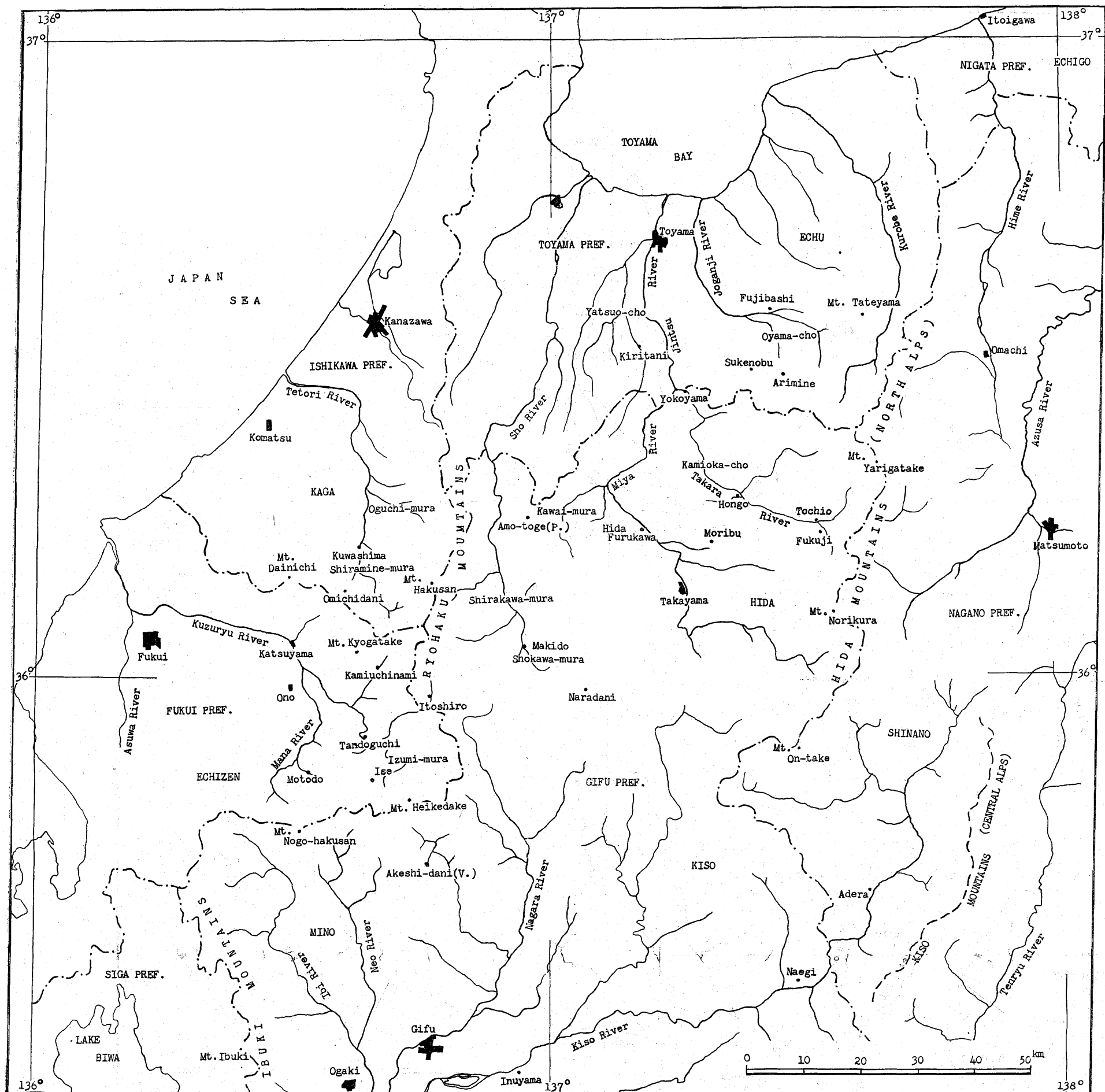
The Paleozoic system of the Para-Akiyoshi facies is always in thrust-contact with the Late Mesozoic system. It generally abounds in schalstein, chert and limestone, and scarcely contains clayslate and sandstone.

Crystalline schist-Semischist. Crystalline schists are exposed in places along the line connecting Itoigawa, Mt. Yarigatake, Fukuji, and Ise, forming approximately a narrow belt. They represent a metamorphosed facies of the Paleozoic system consisting chiefly of green schists. They are locally accompanied by semi-schists, and occasionally grade into the non-metamorphosed part of the Carboniferous system.

Silurian and Devonian system. The beds belonging to the silurian—Devonian systems, occur in small areas adjacent to the belt of crystalline schists. The representative exposures are in three places, Ise, Naradani and Fukuji, and are respectively named the Kamianama group, the Naradani group and the Fukuji group. All three beds yield *Favosites* cf. *baculoides* BARRAND and other fossils. T. KOBAYASHI and H. IGO (1956b) found *Crotalocephalus* from the Silurian system in the vicinity of Fukuji. On the basis of this discovery they separated the Devonian Takaharagawa group from the so-called Silurian system.

Carboniferous system. The Carboniferous system is distributed adjacent to the above-mentioned three areas. It is represented by the Ashidani formation in the vicinity of Ise, the Nobi group in Naradani, the Ichinotani formation in Fukuji and the Arakigawa formation to the west of Fukuji. The first three formations are distributed in narrow areas, while the distribution of the last formation is considerably wide. The Ashidani formation yields *Fusulinella*. Species of the *Fusulinella*, *Fusulina* and *Triticites* subzones were reported by M. KANUMA (1958) from the Nobi group, those of the *Millerella*, *Profusulinella*, *Fusulina* and *Triticites* subzones by H. IGO (1956) from the Ichinotani formation, and *Kueichophyllum* sp. by T. Nozawa and H. ISOMI (1957) from the Arakigawa formation. Rocks of the Carboniferous system are all phyllitic.

Permian system. The Echizen group distributed in the southwestern part of the region belongs to the Permian system. Equivalent formations are the Okumyogata and the Okuzumi formations southwest of Naradani reported by M. KAUNMA (1958), the Mizuyagadani and the Sorayama formations in Fukuji reported by T. KAMEI (1952) and H. IGO (1956), and the Hirayu group southwest of Fukuji reported by H. IGO (1956), all belonging to Lower to Middle Permian. The Echizen group comprises the Tokuyama, Nojiri and Magatoji formations. The Tokuyama formation ranging from the *Pseudofusulina vulgaris* subzone to the *Neoschwagerina margaritae* subzone. The Nojiri formation is divided, in ascending order, into the Otani conglomerate and



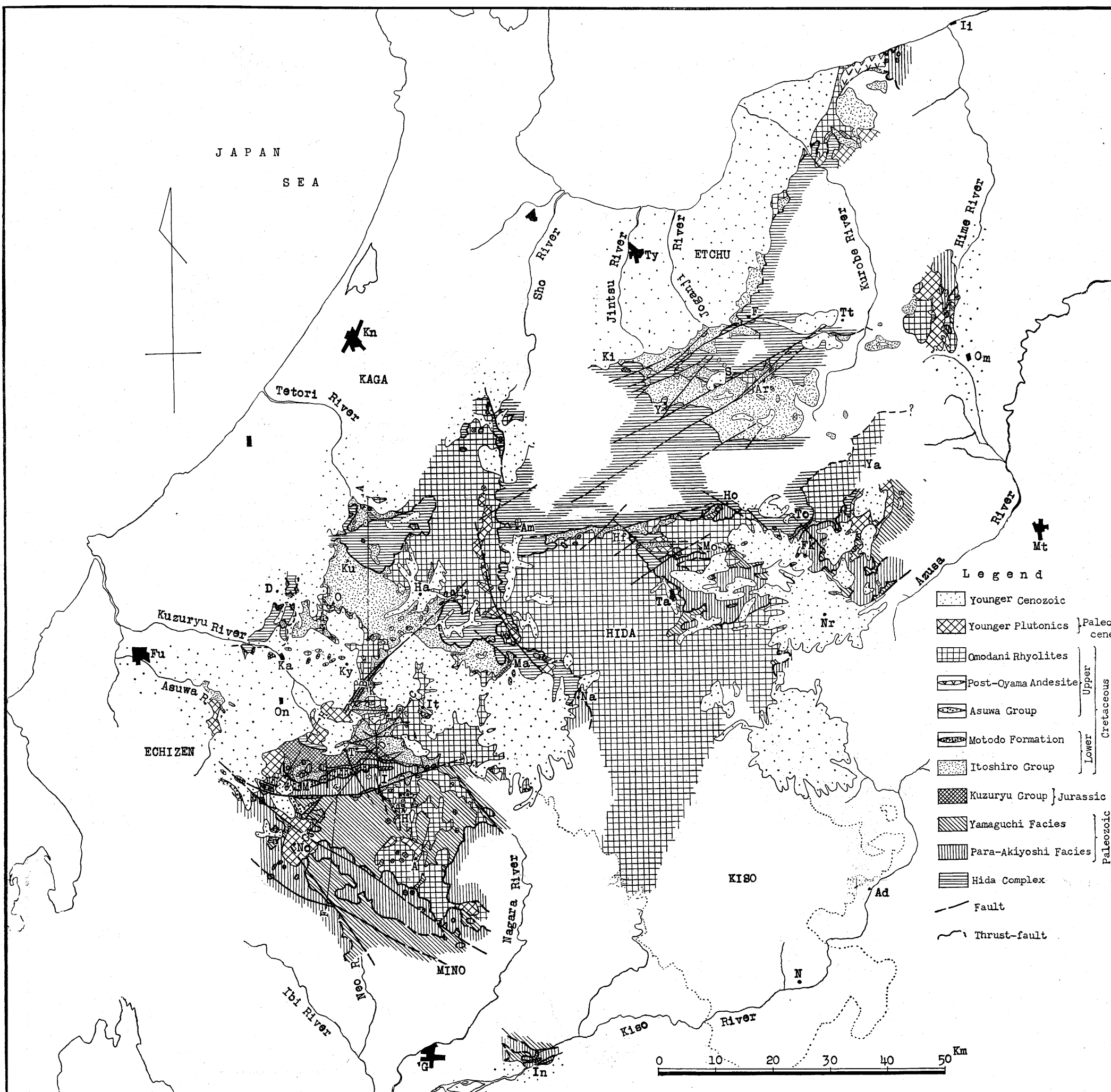


Fig. 2. Compiled geological map of the Hida Plateau, Central Honshu, Japan. Compiled by M. KAWAI based on data of M. KAWAI (1956, 1957b, 1958b, 1959, 1961a & b); M. KAWAI, K. HIRAYAMA & N. YAMADA (1957a); M. KAWAI & T. NOZAWA (1958b); T. NOZAWA & H. ISOMI (1956, 1957); T. NOZAWA & T. SAKAMOTO (1960); K. HIRAYAMA, K. SAWAMURA, M. MURAYAMA & K. MORI (1955); K. ISHII (1937). *Explanation of symbols.* (A) Akeshi-dani (V.). (Ad) Adera. (Am) Amotoge (P.). (Ar) Arimine. (D) Mt. Dainichi. (F) Fujibashi. (Fk) Fukuji. (Fu) Fukui. (G) Gifu. (H) Mt. Heikedake. (Ha) Mt. Hakusan. (Hf) Hida Furukawa. (Ho) Hongo. (I) Ise. (Ii) Itoigawa. (In) Inuyama. (It) Itoshiro. (K) Kamiuchinami. (Ka) Katsuyama. (Ki) Kiritani. (Kn) Kanazawa. (Ku) Kuwashima. (Ky) Mt. Kyogatake. (M) Motodo. (Ma) Makido. (Mo) Moribu. (Mt) Matsumoto. (N) Naegi. (Na) Naradani. (No) Mt. Nogo-hakusan. (Nr) Mt. Norikura. (O) Omichidani. (Om) Omachi. (On) Ono. (S) Sukenobu. (T) Tandoguchi. (Ta) Takayama. (To) Tochio. (Tt) Mt. Tateyama. (Ty) Toyama. (Y) Yokoyama. (Ya) Mt. Ydrigatake.

