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By

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POSTCRANIAL SKELETONS OF JAPANESE DESMOSTYLIA

LIMB BONES AND STERNUM OF *DESMOSTYLUS* AND *PALEOPARADOXIA*, WITH CONSIDERATIONS ON THEIR EVOLUTION

By

Tokio SHIKAMA

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CONTENTS

I. Introduction

The Desmostylia are a special group of mammals which was convergently studied especially in the first half of this century by highly competent investigators of the world in its taxonomical situation. Many opinions offered to its position of Order, such as Monotremata, Multituberculata, Marspialia, Proboscidea and Sirenia, etc. G. SIMPSON's treatment (1945) which put it as Sirenia might represent large parts of different opinions. W. GREGORY's interpretation (1951) was also the same. V. L. VANDERHOOF (1936-42) and R. H. REINHART (1953-59) are the most noteworthy contributors to the general researches of these interesting mammals. Despite the abundant occurrences of isolated teeth in the Pacific coast of the U. S. A. and their wide distribution in the North Pacific Region, the occurrence of fossil skeletons was extremely rare except for a very few fragmental bones. T. NAGAO and S. OISHI's discovery of desmostylid skeleton in 1933 from South Saghalien was hence a centre of keen attention from these viewpoints. NAGAO devoted his life to this study, but his death in 1943 was a great loss to this branch of study, especially for Japanese palaeontologists. After the Great War, in 1950 *Desmostylus* Research Committee (DEREC) was organized by H. YABE, F. TAKAI, S. IJIRI, M. MINATO and the present writer with YABE as the chairman. In the same year the second discovery of a skeleton of desmostylid (*Paleoparadoxia tabatai*) was done from Izumi, Gihu Prefecture and the specimens were submitted to the study of the committee. IJIRI took charge of the skull, the writer was in charge of limb bones and sternum, and TAKAI the other parts. From 1950 to 1953 the committee did an active research work but afterwards it stopped its official activity owing to a cause not to be published. In 1961 IJIRI and T. KAMEI published the results of their studies of skulls. Although the present writer's item of researches has a close relationship with that of TAKAI, he is going to publish his results tentatively and independently as his work confronts rather a difficult situation. It is indispensable to do a comparative study with the Stanford skeleton recently found in America, but he is going to put forth this for the sake of his further study.

Here the writer extends his cordial thanks to Emer. Prof. H. YABE, Professors F. TAKAI, M. MINATO, S. IJIRI for their kind cooperation and valuable assistance. His special appreciation is offered to Mr. Y. HASEGAWA of the National Science Museum of Tokyo who rendered help to his study in many ways (cleaning, reconstructing, mounting, modeling and photographing materials etc.) during his service at Yokohama National University as assistant to the writer. His sincere thanks are also due to many gentlemen who worked as assoiated members of DEREC, such as Prof. T. SAKURAI of Tokyo University, IWASAKI of the National Art Museum of Tokyo, Mr. Y. OUCHI, Mr. Y. EMOTO (in making preparations and modeling), Prof. K. HUZITA of Osaka City University, Dr. S. OGOSE of Tokyo University, Prof. K. WATANABE of Tokyo University of Education (in making a field survey) and Dr. K. CHINZEI (in doing cleaning and modeling), etc. Mr. S. TOMATSU, Mr. M. AZUMA, authorities of Provincial Office of Izumi-machi, Doki City, Gihu Prefecture, authorities of the educational committee of Gihu Prefecture, Prof. Y. SASSA, Mr. H. SATÔ and a group of gentlemen at Hokkaido University, Dr. H. OZAKI, Dr. I. OBATA, Dr. T. FUJIYAMA, Mr. T. TAKAGI and another group of gentlemen at the National Science Museum of Tokyo, Prof. W. HASHIMOTO and Dr. S. KANNO of the Tokyo University of Education, Prof. K. HATAI, Prof. K. ASANO, Prof. J. IWAI, Dr. S. HAYASAKA and the other members of the Institute of Geology and Palaeontology, Tôhoku University, Dr. T. HANAI, Dr. Y. IWASAKI, Mr. Y. TSUNEISHI, Mr. N. IKEYA of Tokyo University, Prof. K. HUZIOKA and late Prof. K. TAN of Akita University, Dr. S. FUJII of Toyama University, Dr. Y. KASENO of Kanazawa University, Dr. T. KAMEI of Kyoto University, Dr. A. MIZUNO and Dr. K. MATSUNO of the Geological Survey, Tokyo offered him many facilities for studying fossils. A number of geologists such as Prof. J. IWAI, Prof. R. IMAIZUMI, Prof. K. YAGI, late Dr. K. KOIKE, Dr. T. SHIBATA, Dr. M. ÔMORI, Dr. Y. SUZUKI, Dr. T. SAITO, Dr. N. KITAMURA, Dr. H. MATSUI and Prof. Y. KAMADA, cooperated with the writer in field works. The writer was able to gain much valuable information and suggestions on the stratigraphical, palaeontological and palaeoecological knowledge concerning the American desmostylids from the following scholars: Prof. R. A. STIRTON of the Museum of Palaeontology, University of California, Berkley, Dr. C. A. REPENNING of the Branch of Palaeontology and Stratigraphy, U. S. Geological Survey, Menlo Park, California and Dr. E. D. MITCELL of the Los Angeles County Museum. He also received kind help from Prof. A. K. ROZHDESTVENSKY of the Museum of Palaeontology, Academy of Sciences, Moscow. The writer is also greatly indebted to the authorities of the Educational Department, the Japanese Government and the Asahi Newspaper Company, Tokyo, who gave a substantial financial support to the work of DEREC and also to Prof. T. MATSUMOTO, Dr. I. HAYAMI, and the other distinguished members of the Palaeontological Committee of Science Council of Japan, the Palaeontological Society of Japan and of the Geological Society of Japan who offered their sincere support to the execution of this work.

II. Short History of Studies

In Japan desmostylid problem dates back to 1902 when S. Yoshiwara and J. Iwasaki reported a fossil skull of a large sized mammal of unknown type from Togari, Mizunami City, Gihu Prefecture. They regarded it as belonging to Proboscidea, with the powerful suggestion of H. F. Osborn, who in 1905 established a new family Desmostylidae for *Desmostylus hesperus* Marsh, 1888 from Albamada County, California and regarded it as a mixed type of Proboscidea and Sirenia. In 1914 S. Tokunaga (=S. Yoshiwara) and J. Iwasaki gave a new name, *Desmostylus japonicus* to the skull from Togari. *Desmostylus watasei* Hay, 1915 given to the Japanese species is a junior synonym of *japonicus*. In 1918 H. Matsumoto published an important paper on dentition morphology and systematics of *Desmostylus;* under the Osbornian influence he adopted the cusp nomination of teeth. L. Joleaud, 1920 referred *Desmostylus* to Sirenia living in littoral area of the Pacific and the American species smaller than the Japanese one as having migrated from Asia, while Vanderhoof, 1934 retained the opinion that the migration took place from America to Asia. O. P. Hay, 1923 classified Sirenia into Trichechiformes and Desmostyliformes, in which he included *Cornwallius* Hay with its type-species, *C. sookensis* Cornwall from Vancouver Island, British Columbia, Canada. It may be notable that A. S. Romer, 1933 put Desmostylidae in Subungulata.

The specimen described by Matsumoto, 1918 is a tooth from Kamikinebetsu valley, Obirashibetsu, Rumoe-gun, Western Hokkoido. Besides this he mentioned Yumachi, Shimane Pref., Yuda and Shikonai, Ninohe-gun, Iwate Pref. and Toshibetsu, Shiribeshi, Hokkaido as its localities. The tooth from Yumachi was already described by Yoshiwara and Iwasaki, 1914. In 1924, Y. Ozawa reported the occurrence of two demostylid teeth from tuffaceous conglomerate bed exposed in a tunnel between Aikawa and Sawane, Sado Island. The discoverer was H. Tabata, a highschool teacher. In 1928, S. Saheki reported a fragmental tooth from Aushi, Kurashi, Noda-machi, Southwestern Saghalien. The materials besides Saheki's tooth were stored in the Saghalien Museum in Toyohara (Yuzhino Sakhalinsk), Saghalin. F. Saito, 1929 wrote the stratigraphy of the locality, regarding the formation of desmostylid as a bluish grey sandy siltstone bed with many molluscan fossils. He also noted another desmostylid tooth found from a cliff along the Aragai River north of Aushi which was later destroyed in a fire. T. Nagao and Y. Sassa, 1933 referred to the occurrence of desmostylid from a manganese mine at Soikon (now Taisei-mura, Kitahiyama-machi), Setana-gun, Southwestern Hokkaido; they wrote that the bed is the Ogawa agglomeratic tuff bed of upper Kunnui Group. They also regarded the so called Toshibetsu desmostylid of Matsumoto as occurring from Mepp manganese mine, Imagane-cho, Setana-gun, Southwestern Hokkaido (the Niseiepets agglomeratic tuff bed, upper Kunnui Group). When H. Yabe, 1934 discussed the relative antiquity of the Naiporo- and Estoru coal bearing groups of Saghalien, he highly evaluated the desmostylid tooth from Kônosu coal mine, Noda-machi, Southwestern Saghalien.

The enormous discovery of Nagao and Oishi was reported by themselves in

March, 1934 and by H. NEMOTO in 1936. NAGAO established a new species, *mirabilis* for the Keton specimens in 1935; he compared it with *D. hesperus* from Oregon and *D. japonicus* from Gihu. In 1937, he furthermore proposed a new species *minor* for a tooth from Asanai-zawa, Ponto-machi, Ponto-gun, Southwestern Saghalien, cf. *minor* for a tooth from Okoppé-zawa, Kamiatsunai, Tokachi-gun, eastern Hokkaido, and a new genus and new species, *Desmostylella typica* for a tooth from Yuda, Iwate Prefecture, which was stored in the Institute of Geology and Palaeontology, Tôhoku University. The Asanai-zawa tooth was first reported by M. TAGAMI, 1936. E. SAKAI, 1935 announced his investigation about the accurate locality of the Yumachi demostylid from the coast of Lake Shinji between Fujina and Fukutomi, 400 m southwest of the entrance of the Noshiro River, Shimane Prefecture. This tooth is stored in the Geological Institute, Tokyo University. S. TOKUNAGA, 1936 reported several teeth from a quarry of Nagakura coal mine, Iwaki City, Fukushima Prefecture under the name of cf. *mirabilis;* the specimens stored in the Geological Survey were noteworthy as they occurred from the Kamenoo shale of early Miocene.

The horizon of the desmostylid tooth that had been found from Nakanoshima, Shiogama City, Miyagi Prefecture was reported by S. NOMURA, 1935, H. YABE, S. NOMURA and K. HATAI, 1939. They regarded it as the lower Shiogama Group associated with *Lepidocyclina* and *Vicarya*. S. HANZAWA, 1962 put it to be the Aziri bed corresponding to the Moniwa—Hatadate beds of the lower Natori Group. He also indicated the occurrence of desmostylid teeth collected by Y. INAI and M. SHIMAKURA from the Hamada bed in the neighbourhood of Nobiru, Naruse-cho, Monô-gun, Miyagi Prefecture. The Hamada bed is correlated with the Aziri bed. The years from 1937 to 39 were a period in which many works about desmostylids were published and keen attention of the Japanese geologists and palaeontologists was directed to this branch. NAGAO, 1937 announced his opinions about dentition, classification and distribution of desmostylids. S. IJIRI, 1938, 39, 40 published notable works about dental anatomy (microstructure) of it; the material he used was the type specimen of *japonicus* from Togari, Gihu Prefecture, which had been stored in the National Science Museum of Tokyo; he cut the cheek teeth.

VANDERHOOF's masterwork of desmostylid published in 1937 is an important monograph and has became an enduring monument to recent studies; he wrote a historical summary, on morphology of skull and jaw, dention, taxonomy, distribution, ecological habits, etc. All species hitherto described of *Desmostylus* are included in *D. hesperus* MARSH of Sirenia by him. He regarded *Cornwallius* as an ancestor of *Desmostylus*, occurring from upper Oligocene, while *Desmostylus* occurs from upper of middle Miocene to lower of upper Miocene. They are both aquatic and lacking in lachrymal foramen; fore limb is related to Pinnipedia or Sirenia, skull is like those of *Dugong* or Manatees (*Trichechus*), teeth have microstructure of entirely Placental. He also pointed out that desmostylid is an excellent guide to trans-Pacific marine Miocene correlation. He mentioned 25 localities in California, of which 12 belong to the Miocene Temblor bed, 7 to the Miocene Briones bed and the other 6 are from the Monterey bed. The fossils in Oregon are all from the Astoria bed, which is correlated to the Temblor bed. He was doubtful as to their occurrence from Alaska. He correlated the Japanese Miocene with the Temblor or Briones from desmostylid. It may be noteworthy that VANDERHOOF mentioned some fragmental postcranial skeleton; he cited distal end of humerus with strong trochlea groove, proximal end of radius and three metacarpi (III, IV and V). O. MARSH himself had already written about some vertebrate in his original description of the type in 1888, and MATSUMOTO, 1918 also mentioned vertebrate and ribs.

In 1938, TAKAI made a short review of desmostylids in his paper on the Japanese Cenozoic mammals and treated *Desmostylus japonicus*, cf. *japonicus*, *mirabilis*, cf. *mirabilis*, *Desmostylella typica* and the other undertermined species of Japan as composing an unique species of *japonicus*. He regarded *minor* as a juvenile of *japonicus*, and *Desmostylus* sp. from Sado Island, Aushi and Soikon, etc. as belonging to old animals of *japonicus*. He cited 17 localities from Saghalien to Honshu. TOKUNAGA, 1939 described a new species, *Cornwallius tabatai* of the two teeth reported by OZAWA, 1924 from Sado, which are brachyodont and carry a very long root. He compared it with *C. sookensis* (CORN.) from Vancouver Island and regarded the bed from which they were found to be the lower Tsurushi bed of middle Miocene. The specimens stored in Waseda University were destroyed during the war. H. SONE, 1941 listed six localities of *D. japonicus*, of which Yamanouchi and Tsukiyoshi, Akiyomura, Toki-gun, Gihu Pref. are erroneous. In 1944, TAKAI reported an upper P 3 from the phosporite bed at Hannoura, Notojima-cho, Noto Peninsula and an incisor (?) from the phosporite bed at Shitsumi, Ukawa, Noto-machi, Fugeshi-gun, Noto. The beds of these fossils belong to the Nanao Group according to TAKAI and H. NIINO. The incisor was possessed by F. ASANUMA of Dainippon Phosphate Company. T. URITA, 1944 reported an occurrence of a *Desmostylus* tooth from Sakura-zawa, Estoru, Saghalien, which had been found by Y. IWABUCHI; URITA pointed out the formation of the desmostylid was shell bearing tuffaceous sandstone of the Akushu pyroclastic member.

In 1940 R. H. PLESHAKOV reported the occurrence of a tooth fragment of *Desmostylus* sp. from the Tigilski Region in Kamchatka; it was a small-sized tooth and found from the upper part of the Vayampolskaya formation (middle Miocene). Furthermore in 1959 I. G. PRONINA wrote an important paper on a new desmostylid *Kronotherium brevimaxillare*, gen. nov. sp. nov. based on a left lower jaw with cheek teeth from the Kronotski Region in east coast of Kamchatka. PRONINA gained it during a geological excursion made in 1955 by the Petroleum Exploring Institute from a sandstone bed at a river cliff of a branch of the Rakitinskaya River. The author regarded the bed as late Miocene, correlated with the Temblor or the Kawabata formations. The specimen was determined by M. P. JUKOVA of the Palaeontological Institute of Academy of Sciences, USSR. The teeth are almost unseparated from those of *Desmostylus hesperus* in outline though rather small-sized.

In 1951-52, short report of the Izumi skeleton were announced by DEREC. K. FUJITA and S. OGOSE, 1951 gave an accurate account of detailed data of the occurrence of the type specimen of *japonicus* at Togari and concluded that the point of *Desmostylus* lies in the *Protorotella-Vicarya* bed and not in the *Felaniella* bed. Some differences in opinions on the stratigraphy of the Togari area are discussed between IJIRI and OGOSE. K. TAN, 1954 reported the occurrence of desmostylid teeth from a cliff west of Nashinoki pass and south of Ushikubi, Tashiro-mura (now Ugo-machi), Ogachi-gun, Akita Prefecture. J. ARAI, 1953 described a desmostylid jaw and eight isolated teeth from a cliff along the Arakawa River, west of Chichibu City (Lat. 36°0′N, Long. 139°0′10″E), which are stored in Chichibu Natural Science Museum in Nagatoro, Chichibu, Saitama Prefecture. Horizon of this important fossils is the Chichibumachi bed of ARAI, upper part of his Chichibumachi Group. In the same year, K. WATANABE announced a general review of desmostylids from a stratigraphical point of view and pointed out that desmostylid is not a pure boreal animal but a land or seaside dweller in warm climatic environment. He also indicated the occurrence of the Akita teeth from his middle Yusawa bed of lower middle Miocene. S. HANZAWA, 1962 explained it as being the uppermost Sugota bed. WATANABE regarded that there are three horizons of desmostylids in Japan, i. e. the Chichibumachi- (Chichibu and Nagakura, Joban), Togari-Tsukiyoshi- (Togari, Sado, Yuda, Shikonai, Shitsumi and Ushikubo) and the Yamanouchi stages (Izumi, Fujina and Shiogama?) in descending order. YABE and IJIRI, 1954 wrote on the trace of fossil blood veins (Arteria alveolaris mandibularis and Vena alveolaris mandibularis) on the tooth of *Desmostylella typica*. In 1956-57, S. ONODERA reported the occurrence of desmostylid teeth found in Jaunary, 1956 from the Osawa tunnel of the Tôhoku railway line, Iwanosawa, Mashiba, Ichinoseki City, Iwate Prefecture. He determined them as *D. japonicus* and regarded the dark green tuffaceous sandstone occurred it as the upper part of the Shimokurosawa formation (=the Kurosawa formation of S. TAKAHASHI) which is marine and carries many mollusca of the Yama-Suenomatsuyama type faunae. The teeth are much worn and assumed to be those of an older animal than those of Keton and Togari. MINATO, M. MATSUI and I. ISHII, 1957 confirmed the stratigraphical position of the desmostylid from Okoppé-zawa, Hokkaido. They regarded it as the Chokubetsu formation of upper Oligocene. This is a very important fact.

T. SHIKAMA, 1957 wrote a short review of the Japanese desmostylids and classified them as follows:

Order Desmostylia REINHART, 1953

Family Desmostylidae OSBORN, 1905

Desmostylus japonicus TOKUNAGA & IWASAKI (Holotype: Togari skull. Skeleton: Keton skeleton). Species *mirabilis* NAGAO is junior synonym.

Family Cornwalliidae, fam. nov.

Cornwallius tabatai TOKUNAGA (Holotype: Sado teeth. Skeleton: Izumi skeleton).

Desmostylella typica NAGAO (Holotype: Yuda tooth).

He gave a general outline of the postcranial skeletons of *japonicus* and *tabatai*. It may be noteworthy that both skeletons have paired sternum and that the Izumi skeleton carries metatarsus of about one third length of metacarpus. He regarded four digits of fore limb and three digits of aft limb as the fact about the Izumi skeleton, but it became clear that this judgement was erroneous as his succeeding researches advanced. He put the samples from Izumi, Hannoura of Noto, Chichibu and Sado into species *tabatai* and regarded *Desmostylella typica* as a distinct type.

REINHART's " A Review of the Sirenia and Desmostylia " published in 1959 is a voluminous work in recent years. He had already in 1953 established a new order Desmostylia under superorder Paenumgulata SIMPSON, but in 1959 he reestablished Desmostylia as a new order of mammalia. He treated *japonicus, mirabilis, minor* and *typica* as junior synonym of *hesperus*. VANDERHOOF's samples of teeth from the Temblor formation of Coalinga, California are nearly two hundreds and REINHART and S. KENT collected the other excellent fossils from another locality eleven miles south of Coalinga. He said, "the tenacity with which some authors cling to the name *D. japonicus* is truely amazing in light of the present information about *Desmostylus*". Concerning the nomination of upper cheek teeth cusps, there was difference of opinion between MATSUMOTO and VANDERHOOF. REINHART agreed with the latter and treated anterior three cusps as anterior accessory cusps in place of MATSUMOTO's talon. He discussed cusp patterns, root system and tooth replacement. It is very important that he described postcranial skeletal bones.* It is uncertain whether or not these bones belong to *Desmostylus* or to other related desmostylid. He proposed *Vanderhoofius coalingensis*, n. gen. n. sp. for a left mandible which carries a pair of tusk, while *Desmostylus* has two pairs of tusk; he regarded it due not to sexual difference but to taxonomic one. Also he proposed *Paleoparadoxia*, n. gen. for *Cornwallius tabatai* TOKUNAGA and described a right mandible from Coalinga, which carries three incisors, a canine and one brachyodont cheek tooth (M3). His reconstructed outline of lower jaw coincides with the Izumi jaw. Five teeth comprise the recorded specimens of *Cornwallius*; they are from the upper Oligocene Sooke formation of Vancouver Island, British Columbia and Oligocene of Baja California. According to REINHART, the cingulum of *Paleoparadoxia* differs from that of *Cornwallius* in extending more than halfway above the crown of tooth, completely encircling the crown, having greater lateral thickness, and forming a far more prominent part of the tooth. Summit of unworn columns are more firmly appressed in *Paleoparadoxia* than in *Cornwallius*. Todays it is known that *Paleoparadoxia* is distinguished from *Cornwallius* only by teeth construction. Skull, jaw and postcranial skeleton of *Cornwallius* are all unknown. It may be questionable whether *Paleoparadoxia* is validly established as a genus, clearly separated from *Cornwallius*, although both are not coeval to each other. It may be said that REINHART was a lamper in species taxonomy but not in genus one. He regarded *Cornwallius* as an ancestral genus of *Desmostylus* and *Vandrhoofius* and proposed Paleoparadoxidae, n. fam. for *Paleoparadoxia*. Cornwalliidae SHIKAMA, 1957 bears *Cornwallius tabatai* TOK. (=*Paleoparadoxia tabatai* (TOK.) of REINHART) as a type genus. Hence Paleoparadoxidae becomes a junior synonym of Cornwalliidae, excluding the adequateness of the name.

YABE, 1959 wrote on geological range and geographical distribution of desmostylid. He, confirming the teeth from Obirashibetsu (the Tappu formation), Okoppézawa (the Chokubetsu formation) and from Asanai-zawa (the Hacchorei formation) as upper Oligocene in age, pointed out that in Japan and Saghalien there lived *Desmostylus* in upper Oligocene and the *Desmostylus*, *Cornwallius* or *Paleoparadoxia* (he said near allies of *Cornwallius*) occurred in Miocene of Japan. Furthermore he assumed that desmostylid migrated from the Asiatic coast to the American coast

* REINHART mentioned NAGAO's paper on *Demostylus* skeleton (NAGAO, 1941: On the skeleton of *Desmostylus*, YABE Jub. Publ., pp. 43-52), but this is erroneous because there is not announced such a paper in this publication. This mistake was repeated by IJIRI and KAMEI, 1961.

and *Cornwallius* westward from the latter to the former. IJIRI and KAMEI's work, 1961 on the skulls of Keton and Izumi is very important. They treated the Keton skeleton, Ponto tooth and Okoppé-zawa tooth as *D. mirabilis* and a tooth from Aushi and Nagakura remains from Fukushima as *D.* cf. *mirabilis.* They mentioned 31 localities including 6 in Saghalien and cited a tooth from Iwate Prefecture (in Saito Ho-On-Kai Museum in Sendai) and a tooth from Gihu Prefecture (Ôgaki Provincial Museum, Gihu Prefecture). There can be seen no distinct difference between the jaws of Izumi and Coalinga; the name *Paleoparadoxia tabatai* (TOK.) of REINHART was adopted by them. Also the difference between the skulls of *Paleoparadoxia* and *Desmostylus* is discussed and palaeoecology of them is mentioned. They assumed that *Desmostylus* and *Paleoparadoxia* to be hervivorous animals and most closely related to Perissodactyla, next to Sirenia and Proboscidea. Both genera can distinctly be separated from each other taxonomically when judged from their dental formulae. In minor structure of teeth, they are more like that of *Tapirus*, next Proboscidea and Suina. Hervivorous character is assumed from the following elements; mammillon, existence of cement on tooth crown, disappearance of root in I and M, root lacking C, occulusion pattern of I like those of *Bos*, I like C, horizontal replacement of teeth, etc. *Paleoparadoxia* is grazing, with omnivorous character and *Desmostylus* is browsing.* Desmostylid made an active motion with its head in vertical direction like *Tapirus* and *Bos*, assuming from occipital condyle, supra occipital crest, squma occipitalis and sutures of cranium, etc. *Paleoparadoxia* has a strong snout like *Dugong* and Suina, while *Desmostylus* might prepare upper lip like *Tapirus* or Proboscidea. Desmostylid is better adapted to aquatic life than *Hippopotamus* and *Tapirus*, assuming from its lack of naso-lachrymal canal on lachrymal.

F. M. BYERS, 1959 and H. DREWES et al., 1961 quoted the occurrence of desmostylid teeth and bones from volcanic graywacke bed in Unalaska Island, the Aleutian Islands, Alaska which were identified by E. LEWIS as *Cornwallius.* F. S. MACNEIL et al., 1961 pointed out its horizon as basal Miocene with *Mya grewingki* MAKIYAMA. S. FUJII, 1961 and S. FUJII and G. MORI, 1964 reported the occurrence of a desmostylid tooth (P 4 ? of *Paleoparadoxia*) from the Nampo silt bed of upper Yatsuo Group (uppermost Miocene, G) at Akebi, Nyuzen-machi, Shimoniikawa-gun, Toyama Prefecture; it occurred together with *Aturia minoensis* KOBAYASHI, *Conus* sp. and *Ostrea gravitesta* YOKOYAMA, etc. E. D. MITCHELL, 1963 reported some teeth of brachyodont desmostylid under the name of *Paleoparadoxia* sp. from the early Miocene of San Clemente Island, California. He and C. A. REPENNING, 1963 wrote about historical and geographic distribution of desmostylid, with a short description of two ckeek teeth of *Paleoparadoxia* sp. from the late Miocene Santa Margarita formation of the Santa Cruz area, California. They confirmed the stratigraphical range of the Japanese desmostylid from Oligocene to latest Miocene. They regarded the Neroly as coeval with Fujina of Y. TAI. This may be a problem to be discussed in future. In 1964, Y. KASENO reported a cheek tooth from the Iori sandstone member of the Nanao Group at Shiratori, southern Noto and pointed that the

* The present writer thinks this is contrary.

geological horizon of *Desmostylus* in the Sanin-Noto area is a little younger than those of the other areas in Japan. Finally in 1965, very important writing about the third desmostylid skeleton from California by M. WOODBURN was announced in News Bulletin no. 73 of S. V. P. This news became a momemtum to promote this publication. The skeleton which was found in October, 1964 from a land belonging to Stanford University, shall be placed in the University of California Museum of Paleontology and submitted to the study of C. A. REPENNING of U. S. Department of the Interior Geological Survey, Menlo Park, California.

III. Discovery, Excavation and Activities of DEREC

A. Keton Skeleton

The locality of the Keton desmostylid is situated at a fourth dam of Hatsuyukizawa tributary of the Keton River which runs in west-to-east direction and pours into the Poronai River (Lat. 49°51′N, Long. 142°33′E).* The tributary runs from northwest to southeast. Keton along the Keton River, about 60 km north-northeast of Shiska (Palokaisk) is a town nearby. The dam is constructed for transportation of cut wood by running water and just below the dam the river floor is aceessible due to decrease in water. In May 1933, M. Kudô, a labourer engaged in transportation of wood found a skull preserved in a hard nodule on the river floor below the dam. He also observed that there was another large block bearing fossil bones at another point of the floor. He brought the skull to the Department of Geology and Mineralogy, Hokkaido University, Sapporo. Nagao determined it to be a desmotylid skull. Though much deformed and lacked rostrum and large part of lower jaw, the skull was a good sample for study. Also there were two and a part of vertebrae. In October, Nagao and Oishi visited the locality and confirmed large nodules bearing fossil bones lying on the river floor.

In September 1934, Nagao and Oishi went on an excavation trip to the locality together with Y. Nemoto, W. Hashimoto, then a student of Tôhoku University, S. Mashiko and Miyamoto; the last two of them were stone cutter. They arrived there on September 1st. The nodules in question had been carried away to the other points by running water from the point observed by Nagao and Oishi in 1933. The bone bearing large nodule was suboval in outline, about $3\times2\times1.5$ m in size and about 1.5 ton in weight (block A). From September 2nd to 4th, they divided the block into eleven small blocks and lifted up from the river floor. The river water was pumped out. At a point about 100 m down stream from the point of block A, there was an another block bearing scapula and the other fossil bones (block B). The point where Kudô gained the skull (block C) was about 50-60 m down-stream from the point of block A. The nodules were very hard grey calcareous siltstone and surface of it was yellowish brown. There were found many molluscan fossils and plant impressions. The long axis of block A ran in NS direction. It was assumable that there had been a large nodule block carrying the desmotylid skeleton which had been detached from mother rocks of the bed and when separated into several blocks, some of them had been lost. Some bones were furthermore destroyed by men. Nagao and the others procured a part of cervic vertebra at a point just below the dam (sample D). On September 6th, finishing the excavation, they left the locality.

Preparators segregated the blocks A, B and C and picked up bones in about a month; owing to the hardness of the rock of the block, the preparation work was

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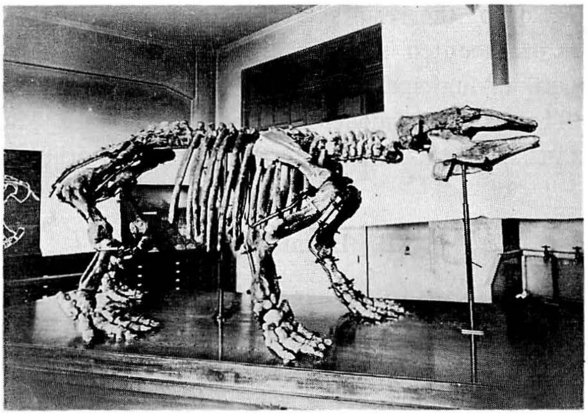
* 敷香郡敷香町気屯二股初雪沢第4号堤

rather difficult. HIGASHIGAWA submitted a part of rostrum bearing canine and an incisor to NAGAO's study. This was also gained from the locality previously. From block A he gained pelvic girdle, large parts of vertebrae, large parts of costae and sternum, and from block B fore limb and a part of costae.

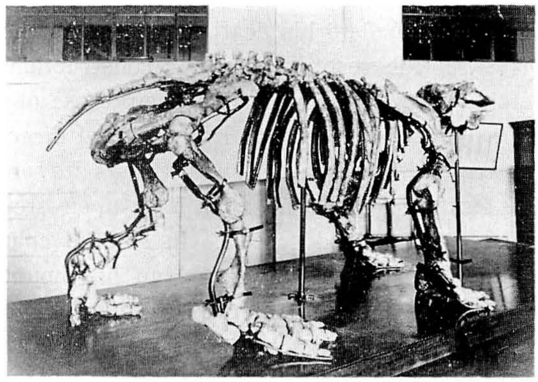
NAGAO's study was continued to his death in 1943. As the large part of bones was deformed by pressure, the restoration and reconstruction were very difficult. He said that the Keton animal is older in age than those of Oregon and Togari. The skull was pressured from left dorsal to right ventral direction, so it was lower in cranial height, flatter and narrower in width than its original condition. He mounted the skeleton tentatively, setting each bone upon steel frame using metal shackles of curved plates, wires and screws. In 1941 he changed his official post from Hokkaido University to Tôhoku University, but his mounted skeleton was left in the Department of Geology and Mineralogy, Hokkaido University, because YABE, NAGAO and the other palaeontologists were afraid that an unexpected disaster might happen to the skeleton, if it were transported from Sapporo to Sendai, passing Tsugaru Strait. During the War the skeleton was dismounted, all the bones were packed in boxes and were buried in the earth, to avoid the destruction by bombing, fire and the other war events. NAGAO left his manuscripts of the Keton skeleton. The studies of manus and pes were most difficult because the bones were preserved in a scattered condition after decomposing the dead animal.



Textfig. 1. The Keton skeleton stored in the Department of Geology and Mineralogy, Hokkaido University (UHR no 18466), mounted by NAGAO.

In 1948 the authorities of the Department of Geology and Mineralogy, Hokkaido University remounted the skeleton according to NAGAO's plan and system in commemoration of the Emperor's visit to Hokkaido University. This tentatively mounted skeleton is now stored in the Department. In April of 1950 the necessity of restudying the skeleton by vertebrate palaeontologists was talked about among YABE, TAKAI and IJIRI, etc. In June the writer joined this group and on July third the organization of DEREC was established. The first and main object was the work of strengthening the bones using some synthetic resin as acrylie-acid resin or polyvinyl chloride resin, etc. and of making a gypsum model of bones. YABE, TAKAI, IJIRI and the writer stayed in Sapporo during the month of August with SAKURAI and

IWASAKI working as strengthening preparators and Y. OUCHI and Y. EMOTO as model makers. The model was completed on August 29th and the members stayed in Sapporo till September 14th.



Textfig. 2. Posterolateral side of the Keton skeleton mounted by NAGAO.

From August 2 to 23 of 1951, YABE, TAKAI, IJIRI, SAKURAI, IWASAKI and the writer stayed in Sapporo. On August 14 the writer finished his description of the bones of which he was in charged. As the Izumi skeleton of relatively fine preservation was found, the comparative study of the Keton and Izumi skeletons became necessary, so the publication of the results of the study on Keton bones was much delayed. The models of mounted skeleton are nowadays stored in National Science Museum, Tokyo, Ôsaka Municipal Museum, Ôsaka City and in Sado Museum, Niigata Pref., etc. The skeleton model of National Science Museum, Tokyo was mounted by H. OZAKI, M. NAKAYAMA and S. HONDA and others.

B. Izumi Skeleton

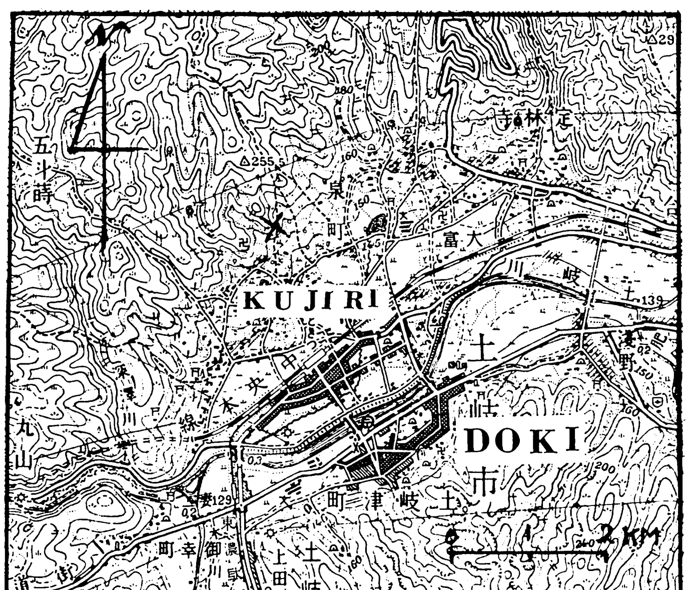
A small hill named Inkyo-yama lies in Kujiri, Izumi-machi, Doki City, Gihu Prefecture.*, 1 km northeast of Tokitsu railway station (Lat. 35°21′45″N, Long. 137° 10′40″E). It is about 180 m above sea level, 30 m above the valley floor running just west of the hill and occupying the southern slope of the low mountain range of the Kani-Doki area, which runs from east to west as right wall of the Mizunami-Doki valley.

In October 1950, S. TOMATSU, then a teacher of Shiroyama Middle School, Nagoya City and M. AZUMA, then a student of Tazimi High School found the skeleton of an unknown animal at a cliff on the southern slope of Inkyo-yama. A part of bones was exposed on a roadside cliff. They excavated the skeleton with the help of two local men for four days. It was a wise treatment that they planned to transport it enclosed in a large block in situ. Bones were rather weak though in good preservation. But the materials were kept in a chamber of Izumi Town Hall in compliance with the strong insistance of the authorities of Izumi town.

On April 7, 1951, TAKAI, IJIRI and the writer visited the Izumi Town Hall, and

* 岐阜県土岐市泉町久尻隠居山

seeing the skeleton, they confirmed it as that of desmotylid. The members of DEREC had often held meetings to discuss the problem of Izumi skeleton. On June 4th and 5th TAKAI, SAKURAI and IWASAKI with HATTORI of the Educational Department, Japanese Government stayed in Izumi, doing a work of strengthening the skeleton. It was determined by the authorities of Izumi-town, Department of Education, Japanese Government, members of DEDEC and the finders, etc. that the Izumi skeleton should be submitted to DEREC for study and be transported to the Geological Institute, Yokohama National University for laboratory work. On June 8th and 9th, YABE, TAKAI, IJIRI, SAKURAI, OGOSE and the writer engaged in packing, transporting and other necessary operations in Doki City. On June 14th the skeleton arrived at the Institute. Many persons who had to do with this study visited the Institute in Yokohama.



Textfig. 3. Locality map of Inkyo-yama, Kuziri, Izumi-machi. × Fossil locality.

Unpacking, decomposing matrix of block, cleaning fossils, strengthening bones with resin, and other kinds of indoor work were done by the members of DEREC with constant help of Y. HASEGAWA, K. CHINZEI and the other geologists of the Institute. It was continued to the end of 1952. From November first to ninth of 1951, the members of DEREC surveyed the geology of Inkyo-yama and its neighbourhood with S. OGOSE, K. FUJITA, K. WATANABE and T. MIZUNO. Reexcavation was done at Inkyo-yama and Togari where the holotype of *D. japonicus* had been found. About twenty fragmental bones were procured from Inkyo-yama after excavating mother rock of 5.7×2.7×0.7 m in dimensions. OGOSE's opinion on stratigraphy of Inkyo-yama was a little different from those of IJIRI and others. FUJI, a geologist in Nagoya and AZUMA, the finder helped the work of DEREC. In Spring of 1951, TAKAI, as a member of DEREC, lectured on the Izumi desmotylid at the annual meeting of the Geological Society of Japan held in Kyoto. The question of male and female was discussed.

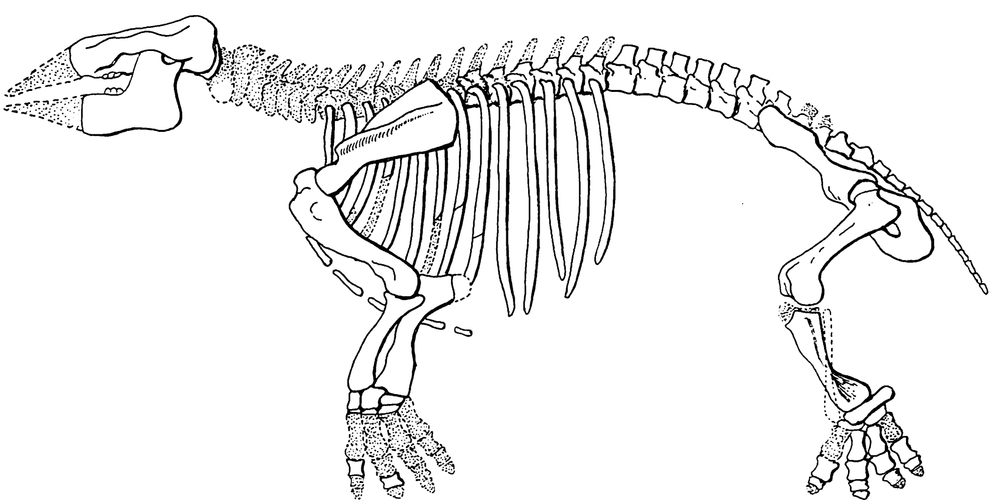
In 1953, the samples in a charge of TAKAI were carried to his room of the Geological Institute, Tokyo University and he engaged in the work of reconstruction and description. In 1959 the skeleton came to be stored in the National Science Museum, Tokyo. Descriptive work of the writer about the part in his charge was energetically done from January to July of 1960. Analysis of burying mechanism of the skeleton was done from September of 1960 to January of 1961. In October of the year, a special display of *Paleoparadoxia* skeleton was held at the museum to show its burial state. On January 15 of the year the writer lectured on the palaeoecology of *Paleoparadoxia* at the annual meeting of Palaeontological Society of Japan held in Tokyo. In 1962 HASEGAWA and T. TAKAGI engaged in photographical work of the Izumi skeleton. A part of the work was also done in October and November of 1964 at the National Science Museum, Tokyo.

The members of DEREC also made field surveys and had discussions on stratigraphical problem of desmostylid. In February 1952, TAKAI, IJIRI and the writer visited Chichibu area and observed the locality of *Paleoparadoxia* in Chichibu. In June of the year, they visited Sendai-Shiogama area and observed the locality of *Desmostylus* in Shiogama. J. IWAI, K. YAGI, R. IMAIZUMI, N. KITAMURA, T. SHIBATA, Y. OIDE and others guided and attended the party. In June of 1953, they visited the Jôban area and observed the locality of *D.* cf. *mirabilis* in Nagakura. K. KOIKE, M. ÔMORI, Y. SUZUKI, T. SAITO, J. IWAI and H. MATSUI joined the party. On May 11, a stratigraphical symposium of desmostylid was held at Tokyo University; YABE, TAKAI, IJIRI, ÔMORI, SUZUKI and Y. FUJITA attended.

IV. ANALYSIS OF FOSSIL SKELETONS

A. Keton Skeleton

NAGAO procured large part of vertebrae and costae, pelvis, hind limbs and sternum; however the anterior portion of the skeleton is rather poor in preservation. He gained only left scapula, left fore limb, a part of right manus and anterior part of costae from block B. Posterior part of skull was gained from block C and from block D is known only one cervic vertebra (atlas?). From second to seventh cervic- and from first to eight thoracic vertebrae and right fore limb except a part of manus are destroyed or lost either by the natural force or by human labor. Anterior part of the skull is also the same, NAGAO took a photo of a block (B′)



Textfig. 4. Left side of the Keton skeleton (ca. ×0.05).
The dotted portions are unpreserved.

carrying phalanges of right manus, which is very important for determining the relative positions of phalangeal bones. It was situated on the right side of the body. Already at the locality NAGAO and other members had cut the block A into eleven sections. The relative position of each bone in buried condition is almost unknown. NAGAO described that sternum was preserved at a dorsal part of sacrum. Of 194 bones, 110 bones are preserved and 84 bones are unpreserved, hence 57% of all the bones of the skeleton is preserved; this is the percentage of preservation.* But if sesamoid of about 28 as seen in the Izumi skeleton is appeared in the Keton skeleton, the percentage of preservation becomes 50%.

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* All bones composing skull are calculated as one.

Table 1. Denomination and analysis of each bone in the Keton skeleton. The nominae of each bone remarked in parentheses show those under preparation. * Incomplete or fragmental in preservation. ** Almost complete. *** Hypothetical.

UHR no 18466				Right	Left
Fore limb		Humerus		———	** UHR no 18466-3
		Ulna		———	** UHR no 18466-4
		Radius		———	** UHR no 18466-5
	Carpus	Scaphoid		———	** UHR no 18466-6 (B)
		Lunar		———	** UHR no 18466-7 (C)
		Cuneiform		———	** UHR no 18466-8 (A)
		Trapezoid		** UHR no 18466-9 (F′)	** UHR no 18466-10 (F)
		Trapezium***		———	———
		Magnum		** UHR no 18466-11 (E′)	** UHR no 18466-12 (E)
		Unciform		** UHR no 18466-13 (D′)	** UHR no 18466-14 (D)
		Piciform***		———	———
	Metacarpus		I	———	———
			II	———	———
			III	———	———
			IV	* UHR no 18466-15 (K)	———
			V	* UHR no 18466-16 (J)	———
	Phalanges	Proximal	II	———	** UHR no 18466-17 (1)
			III	** UHR no 18466-18 (c)	———
			IV	———	———
			V	** UHR no 18466-19 (h)	———
		Middle	II	** UHR no 18466-20 (a)	———
			III	** UHR no 18466-21 (d)	** UHR no 18466-22 (d′)
			IV	** UHR no 18466-23 (f)	———
			V	** UHR no 18466-24 (i)	———
		Distal	II	** UHR no 18466-25 (b)	———
			III	** UHR no 18466-26 (e)	———
			IV	** UHR no 18466-27 (g)	———
				Block B′	
			V	———	———
Aft limb		Femur		** UHR no 18466-28	** UHR no 18466-29
		Tibia		———	* UHR no 18466-30
		Fibula		———	———
	Tarsus	Astragalus		———	** UHR no 18466-31
		Calcaneum		———	** UHR no 18466-32
		Navicular		———	———
		Cuboid		———	———
		Ectocuneiform		———	** UHR no 18466-34 (C)
		Mesocuneiform		———	** UHR no 18466-33 (B)
	Metatarsus		I***	———	———
			II	———	———
			III	———	** UHR no 18466-35 (E)
			IV	———	** UHR no 18466-36 (D)
			V	———	———

Aft limb	Phalanges	Proximal	II	———	** UHR no 18466-37 (M)
			III	———	** UHR no 18466-38 (F)
			IV	———	** UHR no 18466-39 (H)
			V	———	** UHR no 18466-40 (K)
		Middle	II	———	** UHR no 18466-41 (m)
			III	———	** UHR no 18466-42 (G)
			IV	———	** UHR no 18466-43 (I)
			V	———	** UHR no 18466-44 (L)
		Distal	II	———	———
			III	———	———
			IV	———	———
			V	———	** UHR no 18466-45 (J)
Sternum		Praesternum	I	** UHR no 18466-46	** UHR no 18466-47
		Mesosternum	II	** UHR no 18466-48	** UHR no 18466-49
			III	** UHR no 18466-50	** UHR no 18466-51
		Xiphisternum	IV	** UHR no 18466-52	** UHR no 18466-53
			V	** UHR no 18466-54	

Table 2. Chart of bones preserved in the Keton skeleton.
R: Right. L: Left.

Block		Bones	Preserved		Missing		Total		
			R	L	R	L	R	L	
C		Skull	1		—		1		1
D	Vertebrae	Cervic	1	28	6		7		42
A		Thoracic	6		8		14		
		Lumbar	6		—		6		
		Sacral	4		—		4		
		Caudal	11		—		11		
		Costa	12	14	2	—	14	14	28
B	Pectral girdle	Scapula	—	1	1	—	1	1	58
		Humerus	—	1	1	—	1	1	
		Ulna	—	1	1	—	1	1	
		Radius	—	1	1	—	1	1	
		Carpus	3	6	5	2	8	8	
		Metacarpus	2	—	3	5	5	5	
		Phalanges	9	2	3	10	12	12	
A	Pelvic girdle	Pelvis	1	1	—	—	1	1	56
		Femur	1	1	—	—	1	1	
		Patella	—	—	1	1	1	1	
		Tibia	—	1	1	—	1	1	
		Fibula	—	—	1	1	1	1	
		Tarsus	—	4	6	2	6	6	
		Metatarsus	—	2	5	3	5	5	
		Phalanges	—	9	12	3	12	12	
		Sternum	4 (1)	4	— (—)	—	4 (1)	4	9
		Total	110		84		194		

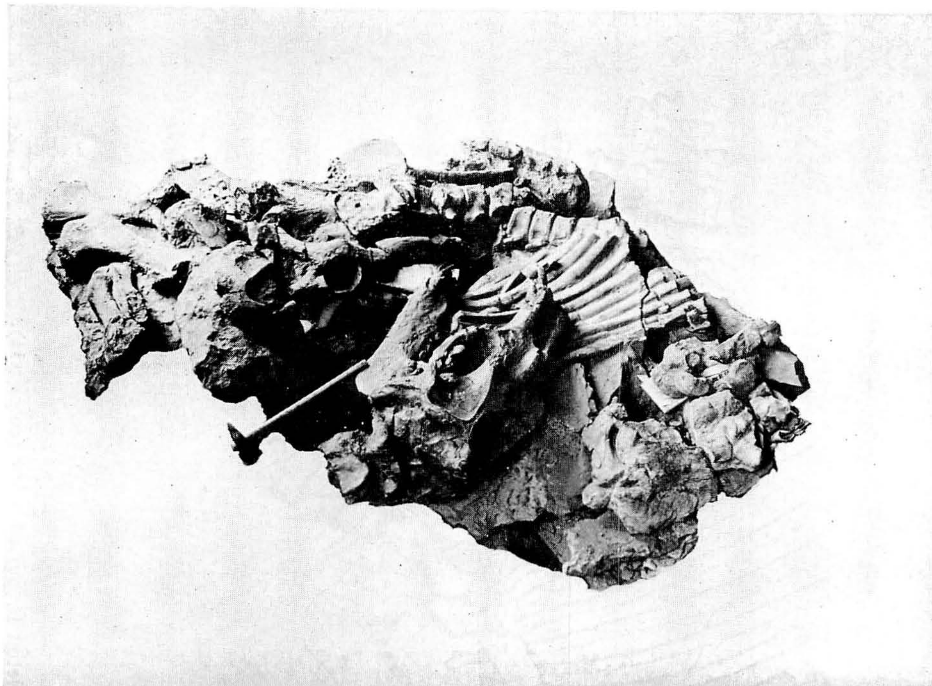
B. Izumi Skeleton

A vertebral column jointed from 13th thoracic- to 11th caudal vertebrae lies setting its ventral side upward; the general orientation of its anterior portion is N-S. Both right and left pelvis are presered jointed to sacrum, setting their ventral side upward. Skull with first- to third cervic vertebrae is situated at left side of the body, setting its left side upward and running from east to west. Left costal bones from 1st to 12th are not disturbed in their relative positions, with their ventral side set upward but their fore and aft direction reversed. Proximal end of first left costa lies near the anterior end of lower jaw. The jointed portion of left costae is shifted from its original position. In general, bones are detached from each other tolerably, except vertebral column, pelvis and costae. One hundred and twenty four bones preserved and 98 bones unpreserved out of 224 bones of the skeleton. Percentage of preservation is 56%, better than that of Keton. Manus phalanges are preserved of right six and left five, unpreserved of right six and left seven. Pes phalanges are preserved of right eight and left two and unpreserved of right four and left ten. From the block procured by TOMATSU and AZUMA, ten four- and six aft phalanges are gained; the other five bones are gained from the other small blocks sporadically. All elongate and platy bones are buried parallel with laminae plane of bed, except 5th and 8th right costae running vertical to it at a point adjacent to the tip of the lower jaw. Each bone of the skeleton is buried in a thin bed of 20–30 cm thick, which may indicate the time range of deposition for burying the skeleton. Remaining four cervic vertebrae and large part of thoracic vertebrae (12 in number) are unpreserved, probably destroyed by erosion. Distal part of left scapula and right humerus are also the same. They are detached from the surface of cliff. Right costal bones are all distinctly detached from their original positions, and some of them are set below left costae. Six paired platy bones of sternum are preserved turning their ventral side upward, with anterior side reverse to vertebral column and with a rightward shift from the body. Left ulna, radius and pes on the other hand are located rather near their original positions.

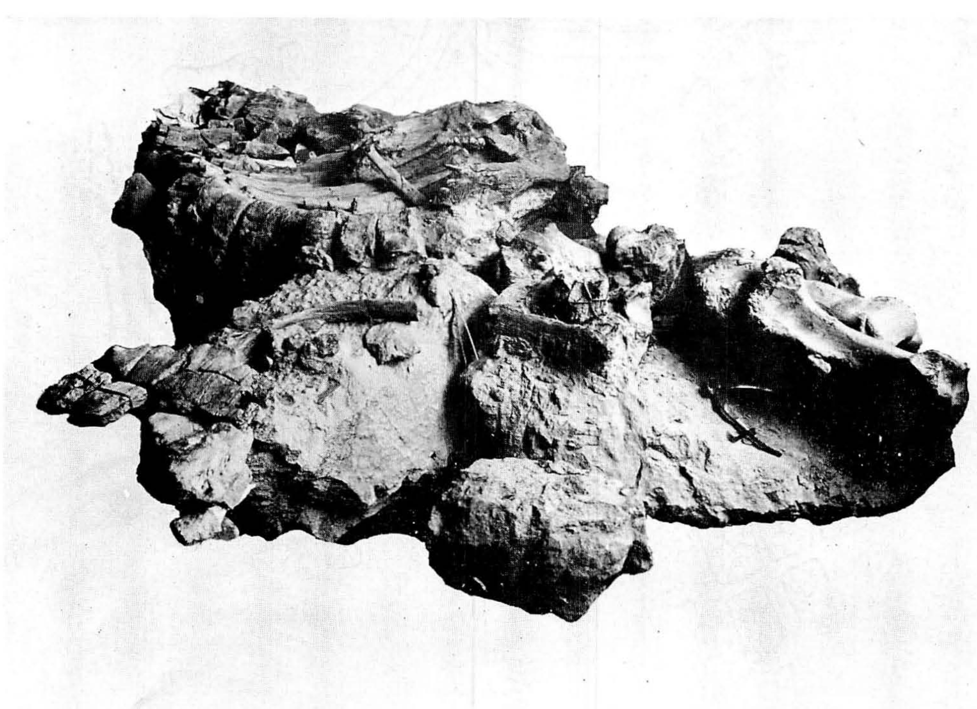
It may be noteworthy that caudal vertebrae are well preserved in their original jointed positions and that pelvis is not detached from sacrum, while the anterior portion of the skeleton is distinctly discharged. The cervic portion is separated between third- and fourth cervic vertebrae. It may be supposed that the cadabel was tolerably decomposed in water during its transportation in water. It settled on the surface of depositing sands with its lumbar portion; first sacral, caudal and lumber portions were buried together with hind limbs which were set below sacrum. Thoracic, prethoracic portions and fore limbs were discharged while they were exposed from sands in water.

When we see the orientation of each bone shifted from its original position, we can notice that some kind of rotation, which may indicate the direction of running water of a kind of turbidity current happened at a point near sea shore bottom. Also notable is that cadabels of shark are mixed in that of *Paleoparadoxia*, because teeth of *Galeocerdo* have been picked up from among the bones.

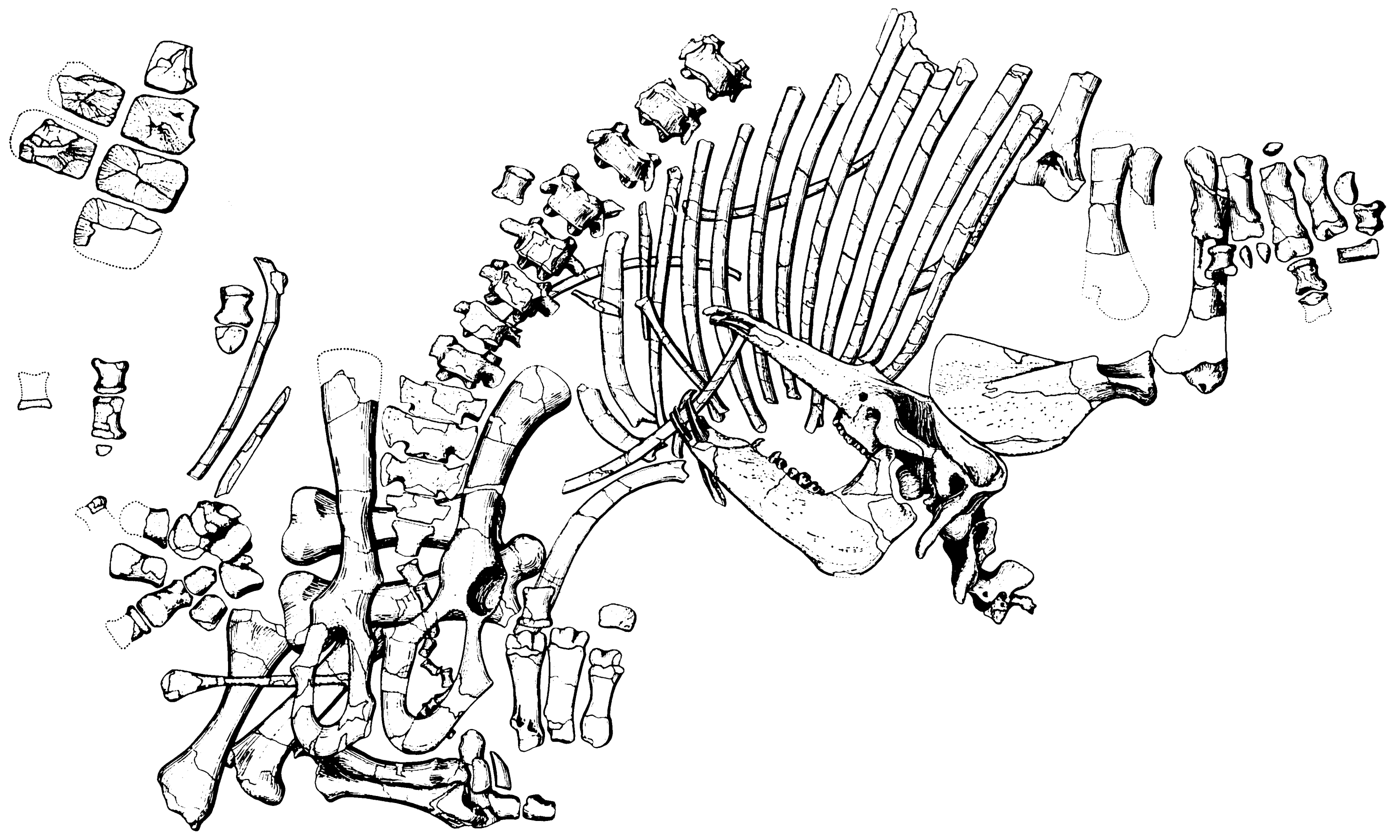
It was rather easy to segregate each bone of the samples. Preparation number



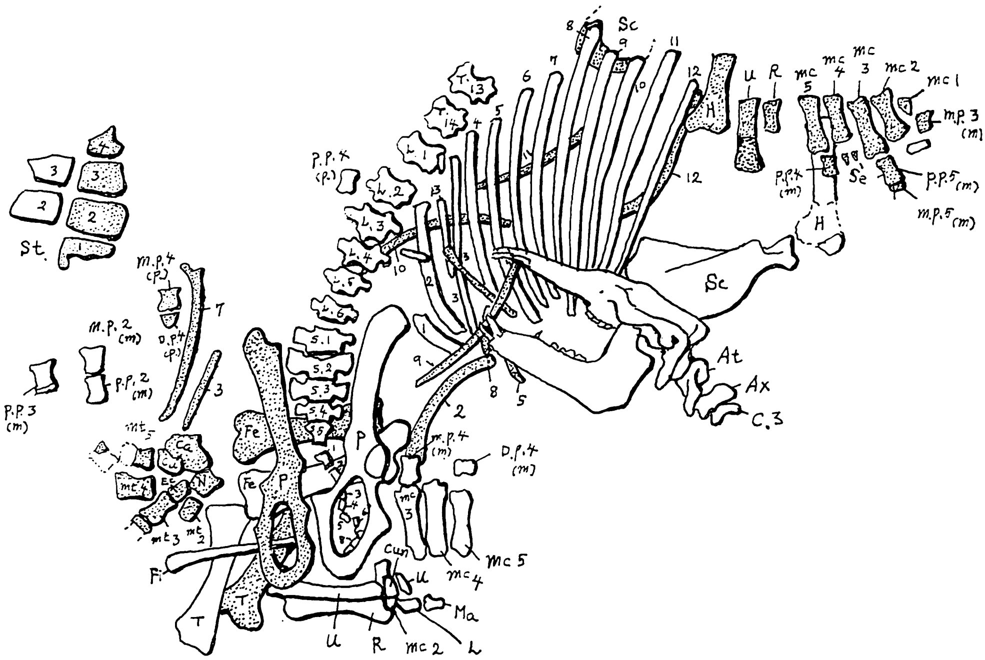
Textfig. 5. The Izumi skeleton in preparation.



Textfig. 6. The Izumi skeleton in preparation. Sternum at left end of the block.



Textfig. 7. Diagramatic sketch of the Izumi skeleton in buried state (ca. $\times 0.11$).

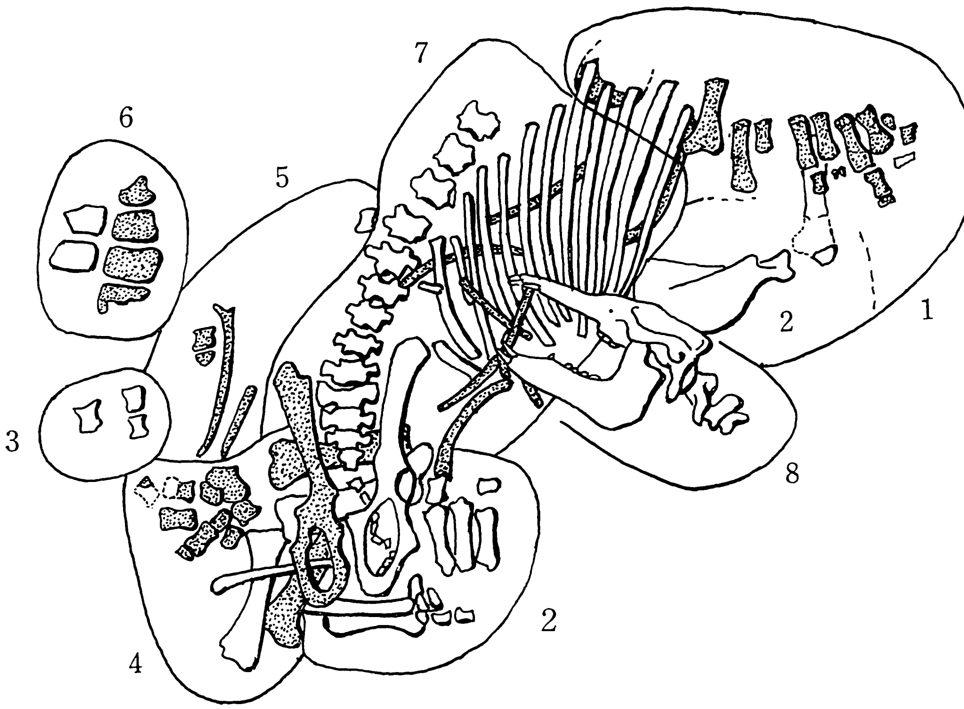


Textfig. 8. Diagramatic sketch of the Izumi skeleton in buried state. The dotted portion are right side. At, Atlas; Ax, Axis; C, Cervic vertebra; T, Thoracic vertebra; L, Lumbar vertebra; S, Sacral vertebra. Sc, Scapula; H, Humerus; U, Ulna; R, Radius; L, Lunar; Cun, Cuneiform; Ma, Magnum; U, Unciform; Mc, Metacarpus; P. p.(p), Proximal phalange of pes; M. p.(p), Middle phalange of pes; D. p.(p), Distal phalange of pes; Se, Sesamoid; St, Sternum.

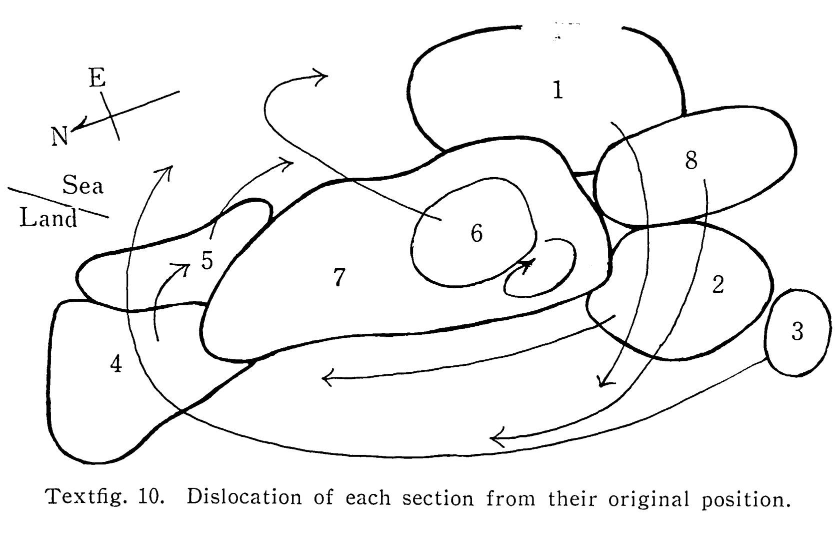
and nominae were given to each bone exposed and obtained. The large block including main part of the skeleton is classified into eight sections as follows:

Section 1: Right fore limb.
,, 2: Left fore limb.
,, 3: Left manus
,, 4: Left and right hind limbs.
,, 5: Right pes.
,, 6: Sternum.
,, 7: Vertebrae and costae.
,, 8: Skull and cervic vertebrae.

The relative positions are as shown in textfig. 9. In each section, bones are not much disturbed in their relative positions. When we restore the original relative position of each section on the cadabel falling on its back, succession becomes 8-6-7-4 from cervic to caudal direction, with section 1 on right side of section 7, 2 and 3 on left sine of 7 and with 5 on right side of 4, as shown in textfig. 10. Hence each section was detached and settled to its preserved position by water current action in a kind of clockwise rotation.



Textfig. 9. Sections of block which bears the Izumi skeleton.
Sec. 1, Right fore limb; Sec. 2, Left fore limb; Sec. 3, Left manus; Sec. 4, Hind limbs; Sec. 5, Right pes and costa; Sec. 6, Sternum; Sec. 7, Vertebrae and costae; Sec. 8, Skull and cervic vertebrae.



Textfig. 10. Dislocation of each section from their original position.

Table 3. Denomination and analysis of each bone in the Izumi skeleton. The number and nominae of each bone in parentheses show those under preparation. * Incomplete or fragmental in preservation. ** Almost complete. *** Hypothetical.

NSMT-P-5601				Right	Left
Fore limb		Humerus		* NSMT-P-5601-3	** NSMT-P-5601-4
		Ulna		* NSMT-P-5601-5	** NSMT-P-5601-6 (32)
		Radius		* NSMT-P-5601-7	** NSMT-P-5601-8 (40)
				Sec. 1	
	Carpus	Scaphoid		———	———
		Lunar		———	** NSMT-P-5601-9 (34) (B)
		Cuneiform		———	** NSMT-P-5601-10 (33′) (A)
		Trapezoid		** NSMT-P-5601-11 (4)	** NSMT-P-5601-12 (E)
		Trapezium***		———	———
		Magnum		———	** NSMT-P-5601-13 (38) (D)
		Unciform		———	** NSMT-P-5601-14 (36) (C)
		Piciform***		———	———
	Metacarpus		I	** NSMT-P-5601-15 (26)	———
			II	** NSMT-P-5601-16 (4)	** NSMT-P-5601-17 (4′)
			III	** NSMT-P-5601-18 (3)	** NSMT-P-5601-19 (37)
			IV	** NSMT-P-5601-20 (チ)	** NSMT-P-5601-21 (39) (2)
			V	** NSMT-P-5601-22 (ト)	** NSMT-P-5601-23 (30) (35)
				Sec. 1	Sec. 2
	Phalanges	Proximal	II	———	* NSMT-P-5601-24 (5=21) (6=22)
			III	** NSMT-P-5601-25 (32) (へ)	* NSMT-P-5601-26 (9=25)
			IV	** NSMT-P-5601-27 (27)	———
			V	** NSMT-P-5601-28 (D)	———
		Middle	II	———	** NSMT-P-5601-29 (3=19) (4=20)
			III	* NSMT-P-5601-30 (α)	——— Sec. 3
			IV	———	** NSMT-P-5601-31 (F) (G)
			V	* NSMT-P-5601-32 (E)	———
		Distal	II	———	———
			III	** NSMT-P-5601-33 (26)	———
			IV	———	** NSMT-P-5601-34 (H)
			V	———	———
	Sesamoid of Metacarpus		II	———	———
			III	** NSMT-P-5601-35 (44) ** NSMT-P-5601-36 (44′)	———
			IV	** NSMT-P-5601-37 (リ) ** NSMT-P-5601-38 (ホ)	———
			V	——— Sec. 1	** NSMT-P-5601-39 (28)
					Sec. 2

Aft limb		Femur		** NSMT-P-5601-40	** NSMT-P-5601-41
		Tibia		** NSMT-P-5601-42	** NSMT-P-5601-43
		Fibula		———	** NSMT-P-5601-44
	Tarsus	Astragalus		———	———
		Calcaneum		* NSMT-P-5601-45 (8) (D)	———
		Navicular		** NSMT-P-5601-46 (7) (B)	———
		Cuboid		** NSMT-P-5601-47 (5) (A)	———
		Ectocuneiform		** NSMT-P-5601-48 (4) (C)	———
		Mesocuneiform		———	———
	Metatarsus		I***	———	———
			II	* NSMT-P-5601-49 (3) (E)	———
			III	** NSMT-P-5601-50 (1) (F)	———
			IV	** NSMT-P-5601-51 (2) (G)	———
			V	** NSMT-P-5601-52 (6) (H)	———
	Phalanges	Proximal	II	Sec. 4	** NSMT-P-5601-53 (50)
			III	* NSMT-P-5601-54 (4) (5)	———
			IV	* NSMT-P-5601-55 (1) (2)	** NSMT-P-5601-56 (16b)
			V	* NSMT-P-5601-57 (45) (47)	———
		Middle	II	———	———
			III	** NSMT-P-5601-58 (16a)	———
			IV	** NSMT-P-5601-59 (13) (14)	——— Sec. 5
			V	** NSMT-P-5601-60 (48)	———
		Distal	II	———	———
			III	———	———
			IV	** NSMT-P-5601-61 (15)	———
			V	** NSMT-P-5601-62 (46)	———
	Sesamoid of metatarsus		II	———	———
			III	** NSMT-P-5601-63 (11) ** NSMT-P-5601-64 (10)	———
			IV	** NSMT-P-5601-65 (b)	———
			V	——— Sec. 4	———
Sternum	Praesternum		I	* NSMT-P-5601-66	———
			II	** NSMT-P-5601-67	** NSMT-P-5601-68
	Mesosternum		III	** NSMT-P-5601-69	** NSMT-P-5601-70
	Xiphisternum		IV	* NSMT-P-5601-71	———
				Sec. 6	

Table 4. Chart of bones preserved in the Izumi skeleton.
R : Right. L : Left.

