Landform and Weathering of the Chugoku Mountainous Region (Japan)

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Abstract

Chugoku District is characterized by gently undulated mountains in which three flatland levels are differentiated. The largest flatland level, the so called "Kibi Highland Level", is a presumed elevated peneplain. Deep weathering of different kinds of rocks and sediments in Chugoku District, which has been noted for many years, was found to be tightly associated with the flatland levels.

Introduction

Steep landforms in Japan Islands were made by the upheaval movement which was accompanied with abrupt mountain buildings since Quaternary. The amount of debris flows caused by the slope erosion is one of the largest throughout the world. In Chugoku District (Fig. 1), however, elevation is rather low and basement emergence is least in Japan Islands. There is a mountain chain called Chugoku Mountains which extends east and west, wide highland areas around it, and narrow lower flatlands along the coast. It forms a gently-sloping landform as a whole and wherein three flatland levels (upper, middle, and lower) are observed.

Chugoku District consists of volcanic rocks, granitic rocks, and sediments. It is notable that granitic rocks are widely distributed. Thick weathering layers of granitic rocks, which cause large landslide disasters, are frequently observed. Extensive investigation of weathered rocks throughout Chugoku District indicated a close relationship between the distribution of rocks (any kind in igneous, sedimentary, or metamorphic rocks) and the flatland levels.

Islets in Hiroshima Bay, composed of granitic rocks, look like volcanic islands from their conical shape. Slopes of the mountains along the bay show smooth variations which give a wonderful landscape.

In the lower and middle flatland levels, and also sometimes on hilltops and in valleys of the same elevation, least selected sand-gravel sediments, sometimes containing striated gravel layers, are distributed. These sediments may form "Kusari-reki" (weathered gravel). It is fascinating to observe erratic blocks and smooth base rocks

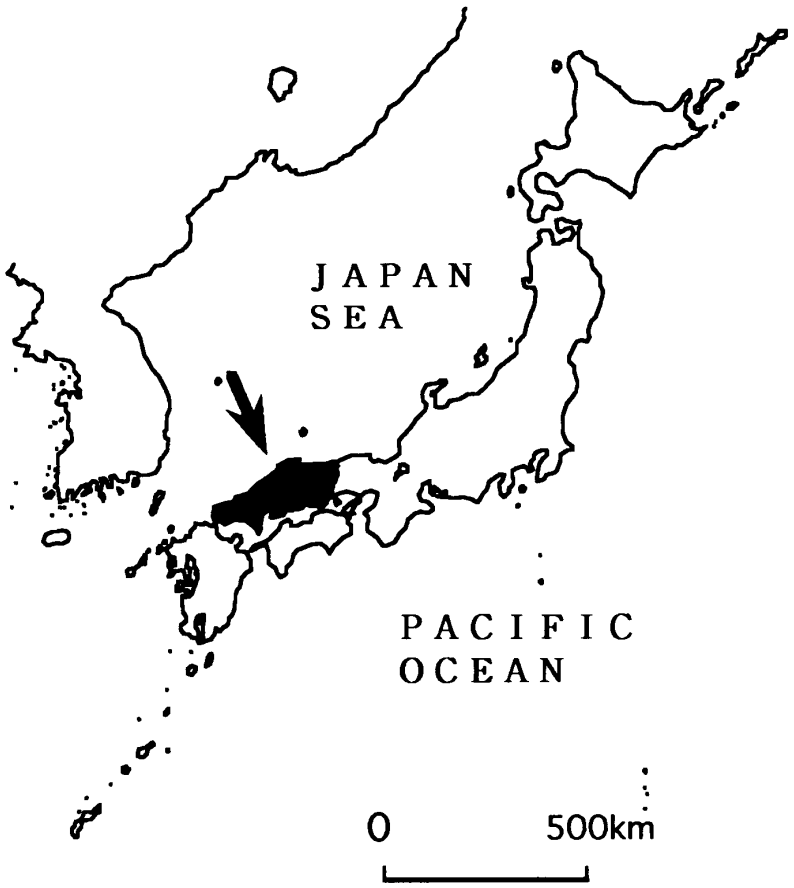

Fig. 1 Location map of Chugoku District.

in these levels, along with red soil layers with scarce continuity.

