Structurally Controlled Geomorphology on the Southern Boso Peninsula, Central Japan : Investigation Using Seismic Reflection Profiling

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A graben is defined geologically as a topographic depression generated by dip-slip faulting. The Kamogawa Graben on the southern Boso Peninsula, central Japan, is considered to be a typical graben, although it has yet to be geomorphologically or geologically verified. In this study we use seismic reflection profiling and analyses of geomorphic and geologic data to reexamine the unsolved question of whether this structure is in fact a graben. We present an interpretation of the structure in terms of its structurally controlled geomorphic evolution. On the basis of our analysis, we conclude that the so-called Kamogawa Graben is not actually a graben, as graben structures are not observed in seismic images and there is no positive cumulative deformation recorded by active faults at the surface. The topographic lineaments that bound the depression between the Kazusa Hills and the Awa Hills constitute fault-line valleys and obsequent fault-line scarps. The northern lineament has developed along the geologic contact between fractured shale of the Hota Group and mudstone and sandstone of the Miura Group, while the southern lineament has developed between mudstone and sandstone formations within the Hota Group, along the Sorogawa Fault. These observations suggest that differential erosion of shale, mudstone, and sandstone strata produced the observed graben-like relief. Weathered shale is especially susceptible to erosion and is marked by areas of relatively low relief. The presence of paleo-river channels and obsequent fault-line scarps leads us to the proposal that an earlier river system developed on the pre-erosion mountainous topography that overlaid the present Mineoka Mountains. Such a geomorphic evolution of the southern Boso Peninsula is therefore structurally controlled, and the Kamogawa Graben is in fact a structural depression rather than a graben.

Keywords : graben, structural geomorphology, differential erosion, Boso Peninsula, seismic reflection profiling

I. Introduction

Geomorphic depressions or basins generated by vertical faulting (relative subsidence) are clas-

sically termed grabens if bounded by normal faults (Illies, 1974) or ramp valleys if bounded by reverse faults (Willis, 1928). Generally speaking, a graben is a tectonic depression that con-

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sists of a narrow block that has dropped down between two normal faults; however, graben-like depressions can also result from differential erosion. Such depressions are usually described as lowlands bounded by fault-line scarps. This kind of structural control on geomorphology is commonly observed along fault lines. It is commonly difficult to determine whether a depression is tectonic or structural in origin, as it is rare that topographic lineaments are clearly recorded along both margins of a depression, and geologic outcrops are

generally sparsely distributed. In such cases, where an interpretation of the origin of a graben is hampered by a lack of surface geologic information, an alternative technique is required.

The Boso Peninsula, central Japan, consists of fore-arc basin deposits, and has been an accretionary complex since the Miocene. The southern peninsula consists of hills and lowlands that are characterized by east-west geologic structures deformed by faults and folds. One of the lowland areas is termed the Kamo-

Fig. 1 Landsat satellite image (upper) and geologic map (bottom) based on Mitsunashi and Suda (1980) and Nakajima *et al.* (1981) in the southern Boso Peninsula

To: Toyohide F., Ha: Hatake F., Kg: Kagamiura F., An: Anno F., Ck: Chikura F., Ky: Kiyosumi F., In: Inagosawa F., Am: Amatsu F., Is: Ishido F., Kn: Kinone F.

gawa Graben, which is considered to be a tectonic depression produced by Quaternary active faults (Murai and Kaneko, 1975). Otuka (1949) considered that the southern margin of the graben was not tectonic in origin, but instead was similar to obsequent fault-line scarps that originate from differential erosion, as shown by Cotton (1942). Subsequent studies have interpreted the Kamogawa Graben as either a tectonic graben or an erosional lowland, leading to a long period of controversy concerning the origin of the Kamogawa Graben.

Since the 1990s, seismic reflection profiling studies have been successfully used in Japan to obtain geologic images that aid our understanding of sedimentary structures and fault structures (e.g. Ito *et al.*, 1996; Sato and Hirata, 1998; Ishiyama *et al.*, 2004; Sato *et al.*, 2005). This technique is useful for imaging hidden subsurface geologic structures that control geomorphology. In the current paper, we use seismic reflection profiling and geomorphologic and geologic data to advance the interpretation that landforms of the southern Boso Peninsula are structurally controlled.