	Bones	Preserved R.	Preserved L.	Missing R.	Missing L.	Total R.	Total L.	Total
	Skull	1		—		1		1
Vertebrae	Cervic	3	26	4		7		42
	Thoracic	2		12		14		
	Lumbar	6		—		6		
	Sacral	5		—		5		
	Caudal	10		?		10?		
	Costa	11	13	3	1	14	14	28
Pectral girdle	Scapula	1	1	—	—	1	1	70
	Humerus	1	1	—	—	1	1	
	Ulna	1	1	—	—	1	1	
	Radius	1	1	—	—	1	1	
	Carpus	1	5	7	3	8	8	
	Metacarpus	5	4	—	1	5	5	
	Phalanges	6	5	6	7	12	12	
	Sesamoid	4	1	2	5	6	6	
Pelvic girdle	Pelvis	1	1	—	—	1	1	72
	Femur	1	1	—	—	1	1	
	Patella	—	—	1	1	1	1	
	Tibia	1	1	—	—	1	1	
	Fibula	—	1	1	—	1	1	
	Tarsus	4	—	2	6	6	6	
	Metatarsus	4	—	1	5	5	5	
	Phalanges	8	2	4	10	12	12	
	Sesamoid	3	—	5	8	8	8	
	Sternum	4 —	2	— 1?	2	4	4	9?
	TOTAL	124		98				222

V. DESCRIPTION

Correct and accurate determination of each bone in manus and pes is rather difficult owing to the scattered condition of the preservation as stated above. So the writer is going to use the letters or numbers used in preparation work for these bones. NAGAO's manuscript of the Keton skeleton was very significant. For the determination, the comparison between the corresponding bones of the both skeletons was very useful. Furthermore, REPENNING's personal communication about the American skeleton gave the writer very important and significant suggestion. There are some differences between his restored arrangement of bones and that of the writer, but this should be left to further study. The nominae of the bones described here are given tentatively. Unpreserved or doubtful bones were determined by comparing and hypothetical methods. Measurements of bones are shown in mm.

A. Fore limb

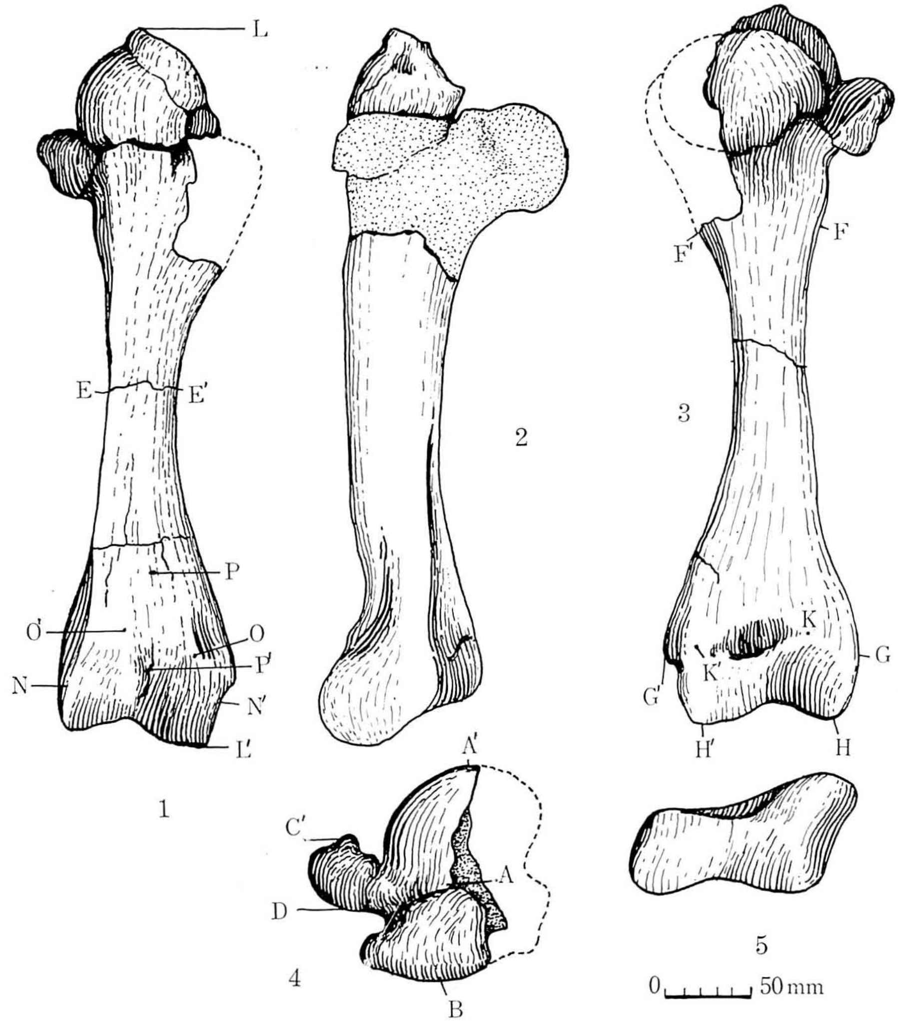
1. Humerus

a. Izumi (NSMT-P-5601-3, 4)

(Pl. 1, Figs. 1-12, Textfig. 11)

Right (NSMT-P-5601-3) preserved distally and a part of head; left (NSMT-P-5601-4) preserved largely except proximoouter corner. Shaft strong, heavy, straight, not short, flat laterally, with longest outer and shortest posterior borders; inner and posterior borders rather flat while outer gently curved. In anterior view, deltoid ridge running from median proximal corner to inner distal corner and a sharp ridge between outer and inner borders lying interiorly. Ectocondylar edge sharp but indistinct. Posterior border very flat distally just above supratrochlea fossa. Proximal end relatively small compared with the size of shaft but distal end relatively large. Head unpreserved in outer half, so that it is very difficult to determine its general outine. In posterior view, anterior border of head (major tubercle) rather running straight while posterior border gently curved; anterior corner rugose carrying many depressions. Inner tubercle very eminent and projected posteriorly. Outer tubercle lying foreside of head, unpreserved exteriorly. It projects proximally more distinctly than head. Bicipital groove broad and shallow, running from anterior inner to posterior outer corners. Major tubercle not so much projected proximally from head.

Internal condyle broken in both right and left humeri, seems flat and smooth. Trochlea very large with large and deep supra-trochla fossa but without supra-trochlea foramen. Anterior side of coronoidal fossa trigonal in anterior view and rather deep. External condyle very small compared with internal one and suboval in outer view. In distal view, inner trochlea much projected backward and larger than outer trochlea; both anterior and posterior borders gently curved. In the same view, outer trochlea trapezoidal in general outline with longest aft margin;



Textfig. 11. Left humerus of Izumi (NSMT-P-5601-4).
1, Fore side; 2, Outer side; 3, Aft side; 4, Proximal side; 5, Distal side.

inner trochlea also trapezoidal with longest inner margin slightly curved; fore margin almost straight.

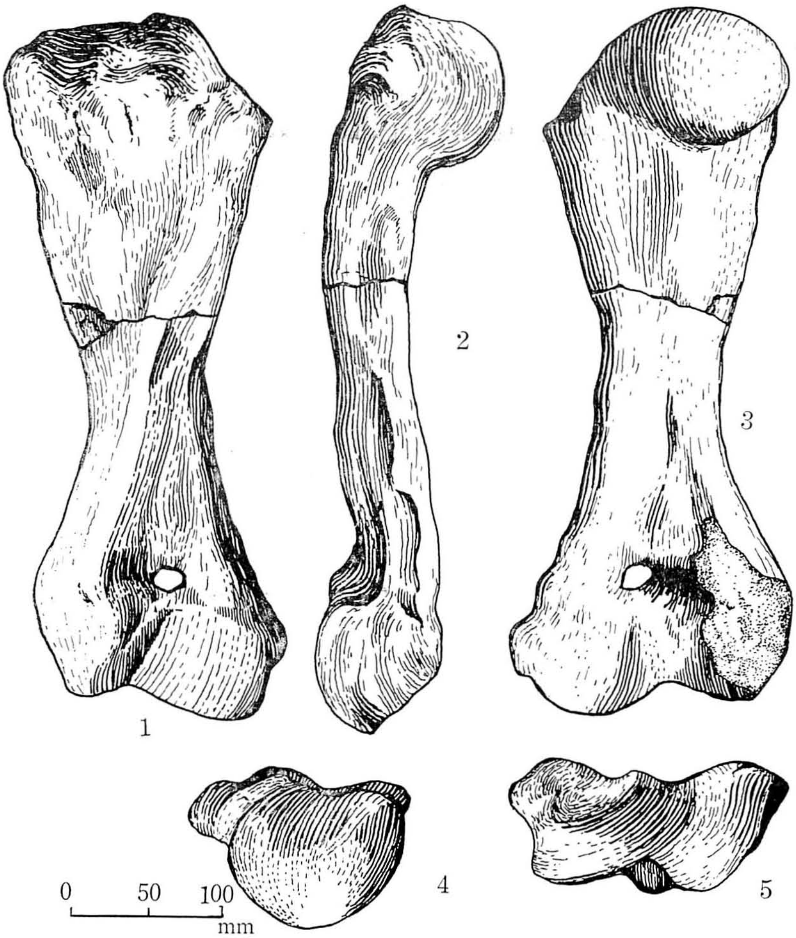
	Right	Left
Length of shaft as preserved (LL′)	—	402
Lateral width of shaft below head (FF′)	—	66
Ditto at middle (EE′)	—	37
Fore-&-aft width of proximal end (A′B)	—	69
Ditto of head (AA′)	—	122
Ditto of major tubercle (AB)	—	75
Ditto of inner tubercle (C′D)	—	52
Lateral maximum width of distal end (GG′)	106+	118
Fore lateral width of trochlea (NN′)	100±	75
Aft lateral width of ditto (HH′)	67+	83
Proximodistal length of internal condyle (MM′)	—	72

Lateral width of coronoidal fossa (OO′)	43	44
Proximodistal length of ditto (PP′)	40	44
Lateral width of olecranon fossa (KK′)	60	61

b. Keton (UHR no 18466-3)

(Textfig. 12)

Left humerus preserved, but a part of proximal end of it broken and much deformed by pressure. Shaft relatively short, strong, heavy and straight. It is distinctly compressed and flat anteroposteriorly with a transverse section of subtriangular outline. Anterior proximal surface becoming flat by pressure, undulating and median longitudinal ridge becomes rather obsolete. Shaft in lateral view slightly curved backward. NAGAO made a tolerable restoration by cementing. In anteroposterior view, shaft expanding much proximodistally and triangular in general outlines of upper and lower halves. Head preserved but major tubercle broken and inner tubercle very poor in preservation. Deltoid ridge also depressed in its upper



Textfig. 12. Left humerus of Keton (UHR no 18466-3).
1, Fore side; 2, Outer side; 3, Aft side; 4, Proximal side; 5, Distal side.

half. Ectocondylar ridge rather sharp.

Head relatively large in comparison with shaft, subglobose and suboval in outline. In proximal view, anterior border of head running straight but median portion of it recurved; inner border curved more strongly than outer. Major and outer tubercles situated in anterior outer side of head, well separated from it by a narrow and shallow bicipital groove running from anterior inner to posterior outer corners. In proximal view, major and outer tubercles subtriangular in outline, much deformed from its original outline by anteroposterior pressure; two shallow grooves running parallel with bicipital groove.

Coronoidal- and olecranon fossae distinct, triangular with an oval and relatively large sized supra-trochlea foramen. In anterior view, outer trochlea larger than inner trochlea, projecting distally, with a large trochlea surface generally curved. Posterior surface of inner trochlea broken. Median depression of trochlea eminent. Distal border of inner trochlea more strongly projected than outer. In distal view, both fore and aft borders gently curved; inner trochlea trapezoidal with longest and straight internal condylar margin and convex anterior margin. Distal surface of inner trochlea wider than that of outer trochlea anteroposteriorly. External condyle much projected outward with rugose tuberosity.

Length of shaft as preserved (LL′)	420
Lateral width of shaft below head (FF′)	125
Ditto at middle (EE′)	71
Fore-&-aft width of proximal end (A′B)	84
Ditto of head (AA′)	85
Ditto of major tubercle (AB)	94
Ditto of inner tubercle (C′D)	—
Lateral maximum width of distal end (GG′)	166
Fore maximum width of trochlea (NN′)	105
Aft lateral width of ditto (HH′)	106
Proximodistal length of internal condyle (MM′)	83
Lateral width of supratrochlea foramen (OO′)	23
Proximodistal length of ditto (PP′)	14
Lateral width of olecranon fossa (KK′)	54

Keton humerus is a little longer ($\times 1.5$) than Izumi humerus, but middle width of it (EE′) is 2.27 times greater than that of Izumi, indicating compression of anteroposterior direction deducing expansion of shaft width to above twice. Lateral maximum width of distal end in Keton is also 1.4 times greater than that of Izumi, while proximodistal length of internal condyle in Keton is 1.15 times greater than that of Izumi. If deformation is corrected, shaft becomes more straight and longer than the specimen, probably about 1.15 times as long as Izumi's and measures 462 mm, more or less. It is rather impossible to assume the precise original aspect of Keton humerus. Of course there is a taxonomic difference between the two. Compared with Izumi, major tubercle is very small, narrow anteroposteriorly even though compressed. Inner tubercle is also obsolete. Perhaps major and outer tubercles were shifted from anterior to outer corners in deformation process. Distal aspect of inner trochlea of Keton is rather like that of Izumi, but those of outer trochlea and external condyle differ greatly; external condyle is compressed, much wider anteroposteriorly and distal end of ectocondylar ridge is eminent. The existence of supratrochlea foramen in Keton and absence of it in Izumi may be notable.

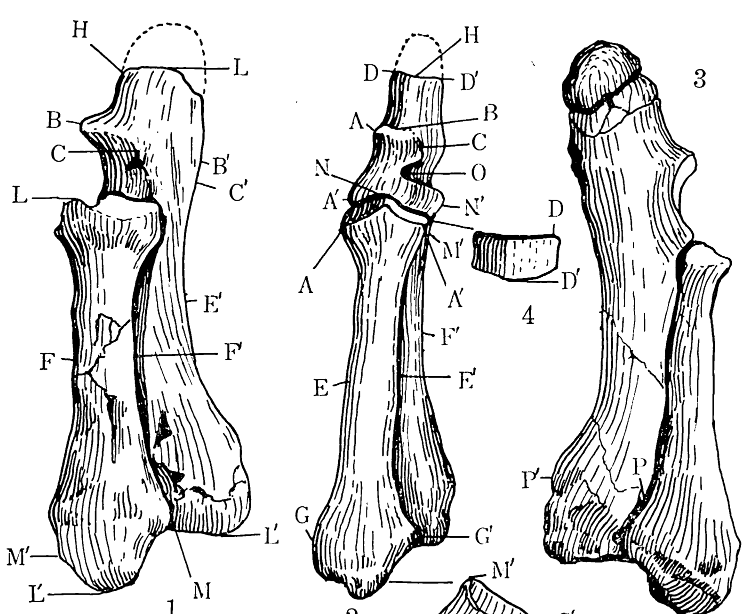
2. Ulna

a. Izumi (NSMT-P-5601-5, 6)

(Pl. 1, Figs. 13-18, Pl. 2, Figs. 1, 7, 8, Textfig. 13)

Left ulna (NSMT-P-5601-6) well preserved jointed with radius, while right one NSMT-P-5601-5) preserved only in middle of shaft; left ulna broken proximally and distally.

Ulna short and slender but not becoming narrower distally. In inner view, fore margin straight and aft margin gently curved. Shaft stout and triangular in cross section with broad inner and narrow outer borders; surface of shaft smooth but that of fore border rugose and broad anteriorly; fore margin of it concave forward. Epiphysis of head detached, globular and convex proximally. Articulating surface with trochlea (incisura semilunaris) shallow, recurved, smooth and subtriangular in general outline; sigmoid fossa on outer margin sharp, deep and V-shaped in anterior view; valley head of the fossa lying in almost middle of the articulating surface. Interior proximal margin of the surface about one half the length of exterior proximal margin and both almost straight. Inner margin of the surface gently



Textfig. 13. Left ulna (NSMT-5601-6) and radius (NSMT-P-5601-8) of Izumi. 1, Anterior outer side; 2, Fore side; 3, Inner side; 4, Proximal side of radius; 5, Distal side of ditto.

curved while outer margin strongly crenulated. Anterior side of olecranon carrying a sharp median longitudinal keel. Posterior surface of olecranon rugose and becoming broader proximally. Axis of olecranon making an angle of 18° with that of shaft.

Length of shaft as preserved (LL′)	330
Lateral width of shaft below olecranon (MM′)	70
Ditto at middle (FF′)	44
Ditto at middle of olecranon (DD′)	44
Maximum fore-&-aft width of olecranon (BB′)	87
Fore-&-aft width of shaft at middle (EE′)	36
Ditto of styloid process (PP′)	71
Ditto of olecranon at above sigmoid notch (CC′)	46
Length of lower margin of sigmoid notch (ON′)	37
Ditto of inner margin of incisura semilunaris (AA′)	62
Ditto of proximal margin (AC)	43
Ditto of distal margin (A′N′)	76
Direct proximodistal length of incisura semilunaris (BN)	53
Anterior length of olecranon (HB)	67
Distance between proximal end of olecranon and distal inner corner of incisura semilunaris (HA′)	112

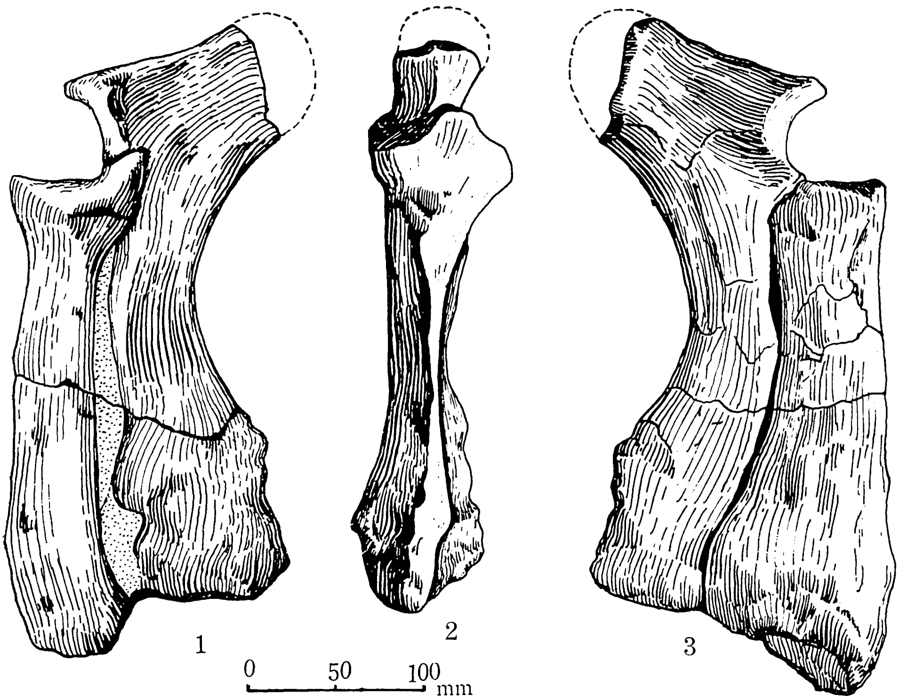
b. Keton (UHR no 18466-4)

(Textfig. 14)

Left ulna preserved jointed with radius: much compressed laterally, cracked and deformed. Fore side largely unknown, hidden by radius.

Ulna short and stout. In inner view, shaft strongly curved and olecranon much bent backward. Axis of it making an angle of 60° with that of shaft. Hind margin almost semicircular and fore margin nearly straight. Olecranon relatively large, becoming narrower distally; its distal end broken off. Fore margin of olecranon almost straight, making an angle of 90° with general trend of articulating surface (incisura semilunaris), which is shallow, recurved, smooth and quadrangular in general outline. Sigmoid fossa on outer margin unknown, probably lacking in original condition. Inner and proximal margin slightly curved. Anterior surface of olecranon carrying an eminent median longitudinal keel. Inner and outer surfaces of olecranon partially damaged. Styloid process large and a little expanded. In lateral view distal margin nearly straight and posterior margin irregularly crenulated. Dimensions as follows:

Length of shaft as preserved (LL′)	335
Lateral width of shaft below olecranon (MM′)	93
Ditto at middle of olecranon (DD′)	49
Maximum fore-&-aft width of olecranon (BB′)	115
Ditto of styloid process (PP′)	108±
Fore-&-aft width of shaft at middle (EE′)	48
Ditto of olecranon at above sigmoid notch (CC′)	75
Length of inner margin of incisura semilunaris (AA′)	57
Anterior of olecranon as preserved (HB)	117
Distance between proximal end of olecranon as preserved and distal inner corner of incisura semilunaris (HA′)	167



Textfig. 14. Left ulna (UHR no 18466-4) and radius (UHR no 18466-5) of Keton. 1, Outer side; 2, Fore side; 3, Inner side.

3. Radius

a. Izumi (NSMT-P-5601-7, 8)

(Pl. 1, Figs. 13-18, Pl. 2, Figs. 2-6, 9-13, Textfiig. 13)

Left radius (NSMT-P-5601-8) perfectly preserved but right one (NSMT-P-5601-7) known only in distal fragment. Radius shorter than ulna with straight shaft and expanded at both ends. Shaft about the same size as that of ulna, oval in cross section with longer side-to-side diameter, wider laterally than anteroposteriorly. In anterior view, outer margin of shaft more strongly curved than inner. Head much expanded in the same view, subtrigonal with slightly curved inner and outer proximal margins; middle point of proximal margin projected upward. In posterior view, proximal margin of head rather straight. In proximal view, head quadrate with straight and short lateral margins and curved at both anterior and posterior margins; outer articulating surface larger and more depressed than inner one which bent backward in general. Posterior surface of head slightly depressed and rugose. Shaft becoming much broader distally and distal end very thick, large and more eminently projected than that of ulna. In anterior and posterior views, distal end rhomboidal in general outline with strong projection of middle point; anterior surface with no distinct longitudinal groove. In lateral view, distal expansion trigonal in general outline with long posterior margin which runs oblique to fore margin of shaft. Terminal point of distal end situated anteriorly just below axis of shaft. In distal view, articulating surface quadrangular in general outline, with sharply projected anterior middle point. The surface slightly depressed.

Length of shaft as preserved (LL′)	267
Lateral width of head (AA′)	86
Ditto of shaft at middle (EE′)	39
Ditto of distal expansion (GG′)	92
Anteroposterior width of head (DD′)	41
Ditto of shaft at middle (FF′)	34
Ditto of distal expansion (MM′)	82

b. Keton (UHR no 18466-5)

(Textfig. 14)

Left radius preserved jointed with ulna, unseparated from it and much compressed laterally, deducing an unusual anterior aspect of slender column. Head large and uncompressed. Transverse section of middle of shaft sublenticular with longer axis in anteroposterior direction. In Izumi bone the longer axis of oval section lying in lateral direction. The pressure produced such an exceeding deformation being very large.

In anterior view, middle point of proximal margin of head much projecting upward and interior proximal margin longer than exterior. In proximal view, articulating surface of head quadrate with straight and longer fore and aft margins; outer articulating surface larger than inner. Anterior surface of shaft carrying a strong median longitudinal keel which is undulated. In inner view, fore margin of shaft very straight, while aft margin gently curved; shaft much wider than that in anterior view. Styloid process stout and eminent with anterior projection. In outer view, styloid process not so large as that in inner view. Surface of styloid process partially damaged. Cross section of the process subtrigonal with slightly recurved margins of equal length.

Length of shaft as preserved (LL′)	290
Lateral width of head (AA′)	88
Ditto of shaft at middle (EE′)	25
Ditto of distal expansion (GG′)	55
Anteroposterior width of head (DD′)	77
Ditto of distal expansion (MM′)	96

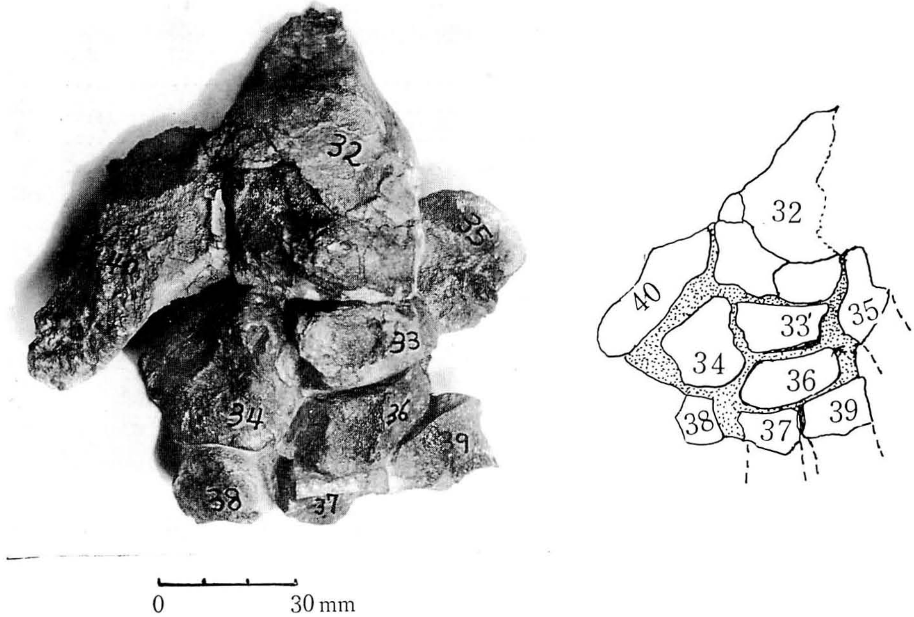
Keton radius is a little longer (×1.09) than that of Izumi and this ratio also exceeds that of ulna. Short axis/long axis of head is 0.48 in Izumi and 0.88 in Keton; short axis of Keton becomes much larger than that of Izumi, reflecting the lateral compression.

4. Carpus

a. Izumi

(Textfigs. 15, 17, 18)

Five bones (A, B, C, D and E) of left carpus were preserved in Sec. 2 of a large block. A (no. 33′ in preparation), B (no. 34), C (no. 36), D (no. 38) were jointed with



Textfig. 15. Left carpal bones of Izumi in their preserved relative position. 32, Bone 32 (ulna) ; 40, Bone 40 (distal end of radius) ; 33′, Bone 33′ (cuneiform) ; 34, Bone 34 (lunar) ; 35, Bone 35 (proximal end of fifth metacarpus) ; 36, Bone 36 (unciform) ; 37, Bone 37 (proximal end of third metacarpus) ; 38, Bone 38 (magnum) ; 39, Bone 39 (proximal end of fourth metacarpus).

each other, together with ulna, radius, third (no. 37) and fourth metacarpi (no. 39). Both metacarpi were in direct contact with bone C; ulna with bone A and radius with bone B; bone D was connected with bone B. Jointing of bones A, B, C and D by their articulating surfaces was very natural. From these interrelation the writer regarded bone A as cuneiform, bone B as lunar, bone C as unciform and bone D as magnum. Bone E in separated condition seems to be trapezoid; hence all bones except scaphoid, trapezium and piciform are known.

b. Keton

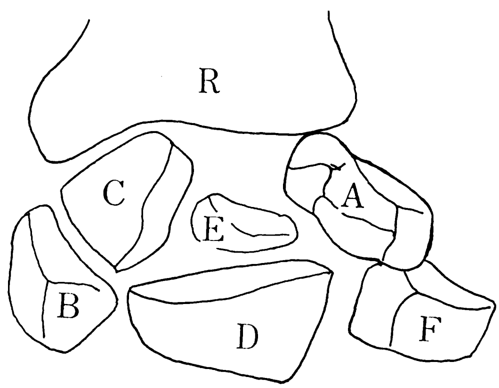
(Textfigs. 16, 17)

NAGAO gained three right and six left carpal bones but their interrelations were rather unknown. He recorded the original positions of these bones in rock, though left no description but a provisional designation in his manuscript, arranging six left bones in carpal combination in a photo. The writer nominated them A, B, C, D, E and F, made a comparison with each bone of Izumi and reached his final determination as follows:

	The writer	NAGAO's position in his photo
Bone A	Cuneiform	Lunar
„ B	Scaphoid	Trapezoid

,,	C	....	Lunar	....	Cuneiform
,,	D	....	Unciform	....	Unciform
,,	E	....	Magnum	....	Cuneiform
,,	F	....	Trapezoid	....	Magnum

Right three bones corresponded to D, E and F are nominated as D′, E′ and F′. Carpal bones of Keton are known in all elements except trapezium and piciform, which are unknown either in Izumi or in Keton.



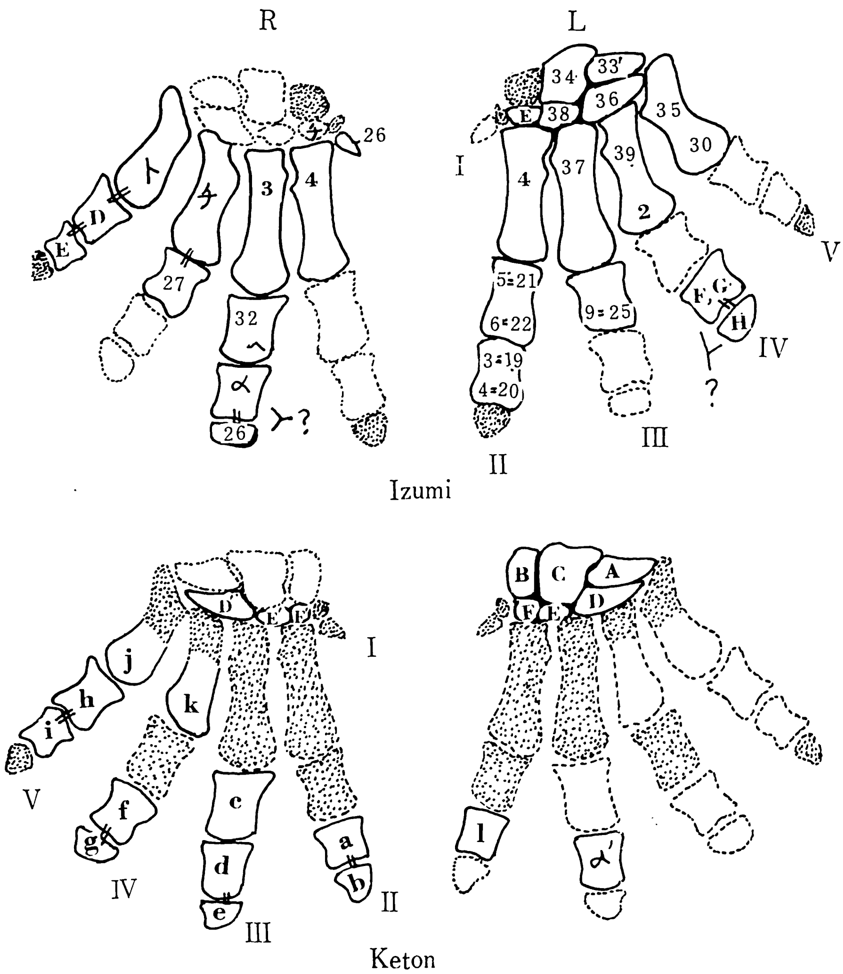
Textfig. 16. Left carpal bones of Keton in their preserved relative position according to NAGAO's manuscript.
R, Radius; A, Anterior outer side of cuneiform; B, Fore side of scaphoid; C, Fore side of lunar; D, Proximal side of unciform; E, Outer side of magnum; F, Outer side of trapezoid.

4A. Scaphoid

(Textfigs. 16, 19)

Represented by left scaphoid of Keton (bone B) (UHR no 18466-6). Bone cubic with undulated surfaces. In fore view, bone quadrate with long and almost straight inner margin; distal margin straight while proximal margin short and slightly curved; outer margin moderately undulated. Anterior surface convex forward. In aft view, bone also quadrate and surface depressed with transverse groove running near distal margin. In inner view, bone quadrate or subcircular, with a little truncate fore margin; surface of fore distal corner partially damaged; surface of bone undulated. In outer view, bone subquadrate with much undulated and long aft margin; distal margin nearly straight and posterodistal corner projected; centre of surface moderately depressed. In proximal view, bone quadrate with long anteroposterior axis; outer margin almost straight; surface smooth and convex.

Height of bone on outer surface (FF′)	50
Ditto on another point (EE′)	51
Ditto on inner surface (DD′)	54
Lateral width of bone on proximal surface (HH′)	40
Ditto on distal surface (II′)	38
Anteroposterior length on inner surface (LL′)	64



Textfig. 17. Manus of Izumi (upper) and Keton (lower). Dotted portions are unpreserved.

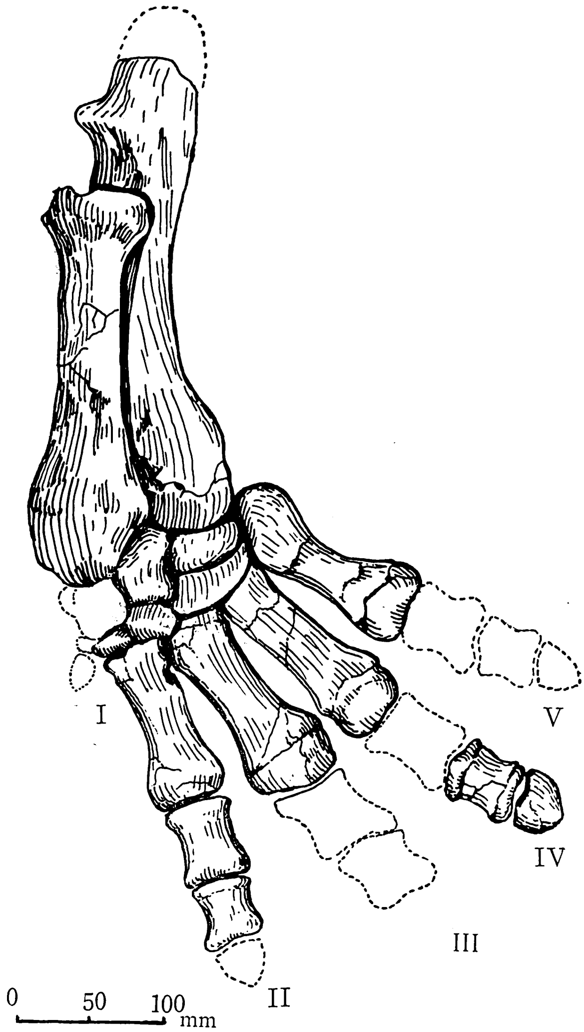
4B. Lunar

a. Izumi (NSMT-P-5601-9)

(Pl. 4, Figs. 20-25, Textfigs, 15, 18, 20)

Represented by left lunar (bone B, no. 34). Bone irregularly cubic, stout, dense and largest of all carpal bones.

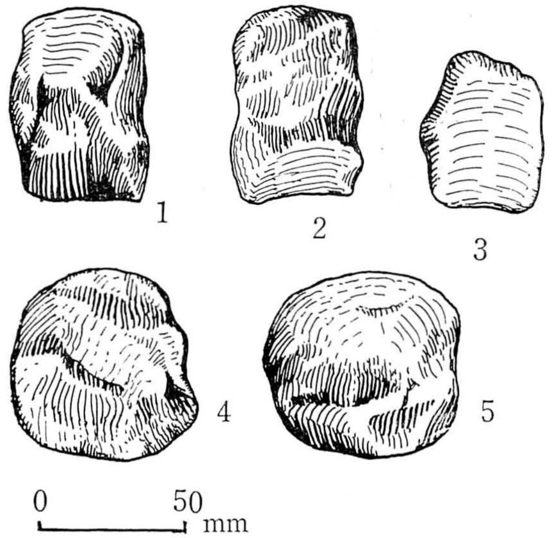
In anterior view, bone subquadrate with longest and almost straight proximal, shortest and slightly curved inner, much recurved outer and with moderately curved distal margins. Surface a little rugose and upper half slightly depressed. Distal surface very smooth, subquadrate with much curved fore and gently curved aft margins; median longitudinal ridge eminent, dividing inner and outer facets; inner margin almost straight. Proximal surface also very smooth, curved and irregularly



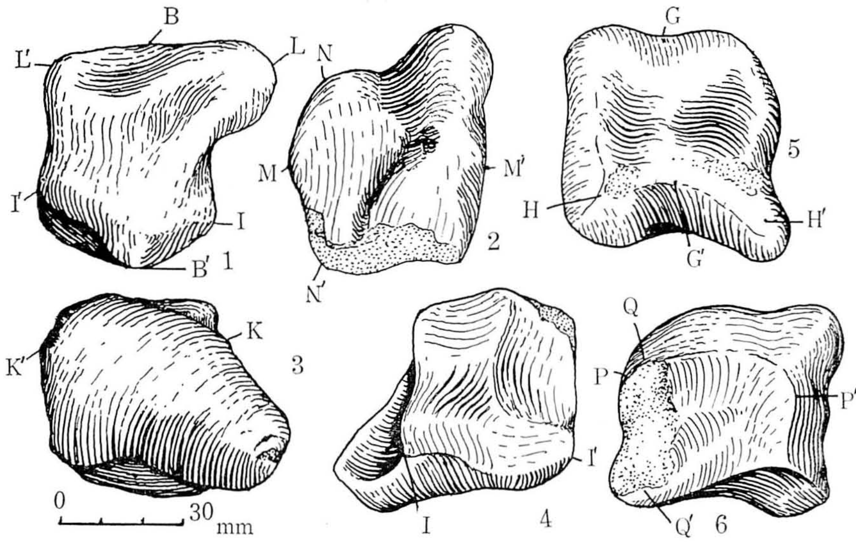
Textfig. 18. Left manus of Izumi.

triangular with longest and gently curved posterior outer margin; inner margin shortest and straight while fore margin slightly curved. Anterior outer corner projecting anteroinward.

In posterior view, bone irregularly quadrate with longest and moderately curved proximal margin; outer margin irregular and much curved with median depression; inner margin broken; exterior proximal corner projecting proximalward; middle point of outer margin projected exteriorly; median transverse groove rather narrow, deep running from exterior proximal to interior distal corners. In outer view bone subrhombic with rugose surface; a broad and eminent transverse groove running with a curve from anteromedian to posteromedian points; posterior distal corner sharply projected while anterior distal corner obtusely projected. Fore margin nearly straight while the other three recurved; posterior proximal corner obtusely curved. Inner surface small sized, irregularly trapezoidal with shortest fore and longest and



Textfig. 19. Left scaphoid of Keton (UHR no 18466-6).
1, Fore side; 2, Aft side; 3, Proximal side (fore side is in below); 4, Outer side; 5, Inner side.



Textfig. 20. Left lunar of Izumi (NSMT-P-5601-9).
1, Fore side; 2, Aft side; 3, Proximal side (fore side is in below); 4, Distal side (fore side is in below); 5, Outer side; 6, Inner side.

almost straight distal margins; proximal margin gently curved and aft margin broken; anterior half of the surface shallowly depressed.

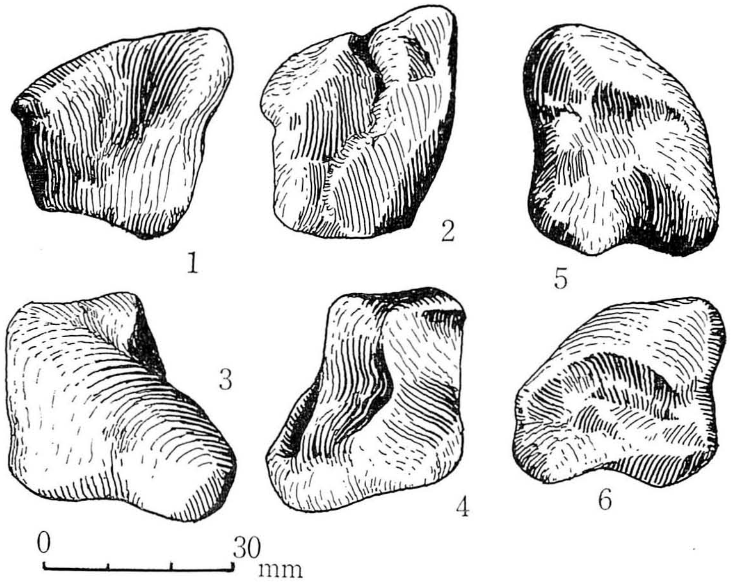
Outer surface in contact with proximoinner surface of cuneiform; outer other half of distal surface in contact with proximal surface of unciform, and inner half of distal surface in contact with other surface of magnum. Proximal border of inner surface in contact with proximal border of scaphoid. Proximal surface in contact with distal end of ulna and exterior distal border of radius.

Height of bone on anterior surface (BB′)	52
Ditto on posterior surface (MM′)	44
Ditto on posterior half of inner surface (QQ′)	32
Ditto on median part of outer surface (GG′)	30
Transverse width along anterior proximal margin (LL′)	54
Ditto along anterior distal margin (II′)	43
Ditto along posterior distal margin (NN′)	42
Ditto along posterior proximal margin (KK′)	41
Anterorposterior length along exterior distal margin (HH′)	37
Ditto along interior proximal margin as preserved (PP′)	24+

b. Keton (UHR no 18466-7)

(Textfigs. 16, 21)

Represented by left lunar (bone C). Bone like the Izumi bone in general aspect, dense, stout and largest of all carpal bones. In anterior view, bone subrhombic with longest and gently curved proximal, shortest and straight inner, short and slightly recurved distal and with long and moderately curved outer margins. Surface uneven and upper half distinctly depressed. Proximoouter corner not so strongly projected as that of the Izumi bone and outer margin not so eminently recurved as that of the latter. Distal surface subquadrate with anteroposterior long axis; aft margin short and almost straight; anterior and posterior margins parallel with each other and slightly curved; fore margin undulated. Median longitudinal ridge strong, dividing depressed inner and outer facets; the ridge abruptly curved at middle point and anterior half turning in anterior outer direction.



Textfig. 21. Left lunar of Keton (UHR no 18466-7).
1, Fore side; 2, Aft side; 3, Proximal side (fore side is in below); 4. Distal side (fore side is in below); 5, Outer side; 6, Inner side.

Proximal surface smooth, curved and subtriangular with longest and gently curved posterior outer margin; inner margin short and straight, while fore margin gently curved; anterior outer projection very eminent and blunt.

In posterior view, bone irregularly quadrangular with longest and gently curved proximal margin; outer margin undulated with median depression; inner margin shortest and slightly curved; exterior proximal corner strongly projected and more sharply pointed than that of the Izumi bone, median transverse groove eminent, deep with large basin-like depression in the middle portion, running undulating from middle point of outer margin to distal half of inner margin. In outer view, bone subtriangular with longest and gently curved proximoposterior margin, much recurved distal and moderately curved fore margins; a broad and eminent transverse groove running from middle of fore to middle of aft margins; upper facet smaller than lower facet which is linguiform and strongly projected of its posterior proximal corner. Inner surface small sized, irregularly trapezoidal with long and curved proximal and distal margins; median groove moderate, broad and parallel with the margin just mentioned.

Height of bone on anterior surface (BB′)	66
Ditto on median part of inner surface (EE′)	38
Ditto on posterior half of outer surface (DD′)	59
Transverse width along anterior proximal margin (LL′)	70
Ditto along posterior distal margin (JJ′)	45
Anteroposterior length along exterior distal length (HH′)	62
Ditto along exterior distal margin (CC′)	52

Keton lunar is a little higher ($\times$1.27) and wider ($\times$1.29) than the Izumi bone. LL′/BB′ is 1.04 in Izumi and 1.06 in Keton, not differing so much from each other. Deformation by pressure is precisely unknown in the Keton bone. This is probably due to the stout cubic construction of the bone.

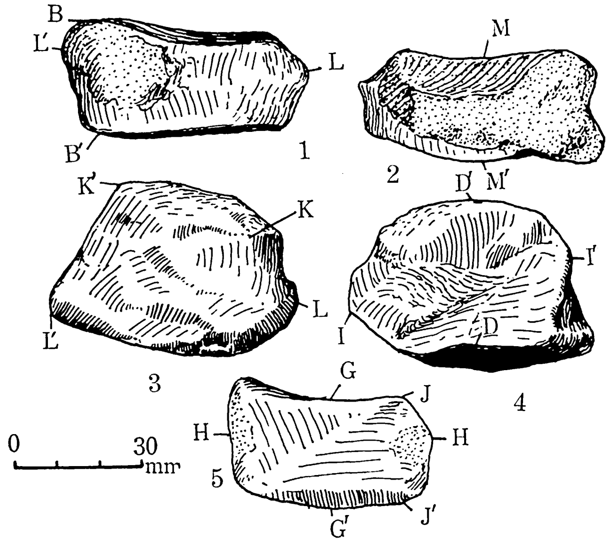
4C. Cuneiform

a. Izumi (NSMT-P-5601-10)

(Pl. 4, Figs. 9-13, Textfigs. 15, 22)

Represented by left cuneiform (bone A, no. 33′). Bone thick platy or cubic with transverse long axis. Anterior surface smooth, convex and subquadrate in outline with almost straight proximal and distal margins; inner half of the surface partially damaged; middle point of inner margin projected inward. In anterior view, proximal margin slightly bent inward, and the bone becoming thinner outward. Posterior surface largely damaged and general outline of it like that of anterior; it is larger than the latter and distal half of the surface depressed.

In proximal view, bone subquadrate with long and gently curved fore margin; inner margin almost straight and outer margin irregularly convex outward; aft margin rather straight; distal surface like the proximal in general outline; inner margin short and undulated with middle point projected; distal surface rather flat and smooth. In outer view, bone quadrate with anteroposterior long axis; proximal margin concave upward and posterior margin short and convex posterior-



Textfig. 22. Left cuneiform of Izumi (NSMT-P-5601-10).
1, Fore side; 2, Aft side; 3, Proximal side (fore side is in below); 4, Distal side (fore side is in below); 5, Outer side.

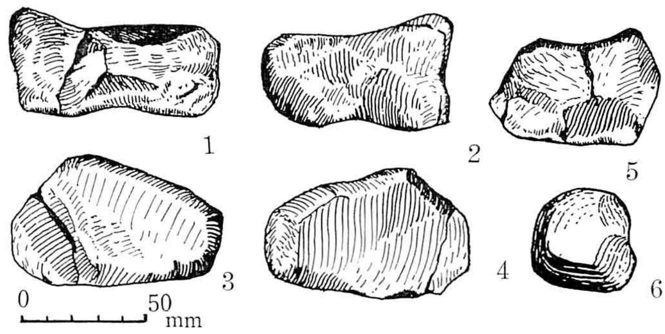
ly; the surface uneven and convex. Proximal surface in contact with outer half of articulating distal surface of radius, and inner surface in full contact with median transverse groove in outer surface of lunar.

Height along interior fore margin (BB′)	27
Ditto along exterior aft margin (JJ′)	22
Ditto along median point of aft surface (MM′)	25
Ditto along median point of outer surface (GG′)	20
Transverse width along anterior proximal margin (LL′)	59
Ditto along median line of distal surface (II′)	50
Ditto along posterior proximal margin (KK′)	35
Anteroposterior length along median line of distal surface (DD′)	34
Ditto of outer surface (HH′)	35

b. Keton (UHR no 18466-8)

(Textfigs. 16, 23)

Represented by left cuneiform (bone A). Bone cubic with transverse long axis. In anterior view, bone subquadrate with long and slightly curved proximal and distal margins; the former concave upward and the latter ditto downward; interior proximal corner much projected; outer margin short and straight; surface uneven and convex. Posterior surface rather flat though uneven with general outline corresponding with that of anterior; bone of posterior side a little higher than anterior. In proximal view, bone subquadrate with longest and almost straight fore margin; inner margin convex inward and outer margin shortest and straight; aft margin straight and much bent toward fore margin; surface smooth and a little depressed. Distal surface flat and smooth, its general outline corresponding with that of proximal, but inner margin partly truncated.



Textfig. 23. Left cuneifo⊢m of Keton (UHR no 18466-8).
1, Fore side; 2, Aft side; 3, Proximal side (fore side is in below); 4, Distal side (fore side is in below); 5, Outer side; 6, Inner side.

In inner view, bone subquadrate with anteroposterior long axis; fore margin much convex anteriorly; proximal margin concave upward and distal margin almost straight; lower half of aft margin projected backward; the surface uneven with median transverse depression. In outer view, bone quadrate with uneven posterior margin and with the other margins almost straight; the surface rather flat and smooth.

Height along interior fore margin (BB′)	40
Ditto along exterior aft margin (JJ′)	37
Ditto along interior aft margin (HH′)	36
Transverse width along anterior proximal margin (LL′)	85
Anteroposterior length on interior distal surface (EE′)	55
Ditto on exterior distal surface (CC′)	43

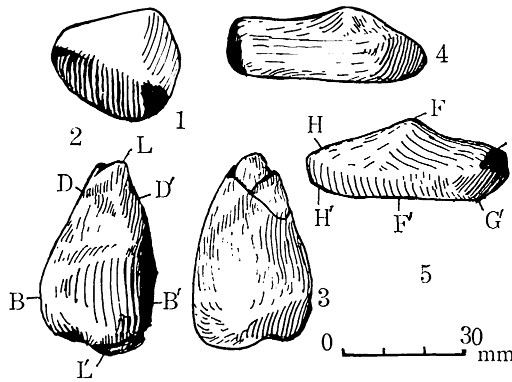
Keton cuneiform is much higher (×1.48) and wider (1.44) than Izumi; inner margin is straight in the Izumi bone and convex to truncated convex in the Keton bone, fore and aft borders are nearly parallel with each other in the Izumi bone, while they are oblique to each other in the Keton bone. These differences of outline may be due to taxonomical distinction or to deformation. Ratio of height to transverse width is 0.46 in the Izumi bone and 0.47 in the Keton bone, both almost accorded with each other; probably deformation has not done much to the Keton bone.

4D. Trapezoid

a. Izumi (NSMT-P-5601-11,12)

(Pl. 4, Figs. 26–30, Textfigs. 15, 24)

Represented by right (bone 4) (NSMT-P-5601-11) and left trapezoid (bone E) (NSMT-P-5601-12) which were found separated from the other carpal bones. Bone small sized, platy and linguiform in general outline. In proximal view, irregularly triangular with long and straight inner and gently curved outer margins; fore margin uneven and short; the surface convex upward in the middle portion. Distal side corresponding to the proximal with rather flat surface. In anterior view, bone



Textfig. 24. Left trapezoid of Izumi (NSMT-P-5601-12).
1, Fore side; 2, Proximal side (fore side is in below); 3, Distal side (fore side is in below); 4, Inner side; 5, Outer side.

subtrigonal with curved three margins. In outer view, bone trigonal with long and straight distal margin and declined anterior proximal margin; posterior half of proximal margin a little depressed.

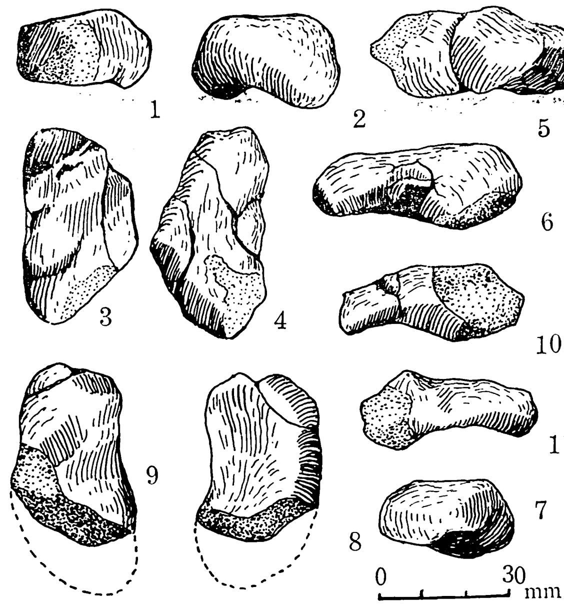
	Right	Left
Height along exterior fore margin (HH')	10	11
Ditto along exterior aft margin (GG')	11	12
Ditto on median exterior surface (FF')	16	20
Transverse maximum width (BB')	26	26
Transverse width on posterior proximal surface (DD')	16	19
Anteroposterior length on outer portion (LL')	38	40

b. Keton (UHR no 18466-9, 10)

(Textfigs. 16, 25)

Represented by right (bone F') (UHR no 18466-9) and left trapezoid (bone F) (UHR no 18466-10) which are quite like those of the Izumi bone in general outline. Right bone broken anteriorly but left one rather well preserved though its anterior portion partially damaged. Bone linguiform. In proximal view, subtrianglar with almost straight inner and outer margins; the latter longest; fore margin gently curved and the surface nearly flat. Distal surface smooth and convex with outline corresponding with the proximal. In anterior view, bone subquadrate with recurved proximal and depressed distal margins. In outer view, bone elongate quadrate with long proximal and distal margins which are parallel to each other. Anterior proximal margin bent forward.

	Right	Left
Height on median anterior surface (CC')	23	23
Ditto on median outer surface (FF')	18	14±
Transverse maximum width (BB')	37	34±
Transverse width on posterior proximal surface (DD')	29	29
Anteroposterior length on outer portion (LL')	57	49+



Textfig. 25. Right (7-11) (UHR no 18466-9) and left trapezoid (1-6) (UHR no 18466-10) of Keton.
1, Fore side; 2 and 7, Aft side; 3 and 9, Distal side (fore side is in below); 4 and 8, Proximal side (fore side is in below); 5 and 10, Outer side; 6 and 11, Inner side.

Keton trapezoid is lower (×0.9), much wider (×1.42) and longer (×1.42) than Izumi. Probably the bone received no distinct deformation.

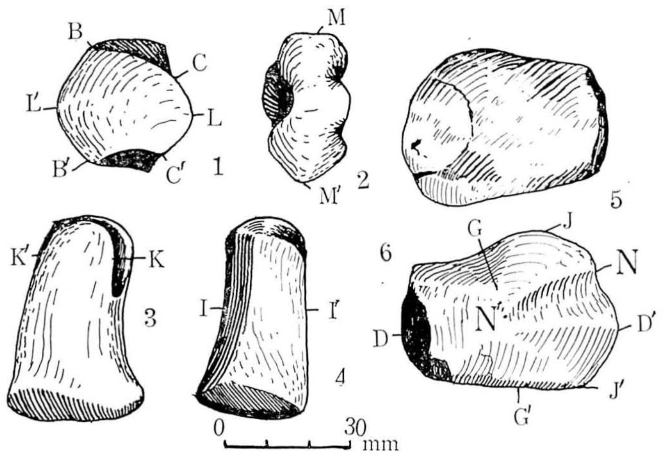
4E. Magnum

a. Izumi (NSMT-P-5601-13)

(Pl. 4, Figs. 14-19, Textfigs. 15, 26)

Represented by left magnum (bone D, no. 38) which is in fine preservation. Bone cubic and linguiform. In anterior view, bone subtrapezoid with longest and almost straight proximal, shortest and gently curved outer margins; inner margin moderately convex outward and distal margin recurved; interior proximal corner a little depressed; the surface smooth and nearly flat. In proximal view, bone subquadrate with anteroposterior long axis; anterior margin wider than posterior ones and slightly curved, while the latter convex aftward; both inner and outer margins slightly recurved; the surface smooth and a little depressed. Distal side like the proximal in general outline, but the fore margin much wider than aft one; both inner and outer margins gently curved; the surface smooth and depressed.

In inner view, bone irregularly quadrate with long and straight distal margin; fore margin also straight while aft and proximal margins undulated. The surface almost flat but posterior corner depressed. Outer side of bone corresponds with the inner; anterior proximal corner much depressed and posterior proximal corner



Textfig. 26. Left magnum of Izumi (NSMT-P-5601-13).
1, Fore side; 2, Aft side; 3, Proximal side (fore side is in below);
4, Distal side (fore side is in below); 5, Inner side; 6, Outer side.

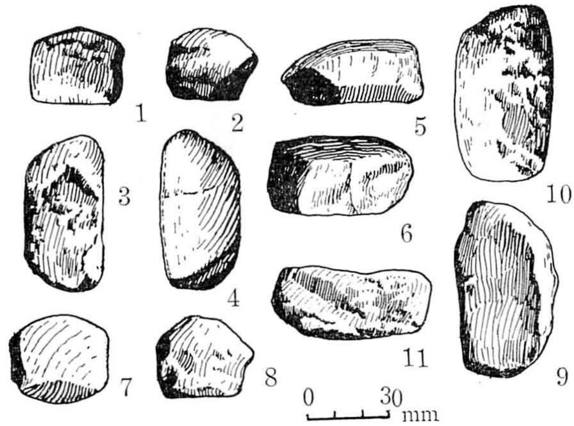
vaulted; shallow and broad median transverse fossa running from middle point of aft margin to middle point of the surface; both proximal and distal margins of the fossa very sharp. In posterior view, bone irregularly quadrangular with long and much undulated inner and outer margins; median portion of outer margin much depressed, corresponding with median transverse fossa of outer surface. Proximal surface in contact with distal surface of lunar; distal surface ditto exterior proximal surface of second metacarpus; inner surface ditto exterior distal corner of unciform and exterior proximal surface of third metacarpus.

Height along exterior fore margin (BB′)	26
Ditto along interior fore margin (CC′)	22
Ditto along median line of aft surface (MM′)	37
Ditto along posterior outer margin (JJ′)	38
Ditto on median outer surface (GG′)	24
Transverse maximum width on fore surface (LL′)	32
Transverse width of median distal portion (II′)	22
Ditto along posterior proximal margin (KK′)	22
Maximum anteroposterior length (DD′)	49
Anteroposterior length on median outer surface (HH′)	44
Length of median transverse fossa of outer surface (NN′)	23

b. Keton (UHR no 18466-11, 12)

(Textfig. 16, 27)

Represented by right (bone E′) (UHR no 18466-11) and left bones (bone E) (UHR no 18466-12) which are rather well preserved. Bone stout and cubic. In anterior view, bone subquadrate, wider than high, with straight distal margin; proximal margin convex upward and the surface smooth. In proximal view, bone subtrapezoidal with longest and straight inner margin; fore margin gently curved and posterior inner corner projected backward; both inner and outer margins almost parallel with each other; the surface smooth, almost flat and middle portion of it slightly inflated. Distal side of right magnum linguiform and that of left subtrapezoidal; inner border of the latter partially damaged; outer margin of right bone gently curved, while that of left one straight and parallel with inner margin; the surface smooth and a little depressed.



Textfig. 27. Keton magnum of right (7–11) (UHR no 18466–11) and left sides (1–6) (UHR no 18466–12).
1 and 7, Fore side; 2 and 8, Aft side; 3 and 9, Proximal side (fore side is in below); 4 and 10, Distal side (fore side is in below); 5 and 11, Inner side; 6, Outer side. Scale is given for figs. 1–8, 11

In inner view, bone irregularly quadrate with long anteroposterior axis; proximal margin slightly curved and distal margin almost straight; fore margin also straight and bent forward. Outer side corresponding with inner side in outline; the surface smooth and flat; median transverse fossa broad, shallow, running from posterior proximal corner to middle of the surface; fossa of right bone more distinct than the left one. Posterior side of the bone like anterior side in outline.

	Right	Left
Height along interior free margin (BB′)	26	25±
Ditto along interior aft margin (AA′)	25	25±
Ditto along exterior fore margin (CC′)	24	26
Transverse width along posterior proximal margin (KK′)	35	33
Ditto along posterior distal margin (EE′)	36	29±
Ditto along anterior distal margin (FF′)	27	27±
Anteroposterior length on median distal surface (MM′)	64	63

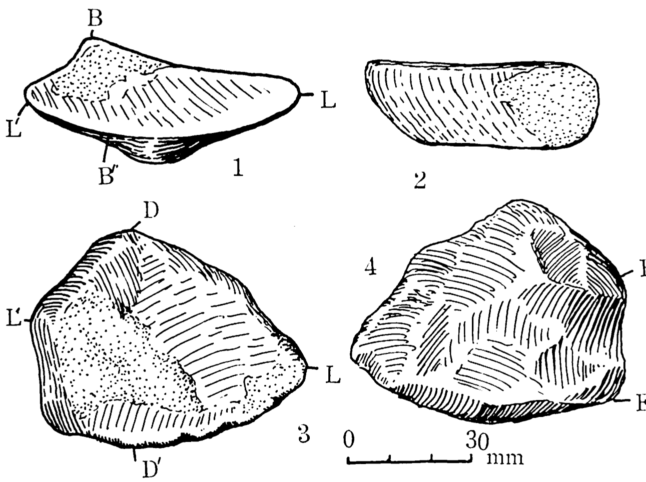
Keton magnum is tolerably distinct from the Izumi bone, much lower (×0.85) and longer (×1.4) and has deeper median transverse fossa of outer surface. This may be taxonomic character.

4F. Unciform

a. Izumi (NSMT-P-5601-14)

(Pl. 4, Figs. 5-8, Textfigs. 15, 28)

Represented by left unciform (bone C, no. 36) which is relatively large and platy with four surfaces. In anterior view, bone elongate trigonal with longest and gently curved distal margin; proximal margin straight and long; inner margin shortest, recurved and bent inward; the surface smooth and flat. In distal view, bone trigonal with long and curved fore and posterior outer margins; inner margin short and convex inward; the surface smooth and curved, posterior inner corner of which depressed. Proximal side corresponding with distal in outline; the surface flat and



Textfig. 28. Left unciform of Izumi (NSMT-P-5601-14).
1, Fore side; 2, Aft side; 3, Proximal side (fore side is in below);
4, Distal side (fore side is in below).

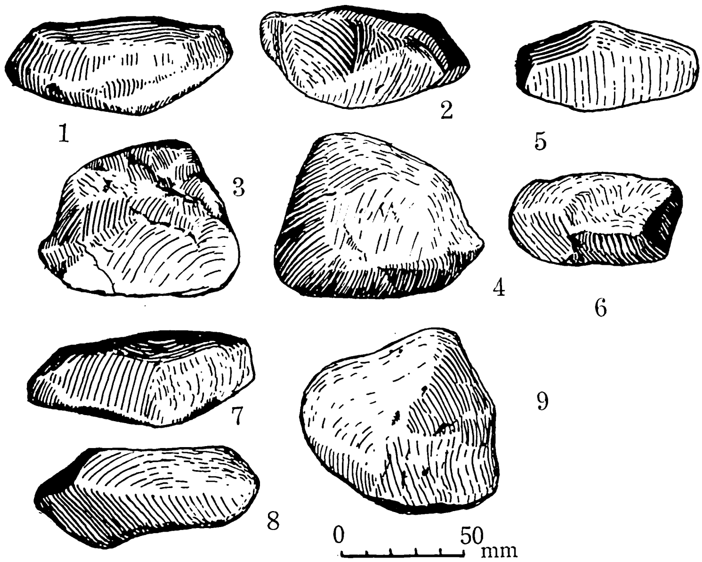
partially damaged. Posterior outer side elongate trigonal, corresponding with anterior side in outline, with curved distal and almost straight proximal margins; the surface uneven and convex. In inner view, bone subquadrate with long proximal and distal margins, which are parallel with each other; anterior half of the surface damaged. Inner surface in contact with exterior distal surface of lunar and upper half of outer surface of magnum; proximal surface in contact with distal surface of cuneiform; distals urface in contact with proximal end of third and fourth metacarpi.

Transverse width on fore surface (LL')	63
Maximum height (BB')	25
Maximum anteroposterior length (DD')	48
Anteroposterior length along exterior distal margin (EE')	31
Ditto and inner surface (HH')	55

b. Keton (UHR no 18466-13, 14)

(Textfigs. 16, 29)

Represented by right (bone D') (UHR no 18466-13) and left unciform (bone D) (UHR no 18466-14); left bone in perfect preservation while right one damaged on inner border. Bone platy and subtrapezoidal. In anterior view, bone elongate trigonal or lingual with straight proximal and moderately curved distal margins;



Textfig. 29. Keton unciform of right (7-9) (UHR no 18466-13) and left sides (1-6) (UHR no 18466-14).
1 and 7, Fore side; 2 and 8, Aft side; 3, Proximal side (fore side is in below); 4 and 9, Distal side (fore side is in below); 5, Outer side; 6, Inner side.

outer corner and interior distal corner projected; the surface flat and smooth. In proximal view, bone subtrapezoidal with longest and gently curved fore margin; outer margin almost straight, aft margin slightly curved and inner margin recurved. The surface smooth, almost flat but middle portion of it inflated. Distal side corresponding with proximal in general outline. Inner side subquadrate in left bone with slightly curved proximal and distal margins; fore margin nearly straight; upper half of the surface sloping downward and sharp transverse edge running on middle height. Inner side of right bone damaged and repaired by NAGAO. Outer side subquadrate, becoming thinner posteriorly; distal margin straight while proximal slightly curved.

	Right	Left
Maximum height (BB')	37	39
Transverse width on fore surface (LL')	—	90
Ditto along posterior margin (CC')	66	59
Maximum anteroposterior length (DD')	75	67

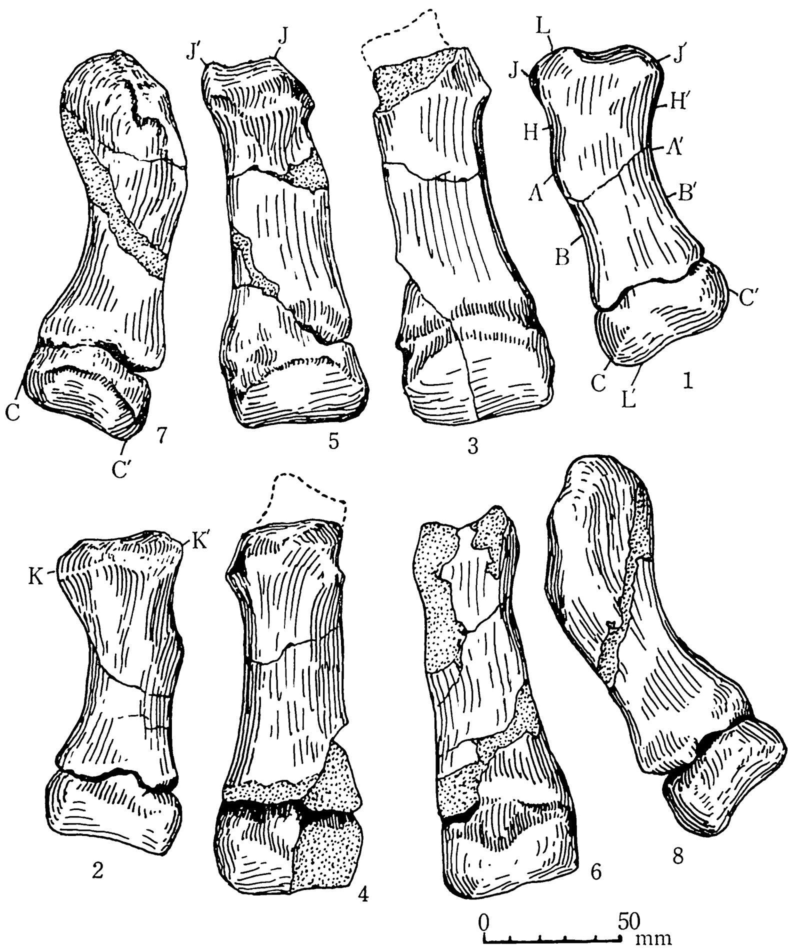
Keton unciform is much higher (×1.48), wider (×1.43) and longer (×1.56). Ratio of height to transverse width is 0.4 in Izumi and 0.43 in Keton, and both almost in accord with each other.