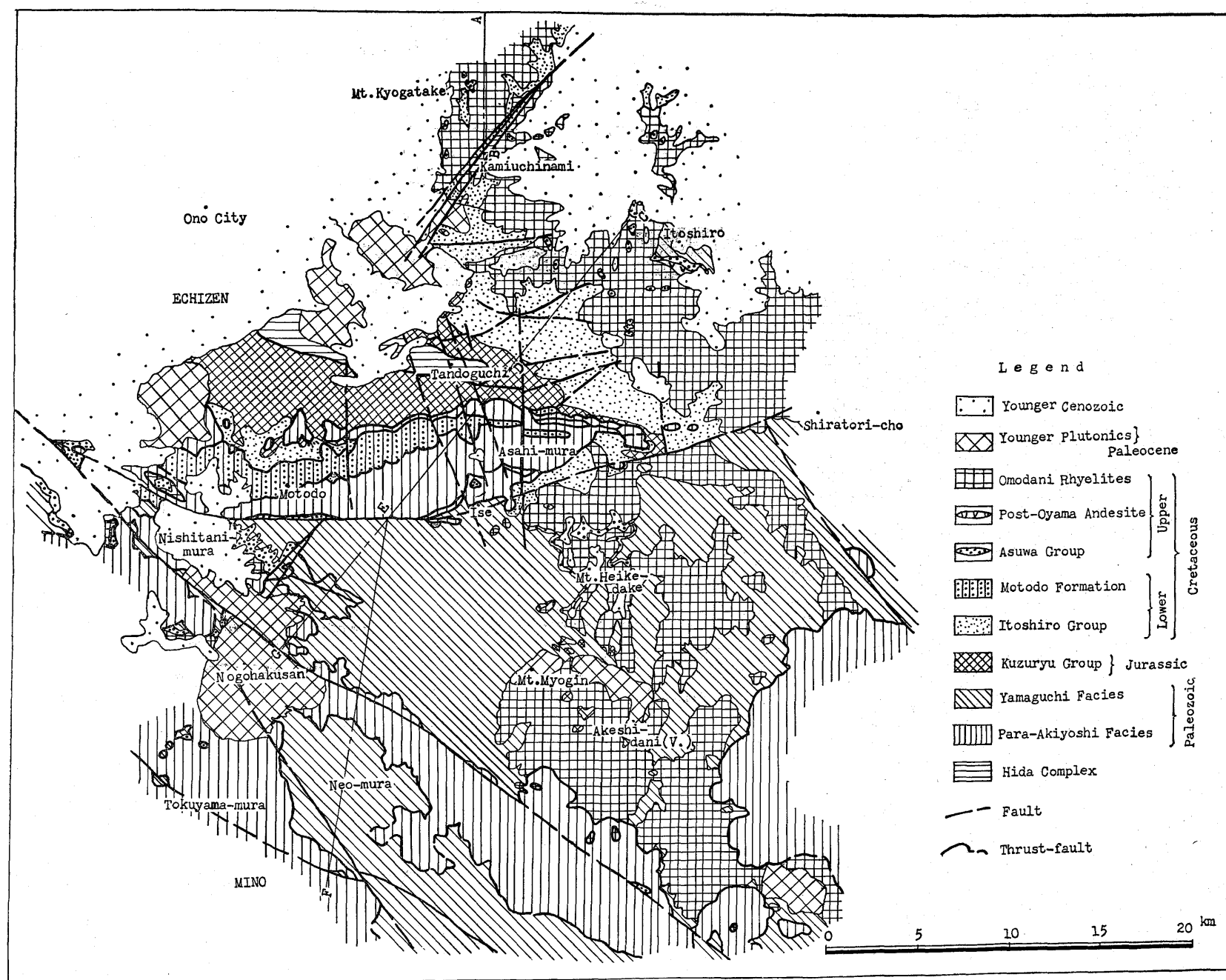


Fig. 3. Geological map of the southwestern part of the Hida Plateau, Central Honshu, Japan.

Tomedoro schalstein members which yield *Parafusulina japonica* CUMBEL, and the Komukudani clayslate member containing in plenty *Lyttonia richthofeni* KAYSER & HAYASAKA and other brachiopods. The Magatoji formation abundantly contains *Neoschwagerina margaritae* and *Yabeina katoi*. The Mizuyagadani formation is conformable (?) with the Carboniferous Ichinotani formation, and the Nojiri and Sorayama formations contain conglomerate at their base.

II. Late Mesozoic

H. T. GEYLER (1877) studied plant fossils collected at Kuwajima in the upper reaches of the Tetori River, and defined their age as Upper Jurassic. M. YOKOYAMA (1890) studied plant fossils from the same bed in various places and named the bed the Tetori series. He (1904) also studied ammonite fossils from the Tetori series, by which he determined the age of the Tetori series as Middle to Upper Jurassic.

R. UEDA and H. MATSUO (1950) discovered an unconformity in the upper reaches of the Kuzuryu River and divided the Tetori series into the upper and lower parts. S. MAEDA (1952a, b) thought that there should be another unconformity and that the unconformable relation grades into a conformable one, and he divided the Tetori series into three subgroups (or groups), namely, Kuzuryu, Itoshiro and Akaiwa, in ascending order. He also found Omichidani flora in his Akaiwa subgroup. The plant fossils were identified by M. AMANO and S. ENDO (1952), who concluded the Upper Cretaceous age of the flora. Thus, it was ascertained that the Tetori group consists of a serial geological systems ranging from Middle Jurassic to Upper Cretaceous.

H. MATSUO and S. KIDA (1953) collected Upper Cretaceous plant fossils in the upper reaches of the Asuwa River and proposed to call the beds containing the Asuwa flora by the name of Asuwa series.

The writer has recognized that certain beds, which were assigned to the Tetori series in the past and show a fairly wide distribution in the upper reaches of the Kuzuryu River, are mostly composed of the Permian Samondake formation, and that the Samondake formation is covered by the Heikedake formation (Asuwa group) which, in turn, is conformably overlain by the Omodani rhyolites. The relation between the Asuwa group and the Omodani rhyolites is locally unconformable; occasionally altered andesite is intercalated between the two.

The younger plutonics were intruded after the extrusion of the Omodani rhyolites, and are older than other igneous rocks of Cenozoic era. Granites among the younger plutonics are similar, in both lithology and mode of occurrence, to the Naegi granite on the southeast. The age of the Naegi granite was determined as 60 million years old on the basis of the dating of naegite by K. KIMURA and Y. MIYAKE (1932). The younger plutonism may have occurred in a period ranging from the latest Neocretaceous to the earliest Paleogene.

III. Cenozoic

The Cenozoic system of the Hida Plateau consists, in ascending order, of the

Nishitani rhyolite, the Hokuriku group, the Ushigadani formation, the older andesites, the Issiki formation, the younger andesites, and the alluvial beds; Table 1 shows their geological ages.

Late Mesozoic

Correlation of the Late Mesozoic system of separated outcropping areas in this region is given in Table 2.

I. Tetori super-group

The Tetori super-group consists of the Kuzuryu and Itoshiro groups. The former is marine in the main part but partly not; the latter is mostly non-marine and only locally contains marine beds. Plant fossils of the Tetori super-group are listed by horizon in Table 3.

A. Kuzuryu group

The Kuzuryu group is distributed in the upper reaches of the Kuzuryu River, the Sho-kawa (R.), the Jintsu River and the Joganji River. The outcropping area in the upper reaches of the Kuzuryu River is considerably extensive but others are extremely narrow.

1. Kuzuryu group in the upper reaches of the Kuzuryu River

The Kuzuryu group of this area shows two cycles of sedimentation.

Arashimadani formation. This formation, unconformably covering the Hida complex, is divided into the Shimoyama conglomerate member (zero to 300 m thick) in the lower part, and the Shimowakogo alternation member (300 to 400 m thick) in the upper part. The Shimowakogo alternation yields many plant fossils and some belemnites.

Shimoanama formation. The Shimoanama formation is generally conformable with the underlying Arashimadani formation, although there may exist a local unconformity. The formation is divided into the Kamiwago conglomerate member (230 to 250 m thick), the Kaizara shale member (200 to 300 m thick) and the Yambarazaka alternation member (90 to 150 m thick), in ascending order. The Kaizara shale member yields *Perisphinctes* (*Arisphinctes* or *Kranosphinctes*) *matsushimai* YOKOYAMA, *Decipia kochibei* (YOK.), *Calliphylloceras* sp., etc. The majority of the ammonites hitherto reported are from this formation, and "*Oppelia*" *echizenica* YOKOYAMA, "*Perisphinctes*" *hikii* YOK., "*P.*" *kaizaranus* YOK., *Ataxioceras* sp., *Katrolliceras yokoyamai* KOBAYASHI & FUKADA, "*Kepplerites*" "*(Seymourites)*" *japonicus* KOBAYASHI, "*K.*" "*(S.)*" *acuticostus* KOB., "*K.*" "*(S.)*" *kuzuryuensis* KOB., etc., are known. Accompanying these ammonites, some plant fossils occur. From the Yambarazaka alternation member S. MAEDA (1952b) reported *Perisphinctes* (*Arisphinctes* or *Kranosphinctes*) aff. *matsushimai* YOK. and *Calliphylloceras* sp. As trigonians, *Latitrigonia tetoriensis* KOBAYASHI, *L. orbicularis* KOB., and *Myophorella* (*Promyophorella*) *orientalis* KOBAYASHI & TAMURA are known. A doubt about the identification of *Seymourites* from the Tetori super-group was pointed out by ARKELL (1956, p. 426).

2. Kuzuryu group in the upper reaches of the Sho-kawa (R.)

Table 2. Correlation of the Late Mesozoic system of the respective areas.