Geology in general

Geology of Chugoku District is almost composed of granitic rocks and diorites of Late Cretaceous to Palaeogene and volcanic rocks as follows: gabbro, granitic porphyry, rhyolite, andesite, and dacite (Fig. 2). In the northern side of the backbone, volcanic rocks such as andesite, rhyolite, and dacite of Neogene are widely distributed, along with hornblende andesite of late Pleistocene to Holocene. Geology of the southern side of the backbone is rather complicated. Sediments composed of limestone, mudstone, sandstone, chert, basalt, and sometimes ultramafic rocks and gabbro of Paleozoic to Mesozoic are distributed in relatively wide areas, along with high-pressure type metamorphic rocks consisting of crystalline schist and phyllite. In the inland areas, sediments composed of marine sandstone, mudstone, conglomerate, and tuff, and lacustrine sediments of early Pleistocene are distributed. Oki Islands in Japan Sea are mainly made of andesite and rhyolite of Miocene, rhyolite and alkali basalt of Pleiocene to Early Pleistocene, and metamorphic rocks such as crystalline schist. Islands and islets in Seto Inland Sea are mainly made of granitic rocks of Late Cretaceous to Early Paleogene. Sediments of Paleozoic to Mesozoic are infrequently observed as roof pendants. They formed hornfels by the cotact metamorphism. Around

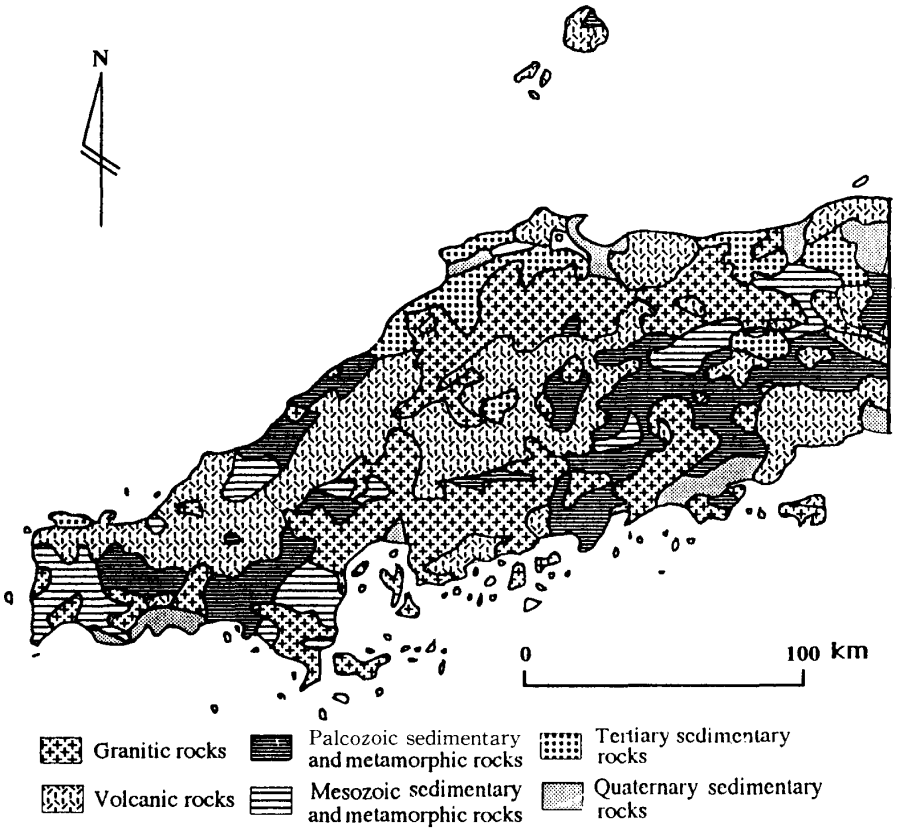

Fig. 2 Geological map of Chugoku District (After Geological Atlas of Japan 1992).

a mouth of a large river, alluvium made of sand, mud, and gravel was developed.