5. Metacarpus

a. Izumi

(Textfigs. 17, 18, 30, 31)

Five right metacarpal bones are preserved together in sec. 1, in their natural positions, associating their phalanges. Four left metacarpal bones are found in sec. 2; third to fifth metacarpi are put in the same portion associating some phalanges; proximal part of third and fourth metacarpi are separated from this portion and preserved near ulna, radius and carpus together with second metacarpus. First metacarpus is exceedingly small sized, rudimentary, while the other four are very large and stout, hence the animal has five digits anatomically but four functionally.

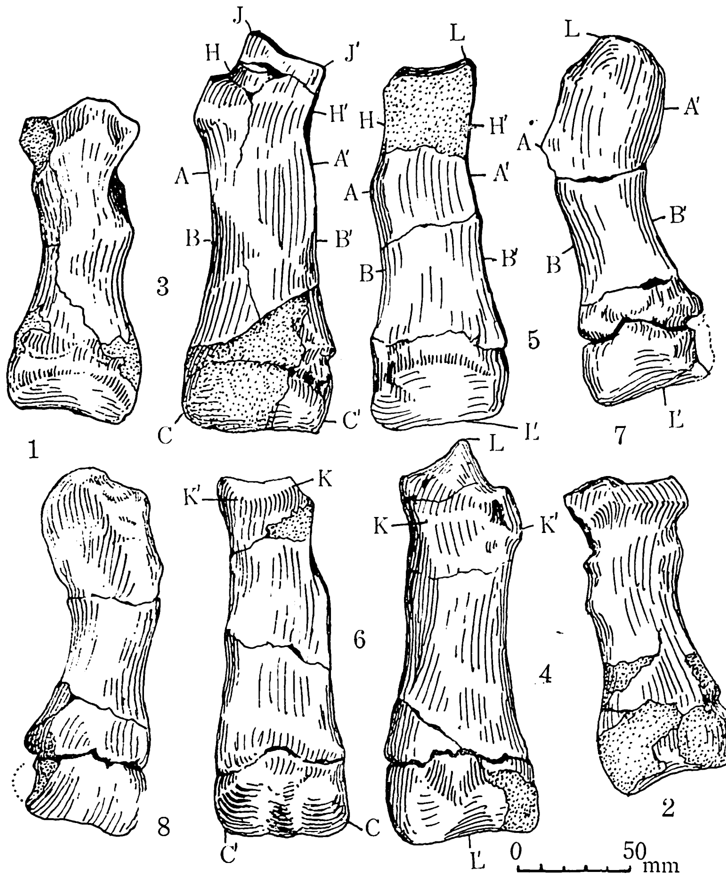


Textfig. 30. Right metacarpi of Izumi (NSMT-P-5601-16, 18, 20, 22).
Upper, Fore side; Lower, Aft side.

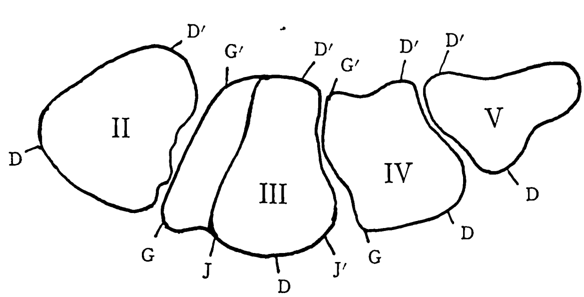
b. Keton

(Textfig. 17)

Keton metacarpus is very poor in preservation. NAGAO designated two right bones (J and K) as third and fourth metacarpi; they are distal end of fourth (K) and fifth metacarpi (J). In his reconstruction NAGAO regarded the existence of large-sized five digits, but he could not know the rudimentary first metacarpus of the Izumi skeleton. On the other hand third to fifth metacarpi described by VANDERHOOF from the Temblor Miocene of Coalinga, California are quite like those of the Izumi metacarpi. It seems that essential difference does not exist between the metacarpi of *Desmostylus* and *Paleoparadoxia*.



Textfig. 31. Left metacarpi of Izumi (NSMT-P-5601-17, 19, 21, 23).
Upper, Fore side; Lower, Aft side.



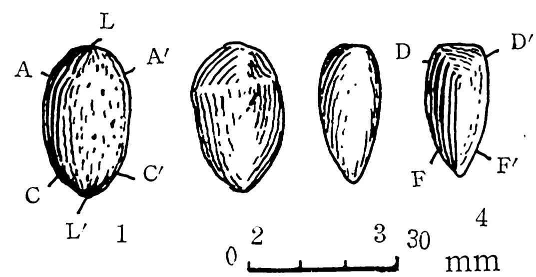
Textfig. 32. Proximal side of left metacarpi of Izumi.

5A. First Metacarpus

(Pl. 4, Figs. 31-33, Textfig. 33)

Represented only by right metacarpus of Izumi (no. 26) (NSMT-P-5601-15), which is preserved near proximal end of right third and fourth metacarpi. Bone small sized, globular and well preserved. In fore-&-aft views, it is oval, becoming thicker proximally and pointed at its distal corner; fore surface moderately curved; inner surface very rugose while outer rather smooth; exterior proximal and outer surfaces flat and smooth with sharp edges; the former sloping down outward and articulating with posterior inner corner of proximal portion of second metacarpus.

Maximum length (LL′)	31
Transverse width at proximal portion (AA′)	19
Ditto at distal portion (CC′)	14
Anteroposterior thickness at proximal portion (DD′)	15
Ditto at distal portion (FF′)	11



Textfig. 33. Right first metacarpus of Izumi (NSMT-P-5601-15). 1, Fore side; 2, Aft side; 3, Inner side; 4, Outer side.

5B. Second Metacarpus

(Pl. 6, Figs. 5-12, Textfigs. 17, 30-32)

Represented by right (no. 4) (NSMT-P-5601-16) and left metacarpi (no. 4′) (NSMT-P-5601-17) of Izumi; distal portion of left metacarpus much damaged but right one well preserved; epiphysis detached. Bone stout, dense, irregularly cubic and rather flat. In anterior view, both inner and outer margins curved moderately; upper half of the latter undulated with an obtuse projection at middle point of the whole length; outer margin just above this point distinctly concave outward. Proximal margin moderately recurved and bent inward. Distal portion expanded laterally and distal margin almost straight; fore surface of distal end smooth, semioval in outline with marked border line gently curved; fore surface smooth and gently curved. Aft side corresponding to fore side in outline; a transverse ridge running on proximal border and the surface below it moderately depressed; the surface smooth and flat with two small oval-shaped foramens on proximoouter portion.

In lateral view, proximal end distinctly expanded, and much broader than distal end; shaft narrow at middle and becoming thicker gradually both proximally and distally; aft margin more strongly curved than fore one; exterior proximal surface wider than interior proximal surface with median depression; surface above it rather flat and irregularly triangular with undulated border line. Inner projection of proximal end strong but not sharp. Distal margin convex distally. Proximal end triangular in proximal view with long anterior and posterior margins; outer margin short and straight; the surface smooth and a little depressed. Distal end subquadrate in distal view.

	Right	Left
Maximum length on fore surface (LL′)	129	128
Minimum transverse width on fore surface (BB′)	34	35
Transverse width at middle projection on fore surface (AA′)	38	40
Ditto above middle projection on fore surface (HH′)	39	37
Ditto along anterior proximal margin (JJ′)	53	52
Ditto along posterior proximal margin (KK′)	54	—
Ditto at distal end (CC′)	52	51
Anteroposterior thickness at middle of shaft (EE′)	18	18
Ditto along proximoouter margin (DD′)	47	48
Ditto at proximoinner margin (GG′)	29	—
Ditto at exterior distal portion along epiphysis (FF′)	29	30
Ditto at interior distal portion (MM′)	34	31

5C. Third Metacarpus

(Pl. 5, Figs. 13-16, Pl. 6, Figs. 1-4, Textfigs. 17, 30-32)

Represented by right (no. 3) (NSMT-P-5601-18) and left metacarpi (no. 37) (NSMT-P-5601-19) of Izumi, which are largest of all metacarpal bones. Anterior distal portion of left bone and proximal end of right bone broken. Bone stout, dense, flat cubic with proximal and distal expansions. Distal end elongate quadrate in distal view and proximal end subtrapezoidal in proximal view with longer and gently curved fore margin; both lateral margins recurved. The surface flat and smooth.

In anterior view, both inner and outer margins gently curved; proximal margin straight and bent outward; proximoinner margin truncated at about one sixth length of the shaft from proximal end, and projected inward at the next one sixth length; margin below the projection moderately concave; shaft gently expanded distally; axis of shaft at about one sixth length from proximal margin bent outward; also proximoinner margin at the same length bent exteriorly; fore surface almost flat and smooth. Aft side corresponding to fore side in outline. Median proximal portion projected aftward. In lateral view, proximal end broader than distal, trigonal in outline with gently curved proximal margin. Shaft becoming broader proximally and distally; posterior margin more strongly curved than anterior. Proximal median portion carrying shallow depression of subtrigonal shape. Distal end much convex distally and distal surface very rugose. Distal epiphysis undetached but not fully fused with shaft. Median longitudinal ridge moderate and more distinct posteriorly than anteriorly.

	Right	Left
Maximum length on fore surface (LL′)	146	157
Minimum transverse width on fore surface (BB′)	42	41

Transverse width at above middle of shaft on fore surface (AA′)	42	43
Ditto at above proximal projection (HH′)	—	42
Ditto along anterior proximal margin (JJ′)	—	33
Ditto along posterior proximal margin (KK′)	36	36
Dioto at distal end (CC′)	54	56
Anteroposterior thickness at middle of shaft (EE′)	19	18
Ditto along proximoouter margin (DD′)	—	48
Ditto along proximoinner margin (GG′)	—	44
Ditto at exterior distal portion (FF′)	—	35

5D. Fourth Metacarpus

a. Izumi (NSMT-P-5601-20, 21)

(Pl. 5, Figs. 4-12, Textfigs. 17, 30-32)

Represented by right (bone チ) (NSMT-P-5601-20) and left metacarpi (bone no. 39; 2 (NSMT-P-5601-21), which is next largest of all metacarpal bones. Bone stout, cubic, flat and straight, more straight than third. Anterior proximal portion of left bone and posterior proximal portion of right bone broken. Proximal and distal ends moderately expanded. In anterior view, both inner and outer margins of proximal shaft bent outward; inner margin at about one tenth length of shaft from proximal end straight and much bent outward; a point of distal end of this margin sharply projected; inner margin at about one fourth length of shaft below the point moderately projected; inner margin at about one fourth length of shaft below the point moderately recurved; fore surface flat and smooth, but proximally a little inflated and rugose.

Proximal side quadrate in proximal view, with long and moderately curved inner and outer margins; both fore and aft margins nearly straight and the former a little longer than the latter. In lateral view, shaft very narrow, eminently expanded both proximally and distally; proximal surface flat and triangular, with large-sized median triangular depression; surface anterior of the depression on outer surface very flat and lingual shaped. Distal epiphysis almost fused with shaft; fore surface of distal end semioval with distinct border line which is gently curved just below suture line of epiphysis. Aft surface of distal end carrying median longitudinal ridge disappearing at fore side.

	Right	Left
Maximum length on fore surface (LL′)	141	144
Minimum transverse width on fore surface (BB′)	40	42
Transverse width at projection above middle of shaft on fore surface (AA′)	40	43
Ditto at proximal constriction on fore surface (HH′)	34	—
Ditto along anterior proximal margin (JJ′)	33	—
Ditto along posterior proximal margin (KK′)	—	25
Ditto at distal end (CC′)	53	53
Anteroposterior thickness at middle of shaft (EE′)	16	16
Ditto along proximo inner margin (GG′)	—	44
Ditto along proximo outer margin (DD′)	37±	39±
Ditto at interior distal portion (FF′)	35	34

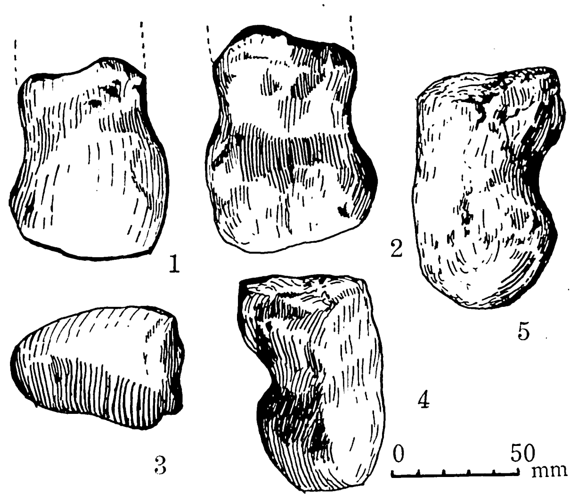
b. Keton (UHR no 18466-15)

(Textfigs. 17, 34)

Represented by distal portion of right metacarpus (bone K) which is solid, dense, stout and cubic. Epiphysis perfectly fused with shaft and no marked border line visible on fore surface. Distal portion expanded laterally and terminal surface broad and smooth. In anterior view, bone irregularly quadrate with gently curved distal margin; lateral margin moderately curved. In lateral view, posterior margin distinctly concave aftward while anterior margin rather straight. Proximal border of the bone is probably the portion just above epiphysial suture. In aft view median portion of bone much depressed. Distal surface narrow anteroposteriorly and subtriangular; median longitudinal ridge obsolete; inner margin much longer than outer one.

Length as preserved (LL′)	80
Minimum transverse width (OO′)	42
Transverse width at distal end (CC′)	64
Anteroposterio thickness at exterior distal portion (FF′)	45
Ditto at exterior proximal margin as preserved (PP′)	47

Keton bone is wider (×1.2) than Izumi. Posterior depression of Keton may correspond with epiphysial portion. The obsoleteness or disappearance of median longitudinal ridge on distal end may be significant.



Textfig. 34. Right fourth metacarpus of Keton (UHR no 18466-15). 1, Fore side; 2, Aft side; 3, Distal side (fore side is in upper); 4, Outer side; 5, Inner side.

5E. Fifth Metacarpus

a. Izumi (NSMT-P-5601-22, 23)

(Pl. 4, Figs. 34-38, Pl. 5, Figs. 1-3, Textfigs. 17, 30-32)

Represented by right (bone k) (NSMT-P-5601-22) and left metacarpi (bone no. 30, 35) (NSMT-P-5601-23) which is flat and much curved. Exterior distal corner of right bone and exterior proximal corner of left bone damaged. In anterior view, both proximal and distal ends much expanded laterally; inner margin of shaft nearly straight while outer margin moderately curved. Proximoinner margin of about one fourth length of shaft almost straight and much bent outward. Distal margin gently convex proximally; axis of proximal shaft making an angle of 30° with that of main shaft; distal margin almost straight; the surface smooth and flat. Aft side corresponding with fore side in outline; the surface also smooth and nearly flat but median proximal portion moderately depressed.

Interior proximal surface irregularly triangular in inner view, with almost straight fore and posterior proximal and slightly recurved posterior distal margins; surface smooth and articulating with exterior distal corner of ulna, exterior corner of cuneiform and unciform, with exterior proximal corner of fourth metacarpus. Hind corner of interior proximal border nodulous and much projected backward. In lateral view, shaft narrowest at middle, becoming gradually broader distalward. Epiphysis not fully fused with shaft and right one detached. Fore surface of distal end smooth and suboval in outline; aft surface of it also smooth and much depressed. In distal view, distal surface nearly quadrate with truncated corners; outer margin of it a little longer than inner one.

	Right	Left
Maximum length on fore surface (LL′)	141	141
Minimum transverse width on fore surface (BB′)	34	33
Maximum transverse width of proximal shaft on fore surface (AA′)	51	50
Ditto at distal end (CC′)	47	46±
Anteroposterior thickness at middle of shaft (EE′)	14	15
Ditto on proximoinner border (GG′)	36	36
Ditto at interior distal portion (FF′)	29	32
Ditto at exterior distal portion (QQ′)	32	34

b. Keton (UHR no 18466-16)

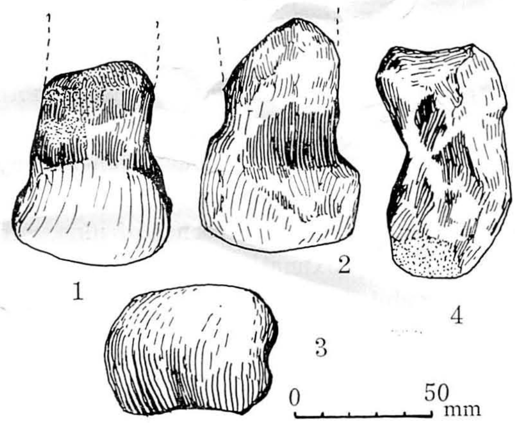
(Textfigs. 17, 35)

Represented by distal portion of right metacarpus (bone J) which is solid, stout and cubic like the fourth metacarpus. Epiphysis perfectly fused with shaft and distal portion expanded laterally with broad and smooth terminal surface. Shaft subtrapezoidal in cross section. In anterior view, bone irregularly quadrate with gently curved distal margin; outer margin undulated while inner margin almost straight; the surface smooth and slightly curved. Proximal border of the bone probably the portion a little above epiphysial suture. Posterior side corresponding with the anterior in outline; median portion much depressed. In distal view, bone quadrate with gently curved fore margin; inner margin convex inward and outer margin concave outward; the surface smooth and moderately curved.

Length as preserved (LL′)	82
Minimum transverse width (OO′)	45

Transverse width at distal end (CC′)	57
Anteroposterior width at exterior distal portion (FF′)	40
Ditto at exterior proximal margin as preserved (PP′)	42

Keton bone is wider (×1.2) than Izumi, the same way as in fourth metacarpus. Posterior depression of the Keton bone also corresponds with epiphysial portion.



Textfig. 35. Right fifth metacarpus of Keton (UHR no 18466-16). 1, Fore side; 2, Aft side; 3, Distal side (fore side is in upper); 4, Outer side.

5F. On the Coalinga Metacarpus

Three left metacarpal bones designated by VANDERHOOF are very important and interesting samples to be compared with the Izumi bones. The anterior aspect of them is like those of Izumi, but in the Coalinga bones, exterior proximal corner of fifth metacarpus is not projected; also proximal end of third metacarpus is not bent outward. If the proximal border of the Coalinga bones is undamaged natural surface, their straight margin is distinct from the Izumi bones. Coalinga metacarpus may belong to *Desmostylus*, not to *Paleoparadoxia*, hence this may fill the lack of knowledge about proximal portion of metacarpus of Keton *Desmostylus*.

6. Manus Phalanges

a. Izumi

(Textfig. 17)

In section 1, five phalanges are preserved associated with right metacarpus, and in section 2 there are preserved two phalanges associated with left metacarpus. Of five right phalanges, two (bone no. 27, bone D) are proximal, two (bone E, bone α) are middle and one (bone no, 26) is distal. Bones D and E are jointed and linked with fifth metacarpus. Bone no. 27 is preserved between fourth and fifth metacarpi. Bones α and no. 26 are preserved together with third metacarpus.* Of two left phalanges, one (bone F, G) is middle and preserved between third and fourth metacarpi; the other (bone H) is distal and dreserved before fifth metacarpus.* In section 3, there are found three phalanges (pone no. 9=25, no. 5=21, 6=22, no. 3=19 4=20), of which the latter two are jointed with each other. These are regarded as left bones. Also at a point near right fourth and fifth metacarpi is found a proximal phalange (bone no. 32, ∧) which is regarded as right one. Hence three proximal, two middle and one distal bones of right manus, and two proximal, two middle and one distal bones of left manus are known. Comparing them the writer arranged them as follows.

		Right	Left
Proximal	II	—	5=21, 6=22
	III	32, ∧	9=25
	IV	27	—
	V	D	—
Middle	II	—	3=19, 4=20
	III	α	—
	IV	—	F, G
	V	E	—
Distal	II	—	—
	III	26 (?)	—
	IV	—	H (?)
	V	—	—
Total		6	5

b. Keton

(Textfig. 17)

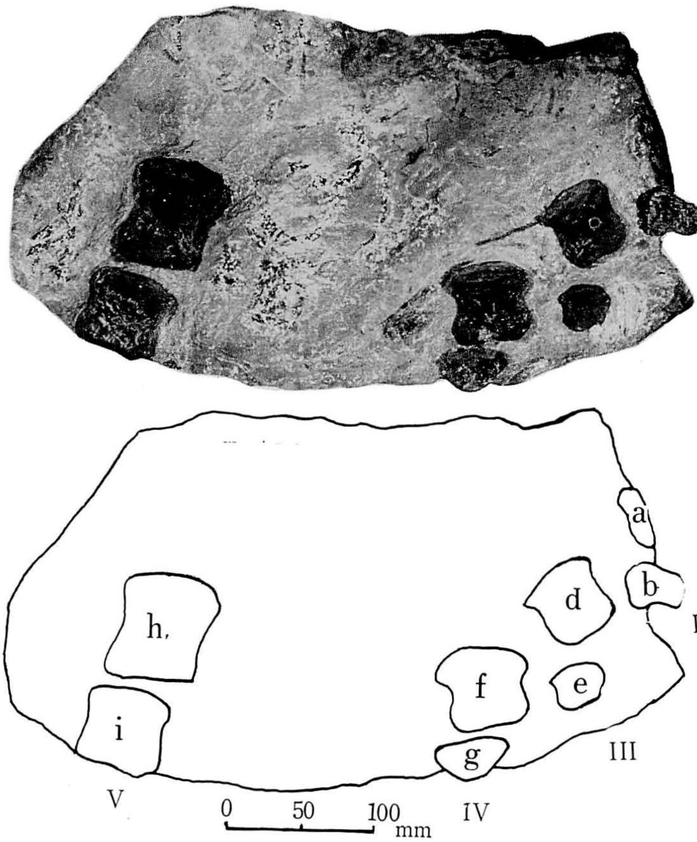
In block b, there are preserved eight phalanges in jointed positions. NAGAO left a photo of this block and the writer nominates them as a, b, c, d.... i following their relative positions. NAGAO regarded them as right manus phalanges. Bones a and b are jointed with each other, bones d and e, bones f and g and bones h and i are also jointed in the same way. The writer thinks NAGAO's designation is quite right although he writes fifth digit as fourth. It is paradoxical that he reconstructed five large digits in his mounted skeleton inspite of the fact that his photo shows four digits as preserved. Besides the right eight phalanges there are known two left phalanges (bone d' and 1) and one right proximal phalange (bone c). The writer arranges these bones as follows:

		Right	Left
Proximal	II	—	—
	III	c	—
	IV	—	—
	V	h	—
Middle	II	a	1
	III	d	d′
	IV	f	—
	V	i	—

* Two distal phalanges (bone H and bone no. 26) are very distinct from those of the Stanford skeleton; perhaps they may belong to pes phalanges and there is a probability that bone H is left second distal and bone no. 26 is left third distal, but from their situation of preservation, the writer is going to treat them as those of manus tentatively.

Distal	II	b	—
	III	e	—
	IV	g	—
	V	—	—
Total		9	2

Thus all phalangial bones except fifth distal bone are known, if we accept no essential difference of construction between *Desmostylus* and *Paleoparadoxia*.



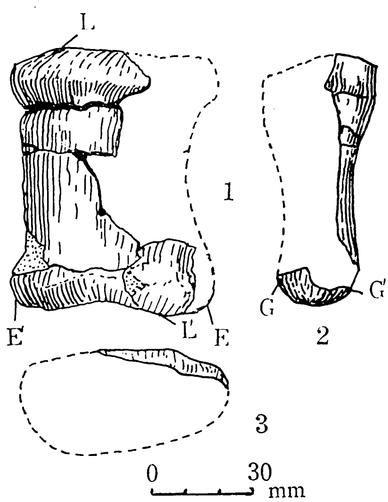
Textfig. 36. Phalanges of right manus of Keton in mother rock. a and b, Middle and distal phalanges of second digit; d and e, Middle and distal phalanges of third digit; f and g, Middle and distal phalanges of fourth digit; h and i, Proximal and middle phalanges of fifth digit.

7. Proximal Phalanges

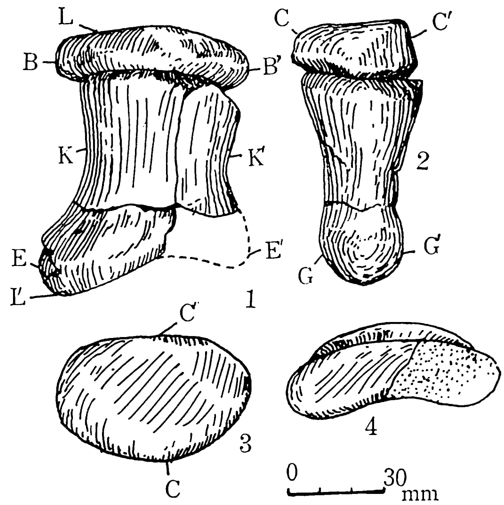
7A. Second Proximal Phalange

(Pl. 10, Figs. 1, 2, Textfig. 37)

Represented by a left bone of Izumi (bone no. 5=21, 6=22) (NSMT-P-5601-24) which is very poor in preservation, only posterior outer portion known. Epiphysis detached. Posterior surface flat but damaged; outer margin straight and distal margin moderately concave distally.



Textfig. 37. Left second proximal phalange (manus) of Izumi (NSMT-P-5601-24). 1, Fore side; 2, Inner side; 3, Proximal side (fore side is in below).



Textfig. 38. Right third proximal phalange (manus) of Izumi (NSMT-P-5601-25). 1, Fore side; 2, Inner side; 3, Proximal side (fore side is in below); 4, Distal side (fore side is in upper).

7B. Third Proximal Phalange

a. Izumi (NSMT-P-5601-25, 26)

(Pl. 9, Figs. 50-56, Textfig. 38)

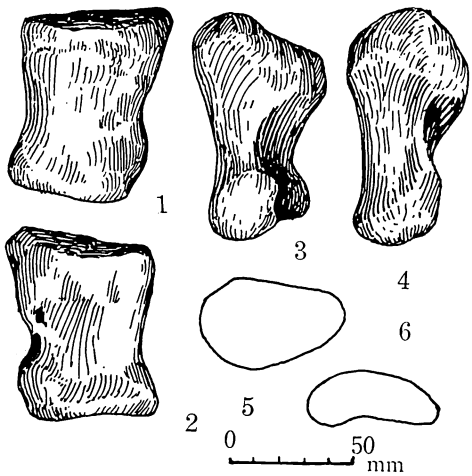
Represented by a right (bone no. 32) (NSMT-P-5601-25) and a left bones (bone no. 9=25) (NSMT-P-5601-26); the former broken in interior distal portion and the latter preserved only in proximal end. In fore-&-aft views, right bone subtrapezoidal with margin slightly curved and proximal epiphysis unfused with shaft but undetached, which is oval, disc like and wider than shaft just below epiphysial suture. Inner margin much concave outward and outer margin gently curved. In lateral view shaft becoming much thicker proximally and distal end convex distally; fore margin a little more curved than aft one. Posterior surface smooth and almost flat. Distal surface subcrescentic with obtuse both lateral ends. Left bone very fragmental, retaining anterior half of proximal end.

b. Keton (UHR no 18466-18)

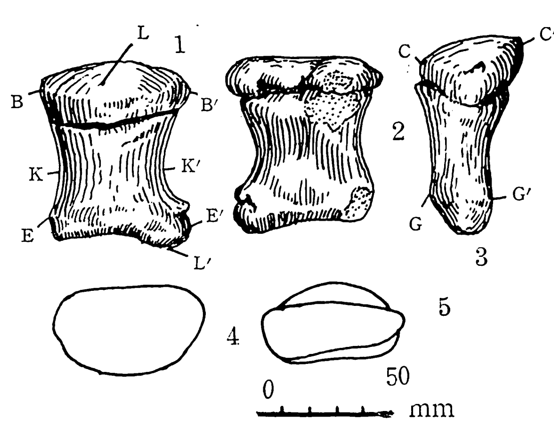
(Textfig. 39)

Represented by a right bone (c) which is well preserved. Bone thick, platy and stout. In anterior view, it quadrate with long proximodistal axis; proximal margin straight and bent outward; both inner and outer margins moderately curved and middle of the former eminently concave inward; distal margin slightly curved; the surface smooth and slightly depressed. Posterior side corresponds to the anterior one in outline; the surface smooth and depressed especially at its median distal portion. In lateral view, shaft becomes much thicker proximally and aft margin eminently concave aftward; proximal margin almost straight and bent forward. Distal surface elongate suboval in distal view and fore margin more curved than aft one. Proximal surface in proximal view nearly semicircular.

Keton bone is tolerably different from Izumi, without any strong exterior distal projection; shaft relatively narrower and thicker. It is 1.27 times longer, 1.02 times wider at proximal and 1.38 times thicker at the same portion.



Textfig. 39. Right third proximal phalange (manus) of Keton (UHR no 18466-18).
1, Fore side; 2, Aft side; 3, Inner side; 4, Outer side; 5, Proximal side (fore side is in below); 5, Distal side (fore side is in upper).



Textfig. 40. Right fourth proximal phalange (manus) of Izumi (NSMT-P-5601-27).
1, Fore side; 2, Aft side; 3, Inner side; 4, Proximal side (fore side is in below); 5, Distal side (fore side is in upper).

7C. Fourth Proximal Phalange

(Pl. 9, Figs. 45-49, Textfig. 40)

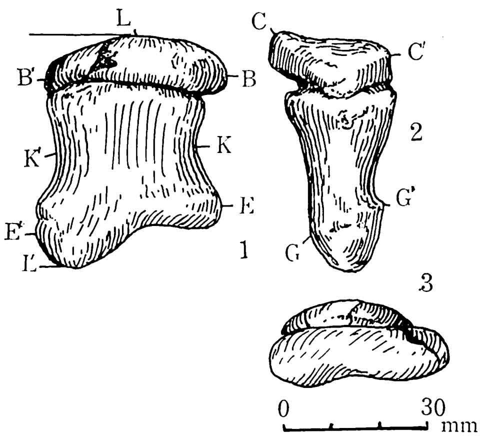
Represented by a right bone of Izumi (bone no. 27) (NSMT-P-5601-27) which is a little damaged on its posterior aft surface. Bone thick, platy and stout, becoming thicker proximally. In anteroposterior views, bone subquadrate with truncate four corners; proximal margin straight while both lateral and distal margins recurved; inner margin more strongly curved than outer one. Proximal epiphysis platy, unfused with shaft but undetached. The surface smooth and a little depressed with a sharp and curved edge. Aft surface also smooth and more depressed than fore surface. Interior distal corner more eminently projected than exterior distal corner. Proximal surface flat, bent forward and nearly suboval in proximal view with almost straight aft and much curved fore margins.

7D. Fifth Proximal Phalange

a. Izumi (NSMT-P-5601-28)

(Pl. 9, Figs. 40-44, Textfig. 41)

Represented by a right bone (bone D) which is well preserved, stout and platy. Bone flat and becomes thicker proximally. In anterior view, it is subquadrate with truncated four corners and gently curved proximal margins; the other three margins eminently recurved; outer margin longer than inner; exterior distal corner eminently projected exteriorly, while interior distal one not so strong as former one. Anterior surface smooth and a little depressed. Proximal epiphysis unfused with shaft but undetached. Proximal surface flat, bent forward, slightly depressed and suboval in proximal view with strongly curved aft margin. In lateral view shaft elongate triangular; fore margin shorter than aft one and its distal portion moderately concave forward. Distal surface more elongate oval and narrower than proximal.

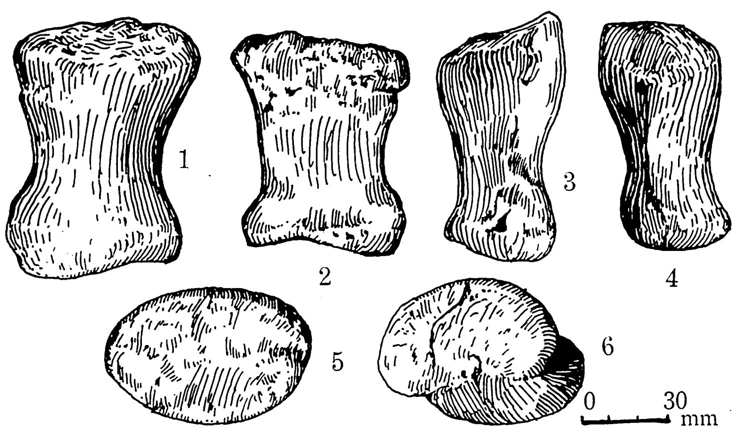


Textfig. 41. Right fifth proximal phalange (manus) of Izumi (NSMT-P-5601-28).
1, Fore side; 2, Outer side; 3, Proximal side (fore side is in upper).

b. Keton (UHR no 18466-19)

(Textfig. 42)

Represented by a right bone (bone h) which is damaged at anterior proximal portion. Bone dense, stout, platy and becomes much thicker proximally. In anterior view, it is quadrate with four truncated corners; proximal margin almost straight, distal margin gently curved while both inner and outer margins much recurved. Exterior distal corner more strongly projected than interior distal one. Fore surface smooth and a little depressed. In lateral view, proximal portion nearly trigonal; aft margin more strongly curved than fore one and distal margin slightly curved.



Textfig. 42. Right fifth proximal phalange (manus) of Keton (UHR no 18466-19). 1, Fore side; 2, Aft side; 3, Inner side; 4, Outer side; 5, Proximal side (fore side is in below); 6, Distal side (fore side is in upper).

Proximal surface smooth, bent forward, slightly vaulted at middle, suboval in proximal view; fore margin more eminently curved than aft one. Distal surface more elongate oval and narrower than proximal surface.

Keton bone is much longer (×1.64) and wider (×1.35) than that of Izumi. In general shape they correspond with each other.

Table 5. Measurements of proximal phalanges (manus).

R: Right. L: Left.

	Izumi					Keton	
	II	III		IV	V	III	V
	L	R	L	R	R	R	R
Maximum length as preserved (LL′)	62	63	—	59	56	80	92
Maximum transverse width of proximal end (BB′)	—	58	48+	49	45	59	66±
Minimum transverse width of shaft (KK′)	—	36	—	34	34	47	46
Maximum transverse width of distal end (EE′)	50	54	—	44	47	57	61
Maximum thickness of proximal end (CC′)	—	31	—	33	30	43	42±
Ditto of distal end (GG′)	22	20	—	21	17	28	34

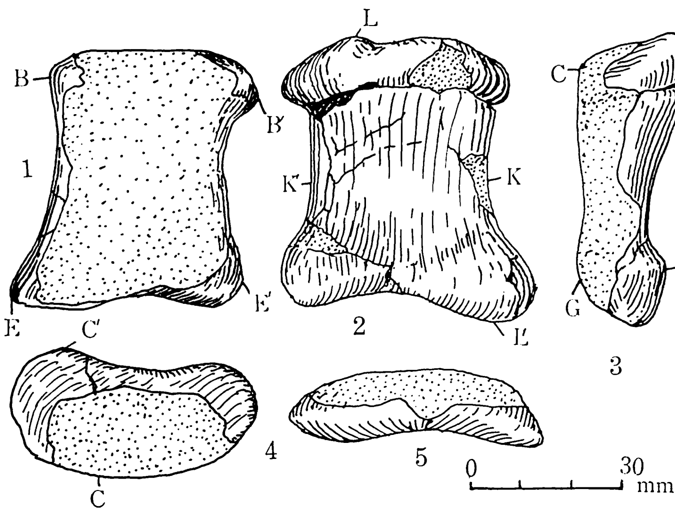
8. Middle Phalanges

8A. Second Middle Phalange

a. Izumi (NSMT-P-5601-29)

(Pl· 10, Figs, 3-6, Textfig. 43)

Represented by a left bone (bone no. 3=19, 4=20) which is preserved only in its aft surface. Bone flat and platy. In posterior view it is subquadrate with four truncated corners; proximal margin gently curved while the other three margins much recurved; inner margin longer and more strongly curved than outer one; median portion of distal margin much concave distally; interior distal corner tolerably projected inward. Proximal epiphysis detached. Proximal surface suboval in proximal view with recurved aft margin; in lateral view it seems to be bent forward.

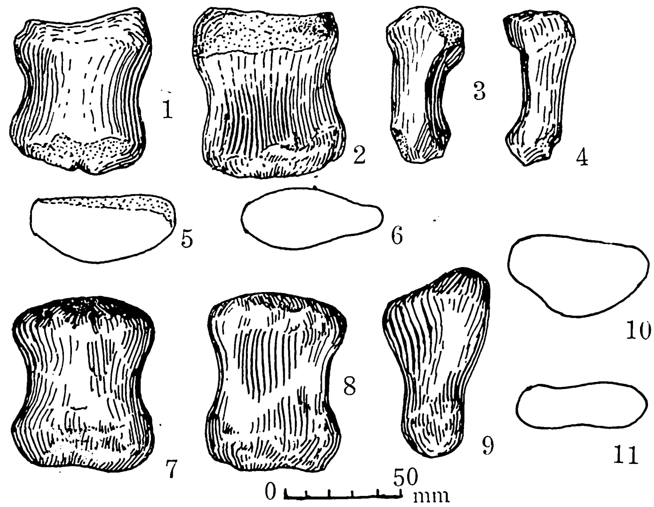


Textfig. 43. Left second middle phalange (manus) of Izumi (NSMT-P-5601-29). 1, Fore side; 2, Aft side; 3, Outer side; 4, Proximal side (fore side is in below); 5, Distal side (fore side is in upper).

b. Keton (UHR no 18466-20, 17)

(Textfig. 44)

Represented by a right (bone a) (UHR no 18466-20) and a left (bone 1) (UHR no 18466-17) bones, which are well preserved, thick and platy. In anterior view, right bone subquadrate with four truncated corners, longer than wide; proximal margin gently curved, distal margin slightly recurved and both lateral margins moderately recurved; the surface smooth and depressed; interior distal corner eminently projected inward. In lateral view, shaft trigonal and becomes much thicker proximally; fore margin distinctly oblique to aft margin and distal portion concave forward; proximal margin straight and bent forward. Aft side corresponds with fore side in outline; the surface smooth and slightly depressed. Axis of shaft makes an angle of



Textfig. 44. Right second (7-11) (UHR no 18466-20) and left (1-6) (UHR no 18466-17) middle phalanges (manus) of Keton.
1 and 7, Fore side; 2 and 8, Aft side; 3, Outer side; 4 and 9, Inner side; 5 and 10, Proximal side (fore side is in below); 6 and 11, Distal side (fore side is in upper).

80° with proximal and distal margins.

Keton bone is a little longer (×1.24) and wider (×1.22) than Izumi. In outline they well correspond to each other.

8B. Third Middle Phalange

a. Izumi (NSMT-P-5601-30)

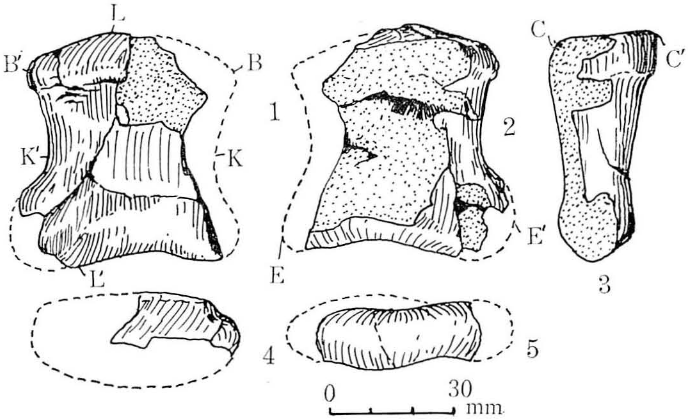
(Pl. 9, Figs. 63-68, Textfig. 45)

Represented by a right bone (bone α) which is much damaged on its exterior fore surface and exterior aft border; interior aft corner is also broken. Bone flat, platy and subtrapezoidal as preserved in fore-&-aft views. When restored, it is subquadrate in posterior view, with moderately recurved distal margin; distal margin convex upward and both inner and outer margins tolerably recurved. Aft surface smooth and flat. Proximal surface seems to be elongate oval in proximal view and distal surface more elongate than proximal.

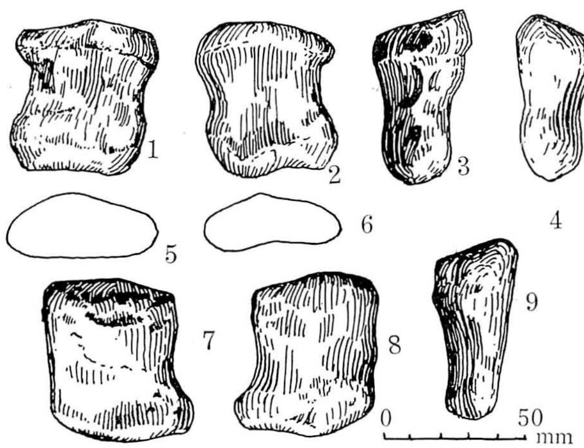
b. Keton (UHR no 18466-21, 22)

(Textfig. 46)

Represented by a right (bone d) (UHR no 18466-21) and a left (bone d') (UHR no 18466-22) bones; the former is well preserved and the latter damaged on exterior distal portion of fore surface and exterior proximal portion of aft surface. Bone flat, platy and becomes thicker proximally.



Textfig. 45. Right third middle phalange (manus) of Izumi (NSMT-P-5601-30). 1, Aft side; 2, Fore side; 3, Inner side; 4, Proximal side (fore side is in below); 5, Distal side (fore side is in upper).



Textfig. 46. Right third (1-6) (UHR no 18466-21) and left (7-9) (UHR no 1946-22) middle phalanges (manus) of Keton. 1 and 7, Fore side; 2 and 8, Aft side; 3, Inner side; 4 and 9, Outer side; 5, Proximal side (fore side is in upper); 6, Distal side (fore side is in upper).

In anteroposterior views, it is quadrate with four truncated corners and both lateral margins which are much recurved; proximal margin gently curved while distal moderately recurved; exterior distal corner more eminently projected than interior distal. Fore surface smooth and slightly depressed. In lateral view, bone elongate subtrigonal; proximal margin bent forward and aft margin longer than fore. Proximal surface smooth and elongate oval in proximal view; fore margin gently curved and aft margin almost straight. Distal surface smaller than and corresponding with proximal surface.

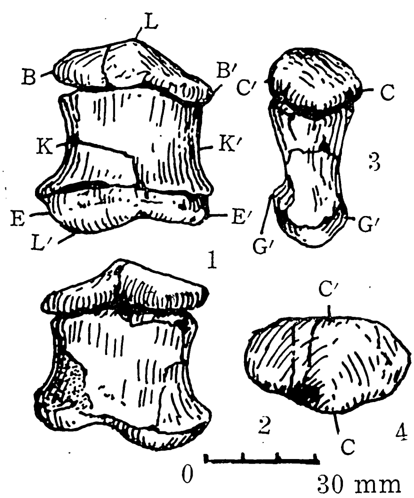
Keton bone is very much like Izumi bone but a little longer ($\times 1.09$) and wider ($\times 1.09$) than it.

8C. Fourth Middle Phalange

a. Izumi (NSMT-P-5601-31)

(Pl. 9, Figs. 58-62, Textfig. 47)

Represnted by a left bone (bone F, G) which is fine in preservation and proximal epiphysis of it detached while distal one of it undetached though unfused with shaft. Bone thick, platy and becomes much thicker proximally. In anteroposterior views, it is quadrate with much convex proximal margin; both lateral and distal margins recurved and interior distal corner larger and more eminently projected than exterior distal one. Fore surface smooth and depressed. In lateral view, bone irregularly trigonal with semicircular distal margin and much convex proximal margins; aft margin more strongly curved than fore one. Proximal surface smooth and suboval in proximal view with curved fore and almost straight aft margins.



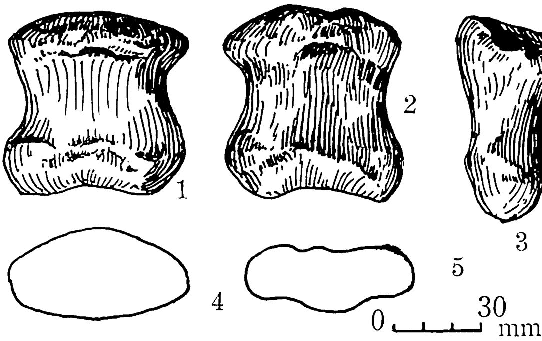
Textfig. 47. Left fourth middle phalange (manus) of Izumi (NSMT-P-5601-31).
1, Fore side; 2, Aft side; 4, Proximal side (fore side is in below).

b. Keton (UHR no 18466-23)

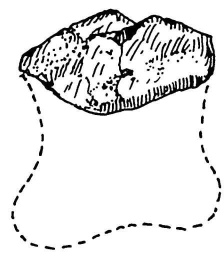
(Textfig. 48)

Represented by a right bone (bone f) which is also fine in preservation and flat, platy and becoming thicker proximally. In anteroposterior views, bone is quadrate with moderately curved proximal and tolerably recurved the other margins; exterior distal corner a little more projected than interior distal corner; fore surface smooth and depressed; epiphysial suture visible at proximal portion. In lateral view, bone is elongate trigonal and proximal margin bent forward; aft margin longer than and almost equally depressed as aft one. Proximal surface smooth and oval in proximal view with anterior margin a little more curved than posterior one. Distal surface elongate and narrower than proximal surface.

Keton bone is a little longer (×1.17) and wider (×1.27) than Izumi. They are rather like one another in general outline, but the proximal margin of Keton bone is not so distinctly convex upward as those of Izumi.



Textfig. 48. Right fourth middle phalange (manus) of Keton (UHR no 18466-23).
1, Fore side; 2, Aft side; 3, Outer side; 4, Proximal side (fore side is in below); 5, Distal side (fore side is in upper).



Textfig. 49. Right fifth middle phalange (manus) of Izumi (NSMT-P-5601-32). Fore side.

8D. Fifth Middle Phalange

a. Izumi (NSMT-P-5601-32)

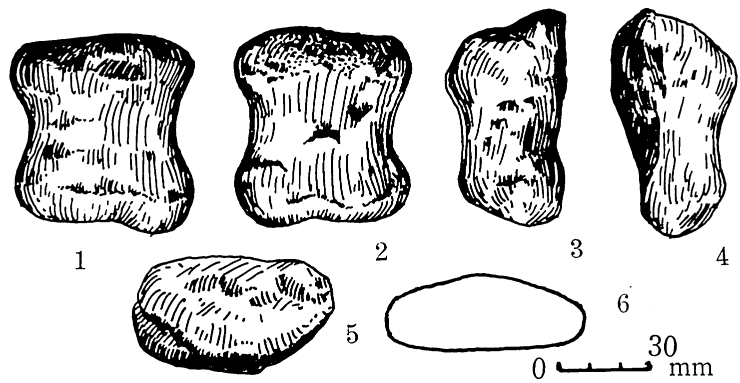
(Pl. 10, Fig. 7)

Represented by a right bone (bone E) which is very fragmental, only retaining a proximal border and subrhombic in proximal view. The surface a little damaged and uneven.

b. Keton (UHR no 18466-24)

(Textfig. 50)

Represented by a right bone (bone i) which is well preserved, thick and platy, becoming thicker proximally. Bone quadrate in anterorposterior views with truncated four corners, longer than wide; proximal margin slightly curved and distal margin a little recurved and both lateral margins moderately recurved; interior distal corner a little more projected than exterior distal one. Fore and aft surface smooth and a little depressed; posterior proximal border damaged. In lateral view, bone elongate trigonal with proximal margin bent forward; aft margin longer than fore one which is more recurved than the former. Proximal surface elongate oval in proximal view with straight aft and moderately curved fore margins. Distal surface also elongate oval in distal view and narrower than proximal.



Textfig. 50. Right fifth middle phalange (manus) of Keton (UHR no 18466-24). 1, Fore side; 2, Aft side; 3, Inner side; 4, Outer side; 5, Proximal side (fore side is in below); 6, Distal side (fore side is in upper).

Table 6. Measurements of middle phalanges (manus).

R: Right. L: Left.

	Izumi				Keton					
	II	III	IV	V	II		III		IV	V
	L	R	L	R	R	L	R	L	R	R
Maximum length as preserved (LL′)......	57	55	53	—	71	70	60	63	62	66
Maximum transverse width of proximal end (BB′).............................	45	50±	45	—	56	57	56	51	61	62
Minimum transverse width of shaft (KK′)	37	41±	37	—	45	48	44	47	47	50
Maximum transverse width of distal end (EE′).............................	54	—	46	—	55	56	53	55	60	61
Maximum thickness of proximal end (CC′)	27±	25±	25	—	36	31	28	27±	31	34
Ditto of distal end (GG′)...........	—	19±	21	—	21	28	19	17±	25	23

9. Distal Phalanges

9A. Second Distal Phalange

(Textfig. 53)

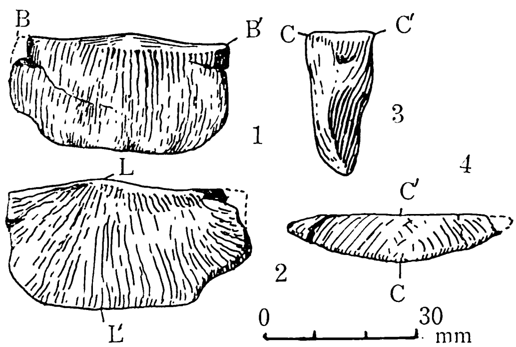
Represented by a right bone of Keton (bone b) (UHR no 18466-25) which is well preserved, flat and platy. In anteroposterior views, it is lingual, longer than wide, with distinctly convex proximal margin; outer margin eminently concave outward while inner margin almost straight; distal margin gently curved; fore surface gently curved and unsmooth while aft surface almost flat. In lateral view, bone elongate trigonal with projected distal end; proximal margin much convex upward. Proximal surface semicircular with curved anterior and straight posterior margins.

9B. Third Distal Phalange

a. Izumi (NSMT-P-5601-33)

(Pl. 10, Figs. 13-17, Textfig. 51)

Represented by a right bone (bone no. 26), well preserved, which is flat, platy and subquadrate in anteroposterior views, much wider than long; proximal margin slightly convex upward and distal margin largely straight and its inner portion abruptly curved upward; inner margin straight while outer margin convex outward. Fore surface smooth and slightly inflated at its median proximal portion. Aft surface nearly flat and rugose. In lateral wiew, bone elongate trigonal with shortest and straight proximal margin; distal end obtusely projected. Posterior margin a little undulated. Proximal surface semilenticular in proximal view, with curved fore and straight aft margins; the surface smooth and flat. Distal border also sublenticular in distal view.



Textfig. 51. Right third distal phalange (manus) of Izumi (NSMT-P-5601-33).
1, Fore side; 2, Aft side; 3, Inner side; 4, Proximal side (fore side is in below).

b. Keton (UHR no 18466-26)

(Textfig. 53)

Represented by a right bone (bone e) which is well preserved, flat and platy, becoming thicker proximally. Bone irregularly trigonal in anteroposterior views, rather longer than wide, with longest and moderately curved inner margin; outer margin shortest and distinctly concave outward at its middle portion; proximal margin gently curved and distal margin distinctly projected exterodistally. Fore surface smooth and a little inflated while aft surface depressed. In lateral view, bone elongate trigonal with shortest proximal margin which is bent forward. Proximal surface elongate oval in proximal view with inner end distinctly projected.

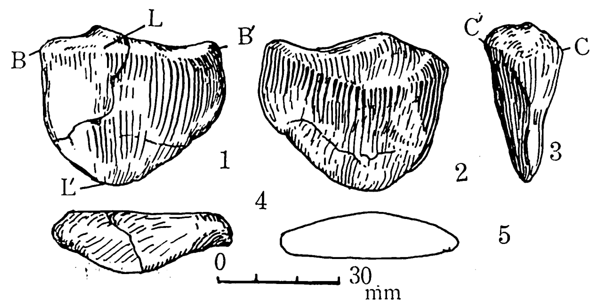
Keton bone is longer ($\times 1.48$) and narrower ($\times 0.85$) than that of Izumi. They are much distinct in outline from each other.

9C. Fourth Distal Phalange

a. Izumi (NSMT-P-5601-34) (?)

(Pl. 10, Figs. 8-12, Textfig. 52)

Represented by a left bone (bone H) which is in fine preservation, flat and platy, becoming thicker proximally. In anteroposterior views, it is wider than long, subtrigonal with undulated proximal and feebly curved lateral margins; distal margin projected distally at its interior corner. Fore surface smooth and slightly inflated, while aft surface slightly depressed and a little rugose. Distal margin sharp and edged. In lateral view, bone elongate trigonal with shortest proximal margin which is bent forward. Proximal surface semilenticular in proximal view with curved fore and straight aft margins.



Textfig. 52. Left fourth distal phalange (manus) of Izumi (NSMT-P-5601-34). 1, Fore side; 2, Aft side; 3, Inner side; 4, Proximal side (fore side is in below); 5, Distal side (fore side is in upper).

b. Keton (UHR no 18466-27)

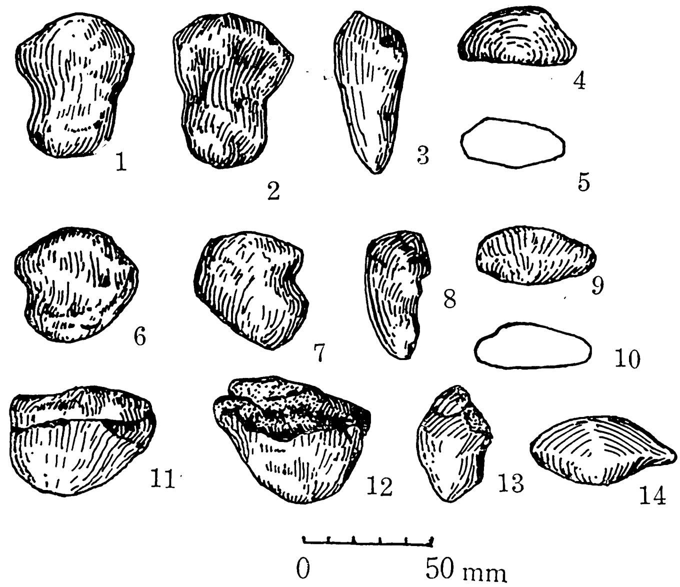
(Textfig. 53)

Represented by a right bone (bone g) which is rather well preserved but posterior proximal portion is damaged. In anteroposterior views, bone lingual or subtriangular, wider than long and projected exterodistally; proximal margin undulated and inner margin longest and slightly recurved; outer margin shortest and gently curved; fore surface smooth and a little depressed. In lateral view, bone subtriangular becoming thicker proximally and with shortest proximal margin bent forward; anterior margin moderately convex foreward, while posterior one distinctly concave aftward at its middle. Proximal surface irregularly oval in proximal view.

Keton bone is shorter (×0.95) and wider (×1.04) than that of Izumi. In Keton manus, distal phalanges are all projected exteriorly, but in Izumi manus they are rather unclear owing to poor preservation.

Table 7. Measurements of distal phalanges (manus).

R: Right. L: Left.	Izumi		Keton		
	III	IV	II	III	IV
	R	L	R	R	R
Maximum length as preserved (LL′)	31	38	46	37	36
Maximum transverse width of proximal end (BB′)	47	46	38	40	48
Minimum transverse width of shaft (KK′)	—	—	26	31	38
Maximum transverse width of distal end (EE′)	—	—	24	24	33
Maximum thickness of proximal end (CC′)	14	16	21	18	22
Ditto of distal end (GG′)	—	—	10	9	15



Textfig. 53. Right distal phalanges (manus) of Keton (UHR no 18466-25, 26,27). 1-5, Second; 6-10, Third; 11-14, Fourth; 1, 6, 11, Fore side; 2, 7, 12, Aft side; 3, 8, 13, Inner side; 4, 5, Proximal side (fore side is in upper); 5, 10, 14, Distal side (fore side is in below).

10. Sesamoid of Metacarpus

In Izumi skeleton, sesamoid bones are preserved together with right third, right fourth and left fifth metacarpi. They are attached to the posteror distal surface of metacarpi. Paired bones (bones 44, 44') are on third metacarpus, ditto (bones リ, ホ) on fourth metacarpus and one (bone no. 28) on fifth metacarpus. They are well preserved.

10A. Inner Bone on Right Third Metacarpus (NSMT-P-5601-35)

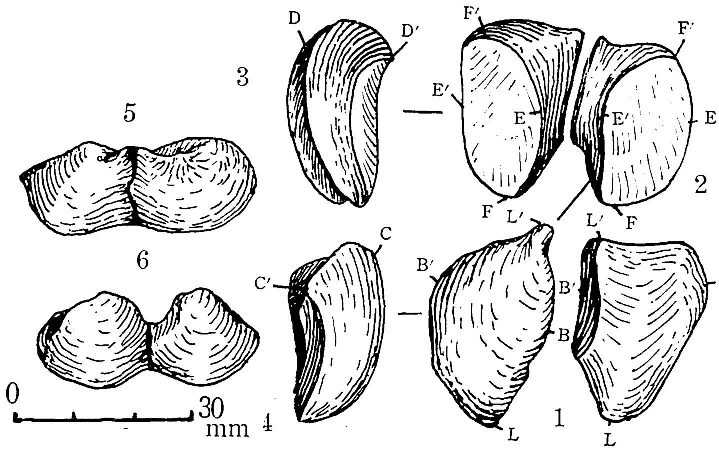
(Pl. 7, Fig. 71, Pl. 9, Figs. 14-17, Textfig. 54)

Bone (no. 44) is small sized, cubic and solid. In posterior view, it is suboval with curved outer margin which is articulated with the corresponding inner margin of the paired outer bone. Inner margin gently curved and proximal margin almost straight; interior proximal corner sharply pointed. Aft surface smooth and inflated. In anterior view, facet for metacarpus suboval, longer than wide, smooth and moderately depressed; outer margin of the surface sharply edged and distinctly curved. In outer view, bone subtrigonal with strongly curved posterior and moderately recurved anterior margins; distal end sharply pointed downward.

10B. Outer Bone on Right Third Metacarpus (NSMT-P-5601-36)

(Pl. 7, Fig. 71, Pl. 9, Figs. 18-21, Textfig. 54)

Bone (no. 44') corresponds in outline to the inner one in the opposite direction. Aft side a little shorter and narrower than that of inner one, but fore side is rather longer than the latter. In posterior view, bone irregularly quadrate, longer than wide and distal margin obtusely projected upward. In anterior view, proximal margin of the bone straight and vertical to outer margin of anterior surface. Bone thicker proximally and aft surface much convex aftward.



Textfig. 54. Sesamoid bones of right third metacarpus of Izumi. Inner bone (NSMT-P-5601-35) is in the left and outer bone (NSMT-P-5601-36) is in the right sides.
1, Aft side ; 2, Fore side ; 3, Outer side ; 4, Inner side ; 5, Proximal side (fore side is in upper) ; 6, Distal side (fore side is in upper).

10C. Inner Bone on Right Fourth Metacarpus (NSMT-P-5601-37)

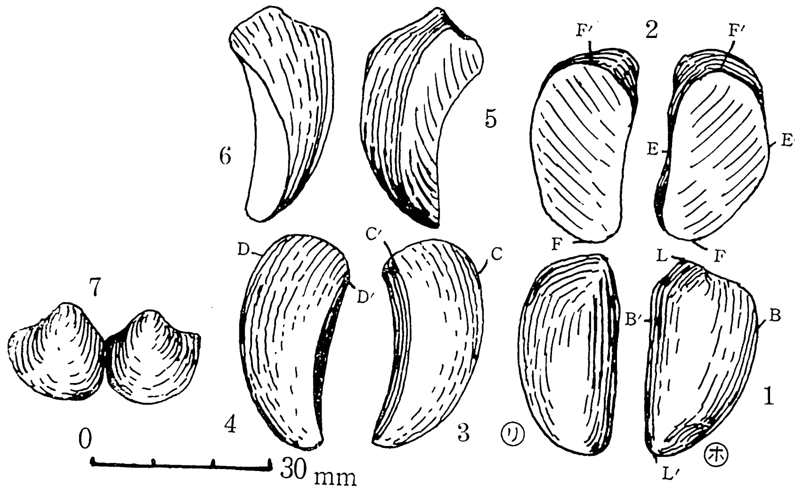
(Pl. 7, Fig. 72, Pl. 9, Figs. 6-9, Textfig. 55)

Bone (bone リ) small sized, cubic and solid. In anteroposterior views, it is lingual with much curved inner and straight outer margins; distal and exterior proximal end pointed; aft surface smooth and much inflated. In lateral view, bone elongate trigonal with shortest and gently curved proximal margin; aft margin more strongly curved than fore one. In anterior view, bone suboval and facet for metacarpus very smooth and depressed; margin of facet sharply edged; distal end more strongly curved than proximal. In proximal and distal views, bone subcircular.

10D. Outer Bone on Right Fourth Metacarpus (NSMT-P-5601-38)

(Pl. 7, Fig. 72, Pl. 9, Figs. 10-13, Textfig. 55)

Bone (bone ホ) corresponds in outline to the inner one in the opposite direction. Aft side a little shorter, while fore side longer and wider. In posterior view, outer margin not so strongly curved as inner margin of inner bone.

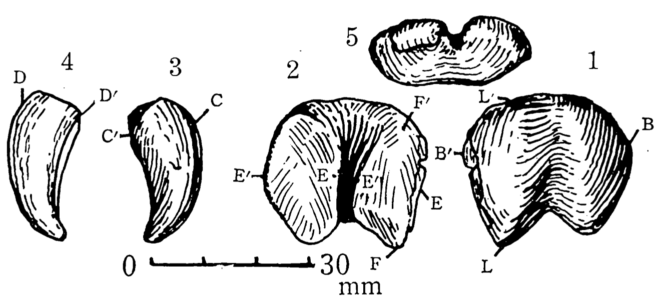


Textfig. 55. Sesamoid bones of right fourth metacarpus of Izumi. Inner bone (NSMT-P-5601-37) is in the left side and outer bone (NSMT-P-5601-38) is in the right sides.
1, Aft side; 2, Fore side; 3, Inner side of inner bone; 4, Outer side of inner bone; 5, Outer side of outer bone; 6, Inner side of outer bone; 7, Distal side.

10E. Bone on Left Fifth Metacarpus (NSMT-P-5601-39)

(Pl. 7, Figs. 22, 23, Pl. 9, Figs. 1-5, Textfig. 56)

Right and left sesamoid bones are confluent to a platy bone (no. 28) which becomes thicker proximally, hexagonal in aft view with gently curved proximal margin; median portion of distal margin eminently concave upward and both inner and outer corners of it strongly projected; the latter of which more sharply pointed than the former. Aft surface gently inflated with a median longitudinal shallow depression; proximal half of the surface rather rugose. Fore surface consists of



Textfig. 56. Sesamoid bone of left fifth metacarpus of Izumi (NSMT-P-5601-39).
1, Aft side; 2, Fore side; 3, Outer side; 4, Inner side;
5, Distal side (fore side is in upper).

inner and outer facets for metacarpus and median longitudinal deep groove. The facet suboval in anterior view with sharp edged margin; outer margins of both facets straight, while inner ones strongly curved; outer facet suboval, longer and wider than one of semicircular shape. Median groove more widely expanded proximalward than distalward. In proximal and distal views, bone irregularly oval with undulated both fore and aft margins; median portion of fore margin abruptly depressed.

Table 8. Measurements of sesamoid (metacarpus).

I: Inner. O: Outer.

	III		IV		V	
	I	O	I	O	I	O
Maximum length as preserved of aft surface (LL′)	28	28	33	32	30	29
Ditto of fore facet (FF′)	24	21	27	29	24	27
Maximum transverse width of aft surface (BB′)	18	20	17	17	33	
Ditto of fore facet (EE′)	14	15	18	19	15	16
Anteroposterior thickness on outer corner (CC′)	10	15	15	16	16	15
Ditto on inner corner (DD′)	13	11	15	16	—	—

B. Aft Limb

1. Femur

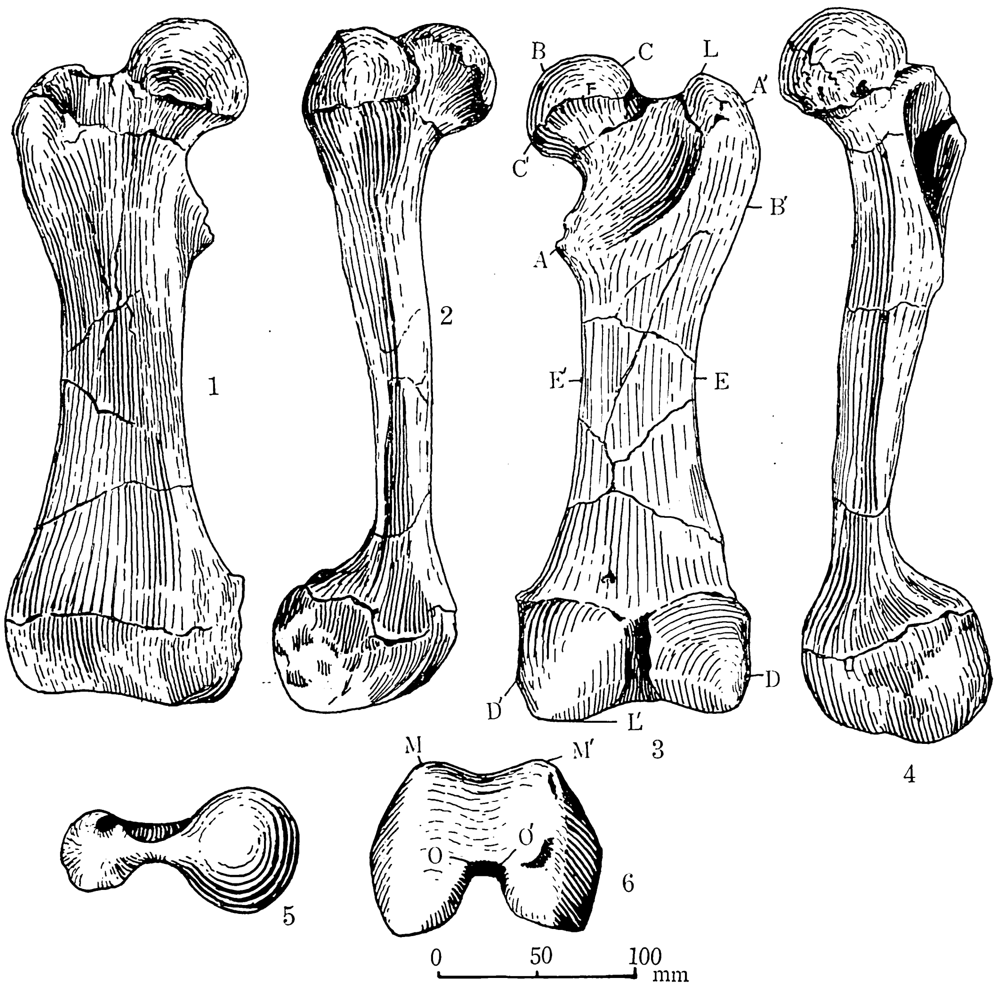
a. Izumi (NSMT-P-5601-40, 41)

(Pl. 2, Figs. 14-20, Pl. 3, Figs. 1-3, Textfig. 57)

Both right (NSMT-P-5601-40) and left femora (NSMT-P-5601-41) are well preserved, the former in a little better condition than the latter which is partially damaged at its posterior surface. Head and great trochanter of left femur are detached from shaft along proximal epiphysial suture.