GEOL. AGE	AREA	FUKUI PREFECTURE		ISHIKAWA PREF.	GIFU PREFECTURE			TOYAMA PREFECTURE	CRUSTAL MOVEMENT	STAGE	IGNEOUS ACTIVITY			
		KUZURYU RIVER		TETORI RIVER	SHO-KAWA (R.)	MIYA-KAWA (R.)								
		ONO CITY-- IZUMI-MURA	KATSUYAMA CITY	SHIRAMINE-MURA --OGUCHI-MURA	SHIRAKAWA-MURA --SHOKAWA-MURA	KAWAI-MURA-- FURUKAWA-CHO	KAMIOKA -CHO	YATSUO-CHO -OYAMA-CHO						
TERTIARY		Andesites	Older Andesites (Ushigadani formation)		Nirehara formation	Andesite		Iwaine vol.						
		Nishitani rhyolite		Nishitani rhyolite			Nirehara f.							
		Nogohakusan granod. & Myojinyama-Akeshidani granite	(Diorite)		Shirakawa granites & Quartz Porphyry	Kokufu granite & Quartz Porphyry			Block movement	11	Dyke rocks			
CRETACEOUS	NEOCRETACEOUS								Disturbance	10	Younger plutonism			
									Ura-Nippon thrust system	9				
									Omote-Nippon thrust syst.	9				
		Omodani rhyolites					(Quartz Porphyry)			8c	Rhyolite			
		Post-Oyama andesite							Disturbance	8b	Andesite			
		Oyama form.	Asuwa group (Heikedake f., Omichidani f. & its equivalent)			Equivalent	?			8a	(Rhyolite)			
		(Shimozai-sho gr.)	(Mino gr.)		Myogatani form.	(Choshidani form.)			Violent Disturbance	7				
	PALEOCRETACEOUS	Tetori super group	Kuzuryu group	Itoshiro group	Nochino formation	(Akaiwa formation)	Akaiwa formation	Oshudodani formation	Inagoshi formation	Atotsugawa formation		Spasmodically disturbance	6	Felsite-Quartz Porphyry
					(Oguchi formation)	(Oguchi formation)	Oguchi formation	Ogamigogawa formation	Furukawa formation	Nagatogawa formation	?		5	(Andesite?)
					Shimoanama formation			Shokawa formation		Higashisakamori formation			4	(Rhyolite)
Arashimadani formation												3		
JURASSIC	Upper Jura.	Tetori super group	Kuzuryu group	Itoshiro group							Disturbance	2		
													Regression	3
	Middle Jura.	Tetori super group	Kuzuryu group	Itoshiro group							Transgression	2		
												Subsidence	1b	
	Lower Jura.	Tetori super group	Kuzuryu group	Itoshiro group								1a		
BASEMENT		Hida complex (& Mino group)		Hida complex			Hida complex & Moribu formation	Hida complex						

Table 3. List of "Tetori fossil flora".

Species	Horizon	Kuzuryu gr.	Oguchi f.	Akaiwa f.	Myogadani f.	Remarks
1. <i>Marchantites Yabei</i> KRYSTOF.		K	K	K		K: KAWAI's coll
2. <i>M.</i> sp.		A	A			A: Add. (After S.
3. <i>Equisetites ushimarensis</i> (Y.)		K	K	K		OISHI, N. FUJI,
4. <i>E.</i> sp.			A	K		S. MAEDA & T.
5. <i>Todites Williamsoni</i> (BRONGN.)			K			KIMURA)
6. <i>Gleichenites nipponensis</i> OISHI		A	K			
7. <i>Coniopteris burjensis</i> (ZALES.)		A	K	K		
8. <i>C. Heeriana</i> (YOKOYAMA) YABE			A			
9. <i>C. himenophylloides</i> (BRONGN.)			K	K		
10. <i>C.</i> sp.			A			
11. <i>Endoa ceratopteroides</i> KIMURA		?	?			
12. <i>Hausmania</i> sp.			A			
13. <i>Onychiopsis elongata</i> (GEYLER)		K	K	K	K	
14. <i>Adiatites Sewadi</i> YABE			K	K		
15. <i>A.</i> sp.		?	?			
16. <i>Sphenopteris Goepperti</i> DUNK.		A	K	K		
17. <i>S. Kochibeana</i> (YOKOYAMA)			K			
18. <i>S. nitidula</i> (YOKOYAMA) OISHI			K	?	?	
19. <i>S.</i> sp.			K	K		
20. <i>Cladophlebis argutula</i> (HEER)		?	K	?		
21. <i>C. Browniana</i> (DUNKER)			A			
22. <i>C. denticulata</i> (BRONGN.)		K	K	K	A	
23. <i>C. distans</i> (HEER) em YABE		A	K	K	A	
24. <i>C. exiliformis</i> (GEYLER)		K	K	A	?	
25. <i>C. (Kulkia) fertilis</i> KIMURA		?	?			
26. <i>C. hukuiensis</i> OISHI		K	K	K		
27. <i>C. ishikawaensis</i> OISHI		A	K	K		
28. <i>C. kuwashimaensis</i> OISHI		A	K			
29. <i>C. kuzuryuensis</i> KIMURA		?	?			
30. <i>C. minima</i> KIMURA (MS)			A			
31. <i>C. (Eboracia?) lobifolia</i> (PHIL.)			K	K		
32. <i>C. shinshuensis</i> TATEIWA			A			
33. <i>C. triangularis</i> OISHI			K	K		
34. <i>C.</i> sp.			K	K		
35. <i>Ctenis Kaneharai</i> YOKOYAMA			A			
36. <i>Nilssonia densinerve</i> (FONT.)		A				
37. <i>N. nipponensis</i> YOKOYAMA		A	K	?		
39. <i>N. orientalis</i> HEER		A	K	K		
40. <i>N. Tanakai</i> KIMURA		?	?			
41. <i>N.</i> sp.			K			

42. <i>Pseudoctenis lanei</i> THOMAS	A				
43. <i>Dictyozamites falcatus</i> (MOR.)	A	A			
44. <i>D. Imamurae</i> OISHI	A	A			
45. <i>D. Kawasaki</i> TATEIWA		K			
46. <i>D. reniformis</i> OISHI	A	A			
47. <i>D. ? sp.</i>	?	K			
48. <i>Otozamites Klipsteinii</i> (DUNK.)	A	K	K		
49. <i>O. Sewardi</i> OISHI	A				
50. <i>O. sp.</i>	?	K			
51. <i>Pseudocycas ? acutifolia</i> OISHI	?	K			
52. <i>Pterophyllum ctenoides</i> OISHI		A			
53. <i>P. lyellianum</i> DUNKER	A	K			
54. <i>Ptilophyllum pachyrachis</i> OISHI	?	K			
55. <i>Zamiophyllum ? sp.</i>		?			
56. <i>Sagenopteris paucifolia</i> (PHIL.)	?	K			
57. <i>S. sp.</i>		K			
58. <i>Baiera sp.</i>	A				
59. <i>Ginkgoites digitata</i> (BRONGN.)	A	K			
60. <i>G. sibirica</i> (HEER) SEWARD	?	A			
61. <i>Ginkgoidium nathorsti</i> YOKOYAMA		K	K	K?	
63. <i>Czekanowskia rigida</i> HEER		K	K		
64. <i>C. sp.</i>	K				
65. <i>Brachyophyllum sp.</i>		K			
66. <i>Elutocladus tenndrima</i> (FEIST).		A			
67. <i>E. sp.</i>		K	K		
68. <i>Taxodium sp.</i>		K	K		
69. <i>Sequoia sp.</i>		?	?	A	
70. <i>Pityophyllum Nordenskijoldi</i> H.		A			
71. <i>Podozamites Griesbachi</i> SEWARD	?	K	K	?	
72. <i>P. lanceolatus</i> (LIND. & HUTT.)	K	K	K	K	
73. <i>P. l. subsp. multinervis</i> T.	A	A			
74. <i>P. Reinii</i> GEYLER	?	K	K		
75. <i>P. sp.</i>	K	K	K		
76. <i>Aphlebia nervosa</i> OISHI		A			
77. <i>Taeniopteris emarginata</i> OISHI		K			
78. <i>T. Richihofeni</i> (SCHENK)		A	?		
79. <i>T. undulata</i> KIMURA	?	?			
80. <i>T. sp.</i>		?	?		
81. <i>Xenoxylon latiporosum</i> (CRAMER)		K	K	K	

Shokawa formation. The Shokawa formation can be divided, in ascending order, into the Sandani conglomerate member (20 to 30 m thick), the Nonomata alternation member (100 to 150 m thick) and the Mitarai shale member (about 200 m thick). The Nonomata alternation yields *Inoceramus?* sp., and the Mitarai shale contains *Ataxioceras* sp. and *Inoceramus* sp. Both members yield plant fossils although in a small amount.

3. Kuzuryu group in the upper reaches of the Jintsu and Joganji Rivers

The Kuzuryu group in the upper reaches of Joganji River is called the Higashisakamori formation and the one in the upper reaches of the Jintsu River is the Kiritani formation.

Higashisakamori formation. This formation is distributed in a small area in the vicinity of Arimine. It unconformably rests on the Hida complex and is covered by the Itoshiro group with unconformity. It consists of the Magawa sandstone conglomerate member (about 150 m thick) and the Arimine shale member (more than 150 m thick) in ascending order. In the basal conglomerate are found *Myophorella* (*Promyophorella*) cf. *orientalis* KOBAYASHI & TUMURA, *M. (P.)* aff. *obsoleta* KOB. & TAM., *M. (P.)* sp., etc., and the Arimine shale yields *Ataxioceras* aff. *torquatus* (SOWERBY), *A.* sp., and *Inoceramus* sp.

Kiritani formation. The lower limit of this formation is unknown. Conglomerate occurs in the lower part, but the upper part is predominated by shale. Fossils hitherto known are *Lithacoceras* (?) sp., *Nipponotrigonia sagawai* (YEHARA), *Dichotomosphinctes kiritaniensis* SATO (MS), etc.

Ammonite^s from the Kuzuryu group are assigned to Callovian-Kimmeridgian (ARKELL, 1959, p. 426), although further is necessary for their taxonomy and stratigraphic occurrence. Considering also other available evidences, the writer has tentatively assigned the main ammonite-bearing beds to Oxfordian-Kimmeridgian and regarded the lower limit as the later stage of Middle Jurassic, as has been generally accepted.

B. Itoshiro group

The Itoshiro group consists of thick conglomerate for the greater part, and generally rests on the Hida complex. In the upper reaches of the Kuzuryu River, it locally overlies the Kuzuryu group and the Mino group with unconformity. In the upper reaches of the Shokawa (R.) it has a thin bed of basal conglomerate which unconformably covers the Shokawa formation. As in the case of the Kuzuryu group, most of the constituent materials of the Itoshiro group were supplied from the Hida complex. For convenience' sake, the Itoshiro group is described separately in four areas as follows.

1. Itoshiro group in the upper reaches of the Kuzuryu River

The Itoshiro group of this area shows two cycles of sedimentation.

Oguchi formation. The Oguchi formation can be divided, in ascending order, into the Dosaiyama conglomerate member (370 to 400 m thick), the Kakunomaesaka alternation member (100 to 130 m thick) and the Ittuki shale member (80 to 100 m thick). Non-marine shell fossils such as *Corbicula* (*Mesocorbicula*) *tetoriensis* KOBAYASHI & SUZUKI, *C. (Tetoria) antiqua* KOB. & SUZ., "*Batissa*" *yokoyamai* KOB. & SUZ., *Viviparus*

(*Sinotaia*?) *onogoensis* KOB. & SUZ., "*Melanoides*" *vulgaris* KOB. & SUZ., etc. are found in the middle part of the Dosaiyama conglomerate and in the Ittsuki shale. The Kakunomaesaka alternation yields abundant plant fossils.

