On Tectonic Features around the Matsumoto and Suwa Basins, Central Japan

On Tectonic Features around the Matsumoto and Suwa Basins, Central Japan

Takashi NAKATA and Noboru CHIDA

Introduction

Along the western fringe of the Fossa Magna (Nauman 1885), several tectonic depressions, namely, the Himekawa Valley, the Matsumoto, Suwa and Kofu Basins, and the Fuji Valley stretch in a row from the north to the south bounded by the Itoigawa-Shizuoka Tectonic Line on their western margin (Yabe 1918). This line was first regarded as the major boundary between the Northeast and the Southwest Japan Arcs (Nauman 1885, Yabe 1918), but later it was treated as a huge discontinuity inside the Southwest Japan Arc, considering from geological structure (Mochizuki 1951, Yamashita 1970).

Geological and topographical contrasts distinctly exist between two sides of the tectonic line. The western part mainly composed of pre-Tertiary rocks forms high mountain ranges, whereas the eastern part chiefly composed of Tertiary volcanics so-called "Green Tuff" (Minato *et al.* 1956) forms lower mountains.

Large-scale tectonic features of Central Japan were discussed by Tokuda (1927) and Fujiwhara (1925). The former demonstrated the process of the formation of high mountain ranges with *en échelon* arrangement and deduced that the pressure from a marginal sea was a major factor of their origin. Recently, Kaizuka (1972) presents a new explanation that the *en échelon* arrangement of the mountain ranges in Central Japan is attributed to the subduction of the Pacific Plate with an oblique direction along the Japan-Shichito-Ogasawara Trenches. However, they did not discuss the process of formation of longitudinal basins along the Itoigawa-Shizuoka Tectonic Line. Since Gorai (1952) found the extension of the Outer Zone of Southwest Japan to the east of the Itoigawa-Shizuka Tectonic Line and proposed the left-lateral displacement of the Outer Zone about 12 km along the tectonic line. Though this lateral movement was believed to have almost completed by early Miocene as the Enrei Formation in the area has not been displaced along the tectonic line (Fossa Magna Research Group 1958), Kobayashi (1968) and Kaneko (1972) are inclined to believe that the Matsumoto and Suwa Basins were formed filling tectonic depressions caused by the lateral movement.

Topographical contrast between both sides of the Itoigawa-Shizuoka Tectonic Line has been achieved in the Quaternary period. Kobayashi (1968) concluded that the Matsumoto and Suwa Basins and the Hida and Kiso Mountains were built contemporaneously during the Pleistocene, after the formation of the low-relief surface "Omine Surface".

Around the Matsumoto and Suwa Basins, crustal movements in the Quaternary period are clearly recorded on topography. However, quite few geomorphological studies on tectonic features in the area have been done. Therefore, the present writers try to clarify modes of crustal movements of the area from geomorphic point of view and to deduce their regional characteristics in the western fringe of the Fossa Magna.

General Discription of Topography

The most impressive topographic features in the Central Part of Japan are the longitudinal depressions, i.e. the Matsumoto and Suwa Basins, bounded by steep straight escarpments on both sides (Fig. 1). These basins are tectonic in origin and crustal movements have been recorded on geomorphic surfaces, namely alluvial fans and cones, and river terraces which develop in marginal area of the basins. The eastern slope of the high mountain range of Hida, fringing the western side of the Matsumoto Basin is steep but not straight as the outlets of the rivers are indented into the mountains. On the other hand, the eastern side of the Matsumoto Basin and both sides of the Suwa Basin are steep and straight clearly indicating their tectonic origin in recent geological period. High erosional surfaces found in the mountain area are classified into several levels and the displacement of the erosional surface is considered to have been proceeded in accordance with the process of the mountain and basin building in the Quaternary period (Kobayashi 1953). Amounts of the crustal movements during the Quaternary period are calculated from the heights of these surfaces and it is known that the maximum amount of upheaval took place during the period in the central part of Japan (Research Group for Quaternary Tectonic Map 1968).

The modes of recent crustal movements are expectedly elucidated from the deformation of geomorphic surfaces in and around the study area. Though many workers have been engaged in geomorphological study in this area, they spent most of their time in tephrochronology, and geomorphic maps were prepared on rather limited area. Fig. 2 is a geomorphic map around the Matsumoto and Suwa Basins prepared by the present writers. The nomenclature of the geomorphic surfaces follows after Shinshu Research Group's work (1969).

Geomorphic surfaces in the area are encountered either as fluvial fan, river terrace or piedmont depositional surface composed of detritus.