Bone dense, stout, straight and flat. Head hemispherical and nearly circular in proximal view; in anterior view it is almost semicircular with straight distal margin; inner margin longer than outer one. Surface rather smooth. Neck distinct. In anterior view inner margin much curved and longer than outer margin which is straight and becomes proximal end of shaft. Axis of head and neck makes an angle of 32° with those of shaft in anterior view and 22° in inner view; they project forward from shaft in the latter view. Large trochanter not eminent but well developed with sharp median ridge of crest like aspect which becomes broader downward. Exterior border gently curved in posterior view and 62 mm long of right bone. Proximal border very rugose with many tubercles and pores. Trochanter not much projected proximally from proximal end of shaft and feebly prolonged exteroproximally from shaft. In inner view, trochanter subrhombic in general outline, about 105 mm long on right bone, attaining near one third of total length of femur. Third trochanter invisible. In posterior view, inner margin of trochanter much recurved and carrying eminent depression on its median portion. Trochanteric fossa distinct, relatively deep, elongate oval in inner view and its crest like distal margin running oblique to axis of shaft.

Small trochanter rather distinct and projects inward but distal portion damaged on both sides. In posterior view, it is subtrigonal with straight proximal and distal



Textfig. 57. Right femur of Izumi (NSMT-P-5601-40).
1, Fore side; 2, Outer side; 3, Aft side; 4, Inner side; 5, Proximal side (fore side is in below); 6, Distal side (fore side is in upper).

margins. In anterior view, it is subtrigonal with straight proximal and distal margins. In anterior view, a longitudinal shallow depression lies between shaft and trochanter, about 65 mm long on right bone.

Shaft relatively short and very flat; both inner and outer borders carry sharp edges, of which outer one is distinct. In anterior view, inner margin nearly straight while outer margin gently curved. Shaft becomes wider distally and elongate rhombic in cross section. In lateral view shaft becomes thicker proximally and narrowest at just above condyle; fore margin very straight.

Condyle stout, eminent and large. In anterior view, interior distal corner larger than exterior distal one. Median longitudinal depression shallow and broad. Epiphysial suture visible on fore surface and distinct on outer and aft surfaces. Entocondyle longer and wider than ectocondyle. On right femur the former is 97×59 and the latter 87×52 mm. In posterior view, both condyles subquadrate; proximal margin of them convex upward; ectocondyle with both inner and outer margins a little undulated; entocondyle carries both inner and outer margins slightly curved. Surface of condyle very smooth. Intercondylar notch deep, narrow, sharply marked and becomes wider both proximally and distally. In lateral view, condyle much projected aftward from axis of shaft.

	Right	Left
Maximum length of bone as preserved (LL′)	370	375
Minimum width of shaft at middle (EE′)...........................	58	68
Maximum length between large and small trochanters (AA′)......	132	131
Length between head top and below of large trochanter (BB′)	150	154
Maximum transverse width of head (CC′)	67	66
Maximum transverse width of condyle (DD′)......................	122	118
Length of anterior distal margin of condyle (MM′)................	75	69
Distal width of intercondylar notch (OO′)...........................	29	27
Length between top of small trochanter and middle of posterio-distal margin of head (AF)	86	88

b. Keton (UHR no 18466-28, 19)

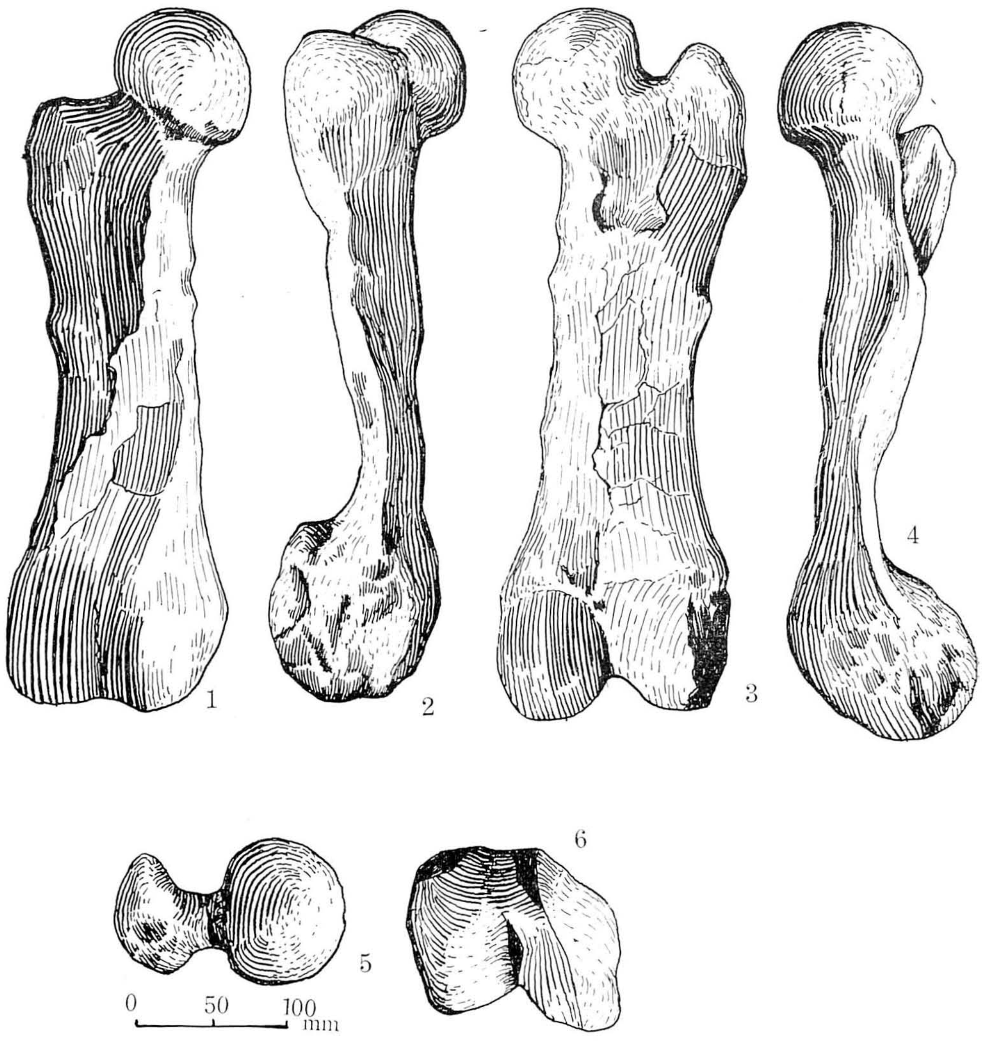
(Textfig. 58, 59)

Right (UHR no 18466-28) and left femora (UHR no 18466-29) are well preserved, but fractured on fore and aft surfaces of both shafts, showing compression. Proximal and distal aspects of right and left femora are tolerably different, owing to deformation by pressure. Bone dense, stout and flat with relatively eminent distal expansion.

Head hemispherical and subcircular in proximal view with relatively straight outer margin; in left femur head longer than wide anteroposteriorly. In anterior view, head subcircular and distal surface of left bone a little damaged. Surface rather smooth. Neck distinct, broad, with inner margin longer than outer one and axis of it makes an angle of 17° with that of shaft in anterior view, and 22° in inner view. They project forward from shaft in lateral view. Upper margin of neck straight and becomes proximal margin of shaft.

Large trochanter well developed, rugose and crest like in posterior view; it curved moderately outward and inner margin about 102 mm long in right one; trochanter becomes wider distally in the same view and internally bordered by trochanteric fossa which is distinct, deep, suboval in aft view and elongate oval in inner view. Small trochanter obsolete compared with that of Izumi, and very small, subtrigonal in posterior view, obtusely projected from shaft at a point about one third length of shaft from proximal end in left femur. In anterior view, neither longitudinal depression nor crest is visible on anterior of the trochanter.

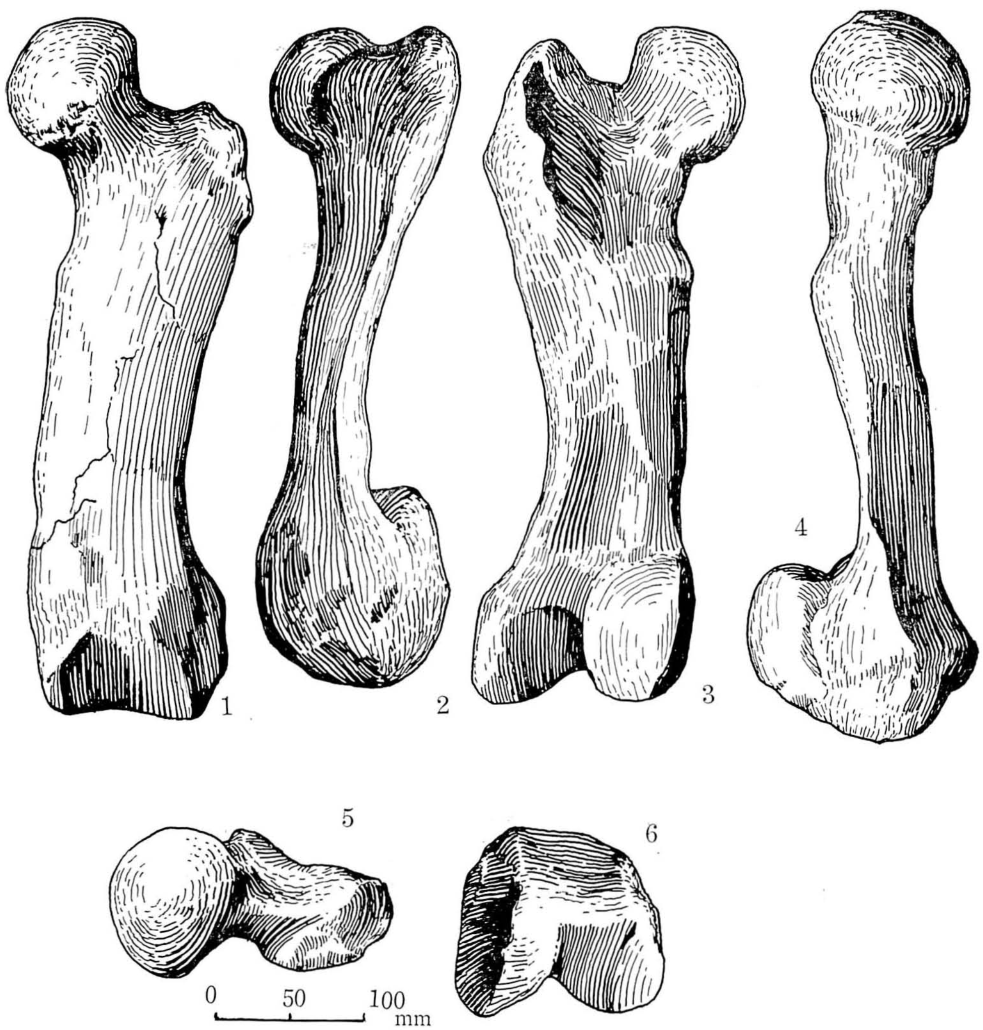
Shaft very flat and relatively short. In anterior view, both lateral margins almost parallel with each other and not so much expanded lateralward both proximally and distally especially in posterior view of right femur and anterior view of left one. Inner margin almost straight and outer margin gently curved. In lateral view, shaft becomes thicker proximally, narrowest just above condyle and has straight fore margin. Crestlike inflation of small trochanter distinct in outer view. Shaft of left femur elongate subtrigonal in cross section below small trochanter with recurved fore and straight aft margins; inner margin undulated and shortest. Transverse section of shaft above condyle irregularly crescentic with straight fore and recurved aft margins.



Textfig. 58. Right femur of Keton (UHR no 18466-28).
1, Fore side; 2, Outer side; 3, Aft side; 4, Inner side; 5, Proximal side (fore side is in below); 6, Distal side (fore side is in upper).

Condyle large and eminent. Ecto- and entocondyles are about the same size. In posterior view, entocondyle longer and narrower than ectocondyle; the former suboval and the latter subquadrate in aft view. Surface of condyle very smooth. Intercondylar notch very distinct, narrow and deep. In aft view, surface of shaft just above condyle moderately depressed. In lateral view, condyle much projected posteriorly from axis of shaft.

	Right	Left
Maximum length of bone as preserved (LL′)	376	370
Minimum width of shaft at middle (EE′)	85	83
Maximum length between large and small trochanter (AA′)	150±	146
Length between head and below of large trochanter (BB′)	156	171
Maximum transverse width of head (CC′)	75	75
Maximum transverse width of condyle (DD′)	119	116
Length of anterior distal margin of condyle (MM′)	95	89
Distal width of intercondylar notch (OO′)	31	31
Length between top of small trochanter and middle of posterior distal margin of head (AF)	119	106



Textfig. 59. Left femur of Keton (UHR no 18466-29).
1, Fore side; 2, Outer side; 3, Aft side; 4, Inner side; 5, Proximal side (fore side is in below); 6, Distal side (fore side is in upper).

Keton femur is near in maximum length of Izumi femur but middle of shaft of the former becomes wider than that of the latter, ×1.47 in right and ×1.22 in left. Proximal end of right femur in Keton is much narrower than that of left transversally and distal border of it is twisted from inner to outer. When the distal surface of left femur is compared to that of Izumi, bone is much narrower transversally and thicker anteroposteriorly, indicating compression of lateral direction. Lateral aspect of Keton bone is rather like that of Izumi, while that of right in Keton tolerably differs. In this case, compression might be stronger in proximal portion than in distal one. Ratio of LL′ to EE′ in right femur is 6.38 in Izumi and 4.42 in Keton, i.e. Keton shaft is relatively wider than Izumi shaft. Obsoleteness of small trochanter in Keton is distinct, may be due to original character.

2. Tibia

a. Izumi (NSMT-P-5601-42, 43)

(Pl. 3, Figs. 4-13, Textfig. 60)

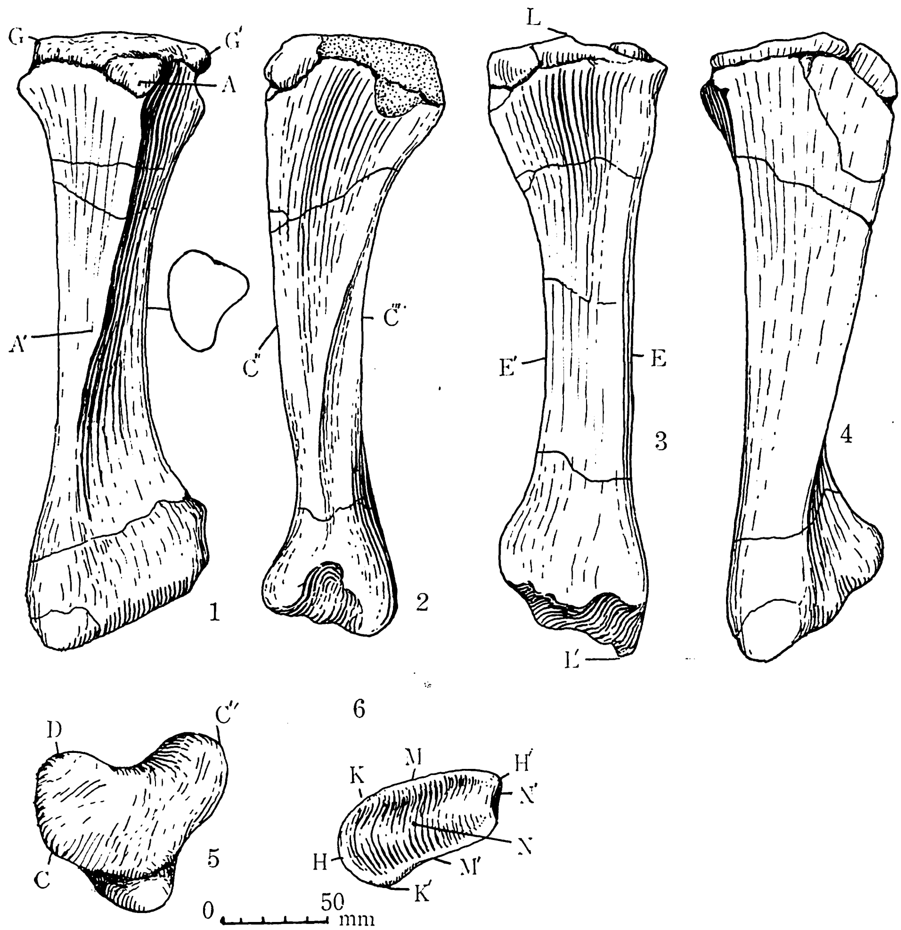
Right (NSMT-P-5601-42) and left tibiae (NSMT-P-5601-43) are rather well preserved although distal surface of right one is partially damaged. Proximal end of cnemial crest of right femur is detached from shaft along epiphysial suture. Bone stout, straight and moderate in length. Upper articulating surface in proximal view irregularly trigonal with gently curved inner margin; outer and aft margins distinctly recurved; fore corner obtusely projected anteriorly, so are interior aft and posterior aft corners; surface flat and uneven; articulating surface with entocondyle subquadrate and larger than articulating surface with ectocondyle which is suboval.

Shaft straight and relatively long in anterior view, becoming gradually wider proximal- and distalwards. It is triangular in cross section with longest and gently curved inner margin; posterior margin shortest and gently curved while outer margin moderately recurved. In lateral view, fore margin almost straight while aft margin distinctly curved. Cnemial crest distinct, running from exterior proximal to interior distal corner for about one third length of shaft from proximal end. Distinct longitudinal depression lies exterior to cnemial crest.

Distal end much expanded laterally, subtriangular in fore-&-aft views; inner corner eminently projected distalward and distal margin runs oblique to axis of shaft. The fore and aft surfaces very flat and smooth. In outer view, distal portion subtrigonal with much projected posterior distal corner; anterior distal margin recuved and articulating surface with distal end of fibula large and depressed on median part of the bone. In distal view, distal end subquadrate with long lateral diameter which runs from exterior fore to interior aft directions; fore margin long and gently curved; inner half a little wider than outer one anteroposteriorly; outer corner truncated, corresponding to the articulating surface with distal end of fibula.

	Right	Left
Maximum length of bone as preserved (LL′)	345	340
Minimum width of shaft at middle (EE′)	44	44
Maximum transverse width of head (GG′)	127	113

Length of posterior margin of head (C′D)	80	80
Transverse width of distal end (long axis of distal quadrate surface) (HH′)	117±	120
Maximum anteroposterior thickness of ditto (KK′)	69	65
Minimum thickness of ditto (MM′)	61	58
Transverse length of exterior half of distal surface (NN′)	70±	64
Maximum anteroposterior thickness of head (CC′)	129	123
Anteroposterior thickness of shaft at middle (C″C‴)	64	66
Length of cnemial crest (AA′)	97±	118



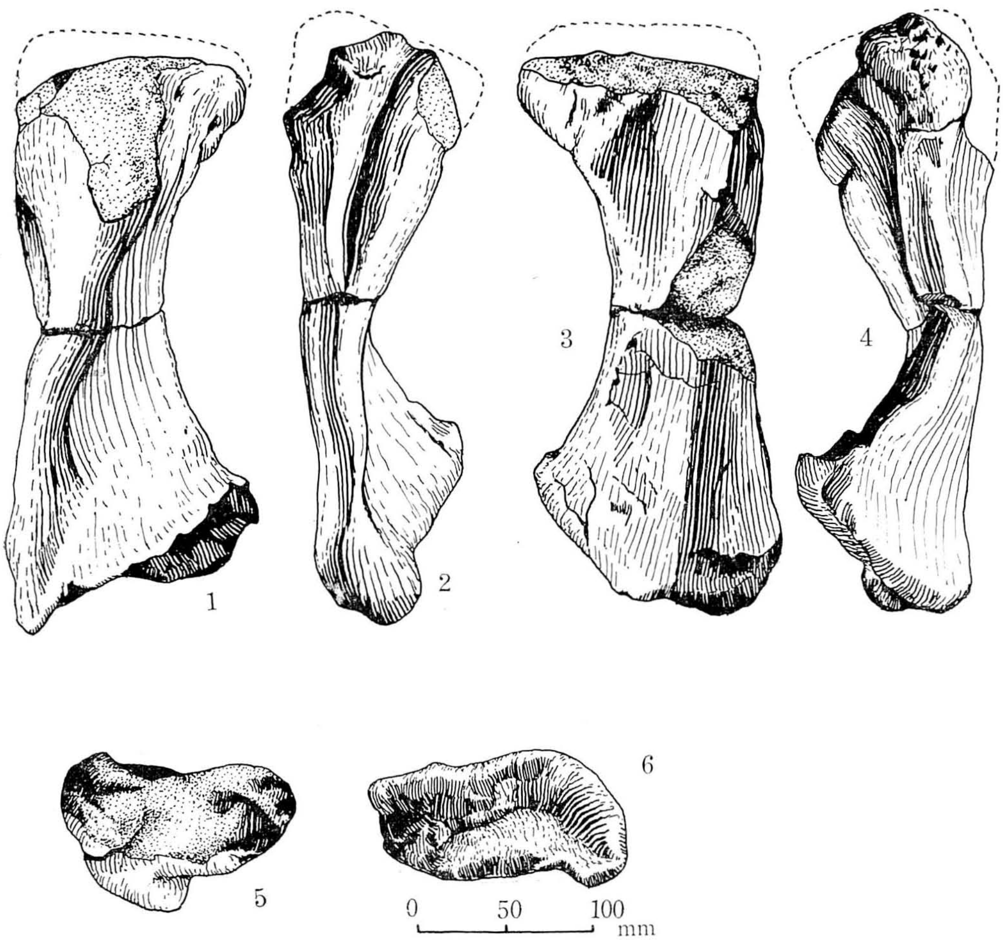
Textfig. 60. Left tibia of Izumi (NSMT-P-5601-43).
1, Fore side; 2, Outer side; 3, Aft side; 4, Inner side; 5, Proximal side (fore side is in below); 6, Distal side (fore side is in upper).

b. Keton (UHR no 18466-30)

(Textfig. 61)

Left tibia broken proximally and distally, much damaged and deformed; original aspect of the bone is almost impossible to obtain.

In proximal view, bone irregularly trigonal with much recurved inner and outer margins; posterior border broken and irregularly undulated; in outline bone rather like that of Izumi. In anterior view, shaft subtrapezoidal with almost striaght inner and much curved outer margins; portion of cnemial crest much damaged, but the crest itself rugose and eminent, becoming wider proximally and deep longitudinal depression runs on exterior side of the crest. A distinct crack runs transversally on middle of shaft. Lower half of shaft below the crack trigonal with undulated distal margin. Fore surface smooth and depressed. In posterior view, outline of shaft corresponds to that of anterior view; aft surface smooth and flat.



Textfig. 61. Left tibia of Keton (UHR no 18466-30).
1, Fore side; 2, Outer side; 3, Aft side; 4, Inner side; 5, Proximal side (fore side is in below); 6, Distal side (fore side is in below).

In inner view, aft margin very straight and fore margin runs oblique to it; distal portion of the margin projects forward. In outer view, fore margin straight and cnemial crest runs from posterior proximal to anterior distal corners; median longitudinal depression deep, narrow and distinct. In distal view, distal end subquadrate with long and undulated fore and aft margins; outer margin short and truncated while inner margin much curved and interior fore corner strongly projected. Depression of anterior distal surface very eminent.

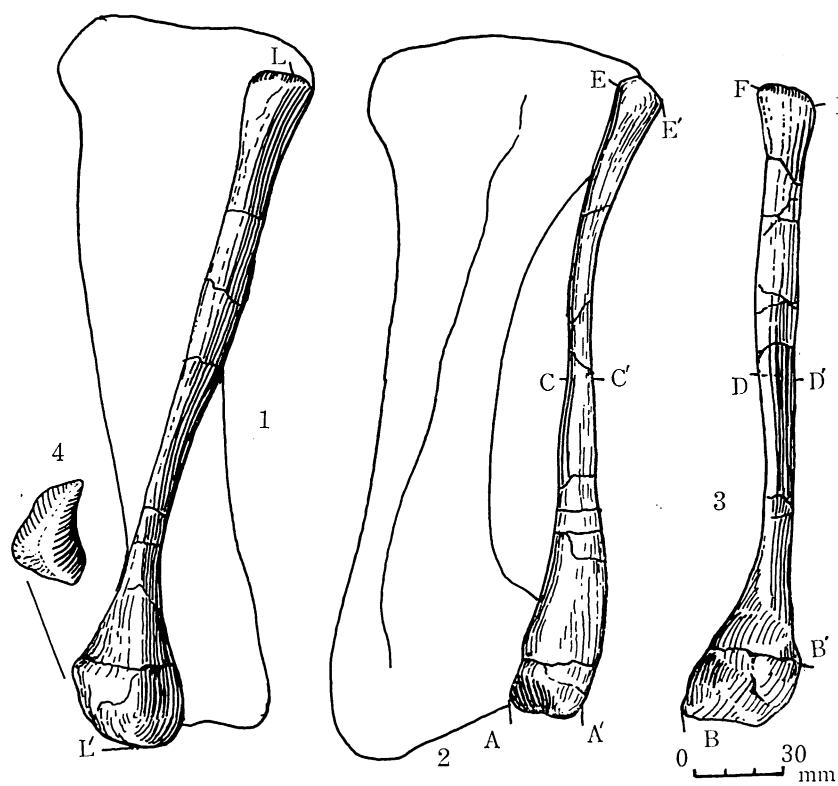
Maximum length of bone as preserved (LL′)	327
Maximum transverse width of head (GG′)	129
Transverse width of distal end (HH′)	153
Minimum anteroposterior thickness of ditto (MM′)	64
Transverse length of interior half of distal surface (NN′)	81
Maximum anteroposterior thickness of head (CC′)	107
Anteroposterior thickness of shaft at middle (C″C‴)	46
Length of cnemial crest (AA′)	114

Distal end of Keton bone is 1.27 times wider and 1.1 times thicker than that of Izumi. Middle of shaft in Keton is 0.69 of that of Izumi, i. e. much compressed anteroposteriorly. It is very difficult to compare the original outline of Izumi tibia with that of Keton.

3. Fibula

(Pl. 4, Figs. 1-4, Textfig. 62)

Represented by left fibula of Izumi (NSMT-P-5601-44) which is partially damaged. Bone narrow, slender and rodlike with large distal end which is rugose and expanded anteroposteriorly.



Textfig. 62. Left fibula of Izumi (NSMT-P-5601-44).
1, Outer side; 2, Fore side; 3, Inner side; 4, Distal side (fore side is in below).

In distal view, distal end subtrigonal with long and straight anterior outer margin; anterior inner margin long and recurved while posterior margin shortest and straight. Distal surface smooth. Anterior outer and inner surfaces of distal end subquadrate and proximal portion of the latter just below shaft distinctly depressed. Inner surface of distal end articulated with exterior distal corner of tibia. Shaft slender, narrow, flat and twisted; it is wider laterally than anteroposteriorly at middle and proximal portion, but vice verse at distal. Cross section of shaft oval proximally and trigonal distally; aft margin straight and longest. In outer view, sharp median longitudinal ridge runs from anterior distal to posterior proximal corners.

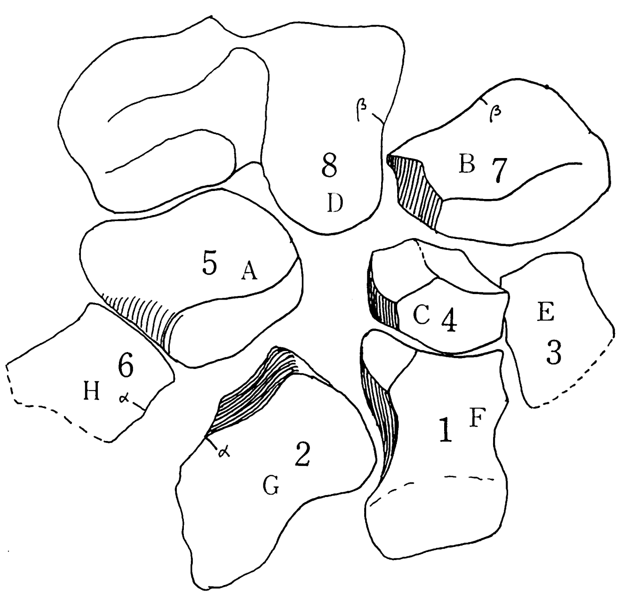
Maximum length of bone as preserved (LL′)	282
Maximum transverse width of distal end (AA′)	43
Transverse width of shaft at middle (CC′)	17
Ditto of proximal end (EE′)	26
Anteroposterior thickness of distal end (BB′)	48
Ditto of shaft at middle (DD′)	11
Ditto of head (FF′)	26±

4. Tarsus

a. Izumi

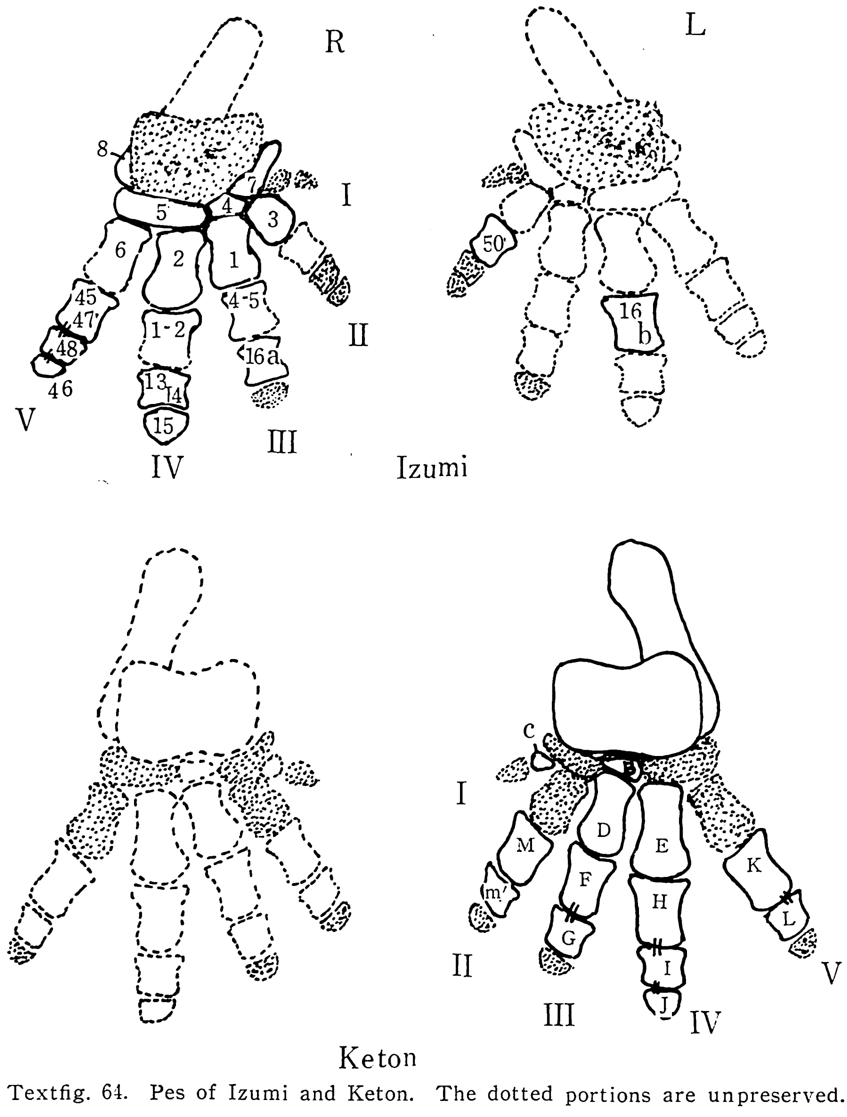
(Textfigs. 63-65)

In section 4 of a large block there were preserved four bones of tarsus (A, B,

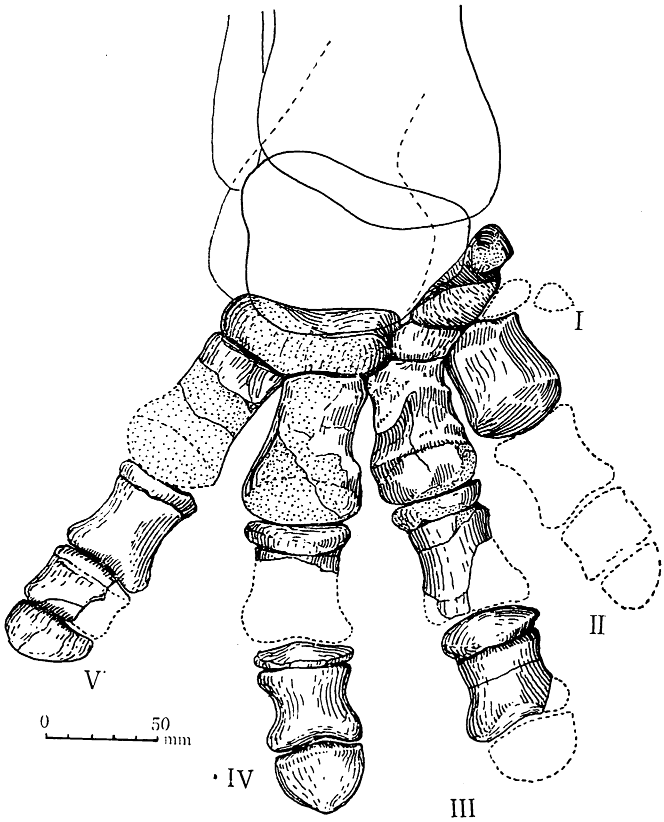


Textfig. 63. Right tarsal bones of Izumi in their preserved relative position. 1, Bone F, third metatarsus (fore side); 2, Bone G, fourth metatarsus (fore side); 3, Bone E, second metatarsus (fore side); 4, Bone C, ectocuneiform (fore side); 5, Bone A, cuboid (interior proximal side); 6, Bone H, fifth metatarsus (fore side); 7, Bone B, navicular (anteroproximal side); 8, Bone D, calcaneum (fore side).

C and D) jointed with four metatarsi (E, F, G and H). Bone D (no. 8) is largest but broken and regarded without doubt as a part of calcaneum. Bone A (no. 5) is in close contact with bone D and jointed with bone H. On the other point bone B (no. 7) is jointed with bone D. Below bone B there are preserved bone C (no. 4), bone E (no. 3), bone F (no. 1) and bone G (no. 2) jointed closely with each other. When the writer sets each bones in their original position, bones B and C joint naturally and he gains a relative position as shown in Textfigs. 64 and 65. It is very regretable that astragalus is unpreserved. This position may indicate the right side of pes, although its interrelation with tarsal bones is very unique. Hence the writer regards bone B as navicular, bone C as ectocuneiform, bone A as cuboid, bone E as second proximal phalange, bone F as third, bone G as fourth and bone H as fifth one. In a reconstruction a gap is seen between inner side of navicular (B) and proximal side of second metatarus (E), indicating an existence of bone of



Textfig. 64. Pes of Izumi and Keton. The dotted portions are unpreserved.



Textfig. 65. Right pes of Izumi.

mesocuneiform. Very curious point is that navicular (B) does not joint with cuboid (A). Probably first metatarsus joints with mesocuneiform or with distal portion of navicular.

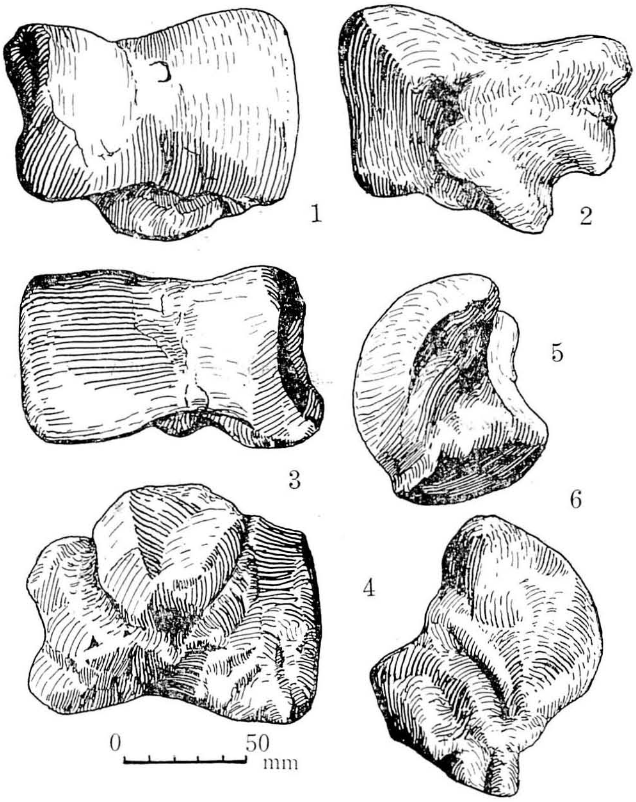
b. Keton

In NAGAO's manuscript there were found left calcaneum, astragalus, the other two small tarsal bones, metatarsi and phalanges together with left tibia from the same portion of block A. Of two small bones, bone B may be ectocuneiform and bone C mesocuneiform. Thus all elements of tarsus are known from bones of Izumi and Keton.

4A. Astragalus

(Textfigs. 66, 67)

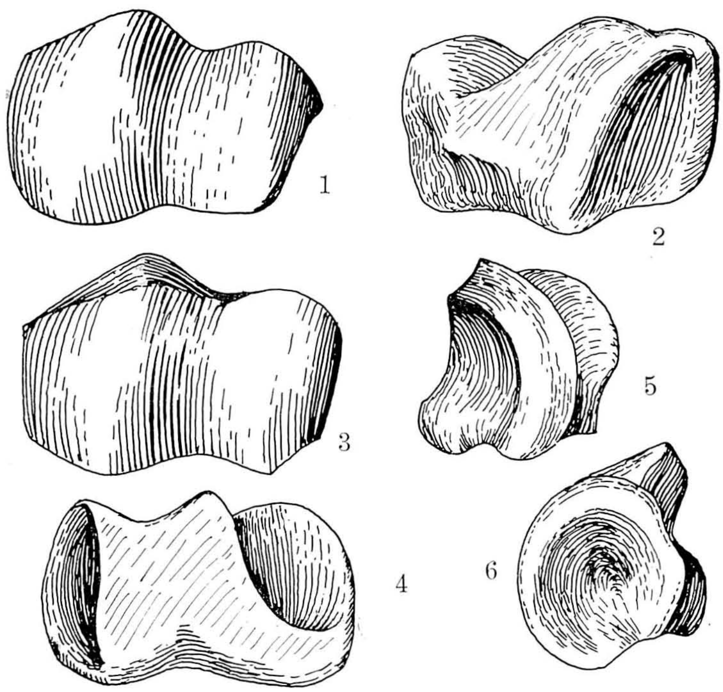
Represented by left astragalus of Keton (UHR no 18466-31) which is well preserved, dense, stout, wider than high, with eminent condyle. In fore view, it is irregularly pentagonal with transverse long axis; outer margin gently curved, proximal and inner margins much recurved. Upper facet of condyle smooth and much curved with shallow and wide median longitudinal depression; outer fact larger than inner one which corresponds to a tibial facet. Posterior projection visible at median part of distal border which is elongate trapezoidal.



Textfig. 66. Left astragalus of Keton (UHR no 18466-31).
1, Fore side; 2, Aft side; 3, Proximal side (fore side is in upper); 4, Distal side (fore side is in lower); 5, Outer side; 6, Inner side.

In outer view, bone irregularly quadrate with longest and much curved fore and proximal margins; aft margin irregularly undulated and distal margin nearly straight. Facet for calcaneum trigonal and depressed, while free facet more elongate than that; condyle itself not thick. In inner view, bone irregularly quadrate and posterior projection longer than that of inner side; facet for cuboid subqudrate and large. In posterior view, details of posterior projection disappeared in preservation. Outer facet for calcaneum large and runs for median proximal corner to median distal corner; facet for navicular and cuboid projected respectively interior distalward. Outer facet large and depressed; upper margin gently recurved. Margin of facets for calcaneum, navicular and cuboid not sharp.

In proximal view, bone subquadrate with transverse long axis; outer margin slightly curved and inner one moderately recurved; posterior projection visible behind median longitudinal depression. In distal view, outer facet for calcaneum much curved with eminent median longitudinal ridge. Facet for cuboid and inner facet



Textfig. 67. Reconstructed right astragalus of Izumi.
1, Fore side; 2, Aft side; 3, Proximal side (fore side is in below); 4, Distal side (fore side is in below); 5, Outer side; 6, Inner side.

for calcaneum flat, smooth and quadrate. There is a wide and eminent fossa between facets and outer facet for calcaneum, which is flat, smooth and trigonal.

Maximum transverse length (AA′)	105
Transverse length of lower margin (GG′)	111
Maximum longitudinal length of bone (LL′)	90
Ditto of inner facet (DD′)	79
Ditto of outer facet (EE′)	76
Longitudinal length of median depression of upper facet (HH′)	61
Transverse width of inner facet (FF′)	54
Ditto of inner side of bone (CC′)	94
Thickness of condyle at outer side (PP′)	23

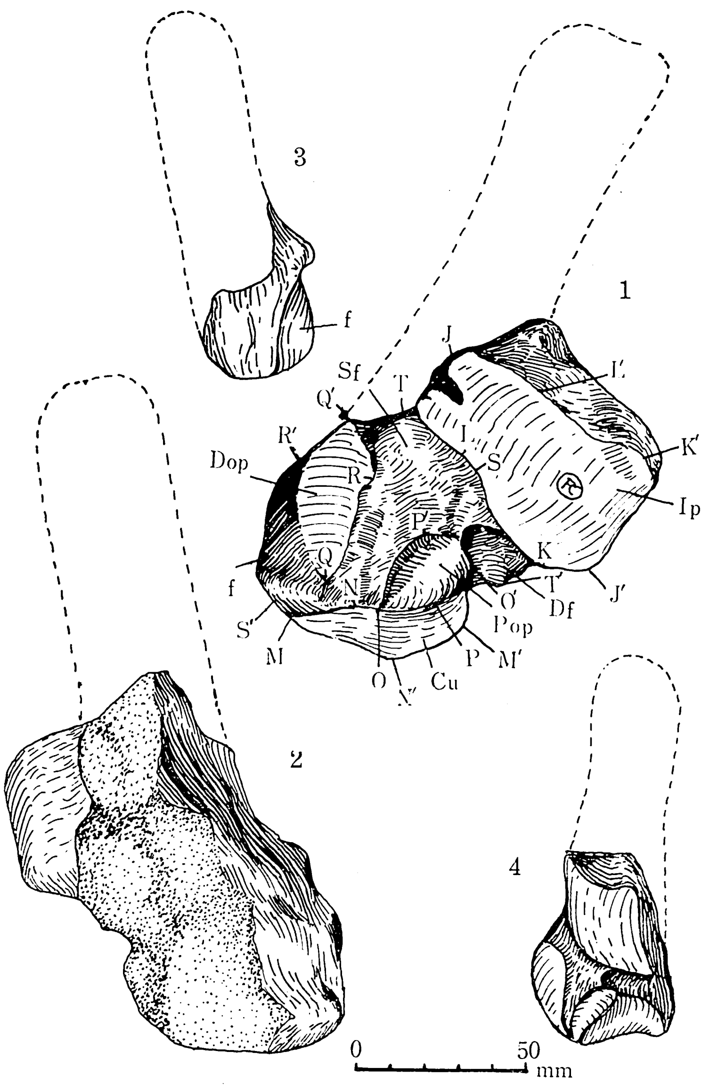
The writer and HASEGAWA reconstructed Izumi astragalus theoretically from relative positions of the other tarsal bones and tibia. The bone thus obtained is rather like in outline those of Keton. Facet for cuboid occupying large part of distal portion subtrapezoidal and rather flat with long and curved anterior margin; outer facet for calcaneum eminently depressed while inner one of it subtrigonal and irregularly curved; both occupy large part of posterior portion; facet for navicular subcircular, shallowly depressed and occupies inner portion. In outer view, outer facet for calcaneum subtrigonal with gently curved fore margin.

4B. Calcaneum

a. Izumi (NSMT-P-5601-45)

(Pl. 7, Figs. 1-7, Textfig. 68)

Right calcaneum (bone D, no. 8) preserved proximally and tuber calcis perfectly broken; facet for astragalus well preserved. Bone large, dense and stout. In anterior view, bone as preserved subquadrate in outline, with large and smooth surface of inner peronal surface for astragalus, which is subquadrate with long transverse axis; proximal and distal margins long and undulated; inner margin a little concave inward; surface undulated gently. Just below the surface runs a shallow fossa vertical to the long axis of the surface and a deep fossa parallel with it; surface



Textfig. 68. Right calcaneum of Izumi (NSMT-P-5601-45).
1, Anterior inner side; 2, Aft side; 3, Outer side; 4, Inner side.
Scale is given for Figs. 1, 2.

of the former uneven, rugose and elongate lingual in outline with sharp marked margins; border between the two fossae also sharp and clear. In exterior of the shallow fossa there is a small sized distal part of outer peronal facet for astragalus, which is rhombic with two proximal margins long and gently curved; proximal and distal corners projected sharply. In interior of the shallow fossa there is proximal part of outer peronal facet for astragalus, which is like in outline the distal part and a little depressed; margin sharp and a little edged. In exterior of distal part of outer peronal facet for astragalus there is a facet for fibula which is elongate trigonal, smooth and gently curved.

In posterior view, sustentaculum subquadrate and almost vertical to long axis of tuber calcis.

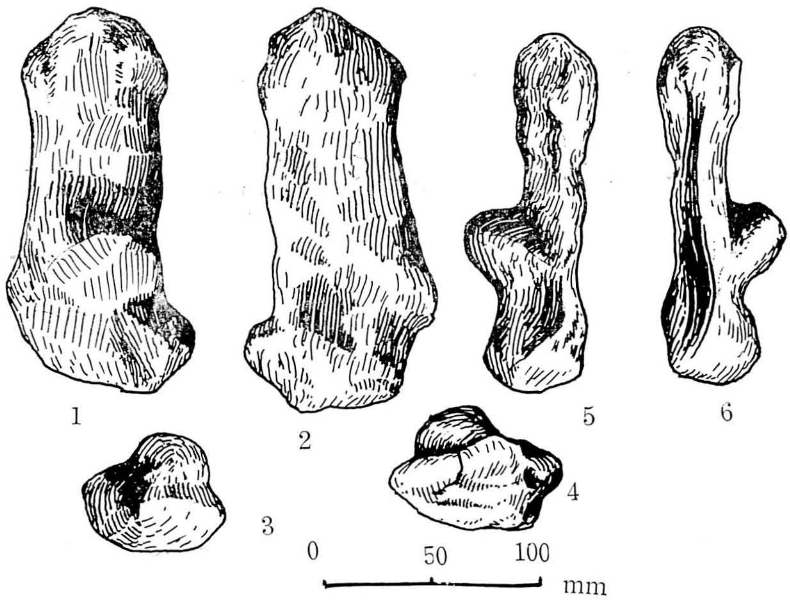
Maximum transverse width of inner peronal facet for astragalus (JJ′)	60
Outer longitudinal length of it (LL′)	28
Inner of ditto (KK′)	42
Maximum transverse width of proximal part of outer peronal facet for astragalus (PP′)	16
Longitudinal length of ditto (OO′)	31
Transverse width of distal part of outer peronal facet for astragalus (RR′)..	14
Longitudinal length of ditto (QQ′)	37
Transverse length of facet for cuboid (MM′)	52
Longitudinal length of ditto (NN′)	46
Ditto of shallow fossa (SS′)	50
Maximum transverse length of both fossae (TT′)	52
Transverse length of facet for fibula (WW′)	43

b. Keton (UHR no 18466-32)

(Textfig. 69)

Left calcaneum is well preserved, large and stout. Bone platy and much longer than broad. In anterior view, it is elongate subquadrate with long axis bent inward; tuber calcis elongate, thick and expanded laterally; outer margin almost straight and inner one gently recurved; proximal margin irregular and oblique to long axis; exterior distal corner projected outward; fore surface almost smooth and flat but depressed above sustentaculum which is eminent, projects forward and a little inward. Sustentacular facet runs vertical to tuber calcis. Peronal surface for astragalus depressed moderately. Posterior inner corner broken. Distal side irregularly rhombic with long inner margins; anterior inner corner distinctly and outer corner obtusely projected; fore-&-aft median projection lies nearer to outer corner than to inner corner; distal surface smooth, a little depressed with median longitudinal keel. In posterior view, bone becomes gradually broader distally and aft surface smooth and flat. In inner and outer views, sustentabulum rugose, large and projects from a portion at one third length of bone from distal end. Bone narrowest just above sustentaculum and becomes broader proximally; proximal end expanded anteroposteriorly. Posterior distal corner moderately projected.

Peronal surface for astragalus articulates with inner and outer facets for calcaneum of astragalus; sustentacular facet for astragalus articulates with posterior



Textfig. 69. Left calcaneum of Keton (UHR no 18466-32).
1, Fore side; 2, Aft side; 3, Proximal side (fore side is in upper); 4, Distal side (fore side is in upper); 5, Outer side; 6, Inner side.

outer part of upper facet of astragalus. When calcaneum is closely jointed with astragalus, it declines much inward; this may be due to deformation of astragalus and calcaneum. It is also rather difficult to gain precise original outline of calcaneum.

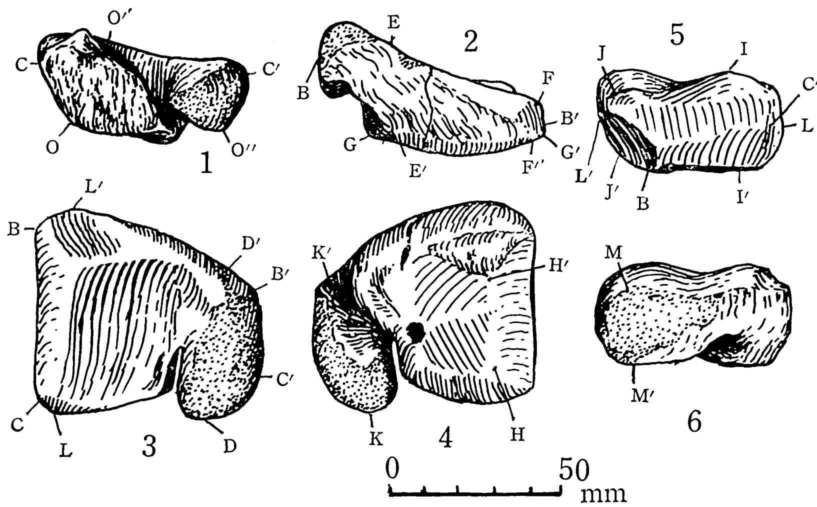
Maximum longitudinal length (LL′)	188
Longitudinal length above sustentaculum (BB′)	82
Maximum transverse length of tuber calcis (CC′)	70
Ditto of bone below sustentaculum (EE′)	76
Anteroposterior thickness of proximal end (AA′)	45
Ditto of bone at sustentaculum (DD′)	64

4C. Navicular

(Pl. 7, Figs. 8–10, Pl. 8, Figs. 1–5, Textfig. 70)

Represented by right navicular of Izumi (bone B, no. 7) (NSMT-P-5601-46) which is relatively large and flat, broken on interior proximal surface. In exterior proximal view, bone subquadrate with longest and straight aft margin; lower margin almost straight while upper margin gently curved; fore margin irregularly undulated with deep and narrow fossa at its upper half. Facet for astragalus smooth, much depressed, deepest at a point of the head of fossa; it is subquadrate in outline with sharp fore-&-aft and obsolete upper and lower edges. Bone wider distally than proximally in fore-&-aft direction.

In fore view, bone elongate subtrigonal with straight interior distal margin; exterior proximal margin also straight and oblique to it; exterior distal margin straight and oblique to interior distal margin; it is closely jointed with interior proximal margin of fore surface of middle cuneiform; interior distal margin almost parallel with interior distal margin of upper facet of astragalus and oblique to shaft axis of tibia. Facet for astragalus basin-like, recalling slope of volcanic vent. Median fossa narrow, deep, lying in proximal half of interior distal margin and divides fore surface into upper and lower parts, the latter of which larger than the former, subquadrate with longest upper and shortest inner margins; the surface very rugose.



Textfig. 70. Right navicular of Izumi (NSMT-P-5601-46).
1, Fore side; 2, Aft side; 3, Exterior proximal side (fore side is in below); 4, Interior distal side (fore side is in below); 5, Lower side; 6, Upper side.

In aft view, bone irregularly triangular with straight and longest exterior proximal margin; interior distal margin long and almost straight; median portion of interior proximal margin much concave proximally. Aft surface rather rugose. In interior distal view, bone corresponded with exterior proximal side in outline; lower margin much wider than upper and posterior distal corner strongly projected. Facet for first metatarsus smooth, flat and irregularly quadrate with almost straight lower and aft margins; foramen of circular shape lies at interior upper corner of the surface. Narrow groove like depression runs on upper portion from posterior proximal corner to upper half of fore margin; anterior part of the depression eminently notched, becoming narrow fossa of fore margin of exterior proximal side; the notch 14 mm long, 7 mm wide and 11 mm high in interior distal view. Facet for middle cuneiform smooth, flat and elongate quadrate with long and gently curved exterior distal margin.

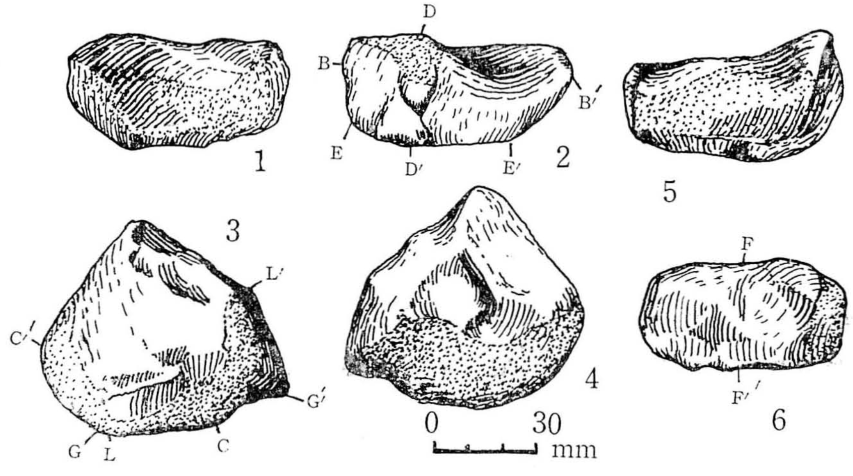
In proximal view, bone irregularly elongate with long and undulated outer margin; inner margin also long and almost straight with eminent narrow notch at its posterior half. In distal view, bone elongate hexagonal with much recurved outer margin; anterior and posterior margin eminently projected; a distinct notch lies at posterior half of inner margin.

Longitudinal length of exterior proximal margin on fore surface (CC′)	63±
Ditto on aft surface (BB′)	66
Ditto of interior distal margin of fore surface (OO″)	49
Ditto on aft surface (GG′)	58
Width of lower half of fore surface (OO′)	24
Ditto of distal end of aft surface (FF′)	14
Ditto of proximal part of aft surface (EE′)	29
Ditto of fore part of upper surface (MM′)	25
Ditto of lower surface (II′)	32
Ditto of aft part of lower surface (JJ′)	23
Maximum anteroposterior width on lower part (LL′)	59
Anteroposterior width along lower edge (C′B)	44
Ditto of upper part on proximal surface (DD′)	44
Ditto on interior distal surface (KK′)	35
Length of lower margin of facet for first metatarsus (HH′)	32

4D. Cuboid

(Pl. 6, Figs. 13-20, Textfig. 71)

Represented by right cuboid of Izumi (bone A, no. 5) (NSMT-P-5601-47) which is very low, flat, large and broken in its interior distal portion. Bone platy, relatively thick and stout. In posterior view, it is irregularly trapezoidal with longest and tolerably curved upper margin, outer half of which is depressed; outer margin short, straight and bent exteriorly, while inner margin vertical to distal margin which is almost straight; aft surface rather rugose. In proximal view, bone subquadrate with longest and irregularly curved aft margin; outer and fore margins straight, while inner margin much undulated and projected inward at a point of one third length of the margin from aft end; anterior inner margin straight and posterior inner one recurved; posterior outer angle about 90°; the surface smooth, posterior half of



Textfig. 71. Right cuboid of Izumi (NSMT-P-5601-47).
1, Fore side; 2, Aft side; 3, Proximal side (fore side is in below); 4, Distal side (fore side is in below); 5, Inner side; 6, Outer side.

which slopes down aftward; anterior half of the surface slopes down anteroinward; interior aft corner highest. Proximal surface articulates with facet for cuboid of astragalus. Distal side nearly triangular in outline with longest interior fore margin; aft and outer margin almost straight; distal surface smooth, nearly triangular and carries indistinct median transverse ridge; the surface articulates with proximal surface of fourth and fifth metatarsi. Outer side subquadrate in outline with long and almost straight upper and lower margins; outer surface smooth, flat, bent outward and articulates with outer surface of ectocuneiform. Inner side corresponds to outer one in outline; posterior end higher than anterior.

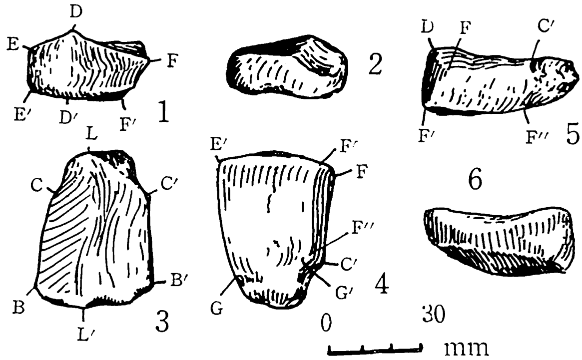
Maximum transverse length of aft side (BB′)	75
Distance between exterior fore corner and middle projection of inner margin on proximal surface (CC′)	64±
Transverse length along posterior distal margin (EE′)	47
Maximum height at interior aft surface (DD′)	31
Ditto at median portion of outer side (FF′)	33
Maximum anteroposterior length of inner half on proximal side (LL′)	70±
Anteroposterior length along outer border (AA′)	54±
Ditto along inner border (GG′)	60

4E. Ectocuneiform

a. Izumi (NSMT-P-5601-48)

(Pl. 7, Figs. 11-15, Textfig. 72)

Represented by right ectocuneiform (bone c, no. 4) which is small, platy and in perfect preservation. In proximal view, bone elongate subpentagonal with long fore-&-aft axis; fore margin relatively long and slightly curved; inner margin straight, posterior inner margin almost straight and outer margin tolerably curved; posterior end obtusely projected aftward. Facet for navicular broader than that for astragalus transversally at fore portion; dividing longitudinal ridge of both facets obsolete and curved; fore margin of facet for navicular longer than aft margin of it; surface of both facets smooth and almost flat.



Textfig. 72. Right ectocuneiform of Izumi (NSMT-P-5601-48).
1, Fore side; 2, Aft side; 3, Proximal side (fore side is in below); 4, Distal side (fore side is in upper); 5, Inner side; 6, Outer side.

In anterior view, bone wider than high, elongate pentagonal with longest and straight distal margin; interior proximal margin long and slightly recurved while exterior proximal and outer margins short and straight; inner margin bent inward; fore surface rugose. In inner view, bone irregularly quadrate with rugose and projected posterior corner; upper and lower margins long and slightly curved; facet for second metatarsus smooth, flat and quadrate with long and a little curved proximal and distal margins. Distal side of both corresponds to proximal side in outline; surface for third metatarsus smooth, almost flat, subquadrate with long fore-&-aft axis; aft margin eminently projected posteriorly, while the other three margins almost straight. Posterior side rugose, irregularly quadrate in outline and has sharp marginal edge; surface near the edge tolerably depressed.

Length along distal margin of fore surface (E′F′)	30
Ditto along interior proximal margin of fore surface (DF)	26
Ditto along exterior proximal one (DE)	14
Ditto of posterior margin of facet for third metatarsus (GG′)	25
Transverse width of anterior proximal surface (BB′)	38
Ditto of posterior one (CC′)	32
Maximum height of fore surface (DD′)	21
Height along exterior margin of fore surface (EE′)	14
Ditto along interior one (FF′)	12
Ditto along aft margin of facet for second metatarsus (C′F″)	15
Maximum anteroposterior length of proximal side (LL′)	46
Anteroposterior length along inner margin of facet for navicular (B′C′)	28
Ditto along outer margin of facet for third metatarsus (E′G)	32
Ditto along inner one (F′F″)	28

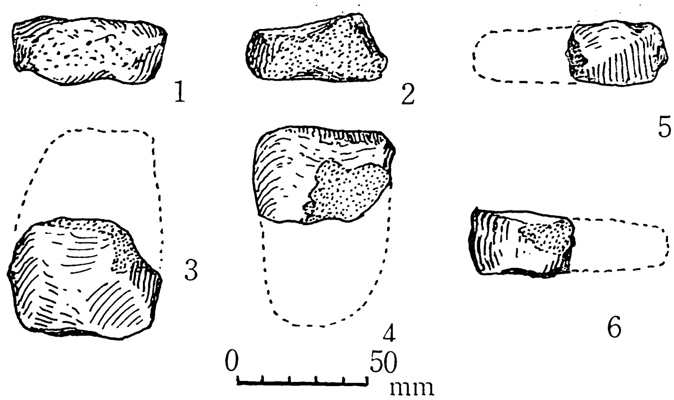
b. Keton (UHR no 18466-33)

(Textfig. 73)

Represented by left ectocuneiform (bone B) which is small platy and preserved anteriorly; posterior half unpreserved. Bone cubic, stout and broader than high. In anterior view, it is quadrate with long and straight distal margin; proximal margin long and slightly undulated, outer one short and almost straight and inner one oblique to distal margins; interior distal corner eminently projected; fore surface very rugose and nearly flat. Posterior side damaged and corresponds with fore side in outline. In both lateral view, bone subquadrate with straight fore margin; inner surface smooth and almost flat. In proximal and distal views, bone subquadrate with long transverse axis; both lateral margins straight and parallel with each other.

Transverse width of fore surface on proximal portion (BB′)	60
Height of fore surface at inner side (CC′)	23
Ditto at outer side (GG′)	28
Maximum anteroposterior length as preserved (EE′)	47

Keton bone is much broader (×1.9) transversally and a little higher (×1.3) than Izumi bone. Sharp edges as seen in Izumi bone have all disappeared and surfaces are not so smooth as in those of Izumi. These may be due to deformation.

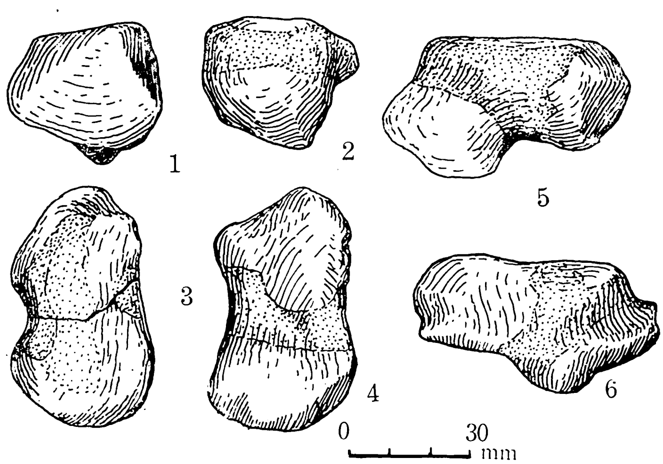


Textfig. 73. Left ectocuneiform of Keton (UHR no 18466-33).
1, Fore side; 2, Aft side; 3, Proximal side (fore side is in below); 4, Distal side (fore side is in upper); 5, Inner side; 6, Outer side.

4F. Mesocuneiform

(Textfig. 74)

Represented by left mesocuneiform of Keton (bone c) (UHR no 18466-34) which is small, thick platy and in poor preservation; both lateral sides and median portion of distal and posterior sides much damaged. Bone cubic, longer than broad antero-posteriorly, becoming higher posteriorly and broader anteriorly. In proximal view, bone subpentagonal with longest and almost straight outer margin; inner margin tolerably recurved; both fore and aft margins gently curved and oblique to inner margin; proximal surface smooth, sloped down inward without any longitudinal ridge. Distal side corresponds with proximal one in outline with eminent posterior projection; distal surface a little depressed. In lateral views, bone elongate sub-



Textfig. 74. Left mesocuneiform of Keton (UHR no 18466-34).
1, Fore side; 2, Aft side; 3, Proximal side; (fore side is in below); 4, Distal side (fore side is in below); 5, Inner side; 6, Outer side.

pentagonal with long and straight proximal margins; posterior margin short, recurved and bent aftward; posterior distal margin long and moderately recurved; anterior margin short and convex forward; bone relatively high.

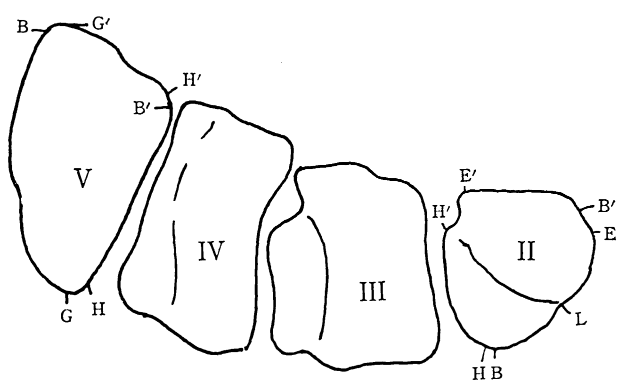
Transverse width of anteroproximal surface (BB′)	34
Ditto of posterior one (CC′)	35
Ditto of median constriction of proximal surface (HH′)	30
Maximum height of fore border (DD′)	28
Ditto of aft border (II′)	35
Maximum anteroposterior length of proximal side (LL′)	56

5. Metatarsus

a. Izumi

(Textfigs. 65, 76)

Four metatarsi (bones, E, F, G and H) preserved in section 4 jointed with right tarsus belong to right second to fifth metatarsi. They are found almost in their natural positions and relationship. Second metatarsus is closely set with mesocuneiform and partially with ectocuneiform and navicular. Third metatarsus is closely ankylosed with ectocuneiform while fourth and fifth metatarsi are closely ankylosed with cuboid. Izumi aft limb has five digits anatomically and four digits functionally.



Textfig. 75. Proximal side of four right metatarsi of Izumi in their natural position. Fore side is in below.

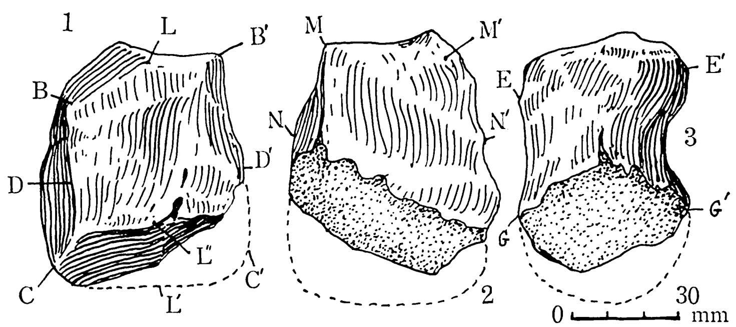
b. Keton

Two metatarsal bones (bones D and E) are preserved jointed with left proximal phalanges in block A. They are neighbouring median metatarsal bones, running in an opposite direction to Izumi metatarsal bones, regarded as third and fourth left metatarsi. NAGAO also regarded them as third and fourth bones. All digits of Izumi and Keton turn exteriorly.

5A. Second Metatarsus

(Pl. 7, Figs. 16-19, Pl. 8, Fig. 17, Textfig .76)

Represented by right metatarsus of Izumi (bone E, no. 3) (NSMT-P-5601-49), which is smallest of all metatarsi, cubic, stout, short and broken distally. In anterior view, bone irregularly pentagonal with longest and gently recurved inner margin; interior proximal and exterior proximal margins nearly of the same length, the former of which slightly recurved and the latter slightly curved; interior proximal corner truncated; exterior proximal corner a little truncated. The fore surface smooth and slightly depressed; interior distal portion broken and median longitudinal ridge obsolete, proximal end of which meets at the middle point of fore margin of facet for navicular. Facet for interior of median longitudinal ridge smaller than that for exterior of it. Proximal border of fore surface rather rugose.