Akaiwa formation. The Akaiwa formation of this area is called the Nochino conglomerate member. Its thickness exceeds 800 meters. It contains plant fossils including *Xenoxylon latiporosum* (CRAMER) and *Onychiopsis elongata* (GEYLER).

2. Itoshiro group around Haku-san (Mt.)

The area around Haku-san (Mt.) is the type locality of the Itoshiro group. The group is divided, from lower to upper, into the Oguchi, Akaiwa and Myogadani formations.

Oguchi formation. This formation corresponds to what was previously called the Itoshiro subgroup. It consists of the Gomishima conglomerate member (300 to 350 m thick) in the lower part and the Kuwajima alternation member (350 to 400 m thick) in the upper part. The lower part of the Kuwajima alternation is predominantly sandstone, whereas shale predominates in the upper part; they respectively correspond to the Kakunomaesaka alternation member and the Ittsuki shale member. In the vicinity of Makido on the southeast, which is supposed to be the center of the sedimentary basin, the basal conglomerate is called the Otaniyama conglomerate member. The thickness of the conglomerate is only 30 meter or so, and the unconformity at the base is not very distinct. The Ushimaru shale member (400 to 450 m thick), which is correlated with the Kuwajima alternation member, yields non-marine shell fossils at many horizons. The Kuwajima alternation contains *Xenoxylon latiporosum*, fossil of standing or drift tree, and the majority of plant species belonging to the so-called Tetori fossil flora, and also *Corbicula* (*Mesocorbicula*) *tetoriensis* and other non-marine shells. From a locality north of Katsuyama, *Nakamuranaia chingshanensis* (GRABAU), *Platounio* sp., *Trigonioides kodairai* KOBAYASHI & SUZUKI are known, instead of *C. (M.) tetoriensis*.

Akaiwa formation. This formation consists of coarse sediments and contains a considerable amount of the Tetori fossil plants. Although an intraformational unconformable plane is found locally it does not represent a time gap. The formation is conformable with the Oguchi formation. Five or six minor rhythms of sedimentation, though not very distinct, are discerned. The thickness of the formation is 1,350 m to 1,500 m in the upper reaches of the Tetori River and about 1,600 m in the upper reaches of the Ogamigo River (near Makido).

Myogadani formation. Distribution of this formation is known only in the upper reaches of the Tetori River. The formation has slightly more shales than the Akaiwa formation, but like the Akaiwa formation it yields *Xenoxylon latiporosum* and plant fossils including *Sequoia* sp. Also, *Corbicula*? sp. and *Viviparus* sp. are found in smaller number. Two minor sedimentation rhythms are recognized. The lower part is 200 to 250 m thick, and the upper is about 280 m.

3. Itoshiro group in the upper reaches of the Joganji and Jintsu Rivers

The Itoshiro group extending northward from the vicinity of Arimine is cut by many faults. The group is divided into the Nagatogawa formation in the lower part and the Atotsugawa formation in the upper part. The group in the northern-

most region is locally undivided.

Nagatogawa formation. This formation covers the Kuzuryu group and also the Hida complex with unconformity. The formation comprises the Ihoridanitoge conglomerate member (100 to 200 m thick) in the lower part and the Inotani alternation member (200 to 350 m thick) in the upper part. In some cases, both members become thin, less than twenty meters, where they overlap the Hida complex. The Inotani alternation contains plant fossils in abundance. Non-marine shell fossils do not occur in this area. The Inotani alternation in the eastern part is predominantly conglomerate.

Atotsugawa formation. This formation is generally conformable with the Nagatogawa formation, but felsite and quartz porphyry (Ashidani felsite) are locally intruded in age between the two formations. Therefore, in places the Atotsugawa formation unconformably covers the Ashidani felsite. The formation comprises the Minamimatadani conglomerate member (70 to 150 m thick) in the lower part and the Wasabu alternation member (more than 500 m thick) in the upper part. The Minamimatadani conglomerate abundantly contains felsitic material and angular gravels of shale. The Wasabu alternation abounds in plant fossils. The Atotsugawa formation corresponds to the Akaiwa formation.

The northernmost area has not been surveyed by the writer, but occurrence of *Sequoia* sp. was reported by S. MAEDA. (1956), so there may exist an equivalent of the Myogadani formation.

Ashidani felsite. The Ashidani felsite consisting of felsite and quartz porphyry effused and intruded prior to, and also during the early period of, the deposition of the Atotsugawa formation.

4. *Itoshiro group in the vicinity of Takayama*

The Itoshiro group, extending eastward from west-northwest of Takayama, consists of the Furukawa formation in the lower part and the Inagoshi formation in the upper part. The name Tochio formation was given to the undifferentiated part of this group.

Furukawa formation. This formation is divided, in ascending order, into the Tanemura conglomerate member (150 to 350 m thick), the Numamachi alternation member (150 to 200 m thick), the Sugizaki sandstone member (150 to 320 m thick), and the Taie shale member (150 to 180 m thick). The Sugizaki sandstone north of Furukawa yields *Nipponotrigonia* (?) sp. and some belemnites. This is the only marine formation among the members of the Itoshiro group. The Sugizaki sandstone in the south of the above locality does not yield shell fossils. The Taie shale member contains *Corbicula* (*Mesocorbicula*) *tetoriensis*, *Ostrea* sp., *Viuiparus* (*Sinotaia*?) *onogoensis*, etc. *Xenoxylon latiporosum* and other Itoshiro type plant fossils are contained also. The Itoshiro group of this area, like that in the upper reaches of the Kuzuryu River, locally overlies the Paleozoic system with unconformity.

Inagoshi formation. Lithologically the lower part resembles the Minamimatadani conglomerate and the upper part is similar to the Wasabu alternation. This formation yields *Ostrea* sp. and *Gryphaea* (?) sp., and is equivalent to the Atotsugawa formation. The thickness is more than 350 meters.

Tochio formation. This formation is exposed in a very narrow area Tochio east

of Takayama. The lower limit is unknown, as the formation is cut by faults all around and is covered by younger rocks. From this formation S. MAEDA (1959) reported *Polimesoda* (*Isodomella*) *kobayashii* MAEDA, *P. (Paracorbicula) sanchuensis* (YABE & NAGAO), etc. The formation is correlated with the non-marine Sugizaki sandstone and Inagoshi formation.

Some geologists maintain that the Tetori series is Upper Jurassic in age, on the basis of ammonite fossils. On the other hand, S. OISHI (1940) pointed out that the Tetori fossil flora belongs to the *Onychiopsis* series and is affined to the flora of the Naktong series and Shiragi series, South Korea, and the Toyonishi group of western Chugoku district, Japan. In the past, the non-marine shell fossils were assigned to Jurassic, but it has become known lately that the fossils are closely related to those in the Yoshimo formation of the Toyonishi group, and that *Nakamuranaia*, *Nippononaia*, *Plicatounio*, etc. are common with the Lower Cretaceous Naktong-Shiragi series and the Wakino subgroup (Kwanmon group) of western Chugoku and northern Kyushu (HASE, 1960; OTA, 1960). The non-marine shell fossil were previously thought to occur beneath the ammonite-bearing bed, but in fact they occur only in the Ito-shiro group above the unconformity. Thus, the Oguchi formation is considered to consists chiefly of Early Paleocretaceous (Kochian) beds, although it cannot be concluded that Tithonian does not occur.

The Asuwa group separated from the Tetori super-group is thought to belong to the Neocretaceous system (around the Urakawan stage) on account of the Asuwa flora and the so-called Omichidani flora. If the Myogadani formation could be assigned to latest Paleocretaceous (late Miakoan) or Early Neocretaceous (Gyliakian) as suggested by the occurrences of *Sequoia* sp., then the geological age of the Akaiwa formation would become Middle to Upper Paleocretaceous (Aritan to Miakoan).

II. Motodo formation (Inkstone group?)

The Motodo formation near Motodo in the southwestern area constitutes a part of the thrust sheet. The formation is divided into the Kagero conglomerate member (150 m thick) and the Sasabugawa conglomerate member (about 600 m thick).

The formation is bounded by low-angle faults, and the above two conglomerate members are also in fault contact. The Sasabugawa conglomerate contains much andesitic material, and *Yabeina* sp. was reported from limestone pebbles by M. KOBAYASHI (1954). Lithologically the Sasabugawa conglomerate resembles the Inkstone group (Kwanmon group) in western Chugoku district.

The Motodo formation rides over the Paleozoic rocks of the Para-Akiyoshi facies. The sediments of the formation contain andesitic material and abundant debris of the Paleozoic rock. Other hand, the Itoshiro group widely overlies the Hida complex and composed chiefly of debris of the complex. Therefore, lithological facies of two sediments are quite unlike.

III. Asuwa group

The Asuwa group was deposited in small depressions around the Omodani rhyolites regions during the early period of, and also prior to, the effusion of the

Omodani rhyolites. Therefore, the group occurs in places as thin beds containing a great amount of dacitic or rhyolitic substances. The principal formations are Heikedake, Oyama and Omichidani formations which are correlated with the Asuwa formation (in a narrow sense) in the upper reaches of the Asuwa River.

Heikedake formation. This formation is distributed in the mountainous areas around Heikedake (Mt.) and rests on the Mino group. It is divided, in ascending order, into the Sintani conglomerate member (8.5 m thick), the Urushidani coal-bearing member (10 to 50 m thick), and the Saruzuka conglomerate member (80 m thick). The Shintani conglomerate is composed of rhyolitic angular gravels and tuff-breccia. The Urushidani coal-bearing member consists of shale and sandstone intercalated with coal seams, *Podozamites Griesbachii* SEWARD and *Sequoia* sp. are found in a coaly shale. The Saruzuka conglomerate is a volcanic conglomerate with rhyolite intercalates. Its upper part grades into the Omodani rhyolites. The conglomerate locally abounds in angular gravels of andesite.

Oyama formation. The Oyama formation south of Itoshiro overlies the Carboniferous Shimozaisho group and is covered by the post-Oyama andesite. The basal conglomerate, 10 to 30 m thick, consists of angular gravels of Paleozoic rocks and andesite cemented with andesitic substance. A member of alternating sandstone and shale above the basal conglomerate is 60 to 70 m thick, and is intercalated with seams of tuff and coal. S. MAEDA (1957d) collected *Onychiopsis elongata* (GEYLER) from this member.

Omichidani formation. The plant fossils collected by S. MAEDA from Omichidani (V.) in the upper reaches of the Tetori River were studied by M. AMANO and S. ENDO (1952). Twelve genera and fifteen species were identified: *Sequoites* cf. *smitiana* (HEER), *S.* cf. *heterophylla* VELENOUSKY, *S.* sp., *Pinus* sp., *Ginkgoites* cf. *digitata* (BRONGN.), *Cladophlebis* cf. *frigida* (HEER), *Sagenopteris* sp., *Osmunda*? sp., *Trapa* (*Trapella*?) n. sp., *Nyssidum* n. sp., *Phyllites* sp., *Carpolites* sp., *Cyperites* sp., *Nilssonina* spp. *Woodwardia*? sp. occurs also. As a result, the age of the flora was assigned to Neocretaceous. The formation consists of rhyolite to rhyolitic breccia (several to 30 m thick) in the lower part and black shale (20 to 30 m thick) in the upper part. It is conformable with the overlying Omodani rhyolites. Beds corresponding to the Omichidani formation are sporadically distributed beneath or in the lower part of the nearby Omodani rhyolites. These beds locally abound in conglomerate, or accompanied by coal seams, or yield *Onychiopsis elongata* (GEYLER)?, *Podozamites lanceolatus* (L. & H.), and *P. Griesbachii* SEWARD.