The present writers newly recognized two surfaces. One is the Nagase Surface on the left bank of the Narai River and the other the Kumai Surface at the

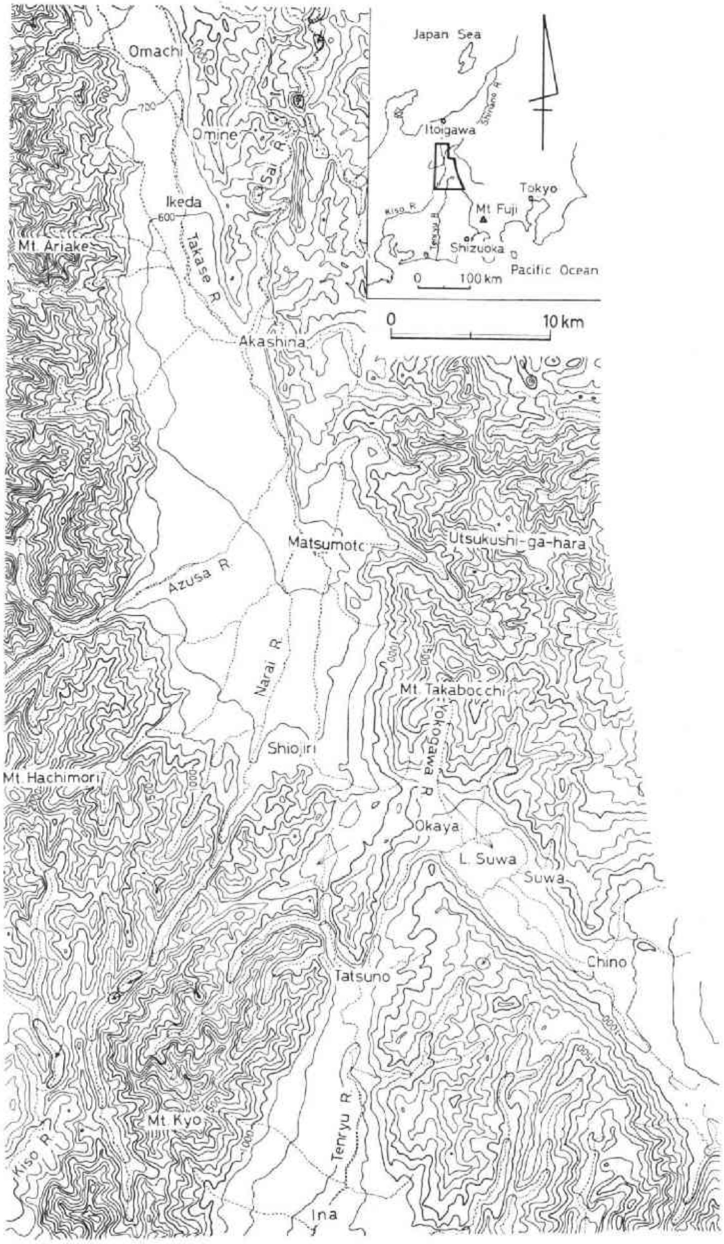

Fig. 1 Restored map of the central part along the western fringe of the Fossa Magna, eliminating valleys less than 500 m across (Contour interval: 100 m)

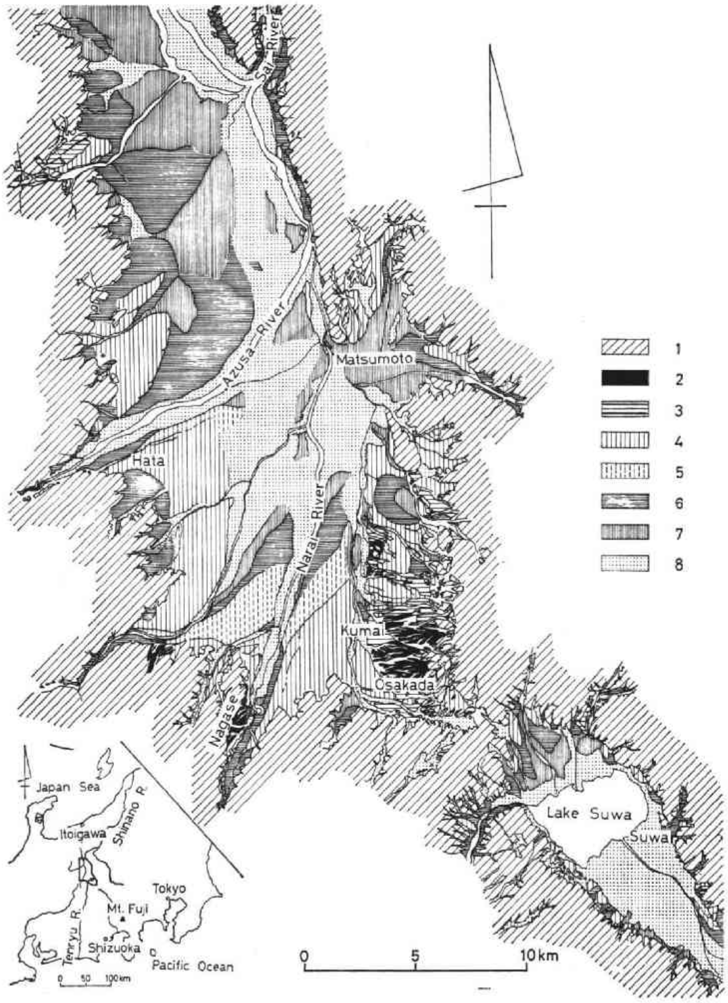

Fig. 2 Geomorphic map around the Matsumoto and Suwa Basins 1: Mountain and Hilly Land 2: Nagase and Osakada Surfaces 3: Kumai Surface 4: Hata Surface 5: Moriguchi Surface 6: Kamikaido Surface 7: Oshide Surface 8: Alluvial Plain