Textfig. 76. Right second metatarsus of Izumi (NSMT-P-5601-49).
1, Fore side; 2, Aft side; 3, Inner side.

In inner view, bone irregularly quadrate with short and gently curved proximal margin; fore margin a little recurved while aft margin much concave aftward. Surface of shaft rugose, narrow and convex. Outer side of the bone more complicated than inner one; shaft broader than that of inner one; surface rugose, uneven but not convex as inner side; proximal margin a little bent forward and a shallow and broad fossa runs posterior of facet for third metatarsus and ectocuneiform, posterior margin of which is sharp; four tubercles lie at proximal border of shaft. In proximal view, bone suboval with posterior margin irregularly curved; facet for navicular triangular with straight outer margin which corresponds to a median longitudinal edge; the facet smooth and depressed. Facet for third metatarsus and ectocuneiform also triangular and higher than the facet just mentioned; it slopes down outward. Posterior shallow fossa narrow and elongate rhombic in outline. Posterior side irregularly quadrate with recurved margins; surface smooth and moderately depressed.

Maximum length of bone (LL′)	59
Ditto on fore surface (LL″)	39
Transverse width of fore surface at proximal portion (BB′)	45
Ditto at middle (DD′)	48

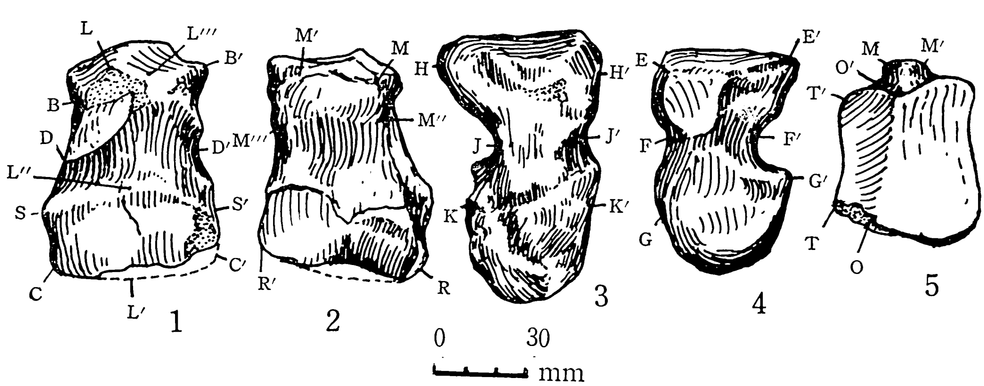
Ditto at distal portion (CC′)	50
Ditto at aft surface at proximal portion (MM′)	37
Ditto of aft surface at middle (NN′)	45
Length of fore margin of facet for navicular (LB′)	26
Ditto of facet for third metatarsus and ectocuneiform (BL)	23
Anteroposterior thickness of inner surface at proximal portion (EE′)	39
Ditto at distal portion (GG′)	27±
Ditto of anterior inner surface at middle (II′)	17
Ditto of outer surface at proximal portion (HH′)	40
Ditto at middle (JJ′)	30
Ditto at distal portion (KK′)	39

5B. Third Metatarsus

a. Izumi (NSMT-P-5601-50)

(Pl. 8, Figs. 22–26, Textfig. 77)

Represented by right metatarsus (bone F, no. 1) which is larger than second and smaller than fourth metatarsi, cubic, dense, stout and relatively short; interior distal portion damaged; proximal portion longer than broad and distal broader than long in fore-&-aft direction; shaft bent inward and distal end eminently expanded laterally with very large condylar facet which is smooth and rather flat. In anterior view, bone irregularly quadrate with longest and undulated outer margin; middle portion of it moderately recurved and bent inward while distal portion straight and vertical to distal margin; interior distal portion broken. Exterior proximal corner truncated and short proximal margin tolerably concave upward; interior proximal corner truncated and short proximal margin tolerably concave upward; interior proximal corner eminently projected. Interior margin undulated and almost straight to distal margin. Surface of shaft smooth, depressed and separated from condylar facet of subquadrate shape by sharp edge which is gently curved; interior proximal portion of the shaft surface triangular, 30 mm long, 12 mm wide and a little elevated.



Textfig. 77. Right third metatarsus of Izumi (NSMT-P-5601-50).
1, Fore side; 2, Aft side; 3, Outer side; 4, Inner side;
5, Proximal side (fore side is in below).

In inner view, bone irregularly triangular with much recurved posterior margin; median aft notch very eminent. Proximal margin a little concave upward; median portion of shaft distinctly constricted and distal margin of it subcircular, expanded laterally. Surface of shaft rather rugose; anterior proximal portion lingual, smooth and bordered by a sharp edge from the other surface; posterior proximal portion a little depressed. Outer side rather like inner one in outline but more complicated; a long and narrow fossa runs posterior of facet for cuboid and on middle portion of condyle; posterior proximal corner eminently projected backward. Surface of shaft rugose and uneven.

Posterior side corresponds to anterior one in outline; exterior distal corner strongly projected; surface of shaft smooth and depressed; proximal edge of condylar facet very sharp and divided into inner and outer parts of semicircular shape; proximal margin slightly convex upward. In proximal view, bone subpentagonal with longest and almost straight inner margin; middle portion of aft margin eminently projected aftward; posterior outer margin much concave outward. Anterior inner corner strongly projected forward. Facet for ectocuneiform subquadrate, larger than that for cuboid of elongate quadrate form; both facets smooth and depressed.

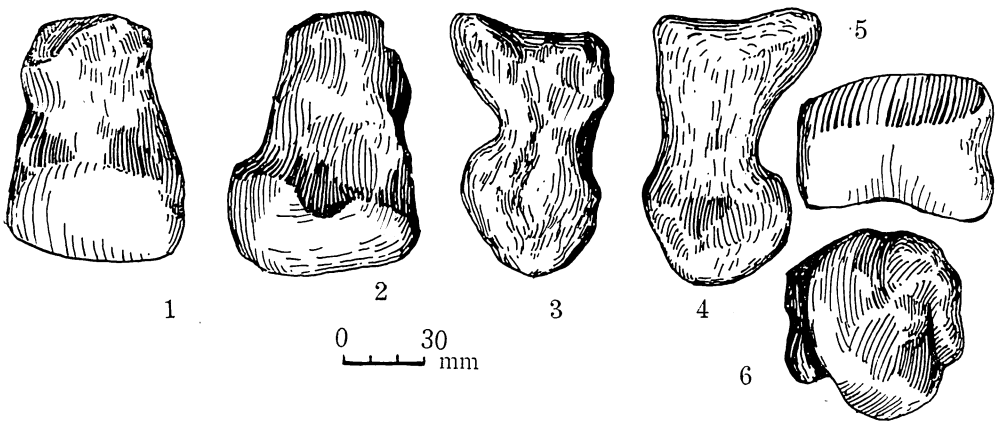
Maximum length of bone (LL′)	73±
Ditto of shaft on fore surface (L″L)	35
Ditto of condyle on fore surface (L′L″)	40
Length of outer margin of interior proximal fore surface (LD)	30
Transverse width of fore surface at proximal (BB′)	38
Ditto at middle (DD′)	42
Ditto at distal (CC′)	54
Ditto of proximal border of fore condylar surface (SS′)	52
Ditto of aft surface at proximal (MM′)	27
Ditto below proximal border (M″M‴)	34
Ditto of aft surface at distal (RR′)	51
Ditto of proximal border of aft condylar surface (QQ′)	46
Anteroposterior thickness of inner surface at proximal (EE′)	41
Ditto at middle (FF′)	24
Ditto at distal portion (GG′)	38
Ditto of outer surface at proximal (HH′)	46
Ditto at middle (JJ′)	22
Ditto at distal portion (KK′)	38
Anteroposterior length of median proximal edge (OO′)	27
Ditto of outer margin of facet for cuboid (TT′)	28

b. Keton (UHR no 18466-35)

(Textfig. 78)

Represented by left metatarsus (bone D) which is dense, stout, cubic, relatively short and a little damaged at its interior proximal corner of fore side and interior distal corner of aft side. Bone bent inward and distal end of it much expanded laterally with large condylar facet.

In anterior view, bone subquadrate with longest and slightly undulated outer margin, proximal half of which a little recurved; distal margin gently curved and runs from interior proximal to exterior distal directions; inner margin undulated and almost vertical to proximal edged border of condylar facet; margin of shaft occupying middle part of the inner margin, tolerably recurved. Surface of shaft smooth and depressed; proximal border of condylar facet distinct and almost straight. Interior proximal portion of shaft surface not elevated or marked.



Textfig. 78. Left third metatarsus of Keton (UHR no 18466-35). 1, Fore side; 2, Aft side; 3, Inner side; 4, Outer side; 5, Distal side (fore side is in upper); 6, Proximal side (fore side is in upper).

In lateral views, proximal border eminently projected backward and aft margin strongly recurved, while fore margin nearly straight and makes an angle of about 90° with proximal margin which is a little concave upward; distal margin convex distally and semicircular. Surface of outer portion rather smooth while that of inner rugose and uneven; narrow fossa visible on median portion of condyle and posterior of facet for cuboid. Posterior side corresponds to anterior one in outline; inner margin almost straight and outer margin moderately recurved. Distal side elongate quadrate with long fore and aft margins which are parallel to each other; exterior aft corner projected backward. In proximal view, bone irregularly quadrate, longer than wide anteroposteriorly and its exterior aft corner much projected backward; outer margin longest and gently curved; aft margin undulated; proximal surface smooth and flat.

Maximum length of bone (LL′)	93
Transverse width of fore surface at proximal (BB′)	48
Ditto at middle (DD′)	47
Ditto at distal (CC′)	69
Anteroposterior thickness of outer surface at proximal (HH′)	65
Ditto at distal (KK′)	53

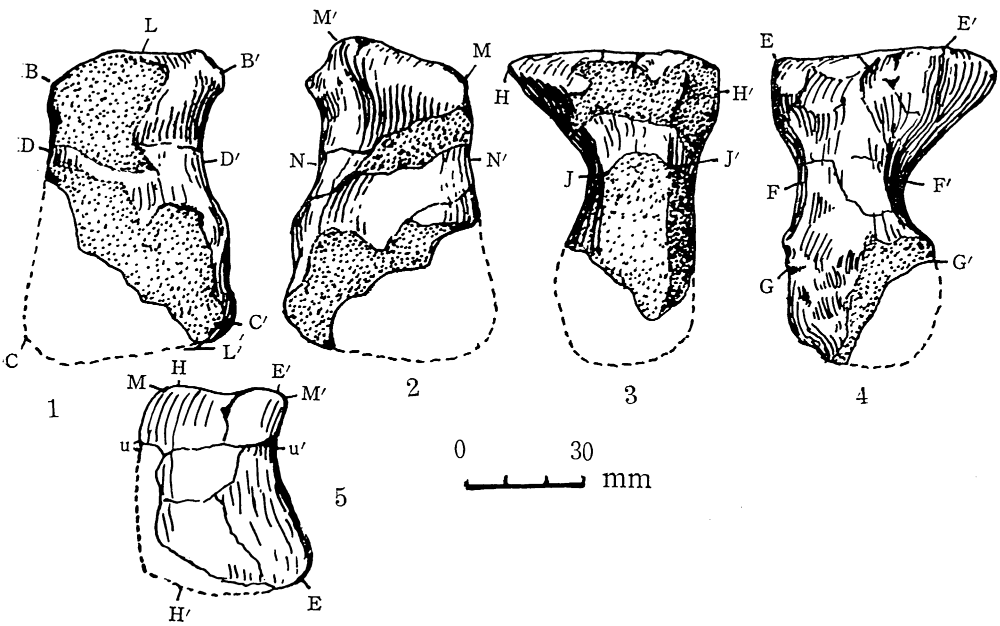
Keton bone is a little longer (×1.27) and wider (×1.26) than Izumi. The ratio between CC′ and LL′ is 0.74 in Izumi and Keton, and the two bones coincide with each other in their shortness. Keton bone is more distinctly projected in its exterior distal and posterior proximal corners than in Izumi bone. Condyle of Keton is more eminently expanded anteroposteriorly than that of Izumi. If so much deformation in preservation did not take place, an articulation of metatarsus with tarsus and phalanges would be stronger in Keton than in Izumi.

5C. Fourth Metatarsus

a. Izumi (NSMT-P-5601-51)

(Pl. 8, Figs. 13-21, Textfig. 79)

Represented by right metatarsus (bone G, no. 2) which is the largest of all metatarsal bones, longer than third metatarsus, cubic, stout, dense and broken distally. Shaft bent inward and becomes proximally longer than broad in fore-&-aft direction and distally broader than long in same direction. Condyle not so eminently expanded laterally as in third metatarsus; condylar facet broken.



Textfig. 79. Right fourth metatarsus of Izumi (NSMT-P-5601-51).
1, Fore side; 2, Aft side; 3, Outer side; 4, Inner side;
5, Proximal side (fore side is in below).

In anterior view, bone subquadrate with shortest and slightly curved proximal margin; inner margin moderately recurved and interior proximal corner truncated; surface of shaft smooth and a little depressed. In inner view, bone irregularly trigonal with gently curved proximal and moderately recurved fore margins; they meet at an angle of about 90° with each other; posterior proximal corner eminently projects backward and aft margin distinctly concave backward. Distal portion expands and its margin seems to be semicircular in original aspect. Surface of shaft smooth and a little depressed; anterior proximal portion inflated, smooth, consisting of suboval anterior and elongate posterior half; distal margin of them clearly edged;

elevated surface articulates with exterior proximal surface of third metatarsus; posterior proximal portion a little depressed. Distal surface rugose and uneven. Outer side corresponds to inner one in outline, but large parts of its distal portion and median proximal portion are damaged; proximal margin straight. Posterior side also corresponds to anterior one in outline; proximal margin irregularly curved and inner margin a little concave inward; surface of shaft smooth and much depressed. Median proximal portion of shaft and distal border of it broken. In proximal view, bone subquadrate with long and almost straight outer margin; inner margin long and much concave inward; fore and aft margins straight and parallel with each other. Proximal surface smooth, undepressed and articulates with cuboid.

Maximum length of bone (LL′)	80
Transverse width of fore surface at proximal (BB′)	46±
Ditto at mindle (DD′)	39
Ditto at distal (CC′)	55±
Ditto of aft surface at proximal (MM′)	34
Ditto at middle (NN′)	38
Median transverse width of proximal surface (UU′)	35
Anteroposterior thickness of inner surface at proximal (EE′)	44
Ditto at middle (FF′)	24
Ditto at distal (GG′)	37±
Ditto of outer surface at proximal (HH′)	49±
Ditto at middle (JJ′)	22

b. Keton (UHR no 18466-36)

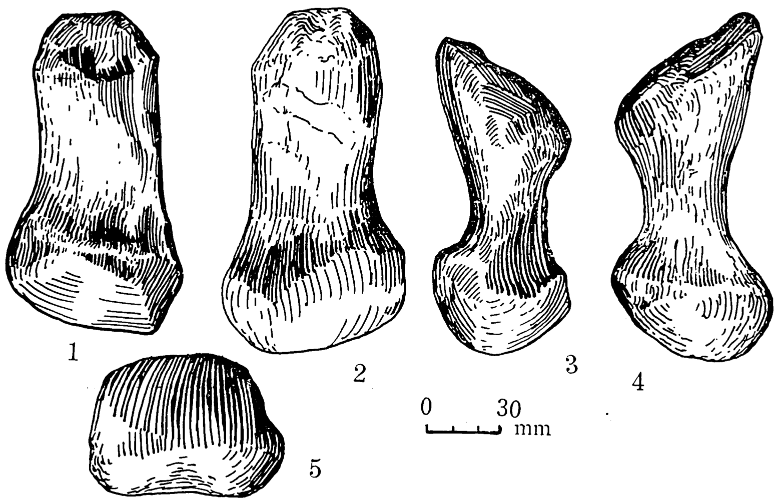
(Textfig. 80)

Represented by left metatarsus (bone F) which is dense, stout, cubic, relatively long and a little damaged partially. Bone bent inward and carries eminent condyle much expanded in anteroposterior direction. In anterior view, bone elongate quadrate with long and straight outer margin; inner margin a little concave inward. Distal region expanded laterally with gently curved distal margin which runs from interior proximal to exterior distal directions; exterior distal corner truncated. Proximal margin irregularly convex upward. Surface of shaft smooth and depressed especially above supracondylar edge; proximal portion of the surface much inbated; condylar surface smooth, broad and moderately curved. In distal view, bone trapezoid with longest aft margin.

In lateral view, bone irregularly quadrate with long and much recurved fore and aft margins; median constriction lies just above supracondylar edge; proximal portion of aft margin very long and nearly straight; proximal margin much bent forward; shaft becomes broader distally and distal margin semicircular. Proximal half of shaft subtriangular in general outline. Anterior proximal corner a little damaged; fore margin makes an angle of about 100° with proximal margin; surface of both lateral sides rather smooth and flat. Posterior side corresponds to anterior one in outline and surface of shaft very smooth and depressed especially above condyle. In proximal view, bone subquadrate with long and almost straight inner margin; outer margin irregularly curved and fore margin moderately projected forward;

the surface smooth, flat and slopes down forward.

Maximum length of bone (LL′)	107
Transverse width of fore surface at proximal (BB′)	51
Ditto at middle (DD′)	49
Ditto at distal (CC′)	73
Anteroposterior thickness of outer surface at proximal (HH′)	60
Ditto at distal (KK′)	55



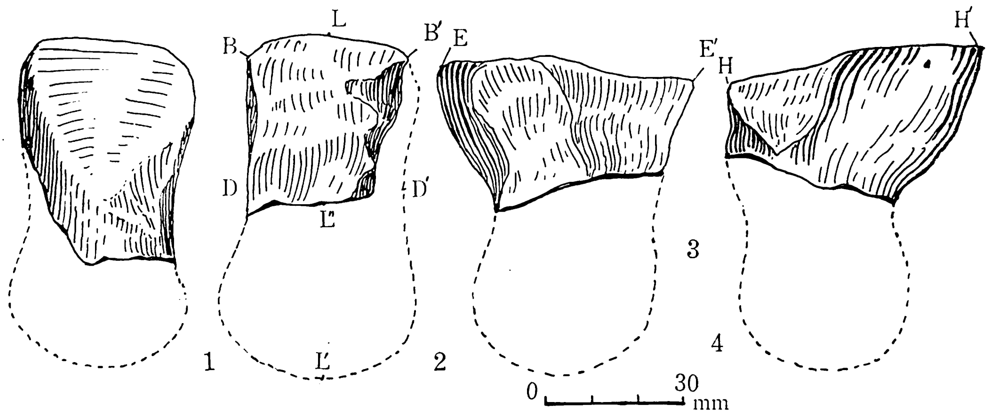
Textfig. 80. Left fourth metatarsus of Keton (UHR no 18466-36).
1, Fore side; 2, Aft side; 3, Inner side; 4, Outer side;
5, Distal side (fore side is in upper).

Keton bone is much longer (×1.7) and slightly wider (BB′ ×1.1) than Izumi bone. The ratio between CC′ and LL′ is 0.68 in Izumi and 0.53 in Keton, i. e. Keton bone is relatively longer than Izumi bone. In general aspect the former is longer, narrower than the latter, and proximal surface more abruptly sloped down in the former than in the latter. Proximal lateral surface of shaft is elongate trigonal in proximo-distal direction in Keton bone but ditto transversally in Izumi bone.

5D. Fifth Metatarsus

(Pl. 8, Figs. 6-12, Textfig. 81)

Represented by right metatarsus of Izumi (bone H, no. 6) (NSMT-P-5601-52) which is dense, thick, shorter than fourth metatarsus, with fore-&-aft expansion of proximal portion and much broken distally. In posterior view, bone subquadrate as preserved with straight inner and proximal margins; aft surface rather rugose proximally and smooth and depressed distally. In inner view, bone trapezoidal as preserved with long and almost straight proximal margin which is bent forward; inner surface rugose, anterior half of the surface depressed, while posterior half of it elevated, subtrigonal, 28 mm long and 16 mm high. Outer side corresponds to inner side in outline; anterior proximal portion smooth and tolerably depressed and anterior proximal end eminently projected forward; posterior margin convex aftward and a small foramen lies at posterior border.



Textfig. 81. Right fifth metatarsus of Izumi (NSMT-P-5601-52).
1, Fore side; 2, Aft side; 3, Outer side; 4, Inner side.

In proximal view, bone subtriangular with distinct projection of anterior corner, much longer than wide anteroposteriorly, longer than fourth metatarsus and with gently curved aft margin; inner margin moderately convex inward; the surface smooth, a little depressed and articulates with cuboid. The original length of shaft quite unknown, probably short and near fourth metatarsus.

Maximum length of bone as preserved (LL'')	37
Ditto restored (LL')	(78±)
Transverse width of aft surface at proximal (BB')	36
Ditto at middle (DD')	38±
Anteroposterior thickness of outer surface at proximal (EE')	58
Ditto of inner surface at proximal (HH')	56

In proximal view of articulated metatarsus, bones become longer outward anteroposteriorly; a small cavity lies on posterior between third and fourth and between second and third metatarsi.

6. Pes Phalanges

a. Izumi

(Textfig. 64)

In section 5 there are preserved three phalanges (bones 13-14, 15 and 16b), and the other three phalanges (bones 45-47, 48 and 46) are found from an isolated block, jointed to each other. The other four phalanges (bones 1-2, 4-5, 16a and 50) were procured in excavation from the other isolated points in separate condition respectively. Judged from the outline of left pes phalange of Keton, they are arranged as follows.

		Right	Left
Proximal	II	—	50
	III	4-5	—
	IV	1-2	16b
	V	45-47	—

Middle	II	—	—
	III	16a	—
	IV	13-14	—
	V	48	—
Distal	II	—	—
	III	—	—
	IV	15	—
	V	46	—
Total		8	2

b. Keton

(Textfig. 64)

NAGAO indicated four digits of left pes and arranged eight phalanges in their original relative positions; they were found in their natural jointing positions with metatarsus and tarsus. The writer named them F, G, H····M and arranged them as follows.

		Right	Left
Proximal	II	—	M
	III	—	F
	IV	—	H
	V	—	K
Middle	II	N	—
	III	—	G
	IV	—	I
	V	—	L
Distal	II	—	—
	III	—	—
	IV	—	—
	V	—	J
Total		1	8

Thus all phalangial bones are known except second and third distal bones. Although NAGAO regarded bone J as fourth distal, the writer puts it to fifth one as stated in the following lines.

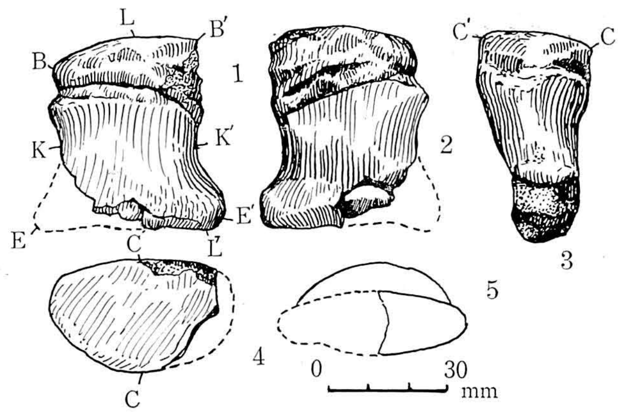
7. Proximal Phalange

7A. Second Proximal Phalange

a. Izumi (NSMT-P-5601-53)

(Pl. 10, Figs. 18-22, Textfig. 82)

Represented by a left bone (bone no. 50) which is broken in interior distal portion. Bone platy, stout, becoming very thicker proximally. In anteroposterior views, bone subquadrate, longer than broad with almost straight proximal and distal margins; inner and outer margins tolerably recurved and exterior distal corner distinctly projected; proximal epiphysis not fully confluent with shaft but unseparated; epiphysial suture distinct; fore surface smooth and a little depressed, while aft surface nearly flat and slightly depressed distally. In lateral view, bone elongate trigonal with short and straight proximal margin bent forward; aft margin more strongly curved than fore one; exterior proximal portion damaged. Proximal surface suboval in outline, smooth and flat; aft margin almost straight but fore margin eminently curved.

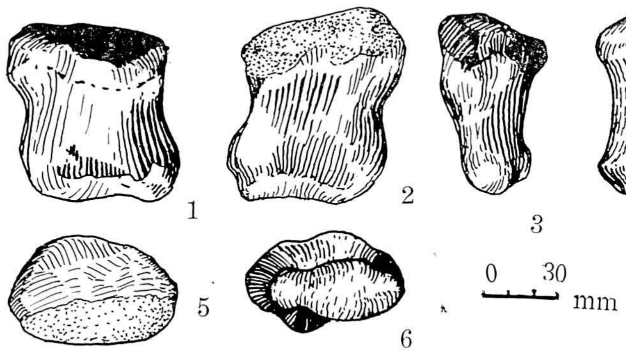


Textfig. 82. Left second proximal phalange (pes) of Izumi (NSMT-P-5601-53). 1, Fore side; 2, Aft side; 3, Inner side; 4, Proximal side (fore side is in upper); 5, Distal side (fore side is in upper).

b. Keton (UHR no 18466-37)

(Textfig. 83)

Represented by a left bone (M) which is platy, short and damaged at its posterior proximal portion. In anterior views, bone subquadrate, longer than broad with recurved inner and outer margins; proximal margin slightly convex upward while distal a little concave downward; proximal portion of inner margin moderately convex inward and both interior and exterior distal corners truncated; shaft runs from interior proximal to exterior- distal directions; fore surface smooth and tolerably depressed, while aft one almost flat. In lateral view, bone elongate trigonal with short and straight proximal margin bent forward; fore margin more strongly curved



Textfig. 83. Left second proximal phalange (pes) of Keton (UHR no 18466-37). 1, Fore side; 2, Aft side; 3, Inner side; 4, Outer side; 5, Proximal side (fore side is in upper); 6, Distal side (fore side is in upper).

than aft one. Proximal surface semicircular with straight aft and curved fore margins; distal surface elongate oval.

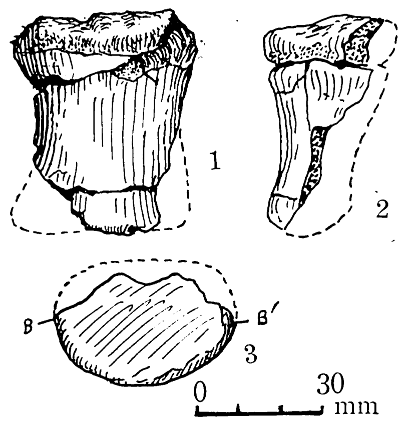
Keton bone is longer (×1.24) and wider (×1.44) than Izumi bone. Exterior distal corner is more strongly projected in Izumi than in Keton.

7B. Third Proximal Phalange

a. Izumi (NSMT-P-5601-54)

(Pl. 10, Fig. 23, Textfig. 84)

Represented by a right bone (bone no. 4,5) of which is preserved only an anterior portion of epiphysis and anterior proximal portion of shaft; epiphysis detached from shaft. In anteroposterior views, bone when restored seems to be quadrate with straight proximal margin; outer margin a little concave outward; fore surface smooth and convex forward; proximal surface smooth, flat and seems to be oval in outline.

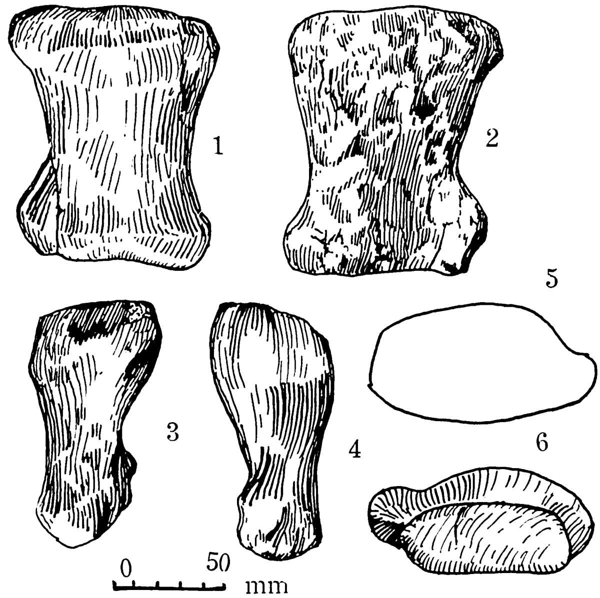


Textfig. 84. Right third proximal phalange (pes) of Izumi (NSMT-P-5601-54).
1, Fore side; 2, Inner side; 3, Proximal side (fore side is in below).

b. Keton (UHR no 18466-38)

(Textfig. 85)

Represented by a left bone (bone F) which is thick, platy, stout and in fine preservation. Epiphysis confluent with shaft and bone becoming thicker proximally. In anteroposterior views, bone subquadrate with long and straight proximal margin; distal margin slightly concave downard and inner margin more strongly curved than outer margin; shaft bent inward and its axis makes an angle of 84° with proximal margin; interior proximal and interior distal corners much projected inward; interior and exterior distal corners and exterior proximal corner truncated; fore surface



Textfig. 85. Left third proximal phalange (Pes) of Keton (UHR no 18466-38). 1, Fore side; 2, Aft side; 3, Outer side; 4, Inner side; 5, Proximal side (fore side is in upper); 6, Distal side (fore side is in upper).

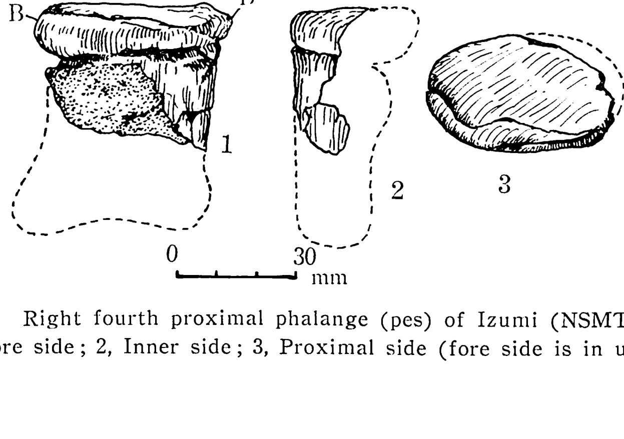
smooth and depressed; aft surface flat proximally and depressed distally. In lateral view, bone elongate trigonal with short and straight proximal margin bent forward; aft margin more strongly curved than fore one. Proximal surface semicircular in outline with almost straight aft and curved fore margins.

Keton bone is much wider (×1.5) than Izumi bone.

7C. Fourth Proximal Phalange

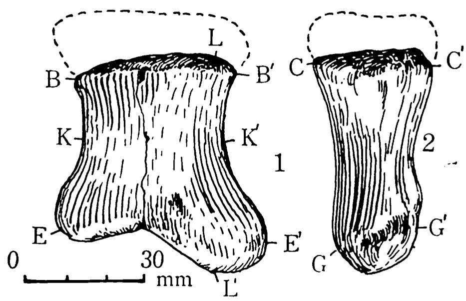
a. Izumi (NSMT-P-5601-55, 56)

(Pl. 10, Figs. 24-31, Textfig. 86)



Textfig. 86. Right fourth proximal phalange (pes) of Izumi (NSMT-P-5601-55). 1, Fore side; 2, Inner side; 3, Proximal side (fore side is in upper).

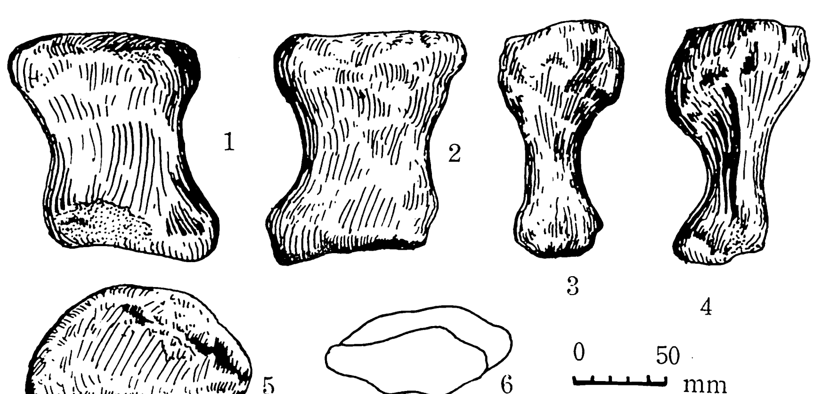
Represented by right (bone no. 1-2) (NSMT-P-5601-55) and left bones (bone 16b) (NSMT-P-5601-56); the former preserved only in proximal surface and a part of interior proximal portion of fore surface; the latter is well preserved, although epiphysis detached and unpreserved. Bone platy and becomes thicker proximally. In anteroposterior views, it is subquadrate with almost straight proximal margin; inner, outer and distal margins tolerably recurved. Exterior distal corner eminently projected outward and axis of shaft makes an angle of 80° with the line running between both interior distal and exterior distal tips, i. e. shaft bent inward. Fore surface smooth and a little depressed. In lateral view, bone elongate trigonal with aft margin more strongly curved than fore one. Proximal surface smooth, flat and oval in outline. Distal surface elongate sublunar with aft margin concave aftward; both inner and outer corners obtuse. Epiphysial suture clear in right bone and epiphysis of it undetached.



Textfig. 87. Left fourth proximal phalange (pes) of Izumi (NSMT-P-5601-56). 1, Fore side; 2, Outer side.

b. Keton (UHR no 18466-39)

(Textfig. 88)



Textfig. 88. Left fourth proximal phalange (pes) of Keton (UHR no 18466-39). 1, Fore side; 2, Aft side; 3, Outer side; 4, Inner side; 5, Proximal side (fore side is in upper); 6, Distal side (fore side is in upper).

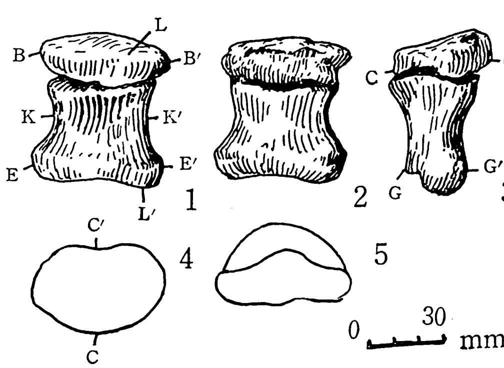
Represented by a left bone (bone H) which is platy, becoming much thicker proximally and in fine preservation; epiphysis fused with shaft. In anteroposterior views, bone subquadrate with long proximodistal axis; proximal and distal margins straight and parallel with each other; both inner and outer margins recurved and the latter more strongly curved than the former; both interior and exterior distal corners truncated; axis of shaft almost makes an angle of 85° with proximal margin, i. e. shaft tolerably bent inward and exterior distal and interior proximal corners projected outward and inward respectively. Aft surface smooth and depressed. In lateral view, bone elongate trigonal with much recurved inner and outer margins, the latter of which more strongly curved than the former; proximal margin short and almost straight. Proximal surface suboval with straight aft and curved fore margins. Distal surface elongate suboval.

Keton bone is wider (×1.31) than Izumi bone and rather like in outline although epiphysial portion of Izumi bone is unpreserved.

7D. Fifth Proximal Phalange

a. Izumi (NSMT-P-5601-57)

(Pl. 10, Figs. 32-36, Textfig. 89)

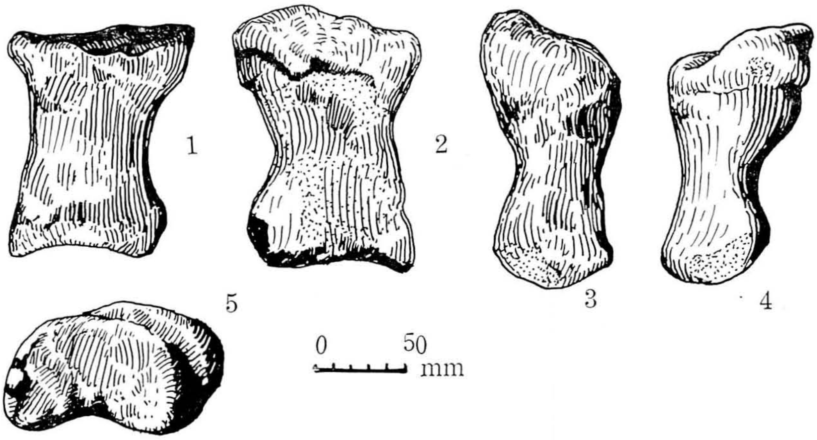


Textfig. 89. Right fifth proximal phalange (pes) of Izumi (NSMT-P-5601-57). 1, Fore side; 2, Aft side; 3, Inner side; 4, Proximal side (fore side is in below); 5, Distal side (fore side is in upper).

Represented by a right bone (bone no. 45-47) which is well preserved and larger than fourth phalange. Bone thick, platy and stout, becoming much thicker proximally. Epiphysis detached. In anteroposterior views, bone subquadrate with straight proximal margin concave downward; both inner and outer margins moderately recurved and exterior distal corner larger than interior distal one. Axis of shaft vertical to proximal margin. In lateral view, bone elongate trigonal with short and straight proximal margin bent forward; aft margin more strongly curved than fore one. Proximal surface suboval with almost straight aft and curved fore margins; posterior proximal corner eminently projected backward and exterior proximal portion damaged.

b. Keton (UHR no 18466-40)

(Textfig. 90)



Textfig. 90. Left fifth proximal phalange (pes) of Keton (UHR no 18466-40).
1, Fore side; 2, Aft side; 3, Inner side; 4, Outer side;
5, Distal side (fore side is in upper).

Represented by a left bone (bone K) which is thick and platy, becoming thicker proximally and in fine preservation though aft surface largely damaged; epiphysis confluent with shaft. In anterior proximal view, bone subquadrate, longer than wide proximodistally and has straight proximal margin which is longer than distal one; inner, outer and distal margins recurved and outer one more strongly curved than inner one; exterior distal corner truncated but interior distal corner projected inward. Axis of shaft almost vertical to proximal margin. Fore surface smooth and median longitudinal ridge divides inner and outer surfaces, the latter of which is larger than the former one; aft surface smooth and flat. In lateral view, bone subquadrate with recurved inner and outer margins and the latter more strongly curved than the former one; distal margin gently curved; posterior proximal corner eminently projected aftward. Proximal surface suboval and median portion of fore margin projected forward. Distal surface sublunar with recurved aft margin and obtuse inner

Table 9. Measurements of proximal phalanges (pes).

R: Right. L: Left.	Izumi					Keton			
	II	III	IV		V	II	III	IV	V
	L	R	R	L	R	L	L	L	L
Maximum length as preserved (LL′)	49	—	—	51	58	61	88	76	95
Maximum transverse width of proximal end (BB′)	38+	45+	49	40	50	55	69	70	68
Ditto of distal end (EE′)	43+	—	—	53	50	45	47	47	44
Minimum transverse width of shaft (KK′)	34	—	—	36	36	53	65	63	69
Maximum thickness of proximal end (CC′)	29	—	35	31	37	31	43	44	46
Ditto of distal end (GG′)	17	—	—	21	24	23	27	29	30

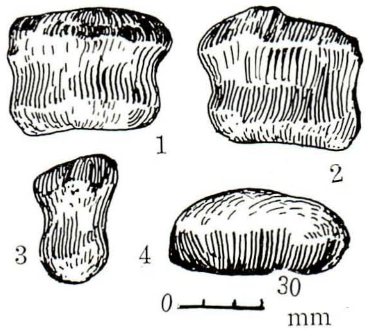
and outer ends.

Keton bone is much longer (×1.6) and wider (×1.4) than Izumi bone. It is relatively longer and more strongly bent inward than Izumi bone.

8. Middle Phalanges

8A. Second Middle Phalange

(Textfig. 91)



Textfig. 91. Left second middle phalange (pes) of Keton (UHR no 18466-41).
1, Fore side; 2, Aft side; 3, Outer side; 4, Distal side (fore side is in upper).

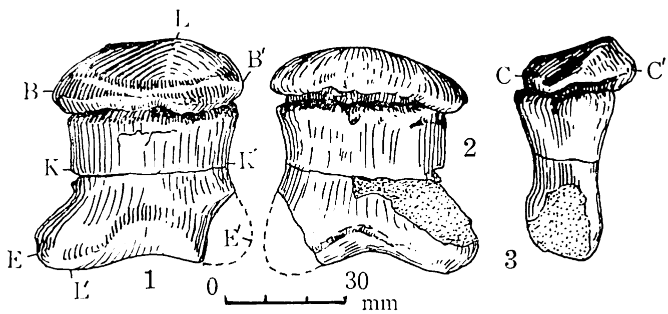
Represented by a right bone of Keton (bone m) (UHR no 18466-41) which is platy and well preserved; epiphysis confluent with shaft. In anteroposterior view, bone quadrate, broader than long proximodistally, and has long and gently curved proximal margin; inner margins moderately recurved and the former more strongly curved than the latter; distal margin a little concave downward. Axis of shaft vertical to proximal margin; fore surface smooth and depressed in its median portion; proximal and distal border inflated; aft surface smooth and depressed. In lateral view, bone subquadrate with short and almost straight proximal margin bent forward; shaft becomes thicker proximally and constricted at its middle portion. Proximal surface smooth, flat and elongate oval in outline; fore margin more strongly curved than the aft one. Distal surface more elongate than proximal.

8B. Third Middle Phalange

a. Izumi (NSMT-P-5601-58)

(Pl. 10, Figs. 37-41, Textfig. 92)

Represented by a right bone (bone 16a) which is platy, a little smaller and thicker than fourth; interior distal and posterior distal portion broken; epiphysis unfused with shaft but undetached; epiphysial suture distinct. In fore-&-aft views, bone subquadrate with slightly convex proximal margin; both lateral and distal margins recurved; interior distal and exterior distal corners much projected and the latter seems to be more eminent than the former ; axis of shaft almost vertical to proximal margin. Fore surface smooth, a little depressed and distal border carries a sharp transverse crest which is eminently curved. In lateral view, bone elongate trigonal, becoming thicker proximally and posterior proximal corner short, slightly concave upward and bent forward ; fore margin more strongly curved than aft one. Proximal surface smooth, flat and semicircular in proximal view ; aft margin almost straight and fore margin curved. Distal surface elongate fusiform in distal view.

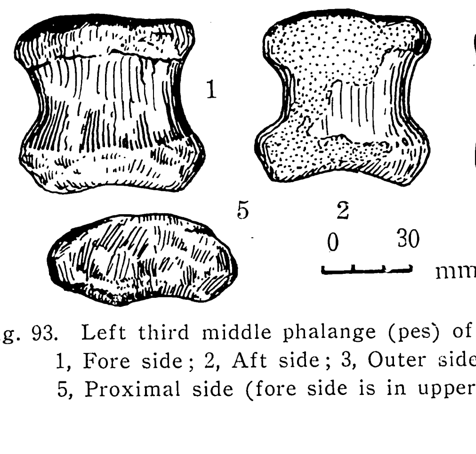


Textfig. 92. Right third middle phalange (pes) of Izumi (NSMT-P-5601-58).
1, Fore side ; 2, Aft side ; 3, Inner side.

b. Keton (UHR no 18466-42)

(Textfig. 93)

Represented by a left bone (bone G), which is platy, becomes a little thicker proximally and well preserved though posterior surface largely damaged ; epiphysis confluent with shaft but epiphysial suture distinct. In anteroposterior views, bone subquadrate, a little longer than broad proximodistally and has slightly curved proximal margin ; both lateral and distal margin recurved and shaft constricted at middle ; interior and exterior distal corner truncated ; axis of shaft almost vertical to proximal margin. Fore surface smooth and a little depressed ; proximal and distal borders inflated. In lateral view, bone elongate trigonal with short and straight



Textfig. 93. Left third middle phalange (pes) of Keton (UHR no 18466-42).
1, Fore side ; 2, Aft side ; 3, Outer side ; 4, Inner side ;
5, Proximal side (fore side is in upper).

proximal margin bent foreward; aft margin more strongly curved than fore one; distal corner obtusely projected. Proximal surface smooth, flat and fusiform; aft margin more strongly curved than fore one. Distal surface corresponds with proximal one in outline.

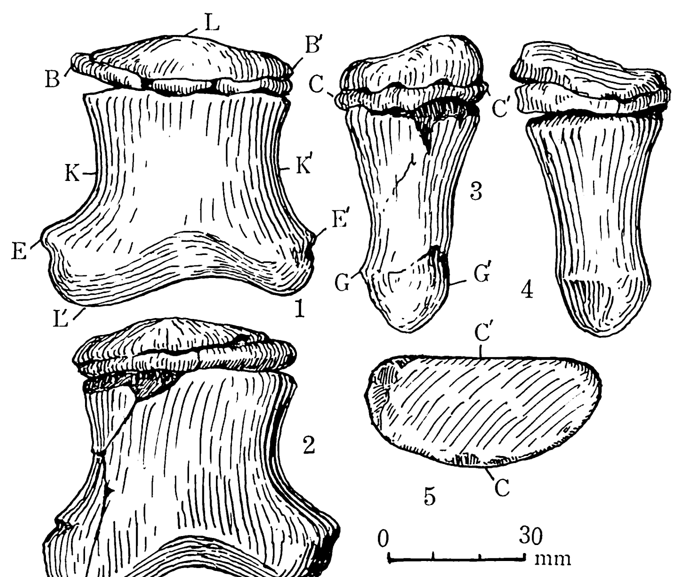
Keton bone is very much like Izumi bone in general outline though a little longer (×1.1) and thicker than it is.

8C. Fourth Middle Phalange

a. Izumi (NSMT-P-5601-59)

(Pl. 10, Figs. 42-46, Textfig. 94)

Represented by a right bone (bone no. 13, 14) which is platy, stout and well preserved; epiphysis (no. 13) detached from shaft (no. 14). In anteroposterior views, bone subquadrate, longer than broad with slightly curved proximal margin; distal margin tolerably concave downward and both inner and outer margins much recurved; outer margin more strongly curved than inner one; exterior distal corner more eminently projected than interior distal one; both tips of them a little truncated; axis of shaft almost vertical to proximal margin. Fore surface smooth and a little depressed. Aft surface also smooth and flat. In lateral view, bone elongate trigonal, becoming thicker proximally; proximal margin short, slightly concave upward and bent forward; both fore and aft margins a little recurved and distal end obtusely projected. Proximal surface smooth, almost flat though a little sloped down both inward and outward, semicircular in proximal view with straight aft and curved fore margins. Distal surface smooth and elongate fusiform in distal view.



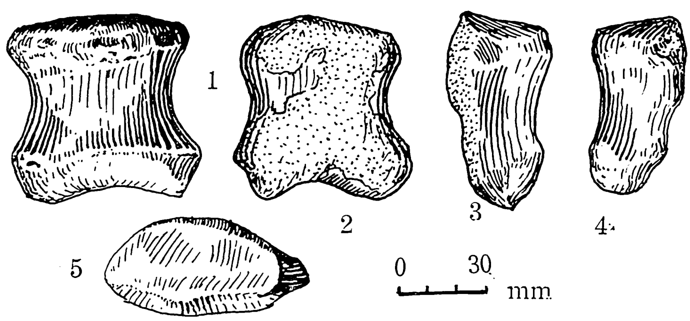
Textfig. 94. Right fourth middle phalange (pes) of Izumi (NSMT-P-5601-59).
1, Fore side; 2, Aft side; 3, Inner side; 4, Outer side;
5, Proximal side (fore side is in below).

b. Keton (UHR no 18465-43)

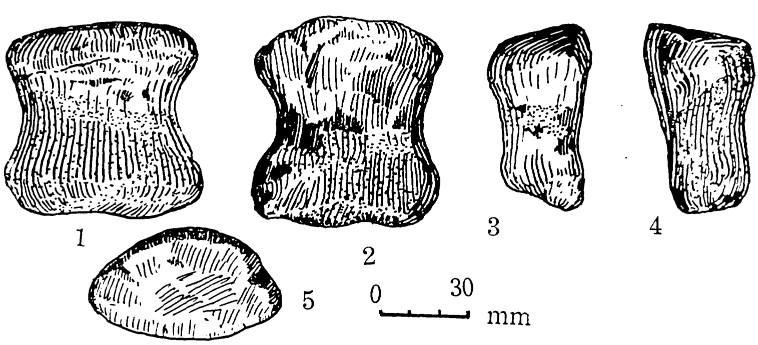
(Textfig. 95)

Represented by a left bone (bone I) which is platy, stout and well preserved, although its posterior surface is largely damaged; epiphysis confluent with shaft but epiphysial suture distinct. In anteroposterior views, bone subquadrate, slightly longer than broad with a little curved proximal margin; both lateral and distal margins recurved; shaft distinctly constricted at middle and both interior distal corners projected and their tips truncated; axis of shaft almost vertical to proximal margin. Fore surface smooth and distinctly depressed with many minute longitudinal striations; proximal and distal borders much inflated. Aft surface almost flat. In lateral view, bone elongate trigonal, becoming thicker proximally; proximal margin short, straight and makes an angle of about 90° with fore margin; aft margin as preserved undulated and distal end obtusely projected. Proximal surface smooth, flat and suboval with inner and outer ends, both of which are acute. Distal surface more elongate than proximal.

Keton bone is a little longer (×1.1) and wider (×1.24) than Izumi bone. They are very much like in lateral outline to each other, but Keton bone is relatively



Textfig. 95. Left fourth middle phalange (pes) of Keton (UHR no 18466-43).
1, Fore side; 2, Aft side; 3, Inner side; 4, Outer side;
5, Proximal side (fore side is in upper).



Textfig. 96. Left fifth middle phalange (pes) of Keton (UHR no 18466-44).
1, Fore side; 2, Aft side; 3, Outer side; 4, Inner side;
5, Proximal side (fore side is in upper).

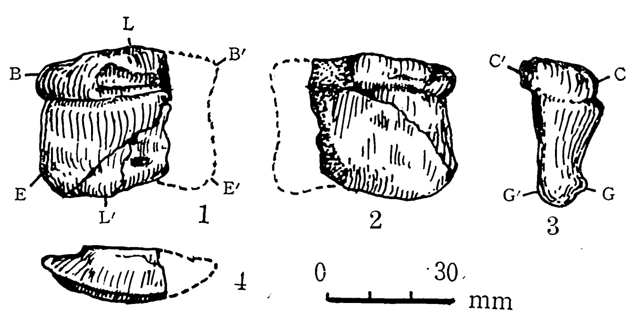
wider proximally than Izumi bone and not so much projected in exterior distal corner than in it.

8D. Fifth Middle Phalange

a. Izumi (NSMT-P-5601-60)

(Pl. 10, Figs. 47-49, Textfig. 97)

Represented by a right bone (bone no. 48) which is small, platy and inner portion of which is broken; epiphysis undetached but epiphysial suture distinct. In antero-posterior view, bone quadrate with wider transverse axis; proximal margin almost straight, while distal one a little convex downward; outer margin short and straight. Exterior distal corner obtuse. In lateral view, bone elongate trigonal with short and straight proximal margin bent forward; fore margin more strongly curved than aft one and posterior proximal corner eminently projected; shaft becomes thicker proximally. Proximal surface smooth, flat and fusiform in proximal view; fore margin more strongly curved than aft one. Distal surface slightly convex, smooth and elongate fusiform in distal view.



Textfig. 97. Right fifth middle phalange (pes) of Izumi (NSMT-P-5601-60). 1, Fore side; 2, Aft side; 3, Outer side; 4, Proximal side (fore side is in below).

b. Keton (UHR no 18466-42)

(Textfig. 93)

Represented by a left bone (bone G) which is platy, well preserved, becoming thicker proximally though posterior surface largely damaged; epiphysis fused with shaft but epiphysial suture distinct. In anteroposterior view, bone subquadrate, a little longer than broad proximodistally and has slightly curved proximal margin; both lateral and distal margins recurved and shaft constricted at middle; interior and exterior distal corners truncated; axis of shaft almost vertical to proximal margin. Fore surface smooth and a little depressed; proximal and distal border inflated. In lateral view, bone elongate trigonal with short and straight proximal margin bent forward; aft margin more strongly curved than fore one; distal corner obtusely projected. Proximal surface smooth, flat and fusiform; aft margin more strongly curved than fore. Distal surface compressed with proximal one in outline.

Keton bone is very much like in general outline Izumi bone though much longer (11.5) and thicker (×1.8) than it is.

Table 10. Measurements of middle phalanges (pes).

R: Right. L: Left.

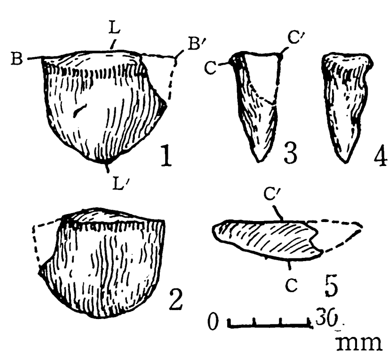
	Izumi			Keton			
	III	IV	V	II	III	IV	V
	R	R	R	R	L	L	L
Maximum length as preserved (LL′)	56	59	38	44	63	66	68
Maximum transverse width of proximal end (BB′)	46	47	31+	55	61	63	64
Ditto of distal end (EE′)	54±	59	32+	50	62	63	64
Minimum transverse width of shaft (KK′)	38	39	—	47	47	48	49
Maximum thickness of proximal end (CC′)	28	27	19	25	30	33	35
Ditto of distal end (GG′)	20	18	15	16	32+	26	26

9. Distal Phalange

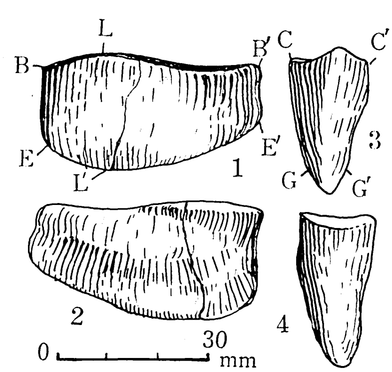
9A. Fourth Distal Phalange

(Pl. 10, Figs. 50–54, Textfig. 98)

Represented by a right bone of Izumi (bone no. 15) (NSMT-P-5601-61) which is platy, relatively thin, larger than third bone and its interior proximal portion broken. In anteroposterior view, bone semicircular, broader than long, with gently curved proximal and much curved distal margins; median point of the latter obtusely projected distally; outer margin makes an angle of 83° with proximal margin; proximal border carries an acute transverse edge. Axis of shaft vertical to proximal margin. Fore surface a little rugose, gently curved and depressed proximally. Aft surface rugose, almost flat with small depression. In lateral view, bone elongate trigonal with short and straight proximal margin; both lateral margins almost



Textfig. 98. Right fourth distal phalange (pes) of Izumi (NSMT-P-5601-61).
1, Fore side; 2, Aft side; 3, Inner side; 4, Outer side; 5, Proximal side (fore side is in below).



Textfig. 99. Right fifth distal phalange (pes) of Izumi (NSMT-P-5601-62).
1, Fore side; 2, Aft side; 3, Inner side; 4, Outer side.

straight and distal end acute. Proximal surface flat and subfusiform in proximal view with lateral ends both of which being acute; fore margin curved and aft one straight.

9B. Fifth Distal Phalange

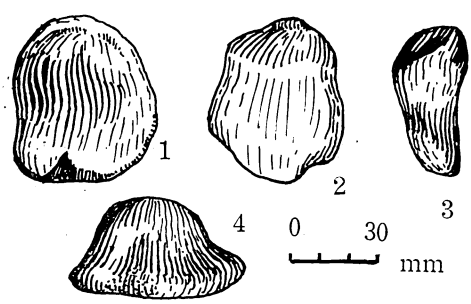
a. Izumi (NSMT-P-5601-62)

(Pl. 10, Figs. 55-59, Textfig. 99)

Reprented by a right bone (bone no. 46) which is small sized, platy and well preserved. In anteroposteior view, bone subquadrate, broader than long, carries longest and gently curved distal margin; inner margin slightly concave inward and longer than outer one which is shortest; interior distal corner projected distally and bone itself higher interiorly than exteriorly; inner half of proximal margin a little convex while outer half of it concave upward. Aft surface rugose and depressed especially at middle. Fore surface also rugose and a little depressed. In lateral view, bone elongate trigonal becoming thicker proximally; fore margin a little more strongly recurved than aft one; distal end sharply projected. Proximal surface smooth, flat and elongate fusiform in proximal view, with straight aft and curved fore margins; both inner and outer ends acute.

b. Keton (UHR no 18466-45)

(Textfig. 100)



Textfig. 100. Left fifth distal phalange (pes) of Keton (UHR no 18466-45).
1, Fore side; 2, Aft side; 3, Inner side; 4, Distal side (fore side is in upper).

Represented by a left bone (bone J) which is platy, relatively large sized and well preserved. NAGAO regarded this as fourth distal bone but it differs much in outline from the bone above mentioned; the writer regards it as fifth one. Probably some mistake was made in NAGAO's preparation or the bone was changed its original position in process of preservation. In fore-&-aft view, bone longer than broad, becoming broader distally and carries long and straight inner margin; distal margin moderately undulated and proximal margin much curved; exterior distal corner eminently truncated. Fore surface rather rugose and much inflated at its median proximal portion. Aft surface almost flat. Axis of shaft vertical to distal margin. In lateral view, bone elongate trigonal with long straight aft margin; anterior proximal corner eminently projected forward and fore margin abruptly projected forward and fore margin abruptly recurved at median portion. Distal end acutely projected. Proximal surface smooth, very flat and nearly semicircular in proximal view with almost straight aft and curved fore margins. Distal surface very narrow and much convex distalward.

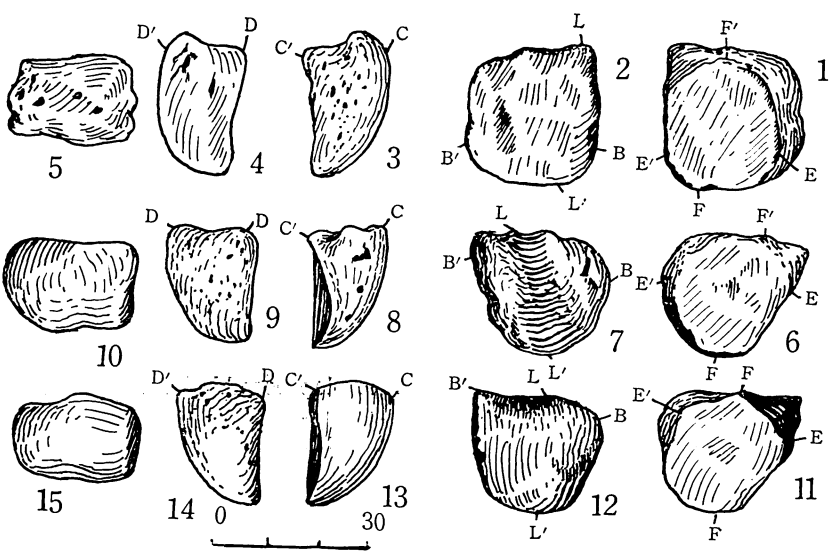
Table 11. Measurements of distal phalanges (pes).

R: Right. L: Left.

	Izumi		Keton
	IV	V	V
	R	R	L
Maximum length as preserved (LL′)	42	27	56
Maximum transverse width of proximal end (BB′)	52±	41	42
Ditto of distal end (EE′)	—	42	49
Minimum transverse width of shaft (KK′)	—	—	44
Maximum thickness of proximal end (CC′)	18	14	24
Ditto of distal end (GG′)	9	9	11

10. Sesamoid of Metatarsus

(Textfig. 101)



Textfig. 101. Sesamoid bones of right metatarsus of Izumi. 1-5, Inner bone of third metatarsus (NSMT-P-5601-63); 6-10, Outer bone of ditto (NSMT-P-5601-64); 11-15, Outer bone of fourth metatarsus (NSMT-P-5601-65). 1, 6, 11, Fore side; 2, 7, 12, Aft side; 3, 8, 13, Inner side; 4, 9, 14, Outer side; 5, Proximal side (fore side is in upper); 10, 15, Distal side (fore side is in upper).

In Izumi skeleton three sesamoid bones (bones no. 10 and no. 11) are preserved together with right third and fourth metatarsi; two bones nos. 10 and 11 are attached to median aft surface of third metatarsus and one bone (bone b) is attached to aft surface of fourth metatarsus. Bone no. 10 is outer bone and no. 11 is inner bone, also bone b is inner one. They are in fine preservation.

10A. Inner Bone on Third Metatarsus (NSMT-P-5601-63)

(Pl. 7, Figs. 24, 25, Pl. 9, Figs. 34-39, Textfig. 101)

Bone (no. 11) is small sized, solid and pentahedral. In posterior view, it is subquadrate, longer than broad, with almost straight outer and proximal margins; distal margin moderately curved; exterior proximal corner rather acutely projected while interior proximal rather obtuse. Posterior surface of it a little depressed. In lateral views bone triangular with long and moderately curved posterior margin; proximal margin recuved, posterior proximal corner projected proximally and distal corner rather acute. Inner surface nearly flat with posterior proximal foramen of irregular shape; outer surface very rugose with many distinct foramens.

Anterior surface corresponds to posterior surface in general outline; facet for metatarsus subcircular, a little longer than broad proximodistally and very smooth, weakly depressed. It articulates with inner half of posterior side of condyle. Proximal surface elongate quadrate with long transverse axis; posterior and anterior margins almost straight; they are parallel with each other; inner and outer margins short, straight, parallel with each other and vertical to interior margin. Distal surface with several small foramens; median portion moderately depressed. Proximal surface also quadrate in outline, shorter in transverse length than distal one; the surface rather rugose.

10B. Outer Bone on Third Metatarsus (NSMT-P-5601-64)

(Pl. 7, Figs. 24, 25, Pl. 9, Figs. 28-33, Textfig. 101)

Bone (no. 10) also small, solid and pentahedral. In posterior view, it is subtriangular with almost straight inner margin; proximal margin concave proximally and outer margin distinctly curved; distal margin convex distally. Posterior surface rugose and median longitudinal portion of it depressed. In lateral views, bone triangular with gently curved posterior margin; exterior proximal and interior fore margin recurved, while exterior fore margin straight, the last of which is vertical to exterior proximal margin. Distal and both interior fore and exterior fore corners acute. Outer surface flat and rather smooth with interior proximal foramen of moderate size. Inner surface rather rugose and convex. Anterior side corresponds to posterior one in outline; facet for metatarsus very smooth, a little depressed and subcircular in outline; it articulates with outer half of posterior side of condyle. Proximal and distal sides quadrate with longer transverse axis; fore and aft margins long and parallel with each other; the latter undulated and inner margin strongly curved. Proximal surface more rugose than distal one.

10C. Outer Bone on Fourth Metatarsus (NSMT-P-5601-65)

(Pl. 9, Figs. 22-27, Textfig. 101)

Bone (b) small in size, solid, pentahedral and rather like bone no. 10 in outline. In posterior view, it is subtriangular with long and gently curved inner margin; proximal margin slightly recurved; interior distal corner acutely projected inward; distal margin eminently curved; aft surface rather rugose and uneven. In lateral view bone elongate trigonal with long and eminently curved posterior margin; proximal margin slightly curved, interior fore margin recurved and exterior fore margin almost straight and vertical to proximal margin; distal and both interior fore and exterior fore corners acute. Inner surface rather smooth and flat, while outer surface rugose with many small foramens. Anterior side corresponds to posterior one in outline; facet for metatarsus very smooth, a little depressed and subcircular in outline; interior proximal corner projected; the facet articulates with outer half of posterior side of condyle. Proximal and distal sides quadrate with longer transverse axis and very much like those of bone no. 10; fore and aft margins long and parallel with each other; anterior distal margin a little convex forward and interior proximal margin a little concave forward. Proximal surface rugose with many distinct foramens. Distal surface rather smooth.

Table 12. Measurements of right sesamoid (metatarsus).

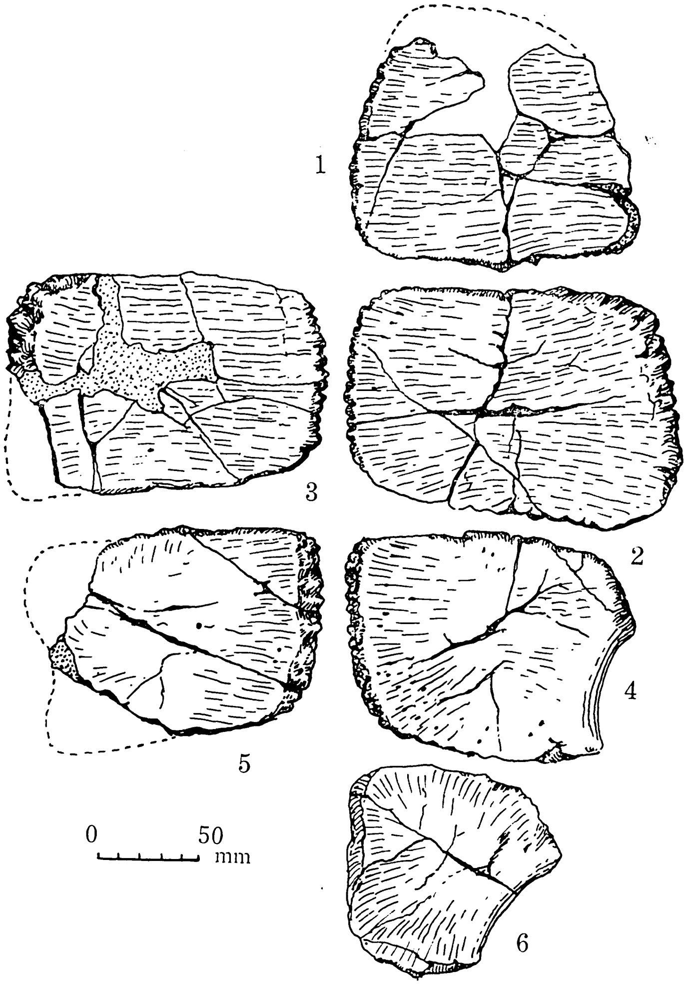
I: Inner. O: Outer.	III		IV
	I	O	O
Maximum length of aft surface (LL′)	30	28	28
Ditto of fore surface (FF′)	25	22	23
Maximum transverse width of aft surface (BB′)	26	27	26
Ditto of fore surface (EE′)	22	20	22
Anteroposterior thickness on outer surface (CC′)	17	20	18
Ditto on inner surface (DD′)	22	20	18

C. Sternum

(Textfigs. 102-107)

In Keton skeleton, at a dorsal side of sacrum there were found eight platy bones in four pairs. These paired bones are unequilateral but symmetrical with each other to a median longitudinal line. They are neither confluent nor sutured with, but entirely separated from each other. Also from a point of pelvic girdle a platy bone was found, which seems to be jointed with the eight bones. These four paired and one platy bones recall a plastron of Chelonia but are clearly distinct from it by absence of suture and sulcus.

In Izumi skeleton, six platy bones were also preserved in section 6. In outline they correspond well with those of Keton; two paired and two isolated bones compose four paired bones. These paired platy bones are unique in character, but may be safely regarded as sternum. At first NAGAO thought the possibility of these



Textfig. 102. Sternum of Izumi (NSMT-P-5601-66-71). Dorsal side. 1, Right praesternum ; 2, Right first mesosternum ; 3, Left first mesosternum ; 4, Right second mesosternum ; 5, Left second mesorternum ; 6, Right first xiphisternum.