Asuwa formation. In the upper reaches of the Asuwa River, H. MATSUO and S. KIDA (1953) studied the beds which were formerly reported as the Tetori series. They named the lower part the Doai sandstone and called the upper part the Sarao alternation. From the Sarao alternation H. MATSUO identified the Asuwa fossil flora comprising *Osmunda* n. sp., *Nelumbo orientalis* MATSUO, *Taxodium* sp., *Sequoia* sp., *Phyllanthium*? sp., *Nilssonina orientalis* HEER, etc., and concluded that the flora is younger than the Ryoseki fossil flora and older than the Hakobuchi fossil flora.

Other corresponding beds. Beds referable to the Asuwa group are sporadically distributed around Nogo-haku-san (Mt.). On its northwest side are found the Ubaga-

take formation and the Subara formation, and on the southwest the Isotani formation occurs. In Ise the Haamidani formation is found. All these formations, excepting the Ubagatake formation, crop out in the fenster of the overthrust sheet of the Omote-Nippon thrust system. They are intercalated with coal seams. The Adera formation of Kiso mountainland reported by M. KATADA and H. ISOMI (1958) possibly belongs to the Asuwa group.

IV. Omodani rhyolites

A. Post-Oyama andesite

The post-Oyama andesite unconformably covers the Oyama formation and is unconformably covered by the Omodani rhyolites. The area of its distribution is extremely limited and the thickness is no more than scores of meters. Both the Oyama formation and the Omodani rhyolites abundantly contain pebbles and blocks of andesite, and the Omodani rhyolites are sometimes interbedded with andesitic tuff or tuff-breccia. Hence, it is concluded that the eruption of the post-Oyama andesite occurred somewhat prior to that of the main body of Omodani rhyolites and that the andesitic activity persisted intermittently to the period of the Omodani rhyolites.

B. Omodani rhyolites (in a narrow sense)

Acid volcanics which erupted in Late Cretaceous in the Hida Plateau are called the Omodani rhyolites. It is composed chiefly of pyroclastic rocks and partly of lavas of rhyolites and related dykes of quartz porphyry, and includes rarely thin sediments. These rocks conformably or unconformably rest on the Asuwa group and unconformably cover the older rocks. The rhyolites effused following to, and also during the early period of, the deposition of the Asuwa group. The thickest part of the rhyolites exceed 1,000 m. The rhyolites were formerly called quartz porphyry and were regarded as a product of a hypabyssal intrusion.

From the fact that the basal conglomerate of the Kuzuryu group and the Ito-shiro group contain pebbles of quartz porphyry and the Itoshiro group is accompanied in places by acid tuff and some sheets of quartz porphyry and felsite (p. 360), it is inferred that the acid volcanic activity already commenced prior to the deposition of the Kuzuryu group, and culminated in the Omodani age toward the end of the Cretaceous period.

V. Younger plutonic rocks

The younger plutonic rocks include all plutonics younger than the Omodani rhyolites and older than any bedded rocks of the Tertiary system in this region. The Shirakawa granites east of Haku-san (Mt.), the Kokufu granite north of Takayama, and the granites in the vicinity of Akeshi-dani (V.) are bosses which are presumably projected parts of a batholith, similar to the Naegi granite of the Kiso mountainland. The granodiorite constituting Nogo-haku-san (Mt.), the diorites and quartz-diorites in the vicinity of Tandoguchi were also produced by the same plutonism.

The alteration-diorite to -gabbro occurring as minor intrusive bodies cutting the

Itoshiro group in the vicinity of Ise may be somewhat older than granites and probably represent the early member of this plutonism.

Geological structure

Four representative geological cross sections of the described area are shown in Figs. 4 and 5.

I. Geological structure of the Paleozoic system of the Yamaguchi facies

Shimozaisho group. The strata of this group generally strike to N-S and steeply dip to west.

Mino group. The main structure of the Mino group in the southwestern area is composed of a northern major syncline of WNW-ESE trend and a southern major anticline NW-SE direction. The major syncline is a synclinorium consisting of one anticline, two synclines and many minor folds. The major anticline is an anticlinorium comprising many faults and minor folds.

On the northeast slope of Nogo-haku-san (Mt.) there are relatively low-angle faults, and strata are partly omitted by them. In the course of the folding, faults seem to have been caused by intraformational sliding, and a part of the Samondake formation, several hundreds to 1,000 meters thick, was displaced, although the whereabouts of the displaced part is unknown. Such displacements occurred in the axial part of the major anticline (See Fig. 4 Cross section (B), and Fig. 5 section (B)).

Moribu formation. The Moribu formation in the eastern part is exposed only fragmentally, as it is covered by younger beds and thrust sheets. Thus, details of geological structure are obscured, but the strata of the formation are repeatedly folded in the direction of ENE-WSW or NE-SW.

II. Geological structure of thrust sheets

Southwestern area. The geological structure of the sheet extending from the south of Tandoguchi to the east of Ise is well known. The Nojiri formation of the Echizen group forms a large syncline in the central part and a large anticline in the western part near the southern margin, both trending generally east-west. At the eastern end of the Nojiri formation, various strata are exposed of the north and south sides. These strata, being separated with one another by low-angle faults, constitute two limbs of the large syncline. The fold axis is reversed toward the south. The Motodo formation, overlying the Nojiri formation by a low-angle fault, occupies the northern flank of, and trends parallel to, the synclinal axis, so the two formations were probably disturbed by the same crustal movement. If the beds were stripped one after another, the following sequence would be revealed (from the upper to the deeper parts); Motodo formation, Nojiri formation, Crystalline schist-Semi-schist, Kamianama group, Ashidani formation, and Magatoji formation, resting on the complex strata of the Mino group, Tetori super-group, Asuwa group and Omodani rhyolites.

The thrust sheet south of the above-mentioned sheet is composed of the Tokuyama formation and is disturbed by many small folds, but on the whole the sheet

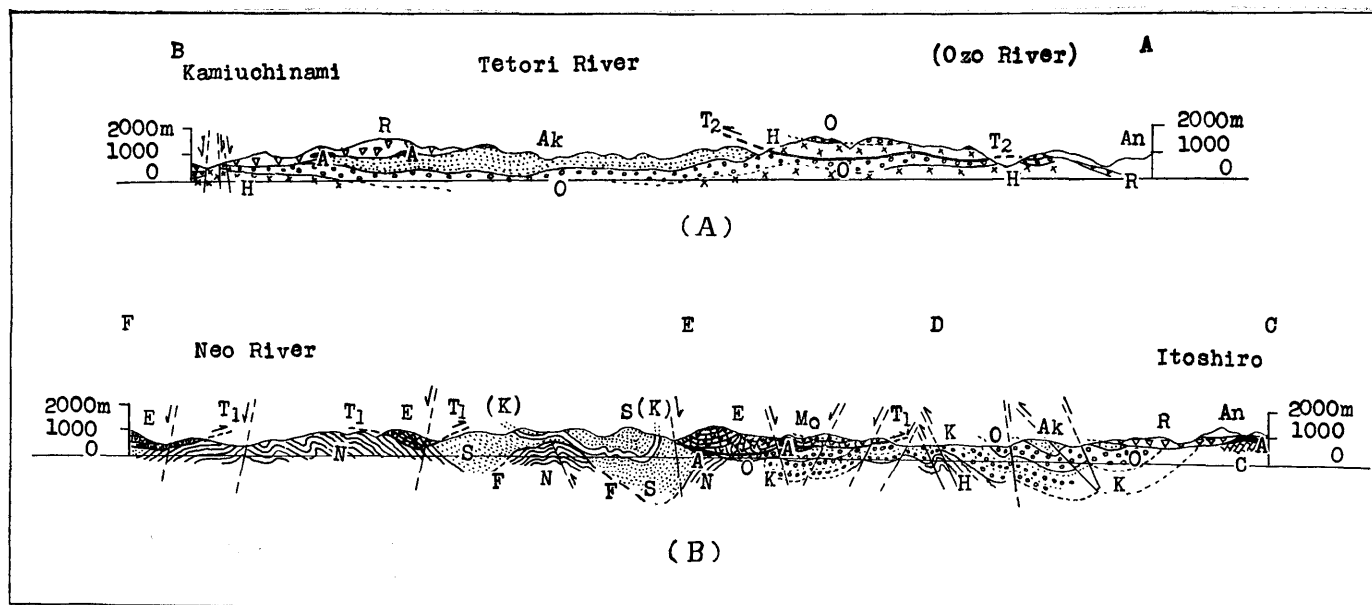


Fig. 4. Cross sections of the western part of the Hida Plateau (I).

(A) Cross section of A-B, Figure 2. Natural scale.

(B) Section of C-D-E-F, Figure 2. Natural scale.

After KAWAI, 1959. Between E and F the lower part of the Samondake formation is cut off by the low-angle fault F, but whereabouts of the cutoff part is unknown.

Explanation of symbols. H Hida complex. Paleozoic sediments, C Carboniferous Shimozaisho group; E Permian Echizen group; Permian Mino group, N Neo formation, S Samondake formation, (K) Key bed (Kuzawa clayslate member). K Jurassic Kuzuryu group. Mainly lower Cretaceous Itoshiro group, O Oguchi formation. Ak, Akaiwa formation, Mo Motodo formation. Upper Cretaceous, A Asuwa group, R Omodani rhyolites. An Quaternary older andesites. T₁ Omote-Nippon thrust system. T₂ Ura-Nippon thrust system. F Low-angle fault.