western foot of the Hachibuse-Takabocchi Range. The former is an old river terrace covered with Older Shinshu Loam as old as P–04 which contains alumina nodules. This surface may be correlated to the Takao Surface (Shinshu Research Group 1969) in the Ina Valley. In Fig. 2, this surface is included in the Osakada Surface for the matter of convenience. The latter is one of the piedmont depositional surfaces composed of detritus from the steep slope of Takabocchi originated in fault activities. This surface is also developed as the higher river terrace along the Tô River in the northeastern side of the Suwa Basin. It is covered with the pumice-fall deposit Pm-1 and is dated between the Osakada and Hata Surfaces.

The Hata Surface is considered to be correlated to the Musashino Surface in South Kanto by Shinshu Research Group (1969), but the present writers consider that the Hata Surface may be correlated to the Tachikawa Surface judging from the tephras on the surface and the extent of surface preservation. Thick deposits of this surface may show that the surface was built during a depositional phase which may be related to the last glacial period in the Hida Mountains.[1] The Kumai Surface can be correlated to the Shimosueyoshi Surface since Pm-1 pumice bed[2] covering the Kumai Surface is correlated with the upper part of Shimosueyoshi (Kissawa) Loam (Machida 1971).

Tectonic features around the Matsumoto Basin

General tendency of the crustal movements of the Matsumoto Basin can be assumed by the mode of developments of fluvial fans, i.e. whether composite fans are of telescopic arrangement or not. If a younger fan is formed in front of older fans displaying the telescopic arrangements, the fan forming area can be considered as an uplifting area together with the mountain land behind. On the other hand, if a younger fan is constructed overlapping older fans around fan head, the area is considered as a subsiding area contrary to the uplifting mountain land behind. The former is the case in the southwestern part of the Matsumoto Basin and the latter in the central to northwestern parts.

Although crustal movements, which attained the distinguished relief contrast between the Hida Mountains and the Matsumoto Basin, must have taken place, the outline of the mountain foot is indented and distinct crustal movements can not be clarified from deformation of geomorphic surfaces.

Eastern fringe of the basin is rather straight in the direction of N-S and recent tectonic features are clearly displayed in this area. These features are most distinguishedly developed in the southeastern fringe of the basin. The geomorphic surfaces, morphotectonic line and lineaments on the area are mapped in Fig. 3.

The Hachibuse-Takabocchi Range (1430 m to 1929 m) runs in the N-S direction and low-relief surface, widely distributed on the top of the range, is

1) This correlation is evidenced by the age of the Hata Loam (26,600±1,600 (Gak-240a) or 27,800±2,000 (Gak-240b) yr. B.P.) which covers the morainic deposits at Ikenotaira in Kiso Mountains (Kigoshi and Endo 1963, Kobayashi and Shimizu 1966).

2) Pm-1 pumice-fall was about 70,000 to 90,000 yr. B.P. based upon the fission track dating of zircon (Machida and Suzuki 1971).