Landform and deep weathering area

1) Characteristic Feature of the Landform

Landforms of Japan Islands were profoundly affected by the diastrophism of Quaternary, particularly the block movement which began in Middle Quaternary and accompanied faults. Abrupt emergence and submergence of the basement and the subsequent erosion made steep mountainous landforms with small flatlands. As a result, association of deep weathering and landform has been hardly observed in Japan Islands.

Chugoku Mountains are rather gently sloping compared with the rest of mountainous areas in Japan Islands, and particularly a flatland level called Kibi Highland Level is widely distributed. This flatland level is defined as gently sloping areas with 400-600 m above sea level.

Peaks in Chugoku Mountain Chain are flat peaks with around 1000 m above sea level. Flatland level of this height is called Dohgoyama Level. Another flatland level is Setouchi Level, which is lower than Kibi Highland level with less than 300 m above sea level, mostly distributed along Seto Inland Sea. Landform of Chugoku District is thus divided into three flatland levels, higher level (Dohgoyama Level), middle level (Kibi Highland Level), and lower level (Setouchi Level) (Fig. 3).

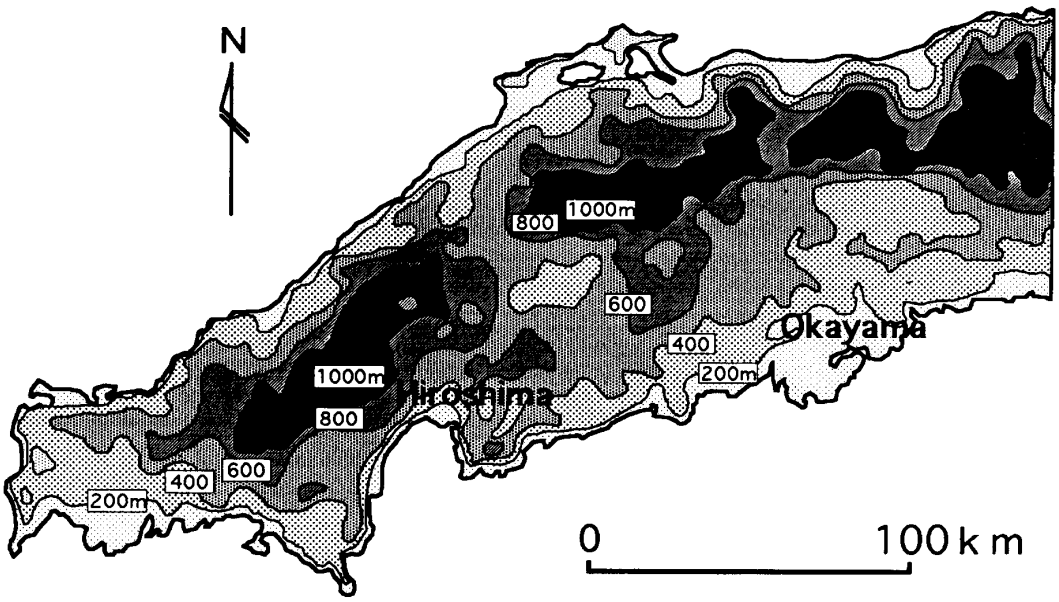

Fig. 3 Topographic map of Chugoku District. (contour lines depicted, 200 m each). The largest flatland level (400～600 m), called Kibi Hignland Level (middle level), is a presumed elevated peneplane.

2) Deep Weathering Area

Deep weathering areas in Hiroshima Prefecture were investigated in detail as follows:

Kamo Platform (Setouchi Level): Kamo Platform, also called Saijo Basin, has besement rocks mainly composed of granitic rocks. The grater part of this platform is covered by lacustrine sedimants. In the basin, both exposed granitic rocks and the covering lacustrine sediment are extensively weathered, 50-60 m in depth. It should be noted that, in the thick lacustrine sediment which covers the basement rocks (mainly granitic rocks), the lower part remains as a fresh sand gravel layer, while the upper part is extensively weathered. Another remarkable point is that granitic rocks beneath the least weathered sand gravel layer (lacustrine layer) are weathered to some extent.