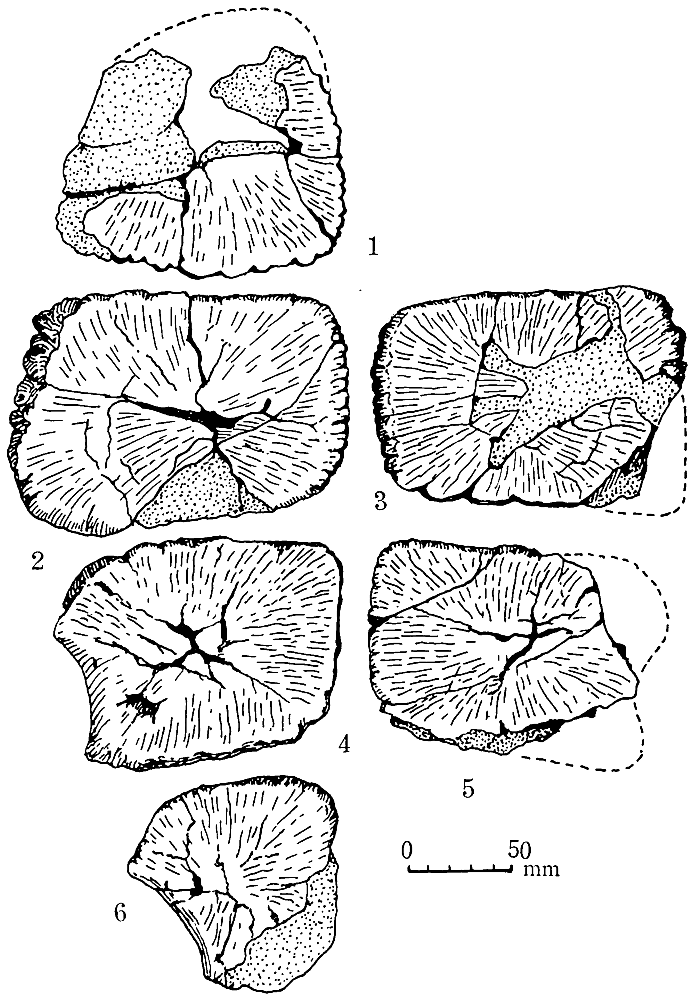
bones belonging to some animal other than desmostylid, but later he was inclined to regard them as sternum. This was confirmed by the second occurrence of Izumi bones. All bones are preserved in Keton, while in Izumi first right, second right and left, third right and left and fourth right bones are preserved. They are all slightly convex ventralward and carry smooth surface and tuberculated marginal borders.

1. Praesternum

a. Izumi (NSMT-P-5601-66)

(Pl. 11, Figs. 1, 2, Pl. 12, Figs. 1-3, Textfigs. 102-104)

Represented by a right bone which is broken in its anterior outer portion of ventral side and in anterior portion of dorsal side. In dorsoventral views, bone subquadrate as preserved, but it may be trigonal in original outline, inner and posterior margins straight and vertical to each other; posterior outer corner thicker than the other two. Surface smooth and flat, with many minute striations which run transversally on dorsal side and radially on ventral side. In posterior view, bone curved at middle, becoming gradually thicker outward. Inner and posterior surface very rugose with many dense tubercles.

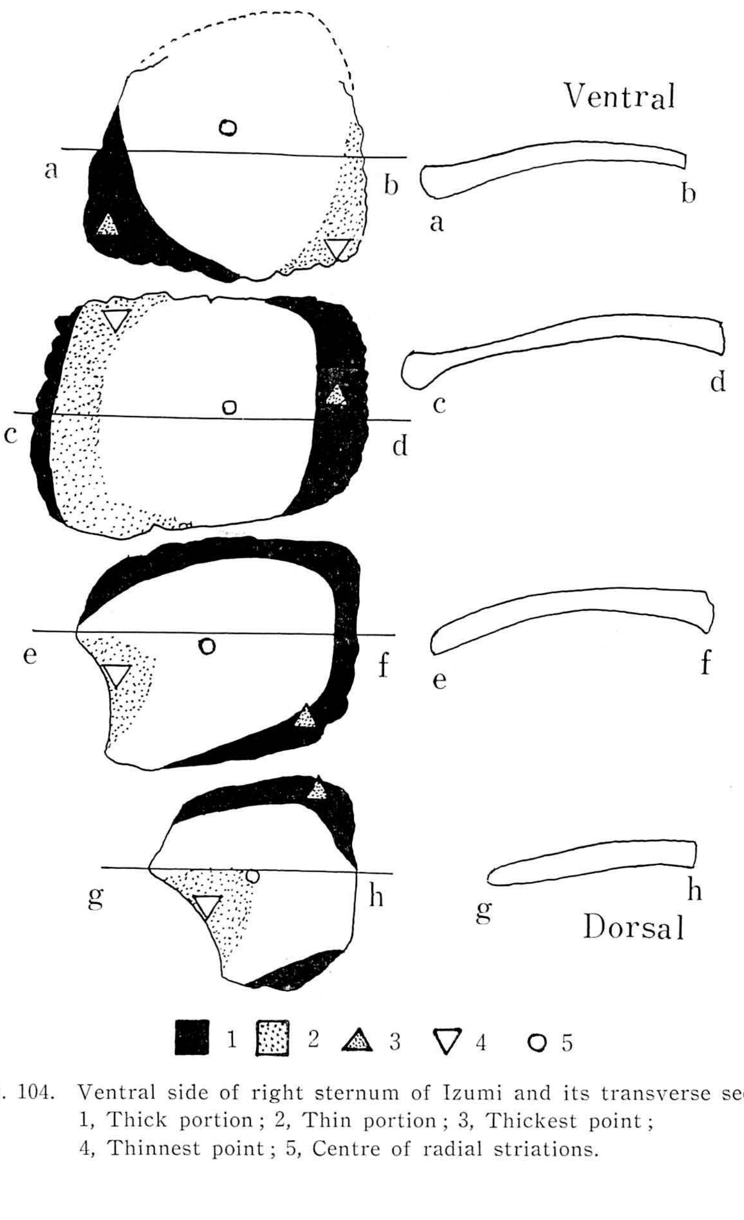


Textfig. 103. Sternum of Izumi (NSMT-P-5601-66-71). Ventral side. 1, Right praesternum; 2, Right first mesosternum; 3, Left first mesosternum; 4, Right second mesosternum; 5, Left second mesosternum; 6, Right first xiphisternum.

b. Keton (UHR no 18466-46, 47)

(Textfigs. 105-107)

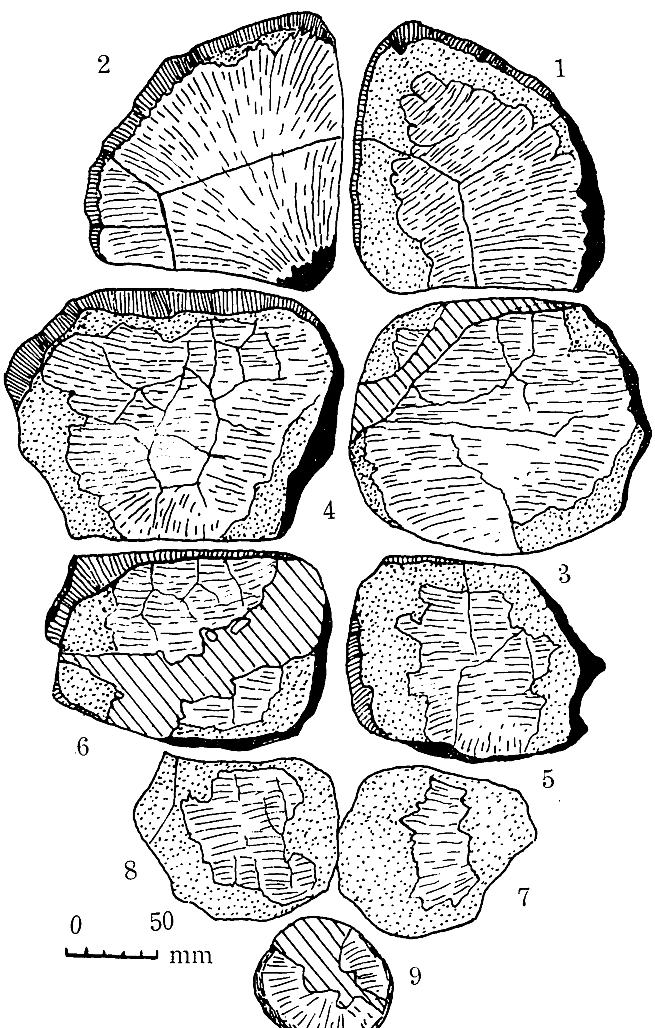
Right (UHR no 18466-46) and left bones (UHR no 18466-47) are well preserved although damaged on marginal portion of ventral side, inner and fore portion of dorsal side in right bone, and on marginal portion of ventral side in left bone. In dorsoventral view, bone subtrigonal with long and moderately curved outer margin; inner margin almost straight and posterior margin moderately recurved; posterior inner corner distinctly truncated. Three corners thicker than marginal portion and posterior inner corner thickest, about 31 mm in right and 26 mm in left, while



Textfig. 104. Ventral side of right sternum of Izumi and its transverse sections. 1, Thick portion; 2, Thin portion; 3, Thickest point; 4, Thinnest point; 5, Centre of radial striations.

median portion of aft margin thinnest. Surface smooth and flat, with many minute striations running transversally on dorsal side and radially on ventral side. Peripheral side unknown being covered by matrix.

Left bone is a little narrower transversally and longer anteroposteriorly compared with right bone. Inner margin is more straight in right bone, and posterior inner corner not so much truncated as in right, perhaps due to preservation. Posterior margin is straight in Izumi bone and recurved in Keton. Median portion of it is thinnest in Keton but not thin in Izumi bone. Keton bone has its thickest portion on its posterior inner corner, but Izumi bone becomes thicker outward. These differences are due not to deformation but to original characters.



Textfig. 105. Sternum of Keton (UHR no 18466-45-54). Dorsal side. 1, Right praesternum; 2, Left praesternum; 3, Right first mesosternum; 4, Left first mesosternum; 5, Right second mesosternum; 6, Left second mesosternum; 7, Right first xiphisternum; 8, Left first xiphisternum; 9, Second xiphisternum.

2. First Mesosternum

a. Izumi (NSMT-P-5601-67, 68)

(Pl. 11, Figs. 3-5, Pl. 12, Figs. 4-9, Textfigs. 102-104)

Right bone (NSMT-P-5601-67) is damaged on its median posterior portion of ventral side, while left bone (NSMT-P-5601-68) is damaged on its median outer portion of ventral side and median inner portion of dorsal side. In dorsoventral views, bone quadrate with long and transverse axis; anterior and posterior margins straight and slightly oblique to each other; inner margin shortest and slightly curved; interior fore and interior aft corners obtusely curved in right bone, while interior aft corner broken in left bone. Bone becomes thicker outward and anterior inner corner thickest, while anterior outer corner thinnest. Surface smooth and flat, with many minute striations running transversally on dorsal side and radially on ventral side. Posterior outer corner of ventral side carries a transverse depression. In posterior view, dorsal margin slightly curved than ventral one and outer border thickest. In anterior view, dorsal and ventral margins curved in the same degree. All marginal surfaces very rugose, with many dense tubercles which are especially well developed at inner and outer borders.

b. Keton (UHR no 18466-48, 49)

(Textfigs. 105-107)

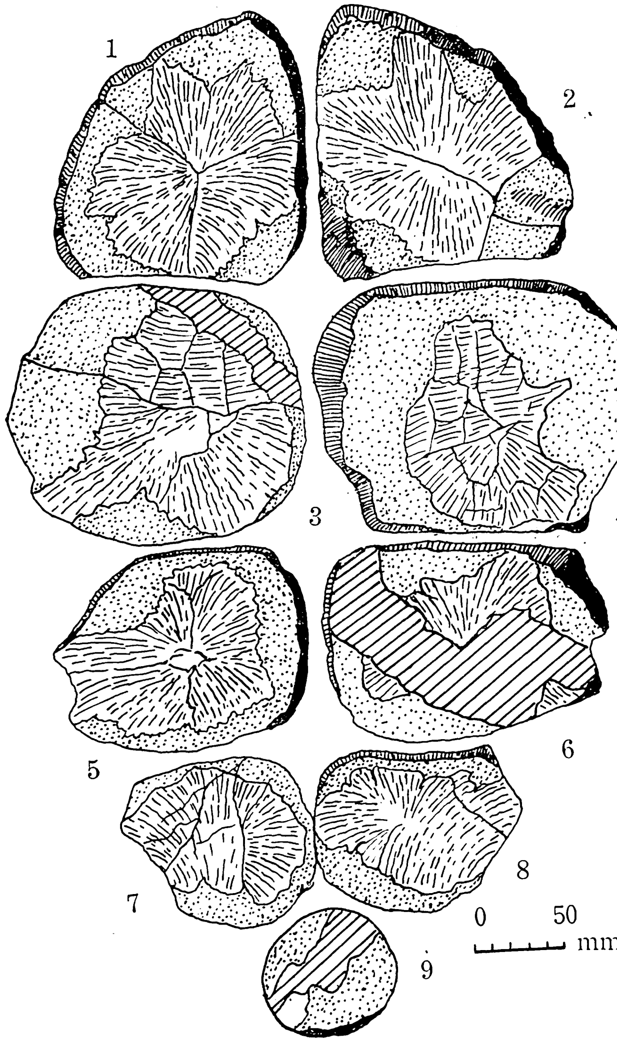
Right bone (UHR no 18466-48) is damaged on its interior fore portion of ventral and dorsal sides, and broken on its outer border. Left bone (UHR no 18466-49) is undamaged on its dorsal surface but broken in its interior aft corner. In dorsoventral views, left bone subquadrate with long and paralleled fore and aft margins but right bone suboval with long transverse axis and fore corners of interior fore-&-aft and exterior fore-&-aft gently curved. Posterior outer corner thinnest and anterior outer corner thickest, 28 mm in right and 24 mm in left. Surfaces smooth and flat, with many minute striations running transversally on dorsal side and radially on ventral side. Ventral surface of left bone damaged on its marginal portion. In posterior view, bone relatively thin and gently curved and ventralward in left bone; in right bone both margins strongly curved interiorly, probably due to deformation by pressure.

General outlines of Izumi and Keton bones are rather like each other, and curvature of platy bone does not differ so much from each other. Left bone of Keton is much longer ($\times 1.5$) and wider ($\times 1.83$) than that of Izumi.

3. Second Mesosternum

a. Izumi (NSMT-P-5601-69, 70)

(Pl. 11, Figs. 9-11, Pl. 12, Figs. 10-14, Textfigs. 102-104)



Textfig. 106. Sternum of Keton (UHR no 18466-45-54). Ventral side. 1, Right praesternum ; 2, Left praesternum ; 3, Right first mesosternum ; 4, Left fitst mesosternum ; 5, Right second mesosternum ; 6, Left second mesosterm ; 7, Right first xiphisternum ; 8, Left first xiphisternum ; 9, Second xiphisternum.

Right bone (NSMT-P-5601-69) is in fine preservation and left one (NSMT-P-5601-70) is broken in its outer portion. In dorsoventral views, bone quadrate with long transverse axis ; anterior and posterior margins long, straight and parallel with each other ; inner margin also straight and vertical to anterior margin. Anterior outer corner eminently projected and posterior half of outer margin recurved, centre of which is thinnest of all margins ; posterior inner corner thickest. Surface smooth and flat, with many minute striations which runs transversally on dorsal side and radially on ventral side ; several cracks distinct due to pressure in bed. Exterior ventral surface much sloped down outward and exterior dorsal margin has a sharp edge. Anterior, posterior and interior surfaces very rugose with many dense tubercles. Posterior of exterior surface smooth. In posterior view, dorsal margin concave dorsalward and ventral margin almost straight.

b. Keton (UHR no 18466-50, 51)

(Textfigs. 105-107)

Right bone (UHR) no 18466-50) is broken in its outer half of fore and aft borders, while left bone (UHR no 18466-51) is broken in its posterior outer corner and its surfaces of dorsal and ventral sides are much damaged; marginal portion of both dorsal and ventral sides of right bone is also damaged. Bone in dorsoventral view subquadrate with short and recurved outer margin. Inner margin of right bone more strongly curved than that of left bone; fore and aft margins of left bone long, straight and parallel with each other. Posterior inner corner thickest and median portion of outer margin thinnest of all margins. Inner margin almost as thick anteriorly as posteriorly. Surface smooth and flat with many minute striations running transversally on dorsal side and radially on ventral side. Shallow valley like depression runs from centre of ventral side of right bone to its median outer margin. In posterior view of left bone, dorsal and ventral margins gently curved and concave dorsalward but outer half of ventral margin a little undulated. Median portion of both margins in right bone strongly bent.

Keton bone is much longer ($\times 1.48$) and wider ($\times 1.39$) than Izumi bone. In both bones, thickest point lies at posterior inner corner and thinnest one at median outer margin. In Keton bone median portion of outer margin is truncated, but in Izumi bone posterior outer margin is truncated.

4. First Xiphisternum

a. Izumi (NSMT-P-5601-71)

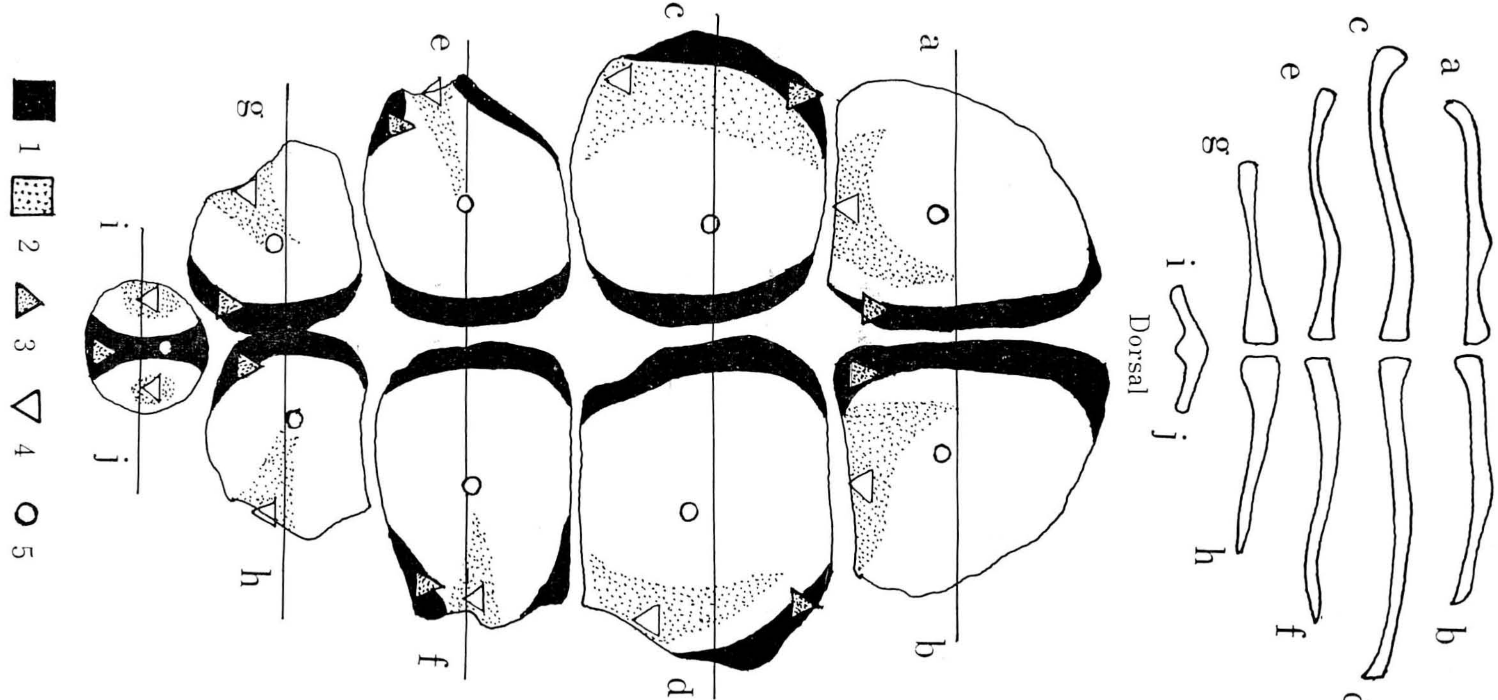
(Pl. 11, Figs. 15-17, Pl. 12, Figs. 15, 16, Textfigs. 102-104)

Represented by a right bone which is much damaged on its posterior inner portion of ventral side. In dorsoventral views, bone subquadrate with moderately curved anterior and gently recurved outer margins; median to outer half of the former tolerably projected anteriorly; inner margin straight and almost vertical to fore margin. Anterior inner corner thickest and posterior outer corner thinnest. Outer margin sharply crested especially at dorsal side. Surface smooth and flat with many minute striations running radially on both sides. Anterior surface very rugose with many dense tubercles.

b. Keton (UHR no 18466-52, 53)

(Textfigs. 105-107)

Right bone (UHR no 18466-52) is broken in its posterior outer portion. Marginal borders of both dorsal and ventral sides are much damaged in right and left bones. In dorsoventral view, bone subpentagonal with long transverse axis; anterior



Textfig. 107. Ventral side of Keton sternum and its transverse sections.
1, Thick portion ; 2, Thin portion ; 3, Thickest point ; 4, Thinnest point ; 5, Centre of radial striations.

margin longest, straight and parallel with straight posterior margin; inner margin tolerably convex inward; anterior outer margin almost straight, while posterior outer one recurved and thinnest of all margins; posterior inner corner thickest, 30 mm thick in right and left bones. Surface smooth and flat with many minute striations which runs transversally on dorsal and radially on ventral sides. In posterior view, bone thinnest at its middle of outer half; ventral margin more strongly curved than dorsal which concave dorsalward; posterior surface rugose.

Keton bone of left side (UHR no 18466-53) is a little longer (×1.12) and wider (×1.23) than Izumi bone. It is relatively longer transversally than Izumi bone.

5. Second Xiphisternum

(Textfigs. 105-107)

Represented by a Keton bone (UHR no 18466-54) which is unbroken but damaged on median anterior portion of both surfaces. In dorsoventral view, bone is circular with median longitudinal crest of ventral side which is thickest especially at its posterior end, about 18 mm. From the crest surface of ventral side slopes laterally and lateral margin flared. Dorsal side depressed like a shallow basin. Dorsal surface carries many minute striations running radially. In posterior view bone is subcrescentic with both lateral ends which are obtuse. Central portion of both lateral hemicycles thinnest.

Table 13. Measurements of sternum (Izumi).

R: Right. L: Left.	Praesternum	Mesosternum 1		Mesosternum 2		Xiphisternum
	R	R	L	R	L	R
Maximum transverse length (LL′)	140	115	110	99	98	75
Maximum fore-&-aft width (AA′)	74+	81	73+	77	71	73
Thickness in middle of proximal border (BB′)	14	28	26	22	22	24±
Ditto of distal border (CC′)	—	16	16	17	—	19

Table 14. Measurements of sternum (Keton).

R: Right. L: Left.	Praesternum		Mesosternum 1		Mesosternum 2		Xiphisternum 1		Xiphisternum 2
	R	L	R	L	R	L	R	L	
Maximum transverse length (LL′)	139	134	163	165	146	146	108	110	99
Maximum fore-&-aft width (AA′)	140	144	131	134	104	99	81	88	89±
Thickness in the middle of proximal border (BB′)	11	16	21	19±	22+	25	28	26	13±*
Ditto of distal border (CC′)	12	12	17	20	9	10	10	11	10**

* Measured at centre of median line.

** Measured at left border.

VI. Characteristics of Skeletons

A. Comparison between Izumi and Keton Skeletons

When we compare the Izumi and Keton skeletons, we face the inevitable phenomena of deformation by pressure of bed seen in the Keton skeleton. Its humerus compressed anteroposteriorly and ulna, radius, femur and tibia are compressed laterally. Because the Keton skeleton is preserved largely in its half side of each element, the difference of deformation degree between right and left sides is almost unknown. It is certainly deduced that some degrees of deformation occurred in each element of Keton skeleton, when we see the existence of cracks, cleavages, unnatural outline of bone, abnormal shape of transverse section of it, abrupt change of gentle curvature or bent of bone, etc. It may be said that deformation is relatively small in a solid bone of small size like bones of manus and pes. To obtain an accurate original outline of bones from deformed fossil bones is exceedingly difficult, so that the true anatomical characteristics of the Keton skeleton is rather obscure compared with that of Izumi.

Next the Keton skeleton is a little larger than the Izumi skeleton which indicates a young mature animal because epiphysis is not completely fused with shaft of long bones; on the contrary the Keton animal may be a full adult. The Izumi animal may be female when judged from poor development of canine or large size of pelvis (os coxae). Each element of the Keton skeleton is larger than that of the Izumi skeleton as follows:

Table 15. Comparison of bone sizes between the Izumi and Keton skeletons.

Humerus	×1.05 longer (originally ×1.15±), ×2.27 wider at middle of shaft, ×1.4 wider at distal portion (maximum lateral width)
Ulna	×1.01 longer
Olecranon of ulna	×1.63 wider anteroposteriorly at upper, ×1.33 wider at middle
Radius	×1.09 longer
Lunar	×1.27 higher, ×1.29 wider
Cuneiform	×1.48 higher, ×1.44 wider
Magnum	×1.4 longer, ×0.85 lower
Trapezoid	×1.42 longer, ×0.9 lower, ×1.42 wider
Second proximal phalange (manus)	×1.3 longer
Third proximal phalange (manus)	×1.27 longer, ×1.02 wider (proximal)
Fifth proximal phalange (manus)	×1.64 longer, ×1.35 wider
Second middle phalange (manus)	×1.24 longer, ×1.22 wider
Third middle phalange (manus)	×1.09 longer, ×1.09 wider
Fourth middle phalange (manus)	×1.17 longer, ×1.27 wider
Third distal phalange (manus)	×1.48 longer, ×0.85 narrower
Fourth distal phalange (manus)	×0.95 shorter, ×1.04 wider

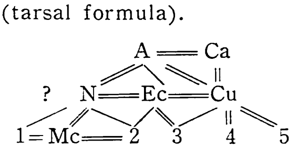
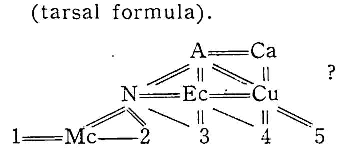
Femur (right)	×1.01 longer, 1.47 wider at middle
Ditto (left)	×0.98 shorter, ×1.22 wider at middle
Ectocuneiform	×1.3 higher, ×1.57 wider transversally
Third metatarsus	×1.27 longer, ×1.26 wider
Fourth metatarsus	×1.7 longer, ×1.1 wider
Second proximal phalange (pes)	×1.24 longer, ×1.44 wider
Third proximal phalange (pes)	×1.5 longer
Fourth proximal phalange (pes)	×1.31 wider
Fifth proximal phalange (pes)	×1.6 longer, ×1.4 wider
Third middle phalange (pes)	×1.1 longer
Fourth middle phalange (pes)	×1.1 longer, ×1.34 wider
Fifth middle phalange (pes)	×1.5 longer
Right praesternum	×0.99 narrower laterally
Right first mesosternum	×1.41 longer laterally, ×1.61 wider anteroposteriorly
Right second mesosternum	×1.47 longer laterally, ×1.35 wider anteroposteriorly
Right first xiphisternum	×1.44 longer laterally, ×1.11 wider anteroposteriorly

Long bones of large size as humerus or femur are nearly of the same size between the two skeletons, but solid bones of phalanges are relatively larger in Keton than in Izumi. Fourth metatarsus, fifth proximal phalange of manus, third and fifth proximal phalange of pes, and fifth middle phalange of pes are 1.5 or more times longer in the former than in the latter. Meso- and xiphisternum are also much longer laterally. Perhaps it may be said that digital bones and sternum are better developed in Keton than in Izumi, suggesting size development of growth and anatomical characteristic of anagenetic osteosis existing in the former.

As far as visible outline of bone is concerned, comparison between the both skeletons follows.

Table 16. Comparison of bone outline between the Izumi and Keton skeletons.

	Izumi	Keton
Humerus	1. Major tubercle large and wide anteroposteriorly. 2. Inner tubercle eminent. 3. Outer tubercle projects upward. 4. Ectocondylar ridge sharp. 5. No supratrochlea foramen. 6. Shaft relatively long anf flat laterally.	1. Major tubercle small and narrow anteroposteriorly. 2. Inner tubercle obsolete. 3. External condyle compressed and wider anteroposteriorly. 4. Ectocondylar ridge eminent. 5. Supratrochlea foramen visible. 6. Deformed by pressure.
Ulna	1. Axis of shaft makes an angle of 18° with that of olecranon. 2. Styloid process large and distinctly projected distalward. 3. Shaft relatively straight and not becoming narrower distally.	1. Axis of shaft makes an angl of 60° with that of olecranon. 2. Styloid process not so large and poor in projection. 3. Shaft curved and compressed laterally.
Radius	1. Relatively short and wide. 2. Short axis of head/long axis of ditto: 0.48. 3. Proximal end convex upward.	1. Deformed by pressure. 2. Short axis of head/long axis of ditto: 0.88. 3. Distal portion not so large as in Izumi.

Carpus	1. Upper series (scaphoid, lunar and cuneiform) higher than lower series (unciform, magnum, trapezoid and trapezium). 2. Lunar>scaphoid>cuneiform>unciform>magnum>trapezoid. 3. Scaphoid low and quadrate in fore view with longer lateral axis. 4. LL′/BB′ of lunar: 1.04. 5. Exterior proximal corner of lunar distinctly projected upward in fore view. 6. Height/transverse width on fore side of cuneiform: 0.46. 7. Interior proximal corner of fore side of cuneiform projected upward. 8. No median groove on outer surface of magnum. 9. United height of lunar and magnum: 78 mm. 10. Height of scaphoid and lunar smaller than that of Keton. 11. Height of magnum and trapezoid larger than that of Keton.	1. Upper series higher than lower series. 2. Lunar>scaphoid>cuneiform>unciform>magnum>trapezoid. 3. Scaphoid high and quadrate in fore view with longer vertical axis. 4. LL′/BB′ of lunar: 1.06. 5. Projection of exterior proximal corner of lunar not so distinct as in fore view. 6. Height/transverse width on fore side of cuneiform: 0.47. 7. Interior proximal corner of fore side of cuneiform not so much projected as in Izumi. 8. Distinct median groove on outer surface of magnum. 9. United height of lunar and magnum: 91 mm. 10. Height of scaphoid and lunar larger than that of Izumi. 11. Height of magnum and trapezoid smaller than that of Izumi.
Phalanges of manus	1. Second middle phalange projected inward. 2. Third distal phalange wider than high, semicircular in fore view. 3. Fourth distal phalange wider than high, subtrigonal in fore view and higher interiorly than exteriorly. 4. BB′/LL′ of third proximal phalange: 0.92. Ditto of fifth proximal: 0.80. Ditto of second middle: 0.79. Ditto of third middle: 0.91. Ditto of fourth middle: 0.85. Ditto of third distal: 1.52. Ditto of fourth distal: 1.21. 5. Proximal phalanges relatively shorter than in Keton. 6. Third and fourth middle phalanges relatively longer than in Keton.	1. Second middle phalange projected outward. 2. Third distal phalange narrow and high, irregularly trigonal in fore view and concave outward. 3. Fourth distal phalange wider than high, subtrigonal in fore view and higher exteriorly than interiorly. 4. BB′/LL′ of second proximal phalange: 0.74. Ditto of fifth proximal: 0.72. Ditto of second middle: 0.77. Ditto of third middle: 0.93. Ditto of fourth middle: 0.98. Ditto of third distal: 1.08. Ditto of fourth distal: 1.33. 5. Proximal phalanges relatively longer than in Izumi. 6. Third and fourth middle phalanges relatively shorter than in Izumi.
Femur	1. Shaft relatively straight. 2. Small trochanter distinct. 3. LL′/EE′ of right bone: 6.38. 4. Transverse width of condyle (DD′): 122 mm (right) and 118 mm (left).	1. Shaft wider than in Izumi. 2. Small trochanter obsolete. 3. LL′/EE′ of right bone: 4.42. 4. Transverse width of condyle (DD′): 119 mm (right) and 116 mm (left).
	1. Combination of tarsal bones (tarsal formula). 	1. Combination of tarsal bones (tarsal formula). 

Tarsus	2. Calcaneum with distinct deep and shallow fossae, proximal and distal ones of outer peronal facet for astragalus. 3. Astragalus in contact with ectocuneiform. 4. Cuboid very low and wide. 5. Ectocuneiform with sharp edge of relatively narrow transversally.	2. Calcaneum deformed. Shallow and deep fossae, proximal and distal ones of outer personal fact for astragalus obsolete. 3. Astragalus probably in contact with ectocuneiform. 4. Cuboid probably rather high and relatively narrow. 5. Ectocuneiform without sharp edge and relatively wide transversally.
Metatarsus	1. Fourth metatarsus longest of all metatarsi. 2. Metatarsus very short. Length of metatarsus/ditto of metacarpus: II 0.45, III 0.5, IV 0.56, V 0.26. 3. CC′/LL′ of third metatarsus: 0.74. Ditto of fourth one 0.68. 4. Condyle of third metatarsus strong. 5. Projection of proximal side of third metatarsus not so eminent as in Keton.	1. Fourth metatarsus longer than third metatarsus. 2. Metatarsus not so short as in Izumi. 3. CC′/LL′ of third metatarsus: 0.74. Ditto of fourth one: 0.53. 4. Condyle of third metatarsus stronger than in Izumi. 5. Proximal side of third metatarsus projected exteriorly and posteriorly.
Phalanges of pes	1. BB′/LL′ of second proximal phalange: 0.78. Ditto of fourth proximal: 0.78. Ditto of fifth proximal: 0.81. Ditto of third middle: 0.82. Ditto of fourth middle: 0.80. Ditto of fifth middle: 0.82. 2. Middle phalanges relatively longer than in Keton.	1. BB′/LL′ of second proximal phalange: 0.90. Ditto of fourth proximal: 0.92. Ditto of fifth proximal: 0.71. Ditto of third middle: 0.97. Ditto of fourth middle: 0.95. Ditto of fifth middle: 0.94. 2. Middle phalanges relatively shorter than in Izumi.
Sternum	1. Thickest portion lies in posterior inner of praesternum, median-inner of first mesosternum, median inner of second mesosternum, anterior inner of first xiphisternum. 2. AA′/LL′ of first mesosternum: 0.70. Ditto of second mesosternum: 0.78. Ditto of first xiphisternum: 0.97. 3. Meso- and xiphisternum relatively shorter transversally than in Keton.	1. Thickest portion lies in posterior outer of praesternum, anterior outer of first mesosternum, posterior outer of second mesosterm, posterior inner of first xiphisternum. 2. AA′/LL′ of first mesosternum: 0.80. Ditto of second mesosternum: 0.73. Ditto of first xiphisternum: 0.75. 3. Meso- and xiphisternum relatively longer transversally than in Izumi.

It may be noted that not any distinct difference of fundamental construction of skeleton exists between Izumi *Paleoparadoxia* and Keton *Desmostylus*. Probably they had a rather like appearance of body style.

B. Comparison with Other Groups

Here the writer is going to use the term of desmostylid for each of the Izumi *Paleoparadoxia* and Keton *Desmostylus*. The desmostylid is a rather large sized animal like a tapir or *Hippopotamus*. It is a quadriped terrestrial animal and not pure aquatic as Sirenia which are very distinct in postcranial skeleton from desmostylid. Probably the desmostylid has no claws but hoofs. In the stoutness of skeleton, the desmostylid is better developed than Hyracoidea or primitive Ungulata such as *Coryphodon*, *Astrapotherium* or *Anthracotherium*. On the other hand, it is less developed than pachydermate Ungulata, such as *Barylambda*, *Uintatherium*, Titanothere, *Hippopotamus*, *Toxodon*, or Proboscidea. Advanced Ungulata like *Camelus*, *Equus*, Cervid or Cavicornia carry more slender specialized limbs. Proboscidea are safely excluded from the affinities, as they have very different type of scapula and pelvis.

In the size of humerus, the desmostylid corresponds to *Diceros*. Straight shaft of humerus may be characteristic with its deltoid ridge unexpanded outward. *Rhinoceros* or *Hippopotamus* are distinct in this point, while *Tapirus* may be nearer. *Bubalus* and *Equus* have shorter humeri. Ulna is characterized by relatively short shaft with well developed styloid process. In size it is like that of *Bubalus*, smaller than that of *Diceros* and larger than that of *Hippopotamus*. Olecranon recalls that of *Hippopotamus* and general outline rather nearer to that of *Diceros*. Radius is relatively short, broad and with proximal end convex upward. It is of the *Diceros* type in size and outline.

Femur is characterized by straight shaft, flat condyle and ectocondyle unprojected anteriorly. *Bubalus* has larger and *Diceros* smaller femora. Disappearance of third trochanter recalls us those of *Hippopotamus* and *Bubalus*, and straight shaft is like those of *Bubalus* and *Tapirus*. Tibia is as large as that of *Tapirus*. It is not so long and slender as in *Bubalus* or *Equus*. Fibula is long, twisted, narrow and has expanded distal end. General outline is near that of tapir. Distal end is not so much expanded as in *Hippopotamus* but witout reduction as seen in *Bubalus* or *Equus*. Relative size with tibia is larger than in *Hippopotamus* or *Diceros* and corresponds with that of tapir.

The desmostylid has five digits anatomically and four digits functionally. *Paleoparadoxia* carries very short metatarsal bones, but in *Desmostylus* they are not so much differing in length from metacarpus. The first digit is rudimentary or disappeared. Phalanges are relatively short. Manus is plantigrade, timely semiplantigrade, while pes is plantigrade or semiplantigrade. Carpus has no centrum and tarsus no entocuneiform. Carpus and tarsus are relatively weak. The writer indicates the articulating relationship of carpal and tarsal bones by carpal and tarsal formulae. Direct and intimate articulation is indicated by = and unintimate one by—.

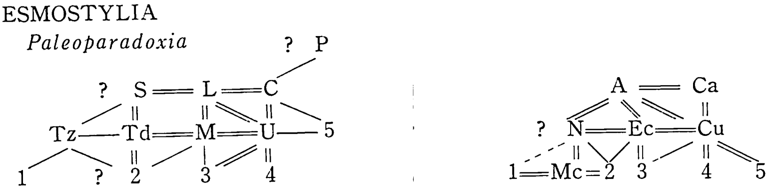
Table 17. Carpal and tarsal formulae of different groups.

S: Scaphoid, L: Lunar, C: Cuneiform, U: Unciform, M: Magnum, Td: Trapezoid, Tz: Trapezium, P: Pisiform, A: Astragalus, Ca: Calcaneum, Cu: Cuboid, N: Navicular, Ec: Ectocuneiform, Mc: Mesocuneiform, 1–5: First to fifth metacarpi or metatarsi.

Carpal formula	Tarsal formula

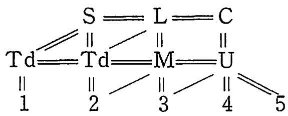
DESMOSTYLIA

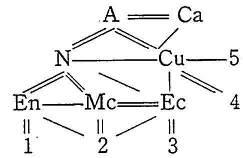
Paleoparadoxia



CONDYLARTHRA

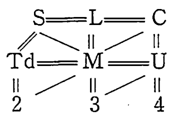
Phenacodus





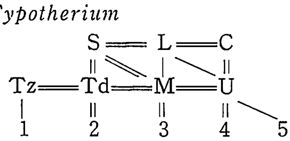
LITOPTERNA

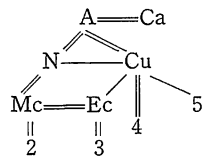
Macrauchenia



NOTOUNGULATA

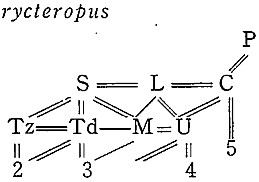
Typotherium

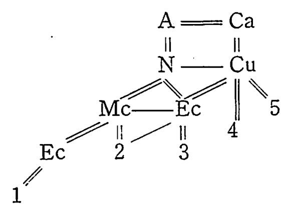




TUBLIDENTTA

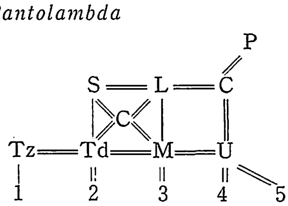
Orycteropus

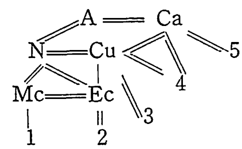




PANTONTA

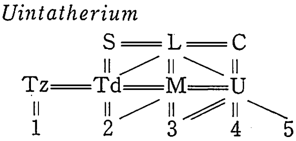
Pantolambda

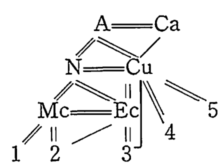




DINOCERATA

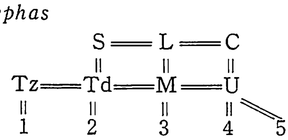
Uintatherium

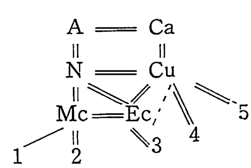




PROBOSCIDEA

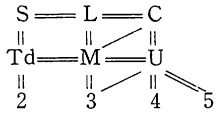
Elephas

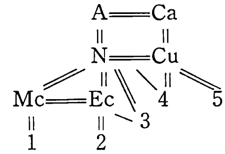




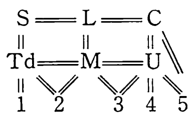
EMBRITHOPODA

Arsinotherium



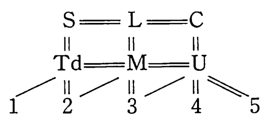


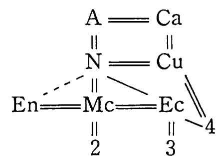
SIRENIA



HYRACOIDEA

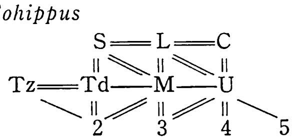
Procavia

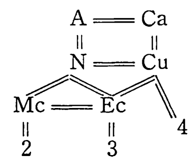




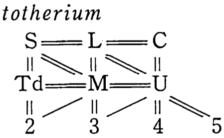
PERISSODACTYLA

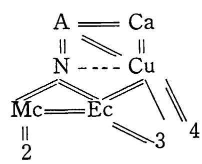
Eohippus



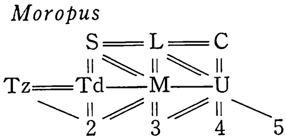


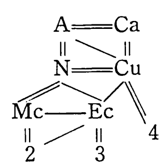
Brontotherium



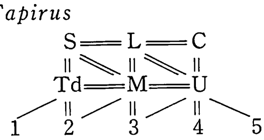


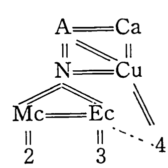
Moropus



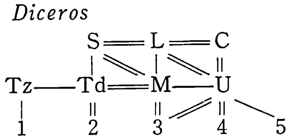


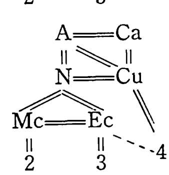
Tapirus

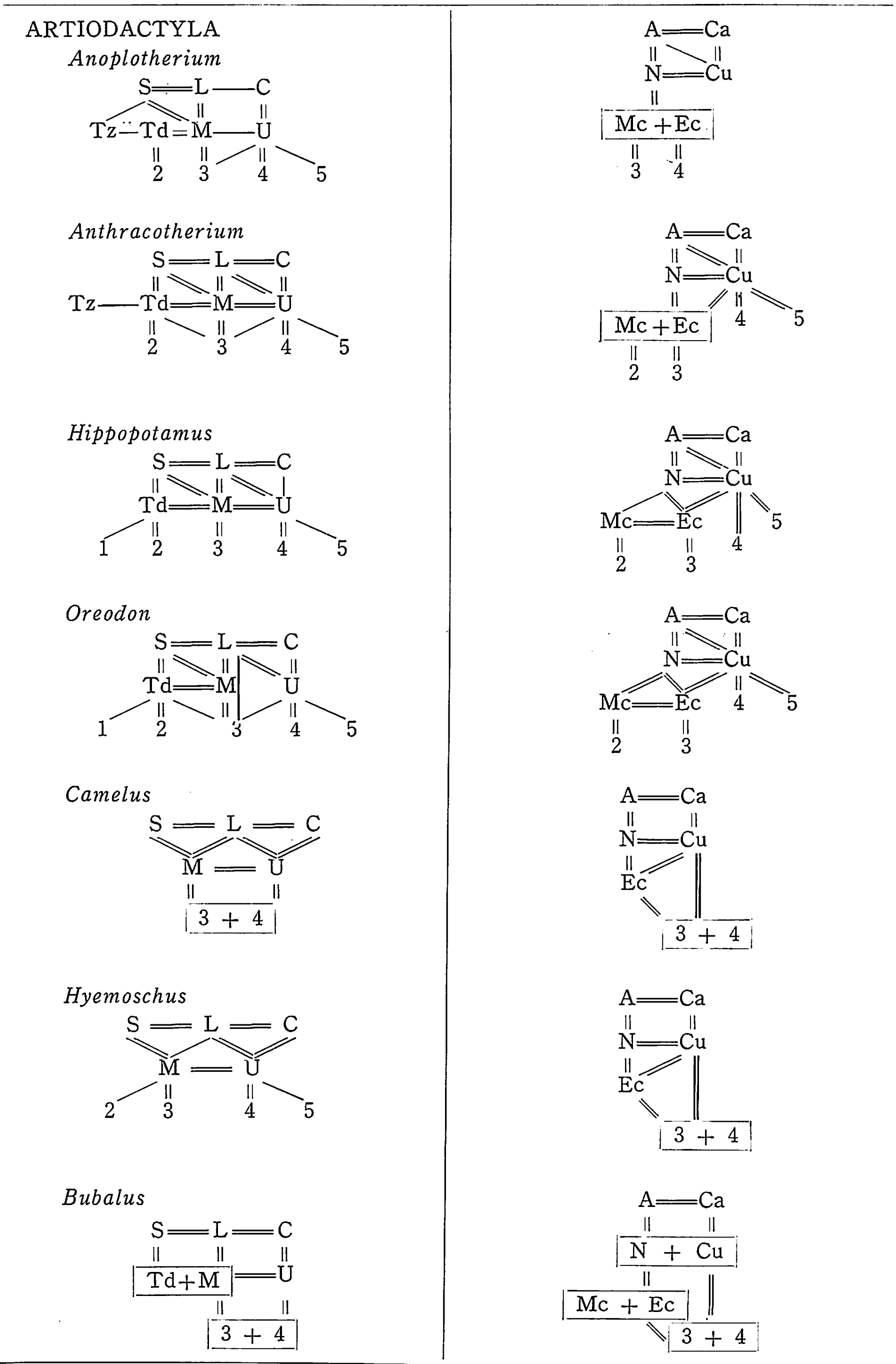




Diceros



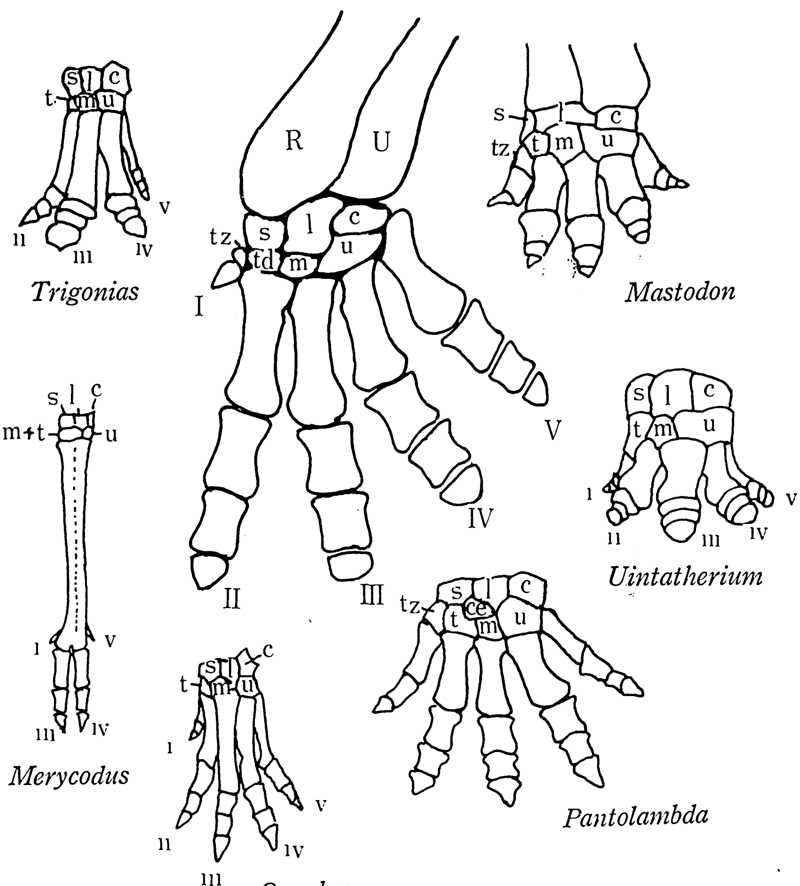




Confluent with each other.

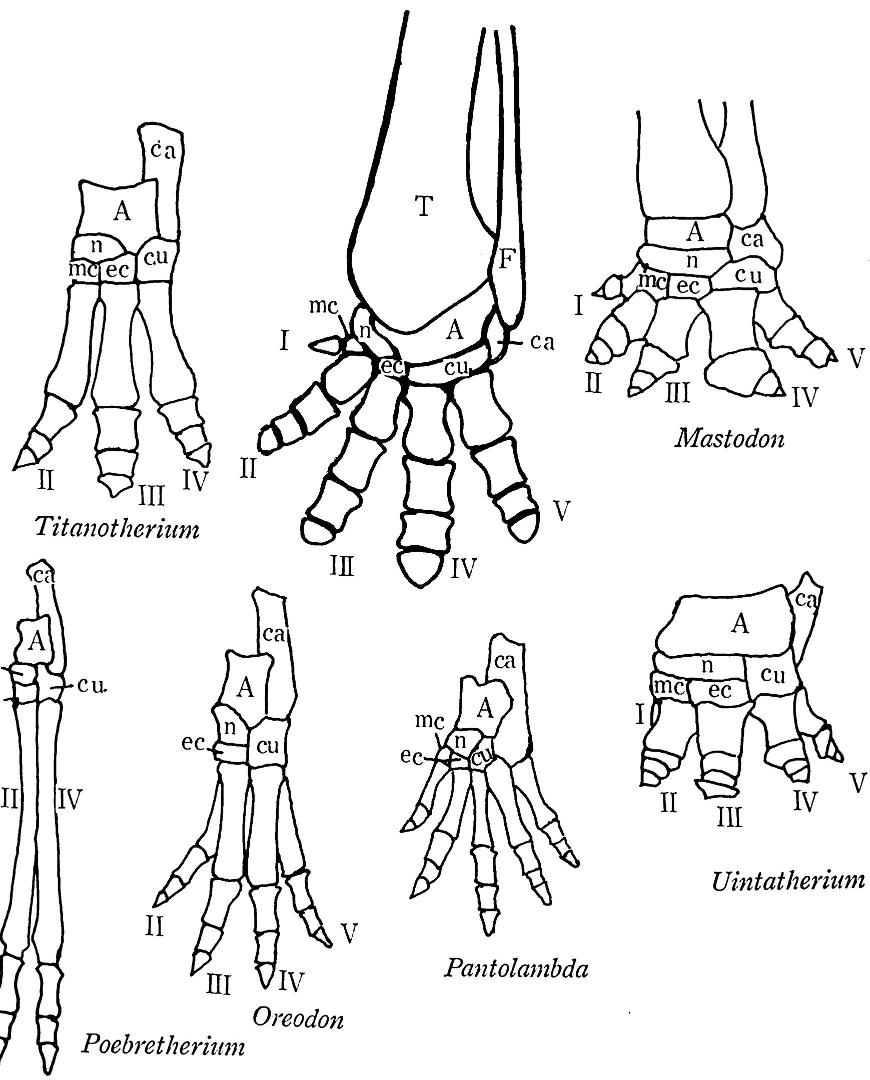
Carpal formula of desmostylid does not coincide perfectly with any formula of ungulate animals. In alternate articulation of metacarpi with lower series of carpus, Condylarthra, Litopterna, Dinocerata, Embrithopoda, Hyracoidea and Perissodactyla may be closer. In intimate articulation of lunar and unciform, Perissodactyla and Artiodactyla may be allied but they are very different by relationship between scaphoid and magnum. Their intimate articulation seen in every form of Perissodactyla and Artiodactyla is not seen in the desmostylid. No relationship between scaphoid and magnum is seen in Proboscidea and Condylarthra, also in Litopterna or Dinocerata it is rather weak. Advanced Artiodactyla is very distinct in reduction or confluency of bone elements. Carpal bones of the desmostylid are arranged in size order as follows: lunar>scaphoid>cuneiform>unciform>magnum>trapezoid (piciform is unknown in the present fossils in hand). In low scaphoid and cuneiform and platy unciform, Proboscidea and Embrithopoda may be related. In general, archaic Perissodactyla, Embrithopoda, Proboscidea, Astrapotheria, Dinocerata, some Notoungulata or Condylarthra are similar to the desmostylid in general outline of carpal bones.

Tarsal formula is also very unique. Navicular has no central role of tarsal



Textfig. 108. Manus of *Paleoparadoxia* in comparison with those of the other groups.

articulation. The desmostylid is very unique in that astragalus is in contact with ectocuneiform; in *Paleoparadoxia* ectocuneiform scarcely articulates with mesocuneiform. The separate situation of navicular and cuboid from one another is neither seen in large parts of ungulate animals; some titanothere may have such a situation. Also very peculiar is that metatarsus perhaps partially joints with navicular. Even if mesocuneiform exists, it does not articulate with ectocuneiform; in ungulated animal they are always articulated very intimately. Metatarsus articulates alternately with lower series of tarsus as in some titanothere, Proboscidea, Dinocerata and Condylarthra. Advanced Artiodactyla are clearly distinct in reduction or confluency of bone elements. Tarsal bones are arranged in size order as follows; astragalus>calcaneum>cuboid>navicular>mesocuneiform>ectocuneiform. Astragalus is relatively large and navicular is small compared with the other tarsal bones. In the



Textfig. 109. Pes of *Paleoparadoxia* in comparison with those of the other groups.

latter character, desmostylid may be near Dinocerata. The former is similar to proboscidea in relatively low cuboid. Relatively long calcaneum recalls us Condylarthra, Litopterna, Notoungulata, Hyracoidea, Perissodactyla or Artiodactyla instead of Proboscidea, Embrithopoda, Astrapotherium, Dinocerata or Pantodonta. Short metatarsus of *Paleoparadoxia* is like those of Condylarthra, Toxodonta, Pantodonta, Dinocerata, Embrithopoda or Proboscidea. The writer does not know the existence of paired large sized sternum bones of the desmostylid in ungulated animals. This is also unique character of the desmostylid.

Condylarthra are distinct by claws, plantigrade five digits, long caudal vertebrae, relatively stout and short femur, relatively large sized scapula and pattern of teeth, etc. In long calcaneum, short metatarsus, alternate jointing between phalanges and lower series of carpus or tarsus or separation of scaphoid and magnum, etc., it may be near desmostylid, but these are only partial coincidence of many elements.

Litopterna and Notoungulata are far distinct group of South America, by construction of teeth and skull, relatively large sized scapula, long ulna-radius and by long metatarsus, etc. *Astrapotherium* of South America is very different in teeth pattern and outline of scapula and pelvis. Plantigrade short digits and general outline of fore and aft limbs may be near desmostylid. Unbalanced development of fore and aft limbs of Astrapotheria is also like that of the desmostylid. Metacarpus is poorer in Astrapotheria than in it.

Pantodonta are very distinct by the pattern of teeth, outline of pelvis, rugose and stout limb bones, huge caudal vertebrae (*Barylambda*) and existence of centrum, etc. Weak development of carpus and tarsus, short digits of pes may be like, but these are not so important as the above mentioned characters or stout archaic style.

Dinocerata are clearly separated by very different type of teeth, skull, scapula, pelvis, humerus, ulna and femur, etc. Plantigrade short digits, alternate articulation of carpus and metacarpus or tarsus and metatarsus, weak jointing of scaphoid and magnum, small sized navicular, etc. may be like those in the desmostylid but these are also not so important as the above mentioned distinct characters.

Proboscidea may be near the desmostylid in some characters of teeth construction, but clearly distinct by perfectly distinct outline of scapula and pelvis, better developed and stout limb bones; humerus and ulna more rugose and femur is longer; calcaneum is shorter. Short plantigrade digits, separation of scaphoid and magnum, and low carpus and tarsus may be similar to those of the desmotylid, but these are also not so important as the above mentioned distinct characters. *Arsinotherium* is quite different in teeth, skull, scapula, humerus, ulna and short tibia and calcaneum, etc. Short plantigrade digits and low carpus and tarsus may be like, but those are also not so strong as to cancel the above mentioned characters. Hyracoidea are far distant from the desmostylid in teeth, skull, slender limb bones, long thoracic and pes, etc.

Advanced ruminant Artiodactyla are all excluded from comparison by its reduction and confluency of carpal, metacarpal, tarsal and metatarsal bones. With bunodont teeth and some characters of skull, Suina may be nearer to than it is. *Hippopotamus* may be cited as a related type of grapivportal, pachydermate and low shouldered animal, but it is distinct by relatively large sized skull, teeth construction, different outline of scapula and pelvis, relatively short humerus and tibia and long pes. *Hippopotamus* is quite distinct by intimate jointing between scaphoid and magnum or between navicular and cuboid, and by alternate jointing of carpus and metacarpus, or of tarsus and metatarsus, etc. *Anthracotherium* also has the same tendency and is far distant from the desmostylid by its cursorial slender manus and pes. Reduction and confluency already appeared in it.

Perissodactyla are noteworthy as a group which is most similar to the desmostylid in body style and construction; it is related in alternated jointing between carpus and metacarpus or between tarsus and metatarsus and in articulation of lunar and unciform, but clearly separated by teeth, close jointing of scaphoid and magnum, intimate articulation of navicular with cuboid, separation of metatarsus from navicular and by three functional digits of pes, etc. Chalicothere such as *Moropus* is firstly excluded from comparison by clows, high shoulder, more stout digits, etc. Advanced Equoidea are very distinct by reduced manus and pes, but archaic Equoidea are a little like in carpal formula and body style. Titanothere such as *Brontotherium* may be near the desmostylid in graviportal body style, unintimate articulation of navicular and cuboid, low carpal bones, relative length of four metacarpi and phalanges, outline of distal phalanges, etc., but it is distinct by outline of scapula, pelvis and relatively long metatarsus, etc. Of course the advanced form such as *Brontops* is far distinct by development of horn boss or stout construction of limb bones, but tne archaic form is generally more related. Tapiroidea are also rather related in body style, balance among each bones, outline of humerus, femur, tibia and fibula and calcaneum, etc. Carpal and tarsal formulae are like those of Titanothere. Rhinoceroidea are also more distinct than Tapiroidea by different outline of pelvis, more stout humerus, femur and tibia, etc. *Amynodon* may be near in body style, but its skull is relatively larger, tibia is shorter, and scapula is better developed besides the above mentioned distinct characters.

Be that as it may, desmostylid skeleton does not perfectly coincide with any of ungulated animals. Archaic Perissodactyla of Equoidea, Titanothere, Tapiroidea or very archaic group such as *Astrapotherium* or Pantodonta may be relatively near in some characters. Perhaps some of them may be attributed to analogy of same ecological habitant, but the ecological situation and function of the desmostylid is very unique, so that attribution of them to taxonomic character may be rather rational. Four digits of manus and pes (anatomically five digits) are very important when we are doing a taxonomic classification of the desmostylid. Third and fourth digits are not much longer than the other digits in manus of the desmostylid. Four digits of pes are also not much differentiated. In these points, Perissodactyla (Mesaxonia) and Artiodactyla (Paraxonia) are both not situated in an intimate relationship. Paenungulata may be a stock in which the desmostylid is included. There is no doubt that Pinnipedia are clearly excluded from comparison even though manus style is partially like each other. In ecological habit they may be near each other, but taxonomically they are quite distinct from each other.

C. General Characteristics

Desmostylian (*Desmostylus* and *Paleoparadoxia*) skeletons are summarized as follows.

1. Graviportal quadriped, amphibious and plantigrade to semiplantigrade.
2. Fore and aft digits five anatomically and four functionally.
3. Length and stoutness of four digits almost undifferentiated.
4. Without claws but with hoofs.
5. Body style like those of tapir, *Amynodon* or archaic titanothere such as *Dolichorhinus* except paddle like manus.
6. Shoulder about 112 cm high and body length from snout to tip of tail about 208 cm in juvenile animal of Izumi; shoulder not high compared with body length.
7. Cervic and caudal vertebrae relatively short.
8. Scapula and pelvis unstout.
9. Sternum consists of four paired platy large bones and an unpaired platy bone.
10. Metatarsus 0.26 to 0.56 long of metacarpus in *Paleoparadoxia*.
11. Metacarpus and metatarsus accompany sesamoid bones.
12. Carpus without centrum; trapezium and pisiform unpreserved and precisely unknown.
13. Tarsus without entocuneiform.
14. Alternate jointing exists between carpus and metacarpus and between tarsus and metatarsus.
15. Reduction and confluency do not occur in carpus, metacarpus, tarsus and metatarsus except first digit.
16. Carpus and tarsus relatively weak and low.
17. Calcaneum relatively long and large.
18. Astragalus not high with moderately developed median longitudinal groove of upper surface.
19. Scaphoid does not articulate with magnum; lunar closely articulates with unciform.
20. Navicular does not articulate with cuboid, but partially with metatarsus.
21. Astragalus joints with ectocuneiform; ecto- and mesocuneiforms do not articulate with each other.
22. Humerus straight with deltoid ridge unexpanded outward.
23. Ulna and radius short with distinct distal expansions; olecranon eminent and distal portion of ulna unreduced. Rotation of ulna and radius unoccurred.
24. Femur straight with flat condyle; ectocondyle unprojected anteriorly and third trochanter disappeared. Patella unpreserved.
25. Tibia long, not slender with flat distal end.
26. Fibula long, twisted, narrow with distal end expanded.
27. United length of fore limb from humerus to phalanges about 80 cm in juvenile animal of Izumi.
28. United length of aft limb (femur to phalanges) about 84 cm in juvenile animal of Izumi.
29. Manus directed outward and pes directed inward. Planes of them parallel with the axis of body.
30. Phalanges stout and flat.

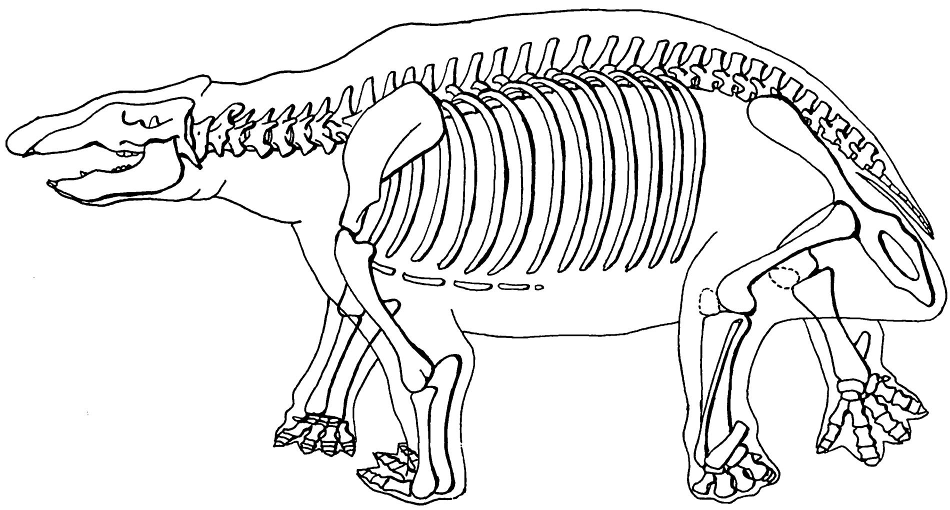
D. Kinetics

When we think of the kinetics and ecological habit of *Paleoparadoxia*, it is very important to note that sternum, rostrum and spatulated lower incisors are eminently developed, nasal opening is situated rather high, symphysial portion of lower jaw is very broad and shovel like, dorsal portion of scapula and ilium are not much expanded, carpus and tarsus are poor in development, metacarpus is long and metatarsus is short, and that manus is directed outward while pes is directed inward. At least the characteristics last mentioned indicate that the animal is not skilful in locomotion on land; it was a slow animal even as terrestrial one.

An interesting and important fact is that the orientation of manus is rather near those of Pinnipedia or some Stegocephalia such as *Eryops* or *Capitosaurus*. Very large and dense platy bones of sternum suggest that the animal often puts its ventral side of thoracic portion directly on the ground, and that in this manner the weight of the hind part of the body was fully supported by the portion of sternum; the short pes directed posterolatelly by its aft side worked pushing the body by kicking the ground. Shovel like lower jaw was also used as a shovel as seen in *Platybelodon* or *Amebelodon*. In these special Proboscidea, lower jaw was purely scooped, but in *Paleoparadoxia* it was slid upon the ground as seen in *Phacochoerus*. Probably ventral side of jaw and cervic portion were all directly put on the ground. When the animal slides forward putting its anteroventral side on the ground and kicking the ground by its hind limbs, the fore limbs act as a supporter, paddle or rudder. Relatively weak construction of carpus suggests that fore limbs are not cursorial but gravipotal in a degree less than Proboscidea, Embrithopoda, Dinocerate or Titanothere. But paddle-like aspect of manus is more significant.

IJIRI and KAMEI write on skull and teeth that desmostylid is essentially herbivorous, living mainly an aquatic life being soaked in sea water and that it is much more related to Sirenia, Proboscidea, Perissodactyla and to Suina than any other living mammals. They also mention that *Paleoparadoxia* is omnivorous and that it moves powerfully its upper rostrum in vertical direction. In a mode of life recalling us those of *Macrauchenia*, *Tapirus*, *Hippopotamus* or *Phacochoerus*, *Paleoparadoxia* was diving in water looking for algae, water plant or some kind of benthonic animals. As VANDERHOOF said, it might be malacophagous and the writer regards it might be even an eater of some crustacea or annelida. *Paleoparadoxia* scooped mud with its foods sliding on sea bottom of near shore enbayment. As *Phacochoerus* does in its locomotion on land (*Phacochoerus* locomotion), so *Paleoparadoxia* did in water.

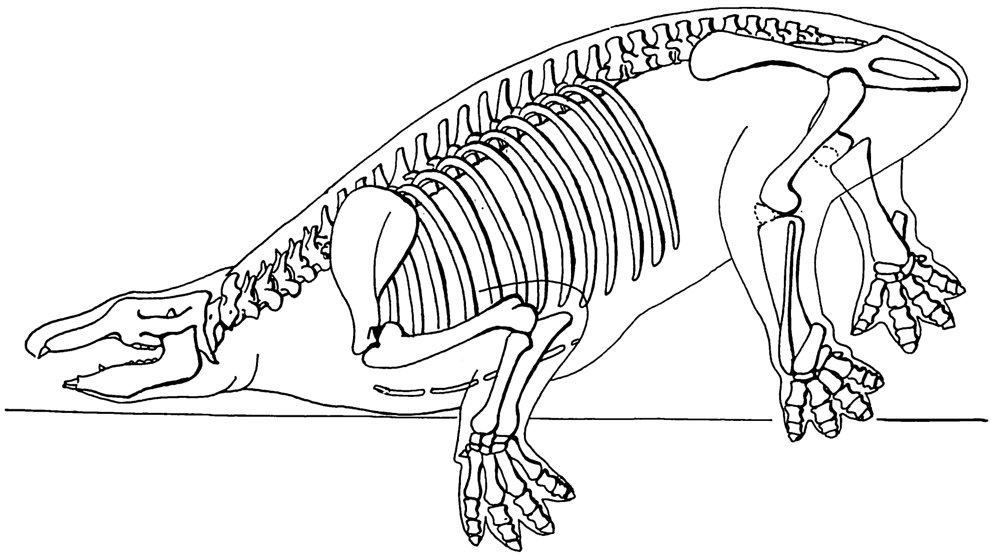
Next problem is what style of walking was usually maintained by *Paleoparadoxia* on land. REPENNING in his personal communication to the writer says, "I think the back feet, with their short metatarsals, had to function plantigrade on land. The front feet, with their longer metacarpals, might have been semi-plantigrade at times but this would appear to have been somewhat awkward because of the rather flat paddle-like foot and because, as indicated by the back legs, the animal could not lift itself very far off the ground. Note also that the peculiar carpal specialization has left metacarpal V in a position where it could not support much of the animal's weight in semi-plantigrade position without dislocating its articulation with the cuneiform." Furthermore he is very skilful in pointing out to the writer the following characteristics.



Textfig. 110. *Paleoparadoxia* in standing (×0.06).