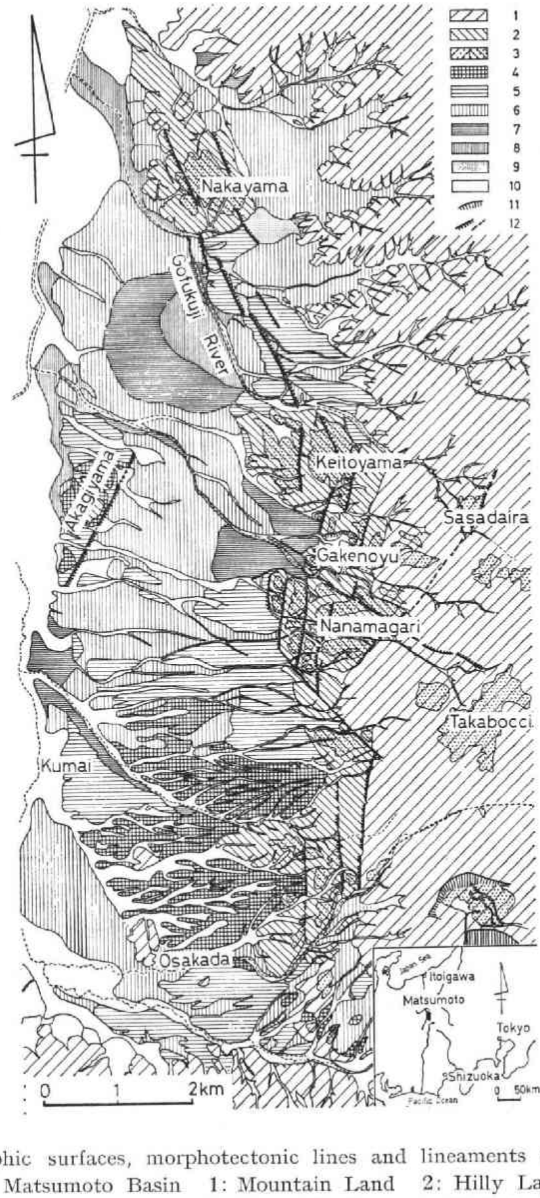

Fig. 3 Geomorphic surfaces, morphotectonic lines and lineaments of the southeastern part of the Matsumoto Basin 1: Mountain Land 2: Hilly Land 3: Low Relief Surface 4: Osakada Surface 5: Kumai Surface 6: Hata Surface 7: Moriguchi Surface 8: Kamikaido Surface 9: Fault Sag 10: Alluvial Plain 11: Landslide 12: Fault and Lineament

displaced along several parallel running faults[3] toward the basin floor. These segmented low-relief surfaces can be traced as fault steps in the hilly land along the foot zone of the range (Photo 1). Geomorphic surfaces below the hilly land are mainly composed of detritus derived by rivers and streams from the steep slope of the range.

The Osakada Surface is highly dissected and covered with Older and Middle Shinshu Loams[4]. Around Akagiyama, the same old loams[5] as covering the Nagase Surface are found below younger gravel beds.

The Kumai Surface maintains low undulation of its original surface and is overlain by the Pm–1 pumice bed. On the right bank of the Gofukuji River, this surface is built up with thick boulder bed composed mainly of huge granite boulders.

In this area, fault lines are grouped into three fault systems according to their strike direction. They are N-S, NNE-SSW and NNW-SSE systems and these directions can be called as the Matsumoto Basin direction, Median Tectonic Line direction and the Suwa Basin direction respectively. The coexistence of these fault systems indicates that the topography of the central part of Japan is attributed to the interaction of these fault systems.

The above mentioned low-relief surface is mainly dislocated by the N-S fault system in the southern part of the area. Photo 1 shows the step-faulted low-relief surface around Nanamagari. These fault lines extend for 6 km and amounts of vertical displacement ranges 20 m to 80 m on each fault. No clear horizontal dislocation[6] is recognized. Younger surfaces below the low-relief surface are not displaced along this fault system, indicating that the fault system has not been active after the formation of the Osakada Surface. The NNW-SSE fault system is clear between Nakayama and Keitoyama, distinctly displacing the Kumai Surface (Photo 2). These faults are arranged *en échelon* and each fault does not extend for more than 1 km.

One of these faults is a high angle reverse fault (N30°W, 70°W) along which boulder bed exclusively composed of gneissic boulders, thrusts over younger gravel bed. Along these faults, Kaneko (1972) pointed out left lateral movement.[7] Fig.

---

3) Shattered bedrock is prominent near escarpments though faults are hardly recognized geologically.

4) Older Shinshu Loam is called Nishibayashi Loam and Middle one Osakada Loam in this area. Pm–1 pumice-fall occurred at the lowest Middle Loam.

5) Older Shinshu Loam

6) Spur bending and stream diversion around Nanamagari to the south of Gakenoyu may suggest the right lateral movement.

7) One of the left lateral stream diversions Kaneko pointed out (1972) may be realized as a small stream piracy caused by headward erosion proceeded along NE-SW fault line.