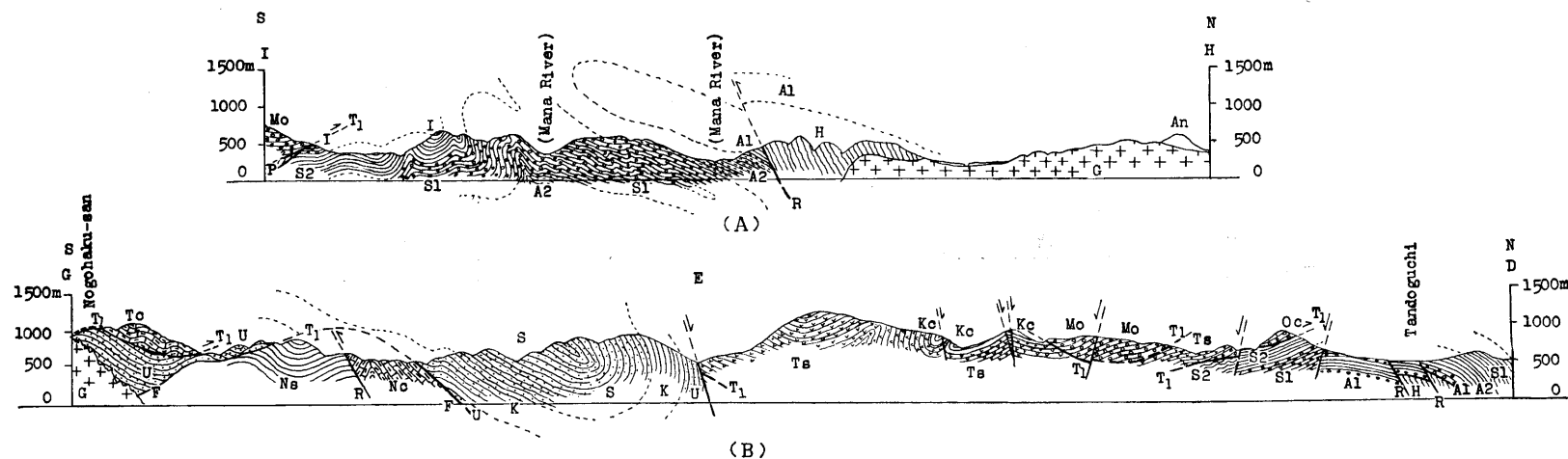


Fig. 5. Cross sections of the western part of the Hida Plateau (II).

(A) Cross section of H-I, Figure 2. Natural scale. After KAWAI, HIRAYAMA & YAMADA, 1957a.

(B) Section of D-E-G, Figure 2. Natural scale.

Explanation of symbols. H Hida complex. Paleozoic sediments, P Carboniferous or Permian (Kumokawa formation); Tc Permian Tokuyama formation; Permian Neo formation, Nc Chert, Ns Clayslate; Samondake formation, U Uosakatoge sandstone member, K Kuzawa clayslate member, S Semaridani sandstone member; Permian Nojiri formation, Oc Otani conglomerate member, Ts Tomodoro schalstein member, Kc Komukudani clayslate member. Jurassic Kuzuryu group, A₁ Shimoyama conglomerate member, A₂ Shimowakogo alternation member, S₁ Dosaiyama conglomerate member, S₂ Kaizara shale member. Lower Cretaceous sediments, Mo Motodo formation. G Early Tertiary granite. An Quaternary older andesites. T₁ Qmote-Nippon thrust system. T₂ Ura-Nippon thrust system. F Low-angle fault. R Reverse fault.

shows a NW-SE trending structure. The anticlinal part of the structure was denuded away, and the thrust sheet is seen to widely distributed in the synclinal part. The thrust sheet extending from Nogo-haku-san (Mt.) to the southeast corresponds to a part of this synclinal structure and is overthrust toward north.

Eastern area. Geological structure of the thrust sheet in the eastern area is not known in detail. It is possible, however, that the sheet has an imbricate structure near Fukuji, as in the vicinity of Ise. The strata, supposedly an extension of the Arakigawa formation and the Hirayu group, strike predominantly in the direction of E-W or NE-SW.

In a general view of the geological structure of the thrust sheets throughout the surveyed region, the axis of folds and the strike of strata are NW-SE in the southwestern area, becoming E-W or ENE-WSW toward the central area, and as the eastern area is reached the direction changes from E-W to NE-SW, thus presenting an arc convex toward south.

Parallelism is roughly recognized in the major structural trends between the thrust sheets and the autochthonous basements, although there are fairly remarkable variations in local or minor structures.

III. Geological structure of the Tetori super-group

The geological structure of the Kuzuryu group has a trend nearly parallel to that of the Itoshiro group, although the former is much more intricate than the latter.

A. Geological structure of the Kuzuryu group

The Kuzuryu group in the southwestern part is intensely disturbed by folds of E-W axis. As seen in the geological cross sections C-D-E (Fig. 4) and H-I (Fig. 5), the strata are markedly overturned and the Hida complex of Tandoguchi, which constitutes the core of the anticline, is thrust above the Kuzuryu group. On the south, the group is bounded by a sheet of the Omote-Nippon thrust system, so the southern limb of the anticlinorium is not exposed.

The semi-dome structure near Makido in the central part is partly composed of the Kuzuryu group on its northwest limb. The Kuzuryu group near Arimine and Kiritani in the northeastern area respectively participate in the semi-basin structures which are occupied by the adjacent Itoshiro group.

B. Geological structure of the Itoshiro group

The Itoshiro group around Haku-san (Mt.) is found several dome structures centering around Mt. Dainichi, Haku-san (Mt.), southeast of Makido, Kamiuchinami and Itoshiro. Between these domes there are semi-basin structures and major synclinal structures composed of combination of minor folds of various directions. Most of the major synclines show indefinite directions, as they are always irregularly warped. The exceptionally well directed synclines are the one which extends from the south of Makido toward west and reaches the northeast of Kamiuchinami, and the other which passes Itoshiro and Tandoguchi with NW-SE trend.

The Itoshiro group in the northeastern area is intensely affected by block movement. Broadly speaking, a major anticline is seen to pass through the vicinity of

Tate-yama (Mt.), and extends in the direction of WSW. On the south side of this anticline there is a structural basin, which is bounded by the Sukenobu thrust on the northeast and by the Yokoyama thrust on the west and southwest. The structural basin in its main part does not exhibit any remarkable folds, but the parts near the above-mentioned thrusts are disturbed and the strata are sometimes intensely reversed. The north side of the major anticline is not much folded either. Faults on the north side are, like those on the south side, running in the direction of NE-SW, often parallel to the strike of the Itoshiro group and the direction of schistosity of the Hida complex. On the whole, the Itoshiro group of this area forms a semi-basin structure with its bottom in the north or northwestern part.

The Itoshiro group in the vicinity of Takayama extends in two rows of E-W trend. The major anticlinal part was denuded away, and only the major syncline remains. Among the minor folds those of the E-W trend are predominant. West of Hongo the Moribu formation and the Hida complex are thrust upon the Itoshiro group by a reverse fault. Although details are concealed beneath the overlying Omodani rhyolites, the geological structure of this area is probably similar to that of the Tandoguchi area where the Hida complex is thrust over the Kuzuryu group.

IV. Geological structure of the Asuwa group and the Omodani rhyolites

The Asuwa group, sporadically distributed in places, is more or less folded and shows minor basin structures. On the whole, the strata of the Asuwa group and the Omodani rhyolites form one and the same geological structure.

The base of the Omodani rhyolites extends in the NW-SE direction and is gently undulating, and the flow structure are roughly parallel to the undulation. The base represents the ground surface at the time of effusion. The considerably regular undulation suggests that the initial ground surface was comparatively level, and due to later folding the regular undulation resulted.

Late Mesozoic crustal movements

I. Thrust faults

The surveyed region is characterized by many thrust faults which are related to one another and can be generally grouped into two systems. The faults with which the sheets of Hida complex are thrust over the Late Mesozoic system are called the Ura-Nippon thrust system, and those with which the sheets of the Paleozoic system of the Para-Akiyoshi facies are thrust over the Late Mesozoic are called the Omote-Nippon thrust system.

The Ura-Nippon thrust system is interpreted to have been caused by the displacement from north to south, judging from the fact that the Hida complex constitutes the basement in the northern area and also the autochthonous basement of the main distribution area of the Tetori super-group. Some of the thrust sheets, e.g. those and that the thrust in the vicinity of Kuwajima, are partly overlain by the Tetori super-group (See Fig. 4 Geological cross section A-B).

Through the Omote-Nippon thrust system, the Paleozoic sheets are displaced

from south to north, as is shown in the geological cross section C-D-E-F, D-E-G and H-I (Figs. 4 and 5).

The Ura-Nippon and Omote-Nippon thrust systems are conjugated in the eastern area where relative movements were from east to west. Whether or not these systems are continuous with those in the western area has not been ascertained yet.

The Yokoyama and Sukenobu thrusts in the northeastern area and the Fujibashi thrust near Fujibashi belong to the Ura-Nippon thrust system in the broad sense. The sheet pushed up along the Yokoyama thrust is undoubtedly continuous with the autochthonous basement which, in turn, is continuous. The relative direction of this displacement of the thrust sheet is from SW to NE. The displacement seems to have been caused by the counteraction of the movement from NE to SW.

II. Age of the thrusting

In the Ura-Nippon and Omote-Nippon thrust systems, some of the thrust sheets are pushed over the Omodani rhyolites. The younger plutonic rocks are penetrating both the thrust sheets and the Late Mesozoic system. Hence, some of the thrusts must have been formed after the effusion of the Omodani rhyolites and before the younger plutonism.

With regard to the order of formation of the thrust systems, the Omote-Nippon thrust system is older than the Ura-Nippon thrust system, as far as the eastern area is concerned. Fig. 6 shows the geology of the Tochio area where the strata reveal the order of formation of the Ura-Nippon and Omote-Nippon thrust systems.

The Yokoyama, Sukenobu and Fujibashi sheets are thrust over the Tetori super-group, but their relation to the Omodani rhyolites is still unknown. Anyhow these thrusts are undoubtedly older than the block movement in early Tertiary, because by their movement the thrust faults themselves were displaced. From the evidence described in the next paragraph it would not be unreasonable to consider that the thrusting, at least partly, already commenced before the effusion of the Omodani rhyolites. It may have been the latest stage of Cretaceous when the thrusting was completed.

III. Late Mesozoic crustal development

The Paleozoic system of the Yamaguchi facies and the Late Mesozoic system were disturbed by the Ura-Nippon and Omote-Nippon thrust movements. The disturbance is greater where strata older. In the Itoshiro group, for example, the Oguchi formation in the lower part is more intensely disturbed by the Myogadani formation in the uppermost part. Thus, it is evident that a serial geological events occurred continuously or intermittently during the period from the beginning of the deposition of the Tetori super-group to the completion of the two thrust systems. The effusion of the great amount of rhyolites without accompanying basic rocks and the succeeding granitic intrusion suggest that these were probably due to a serial igneous activity of acid magmas. The development and completion of the thrust systems and the volcanism and plutonism which took place in succession should not be overlooked as merely incidental events.