II. Geomorphologic and geologic setting

The Boso Peninsula extends into the Pacific Ocean from Honshu Island, central Japan, at a surface altitude of about 300 m. The undulating surface of the peninsula consists of a series of hills and lowlands that trend east-west. The middle part of the peninsula is characterized by a rectangular depression set between two east-west topographic lineaments (Fig. 1, upper figure). The northern lineament can be traced from Hota to north of Kamogawa, while the southern lineament extends from Iwai to south of Kamogawa. Three Holocene lowlands are recognized within the depression, located near Kamogawa on the east coast of the peninsula, and near Hota and Iwai on the west coast. The depression is bound to the north by the Kazusa Hills and to the south by the Awa Hills. Surprisingly, the Mineoka Mountains exist within the depression itself, and contain Mt. Atago (408 m), the highest peak on the peninsula.

The Kazusa Hills, at 200 m elevation, are composed of a 3,000 m sequence of fore-arc basin sediments of alternating sandstone, mudstone,

and conglomerate that were deposited within the basin from 15 Ma to 4 Ma. These north-dipping rocks comprise the Miura Group, and have been raised above sea level via deformation by faults and folds (Fig. 1, lower figure; Nakajima *et al.*, 1981; Kotake, 1988). The geomorphology of the Kazusa Hills is characterized by a series of *cuesta*: alternating sandstone ridges and mudstone valleys. Nakagawa (1961) termed such a rock-controlled feature a *cadena*, which results from differences in the permeability of sandstone and mudstone. Suzuki *et al.* (1985) proposed that this kind of hilly relief is controlled by a combination of rock strength and permeability, irrespective of rock type.

Within the depression and the Awa Hills, the sediments that were accreted from the south since 16 Ma are deformed by east-west trending thrust faults and folds (Figs. 1 and 2). The lower part of the accretionary complex is the Hota Group (16 Ma to 10 Ma), which is exposed and severely fractured within and around the depression. The Hota Group is underlain by sedimentary rocks of the Paleogene Mineoka Group, which was intruded by ultramafic rocks (serpentine) and basalt during the Early Miocene (Arai *et al.*, 1983). Such intrusions of ultramafic rocks possibly occurred along the transform boundary between the Philippine Sea Plate (PHS) and the Eurasian Plate (EUR), while the subsequent subduction of the PHS beneath the EUR generated the accretionary complex currently exposed on the peninsula (Arai, 1991).

The Mineoka Mountains largely coincide with the distribution of the Mineoka Group. The southern geomorphologic lineament of the depression is marked by the Sorogawa Fault, which extends from Iwai to Kamogawa within the Hota Group. The northern topographic lineament corresponds to the boundary between the Miura and Hota Groups.

III. Seismic lines and data acquisition

We set the main seismic reflection line, KAMOGAWA 2000, across the southern margin of the depression (Fig. 2), with a second line, NAKANE 2000, set across the northern margin of the depression by Chiba Prefecture (2001, Fig. 5). Basic data acquisition for each experiment is

Fig. 2 Geology in the vicinity of the seismic reflection survey (KAMOGAWA 2000) Based on Mitsunashi and Suda (1980) and our geologic study. Line A—B and Line C—D are the location of the jointed cross-section in Fig. 6.

described in Table 1, while data processing common to both experiments is shown in Fig. 3. Our procedure for data processing from vertical seismic profiling follows the general treatment described by Ikawa (1994).

The seismic line KAMOGAWA 2000 is 4.2 km long and oriented normal to the general east-west strike of geologic structure in the study area. The line extends through the Mineoka and Hota Groups and the main thrust (Sorogawa Fault), and is therefore the most suitable orientation for geophysical interpretations of subsurface structure. NAKANE 2000 is 0.9 km long and is also oriented normal to the main geologic structure of the Miura and Hota Groups.

This line was selected to reexamine the occurrence of morphotectonic deformation of Holocene fluvial terraces of the Machizaki River across the estimated fault trace along the northern lineament.