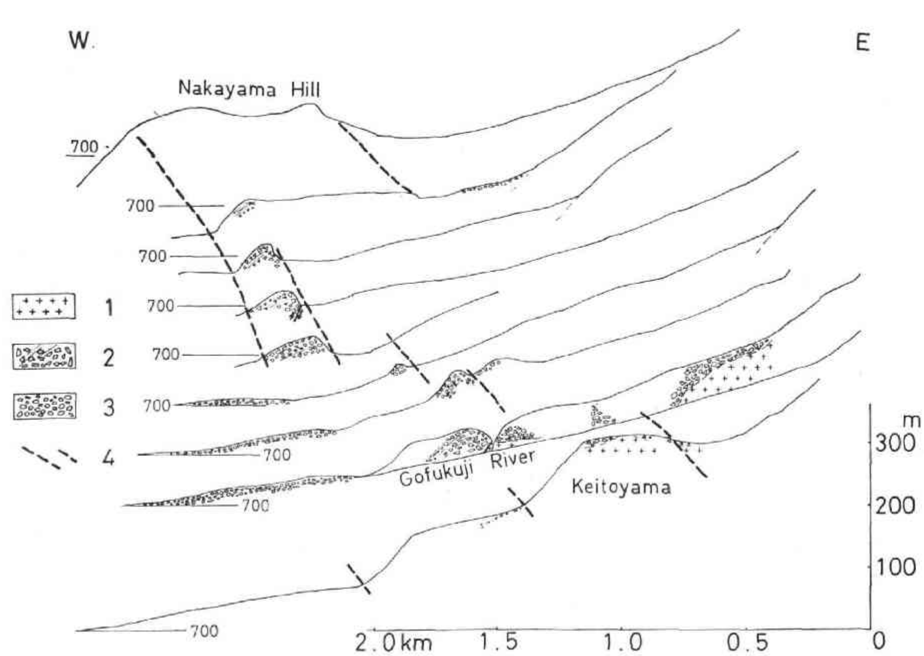

Fig. 4 Cross-sections across the NNW-SSE splintered fault line between Nakayama and Keitoyama

4 illustrates cross-sections across the fault lines. Bedrock under detritus which are mainly composed of angular to subangular granitic boulder gravel, is uplifted and detritus layer is tilted about 25° westward near the top of deformed surface. The deformed surface along the splintered faults exhibit half-dome shape and structure, and the crests of the uplifted blocks extend parallel to the fault lines. This fact shows that these deformed surface have resulted from the vertical displacement along the tectonic line rather than the lateral one, for the latter should have formed the mounds in an oblique direction to the tectonic line. It is peculiar that these splintered fault escarpments face towards the mountain. This should be considered as a result of the counter activity along the tectonic line against the upheaval of the mountain land. Nakayama is a kind of horst bounded by parallel running faults in the same direction and the one in the west continues to the south, and a tectonic escarpment with warped sand layer embedded in the detritus is located on this extension. The eastern margin of the Matsumoto Basin along the Narai and Azusa Rivers to the north of Matsumoto City is considered to follow the northern extension of the fault line and sudden termination of the terraces along the Sai River takes place on this line, indicating that the

subsidence of the Basin and the upheaval of surrounding area have been taking place along the line.

Activities along a fault of the Median Tectonic Line direction, i.e. NNE-SSW, are evidently recognized around Akagiyama. Several levels of old geomorphic surfaces are isolated in younger surfaces due to the differential upheaval caused along the fault line to the east of Akagiyama. In this uplifted block, the older surface has attained more upheaval, suggesting the rather continuous activity along the fault line. This fault facing the mountain has probably acted against the movements of the major fault of the same direction in the mountain along which the terminal facet and fault bench of Sasadaira were formed. The lineaments of the Median Tectonic Line direction are frequently seen on the low-relief surface around Takabocchi. These lineaments follow the strike of the Enrei Formation, therefore it is considered that the tectonic movements initiated probably in Pliocene.

Tectonic Features around the Suwa Basin

The Suwa Basin is shaped out as a graben and both sides of this NNW-SSE elongated basin are steep and straight though the two sides converge at the northern and southern ends.

Arii (1951) illustrated sections of truncated spurs on the southwestern side of the Suwa Basin which were pointed out by Tsujimura (1942).

Alluvial cones have been formed along the foot of the tectonic lines and these cone surfaces are correlated to the geomorphic surfaces in the Matsumoto Basin by tephras and other topographic characteristics (Fig. 5).

Tectonic disturbances are clearly recorded on the geomorphic surfaces as young as the Hata Surface. Figs. 6-a and b show typical cross sections of alluvial cone surfaces correlated to the Hata Surface on the southwestern side of the basin. The amount of vertical displacement on the Hata Surface, here, is 7 m to 24 m[8]. No lateral displacements are recognized in this area either. Geological evidence of the displacement is not so clear in this part and only the distinct boundary between bedrock and detritus composing the cone surfaces, which coincides with the tectonic escarpments, may suggest the existence of normal fault[9] along the escarpments.

On the northeastern side of the Suwa Basin, similar topographic phenomena can be observed. The cone surfaces are also truncated clearly in this area and

8) Local variety of the displacement amount probably depends on the surface shape of the hanging wall. However, the correlation of the surface near Ariga, to the Kumai Surface still remains probable.

9) If the fault is reverse one or thrust, there would be more chance to find out outcrops of faults as the hard bedrock over detritus protect the fault from wearing.