A serial geological events which are related to the Late Mesozoic crustal move-

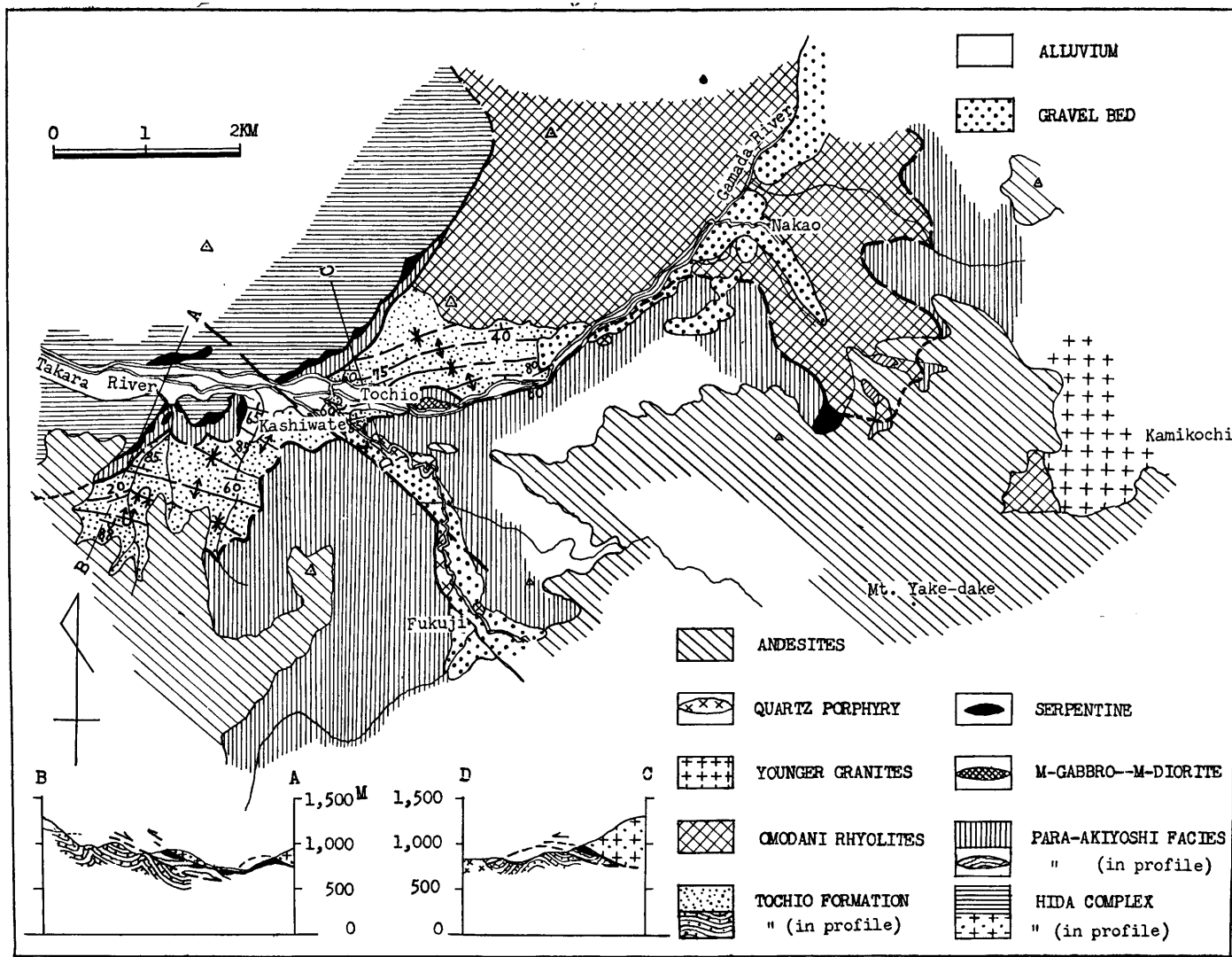


Fig. 6. Geological map and profiles of the Tochio area, Hida Plateau.

ments (in a broad sense) in the Hida Plateau region are as follow : (1) Deposition of the Arashimadani formation and the unconformity prior to this deposition (middle?-late Jurassic), (2) deposition of the Shimoanama, Shokawa, Higashisakamori and Kiritani formations, with a marine transgression (late Jurassic), (3) ground upheaval and denudation of the Kuzuryu group (latest Jurassic), (4) transgressive deposition of the non-marine Oguchi formation and its equivalents (early Paleocretaceous), (5) effusion of the felsite-quartz porphyry, and the formation of local unconformity (early-middle Paleocretaceous), (6) deposition of the non-marine Akaiwa and Myogadani formations (middle to late Paleocretaceous), (7) ground upheaval and folding of the Itoshiro group (about the Mid-Cretaceous or early Neocretaceous?), (8) deposition of the non-marine Asuwa group and volcanic activities of the post-Oyama andesite and Omodani rhyolites (middle to late Neocretaceous), (9) completion of the two thrust systems, (10) younger plutonism (latest Neocretaceous?-early Tertiary), (11) block movement (early Tertiary).

Characteristic Features of the crustal movements in the Hida Plateau

I. Geological history of the movements

During a long period from middle Jurassic to early Tertiary, a serial geological events prevailed step by step. The events in long period of early stages are characterized the deposition of clastic sediments of the Tetori super-group and relatively slight movements. A intense deformation of folding and thrusting seems to have been intermittently progressed during a comparatively long period from Mid-Cretaceous to latest Neocretaceous. The two systems of major thrusts completed in a short epoch between after the eruption of the Omodani rhyolites and before the intrusion of the younger granites, probably in latest Cretaceous. The intense deformation, the furious volcanism and the remarkable plutonism are took place successibly.

Y. OZAWA (1925, 1928) discovered a thrust fault in the Kibi Plateau further west of the Hida Plateau and thought its age as Late Jurassic. He reported that the major thrust line extends from the west and reaches the Hida Plateau and that the thrusting took place from the north to the south. T. KOBAYASHI (1941) also confirmed the existence of this major thrust line, and regarded the age of the deformation characterized by this thrusting as the Oga phase of the early Lower Cretaceous, the paroxysm of his Sakawa Cycle in the Inner Zone of Southwest Japan. In the Outer Zone of Southwest Japan, KOBAYASHI pointed out the occurrence of the Mid-Cretaceous Sakawa main phase of the Sakawa Orogenic Cycle. He recognized the heterogeneous deformation of folding and thrusting in the Hida Plateau and also the antecedent Hida epeirogenesis on the basis of the remarkable unconformity prior to the deposition of the Tetori super-group.

In the Hida Plateau region there are two systems of major thrusts which are contemporaneous but strike in opposite directions, namely, the Omote-Nippon thrust system which moved towards the north or northwest, and the Ura-Nippon system advancing southward or southwestward. The maximum displacement of the thrust sheets exceeds 40 km, occasionally as great as 60 km (See Fig. 2).

Fig. 7 shows the idealized structural evolution of the Hida Plateau region.

Geological structures of the Hida Plateau are similar to some of the well studied examples in the Cordillera of North America (EARDLEY, 1951; KING 1959). Especially the crustal movements in the Cordillera is nearly contemporaneous with that of the Hida Plateau region. The deformations in these two regions are compared below at first from the view point of historical development.

At the eastern marginal-front of the major thrusting in the Rocky Mountains, the Late Mesozoic to Early Tertiary coarse-grained sediments are known with many intraformational angular discordances. The sediments become fine-grained eastward and discordance grades into concordance. Development of the deformation in relation to the deposition of the sediments have been studied in detail there (SPIEKER, 1946; EARDLEY, 1951; KING, 1959).

Likewise, in the Hida Plateau the deformational processes have been clarified on the basis of the abnormal deposition of the Late Mesozoic sediments and the type of igneous activity. Also, as is seen at the eastern marginal front in the Cordillera, the thrust sheets of the Hida Plateau region have advanced along the erosion surface of the underlying rocks, although the development of thrust sheets may have been less conspicuous in the area where the Omodani rhyolites are extensively exposed.

In the Cordillera, the anticlinal uplift took place on the ocean side, and a geosynclinal trough was formed on the continental side, thus materials were rapidly supplied from the uplifted zone to the trough and various sediments were deposited there. It has been verified that at the same time the deformation accompanied by thrusting advanced from the uplifted region to the trough (SPIEKER, 1946; EARDLEY, 1951; KING, 1959). In the Hida Plateau region, a basin came into existence at the southern margin of the Hida complex, and the greater portion of the materials were supplied from the Hida complex. In the Cordillera it is inferred that the compression occurred in close relation to the uplifting of the west side and the subsidence of the east side (SPIEKER, 1946; EARDLEY, 1951; KING, 1959), whereas the Hida Plateau region suffered compression caused by the thrusting which exerted from both sides, i.e., from south or southeast and north or northeast sides.

The compression of the Hida Plateau region had commenced already in the late Middle Jurassic. The Hida complex constituting the core of a large anticline in the vicinity of Tandoguchi is bounded on the south by a high-angle thrust fault plunging to the north, and by this fault the complex was thrust up. The basal conglomerate of the Jurassic Kuzuryu group is seen to overstep on to this core. This indicates that the Hida complex occurring as the core had already been an uplifted mass before the basal conglomerate was deposited.

In the Hida Plateau, the furious volcanism in Late Cretaceous had been erupted before the two major thrust sheets completed. The volcanic rocks are composed of both pyroclastics and lavas of rhyolites and andesites, namely, the Omodani rhyolites (in a broad sense). They were erupted through numerous small vents, and thickly accumulated on a grand plain of a unroughed surfaces. The andesites distributed on local areas and generally effused in early stage. The intrusions of granites are younger than the major thrustings in age, and Paleocene. In the Cordillera, the

intense igneous activities occurred only local areas in the Crazy mountains of South-western Montana and the Yellowstone National Park-Absaroka Mountains of North-western Wyoming, Central Rocky Mountains (EARDLEY, 1951., P. 342-343, 356-358, & 369-372). In the Crazy Mountains area the extrusion of andesites continued from early stage all through the main stage of the Laramide orogeny, and range from Latest Cretaceous to Paleocene. And all the intrusions in this area are divided as Laramide and post-Laramide in age. In the Yellowstone Park-Absaroka area the two volcanic groups in early Tertiary have been divided, each of which is composed of a lower acid breccia, a middle basic breccia, and an upper series of basalt sheets. The early acid breccia in Middle Eocene was erupted just before the Heart Mountain thrust of the late Laramide orogeny occurred, but other volcanic rocks effused later than most of the Laramide.

II. Structural features of deformation

The major thrust planes of Omote- and Ura-Nippon systems are locally high-angle but are generally low-angle, and show wavy undulation due to slight folding; on the whole, they are nearly level. The thrust sheets are assumed to have advanced not uniformly. Owing to this fact and to the topographic relief, these thrust sheets display very irregular form in the geological map. The thrust lines show intense curvature, with klippe and fensters occurring in places.

In the Cordillera and Appalachia as well as in the celebrated Scotland structure many minor thrust faults of low- and high-angles are associated with major low-angle thrust sheets (EARDLEY, 1951; KING, 1959). Similar faults occur in the thrust sheets of the Hida Plateau region, as typically exemplified by the faults in the Ise district in the upper reaches of the Kuzuryu River where some small slices of beds of different ages form an imbricate structure (KAWAI, 1956; KAWAI, HIRAYAMA & YAMADA, 1957a). In the area east-southeast of Takayama, various Permian and Carboniferous beds showing intricate combination are exposed (NOZAWA & ISOMI, 1956 and 1957). At Fukuji farther east, many slice beds of various ages form complex distributions (KAMEI, 1952; IGO, 1956). Perhaps these beds form an imbricate structure like the one near Ise.

Both the strata constituting the thrust sheets and the underlying beds have undergone intense folding accompanied by high-angle thrusting. Folds are generally asymmetrical and are often overturned. They are apt to be pushed and laid down in the direction of the progress of thrusting. At the same time, the folds of the beds below the major thrust plane, which were truncated due to erosion, are pushed down by the thrust sheets, and the folds of the thrust sheets themselves are also pressed down toward the thrust plane. Hence the structures of the beds above and below the thrust plane develop a tendency to be concordant (See Fig. 4, 5 & 7). This is very similar to the complicated structure of the Laramide deformation along the east side of the Sangre de Cristo Range, Colorado (EARDLEY, 1951., P. 378-381 & Fig. 221 adapted from BURBANK and GODDARD, 1937).