Itsukaichi and Its Surroundings (Setouchi Level): Another thick layer of weathered granitic rocks is observed in Itsukaichi, which is located in the piedmont of Suzugamine Mountain near Hiroshima Bay. A physical survey of geology around Itsukaichi, accompanied with tunnel construction of the San'yo bullet train, revealed a relatively horizontal extension of the weathering front, not correlating with the surface undulations. This suggests a tight association of deep weathering and flatland levels.

Sera Platform (Kibi Highland Level): Sera Platform which is adjacent to and 100-150 m higher than Saijo basin has a deep weathering layer, too. In the northern part of the platform, a flatland level called elevated peneplain is well preserved. Basement rocks of Sera Platform are composed of igneous rocks of Cretaceous and Paleozoic sediments. In the northern part, Kohtachi Gravel Layer (which includes pebbles, sands, and muds) of Quaternary are spread belt-wise as if they were plugging the valleys formed

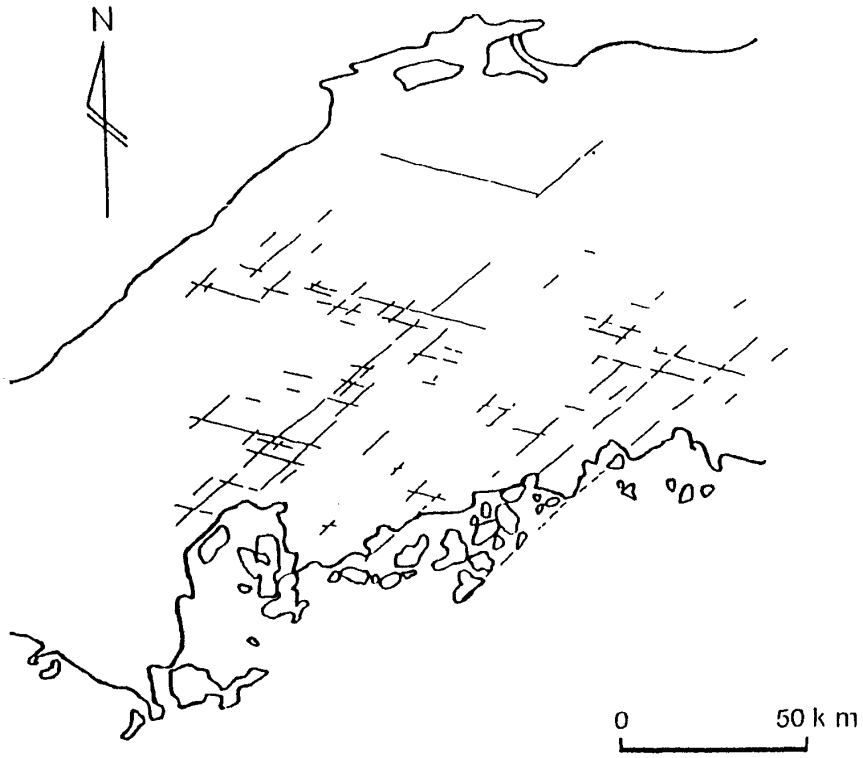

Fig. 4 Direction of major valleys.
As a result of east-west compression held in Middle Pleistocene, conjugate faults NE-SW and NW-SE directions formed rhombic blocks.

in the flatland levels. The grater part of this gravel layer is least selected. It includes various types of rocks most of which are round gravels. Both exposed basement rocks and Kohtachi Gravel Layer form a thick weathering zone (weathering layer). In areas where the thickness of the weathering reaches around 50 m the gravels are extensively weathered so that they form so-called "Kusari-reki" (weathered gravel). In the upper part of the weathered layer, red or red brown-colored zone (so-called red weathering zone) are observed both in the basement and in the gravel layer.

Andesite and rhyolite in the central area of Sera Platform are also extensively weathered. On the south end of Sera Platform, around Kui-cho Town, the landform is slightly sloped and the weathering layer is extremely thin, allowing the exposure of the basement granitic rocks. Small hills with relative height of 20-30 m are scattered in this area. Okamoto (1963, 1967) found an evidence of glaciation of the last glacial epoch in the geology of Kui-cho Town.