IV. Geologic interpretation of seismic data

Time-migrated sections on seismic images were converted to depth sections on the basis of velocity analysis from data processing, as shown in Fig. 4 (left-hand figure) for KAMOGAWA 2000 and Fig. 5 (lower figure) for NAKANE 2000. We describe the geologic interpretation along seismic lines below.

Table 1 Specification of the seismic reflection experiments

Seismic line		KAMOGAWA 2000	NAKANE2000 (Chiba Pref.,2001)
Line length		4.2km	0.9 km
Data acquisition	Energy source	1 Vibroseis	1 Minivibrator
	Number of sweep	16	2
	Sweep length	16 sec	10 sec
	Shot interval	50m	5m
	Number of channels	168	118
	Sweep frequency	8-45 Hz	20-120 Hz
	Peculiar frequency	10 Hz	10 Hz
	Geophone interval	25 m	5 m
	Sampling interval	4 msec	1 msec
	Record length	8 sec	1 sec
Recording system		GDAPS-3 (JGI Inc.)	StrataViewR60 (Geometrics Inc.)

Fig. 3 Data processing flow in the seismic reflection experiments

KAMOGAWA 2000

Two distinct reflective events are recognized in Fig. 4: a south-dipping event with parallel reflective layers below RP.160-115 to 2,000 m

depth, and a north-dipping event with parallel reflective layers below RP.33-1 to 2,800 m depth. Both events face each other below RP.115-33, forming a prism where reflective signal is scattering.

The upper part of the south-dipping layered event is concordant with the geologic boundary between the Mineoka Group and the Furubo Formation of the Hota Group. As the Mineoka Group is also south-dipping along the seismic line, the seismic event is possibly correlated with the Mineoka Group. Such an interpretation indicates that the southern margin of the Mineoka Group is not structurally vertical, but dips to the south.

The northern end of the north-dipping reflective event is considered to represent the Sorogawa Fault developed between the Furubo and Nabuto Formations of the Hota Group, as determined by extrapolation on the basis of the dip of the outcropping reverse fault around RP. 33. South of the Sorogawa Fault, outcrops of the Hota Group are complexly folded, but these folds do not affect the north-dipping event at depth. Three oblique structures are identified within the north-dipping event, which are reasonably recognized as faults F1, F2, and F3. Extrapolating these structures toward the surface on the basis of their observed dips, they correspond to reverse faults within the southern part of the Hota Group. These geologic structures produced asymmetrical south-verging anticlines above the reverse faults. Such an accumulation of similar sedimentary units is characteristic of accretionary complexes.

A further intensive reflective event is clearly identified at depths of 1,000–2,000 m beneath the northern end of the seismic line. The surface equivalent of this event is estimated to appear in the central part of the Mineoka Group, extrapolating the south-dipping in the event. Ultramafic intrusives and basalt are distributed east of the seismic line within the Mineoka Group (Fig. 2). As a high contrast in impedance is expected between ultramafic rock and sedimentary rock of the Mineoka Group, the event possibly represents an ultramafic rock body concealed beneath the Mineoka Group.

NAKANE 2000

A gently folded structural event is recog-

Fig. 4 Seismic depth section (left) and its geologic interpretation (right) on the KAMOGAWA 2000 line

nized at 0–200 m depth beneath RP.20–140 (Fig. 5). Discontinuities in the seismic image are not recognized beneath RP.140 or the surrounding area where Murai and Kaneko (1975) identified a fault line. The part shallower than 0 m is parallel to the surface, but is not affected by tectonic deformation. Interval velocity analysis indicates a marked difference in P-velocity between the upper layer (1,400–1,600 m/s) and the lower layer (>2,000 m/s). On the basis of stratigraphy and drill-core data (Chiba Prefecture, 2001), the upper layer is correlated with Quaternary sediments, while the lower layer is correlated with the Hota Group (Kamikawa Formation). Sandstone and mudstone of the Amatsu Formation (Miura Group) crop out along the northern end of the seismic line from RP.140. The geologic relationship between the Amatsu and Kamikawa Formations is not clear from the seismic image.