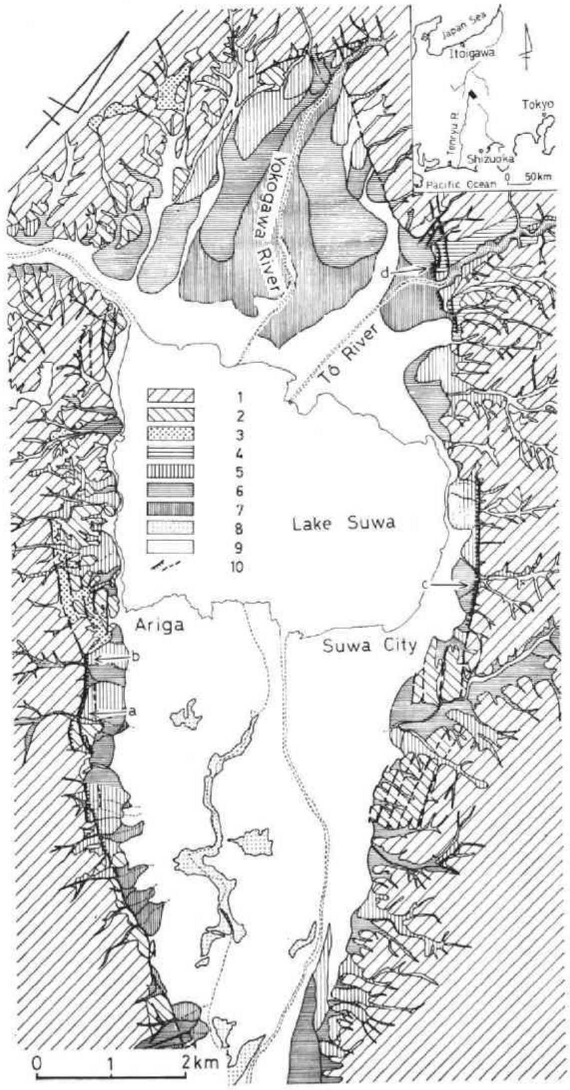

Fig. 5 Geomorphic surfaces, morphotectonic lines and lineaments of the Suwa Basin
1: Mountain Land 2: Hilly Land 3: Gentle Slope 4: Kumai Surface 5: Hata Surface 6: Moriguchi Surface 7: Kamikaido Surface 8: Natural Levee 9: Alluvial Plain 10: Fault and Lineament

even present stream profiles have knickpoints quite close to the tectonic cliff (Fig. 6-c). Along the Tô River, river terraces correlated to the Kumai and Hata Surfaces are displaced over 20 m and 16 m respectively near its outlet from the mountain into the basin (Fig. 6-d) (Photo 3). Main shear joints in the brecciated

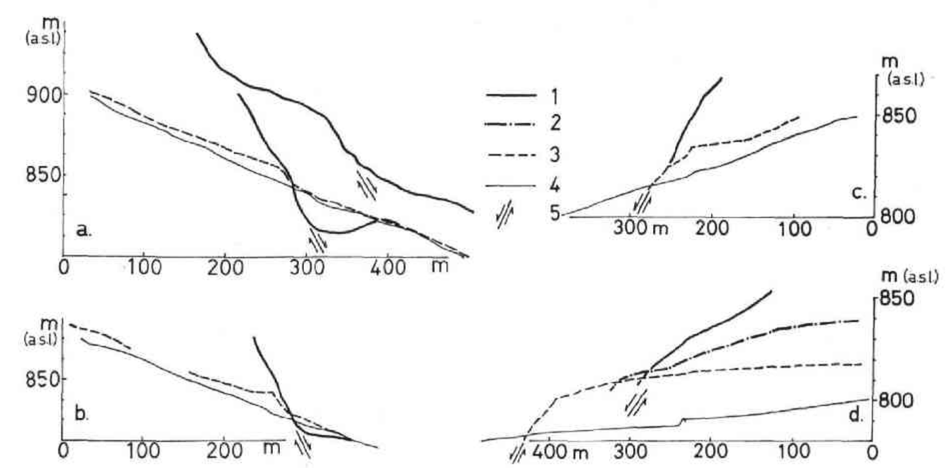

Fig. 6 Cross-profiles of the alluvial cone surfaces correlated to the Kumai and Hata Surfaces on both sides of the Suwa Basin
Locations of profiles are shown in Fig. 5.
1: Mountain and Hilly Land 2: Kumai Surface 3: Hata Surface 4: Present River Bed 5: Mode of Crustal Movement

bedrock have the strike of N25°W and the dip of 54°W, indicating the normal dip-slip activity along the fault (Photo 4). Several lineaments with the Suwa Basin direction are seen in the hilly land and fault step-like arrangements of the hilly land are seen to the east of Suwa City. These types of topography and lineaments are traced under the basin floor. The boring data revealed several levels of fault step-like topography[10] (Inagaki *et al.* 1958, Kobayashi 1960) and hot springs around Suwa City are clearly distributed along these lineaments (Minami *et al.* 1960).

Considering from the mode of deformation of the geomorphic surfaces and geological evidences, the basin forming movements have been taking place even after the formation of the Hata Surface. The small scale development of surface may mean that the contrasting tectonic movements are occurring along the basin fringes. The tectonic movement taking place is of normal dip-slip fault and not lateral one as no horizontal displacement of landform is recognized.

Therefore left lateral movements along the tectonic lines on both sides of the basin deduced from the dislocation of old rocks is earlier than the graben formation around the Suwa Basin.