Kibi Highland close to the Backbone Mountains (Kibi Highland Level): In the vicinity of ToJo-cho Town, granitic rocks, serpentinite, peridotite, andesite, and various sediments of Paleozoic are distributed. All of these rocks show extensive chemical weathering, which results in the formation of viscous chemical weathering zone. Another example of extensive chemical weathering is observed in rhyolite in the vicinity of Shobara City and Miyoshi City.

Thick weathering layers in slightly undulated flatland levels are frequently observed

also in other parts of Chugoku District, that is, in Okayama and Yamaguchi Prefecture (abjacent to Hiroshima Prefecture) as well as in the north side of the backbone mountains (Shimane and Tottori Prefecture).

Formation of landform and development of weathering

Kotoh (1908) proposed that Kibi Highland Level is an elevated peneplain for the first time (quoted from Obata 1991). Presently it is considered that Chugoku District as a whole is a slightly undulated peneplain formed by Early Miocene, Neogene. The residue of peneplain remains in the flat peaks of the backbone mountains (Obata, H. 1991). Distribution of marine sedimentary layer in the backbone indicates the submergence, followed by the uplift in Late Miocene and the formation of primordial Chugoku Mountains extending east and west, accompanied with thrust faults in the south rim of the backbone. Mountains north of the fault scarp were gradually elevated. In Middle Pleiocene peneplaination proceeded in the Kibi Highland areas. Another uplift involving the whole Chugoku District began after the formation of Kibi Level, leading to Kibi Highland Level. Surrounding Kibi Highland Level, a lower flatland level, Setouchi Level, was formed in Late Pliocene. Weathering proceeded in these flatland levels, leading to the formation of deep weathering layer.

A supposed energy source which caused these basement movement is north-south compression of Philippine Sea Plate. It is assumed that a warping movement which made the backbone anticlinal, Miyoshi/Tsuyama Basin synclinal, Sera Platform/ Kamo Platform anticlinal, Seto Inland Sea synclinal (north to south in order), respectively, led to the emergence of the backbone and submergence of Seto Inland Sea. Further weathering presumably proceeded in the flatland levels formed in the inland areas. In Pleistocene, Quaternary, north-south compression by Philippine Sea Plate was replaced by east-west compression by Pacific Plate, which affected Chubu, Kinki, and Chugoku District. Due to this compression, sedimentary basins extending east and west were separated by highlands running north and south. In Middle Pleistocene, the east-west compression reached to the climax, resulting in the formation of conjugate faults from the basement fold, running NE-SW and NW-SE directions. As a result, rhombic blocks were made. It is thus assumed that primordial block landform of Chugoku District was made in this geological age, by emergence, submergence, or tilting of individual blocks (Kakitani, S. 1974, Fig. 4). Erosions may have proceeded in cliffs and fracture zones made by this movement. In flatlands, on the contrary, further weathering must have proceeded, contributing to the increase in the thickness of the weathering layer.

There were presumably much less movements following the big movements held in Middle Pleistocene. In the end of Pleistocene, Philippine Sea Plate was reactivated, leading to the elevation of both Kibi Highland Level and Setouchi Level. This series of movements are supposed to contribute to the formation of characteristic landforms of Chugoku District which has small plain areas and large highland areas.

Conclusion

Granitic rocks, bringing of new and old ages together, are widely distributed throughout Chugoku District. Weathering layer of granitic rocks in the deep weathering area is notably thick. A kind of decomposed granite known as "Masatsuchi" is a typical example. This has been noted by its association with landslide disasters, and also with mining of mountainous iron sands which were collected from the deep weathering layer of granitic rocks. This investigation over status of weathered rocks in Chugoku District, particularly in Hiroshima Prefecture, revealed an extensive weathering of all kinds of rocks distributed in gently sloping flatland levels, whereas thickness, mineral composition, and physicochemical properties vary according to rock species. It was thus concluded that deep weathering is tightly associated with flatland levels in Chugoku District.

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