V. Discussion

1. Is the Kamogawa Graben structure a tectonic graben?

The east-west trending depression between the Kazusa Hills and the Awa Hills is bounded by topographic lineaments (Fig. 1), and has been termed the Kamogawa Graben. Holocene coastal and fluvial lowlands are locally distrib-

uted only in coastal areas at Kamogawa, Hota, and Iwai. The Mineoka Mountains comprise Paleogene rocks and occupy a wide area of the depression. The southern lineament bounding the depression is indeed coincident with the surface trace of the Sorogawa Thrust Fault, although the sense of displacement across the fault is inconsistent with the recorded subsidence of the graben at the foot of the lineament (Fig. 6). These observations suggest that the depression that is termed the Kamogawa Graben is not a tectonic graben.

Several studies have documented the offset of fluvial terraces and alluvial fans across the Sorogawa Fault (Nakajima *et al.*, 1981; Sangawa *et al.*, 1982; The Research Group of Active Faults of Japan, 1991; Shishikura *et al.*, 1999). In particular, vertical offset of Holocene fluvial terraces along the Heguri River has been used as a basis for identifying fault activity. Chiba Prefecture (2001) re-investigated the activity of the fault by trenching at Hegurishimo and geophysical investigations near Iwai, but in contrast to Sangawa *et al.* (1982) and Shishikura *et al.* (1999), determined zero positive offset of fluvial terraces. In addition, seismic reflection images of the northern part of the fault showed no traces of a graben structure. Along the Sorogawa Fault close to the

Fig. 5 Geomorphology (upper), profile of fluvial terrace (center) from Shishikura *et al.* (1999) Seismic depth section and its geologic interpretation (bottom) of the NAKANE 2000 line by Chiba Prefecture (2001). RP : receiver point.

KAMOGAWA 2000 line, positive and cumulative tectonic topography are not recognized in the sense that the southern part is upthrown. This argues against the existence of a graben developed within the geological succession, and indicates that the Sorogawa Fault has been inactive at least since the late Quaternary.

Along the Machizaki River, across the northern lineament, Holocene fluvial terraces occur at four levels (Fig. 5, upper figure). These terraces are not offset along the line where the fault is expected to intersect with the surface, as evident from the flat profile of the highest Kamogawa I surface at *ca.* 7 ka (Fig. 5, middle

Fig. 6 Estimated geologic structure along N-S section and paleogeomorphology before differential erosion in the southern Boso Peninsula

The line of section along A–B–C–D is shown in Fig. 2.

figure). Shishikura *et al.* (1999) describe an absence of fault movement around the northern lineament during the late Holocene. Based on a geologic interpretation of the seismic image (Fig. 5, lower figure), no dip-slip fault is recognized at the expected site of the fault line. The very thin nature of the Quaternary sediments indicates that cumulative tectonic subsidence has not occurred within the lowland area around Kamogawa. Shishikura (2000MS) further noted that discontinuous displacement related to faulting is not evident in Holocene paleoshorelines that cross the northern lineament at Hota. These observations demonstrate that the northern section of the lineament preserves no record of a tectonic graben related to active faulting (Fig. 6).

On the basis of the above data, we consider that the 15-km-wide area between the Kazusa Hills and the Awa Hills is not a tectonic graben. This area is also not a geomorphological lowland, as the area is dominated by hilly relief and the Mineoka Mountains, except for a small area of coastal lowlands (Fig. 2, upper figure). Consequently, we conclude that the term “Kamogawa Graben” is unsuitable to describe the observed topographic feature.

2. Structurally controlled geomorphic evolution

To understand why of the term graben has been misapplied in this case, we need to consider the geomorphic evolution of the area in terms of the relationships between erosion, lithology, and geologic structures. In particular, we concentrate on how the topographic lineaments came to represent the boundaries be-

tween areas of contrasting topography in the study area.