III. Consideration on the origin of thrust systems

It is beyond the scope of the present study to make clear the origin and detailed mechanism of the two thrust systems. Only a few facts are presented herein that would give suggestions for further study of the problem.

(1) In the southwestern area, a part of the Permian Mino group was displaced in association with folding and thrusting, but the whereabouts of the displaced part are unknown.

(2) The mainly Lower Cretaceous Itoshiro group around Mt. Haku-san forms several dome structures caused probably by uplift of the basement Hida complex. The severest uplift is exemplified by the core of the anticline near Tandoguchi, where the strata of the Kuzuryu and Itoshiro groups were overturned and the basement Hida complex was thrust through them.

(3) Along the Yokoyama thrust which separates the mainly Lower Cretaceous Itoshiro group from the Hida complex a great displacement took place in the north-west part, but the thrust disappears in the southeast part, passing into the unconformity beneath the Itoshiro group. Immediately in front of the disappearing point of this thrust a sliding is found along the unconformity plane. A part of the Itoshiro group adjacent to the north of the Yokoyama thrust shows an isoclinal syncline with inclination of about 20°.

Fact (1) is an example of a partial dislocation and transference of strata as a result of intense folding of the Paleozoic system.

Facts (2) and (3) are considered as representing the early stage of the thrusting of the Hida complex over the Late Mesozoic system.

Geological structures indicating the early stage of thrusting are recognized in the Rocky Mountains area of Colorado. BURBANK and GODDARD (1937) for instance, have illustrated a supposed early stage of compression and overthrusting prior to the upthrust of the Precambrian rocks and the downfaulting, and the succeeding structures in the San Luis Valley (EARDLEY, 1951., P. 378-381 & Fig. 222). Also, they have shown that two elongate masses of Precambrian rocks squeezed into the thrusting belts in Huerfano as blocks bounded by high-angle faults (EARDLEY, 1951., P. 381 & Fig. 224; KING, 1959., P. 121-122, & Fig. 70).

Thus, in the structure of the Ura-Nippon thrust sheets the thrusting toward south or southwest is intimately connected with the uplift of the Hida complex.

In the Cordillera the uplift of the metamorphic belt in the western area was followed by eastward thrusting (SMITH & STEVENSON, 1955; SPIEKER, 1946; EARDLEY, 1951; KING, 1959). In the case of the Hida Plateau region, by tracing the direction whence the Omote-Nippon thrust system had come, one will meet with the so-called Ryoke and Sambagawa metamorphic belts on the south or southeast side.

In the upper reaches of the Azusa River in the eastern area, the Paleozoic strata constituting the Omote-Nippon thrust sheets are composed chiefly of cherts, but toward the southeast sandstones and claystones rapidly increase, whereas a reverse tendency is recognized in the group of Paleozoic strata below the thrust plane. The sandstones and claystones which were predominant in the northwestern part of the autochthonous region gradually decrease southeastward and come into

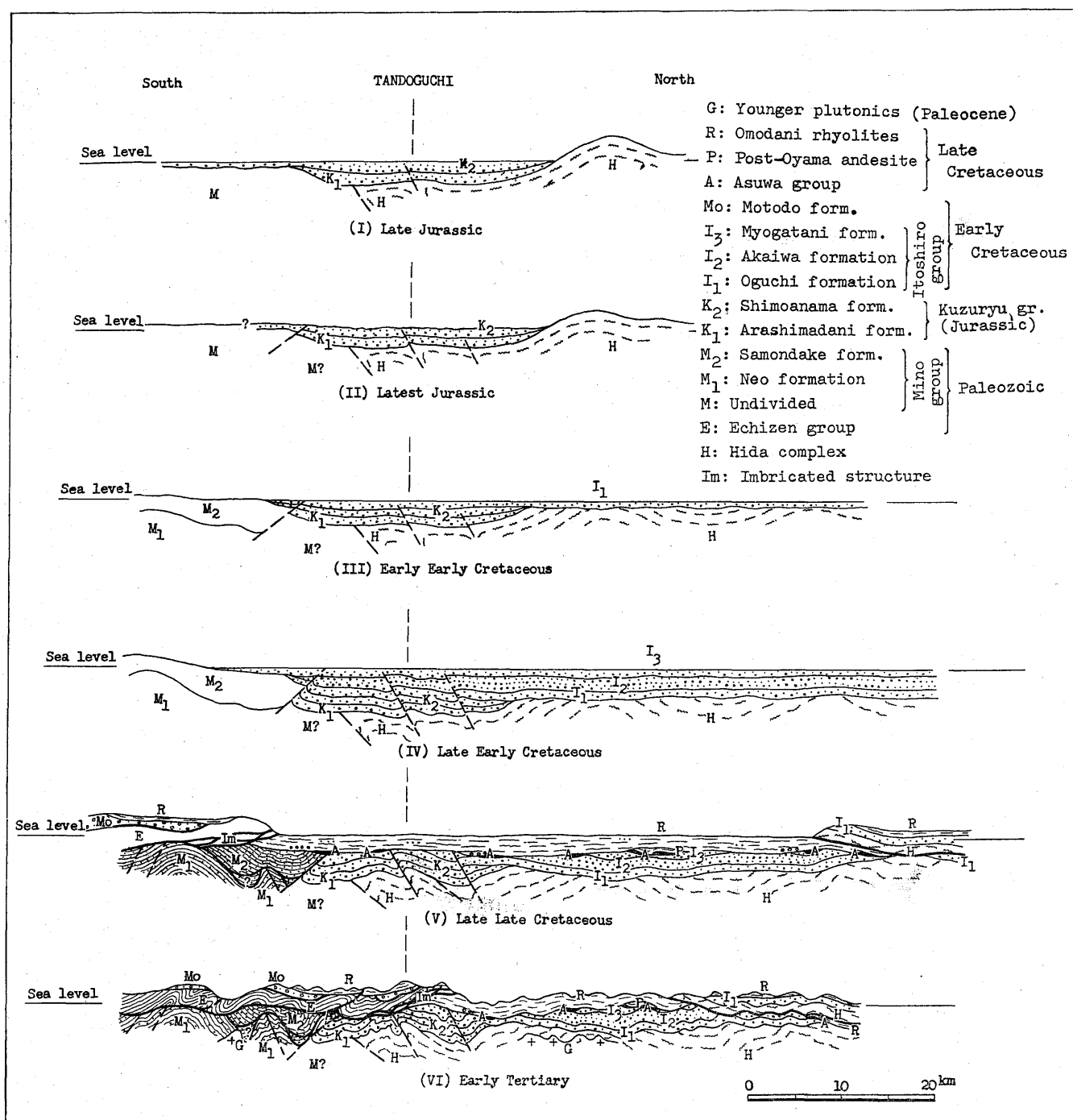


Fig. 7. Structural evolution of the Late Mesozoic to Early Tertiary time in the Hida Plateau. Idealized sections of the same site incorporated from parts of sections A-B and C-D-E-F, Figure 4. (I): Structure as it exists in Late Jurassic time (Upper Kuzuryu), (II): Structure along the same section during the erosion of Latest Jurassic time, (III): along the same section during deposition of Oguchi, early Early Cretaceous time, (IV): Structure along the same section during deposition of Myogatani, late Early Cretaceous time, (V): Structure along the same section immediately after the eruption of Omodani rhyolites, late Late Cretaceous time, (VI): Structure as it exists in Early Tertiary time.

association with thick chert in places. Thus, the lithological characters of the two groups of Paleozoic strata become similar and thrust faults become structurally indistinct. From this fact, it is suggested that the root of the Omote-Nippon thrust probably exists on the east or southeast side of the present area.

Concluding remarks

In the Hida Plateau the Late Mesozoic formations are distributed in the southern marginal area of the Hida gneiss complex, i.e. in and near the boundary region of the two basements—the Hida complex and the Paleozoic of the Yamaguchi facies. They are stratigraphically divided into the Middle?-Upper Jurassic Kuzuryu group, mainly Lower Cretaceous Itoshiro group, which may range down to the uppermost Jurassic and up to lower Upper Cretaceous, and the Upper Cretaceous Asuwa group.

Succeeding to the deposition of the Asuwa group, the post-Oyama andesite and the Omodani rhyolites were effused. The main body of the so-called quartz porphyry which is widely distributed in the Hida Plateau consists of the Omodani rhyolites.

After the effusion of the Omodani, the Ura-Nippon and Omote-Nippon thrust systems were completed. The southwestern extension of the Omote-Nippon thrust sheets are inferred to be continuous with the well-known recumbent masses of Mt. Ibuki and Mt. Ryozen. Both thrust systems show fairly large displacements. The geological age of these thrusts is older than the younger plutonism and is probably latest Neocretaceous.

The geological structures of the Late Mesozoic and older strata are controlled by the two thrust systems, and the older the strata the greater the disturbance. Hence, it is evident that the crustal movements relating to the thrust systems continued since the deposition of the Kuzuryu group.

In this region, deformations advanced along with the development of the encountering two systems of thrusting, one on the north to northeast side and the other on the south to southeast side of the central area.

The crustal movements of the Late Mesozoic era are intensely associated with the severe volcanic activity of intermediate to acid rocks which is followed by the intrusion of granite. These igneous activities occurred from the late age of Neocretaceous to early age of Tertiary.

The crustal movements are not short-period events but progressed intermittently from about Middle? Jurassic to Early Tertiary.

The movement had first formed the Tetori basin at the southern margin of the Hida gneiss complex, the area of the basin gradually expanded, in which the Tetori super-group was deposited. During the Late Cretaceous the Tetori basin disappeared, leaving a vast plain behind. The Asuwa group was deposited in smaller separated depressions with which this plain was dotted, and the lavas and pyroclastics of the Omodani rhyolites accumulated over the Asuwa group.

The Late Mesozoic sediments and volcanics are marked with many discordances. These discordances, excluding the unconformity between the Jurassic Kuzuryu group and the mainly Lower Cretaceous Itoshiro group, do not always represent a great

time gap but may be the results of successive minor deformations.

The deformation of the Hida Plateau region is remarkably similar to that of certain parts in the North American Cordillera. The Cordillera was subjected to long series of severe orogenesis that continued from Early Jurassic to Tertiary, and the resultant deformation progressed from the west to the east. Within such an extensive region, the geological ages of the orogenesis are different from place to place, hence it is called by various names such as Nevadan, Diabran, Oregonian, Santa Lucian, Laramide, etc., in compliance with the respective districts. Some of them overlap occasionally with one and the same district. Similar features may be seen in Japan and adjacent regions of Eastern Asia. As far as the Hida Plateau area is concerned, almost all the stages of the movements from Middle Jurassic to latest Cretaceous are expressed more or less intensely by the deformation of the strata and igneous rocks.

The thrusting activity terminated entirely after the intrusion of Paleocene granitic rocks. It is inferred that the nature of deformation has changed since the granitic rocks were consolidated, and has come to assume a new style. Another renewed cycle of crustal movements is observable since mid-Tertiary in the present area as well as in various parts of Japan.

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