Tertiary structure around the Suwa Basin revealed by Hirabayashi (1968)

10) Near the center of the Basin, the lacustrine deposits are so thick that bore hole did not reach the bedrock even at 371 m deep.

displays a basin structure centering towards Lake Suwa. The Suwa Basin has been formed by tensional faults truncating a synclinal structure and the process of basin formation differs from that of the Rhein Graben which has been formed by tensional gravitational faults near the top of anticlinal structure by uplift of basement rocks (Illies 1970). The Suwa Basin graben is presumed to have been formed by normal faults under E-W tensional stress field. This graben is wider in the north than in the south.

Conclusion

Around the Matsumoto and Suwa Basins, crustal movements in Quaternary period have occurred along faults which extend in three directions. Mode of activity differs on faults in each direction and in cases even on faults of a same direction.

Around the Matsumoto Basin, faults along the eastern foot of the Hida Mountains were said to be thrusts but their activities are not traced on geomorphic surfaces. Along the fault in the southeastern sides of the basin, thrust or reverse faulting has taken place on faults of the NNW-SSE direction and normal faulting on that of the N-S, but nature of faulting on that of the NNE-SSW has not yet been clarified.

Both sides of the Suwa Basin are bounded by fault escarpments of the NNW-SSE direction which are considered to be a manifestation of continuation of graben building in Quaternary period. Mode of faulting on faults of the NNW-SSE direction, i.e. faults parallel to the Itoigawa-Shizuoka Tectonic Line, seems to change from normal faulting around the basin to thrust to the south of Chino City (Otuka 1941, Arii 1951). It is presumed from nature of the above mentioned faults, that the E-W lengthening is taking place around the Suwa Basin whereas the E-W shortening to the south of the Chino City, in the western fringe of the southern Fossa Magna. This movement seems to coincide with a presumable movement which would take place in a later process of the formation of an abrupt turn of strike in the imbricated structure of the outer zone of the Southwest Japan (Mochizuki 1951) in Central Japan.

Although Japan is said to be under the E-W compressive stress in Quaternary (Nakamura 1969) and conjugated fault system has developed in Central Japan to the west of the Itoigawa-Shizuoka Tectonic Line, it is rather difficult to explain modes of faulting in the studied area under a uniform E-W compressive stress.

The writers are grateful to Prof. Kasuke Nishimura of Tohoku University for his continuous and valuable guidance. Acknowledgements also goes to Dr. Shiro Kaneko who discussed openly on this problem during preparation of manuscript.

Mr. Masuji Inagaki of Suwa City Office was kind enough to give the writers useful suggestions on the basement structure of the Suwa Basin.

Reference Cited (* in Japanese ** in Japanese with English abstract)

Arii, T. (1951): Recent Fault Topography near Shiojiri and Nirasaki* Geogr. Studies presented to Prof. K. Uchida (2), 235–255

Fossa Magna Research Group (1958): Tectonic Significance of the Fossa Magna* Earth Science (Chikyu Kagaku) **37** 29–33

Fujiwhara, S. (1925): On Volcanic Zone and Fissure Line of Mountain Mass* Geogr. Rev. Japan **1** 735–758

Gorai, M. (1951): Median Line in the Fossa Magna (M.S.)* in Fossa Magna Research Group (1958)

Hirabayashi, T. (1968): On the Characteristics of the Geological Structure in the Western Fringe of the Northern Fossa Magna* Fossa Magna, 31–35

Illies, J.H. (1970): Graben Tectonics Related to Crust-Mantle Interaction Graben Problems; International Upper Mantle Project Scientific Report **27** 4–27

Inagaki, M., Maki, S. and Nakamura, H. (1958): On the Relation between the Level of Suwa Lake and Quantity of Water from Kamisuwa Hot Spring* Onsen-Kagaku, **9**, 12–25

Kaizuka, S. (1972): Macro-morphology of Island Arc System and Plate Tectonics* Kagaku, **42**, 573–581

Kaneko, S. (1972): Chikei-zusetsu* (Illustrative Geomorphology) 2, Kokon Shoin, 229p

Kigoshi, K. and Endo, K. (1963): Gakushuin Natural Radiocarbon Measurements II Radiocarbon, 5

Kobayashi, K. (1953): Pleistocene Erosion Surfaces in the Western Part of the "Fossa Magna" (I) (II)** Geogr. Rev. Japan, **26**, 291–307

——— (1968): Quaternary Crustal Movements in the Inland Part of the Fossa Magna** The Memoirs of the Geol. Soc. Japan **2** 33–38

Machida, H. (1971): Tephrochronogical Study in South Kanto Part 1** The Quaternary Research, **10**, 1–20

——— **and Suzuki, M.** (1971): Absolute Age of Tephra and Chronology of Late Quaternary* Kagaku, **41**, 263–270