The southern lineament from Iwai to Kamogawa coincides with the surface trace of the Sorogawa Fault (Fig. 1). The fault trace is characterized by narrow valleys and a 200-m-high scarp near the west coast of the peninsula. As no cumulative tectonic displacement is observed, the narrow valleys are considered to be erosional features. Along the eastern part of the fault, the upthrown side of the fault comprising shale of the Furubo Formation is contact with mudstone of the Emi Formation and tuffaceous sandstone and shale of the Nabuto Formation (Fig. 2). Field observations indicate that shale of the Furubo Formation is more weathered and sheared than sediments of the Emi and Nabuto Formations. Similar patterns of weathering are recognized along the Iwai Fault—the western extension of the Sorogawa Fault—where the upthrown side comprises shale of the Hota Group and the downthrown side comprises tuffaceous sandstone of the Kagamiura Formation and mudstone of the Amatsu Formation (Otuka, 1949 ; Fig. 1). These observed relationships between morphology and lithology indicate that weathering condition rather than lithology is the dominant control on the development of differential erosion, especially the degree of weathering of shale. This differential erosion of shale appears to have generated the fault-line valleys and the 200-m-high north-facing scarp.

On the basis of the geomorphic evolution of the area, we consider that some of the rivers that flow south across the Sorogawa Fault (Fig.

1) predate the formation of the fault-line valleys. In other words, the relatively old south-flowing rivers are considered to reflect the direction of maximum dip of the paleo-topographic high. This interpretation implies that mountainous topography existed prior to the initiation of erosion (Fig. 6). Otuka (1949) first suspected such a history of river system development, and presented the hypothesis that differential erosion generated the obsequent fault-line scarp via significant erosion of shale of the Hota Group within the mountainous paleotopography.

In terms of the northern lineament, a fault plane susceptible to erosion is not geologically recognizable along the predicted trace of such a fault line (Fig. 1). The seismic imaging data and presence of non-deformed fluvial terraces also argue against the existence of active faults along the northern lineament (Fig. 5). Although the 200-m-high south-facing scarp along the lineament resembles a fault scarp, especially at the eastern and western ends of the lineament, field evidence and geophysical data do not support a fault origin for the scarp.

We now consider an alternative model of scarp formation. Mudstone (Am and Kn) of the Miura Group is exposed within the scarp and in the Kazusa Hills, while severely fractured shale (Kk and Fk) of the Hota Group is exposed within the lowland at the foot of the scarp (Figs. 1 and 2). In other words, weathered Hota Group has been lowered to the topographic surface of the Miura Group. This indicates that the Miura Group is more resistance to erosion than the Hota Group. Such a contrast in weathering has possibly affected the nature of erosion along the contact between the two groups, which in turn has led to the formation of a 200-m-high south-facing erosional scarp.

Considering the location of the Mineoka Mountains and the pre-erosion topography, a mountainous paleo-topography is estimated to have extended from the Kazusa Hills to the Awa Hills, probably during the early Quaternary (Fig. 6). Subsequently, the structural control of differential erosion of mudstone has likely resulted in lowering of the Hota Group surrounding the Mineoka Mountains, which consists of intrusive rocks.

Based on measurements of rock properties, Suzuki *et al.* (1985) successfully argued that the relationship between morphology and lithology in the Kazusa Hills is controlled by the physical strength and permeability of bedrock. Similar bedrock-controlled erosion may also occur in the present study area, reflected by differential weathering processes within otherwise similar sedimentary rocks. To obtain further insight into such a process, it is necessary to analyze the micro-scale physical and chemical properties of shale, mudstone, and sandstone samples. In particular, it is important to understand the origin and development of weathering (fracturing) in shale, irrespective of age.

VI. Concluding remarks

On the basis of studies of active faults over recent decades, the so-called Kamogawa Graben has been interpreted as a typical tectonic graben, while other studies have interpreted the graben as a product of differential erosion. Previous studies have failed to provide conclusive evidence in favor of either of the competing hypotheses. With the help of seismic reflection profiling that provides subsurface data, we have successfully explained the apparent graben as the result of geomorphic evolution by structural control.

1. Seismic images argue against the existence of a tectonic graben within the depression between the Kazusa Hills and the Awa Hills, southern Boso Peninsula. The cumulative movements of active faults described in previous studies are not supported by geomorphological data from the present study, and substantial lowland areas do not exist except for in small areas near the coast.