1. " Ankylosis between the radius and the ulna was so great that there was no possibility of supination or pronation by rotation of the radius across the ulna. Thus deviation of the orientation of the manus from a sagittal plane had to be accomplished at the scapular-humeral articulation and hence propulsive swimming strokes by the manus were made with the manus held beneath the chest of the animal, the elbows turned outward."
2. " Manus would also be held below the chest and the elbows pointing outward in terrestrial locomotion."
3. " With the knee against the body and the tibia held horizontally, the tibial-astragalus articulation and the plane of the pes was held 45° from the longitudinal axis of the body, the sole of the pes facing posterolaterally. This appears to have been conventional posture for swimming; it did not swim like an otariid with the feet extending well behind and undulating like flippers."
4. " The 45° cant of the distal articulation to the longitudinal axis of tibia was a decided handicap in terrestrial locomotion. If the tibia is placed in a vertical position the plane of the pes is held 45° from horizontal, the weight of the handiquater is placed entirely on the medial edge of the flat foot, and this weight is applied to the tibia-astragalus articulation at a very insecure angle which quite easily could cause dislocation."
5. " Hence on land the animal had to support itself on flexed knees that pointed outward, with its feet beneath its belly, and its tibia held 45° from vertical."
6. " Its belly also rested on the ground without rotating its feet out of the horizontal plane. Its terrestrial locomotion must have been a humping surface."

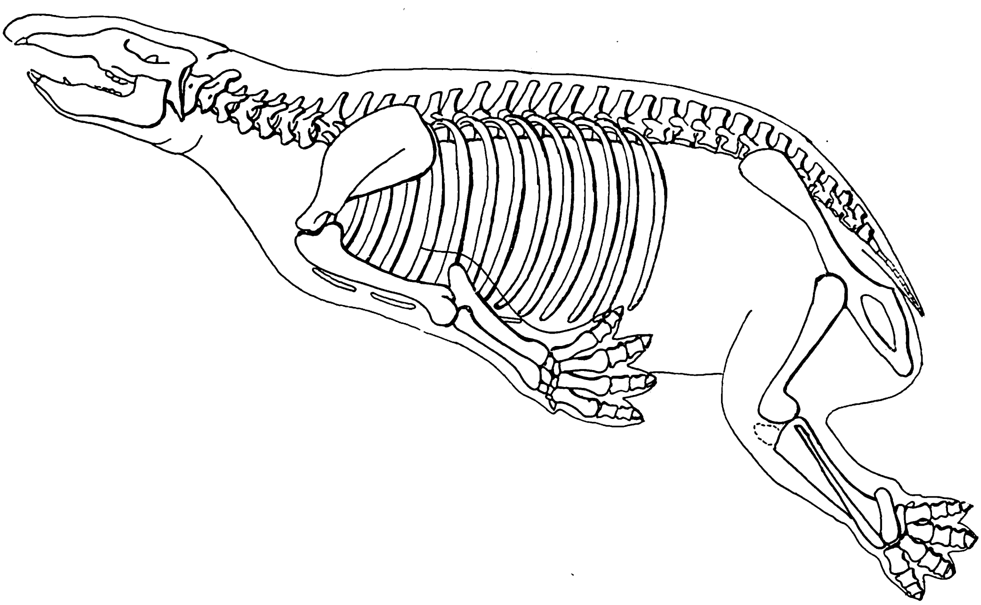
REPENNING's interesting and important idea about the unique styled locomotion of desmostylid will be announced in detail in his future publication. If humerus is set in a parallel situation with the longitudinal axis of body, manus of paddle-like outline turns posterolaterally and the weight of anterior body is placed on distal end of radius and second digit which is not so long. When the animal stands lifting its body on its fore limb in such a style, dislocation should happen in carpal articulation. Hence the animal in a style of lifting its fore body and walking forward, will turn its humerus outward about 90° to the longitudinal axis of body; closely ankylosed proximal and distal articulations of ulno-radius cause manus to turn forward. Otherwise it might flex its manus anterolaterally; this is possible by the distal prolongation of distal and of radius and obliquely running carpal articulation to longitudinal axis of ulno-radius. Probably the animal might put its ventral side of thoracic area on the ground even on land and do a *Phacochoerus* locomotion, but it might be able



Textfig. 111. *Paleoparadoxia* of *Phacochoerus* locomotion on sea bottom (×0.06).

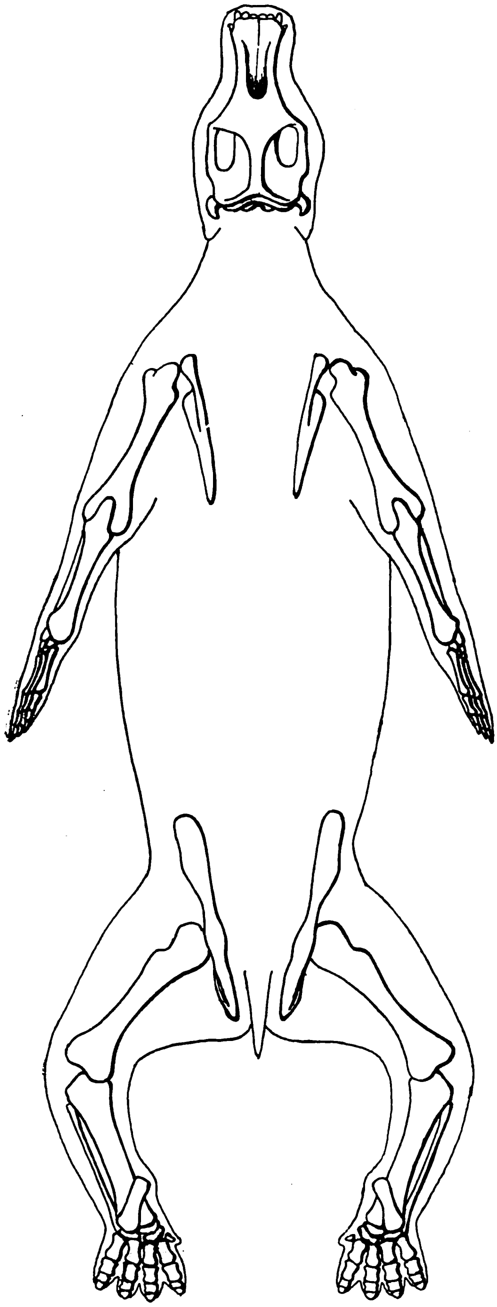
to lift its fore body by flexing its manus and standing on the back of manus. Humerus of desmostylid is relatively long and straight, much differing from the short, robust and curved humerus of Pinnipedia. Paddle-like manus of desmostylid is characterized by flat and undifferentiated digital bones. It should be more suitable for swimming, but the writer has no clear idea of web that existed on manus. In Pinnipedia first digit of manus is longest and strongly constructed, but that of desmostylid has no such characteristic. Otariid uses its strongest first digit of manus efficiently for pushing its body forward on land. When walking forward, the animal might walk on back of flexed manus as seen in *Nothrotherium* and allied Edentata. Eminent expansion of distal portion of ulno-radius and its relatively loose articulation with carpus might suggest such a locomotion. At least a bent of fore side of manus of about 90° to ulno-radius is impossible and normal plantigrade of manus is excluded from manus. As REPENNING says, in semiplantigrade locomotion, fifth metacarpus cannot support the animal weight which is principally placed on the other three metacarpi. It may be more probable that the animal was plantigrade of its flexed manus for walking forward, in a timely semi-plantigrade manner though.

The writer agrees with REPENNING in the posterolateral orientation of pes. Owing to insufficient materials of pes the writer cannot have clear opinions on its plantigrade condition and plane of pes inclined from horizontal plane. But from the aspect of short metatarsus and astragalus and fully developed calcaneum, hind limb might be plantigrade in a degree of *Toxodon* or *Arsinotherium*. Whether or not the distal end of calcaneum or tuber calcis attached on the ground is rather unclear. When the animal does a *Phacocherus* locomotion, semiplantigrade condition of pes may be more beneficial for the animal; in this style the weight of posterior body is not so much placed on hind limb, and the animal could kick the ground in posterolateral direction. Astragalus of desmostylid is not so high and not so well developed in condyle and median groove as in Artiodactyla, but generally corresponds to those of *Diceros* or *Tapirus*. It is better developed than in Proboscidea or *Arsinotherium* and indicates anteroposterior rotation of pes, i. e. kicking land, although metatarsus is very short as in them. Also in *Phacochoerus* locomotion, manus might have not flexed because it did not act a principal role of locomotion.



Textfig. 112. *Paleoparadoxia* in swimming (×0.06).

It may be said that desmostylid was more skilful in swimming than in terrestrial locomotion, but it was not so excellent a swimmer as Pinnipedia; the latter is ichthyvorous while desmostylid is hervivorous or omnivorous and does not need much high speed in swimming. Manus of desmostylid is paddle-like adapted for swimming but not so long compared with united length of scapula-humerus-ulno-radius; In Pinnipedia manus is exceedingly long in comparison with the above mentioned united length. Humero-scapula articulation is much different between desmostylid and Pinnipedia; Sirenia or Suina may be near desmostylid in these points, and thefore limb of desmostylid is not moved from anterooutward to posteroinward directions in



Textfig. 113. *Paleoparadoxia* in swimming. (×0.06)

paddling, but moved from antero-posterior direction, in parallel with the longitudinal axis of body as in Suina. When twisted humerus directs posterolaterally and ulno-radius with ankylosed manus anteroinward with its plane horizontally, the paddling principally acts from anteroinward to posterooutward directions. In this movement paddle-like manus was suitable for pushing water mass backward. Hind limb might have worked as a kind of rudder. At any rate desmostylid might be a better swimmer in surface water than Suina. Its niche lying in sea bottom of near shore embayment, the most favorite locomotion style of desmostylid was diving in water and sliding on sea bottom.

Textfig. 114. *Paleoparadoxia* in water. Drawn by K. SHIMIZU.

VII. Taxonomy

A. Characteristics as Order

Order Desmostylia REINHART, 1953

1953 REINHART: Jour. Geol., vol. 61, no. 2, p. 187.
1957 SHIKAMA: Palaeontology (Asakura), vol. 2, pp. 552–557.
1957 SHIKAMA: Natural Science & Museum, vol. 24, no. 1–2, pp. 16–21.
1959 REINHART: Univ. Calif. Pub. Geol. Sci., vol. 36 no. 1, pp. 64, 65.

Original diagnosis by REINHART: "Range from semi-amphibious forms which were capable of limited terrestrial movement to forms almost completely amphibious; size and habits similar to those of *Hippopotamus*; swampy to brackish-water environment probable. Cranium and mandible of brachycephalic to dolichocephalic proportions; nasal bones well developed, excluded from narial border by premaxillae; wide rostrum; jugals much reduced; mandibular angle broadly rounded; all forms but Family Paleoparadoxia characterized by large ovate globular dental capsule on posteromedial side of mandible, opposite capsule may almost meet in midline; large upper and lower canine procumbent; one or three moderately large upper and lower incisors procumbent; probably three, possibly four, cheek teeth functional at one time; cheek teeth brachyodont to hypsodont, appressed peglike columns, very thick enamel, polydont especially in milk dentition; tooth replacement horizontal in adults; evidence from stoutly built limbs suggests movement in a fore-aft direction; feet plantigrade."

Diagnosis: Quadriped of graviportal and plantigrade to semiplantigrade type with five digits anatomically and four digits functionally, adapted for amphibious life of near shore marine embayment. Length and stoutness of four digits almost undifferentiated. Sternum consists of four paired platy large bones and an unpaired platy bone. Carpus without centrum and tarsus without entocuneiform. Carpus, metacarpus, tarsus and metatarsus indicate neither reduction nor confluency except in first digit. Carpus and tarsus relatively weak and low. Astragalus not high but with median longitudinal groove. Calcaneum relatively long and stout. Ulna and radius relatively short; the latter not rotated on the former. Planes of manus and pes paralleled with longitudinal axis of body; back of manus and sole of pes faced posterolaterally. Skull low, longicephalic with well developed rostrum; symphysial portion of lower jaw expanded. Zygomatic arch robust and posterior of orbital foramen unclosed. Nasal large and narial opening situated high. Lachrymal without naso-lachrymal canal. Cheek teeth consist of many cubic cones and enamel very thick. Incisors well developed, large and flat.

Included in Paenungulata of SIMPSON or Subungulata of ROMER but not perfectly coincided with any order in it.

Relationship: Desmostylia are a valid order. REINHART in 1959 regarded it as derived from a common Paenungulate origin with Proboscidea and Sirenia, inheriting many homologous characters. IJIRI and KAMEI in 1961 pointed out the hervivorous habit of Desmostylia from microstructure of teeth. Until 1945, when SIMPSON and ROMER summarized the large parts of taxonomic opinions on desmostylid and treated it under Sirenia, large parts of vertebrate palaeontologists of the world did not propose any fundamental doubts on its taxonomic position. Suborder Desmostyliformes HAY, 1923 as an archaic group of Sirenia was widely accepted and adopted by them. Tube construction of cheek teeth, tusk-like incisors, development of premaxilla and nasalia, absence of lachrymal foramen, pachyostosed development of postzygomatic arch and dense structure of bone etc. were supporting its Sirenian opinions. In 1905, OSBORN could not decide his new family Desmostylidae as to whether they were purely Sirenia or purely Proboscidea. ROMER in 1933 said that desmostylid is distinct from typical Sirenia by its lower skull, broader snout turning downward but little, smaller jugal and by more anteriorly situated external nare.

Table 18. Opinions on taxonomic position of desmostylid.

Sirenia	Proboscidea	Multituberculata	Marsupialia	Monotremata	Independent Order
MARSH, 1888	TOKUNAGA & IWASAKI, 1902	ABEL, 1924	KISHIDA, 1924	WEBER, 1928	OSBORN, 1905
FLOWER & LYDEKKER, 1891	OSBORN, 1902	KISHIDA, 1933			REINHART, 1953
WATERHOUSE, 1902	ABEL, 1912				SHIKAMA, 1957
SCHLOSSER, 1902	ABEL, 1919				REINHART, 1959
MERRIAM, 1906					
ABEL, 1912					
MATTHEW, 1916					
JOLEAUD, 1920					
HAY, 1923					
SCHLOSSER, 1923					
WOODWARD, 1925					
DIETRICH, 1928					
SIMPSON, 1931					
DAVIES, 1934					
VANDERHOOF, 1937					
ROMER, 1945					
SIMPSON, 1945					
VIRET, 1955					

His Subungulata stock (order or superorder) included Hyracoidea, *Arsinotherium*, Proboscidea and Sirenia. The essential characteristics of Subungulata of ROMER are as follows after his opinions; much enlarged pair of incisors in either jaws, while other front teeth are often reduced; grinding teeth tend to develop cross-lophs, premolars becomes molarized, absence of clavicle; usually land types retain all digits, with a mesaxonic symmetry, while the primitive claws have developed into structures more like nails than hoofs. ROMER declared that desmostylid belongs to Sirenia despite some differences from typical Sirenia and despite lack of data on postcranial skeletons. This may be significant when we discuss the taxonomical position of Desmostylia. Opinions of Multituberculata or Monotremata may be rejected as they only mention few points of developing nasalia and jugomatic arch. Also the possibility of Marspiala can be denied by the lack of inflected angular process of lower jaws and marspial bone of pelvis in desmostylid skeleton.

By the extremely developed paired bones of sternum, peculiar direction of manus and pes, unique combination of tarsal bones, Desmostylia are clearly separated from any orders of mammals. In teeth pattern, Proboscidea and Sirenia may be nearest of all orders, and in many characters of skull, Sirenia, archaic Perissodactyla, archaic Artiodactyla and Pyrotheria may be near. Proboscidea and Sirenia differ much in limb bones, while archaic Perrisodactyla, archaic Artiodactyla, some Protoungulata and Astrapotheria or Notoungulata are rather near. Body style of Desmostylia also recalls us not any of Paenungulata or Subungulata but archaic Perrisodactyla, archaic Artiodactyla or some Subungulata as Astrapotheria, Litopterna or Notoungulata. Desmostylia have some characteristics adapted for aquatic life, such as development of nasal, relatively high position of external nare, absence of naso-lachrymal canal or lachrymal foramen etc., but it is not adapted for swimming life as those of Sirenia or Pinnipedia. Stout hind limb of Desmostylia and absence of it in Sirenia is extremely contrasting. Limb bones of Desmostylia do not indicate pure swimming habit as seen in Sirenia or Pinnipedia.

The writer tabulated relationships of main taxonomic elements of every order of ungulate mammals as shown in Table 19, and gave them weight from 1 to 3. Furthermore he gained the chart of intimate numbers of each order with Desmostylia.

Table 19. Chart of taxonomic elements in comparison with every order of ungulate animals.

◎ Closely near, ○ Rather near, × Distinct

Elements	Weight	Protoungulata					Paenungulata							Mesaxonia	Paraxonia
		Condylarthra	Litopterna	Notoungulata	Astrapotheria	Tubulidentata	Pantodonta	Dinocerata	Pyrotheria	Poboscidea	Embrithopoda	Hyracoidea	Sirenia	Archaic Perissodactyla	Archaic Artiodactyla
Teeth	3	×	×	×	×	×	×	×	×	○	×	×	◎	×	×
Skull	3	×	×	×	×	×	×	×	×○	×○	×	×	○×	○×	○×
Body style	2	×	○	×○	○	×	×	×	?	×	×	×	×	○	○
Scapula	1	×	×	×	×		×	×		×	×	○	○	○×	○×
Pelvis	1	○	×	×	×		×	×		×	?	○	×	○×	○×
Sternum	1	×	×	×	×		×	×		×	×	×	×	×	×
Vertebrae	1	×	×	○	○		×	×		×	×	×	×	×○	×○
Costa	1	○	○	○	○		×	○		○	○	×	×	○	○
Limb bones	2	×	×	×○	○	×	×	×		×	×	×	×	○×	○×
Carpus	2	○	×	×		×	×○	○		○×	○×	×○	○	○×	×○
Tarsus	2	×	×?	×		×	×	×		×	×	×	×	×	×
Digits	2	×	×	×○	○×	×	×○	○×		○×	○×	×	×	○×	○×
Habit		×	○ a	×○ a	×○ a	×	×	×		○× a	×	×	○ A	○× a	○× a

A: Adapted for pure aquatic life, a: Ditto partially.

Table 20. Chart of intimate numbers of taxonomic elements.

Weight \ Order	Protoungulata					Paenungulata							Mesaxonia	Paraxonia
	Condylarthra	Litopterna	Notoungulata	Astrapotheria	Tubulidentata	Pantodonta	Dinocerata	Pyrotheria	Proboscidea	Embrithopoda	Hyracoidea	Sirenia	Archaic Perissodactyla	Archaic Artiodactyla
3	0	0	0	0		0	0		2	0	0	2	1	1
2	1	1	3	3+	?	2	2	?	2	2	1	1	4	4
1	2	1	2	2		0	1		1	1	2	1	4	4
Total	4	3	8	8+	?	4	5	?	11	5	4	9	15	15

by calculating the total number of allied elements multiplied by weight as shown in Table 20. It indicates numerically the degree of intimateness as follows: Perissodactyla and Artiodactyla>Proboscidea>Sirenia, Astrapotheria and Notoungulata >Embrithopoda and Dinocerata>Pantodonta, Condylarthra and Hyracoidea>Litopterna. That is to say, Desmostylia are situated between Subungulata and common ancestor of archaic Perissodactyla and Artiodactyla. Here the writer is ready to say that he was ever impressed by NAGAO's private speaking or his lecture at Tôhoku Imperial University about the taxonomic potition of desmostylid. From this impression and his manuscript it may be said that in 1937 NAGAO regarded desmostylid as rather related to Perissodactylia or archaic Ungulata as Condylarthra, Amblypoda or Dinocerata. He mentioned Perissodactylian relationship from characters of vertebrae, scapula and pelvic girdle etc. Also he noted Amblypoda in astragalus and Embrithopoda in metacarpus of pentadactylian manus, although Keton metacarpals were fragmentary. NAGAO recalled *Amynodon* in body size and some rhinoceroid in body style.

B. Characteristics as Family and Infrageneric Taxonomy

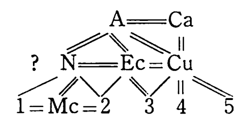
Desmostylia includes two families.

1. Family Cornwalliidae SHIKAMA, 1957

1957 SHIKAMA: Palaeontology (Asakura, Tokyo), vol. 2, p. 556.
1957 SHIKAMA: Natural Science and Museum, vol. 24, no. 1–2, p. 16.
1959 Paleoparadoxidae REINHART: Univ. Calif. Pub. Geol. Sci., vol. 36, no. 1, pp. 94, 95.

Type-genus: *Cornwallius* HAY, 1923

Diagnosis: Dental formula, $\frac{3\cdot1\cdot3\cdot3}{3\cdot1\cdot4\cdot3}$ (IJIRI and KAMEI, 1961, $\frac{3\cdot1\cdot4\cdot3}{3\cdot1\cdot4\cdot3}$). Incisors undifferentiated and canine relatively large. Cheek teeth brachydont, bunodont with long root and relatively small sized. Tubelike cusp low and undeveloped; accessory tubercles developed on eminent basal cingulum. Upper and lower P2 rudimentary and upper P1 disappeared. Lower P1 canine like. Cusp formula; $P1=\frac{0}{1}$, $P2=\frac{?}{?}$, $P3=\frac{3+0}{3+0}$, $P4=\frac{3+2}{4+0}$, $M1=\frac{?}{?}$, $M2=\frac{5+4}{6+(1-2)}$, $M3=\frac{5+4}{5+(3-4)}$. Diastema between C and P rather long. Symphysis of lower jaw relatively short and very broad, with simian shelf. Dentary capsule (os sacculi dentis) absent. Zygomatic arch relatively weak and jugal process large, rugose and eminently projected. Median cranial crest of parietal very distinct. Dorsal margin of scapula expanded. Humerus with an eminent inner tubercle, no supratrochlea foramen and a large major tubercle which is wide anteroposteriorly. Axis of olecranon not so much oblique to that of shaft of ulna and distinctly projected. Scaphoid relatively low and outer surface of magnum with no median groove. Femur has a distinct small trochanter. Cuboid very low and wide. Metatarsus very short, about 0.26-0.56 length of metacarpus. Tarsal formula;



Genus *Paleoparadoxia* REINHART, 1959

1957 *Cornwallius* HAY, SHIKAMA: Paleontology (Asakura, Tokyo), vol. 2, pp. 556, 557 (emend.).
1957 *Cornwallius* HAY, SHIKAMA: Natural Science and Museum, vol. 24, no. 1-2, pp. 16-20 (emend.).
1959 *Paleoparadoxia* REINHART: Univ. Calif. Pub. Geol. Sci., vol. 36, no. 1, pp. 94-96.
1963 *Paleoparadoxia* REINHART, MITCHELL: Bull. South Calif. Acad. Sci., vol. 62, pt. 4, pp. 192-201.

Type-species: *Cornwallius tabatai* TOKUNAGA, 1939

Paleoparadoxia tabatai (TOKUNAGA, 1939)

1939 *Cornwallius tabatai* TOKUNAGA: Jub. Pub. Comm. Prof. YABE Sixt. Birth., vol. 1, pp. 289-299, pl. 19, figs. 1-8 (Sado teeth).
1944 *Desmostylus japonicus* TOKUNAGA & IWASAKI, TAKAI: Mis. Rep. Res. Inst. Nat. Res., no. 5, pp. 59-62, figs. 1a-d (Hannoura tooth).
1953 *Cornwallius* sp. ARAI: Res. Bull. Chichibu Nat. Sci. Mus., no. 3, pp. 65-84, pl. 85, figs. 1-28 (Chichibu lower jaw and teeth).
1957 *Cornwallius tabatai* TOKUNAGA, SHIKAMA: Nat. Sci. Mus., vol. 24, no. 1-2, p. 20 (taxonomy).
1959 *Paleoparadoxia tabatai* (TOKUNAGA), REINHART: Univ. Calif. Pub. Geol. Sci., vol. 36, no. 1, pp. 94-101, figs. 17, 18, pl. 14, figs. a, a′, b, b′ (Coalinga jaw and others).
1961 *Paleoparadoxia tabatai* (TOKUNAGA), IJIRI & KAMEI: Earth Science, no. 53, pp. 6-23, figs. 8-19, pl. 2, fig. 7, pl. 3, figs. 1-5, pl. 4, figs. 1-5, pl. 5, figs. 1-4, pl. 6, figs. 1, 2 (Izumi skull).
1963 *Paleoparadoxia* sp. MITCHELL: Bull. South Calif. Acad. Sci., vol. 62, pt. 4, pp. 192-201, figs. 1a-i (San Clement teeth).

Holotype: An unworn premolar and worn molar, formerly stored in Waseda University, Tokyo and lost in the war.

Type-locality: A tunnel of Nakayama pass between Aikawa and Sawane, Sawada-cho, Sado-gun (Sado Island), Niigata Prefecture.

Neotype (here selected): A skeleton stored in the National Science Museum, Tokyo (NSMT-P-5601).

Type locality of neotype: A small hill named Inkyo-yama, Kuziri, Izumi-machi, Doki City, Gihu Prefecture (Lat. 35°21′45″N, Long. 137°10′40″E).

Geological horizon of neotype: The Yamanouchi bed, Mizunami Group of middle Miocene (F_3).

Referred specimens:

1. Right mandible with C and M3 stored in the University of California Museum of Paleontology (UCMP no. 40862) from Santa Cruz County, California; probably the Santa Margarita formation of Clarendonian (?).
2. An isolated tooth (UCMP no. 32076) from "Center of Sec. 25, T. 16SR 13E, Mount Diablo Base, U.S. Geol. Surv. Monocline Ridge Quadrange", Fresno County, California; the Temblor.
3. A cheek tooth (UCMP no. 45274) from Graham sand pit, Santa Cruz County, California (UCMP loc. V-5555); the Santa Margarita formation.
4. A cheek tooth (UCMP no. 63981) from the Pacific coast Aggregates Company sand pit, 2000 ft NNW of Graham pit; the Santa Margarita formation.
5. Some teeth stored in the Los Angeles County Museum (LACM 4371 a-c) from San Clemente Island, California; early to middle Miocene.*
6. Right mandible and eight isolated teeth stored in the Chichibu Natural Science Museum, Chichibu City, Saitama Prefecture, from a cliff along the Arakawa River, Terao of Odamaki, Chichibu City; upper part of the Coichibu-machi Group, F_2.
7. Upper P3 stored in the National Science Museum, Tokyo (NSMT-P-6059) from Hannoura, Notojima-cho, Kashima-gun, Ishikawa Prefecture; the Nanao Group, F_3-G.
8. A tooth (P4 ?) stored in the National Science Museum, Tokyo (NSMT-P-3214), collected by G. MORI in Toyama from Akebi, Nyuzen-machi, Shimoniikawa-gun, Toyama Prefecture; the Nanpo silt bed of the upper Yatsuo Group, G.

Geological range: Early to late Miocene.

Genus *Cornwallius* HAY, 1923

1923 *Cornwallius* HAY: Pan. Amer. Geol., 39, pp. 105–109.
1924 *Cornwallius* HAY: Proc. U.S. Nat. Mus., vol. 65, pp. 1–8.
1931 *Cornwallius* HAY, KELLOG: Proc. Calif. Acad. Sci., ser. 4, vol. 19, pp. 219–277.
1935 *Cornwallius* HAY, VANDERHOOF: Univ. Calif. Pub. Dept. Geol. Sci., vol. 24, no. 8, p. 191.
1959 *Cornwallius* HAY, REINHART: Univ. Calif. Pub. Geol. Sci., vol. 36, no. 1, pp. 66, 98–99.

Type-species: *Cornwallius sookensis* (CORNWALL, 1922)

Remarks: Based on teeth only and well related to *Paleoparadoxia* and *Desmos-*

* Besides these MITCHELL is studying samples from Aliso Creek (partial skeleeton) and Palos Verdes (partial skeleton).

tylus. In brachyodont and tuberculated cingulum of cheek teeth it is nearer to the former than the latter, but in rounded and relatively smooth cusps it is nearer to the latter than the former. REINHART wrote, " the cingulum of *Paleoparadoxia* differs from that of *Cornwallius* in extending more than halfway above the crown of the tooth, completely encircling the crown, having greater lateral thickness, and forming a far more prominent part of the tooth." *Cornwallius* may be situated as an ancestral stock of *Paleoparadoxia* and *Desmostylus*.

Cornwallius sookensis (CORNWALL, 1922)

1922 *Desmostylus sookensis* CORNWALL: Canadian Field Nat., vol. 36, pp. 121–123, 4 figs.
1923 *Desmostylus sookensis* CORNWALL, CLARK & ARNOLD: Univ. Calif. Pub. Dept. Geol. Sci., vol. 14, pp. 177–179, pl. 39.
1923 *Cornwallius sookensis* (CORNWALL), HAY: Pan Amer. Geol., vol. 39, pp. 105–109.
1935 *Cornwallius sookensis* (CORNWALL), VANDERHOOF: Univ. Calif. Pub. Dept. Geol. Sci., vol. 24, no. 8, p. 191, fig. 2.
1942 *Cornwallius sookensis* (CORNWALL), VANDERHOOF: Jour. Sci., vol. 240, pp. 298–301, 2 figs.
1959 *Cornwallius sookensis* (CORNWALL), REINHART: Univ. Calif. Pub. Geol. Sci., vol. 36, no. 1, p. 66, fig. 9.

Holotype: A lower molar in the Provincial Museum of British Columbia (no. 486).

Type-locality: Near mouth of Coal Creek, Sooke, Vancouver Island, B. C., Canada; the Sooke formation of Upper Oligocene.

Referred specimens:

1. Teeth and bones identified by LEWIS of U. S. Geol. Surv., Denver from Unalaska Island, Aleutian Islands, Alaska; basal Miocene of MACNEIL.
2. A lower molar stored in the University of California Museum of Paleontology (UCMP no. 32682) from Vancouver Island; the Sooke formation.
3. A lower molar stored in the Provincial Museum of British Columbia (no. 491) from Vancouver Island; the Sooke formation.
4. An anterior half of lower molar stored in the University of California Museum of Paleontology (UCMP no. 36079) from San Telmo Point, San Carlos Bay, Baja California (Lat. 25°20′N, Long. 111°W); Oligocene.
5. An upper molar (UCMP no. 36078) from the same locality.*

2. Family Desmostylidae OSBORN, 1905

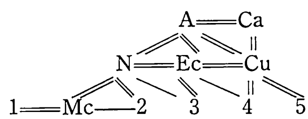
1905 OSBORN: Amer. Geol., vol. 36.
1915 HAY: Proc. U. S. Nat. Mus., vol. 49, pp. 381–397.
1937 NAGAO: Jour. Geol. Soc. Jap., vol. 44, pp. 533, 534.
1957 SHIKAMA: Paleontology (Asakura, Tokyo), vol. 2, pp. 553–555.
1957 SHIKAMA: Natural Science and Museum, vol. 24, no. 1–2, pp. 19, 20.
1959 REINHART: Univ. Cal. Pub. Geol. Sci., vol. 36, no. 1, p. 65.

Type-genus: *Desmostylus* MARSH, 1888

Diagnosis: Dental formula, $\frac{0 \cdot 1 \cdot 3 \cdot 3}{1 \cdot 1 \cdot 3 \cdot 3}$. Canine cylindrical, tube like and larger

* Besides these MITCHELL is studying two teeth from Washington.

than incisor. Cheek teeth hypsodont, consist of closely appressed cylindrical columns; accessory tubercles or basal cingulum absent or obsolete. Cusp formula; $P4=\frac{4}{7}$, $M1=\frac{4-5}{6-(6+1)}$, $M2=\frac{8-9}{6+1}$, $M3=\frac{8-10?}{6-8}$. Diastema between C and cheek teeth very long. Symphysis of lower jaw very long and narrow, with simian shelf. Dental capsule prominent. Zygomatic arch robust, broad and thick. Jugal process and median cranial crest of parietal obsolete. Dorsal margin of scapula relatively unexpanded. Humerus with an obsolete inner tubercle, a supratrochlea foramen and a small major tubercle which is narrow anteroposteriorly. Axis of olecranon much oblique to that of shaft of ulna which is curved; styloid process not so large and weak in projection. Scaphoid relatively high and outer surface of magnum with a median groove. Femur has an obsolete small trochanter. Tarsal formula:



?

astragalus irregularly pentagonal in anterior view. Cuboid high and narrow. Metatarsus not short. Specialization of teeth and skull is more advanced than in Cornwalliidae above mentioned, but that of postcranial skeleton is vice versa.

Genus *Desmostylus* MARSH, 1888

1888 *Desmostylus* MARSH: Amer. Jour. Sci., vol. 35, pp. 94-96.
1925 *Desmostylus* MARSH, SCHLOSSER: ZITTEL's Text-book of Palaeontology, vol. 3, p. 266.
1937 *Desmostylus* MARSH, VANDERHOOF: Univ. Calif. Pub. Bull. Dept. Geol. Sci., vol. 24, no. 8, p. 189.
1945 *Desmostylus* MARSH, SIMPSON: Bull. Amer. Mus. Nat. Hist., vol. 85, p. 136.
1950 *Desmostylus* MARSH, ROMER: Vertebrate Paleontology, 4th ed., p. 419.
1951 *Desmostylus* MARSH, W. K. GREGORY: Evolution emerging, vol. 1, pp. 426-428, vol. 2, pp. 800-802.
1957 *Desmostylus* MARSH, SHIKAMA: Palaeontology (Asakura, Tokyo), vol. 2, pp. 553, 554.
1957 *Desmostylus* MARSH, SHIKAMA: Natural Science and Museum, vol. 24, no. 1-2, p. 20.
1959 *Desmostylus* MARSH, REINHART: Univ. Cal. Pub. Geol. Sci., vol. 36, no. 1, p. 65.

Type-species: *Desmostylus hesperus* MARSH, 1888

Desmostylus hesperus MARSH, 1888

1888 *Desmostylus hesperus* MARSH: Amer. Jour. Sci., vol. 35, pp. 94-96.
1915 *Desmostylus hesperus* MARSH, HAY: Proc. U. S. Nat. Mus., vol. 49, pp. 103-112.
1922 *Desmostylus hesperus* MARSH, HANNIBAL: Jour. Mammal., vol. 3, pp. 238-240, 2 pls.
1923 *Desmostylus hesperus* MARSH, HAY: Pan-Amer. Geol., vol. 39, pp. 105-109, 2 figs.
1937 *Desmostylus hesperus* MARSH, VANDERHOOF: Univ. Calif. Pub. Bull. Dept. Geol. Sci., vol. 24, no. 8, pp. 189-192, figs. 9-52.
1959 *Desmostylus hesperus* MARSH, REINHART: Univ. Calif. Pub. Geol. Sci., vol. 36, no. 1, pp. 68-89, figs. 10-12, pl. 6, figs. a-g, pl. 7, figs. a-r, pl. 8, figs. a-m.

Holotype: An upper molar stored in the Peabody Museum, Yale University, reported by YATES in 1886 (no. 11900).

Type-locality: Mission San Jose, Alamada County, California (Yale Peabody Mus. 1395d).

Referred specimens:*

1. A skull stored in the U. S. National Museum (USNM no. 8191) from Yaquina Bay, Oregon, described by HAY, 1915.
2. Cheek teeth stored in the Condon Mus., University of Oregon (nos. 432, 433) from Yaquina coast, Oregon; Astoria.
3. A lower jaw stored in the University of California Museum of Paleontology (UCMP no. 32742) from Coalinga, California (UCMP loc. V-3512); shell limestone member of the San Pablo formation of late Miocene; described and discussed by VANDERHOOF, 1937 and redescribed and discussed by REINHART, 1959.
4. Isolated teeth (UCMP nos. 5118, 5119, 5120, 5121, 5123) from Mount Diable Base, California (UCMP loc. V-3512); Briones.
5. A lower molar from Mendocino County, California (Cal. Acad. Sci. loc. no. 909); probably Briones.
6. Lower molars (UCMP nos. 29854, 23527) from neighbourhood of San Pablo Dam., California (UCMP loc. V-3408); Briones.
7. A lower molar (UCMP no. 31813) from Contra Costa County, California (UCMP loc. V-3215); Briones.
8. An upper molar stored in the American Museum of Natural History (no. 21937) from Contra Costa County, California; Briones.
9. A lower molar (UCMP no. 31522) from Mount Diablo Base, California (UCMP loc. V-3108); Briones.
10. A lower molar collected by Prof. NORTON (UCMP no. 1606) from the Miocene of California.
11. A left upper molar (UCMP no. 21375) and a fragment of a lower molar (UCMP no. 21373) from *Merychippus* quarry, Coalinga, Fresno County, California; Temblor.
12. A fragment of molar column stored in the California Academy of Science from Sec. 10, T. 19S, R 15 E, Fresno County, California; Temblor.
13. A left upper molar stored in the California Academy of Science from Phoenix Canyon, Coalinga; Temblor.
14. An upper molar (UCMP no. 22342) from Mount Diablo Base, Coalinga; Temblor.
15. Fragmentary molar columns (UCMP no. 26547) from Priest Valley, California; Temblor.
16. Fragmentary column collected by ANDERSON and stored in the California Academy of Science from Lost Hills, California; Temblor.
17. About thirty molar columns stored in the University of California Museum of Paleontology from somewhere near La Panza, San Luis Obiop County, California; Temblor.
18. A lower molar collected by YATES from San Luis, California; Monterey.
19. Fragments of lower jaw with part of a molar in place (UCMP no. 32681) from

* Partly abbreviated, see VANDERHOOF, 1937, pp. 196-203.

Lompoc, Santa Barbara County, California; Monterey.

20. A lower molar stored in the California Academy of Science (no. 4401) from Bakersfield, California; Temblor.
21. A fragmentary molar column (UCMP no. 1056) from Santa Ana, California; Temblor.
22. A molar column stored in the California Academy of Science, dredged from Monterey Bay, California; Monterey.
23. Lower and upper molars stored in the U.S. National Museum (nos. 13630-13636) from Monocline Ridge, Fresno County, California (UCMP loc. V-3301); Temblor.
24. Lower molars (UCMP nos. 32021, 32099, 32683-32692, 32694-32741, 32743-32750, 32782-32787, 32789, 32792, 32794) from the same locality; famous locality of the Reef bed in Temblor, attacked by VANDERHOOF and POE.
25. Several molar columns stored in the California Academy of Science from Canta Creek, Fresno County, California; Temblor.
26. A right upper molar stored in the U.S. National Museum (no. 8300) from Coalinga, California; Temblor.
27. Cheek teeth (USNM 22922, 22923) from Caliente Range, San Luis Obispo County, California (USGS vert. loc. M 1028); the Painted sandstone member of the Vaqueros formation.
28. A cheek tooth (USNM 22925) from Cuyan Valley area, California (USGS vert. loc. M. 1030); the lower Branch Canyon formation of Temblor.
29. A cheek tooth (USNM 22924) from Cuyan Valley area, California (USGE vert. loc. M. 1029); the upper Branch Canyon formation of Barstovian or Clarendonian.
30. Teeth in REPENNING collection from Felton, Santa Cruz (UCMP loc. V-5555); Clarendonian.

Remarks: REINHART's detailed diagnosis is based upon lower jaw of UCMP no. 32742. His restored jaw is tolerably differing from that of VANDERHOOF, especially in symphysial area, posterior ventral margin of horizontal ramus. "Anterior half of mandible deflected slightly down; incisors enlarged to form one pair of straight tusks slightly smaller than pair of canine tusks; vertical thickness of symphysial region greatest anteriorly, thin posteriorly; paraglossal ridges immediately anterior to molars thin, sharp, tapes to a rounded condition anteriorly; stout deep ramus from rear border of symphysis to angle; lateral deflection of angles in region of dental capsules; medial border of dental capsules swollen; pronounced expansion at ventral and posterior ends." He writes that the number of columns in the polydont molars is extremely variable, and it is, therefore, only the most tenuous of evidence to use in establishing a new species of *Desmostylus* and that the larger skull may be one of a growth series. Although VANDERHOOF mentioned a little difference of proportion of bone elements between the skulls of Oregon and Togari, he could not recognize any valid specific difference between the American and Japanese *Desmostylus*. REINHART treated all the Japanese species as junior synonym of *hesperus*. This may be a more convenient treatment at the present knowledge of researches. The present writer is going to recognize some difference between them as mentioned in following lines.

Postcranial elements: Some fragmental materials of postcranial bones perhaps belonged to desmostylid were reported by MARSH and VANDERHOOF, but REINHART was the first who announced a tentative general view of desmostylid skeleton. It is very noteworthy that in the abundant Coalinga materials there were found some postcranial bones of desmostylid, but owing to fragmental materials and coexistence of *Desmostylus* and *Vanderhoofius*, it is extremely difficult to determine the true taxonomic position of these bones. REINHART reported atlas (UCMP no. 39997), first thoracic vertebra (UCMP no. 40863), anterior thoracic rib (UCMP no. 40864), thoracic rib (UCMP no. 39998), scapula (UCMP no. 39986), right humerus (UCMP no. 39999), right radius (UCMP no. 39987), pelvis (UCMP no. 40000), femur (UCMP no. 39985) and metapordials (UCMP no. 32041, 40001, 42002), etc. Known also is a proximal end of radius (UCMP no. 32794) described by VANDERHOOF.

Coalinga humerus is generally like that of Japanese desmostylid. It is more slender, longer, wider anteroposteriorly and has relatively narrow shaft and distal end compared with that of Keton *Desmostylus*. Also like it, Coalinga humerus has a large supratrochlea foramen, which is larger than that of Keton. Even it belongs to *Desmostylus*, it is clearly separated from that of Keton. As Coalinga humerus is young, with detached epiphysis, 222.7 mm in length, these morphological differences may be seen. But eminent development of deltoid ridge and more strongly curved shaft of Coalinga humerus are attributed not to growth stage but to taxonomic one. Both Izumi and Keton humeri having straight shaft and relatively weaker deltoid ridge, the Coalinga humerus perhaps belongs to *Vanderhoofius*.

Coalinga radius is also of young animal with its distal epiphysis detached and 238.5 mm in length; shaft curved forward and much expanded distally and shows slight twist or torsion in middle of shaft. Coalinga radius is more strongly curved than that of Japanese desmostylid, also general outline of them are not so much differing from each other. Coalinga radius perhaps belongs to *Desmostylus* as REINHART pointed out. He writes; "in the described radius referred to *Desmostylus*, the proximal articular surface is wide and the central prominence between articular fossae would have interlocked with the humeral trochlea. This signifies that almost all power of rotation was lost and the elbow joint would be hingelike, moving only in one plane. It is more common for well-adapted aquatic mammals to show great flexibility in the region of the elbow joint but this does not preclude the possibility in one plane of movement, fore-&-aft. In shape and proportions this radius is most similar to that of *Hippopotamus*.

Coalinga femur is relatively short, stout, 351 mm long, shorter than that of Japanese desmostylid and has relatively smaller head, stronger small trochanter, deeper trochanteric fossae and more eminent great trochanter. It tolerably differs from that of Japanese desmostylid and may belong to *Vanderhoofius*. More eminent construction of proximal portion of Coalinga femur suggests the different kind of locomotion of *Vanderhoofius* from *Desmostylus*. From Coalinga femur REINHART concluded that the animal to which the femur belongs is a short, stocky, quadrupedal, terrestrial and modern type of mammal. Also he writes; "it is more probable that the individual is amphibious rather than either terrestrical or aquatic." This suggests an animal similar in habit to *Hippopotamus*.

Desmostylus hesperus japonicus TOKUGAWA & IWASAKI, 1914

1914 *Desmostylus japonicus* TOKUNAGA & IWASAKI: Jour. Geol. Soc. Tokyo, vol. 21, p. 33; based on S. YOSHWARA & IWASAKI, 1902: Jour. Coll. Sci. Imp. Univ. Tokyo, vol. 16, art. 6, pp. 1-13, pls. 1-3 (nomen only about holotype skull described in 1902).

1918 *Desmostylus japonicus* TOKUNAGA & IWASAKI, MATSUMOTO: Sci. Rep. Tôhoku Imp. Univ., vol. 3, pp. 61-94, 1 pl. (Obirashibetu tooth).

1928 *Desmostylus japonicus* TOKUNAGA & IWASAK, SAHEKI: Jour. Geol. Soc. Tokyo, vol. 35, no. 421, p. 569, 1 fig. (Aushi tooth).

1935 *Desmostylus mirabilis* NAGAO: Jour. Geol. Soc. Jap., vol. 42, no. 507, pp. 822-824 (Keton skeleton).

1936 *Desmostylus japonicus* TOKUNAGA & IWASAKI, TAGAMI: Jour. Geol. Soc. Jap., vol. 43, no. 508, pp. 47, 48, figs. 1, 2 (Ponto tooth).

1936 *Desmostylus* cf. *mirabilis* NAGAO, TOKUNAGA: Jour. Geogr. Tokyo, vol. 48, no. 572, pp. 481-484, pl. 6, figs. 1-4, pl. 7, figs. 1-3, pl. 8, figs. 1-2b (Nagakura jaw and teeth).

1937 *Desmostylus minor* NAGAO: Proc. Imp. Acad. Tokyo, vol. 13, no. 2, pp. 46-49, figs. 1-3 (Okoppe-zawa tooth).

1937 *Desmostylella typica* NAGAO: Proc. Imp. Acad. Tokyo, vol· 13, no. 3, pp. 82-85, figs. 1-4 (Yuda tooth).

1937 *Desmostylus japonicus* TOKUNAGA & IWASAKI, IJIRI: Jour. Geol. Soc. Jap., vol. 44, no. 528, pp. 837-856, 2 pls. (Togari teeth).

1937 *Desmostylus japonicus* TOKUNAGA & IWASAKI, IJIRI: Jour. Geol. Soc. Jap., vol. 44, no. 531, pp. 1177-1193, 1 pl. (Togari teeth).

1938 *Desmostylus japonicus* TOKUNAGA & IWASAKI, IJIRI: Proc. Imp. Acad· Tokyo, vol. 14, pp. 220-230 (Togari teeth).

1938 *Desmostylus japonicus* TOKUNAGA & IWASAKI, TAKAI: Jour. Geol. Soc. Jap., 45, no. 541, pp. 745-763 (taxonomy and distribution).

1939 *Desmostylus japonicus* TOKUNAGA & IWASAKI, IJIRI: Jour. Geol. Soc. Jap., vol. 46, no. 548, pp. 220-230, 13 figs. (Togari teeth and dental anatomy).

1939 *Desmostylus japonicus* TOKUNAGA & IWASAKI, IJIRI: Proc. Imp. Acad. Tokyo, vol. 15, pp.135-138 (dental anatomy).

1939 *Desmostylus japonicus* TOKUNAGA & IWASAKI, TAKAI: Jub. Pub. Comm. Prof. H. YABE Sixt. Birth., vol. 1, pp. 189-203 (taxonomy and distribution).

1940 *Desmostylus japonicus* TOKUNAGA & IWASAKI, IJIRI: Jour. Geol. Soc. Jap., vol. 47, no. 563, pp. 318-327, 2 figs. (teeth variation).

1944 *Desmostylus japonicus* TOKUNAGA & IWASAKI, TAKAI: Mis. Rep. Res. Inst. Nat. Res., no. 5, pp. 59-62, figs. 2a-2c (Shitsumi tooth).

1944 *Desmostylus japonicus* TOKUNAGA & IWASAKI, URITA: Jour. Geol. Soc. Jap., vol. 51, no. 607, pp. 115-118, 3 figs. (Sakurazawa tooth).

1954 *Desmostylella typica* NAGAO, YABE & IJIRI: Proc. Imp. Acad. Tokyo, vol. 30, no. 9 (blood vein of Yuda tooth).

1954 *Desmostylella typica* NAGAO, IJIRI: Earth Science, vol. 19, pp. 1-6, 3 figs. (blood vein of Yuda tooth).

1957 *Desmostylus japonicus* TOKUNAGA & IWASAKI, ONODERA: Jour. Geol. Soc. Jap., vol. 63, no. 739, pp. 238-253, 1 pl. (Ichinoseki teeth).

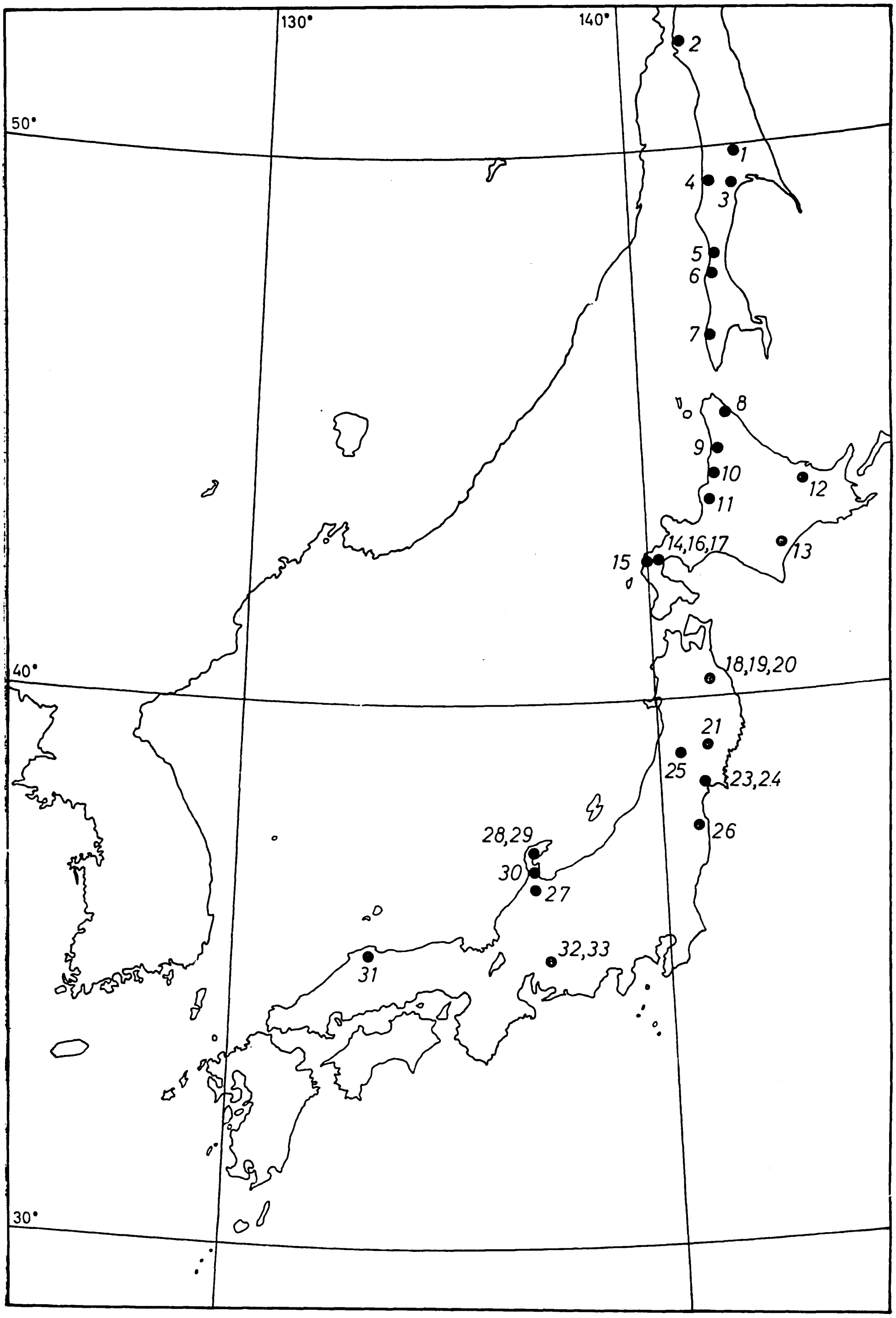
1957 *Desmostylus japonicus* TOKUNAGA & IWASAKI, SHIKAMA: Palaeontology (Asakura, Tokyo), vol. 2, pp. 556, 557, figs. 713, 714, 717 (taxonomy).

1957 *Desmostylella typica* NAGAO, SHIKAMA: Ibid.

1957 *Desmostylus japonicus* TOKUNAGA & IWASAKI, SHIKAMA: Natural Science and Mus., vol. 24, no. 1-2, pp. 16-21, 2 pls. (Keton skeleton and taxonomy).

1959 *Desmostylus hesperus* MARSH, REINHART: Univ. Calif. Pub. Geol. Sci., vol. 36, no. 1, pp. 65, 66 (taxonomy).

1961 *Desmostylus mirabilis* NAGAO, IJIRI & KAMEI: Earth Science, no. 53, pp. 1-27, figs. 1-6, pl. 1, figs. 1-5, pl. 2, figs. 1-6 (Keton skull and teeth).



Textfig. 115. Distribution of *Desmostylus hesperus japonicus* TOK. & IW.

1964 *Desmostylus japonicus* TOKUNAGA & IWASAKI, KASENO: Ann. Rep. Noto Mar. Lab., vol. 4, pp. 59-64, pl. 1, figs. 1-6 (Shiratori tooth).

Holotype: A skull and isolated teeth from Togari stored in the National Science Museum, Tokyo (NSMT-P-5600).

Type-locality: Bôgahora valley, Togari, Mizunami City, Gihu Prefecture; the Togari bed, Mizunami Group of early Miocene, F_2.

Referred specimens:

1. A skeleton in the Department of Geology and Mineralogy, Hokkaido University (UHR no 18466) from Hatsuyuki-zawa, tributary of the Keton River, middle of Saghalien (Lat. 45° 51′ N, Long. 142° 33′ E); the Naihoro coal-bearing formation of Honto Group; middle Miocene, F_3.
2. Fragmentary teeth apparently in the geological collection of the U. S. S. R. at Leningrad, collected by SMIRNOWA, 1926 and reported by KHOMENKO, 1927 from clayay sandstone between the Noiani River and the Siertunai River, North Saghalien (KHOMENKO reported a shoulder blade, vertebrae and the other skeletal parts found).
3. A cheek tooth stored in the Geological Institute, Tokyo University (TUIG M 51) collected by T. TOKUDA from coast of the Kamake River, Naikawa, Nairo-mura, Saghalien; probaly the Kurashi hard shale formation; late Miocene, G.
4. A cheek tooth reported by URITA from Sakura-zawa, Estoru, Saghalien; the pyroclastic member of Honto Group; early Miocene, F_2.
5. A cheek tooth fragment stored in the Department of Geology and Mineralogy, Hokkaido University (UHR no 18467) from Kônosu coal mine, Noda-machi, Saghalien; the Naihoro coal-bearing formation; early Miocene, F_2*.
6. A cheek tooth formerly stored in the Saghalien Museum, Toyohara (Yushino-sakhalinsk) from Aushi, Noda-machi, Saghalien; the Aushi oil and coal bearing formation of Honto Group; early Miocene, F_2.
7. A cheek tooth stored in the Department of Geology and Mineralogy, Hokkaido University (UHR no 7428) collected by TAGAMI and TAKEUCHI from Asanai-zawa, Honto-machi, Saghalen; the Hacchorei hard shale formation of Honto Group; early Miocene, F_1.
8. A cheek tooth reported by Y. ODA from colliery of Fujita coal mine, north of Koishi of Onishibetsu area, Sôya-gun, Hokkaido; a horizon severnal meters above from the base of the Onishibetsu bed corresponding with the Chikubetsu bed of late early Miocene, F_2.*
9. A gypsum model of cheek tooth stored in the Department of Geology and Mineralogy, Hokkaido University (UHR no 18468) from upper stream of the Enbetsu River, Enbetsu, Tomae-gun, Rumoe, Hokkaido; probably the Kotanbetsu bed of upper Kawabata stage; middle Miocene, F_3.*
10. A cheek tooth stored in the Department of Geology and Mineralogy, Hokkaido University (UHR no 18469) from colliery of Uryu coal mine, Asano, Numata-machi, Uryu-gun, Hokkaido; the Hokkaido; the Horoshin sandstone and conglomerate bed of middle Kawabata stage; early Miocene, F_2.*

* Undescribed specimen.

11. A cheek tooth stored in the Institute of Geology and Palaeontology, Tôhoku University (IGPS cat. no. 57239) from from Kamikinebetsu-zawa, Obirashibetsu, Rumoe-gun, Hokkaido; the Tappu shale, correlated with the Poronai Group; Oligo-Miocene, E.
12. A cheek tooth stored in the Department of Geology and Mineralogy, Hokkaido University (UHR no 13655) reported by S. UOZUMI from a river cliff of left side of the Muka River below bridge between Ainonai and Kunneppu, Ainonai, Kitami City, Hokkaido; the Kawabata formation; middle Miocene, F_3.
13. A cheek tooth stored in the Department of Geology and Minaralogy, Hokkaido University (UHR no 7430) collected by H. KIMURA and S. TAKAO from upper stream of Okoppe-zawa, Urahoro-machi, Tokachi-gun, Hokkaido; the Chokubetsu formation; Oligo-Miocene, E.
14. A cheek tooth reported by T. NAGAO and Y. SASSA from Mepp manganese mine, Imagane-cho, Setana-gun, Hokkaido; the Niseiepets agglomeratic tuff bed of the upper Kunnui Group; middle Miocene, F_3.*†
15. A cheek tooth fragment stored in the Department of Geology and Mineralogy, Hokkaido University, reported by T. NAGAO and Y. SASSA from road cutting, Ônari-mura, Kitahiyama-machi, Hutoro-gun, Hokkaido (so called Soikon); the Ogawa agglomeratic tuff bed of the upper Kunnui Group; middle Miocene, F_3.*
16. A cheek tooth stored in the Department of Geology and Mineralogy, Hokkaido University, from Maruyama colliery, Pirika manganese mine, Setana-cho, Hokkaido; base of the Yakumo formation; middle Miocene, F_3.*
17. A cheek tooth stored in the Geological and Mineralogical Institute, Tokyo University of Education (TUE-G-30430) collected by S. NAGAO from Wakamatsu manganese mine, Wakamatsu, Kitahiyama-machi, Hutorogun, Hokkaido; base of the Yakumo formation; middle Miocene, F_3.
18. A cheek tooth reported by H. MATSUMOTO from Shikonai, Nisatai, Fukuoka-cho, Ninohe-gun, Iwate Profecture; the lower Kadonosawa Group of lower Miocene, F_2.*†[1)]
19. A cheek tooth gained by K. ZIMBO and reported by H. MATSUMOTO from Yuda, Kindaichi, Ninohe-gun, Iwate Prefecture; the lower Kadonosawa Group of lower Miocene, F_2.*†
20. A small milk cheek tooth of *Desmostylella typica* collected by S. SHIMIZU from the same locality and horizon, stored in the Institute of Geology and Palaeontology, Tôhoku University (IGPS cat. no. 56701).
21. Isolated cheek teeth belonged to S. ONODERA from Ôsawada tunnel, Iwanosawa, Mashiba, Ichinoseki City, Iwate Prefecture; the upper Shimokurosawa formation of late middle Miocene, F_3.
22. A cheek tooth stored in the Saito Ho-On Kai Museum, Sendai (SHM Reg. no 21784) from Iwate Prefecture which was bought from a collector in Mizusawa City; precise locality and horizon unknown.
23. A cheek tooth fragment stored in the Saito Ho-On Kai Museum, Sendai (SHM

† Storage unknown at present.

1) According to H. YABE's personal communication, he is regarding that No. 18 specimen may be the same as No. 20 specimen.

Reg. no 7033) from Nakanoshima, Shiogama City, Miyagi Prefecture; the Ajiri bed of lower Natori Group; late early Miocene, F_2.

24. Cheek teeth stored in the Institute of Geology and Palaeontology, Tôhoku University (IGPS cat. no. 61461, 61462) collected by Y. INAI and M. SHIMAKURA from southeast of Nishizawa, Naruse-cho, Monô-gun, Miyagi Prefecture (so called Nobiru specimens); the Hamada bed of lower Natori Group: late early Miocene, F_2.
25. Four cheek teeth stored in the Mining Museum, Akita University reported by K. TAN and described by him and the writer from west of Nashinoki pass, Karuisawa or south of Ushigasawa, Tashiro, Ugo-machi, Ogachigun, Akita Prefecture; the Sugota bed of lower Ogashima Group; middle Miocene, F_3.
26. Lower jaw and isolated teeth stored in the Geological Survey, Tokyo (GSJ-F-2071) from Nagakura coal mine, Iwaki City, Fukuskima Prefecture; basal horizon of the Kamenoo shale bed of early Miocene, F_2.
27. A cheek tooth belonged to G. WATANABE from Iwaodaki, Koyabe, Isurugimachi, Nishitonami-gun, Toyama Prefecture; the Iwaodaki glauconitic tuff bed; late Miocene, G.*
28. An incisor stored in the National Science Museum, Tokyo (NSMT-P-6060) from Shitsumi, Noto-machi, Fugeshi-gun, Ishikawa Prefecture; the Shitsumi silt member of Nanao Group; middle Miocene, F_3.
29. A cheek tooth (RM) stored in the Enotomari Primary School from sea coast in Miyanoshita, Shiratori, Nanao City, Ishikawa Prefecture; the Iwori sandstone member of Higashi-bessho stage; late Miocene, G.
30. A tooth reported by S. IJIRI, S. KAMEI and Y. KASENO from Yoshitaki, Himi City, Toyama Prefecture; the Yoshitaki formation of late Miocene, G.*
31. A cheek tooth stored in the Geological Institute, Tokyo University (TUIG B) from coast of lake Shinji between Fujina and Fukutomi; the Fujina bed of upper Shinji Group; late Miocene, G.
32. A cheek tooth (L PM 4) formerly stored in the Ôgaki Museum, Ôgaki City, Gihu Prefecture and lost in the war; precise locality and horizon unknown but may be a part of the holotype.*

Geological range: Upper Oligocene (E) to upper Miocene (G); dominant in F_2-G.

Diagnosis: In fundamental construction not differing from *hesperus*. Cranium and teeth almost indistinct from those of it, but nasalia relatively larger and fronto-maxillary suture not situated anterior of fore end of jugal arch as seen in *hesperus;* outer column of third row in M^3 relatively larger and better developed in that of *hesperus*. Symphysial area of lower jaw poorer than in it and not flared upward. Radius more straight than in it.

Genus *Vanderhoofius* REINHART, 1959

1959 *Vanderhoofius* REINHART: Univ. Calif. Pub. Geol. Sci., vol. 36, no. 1, p. 90.

Type-species: *Vanderhoofius coalingensis* REINHART, 1959

Diagnosis: Mandibular symphysis heavily contructed and elongate, with narrow and poorly developed suprasymphysial depression. Globular dental capsule very prominent. Paraglossal crests rounded dorsally. One large pair of mandibular tusk (C ?). Cheek teeth unknown but probably undistinct so much from those of *Desmostylus*.

Vanderhoofius coalingensis REINHART, 1959

1959 *Vanderhoofius coalingensis* REINHART: Univ. Calif. Pub. Geol. Sci., vol. 36, no. 1, pp. 90-93, 102, fig. 16.

Holotype: Left lower jaw lacking cheek teeth and anterior part of tusk, stored in the University of Californian Museum of Paleontology (UCMP no. 39989).

Paratype: Mandible lacking angle, coronoid process, condylar region, cheek teeth and anterior part of tusks (UCMP no. 39991).

Type-locality: UCMP loc. V-4854. Bottom of Garzas Creek, Coalinga District, California.

Formation: Upper member sandstone.

Geological range: Middle Miocene.

Genus *Kronotherium* PRONINA, 1957

1957 *Kronotherium* PRONINA: Dok. Akad. Nauk. USSR, 117, pp. 21-24.

Type-species: *Kronotherium brevimaxillare* PRONINA, 1957

Diagnosis (*emended*): Lower jaw small sized, relatively thin and short. Horizontal ramus below cheek teeth less than 1.7 times higher than crown of M_2. Lower margin of horizontal ramus just before M_2 gently curved and extending downward. Cheek teeth small in size. Columns closely appressed and rather like in outline those of *Desmostylus hesperus*. Cusps 6 (?) in M_2 and 6 in M_3.

Kronotherium brevimaxillare PRONINA, 1957

1957 *Kronotherium brevimaxillare* PRONINA: Dok. Akad. Nauk. USSR, 117, pp. 21-24, figs. 2 a-c.

Holotype: Left lower jaw stored in the Zoological Institute of Academy of Science, USSR (Leningrad).

Type-locality: River cliff of a branch of the Rakitinskaya River, 0.5 km upstream from river mouth, in Kronotski Region, east coast of Kamchatka.

Formation: Base of the upper Tyushevskaya formation of Rakitinskaya member of I. B. PLESHAKOV, D. S. HESVIT and G. YA BERSON.

Referred specimens: Columns of cheek tooth reported by PLESHAKOY from Tigilski Region, Kamchatka; upper part of the Voyampolskaya formation.

Geological range: Middle Miocene (F_2) to upper of middle Miocene or base of upper Miocene (F_3).

C. Doubtful taxa

E. PFIZENMAYER, 1927 mentioned a cheek tooth of small size and irregular arrangement of enamel columns, which was once described by M. W. PAWLOWA from neighbourhood of the Balyktach River, Kotzelnyi Island of New Sibrian Ialands, under the name of *Elephas* (?) sp. (no. 14), as belonging to desmostylid of Tertiary. J. KHOMENKO in 1928 regarded its horizon as Quaternary and gave a new taxon of the name, *Neodesmostylus primigenius* for either an unknown Proboscidea or a Quaternary descendant of Desmostylia. The writer is going to regard it as a pathologic tooth of Proboscidea, because in Proboscidean tooth anomaly there is sometimes seen such an irregular aggregation of enamel columns. F. TAKAI reported a similar case of *Palaeoloxodon naumanni* from the Inland Sea of Japan. *Neodesmostylus primigenius* is not of Desmostylia, as the columns have very thin enamel wall, are arranged rather irregularly, very high like the ridges of *Mammuthus*, and tooth has no basal cingulum. It may be an anomalous tooth of *Mammuthus*.

G. K. KOENIGSWALD in 1933 proposed a new name, *Cryptomastodon martini* for the cheek teeth from the Pleistocene beds (Boemiajoe bed) of Sangiran and Patiajan in Java. He in his detailed taxonomic discussion, regarded the species as not belonging to Desmostylia but to Proboscidea although OSBORN regarded it as belonging to Sirenia, s. l., including Desmostylia. As KOENIGSWALD wrote, *Cryptomastodon* has thick cement covering many low columns, which are much tapering at grinding surface; the tooth is large sized, subquadrate and very broad; summits of unworn columns unexpose dentine islets. From these morphological characteristics and its geological horizon, the writer is inclined to regard *Cryptomastodon* as not of Desmostylia but of Proboscidea.

VIII. Distribution

A. Geological Range

Japanese *Paleoparadoxia* ranges from the upper Chichibumachi formation (F_2) to the Otogawa Group (G), while American *Paleoparadoxia* is known from the Vaqueros formation of San Clement Island to the Santa Margarita formation. According to MITCHELL and REPENNING, the Vaqueros stage is correlated with upper Aquitanian to Burdigalian (their early Miocene), and the Santa Margarita formation corresponds with Clarendonian (Sarmato-Pontian and their late Miocene) in age. Although there should be many discussion about the correlation between the East and West Pacific Tertiary stages, especially from planktonic foraminifera chronology, the writer is going to do the following correlation in this paper, mainly according to MITCHELL and REPENNING. He treates Aquitanian as basal Miocene or Oligo-Miocene. The letter stages from D to G are essentialy in accord with those of VAN DER VLERK used in Indonesia. EAMES, BANNER, BLOW and CLARK regard D as correlated with Rupelian, middle Oligocene of Europe. IKEBE adopted VAN DER VLERK's letter in Japanese Tertiary by a very conventional and useful method. After the personal communication with MITCHELL, OLMSTED in 1958 considered the *Paleoparadoxia* horizon of San Clemente Island to be middle Miocene or possibly early Miocene in age; MITCHELL regarded it as higher than the Blakely, equivalent to the Vaqueros or above it. It will be delicate problem of correlation which is older in age of the San Clemente and the upper Chichibumachi. Nowadays it may

Table 21. Tentative correlation chart of the East and West Pacific Tertiary, compiled mainly from MITCHELL and REPENNING's chart.