Minami, E., Noguchi, K. *et al.* (1960): Geochemical Study of Kamisuwa Hot Spring* Surveying Report of Kamisuwa Hot Spring, 9–53

Minato, M., Yagi, K. and Hunahashi, M. (1956): Geotectonic Synthesis of the Green Tuff Regions in Japan Bull. Earthq. Res. Inst., Univ. Tokyo **34** 237–265

Mochizuki, K. (1951): The Meeting of Arcuate Mountains in Central Japan** Jour. Fac. Lib. Arts Sci., Shizuoka Univ. **2** 83–93

Nakamura, K. (1969): A Hypothesis on Island Arc Tectonics* Problems on Green Tuff, 31–38

Otuka, Y. (1941): Geology of Mt. Zizô and Hôô, Yamanashi Prefecture, Japan** Bull. Earthq. Res. Inst., Univ. Tokyo **19** 115–143

Research Group for Quaternary Tectonic Map (1968): Quaternary Tectonic Map of Japan** The Quaternary Research, **7**, 182–187

Shinshu Research Group (1969): Quaternary of Shinshu District, Central Japan** Quaternary System of Japan, 217–262

Tokuda, S. (1927): On the Échelon Structure of the Japanese Archipelagoes Jap. Jour. Geol. Geogr. **5** 41–76

Tsujimura, T. (1942): Fault Geomorphology* Kokon Shoin, 397p

Yabe, H. (1918): On the Itoigawa-Shizuoka Tectonic Line* Gendai-no-Kagaku (Modern

Science), 6–3, 1–4
Yamashita, N. (1970): A Proposal of the Kashiwazaki-Choshi Tectonic Line** Island Arc and Ocean, 179–191

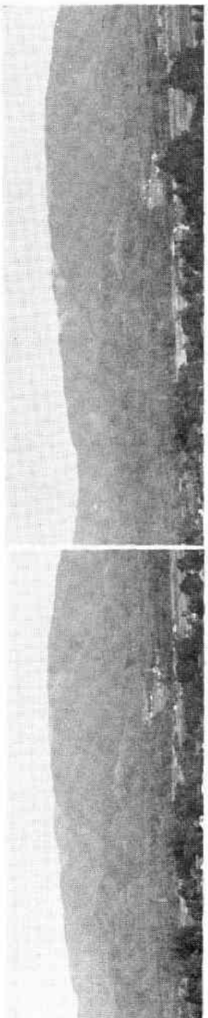

Photo 1 Horizontal stereo view of fault steps in the southeastern part of the Matsumoto Basin

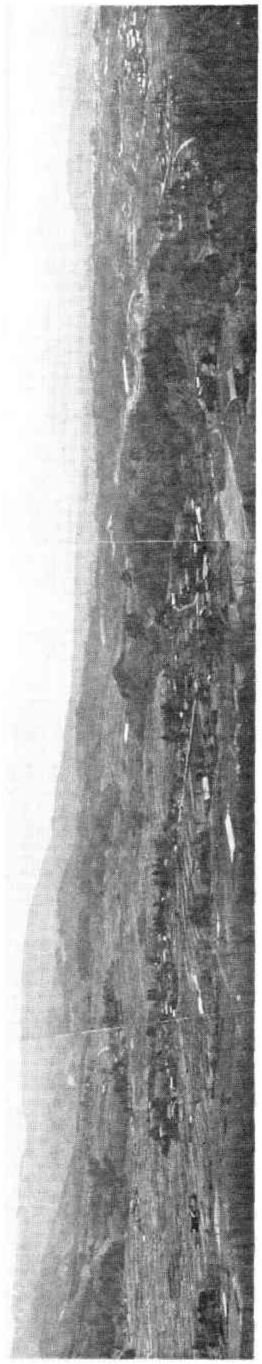

Photo 2 Kumai Surface displaced along the NNW-SSE faults arranged *en échelon* between Nakayama and Keitoyama


Photo 3 A thrust outcrop along the NNW-SSE fault to the south of Nakayama

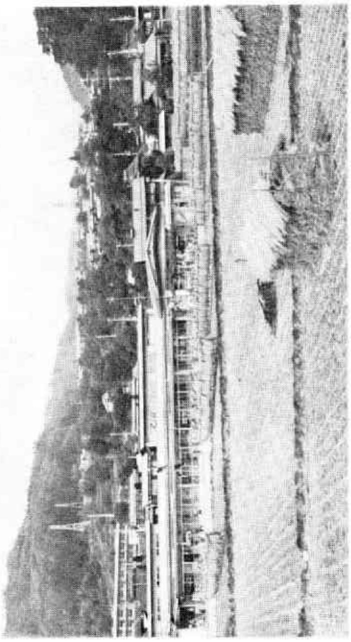
Photo 4 Faulted river terraces of the Tô, around its outlet from the mountain in the northeastern side of the Suwa Basin


Photo 5 Brecciated bedrock at the fault escarpment in the northeastern side of the Suwa Basin