2. The topographic lineaments previously interpreted as active fault traces originated from differential erosion. The northern lineament is mostly observed as a south-facing erosional scarp where fractured shale of the Hota Group has been eroded relative to mudstone and sandstone of the Miura Group. The southern lineament is mostly observed as a fault-line valley, partially by the obsequent scarp along the Sorogawa Fault that developed between shale and mudstone-sandstone of the Hota

Group. The development of differential erosion probably stems from the different degrees of resistance to weathering of shale, mudstone, and sandstone.

3. South-flowing rivers that cross the fault-line valleys predate these structures. The early river system therefore developed upon the mountainous pre-erosion topography that overlaid the present Mineoka Mountains. We conclude that such a geomorphic evolution of the southern Boso Peninsula is structurally controlled.

By taking advantage of geophysical exploration tools, we have advanced the long-standing debate concerning whether the Kamogawa Graben is tectonic in origin; however, our work has also raised the question of the nature of the erosion process related to weathering. This question must be addressed to fully comprehend the evolution of the structurally controlled geomorphology. A micro-scale analysis of physical and chemical properties is necessary to understand the different weathering properties of shale, mudstone, and sandstone.

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References

- Arai, S. (1991) The Circum-Izu Massif peridotite, central Japan, as back-arc basin mantle fragments of the Izu-Bonin arc system. Peters, T. *et al.* (eds.) *Ophiolite genesis and evolution of the oceanic lithosphere* : 807-822, Kluwer Acad. Pub.
- Arai, S., Ito, T. and Ozawa, K. (1983) Ultramafic-mafic clastic rocks from the Mineoka Belt central Japan. *Journal of the Geological Society of Japan (Chishitsugaku-Zasshi)*, 89, 287-297. (J+E)
- Chiba Prefecture (2001) The 2000 reports on the synthesized survey on the Kamogawa fault zone. 142p, Chiba Prefecture.
- Cotton, A. (1942) *Geomorphology*. 215p, Whitcombe & Tombs.
- Ikawa, T. (1994) Exploration of subsurface structures : Reflection seismic method and VSP (vertical seismic profiling). *The Journal of the Seismological Society of Japan (Zishin)*, 47, 103-112. (J+E)
- Illies, J.H. (1974) *Approaches to taphrogenesis*. 167p, Nagele und Obermiller.
- Ishiyama, T., Mueller, K., Togo, M., Okada, A. and Take-mura, K. (2004) Geomorphology, kinematic history, and earthquake behavior of the active Kuwana wedge thrust anticline, central Japan. *Journal of Geophysical Research*, 109, B12408.
- Ito, T., Ikawa, T., Ikuhisa, A., Isezaki, N., Hirata, N., Asanuma, T., Miyauchi, T., Matsumoto, M., Takahashi, M., Matsuzawa, S., Suzuki, M., Okuike, S., Kimura, G., Kunitomo, T., Goto, T., Sawada, S., Takeshita, T., Nakaya, H., Hasegawa, S., Maeda, T., Murata, A., Yamakita, S., Yamaguchi, K. and Yamaguchi, S. (1996) Geophysical exploration of the subsurface structure of the Median Tectonic Line, East Shikoku, Japan. *Journal of the Geological Society of Japan (Chigaku-Zasshi)*, 102, 346-360. (J+E)
- Kotake, N. (1988) Upper Cenozoic marine sediments in southern part of the Boso Peninsula, central Japan. *Journal of the Geological Society of Japan (Chigaku-Zasshi)*, 94, 187-206. (J+E)
- Mitsunashi, S. and Suda, Y. (1980) Geological map of Japan 1 : 200,000 : Yokosuka. Geological Survey of Japan. (J+E)
- Murai, I. and Kaneko, S. (1975) Distribution of active faults in the south Kanto. The analysis of natural hazard data (Sizensaigai-siryō-kaiseki), 2, 77-83. (J)
- Nakagawa, H. (1961) On the cuesta topography of the Boso Peninsula, Chiba Prefecture, Japan. *Science Reports of Tohoku University, 2nd Ser. (Geology)*, spec. 4, 385-391.
- Nakajima, T., Makimoto, H., Hirayama, J. and Tokuhashi, H. (1981) Geology of the Kamogawa district. *Quadrangle Series, 1 : 50,000*, 48p, Geological Survey of Japan. (J+E)
- Otuka, Y. (1949) A sample of subsequent fault-line scarp. *The Monographs of the Otsuka Geographical Association (Otsuka-Chirigakkai-Ronbunshu)*, 79-84. (J)
- Sangawa, A., Kakimi, T., Kato, K., Shimokawa, K. and Tuchiya, N. (1982) Active faults in the southern part of Boso Peninsula, Japan. *Programme and abstracts the Seismological Society of Japan 1982 fall meeting*, 1, 176. (J)
- Sato, H. and Hirata, N. (1998) Deep seismic structure and the evolution of Japanese islands. *Science (Kagaku)*, 68, 63-71. (J)
- Sato, H., Hirata, N., Koketsu, K., Okaya, D., Abe, S., Kobayashi, R., Matsubara, M., Iwasaki, T., Ito, T., Ikawa, T., Kawanaka, T., Kasahara, K. and Harder,

- S. (2005) Earthquake source fault beneath Tokyo. *Science*, 309, 462–464.
- Shishikura, M. (2000MS) Holocene seismotectonics in the southern part of Boso Peninsula, central Japan, analyzed by height distribution and ages of emerged shoreline topography. Doctoral dissertation to Chiba University, 65p.
- Shishikura, M., Goto, Y., Kanai, K. and Miyauchi, T. (1999) Holocene activity of the northern and southern marginal faults of Kamogawa Graben in the Boso Peninsula, central Japan. *Active Faults Research (Katsudanso-Kenkyu)*, 18, 23–30. (J+E)
- Suzuki, T., Tokunaga, E., Noda, H. and Arakawa, H. (1985) Effects of rock strength and permeability on hill morphology. *Transactions, Japanese Geomorphological Union*, 6, 101–130.
- The Research Group of Active Fault of Japan (1991) *Active faults in Japan sheet maps and inventories*. 438p, University of Tokyo Press.
- Willis, B. (1928) The Dead Sea problem, rift valley or ramp valley. *Bulletin of Geological Society of America*, 39, 385–392.
- (J) in Japanese, (J+E) in Japanese with English abstract.

房総半島南部の組織地形とその成立過程

—反射法地震探査からのアプローチ—

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〔要 旨〕

地溝は、縦ずれ断層によって形成された地形的凹地として、地質学的に定義されるものである。房総半島南部には、地形学的にも地質学的にも十分な検証がなされないまま、地溝の典型として“鴨川地溝帯”という名称が使用されてきた。地形学的・地質学的資料に反射法地震探査法を適用して、それが地溝かどうか？について再検討を行い、房総半島南部の地形が構造運動によるものではなく、組織地形として成立してきた可能性について考察した。その結果、反射法探査イメージには地溝の地質構造がみえないこと、これまで活断層とされてきたリニアメントに沿って累積的な変位や沈降がみられないことから、いわゆる鴨川地溝帯の実体はないことが判明した。上総丘陵と安房丘陵の間にある、みかけの凹地を画する2つのリニアメントは、断層線谷や逆断層線崖などの組織地形の様相を示す。北側のリニアメントに沿っては、そのような侵食地形が破碎した保田層群の頁岩と

三浦層群の泥岩の接触部に発達する。南側のリニアメントでは、その地表トレースは曾呂川断層と一致し、断層を境にして接する保田層群の頁岩同士、あるいは頁岩・砂泥岩との接触部に沿って、侵食地形が連続する。これらは、差別侵食がそのような場所に発生し、岩石における抵抗性の違いに由来する地溝状の凹地を生み出したことを示唆している。とくに、風化の著しい頁岩部における選択的侵食低下が著しい。推定される古水系や逆断層線崖の存在に基づく、かつて現在の嶺岡山地をおおう山地が存在し、その斜面上に必従河川の水系が発達していたと考えられる。このように、房総半島南部の地形は、地質構造や岩石(地層)の性状に大きくに影響を受けた組織地形として成立してきたものであり、鴨川地溝帯とされてきた地形は地溝ではなく、組織地形の一部と考えられる。

キーワード: 地溝, 組織地形, 差別侵食, 房総半島, 反射法地震探査

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