Basic chronology			Letter VAN DER VLERK etc.	West Pacific (Hokkaido, Japan)	East Pacific (U. S. A.) Micro-fauna	East Pacific (U. S. A.) Megafauna	East Pacific (U. S. A.) Mammal	Time 10^6 year
Pliocene		Pontian	H_1	Takikawian	Delmontian	Monterey: Neroly	Clarendonian	9.9
						Monterey: Cierbo		
Miocene	Late	Sarmatian	G	Kuromatsunaian	Mohnian	Monterey: Briones	Barstovian	15.4
Miocene	Middle	Vindovonian: Tortonian	F_3	Kawabatian	Luisian	Temblor	Hemingfordian	17.1
Miocene	Middle	Vindovonian: Helvetian			Relizian			
Miocene	Early	Burdigalian	F_2	Takinouean	Saucesian	Vaqueros	Arikareean	19.8
Miocene	Early	Burdigalian	F_1	Fukuyamian	Zemorrian			22.4
Oligo-Mioc.		Aquitanian	E	Poronaian				25.1
Oligocene		Chattian-Rupelian	D	(Nishisonogian)	Refugian	Blakely	Whitneyan	25.6 28.0

Table 22. Range chart of *Paleoparadoxia tabatai.*

	Samples / Stage	F_2	F_3	G–H
East Pacific	1. Stanford skeleton		+	
	2. UCMP 40862 (Santa Cruz)			+
	3. UCMP 32076 (Fresno County)		+	
	4. UCMP 45274 (Graham sand pit, Santa Cruz)			+
	5. UCMP 63981 („)			+
	6. LACM 4371 a–c (San Clemente Is.)		+	
West Pacific	1. Sado (holotype) (lost in Waseda Univ.)	+		
	2. Chichibu (Chichibu Museum)	+		
	3. NSMT-P-6059 (Hannoura)		+	
	4. NSMT-P-5214 (Akebi)			+
	5. NSMT-P-5601 (Izumi) (neotype)	+		

be siad that *Paleoparadoxia* appeared almost in the same stage both in the East and West Pacific.

Cornwallius sookensis and *Vanderhoofius coalingensis* are restricted in East Pacific side insofar the American and Japanese materials are studied. The Sooke formation is important as the oldest formation bearing desmostylid in the East Pacific Territory. J. W. DURHAM in 1944 correlated the Sooke formation with the *Echinophora apta* zone of the uppermost Blakeley formation. C. E. WEAVER and R. M. KLEINPELL in 1963 correlated the Sooke formation with all of the Zemorian and the lower part of Saucesian, with the type Blakeley at the top of the Zemorian. After them the Blakeley s. l. ranges from the bottom of the Zemorian to the lower one third (?) of the Saucesian. If the opinions of WEAVER and KLEINPELL is to be accepted and *Cornwallius* is found in different horizons of the Sooke formation, its range becomes so wide as to cover upper Oligocene to early Miocene. WEAVER and others in 1944 expanded the Refugian stage to include the Sooke formation and also the *E. apta* zone of DURHAM. These opinions concerning the true stratigraphical position of the Sooke formation seem to be different among authors. R. A. STIRTON conclusively wrote to the writer in his private communication, "both megafossil and microfossil correlations would indicate that the Sooke formation is upper Oligocene and can be in part, at least, equivalent to the Zemorian stage and to the entire *Echinophora apta* zone of the Blakeley formation." MITCHELL and REPENNING had a doubt if the tooth of near Nagoya might be *Cornwallius*, from photograph left by TAKAI with SAVAGE, but the specimen is that of neotype of *Paleoparadoxia* from Izumi, after the private communication with TAKAI.

It is significant that the Tyusheoskaya formation from which *Kronotherium brevimaxillare* occurred is correlated by PRONINA with the Kawabata or Temblor formations. Of the Tigilski *Kronotherium* PLESHAKOV designated the following sucession in ascending order on the Tertiary formations of Tigilski Region, Kamchatka.

Smatolskaya formation .... Eo-Oligocene
Kovachinskaya „ .... Late Oligocene

Vayampolskaya	„	(3500 m)..........	lower to middle Miocene
Kavranskaya	„	....	upper Miocene to lower Pliocene
Enemtenskaya	„	....	late Pliocene
Ettelonskaya	„	....	„

Kronotherium was found from the upper part of 500 m thick of the Vayampolskaya formation together with rich molluscan fossils. Although the writer cannot gain sufficient knowledges about the precise horizon of *Kronotherium*, it may be siad that it ranges from F_2 to F_3.

Table 23. Range chart of *Cornwallius*, *Vanderhoofius* and *Kronotherium*.

Samples \ Stage	D-E	F_{1-2}	F_3
Cornwallius sookensis			
1. LEWIS ident. (Unalaska)	+?		
2. Prov. Mus. Brit. Columb. 486 (Vancouver) (type)........	+?		
3. UC MP 32682 (Vancouver)	+?		
4. Prov. Mus. Brit. Columb. 491 (Vancouver)	+?		
5. UCMP 36078 (Baja California)	+?		
6. UCMP 36079 (Baja California)	+?		
Vanderhoofius coalingensis			
1. UCMP 39990 (Coalinga)			+
Kronotherium brevimaxillare			
1. Zool. Inst. Acad. Sci. USSR (Rakitinskaya)			+ (Tyushe-oskaya)
2. Pleshakov rep. (Tigilski, Kamchatka)....................		+ (Voyam-polskaya)	

Large parts of *Desmostylus hesperus* in East Pacific side are known from the Temblor and Briones formations. Only three exceptions (USNM 22922, 22923, USNM 22924 and REPENNING's tooth) occurred from the Vaqueros and the upper Branch Canyon formations (Clarendonian). Especially the Temblor materials are abundant and it may be said that *Desmostylus hesperus* attained its acme in the Temblor age (middle Miocene), then decreased in number in the Briones age (late Miocene) and disappeared in Clarendonian (American Pontian). Noteworthy fact is the coexistence of *Desmostylus hesperus* with primitive *Hipparion* in Clarendonian.

Desmostylus hesperus japonicus in the West Pacific side ranges from E stage (basal Miocene) to G stage (uppermost Miocene) and acquired its acme in late F_2 stage. It is most dominant in late F_2 and middle-late F_3, next distinct in G stage. It first appeared in the upper Poronaian (lower E) which is earlier than the Coalinga *hesperus* of the Vaqueros horizon. As YABE pointed out, the horizon of the Tappu shale and the Chokubetsu bed is very noteworthy as the oldest horizon of *Desmostylus*. The cheek tooth described by MATSUMOTO of the former is a fully grown adult tooth of relatively large size, while the tooth of the latter (no. 13 specimen) is a rather juvenile tooth of relatively small size. The Chokubetsu bed (=the Shiranui Series of SASSA, 1936) corresponding with the Poronai formation of Ishikari coal

Table 24. Range chart of *Desmostylus hesperus*.

Samples \ Stage	F_{1-2}	F_3	G	H
			Monterey	
	Vaqueros	Temblor	Briones	Clarendonian
0. Yale No. 11900 (Alamada County) (type) ..			+	
1. USNM 8191 (Oregon)........................			+?	
2. Condon Mus. nos. 432, 433 (Oregon)			?	
3. UCMP 32742 (Coalinga)			+?	
4. UCMP 5118-5121, 5123 (Mount Diablo Base)			+	
5. CAS (Mendocino)			+	
6. UCMP 29854, 23527 (San Pablo)			+	
7. UCMP 31813 (Contra Costa)			+	
8. AMNH 21937 (Contra Costa)			+	
9. UCMP 31522 (Mount Diablo Base)			+	
10. NORTON's tooth				
11. UCMP 21373 (Coalinga, *Merychippus* quarry)		+		
12. CAS (Fresno County)		+		
13. CAS (Phonix Canyon, Coalinga)		+		
14. UCMP 22342 (Mount Diablo Base)		+		
15. UCMP 26547 (Priest Valley)		+		
16. CAS (Lost Hill)		+		
17. UCMP (La Panza)		+		
18. YATES tooth (San Luis)			+?	
19. UCMP 32681 (Santa Barbara)			+?	
20. CAS 4401 (Bakersfield)......................		+		
21. UCMP 1056 (Santa Ana)		+		
22. CAS (Monterey Bay).......................				
23. USNM 13630-13636 (Monocline Ridge)		+		
24. UCMP 32021-32099, 32683-32692, 32694-32741, 32743-32750, 32782-32787, 32789, 32792-32794 (Monocline Ridge)		+ +		
25. CAS (Fresno County)		+		
26. USNM 8300 (Coalinga)				
27. USNM 22922, 22923 (Caliente Range)	+			
28. USNM 22925 (Cuyan Valley)		+		
29. USNM 22924 (Cuyan Valley)			+	
30. REPENING's tooth (Felton, Santa Cruz)......				+

field or the Asagai bed in Jôban coal field, Honshu. The Hacchorei hard shale formation from which the Asanai-zawa tooth (no. 7 specimen) occurred and the Poronai formation as characterized by the Asagai type molluscan fauna as follows: *Turritella tokunagai* YOKOYAMA, *Ampullina asagaiensis* MAKIYAMA, *Yoldia asagaiensis* MAKIYAMA, *Y. laudabilis* YOKOYAMA, *Venericardia laxata* YOKOYAMA, *Papiridea harrimanni* (DALL), *Clinocardium asagaiense* (MAKIYAMA), *Nemocardium iwakiense* (MAKIYAMA), *Macoma asagaiensis* MAKIYAMA, *M. sejugata* (YOKOYAMA), *Mya grewingki* MAKIYAMA, *Periploma besshoensis* (YOKOYAMA) etc. H. TAKEDA in 1953 reported many shells from the Poronai formation in which are known many borealarctic species of deep sea type (deeper than 100 f.) as *Bathybembix* (*Ginebis*) *sakhalinensis* (TAKEDA), *Trominia japonica* (TAKEDA), *Ancistrolepis modestoides* TAKEDA, *A. hokkaidoensis* HAYASAKA & UOZUMI, *Beringius hobetsuensis* (MATSUI), *Neptunea* (?) *disoar* TAKEDA, *Antiplanes rugosa* TAKEDA, *Solemya tokunagai* YOKOYAMA, *Thyasira* (*Conchocele*) *disjuncta* (GABB), etc. These mollusca indicate the ecological condition of the Okhotsk Sea, the Sea of Japan or the northern Pacific with the currents of Oyashio nowadays. The Asagaian benthonic assemblage of Honshu may indicate a temperate neritic-bathyal condition. It is differing a little from that of the Poronai sea. Be that as it may, it may be said that in early Miocene *Desmostylus* appeared in temperate to boreal sea of the Western Pacific coasts. Planktonic foraminifera is rather scanty in the Poronai formation. K. ASANO regarded the occurrence of a few *Globigerina* cf. *linaperta* FINLAY reported by H. UJIIE from the Poronai formation of Kamiashibetsu, Ishikari as an indication of Eocene in age, and confirmed the Asagai stage to Lattorfian, basal Oligocene, but for the writer it seems to be unnatural that the same unique species of mammal of such a special kind lived a long time from basal Oligocene to basal Pliocene. Some Globigerinologists of the world seem to be inclined to maintain a too self-confident attitude toward establishing a mechanical biozones

Table 25. Range chart of *Desmostylus hesperus japonicus*.

	Samples \ Stage	E	F_1	F_2	F_3	G
Saghalien	1. UHR no. 18466 (Keton)				+ (Naihoro)	
	2. USSR (Noiani-Siertunai)..........					
	3. TUIG-M-51 (Naikawa)					+ (Kurashi)
	4. URITA rep. (Sakura-zawa)........			+ (Akushu)		
	5. UHR no 18467 (Kônosu)..........			+ (Naihoro)		
	6. Saghalien Mus. (Aushi)			+ (Aushi)		
	7. UHR no. 7428 (Asanai-zawa)		+ (Hac-chorei)			
Hokkaido	8. ODA rep. (Onishibetsu)			+ (Onishi-betsu)		
	9. UHR no. 18468 (model) (Embetsu)				+ (Kotan-betsu)	
	10. UHR no. 18469 (Uryu)............			+ (Horoshin)		
	11. IGPS cat. no. 57239 (Obirashibetsu)	+ (Tappu)				
	12. UHR no. 13695 (Ainonai)				+ (Kawa-bata)	
	13. UHR no. 7430 (Okoppe-zawa)	+ (Choku-betsu)				
	14. NAGAO & SASSA rep. (Meppu) ..				+ (Nise-iepets)	
	15. UHR (Soikon)....................				+ (Ogawa)	
	16. UHR (Pirika)				+ (Basal Yakumo)	
	17. TUE-G-30430 (Wakamatsu)				+ (Basal Yakumo)	

Honsyu	18. MATSUMOTO rep. (Shikonai)					
	19. ZIMBO's tooth (Yuda)			+ (Lower Kadonosawa)		
	20. IGPS cat. no. 56701 (SHIMIZU's tooth) (Yuda)...................			+ (Lower Kadonosawa)		
	21. ONODERA's teeth (Ichinoseki)				+ (Upper Shimokurosawa)	
	22. SHM reg. no. 21784 (Iwate)					
	23. SHM reg. no. 7033 (Shiogama) ..			+ (Ajiri)		
	24. IGPS cat. no. 61461, 61462 (Nobiru)			+ (Hamada)		
	25. Akita Univ. Mus. and Z. SATO's tooth (Tashiro)				+ (Sugota)	
	26. GSJ-F-2071 (Nagakura)			+ (Kamenoo)		
	27. WATANABE's tooth (Iwaodaki) ..					+ (Iwaodaki)
	28. NSMT-P-6060 (Shitsumi)				+ (Shitsumi)	
	29. Enotomari Primary School (Shiratori)					+ (Iori)
	30. IJIRI and others rep. (Yoshitaki)					+ (Yoshitaki)
	31. TUIG B (Fujina)					+ (Fujina)
	32. Ôgaki Mus. (Gihu) (a part of holotype ?)					
	33. NSMT-P-5600 (Togari) (holotype)........................			+ (Togari)		

of Tertiary through the world without sufficient consideration for already established megafaunal chronology. *Glogigerina* cf. *linaperta* is not the same as *G. linaperta* and the samples of UJIIE are very few. These problems of contrarieties between micro- and megafossils concerning age determination of the Asagai stage are not yet solved. ASANO wrote that the Poronai sea was a kind of long bay in which the current did not enter from the open sea. Nowadays no *Desmostylus* fossils are found from E stage of Honshu. *Desmostylus* in Hokkaido and Saghalien lived in a sea of allied condition through the stages E and F_1 (Aquitanian to lower Burdigalian).

In the stage of lower F_2 (middle Burdigalian) *Desmostylus* is known from the Kamenoo bed of Jôban area, Honshu. The Kamenoo shale is thin laminated and rich in diatom, radiolaria and such deep sea mollusca as follows: *Solemya tokunagai* YOKOYAMA, *Adulomya chitanii* KANEHARA, *Nuculana pennula* (YOKOYAMA), *Malletia inermis* (YOKOYAMA), *Yoldia sagittaria* YOKOYAMA, *Y. tokunagai* YOKOYAMA, *Y.* cf. *watasei* KANEHARA, *Y.* (*Megayoldia*) *thraciaeformis* STORER, *Acila* (*Truncacila*) *eximia* (YOKOYAMA), *Polynemamussium tairanus* (YOKOYAMA), *Delectopecten tairanus* (YOKOYAMA), *Venericardia laxata* YOKOYAMA, *V. orbica* YOKOYAMA, *V. pacifica* YOKOYAMA, *Calyptogena nipponica* ÔINOMIKADO & KANEHARA, *Thyasira* (*Conchocele*) *disjuncta* (GABB), *T.* (*C.*) *inflata* YABE & NOMURA, *Lucinoma acutilineata* (CONRAD), *L. otukai* HATAI & NISHIYAMA, *Clementia* (*Conpsomyax*) sp., *Siliqua* sp., etc. *Solemya tibai* KURODA well allied to *S. tokunagai* is gained from 30-60 f., off Kashima-nada to south Hokkaido. *Calyptogena soyoae* OKUTANI very much like *C. nipponica* is known from 200-230 f. off southeast of Chôshi and 300 f. in Sagami Bay; it is a purely bathyal species. *Thyasira* (*Conchocele*) *disjuncta* is gained from the same point off Chôshi and deep sea off Kôchi Prefecture, the Japan Sea and east Hokkaido, etc. HANZAWA pointed out that the sea of Kamenoo is a kind of enclosed sea like the Baltic Sea, the Black Sea or the Caspian Sea, without distinct circulation of water. This condition is quite like that of the Poronai sea, and in the same environment the remains of Kamenoo *Desmostylus* was dropped down from surface water to deep sea bottom.

The occurrence of *Paleoparadoxia* from the upper Chichibumachi Group (the Chichibumachi formation of WATANABE, ARAI, and HAYASHI or the Hiranita formation of ARAI and KANNO) is also noteworthy. The Hiranita formation, 300 m thick, consists of alternation of conglomerate and siltstone in the lower and siltstone in the upper. *Paleoparadoxia* occurred from the upper siltstone formation. According to KANNO, the molluscan fauna of the conglomerate is characterized by tropical littoral members such as *Haliotis*, *Tegula*, *Trochus*, *Astraea*, *Cypraea* and *Conus*, etc. Also some corals are associated. On the other hand the siltstone yields some neritic members such as *Solemya gigas* KANNO, *S. tokunagai* YOKOYAMA, *Thyasira* (*Conchocele*) *disjuncta* GABB, *Macoma optiva* (YOKOYAMA), etc. KANNO regarded the assemblage as of warm water of deep sea. The Chichibu basin is very noteworthy of its thick continuous Tertiary sediments from D to F_3 stages, enclosed by Palaeozoic mountainland. WATANABE, ARAI and HAYASHI regarded the Chichibumachi formation as of the environment of bay. In general, the Hikokubo Group is correlated with the Poronai and Asagai formations and the molluscan assemblage of the Nenokami formation is of shallow neritic of warm-temperate water. Here notable fact is that nowadays no desmostylid is known from this shallow sea sediments of the stages E and F_1.

The basal part of the Kadonosawa formation in the Fukuoka District, Iwate Prefecture is named by K. CHINZEI the Tate sandstone and conglomerate member, which is 2-7 m in thickness, bears abundant fossil shells of the so called Kadonosawa fauna or the lower Kadonosawa fauna. Y. OTUKA called it *Ostrea* bed being *Ostrea gravitesta* YOKOYAMA is aggregated in it. He reported the following shells: *Cerithium atukoae* OTURA, *Euspira meisensis* MAKIYAMA, *Polinices* (*Neverita*) *fissurata* KURODA, *Fusinus* sp., *Surculites* sp., *Anadara* (*Diluvarca*) *ninohensis* (OTUKA), *Ostrea gravitesta* YOK., *Patinopecten kimurai* (YOKOYAMA), *Tapes* (*Siratoria*) *siratoriensis* OTUKA, *Clementia yazawaensis* OTUKA, *Cyclina sinensis* GMELIN, *Dosinia nomurai* OTUKA, *Macoma optiva* (YOKOYAMA), *Panope japonica* A. ADAMS. From this littoral-shallow neritic fauna of warm-temperate water, *Desmostylus* teeth of Yuda (specimen nos. 19, 20) were found. The Tate sandstone and conglomerate member grades into the Shikonai siltstone member of 30-60 m in thickness which consists of bluish grey massive siltstone and is characterized by sporadic occurrence of deep neritic to bathyal assemblage as *Turritella* (*Hataiella*) *kadonosawaensis* OTUKA, *Bittium* sp., CHINZEI, *Fulgoraria* sp. CHINZEI, *Solemya tokunagai* YOKOYAMA, *Acila* (*Truncacila*) *insignis* (GOULD), etc. CHINZEI in 1963 divided the F_2-F_3 benthonic assemblages of the Tôhoku Region into the littoral-shallow neritic Kadanosawa fauna and the deep neritic Shikonai fauna. The former corresponds with the *Nipponomarcia-Dosinia* assemblage of the Togari bed and the latter with the *Lucinoma-Cultellus* assemblage of the Yamanouchi bed in Doki basin (J. ITOIGAWA.)

The Ajiri bed of the Shiogama area, Miyagi Prefecture from which occured the *Desmostylus* tooth of Shiogama (no. 23) and the Hamada bed of Nobiru, north of Shiogama from which the Nobiru *Desmostylus* tooth (no. 24) were found, are both coeval with the Hatadate formation of the Sendai area, the geology of which as been attacked by many authors of the Tôhoku University. The typical Hatadate formation consists of alternation of tuffaceous sandstone and shale and yields many neritic mollusca such as *Epitonium yabei* NOMURA, *Ancistrolepis yanamii* KANEHARA, *Neptunea koromogawana* NOMURA, *Dentalium yokoyamai* MAKIYAMA, *Yoldia* cf. *thraciaeformis* STÖRER, *Nuculana* cf. *kongiensis* OTUKA, *Chlamys nisataiensis* OTUKA, *C. notoensis* (YOKOYOMA), *Acesta goliath* (SOWERBY), *Lucinoma acutilineata* (CONRAD), *Tapes* (*Siratoria*) *siratoriensis* OTUKA, *Macoma calcarea* GEMELIN, *M. tokyoensis* MAKIYAMA, *Thracia pertrapezoidea* NOMURA, etc. Also from the Aziri bed *Turritella s-hataii* NOMURA, *Batillaria* sp., *Chlamys notoensis* (YOKOYAMA), *Tapes* (*Siratoria*) *siratoriensis* OTUKA are known together with the Daijima flora. The Ajiri bed may be of a littoral shallow sea. Generally speaking the Ajiri-Hatadate faunae may be included in the neritic Shikonai type.

After TAN, the Ushikubo *Desmostylus* of Akita Prefecture occurred from bluish grey mudstone of the uppermost Sugota bed (=the upper Yusawa bed of WATANABE), from which WATANABE reported *Anadara* sp. aff. *satowi* DUNKER, *Patinopecten kimurai* (YOKOYAMA), *Chlamys* sp., *Cardium* (*Clinocardium*) *shinjiense* YOKOYAMA, *Venericardia* (*Cyclocardia*) *ferruginea* CLESSIN, *Dentalium* sp. and *Thyacodes* sp., etc. The *Desmostylus* bearing bed is named by him the Tonami siliceous tuff bed which carries smaller benthonic foraminifera and mollusca. According to HANZAWA, the molluscan fauna of the Sugota bed is composed of the following Kadonosawa type species: *Tugali decussatoides* NOMURA & HATAI, *Tegula* (*Chlorstoma*) *yokoyami* NOMURA & HATAI, *Euspira meisensis* (MAKIYAMA), *Natica janthostoma* DESHAYES, *Galeodea* (*Sichiheia*) *yokoyamai* (NOMURA & HATAI), *Buccinum* sp., *Glycymeris vestitoides* NOMURA, *Volsella* sp., *Ostrea gravitesta* YOKOYAMA, *Chlamys kaneharai* (YOKOYAMA), *C. protomollitus* (NOMURA), *Patinopecten kimurai agoensis* HATAI & NISHIYAMA, *P. kagamianus* (YOKOYAMA), *Cardita siogamaensis* (NOMURA), *Nemocardium adamsi* TRYON, *Dosinia kaneharai* YOKOYAMA, *Pitar itoi* (MAKIYAMA), *Venus* (*Chione*) *securis* (SCHUMARD), *Tapes* (*Siratoria*) *siratoriensis* OTUKA, *Clementia yazawaensis* OTUKA, *Soletellina minoesis* YOKOYAMA, *Panope japonica* A. ADAMS, etc. HANZAWA regarded the Sugota bed as correlated with the Nishikurosawa bed of Oga Peninsula, Akita Prefecture which yields *Miogypsina kotoi* HANZAWA and *Operculina complanata japonica* HANZAWA as sharp indicators of ecological facies. *Paleoparadoxia* of Sado was gained from bluish grey sandy shale of the Tsurushi bed which is now called the Kasatori bed by R. SUGIYAMA and S. NISHIDA of Niigata University. HATAI reported some shells such as *Anadara makiyamai* HATAI & NISHIYAMA, *Chlamys iwasakiensis* (NOMURA), *Patinopecten kimurai ugoensis* HATAI & NISIYAMA, *Crassatellites* cf. *uchidanus* YOKOYAMA, *Clinocardium shinijiense* YOKOYAMA, *Clementia vatheleti* MABILLE, *Tapes* (*Siratoria*) *siratoriensis* OTUKA, etc. This fauna also may correspond with the Kadonosawa type. HANZAWA correlates the Orito bed with

Miogypsina-Opernulina to the Nishikurosawa bed, hence the underlying Kasatori bed becomes coeval with the Akeyo formation of Doki basin or the Hiranita formation of Chichibu basin. Hence three remains of *Paleoparadoxia* from Sado, Chichibu and Doki are almost of the same geologic horizon.

In the stage of F_2 (late Burdigalian), *Desmostylus* appeared in Japan explosively. Both *Desmostylus* and *Paleoparadoxia* occurred from littoral-shallow neritic fauna of Kadonosawa type and neritic fauna of Shikonai type. They are all fragmentary teeth except the Togari *Desmostylus*, Izumi and Chichibu *Paleoparadoxia*. It may be well to keep in mind that desmostylid is preserved in the sediments of both littoral and neritic sediments. On the other hand it is not found from land fauna like the Hiramaki formation. The tropical fauna of a brackish shallow bay such as the *Vicarya—Cyclina* assemblage of the Tsukiyoshi bed or the *Telescopium—Geloina* assemblage of the Kurosedani formation, Yatsuo Group, Toyama Prefecture, does not bear desmostylid as yet. CHINZEI pointed out that the Kadonosawa fauna is more limited in distribution than the Shikonai fauna due to abundant transgression and volcanism. Insofar as this phenomena are concerned, the fact that almost equal numbers of desmostylid occurred from both faunae indicates that the former fauna was more convenient as a bringer of desmostylid fossils than the latter.

The Naihoro coal bearing formation of south Saghalien from which the *Desmostylus* of Keton (no. 1), Kônosu (no. 5) and Aushi (no. 6) occurred, is to be correlated with the Takinoue—Kawabata stages (F_2-F_3). The benthonic megafossil assemblage of this formation is as follows in Keton area: *Natica janthostoma* DESHAYES, *Neptunea* aff. *modesta* (KURODA), *Acila insignis* GOULD, *Fortipecten* aff. *takahashii* (YOKOYAMA), *Phacoides* sp., *Serripes* cf. *groenlandicus* GMELIN, *S. fujinensis* (YOKOYAMA), *Macoma dissimilis* (MARTIN), *Mya arenaria* JAY. It is allied to the Horoshin (=Haboro) bed of Uryu, Hokkaido, from which the Uryu *Desmostylus* (no. 10) was found, and regarded as the north extension of the Shikonai fauna. Although W. HASHIMOTO and KANNO pointed out that in the Takinoue stage (F_2) of Hokkaido, there were two different types of fauna, the Chikubetsu fauna of cold water and the Takinoue (Sankebetsu) fauna of warm water, it is not clear whether there was a difference of such a kind in the Kawabata stage (F_3). It is said that the Aushi oil and coal bearing bed is situated in the lower part of the Naihoro coal bearing formation, hence the horizon of Aushi and Kônosu may be lower F_2 and the horizon of Keton may be younger, perhaps F_3. The Akushu pyroclastic formation from which the Sakura-zawa *Desmostylus* (no. 4) occurred is correlated with the Noda pyroclastic formation which occupies the boundary of F_1 and F_2 This desmostylid is just succeeding the Hacchorei *Desmostylus* and coeval with the Kamenoo *Desmostylus*. W. HASHIMOTO says that the Naikawa *Desmostylus* (no. 3) reported by T. TOKUDA might be derived from the Kurashi hard shale formation of G stage.

The Niseiepets agglomeratic tuff bed from which occurred the Meppu *Desmostylus* (no. 14) and the Ogawa agglomeratic tuff bed which yielded the Soikon *Desmostylus* (no. 15) belong to the basal Yakumo formation and consist of agglomeratic tuff with some shark teeth such as *Oxyrhina* or *Carcharodon*. The Wakamatsu *Desmostylus* (no. 17) also belongs to the same horizon. According to KANNO's personal information, the manganese deposits of the Setana area, in general, occupy-

Table 27. Correlation chart of West Pacific Neogene, with reference to the desmostylid bearing formations.

Basic chronology		Saghalien: General	Saghalien: Desm.	Hokkaido: General	Hokkaido: Southwest	Hokkaido: Desm.
Early Pliocene	H_1	Shiratori Group: Maruyama f.		Kitami Series: Takikawa stage	Setana f.	
Miocene, Late	G	Shiratori Group: Kurashi hard shale f.	③	Kitami Series: Wakkanai stage	Kuromatsunai f.	
Miocene, Middle	F_3	Honto Group: Naihoro coal bearing f.	①	Teshio Series: Kawabata stage	Yakumo f.; Kunnui f.: Nise-iepetz f.	⑨ ⑫ ⑯⑰ ⑭⑮ ⑧
Miocene, Early	F_2	Honto Group: Naihoro coal bearing f.; Noda pyroclastic f.	⑤ ⑥ ④	Teshio Series: Takinoue stage: Chikubetsu subst.; Haboro subst.	Kunnui f.: Pirika f.; Kami-kunnui f.	⑩
Miocene, Early	F_1	Honto Group: Tokonbo f.; Hacchorei hard shale f.	⑦	Teshio Series: Fukuyama stage	Fukuyama f.	
Oligo-Miocene	E	Maoka Group: Aragai f.; Nishisakutan f.		Poronai Series: Momijiyama stage; Poronai Stage: Tappu subst.		⑪⑬
Oligocene	D–C	Maoka Group; Naibuchi Group: Naibuchi f.		Poronai Series: Poronai Stage: Shimokinebetsu s. s.; Ishikari Series: Ashibetsu stage		

Basic chronology	Honshu: Kitakami (CHINZEI, 1958)	Sendai (SHIBATA, 1958)	Akita (HUZIOKA, 1959)	Jôban (KAMATA, 1962 etc.)	Chichibu (KANNO, 1960)	Doki (ITOIGAWA, 1960)
H_1	Sannohe Group: Shitazaki f.; Tomesaki f.	Sendai Group: Tatsunokuchi f. (Mitaki)	Wakimoto f.			Doki f.
G	Shiratorigawa Group: Suenomatsuyama f. ㉑	Akiu Group: Shirasawa f.; Yumoto f.	Funakawa f.; Onnagawa f.	Taga f.		Mizunami Group: Oidawara f.
F_3	Shiratorigawa Group: Kadonosawa f. ⑲ ⑳	Akiu Group: Tsunaki f.; Natori Group: Hatadate f. ㉓ ㉔	Nishikurosawa f. ㉕	Shirado f.; Yunagaya Group: Misawa f.; Honya f.	Chichibumachi Group: Kami-yokoze f.; Hiranita f. $\boxed{2}$	Mizunami Group: Shukunohora f.; Akeyo F.: Yamanouchi f. $\boxed{5}$
F_2	Shiratorigawa Group: Yotsuyaku f.	Natori Group: Moniwa f. (Takatate)	Daijima f.	Yunagaya Group: Kamenoo f. ㉖	Chichibumachi Group: Saginosu f.; Nagura f.	Akeyo F.: Togari f. ㉝; Tsukiyoshi f.
F_1			Monzen f.; Akashima f.	Yunagaya Group: Mizunoya f.; Goyasu f.	Oganomachi Group: Sakurai f.; Yoshida f.; Miyato f.	Mizunami Group: Nakamura f.
E				Uchigo Group: Shirasaka f.; Asagai f.	Hikokubo Group: Nenokami f.; Ushikubi-tôge f.	
D–C				Uchigo Group: Iwaki f.	Hikokubo Group	

Basic chronology	Honshu: Sado (SUGIYAMA etc.)	Noto-Toyama (KASENO etc. 1961)	Sanin (TAI, 1957)
H_1		Yogawa Group: Ao f.	Matsue f.
G		Yogawa Group: Yoshitaki f. ㉗ ㉙ ㉚; (Fugeshi f.) $\boxed{4}$	Furue G.: Fujina f. ㉛; Ômori f.
F_3	Orito f.	Yogawa Group: Yashiro f. ㉘ $\boxed{3}$; (Nanao f.); (Minatsuki f.)	Furuura Graup: Upper Tamazukuri f.
F_2	Kasatori f. $\boxed{1}$; Suginoura f.	Noto Group: Anamizu f.; Masuho f.	Furuura Graup: Lower Tamazukuri f.; Hata f.
F_1	Aikawa f.		
E			
D–C			

Tectonic stages in N. Honshu (KITAMURA)		Megafaunal succession (KOTAKA)	Megafaunal facies (CHINZEI)		Vertebrate fauna
H_1	V	K *Turritella motidukii*	Tatsunokuchi fauna	Omma-Manganji f.	Lower Sendai fauna *Eumetopias*
G	IV	F (*Neptunea-Buccinum*)	Shiobara fauna	Yama fauna	Shinji fauna *Desmostylus-Kogia-Kurobechelys*
F_3	III	O *Turritella tanaguraensis*	Kadonosawa fauna	Shikonai fauna	
F_2	II	PO *Turritella s-hataii*			Hiramaki fauna *Dicroceros-Anchitherium*
F_1	I	(NS) (*Siphonalia prespadicea*)			Sasebo fauna *Brachyodus-Geoclemys*
E					
D					

○ *Desmostylus* □ *Paleoparadoxia*

ing a boundary between the Kunnui and Yakumo formations, are treated as a basal horizon of the latter (F_3), which is supported by N. IKEYA who is doing a geological survey of the Setana area.* KANNO regards the manganese deposits as deposits of deep sea. There are many opinions on the manganese nodules on the ocean floor. E. BONATTI and Y. R. NAYUDU in 1965 reported some deep sea manganese nodules from the depths of 1260 m (Lat. 40°23′N, Long. 127°59′W, North Pacific), 4240 m (Lat. 41°51′S, Long. 102°01′W, South Pacific) and 5500 m (Lat. 40°14′N, Long. 155°05′W. North Pacifie), etc. In general, the Yakumo formation is composed of hard shale intercalating sandy mud bed, barren of fossils except *Sagarites* cf *chitanii* MAKIYAMA. The Kaigarabashi shell sandstone in the formation, yielding *Placopecten setanensis* KUBOTA, *P. wakuyaensis* MASUDA, *Patinopecten kagamianus hokkaidoensis* KANNO, *Chlamys kumanodoensis* MASUDA, *Nanaochlamys notoensis setanaensis* KANNO and *Coptothyris grayi* (DAVIDSON), etc., is an exceptional fossiliferous member of the formation.

CHINZEI says in his private communication to the writer that the horizon of the Ichinoseki *Desmostylus* corresponds with the lower horizon of his Suenomatsuyama formation (probably upper F_3). Kurosawa—Suenomatsuyama faunae are regarded as the local facies of the Yama fauna which is a typical deep neritic or bathyal fauna of boreal water in G stage. *Ancistrolepis mogamiensis* (NOMURA & ZIMBO), *Buccinum* sp., *Neptunea eos* (KURODA), *Patinopecten yamasakii* (YOKOYAMA), *Thysira* (*Conchocele*) *disjuncta* (GABB), *Lucinoma acutilineata* (CONRAD), *Clinocardium shinjiense* (YOKOYAMA), *Cerastoderma iwakiense* NOMURA, *Serripes makiyamai* YOKOYAMA, *S. yokoyamai* OTUKA, *S. triangularis* NODA, *S. expansus* HIRAYAMA, *Panomya japonica* (A. ADAMS), etc. are known of this fauna. It is said that in the G stage so called Yama fauna widely distributed in Northern Honshu to the Sanin area with an abrupt change in oceanographical condition. T. KOTAKA mentioned the appearance of his Buccinidae—Cardiidae fauna in this stage, attributing it to its introduction from north, owing to the thermal change from F_3 (his O) to G (his F). Cold Oyashio waters became very predominant and along the Sanin—Hokuriku area desmostylid appeared a little more eminently. G stage is a horizon of the last developing phase of desmostylid in Japan.

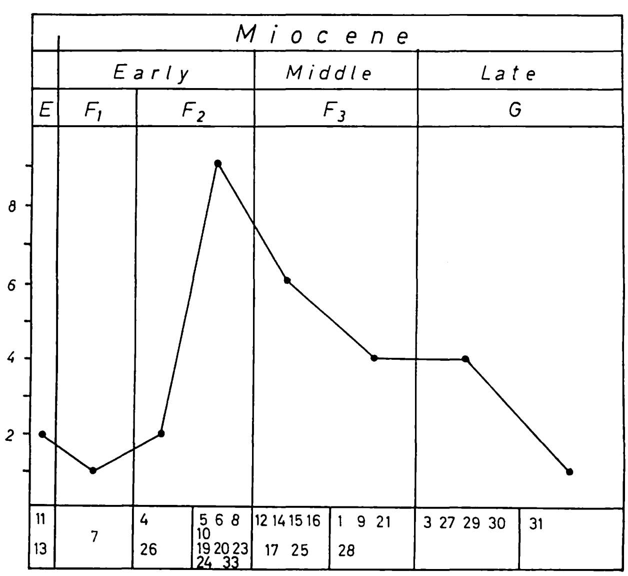
Tolerable numbers of desmostylid remains are known from the area of Noto Peninsula, Ishikawa Prefecture. The Iori sandstone bed, from which the Shiratori *Desmostylus* (no. 29) occurred, and the Iwaodaki tuff bed, from which the Iwaodaki *Desmostylus* (no. 27) occurred, are both included in the lower part of the Otogawa formation of J. MAKIYAMA, N. IKEBE, K. HUJITA and NAKAGAWA, 1949 which consists mainly of sandstone and siltstone, with many neritic shells such as *Turritella motidukii* OTUKA. *Phos iwakianus* (YOKOYAMA), *Anadara amicula* (YOKOYAMA), *Glycymeris crassa* KURODA, *Gloripallium crassivenium* (YOKAYAMA), *Patinopecten kagamianus* (YOKOYAMA), *Nanaochlamys notoensis* (YOKOYAMA), *Thyasira* (*Conchocele*) *disjuncta* GABB, *Dosinia kaneharia* YOKOYAMA, *Mya cuneiformis* BORN, etc. Also *Epistominella pulchella* assemblage and *Martinotiella communis* assemblage are recorded. Otogawa

* T. NAGAO and Y. SASSA in 1933 treated the Niseiepets agglomeratic tuff bed and Ogawa agglomeratic tuff bed as an upper part of the Kunnui formation. This view was supported by K. HATAI, 1960.

fauna belonging to G stage may be a southwestern facies of the Yama—Suenomatsuyama faunae. The Shitsumi mudstone bed from which the Shitsumi *Desmostylus* (no. 28) occurred occupies the middle part of the Yogawa formation. The Yoshitaki formation which yielded the Yoshitakai *Desmostylus* (no. 30) is of G stage and the Nanao formation which bore the Hannoura *Paleoparadoxia* is late F_3 stage. In general, it may be a characteristic that the Neogene of the Ishikawa—Toyama area is complicately splitted and nominated by different methods, bringing useless confusion.

The Fujina bed developed in the southwestern vicinity of Matsue City, Shimane Prefecture consists of tuffaceous sandstone and from it occurred the Fujina *Desmostylus* (no. 31). The bed bears many shells such as *Turritella motidukii* OTUKA, *Galeodea* (*Sichiheia*) *japonica* YOKOYAMA, *Portlandia* (*Megayoldia*) *gratiosa* (YOKOYAMA), *Patinopecten kagamianus* (YOKOYAMA), *Clinocardium shinjiense* (YOKOYAMA), *Serripes fujinensis* (YOKOYAMA), *S.* cf. *groenlandicus* (BRUG), *Mercenaria yokoyamai* (MAKIYAMA), *Macoma optiva* (YOKOYAMA), *Phaxas izumoensis* (YOKOYAMA), etc., indicating a neritic assemblage of cold water which may be an extension of the Yama fauna or the Buccinidae—Cardiidae assemblage of KOTAKA. According to Y. TAI, 1961 the foraminifera assemblage of his Fujina stage is characterized by Buliminidae, Lituolidae, Cassidulinidae, Nonionidae and Anomaliidae, etc., corresponding with the *Epistominella pulcnella—Martinotiella communis* assemblage of the Otogawa or Yogawa formations of G stage. As KASENO in 1964 pointed out it is clear that the desmostylid horizon of the Hokuriku—Sanin area is younger than that of the Pacific side of Honshu. In G stage of the area just mentioned desmostylid appeared along the coast of Yama Sea and preserved in a deep benthonic fauna. Also the notable fact is that from the littoral—shallow neritic fauna of Shiobara type of G stage desmostylid is not known.

Table 26. Numerical range of *Desmotylus hesperus japonicus*. The numbers indicate the numbers of localities.



Be that as it may, the acme of *Desmostylus hesperus japonicus* lies in F_2 which is earlier than that of *D. hesperus* in the East Pacific Territory (F_3). Also *japonicus* appears earlier than *hesperus*, so it may be said that *Desmostylus* migrated from West Pacific to East Pacific Territory. *Desmostylus hesperus japonicus* begins explosively and attains its acme in late F_2, abruptly decreased in number in lower F_3, retains more or less vigorous stage in upper F_3 and becomes extinct in the end of G. Some of its remains are preserved in littoral to shallow neritic deposits of F_2, but larger parts of them are gained from the inland sea or the long bay of Kamenoo, Chichibu or Doki types.

Cornwallius is found only from the late Oligocene of the East Pacific Territory and *Paleoparadoxia* first appeared in F_2 of the West Pacific Territory. The acme of it lies in F_3-G in the both territories.

B. Geographical Distribution

In the West Pacific Territory, the northern limit of *Desmostylus* distribution is Noiani-Siertunai, North Saghalien (Lat. 52°25′N, Long. 142°08′E), the southern limit of it is Bôgahora, Togari, Mizunami City (Lat. 35°21′45″N, Long. 137°14′39″E) and the western limit of it is Fujina, Shimane Prefecture (Lat. 35°28′30″N, Long. 133°E). It occurs more commonly in the area of northern Honshu to Saghalien than in any other area. The northern limit of *Paleoparadoxia* is Nakayama pass, Sado Island (Lat. 38°08′48″N, Long. 138°15′10″E) and the southern limit of it is Inkyoyama, Izumi-machi, Doki City (Lat. 35°21′45″N, Long. 137°10′40″E). Distribution of *Paleoparadoxia* is more limited than that of *Desmostylus*.

In the East Pacific Territory the northern limit of *Desmostylus* distrubution is Yaquina Bay, Oregon (Lat. 46°26′24″N, Long. 123°40′ (?) W) and the southern limit of it is Santa Ana, Southern California (Lat. 33°42′N, Long. 117°48′W). *Desmostylus* numerously occurs from the San Francisco and Temblor area between Lat. 36° and 38°N. The distribution of *Paleoparadoxia* in California is also more restricted than that of *Desmostylus*; it is mainly reported from the Santa Cruz area, south of San Francisco. *Vanderhoofius* is more local in its distribution but *Cornwallius* occurs more widely than *Desmostylus*. It ranges from Unalaska Is., Aleutian Islands (Lat. 53°42′N, Long. 167°12′W) to Lower California, Mexico (Lat. 25°20′N, Long. 111°W).

The sea area of the West Pacific Territory between Lat. 52°N and Lat. 35°N is nowadays under the influence of cold Oyashio current and the northern part of it belongs to the Northwest Pacific Arctic Region, and the southern part of it is treated as a warm-temperate region (Kushiro—Sanriku area). Northern Honshu north of the Cape Inubo and the coast of the Japan Sea are called a warm-temperate sea coast. Of course the oceanographical condition of the West Pacific Territory between Lat. 52°N and Lat. 35°N during Miocene was different from that of today. K. Hatai in 1960 wrote as follows about this problem: "From the view that the known desmostylids are restricted in their distribution to the borderland of the North Pacific north of 33° North latitude, lead some authors (F. Takai, 1939; K. Watanabe, 1953) to claim that it must represent a northern type of animal, and that its migration into southern area is indicative of the southward extension of cold thermal waters (S. HANZAWA, 1950). However, from the fossils occurring in association with it, in strata comformably above or below and from the general acceptance that all mammals originated in tropical regions but later became adapted to the conditions gradually changing with time to be separated at present into aquatic mammals of different distributions, there seems to be no conclusive evidence for considering the desmostylids to be a northern habitant in thermal sense. The conditions in the North Pacific area during the Miocene are deemed to have been uniform and warm from paleontological evidence." He preferred to use the terms Togarian and Hiramakian for the warm stage of marine and land Miocene of Japan. At least subtropical littoral faunae of *Vicarya* or *Telescopium—Geloina* are known from the Tsukiyoshi bed (lower F_2), the Kurosedani formation and the lower Bihoku Group of the Tsuyama area, Okayama Prefecture (lower F_3), but nowadays we do not know the occurrence of desmostylid from these faunae. As stated in the above lines, the desmostylid of F_2—F_3 in Japan are found from the Kadonosawa—Togari type fauna of warm—temperate littoral or shallow neritic water or from the Shikonai—Yamanouchi type fauna of temperate neritic or bathyal water. In the stage of (E—F_1) and (upper F_3—G), desmostylids are likely to be preserved in deep sea benthonic faunae of cold water. Although desmostylid is a North Pacific animal of amphibious habit, it is neither a pure boreal nor arctic animal. It might not be a merely pure subtropic animal either.

It may be significant that desmostylid is mainly distributed in Lat. 52°N—Lat. 35°N of the West Pacific Territory and Lat. 46°N—Lat. 33°N of the East Pacific Territory. The sea area of the latter is nowadays a subtropical area (Californian area). According to J. P. SMITH the molluscan fauna of Vaqueros is called *Turritella inezana* fauna, characterized by *Pecten magnolia*, *P. sespensis* and *Scutella fairbanksi*, composed mainly of *Turritella*, *Rapana*, *Lyropecten*, *Dosinia* and *Chione*, etc. and that it indicates littoral fauna of tropical to subtropical waters. The Temblor molluscan fauna is called *Turritella ocayana* fauna, composed mainly of *Turritella*, *Ficus*, *Trophon*, *Conus*, *Arca*, *Lyropecten*, *Pecten*, *Dosinia* and *Chione*, etc. and indicates tropical to subtropical waters which is warmer than the recent water of southern California. After C. A. REPENNING and J. C. VEDDER, Vaqueros molluscan assemblage (V_3) of eastern Caliente Range is composed mainly of *Turritella inezana* CONRAD, *Rapana vaquerosensis* (ARNOLD) and *Lyropecten magnolia* (ARNOLD), etc. and Temblor (T_3) is shown by *Ficus* (*Trophosycon*) *ocayana* (CONRAD), *Kelletia posoensis* (ANDERSON & MARTIN), *Macron merriami* ARNOLD, "*Phos*" *dumbleanus* ANDERSON, *Oliva california* ANDERSON, *Conus owenianus* ANDERSON, *Megasurcula keepi* (ARNOLD), *Anadara osmonti* (DALL), *Saccella osmonti* (DALL), *Aequipecten andersoni* (ARNOLD), *Chione temblorensis* (ANDERSON), *C. panzana* ANDERSON and MARTIN, etc. Associated with Temblor *Desmostylus*, some land mammals are known as follows: *Amphicyon* aff. *frendens* MATTHEW, *Archaeohippus ultimus* (COPE), *Parahippus* sp., *Meryhippus carrizoensis* DOUGHERTY, *M.* cf. *seversus* (COPE), *Hesperhys vagrans* DOUGLAS, *Prosthennops* (?) sp., *Tricholeptus calimontanus* (DOUGHERTY), Camelid, *Dromomeryx* (?) sp., *Pseudaelurus* sp., etc. R. D. REED and J. S. HOLLISTER wrote that the Vaqueros and Temblor seas were a large embayment with warm littoral water and deep cold water. The Briones—Neroly (S^3) sea has molluscan assemblage of *Turritella car-*

rioaensis padronensis GRANT & EATON, *Siphonalia danvillensis* CLARK and *Lyropecten* cf. *estrellanus* (CONRAD), etc. which is different from the Temblor molluscan assemblage. The geoflora of that age was composed of hard grasses of plain type. R. M. KLEINPELL regarded the foraminifera of the Monterey formation as indicating a shallower and cooler condition than during Temblor time. Among mollusca, *Astrodapsis, Tamiosoma gregaria, Trophon ponderosum, Pecten estrellanus, Ostrea titan,* etc. are known. Transgression was much more progressed during the Monterey than Temblor times. The oceanographical conditions during middle to late Miocene were rather allied to each other between the East and the West Pacific Territories of at least between Lat. 35°N-46°N. R. D. REED and J. S. HOLLISTER mentioned H. G. SCHENCK's opinion that the mollusks and foraminifera of the California Miocene belong to a fauna that may prove to be world-wide.

IX. PALAEOECOLOGY

The Neogene geoflora of Japan has been described and discussed by different authors such as R. W. CHANEY, S. ENDO, K. HUZIOKA, S. MIKI, H. OKUTSU, M. SHIMAKURA, K. SUZUKI, N. SUZUKI, K. TAKAHASHI, T. TANAI, S. TOKUNAGA, etc. HUZIOKA in 1944-63 distinguished the Aniai and Daizima (=Utto) florae in the Japanese Miocene geoflora. The former is principally known from F_1 of northern Honshu and indicates a temperate or cool-temperate climate as seen in central to northern China or in northern Japan; annual mean temperature is below 10°C and annual precipitation is below 1500 mm; in summer the climate is somewhat wet, while in winter slightly dry and frequently snowy. *Metasequoia* and *Glyptostrobus* are abundant in the flora. HUZIOKA regards this flora as having derived from the Arcto-Tertiary flora. The Daijima flora is first established in F_2—F_3 stage of northern Honshu and indicates a warm temperate climate with subtropical plants; annual mean temperature and precipitation exceed 20°C and 1500 mm respectively. The flora is closely similar to the present lowland vegetation of central southern China or of Formosa. Desmostylid associates with this type flora in Uryu, Hokkaido, Hatatate of Sendai, and Doki basin, etc. TANAI in 1961 furthermore added Ainoura on pre-Daijima and Mitoku on post-Daijima florae. Ainoura flora is known from E stage of north Kyushu and a few beds of Honshu. It indicates a warm-temperate and somewhat humid climate as shown by the lowland vegetation of southern to central china. The Mitoku flora of late F_3 and G stages is similar to the present flora of central to southern Japan and indicates a temperate climate with comparatively well distributed precipitation. Subtropical elements are reduced while conifers and hardwoods are increased. The annual temperature of the Mitoku flora was lower than that of the Daijima flora. TANAI pointed out that warm-temperate and cold-temperate florae appeared in alternate succession during the Japanese Miocene. The following sequence of desmostylid and flora may be recognized in descending order. Here the noteworthy fact is that desmostylid was at least closely associated with the Daijima type flora and that its coexistence with the Aniai—Mitoku florae is not to be denied. This means that desmostylid (a same species of *Desmostylus*) has no intimate relationship with land plant. Here it also should be kept in mind that two allied subspecies of a same species of *Desmostylus* lived independently from each other along a tolerably different geoflora of Daijima and Temblor. The writer is confident that desmostylid lived on sea coast of warm-temperate climate at least during its acme stage of F_2—F_3. Hitherto in the West Pacific Territory, no desmostylid remains have been found from non-marine formations. Even from the mammal fauna of the Hiramaki formation it does not occur. For this reason he regards desmostylid as a semiaquatic or amphibious animal of sea coast.

Furthermore he is inclined to assume that desmostylid mainly ate sea weed as seen in Sirenia. Its niche was very near to that of Sirenia or *Latax*, and it might have eaten some benthonic animals. As stated in the above lines of kinetics, *Paleo-*

Table 28. Sequence of desmostylids in association with different types of flora in the West Pacific Territory.

	Distribution of desmostylid	Sea condition	Geoflora	Climatic condition
G	Sanin-Hokuriku	Boreal (deep neritic) Yama Sea	Mitoku flora	Temperate
Up. F_3	Hokkaido-North Honshu	Yakumo-Kurosawa fauna (deep neritic)	?	
Low. F_3 F_2	Saghalien — Central Honshu	Warm-temperate (littoral to neritic) Kadonosawa-Togari Shikonai-Yamanouchi	Daijima flora	Warm-temperate (subtropic)
F_1	Saghalien	Boreal ? (deep neritic)	Aniai flora	Cold-temperate
E	Hokkaido	Boreal (deep neritic) Poronai Sea	(Ainoura flora) ?	? Warm-temperate

paradoxia scooped mud sliding on sea bottom near shore, looking for algae, water plant of some benthonic animal as bivalves, annelida or crustacea. *Desmostylus* probably had a like habit. Like Suina, desmostylid seems to have been an omnivorous animal rather than a pure hervivorous one. It is said that the hervivorous character is not denied from the microstructure of teeth. Because *Desmostylus* has more hypsodont teeth than *Paleoparadoxia* does, its food might be a little different from that of the latter. It might have eaten some harder materials compared with those of *Paleoparadoxia*. The adaptive zone of them might be a little differentiated.

The fact that desmostylid isolated teeth are often found from deep neritic to bathyal benthonic fauna may be explained from the possibility that desmostylid could swim in surface water like some suina* and it dropped its teeth on sea bottom. Fragmental bones are not so often found as isolated teeth. But we often see unworn cheek teeth of the isolated teeth, and this is not due to the natural dropping from living swimmer. It may be rather accepted that hard materials as teeth are dropped from cadabel floating on sea surface, which are attacked by shark or the other carnivorous fishes. Such a case must have happened frequently in an inland sea or a long bay, because cadabel is not carried away to open sea by rapid current. Transportation from coastal area by undercurrent is excluded because there are not found pebbles or the other allochthonous littoral fossils associated with desmostylid teeth. We cannot see any megafossils besides shark teeth in the manganese bed bearing desmostylid (nos. 14-17) in the Setana area, Hokkaido.

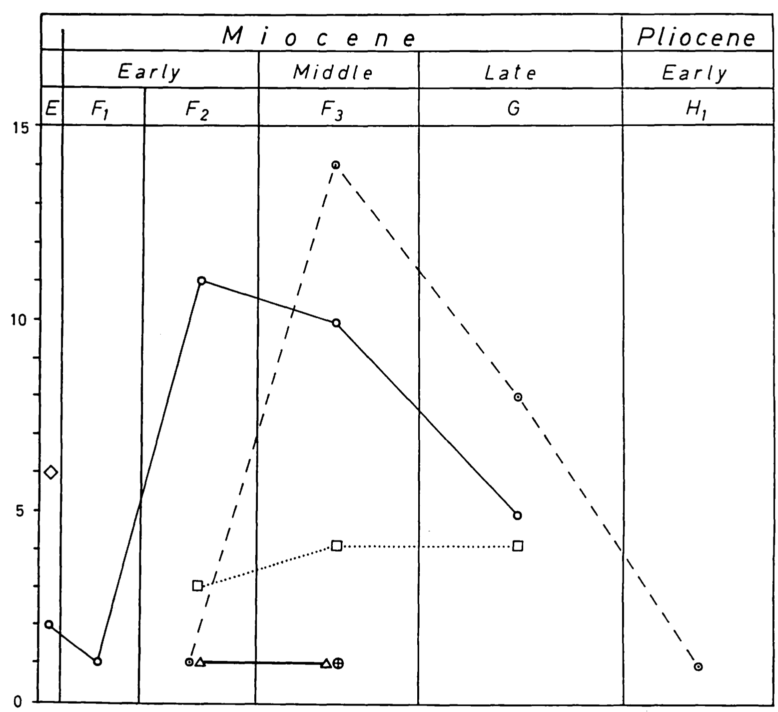
* Interesting lines are seen in "Chubu-Nippon Shinbun", a news paper dated Nov. 1, 1947, which runs as follows: a wild boar was captured on sea. At 10 am. on Oct. 30, Mr. FUKUDA, K. and the other two fishermen found an animal swimming at a very high speed on sea of about 6 km off Kosugai, Chita-gun, Aichi Prefecture. They chased it in a motorboat and killed it drubbing on its head. They were astonished seeing that it was a large sized boar of 15-16 Kan (1 Kan=3.75 Kgr) in weight. The point is situated in the middle of Ise Bay.

X. Evolution

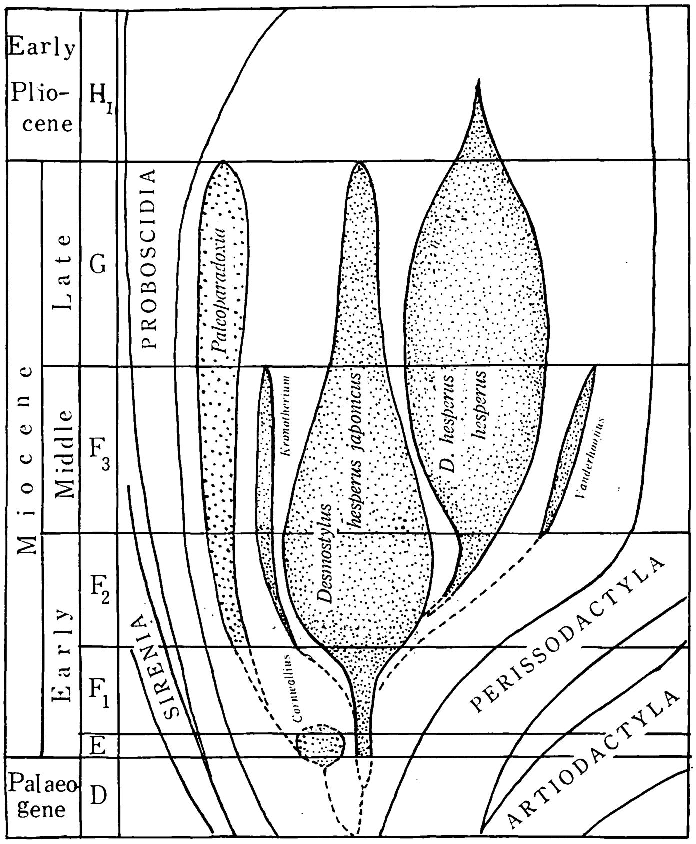
A. Phylogeny

As stated in the lines of distribution, it is an interesting fact that archaic *Cornwallius* and a more advanced *Desmostylus hesperus japonicus* were coeval in the stage E (Aquitanian). Cornwalliidae and Desmostylidae started their evolutionary courses at the same time as basal Miocene or Oligo-Miocene. Nowadays we have no record of Eo-Oligocene desmostylid fossils; perhaps they might have sprung up in pre late Oligocene. Cornwalliidae represented by *Cornwallius* and *Paleoparadoxia* are an archaic lineage, while Desmostylidae represented by *Desmostylus*, *Vanderhoofius* and *Kronotheriim* are an advanced lineage, but as to which is a mother lineage is precisely unknown. Being a side branch sprung from it, the latter may be a mother lineage. *Desmostylus hesperus japonicus* is a bradytelic species. It acquired an existence of about 15.6×10^6 years during Miocene. *Desmostylus* far exceeded *Paleoparadoxia* in number. *Cornwallius*, *Kronotherium* and *Vanderhoofius* are holotelic representatives; *Cornwallius* appeared in the young stage of Desmostylia and the other two in the mature stage of it. *Desmostylus* developed explosively in the stage of F_2 and F_3, which is the acme and mature stage of it. *Desmostylus hesperus*

Table 29. Numerical range of desmostylids.



◊ *Cornwallius*
□ *Paleoparadoxia*
○ *Desmostylus hesperus japonicus*
⊙ *Desmostylus hesperus hesperus*
⊕ *Vanderoosfius*
△ *Kronotherium*



Textfig. 116. Phylogeny of Desmostylia.

japonicus appeared earlier than *D. hesperus hesperus* and the latter survived until a later time. Desmostylid disappeared entirely in early Pliocene (H_1). The adaptive zone of desmostylid type animals closed in early Pliocene or has since remained opening without occupants.

The developing stages of desmosylid may be arranged as follows:

Embryonal stage: Fossils unknown. Unique stock of undifferentiated mother lineage with no distinct specialization as desmostylid. Preadaptation stage but with characteristics as Desmostylia. Palaeogene.

Young stage: Cornwalliidae and Desmostylidae differentiated but very small in number. A kind of typogenesis. Aquired desmostylian adaptive zone. Oligo-Miocene or basal Miocene (E-F_1).

Mature stage: *Desmostylus* explosively developed. Acme of Desmostylia with balanced occupation of adaptive zone. Only two subspecies of *Desmostylus* and a minute daughter lineage of *Vanderhoofius* and *Kronotherium*. Late early to middle Miocene (F_2-F_3).

Old stage: Gradual regression with no new appearance of taxa and extinction. Late Miocene and basal Pliocene (G-H_1).

Desmostylia are a very scanty or poor taxon as an order; it has only two families, five genera, five species and one subspecies. This unique and special order is isolated taxonomically, but occupies an intermediate position among Perissodactyla, Proboscidea, Sirenia and Artiodactyla, retaining some allied characteristics with Astrapotheria, Notoungulata, Embrithopoda and Dinocerata, etc. W. D. MATTHEW and A. ROMER indicated a phylogenetic chart of mammalian orders. They regarded the first appearance of Perissodactyla and Artiodactyla at the base of Eocene. Proboscidea can be traced back to the upper- and Sirenia to the middle Eocene. Hence, the first appearance of Desmostylia may date back to basal Eocene or Palaeocene. The embryonal stage of the order is very long, occupying about 34×10^6 years or more in time duration.

B. Migration and Starting Area

Concerning the migration problem of Desmostylia, it is very important fact that neither Proboscidea did appear in the Palaeogene of North America nor did Proboscidea and Sirenia in that of East Asia. In the Eocene of Afro-Europe, Proboscidea and Sirenia appeared associated with archaic Perissodactyla and Artiodactyla. Hence it is most probable that Desmostylia were born in Afro-Europe. *Halianassa* of Sirenia migrated from Afro-Europe to North America via the West Indies. But amphibious land mammal like Desmostylia may be rather distinct from pure aquatic mammal like *Halianassa* in its mode of migration. I. RUSSELL pointed out that the Bering land bridge existed in late Palaeocene to Eocene, late Eocene to early Oligocene, late Miocene, early Pliocene and middle Pleistocene from the viewpoints of tectonic movements of North America. Desmostylid might have migrated through the Bering Strait between North America and East Asia, even if the Bering land bridge had not existed, because it was a semiaquatic or amphibious animal. At least in early Miocene (late F_1) *Paleoparadoxia* and *Desmostylus* migrated from East Asia to North America. So that the stages of Bering land connection has no direct relationship with the desmostylid migration between the East and West Pacific Territories. *Anchitherium hypohippoides* MATSUMOTO of the Hiramaki fauna may be treated as a Holoearctic element migrated from Bering land bridge or directly from North China, differing from the other Hiramakian elements of Gaj—Lower Siwalik type. If the Bering land bridge had played an important role in the migration of this Japanese *Anchitherium*, its migration stage might have had a close relationship with those of *Paleoparadoxia* and *Desmostylus* in early Miocene (F_1).

In Oligo-Miocene (E) *Desmostylus* was already living in the North Pacific Region. From the starting area of Afro-Europe to North Pacific, which one was selected by desmostylid of the courses Indo-Pacific and Afro-Europe to North America? The writer is inclined to assume that desmostylid selected the former course, from the ecological view point, although we have no fossil records from the Indo-Pacific Palaeogene. Desmostylid might intrude the North Pacific Region immediately along the northern coast of the Tethys Sea. Palaeo-equatorial and Palaeo-Kuroshio currents perhaps helped the rapid eastward and northward migration of desmostylid. Plant has also the same type of distribution in the North Pacific Region as seen in *Sequoia, Osmorhiza* and *Torreya*, but in these cases there were another type of migration throughout the Holaearctic continent. As shown by the distribution of *Liriodendron* and *Liquidambar* (East Asia and Atlantic coast of North America), the influence of the Arcto-Tertiary geoflora was unnegligible. In Japan desmostylid had no close relationship with the Aniai- and Daijima geoflorae, the latter of which had rather intimate contact with the Hiramaki land mammals of Siwalik types.

C. Adaptive Zone and Isolation

In Palaeogene, the ancestral form of desmostylid arrived the North Pacific Region probobly via the northern coast of the Tethys Sea, and in Oligo-Miocene (E) *Cornwallius* appeared in the East Pacific and *Desmostylus* in West Pacific Territory. Desmostylid was mainly distributed in Lat. 52° N-35° N of West Pacific and Lat. 46° N-25° N of East Pacific. These areas may be called a desmostylid belt. Desmostylids lived in a subtropical to warm-temperate littoral sea and its coast as amphibous hervivorous to omnivorous animals. They ate principally soft materials of algae, waterplant and some benthonic animals like mollusca, crustacea or annelide, etc. They liked an inland sea, long bay or lagoon which might have some relationship with desmostylid food and protected it from direct influence of the open sea.

Desmostylids extend northward from the desmostylid belt to Kamchatka and Alaska, Lat. about 60° N, but does not do so southward. They are not known from the Tertiary of South Kyushu, Tane Island, Taiwan, the Philippines, Indonesia, etc. Desmostylids are rather different from *Vicarya* and *Dugong* in distribution pattern. They are not Indo-Pacific but North Pacific animals, although they are warm-temperate or subtropic sea coast dwellers.

V. B. SCHEFFER pointed out that many of marine mammals lost the ability to adjust readily to extreme temperatures, may suffer when they change and that most of them live in cool water. Of course semiaquatic or amphibious desmostylids may not be the same pure marine mammals in these habits, but have allied characteristics. Desmostylids were neither tropical nor boreal animals. They might be stenohaline or a little stenothermal littoral animals of amphibious habit. The subtropic sea of Japan south of Lat. 35°43′ N (off Chôshi, Chiba Prefecture) has surface water of 11°-17° C in February and 20°-25° C in August nowadays. The temperature of surface water in August is not so different nowadays of the East Pacific Territory of North America; it is 15° C off Lower California, 13°-16° C in San Francisco, 16° C off Washington and 14° C off South Alaska; i. e. surface water temeperature of the same latitude is higher in the West Pacific than in the East Pacific Territories of North Hemisphere. This state of the ocean might be seen in Miocene under the influence of Palaeo-Kuroshio current circulation. The warm-temperate condition of surface water, as seen off the coast of San Francisco nowadays, might be seen along Aleutian, Kamchaka, Kurile, Saghalien and Hokkaido in Miocene. If the Bering Strait had been open during Miocene, a cold current might have flowed southward along the West Pacific Territory, hence the warm surface water and the deep cold water might have been seen as can be seen in the Sea of

Japan nowadays. According to H. U. SWERDRUP, M. W. JOHNSON and R. H. FLEMING, a distinct thermocline is seen on the very near sea surface off South California. Temperature and salinity abruptly change on the thermocline. Be that as it may, the desmostylid belt had a special condition of sea water with thermocline lying very near the sea surface. Desmostylid food plant and animals might be influenced by this thermocline. It could not intrude southward because of these controlled oceanographical conditions. Once the ancester of desmostylid migrated into the North Pacific Territory, and its descendant acquired its adaptive zone, it was isolated from the other oceans. In the Atlantic Ocean, the desmostylian ancestor started in Afro-Europe had no successful descendant.

In the East Pacific Territory desmostylids associated with Sirenia such as *Halianassa vanderhoofi* REINHART which did come from Afro-Europe via Caribbean Sea, but in the West Pacific Territory no Sirenia associated with desmostylids. Adaptive zone of desmostylids was in contact with that of Sirenia in the East Pacific Territory, but isolated in the West Pacific Territory. The food plants might be different between Sirenia and Desmostylia. The adaptive zone of desmostylids was divided into *Desmostylus* subzone and *Paleoparadoxia* subzone; the latter was a browsing and omnivorous subzone and the former was a little advanced for grazing. *Desmostylus* subzone was more powerful than *Paleoparadoxia* one. The adaptive peak of *Desmostylus* was higher and more acutely sloped than that of *Paleoparadoxia*. The population of the former was far larger than that of the latter.

D. Acceleration and Extinction

Order Desmostylia are a scanty, unpowerful and isolated taxon like Astrapotheria, Tublidentata, Dinocerata, Pyrotheria, Hyracoidea and Embrithopoda, etc. It is not so much developed as Sirenia but more powerful than Embrithopoda or Tublidentata. It discharged only five genera, five species and one subspecies and is very low in evolution rate.

Table 30. Survivorship of genera in Desmostylia.

Desmostylus	19.6×10^{6} years
Paleoparadoxia	12.4 "
Kronotherium	7.0 "
Vanderhoofius	4.4 "
Cornwallius	0.5 "
Mean	8.78

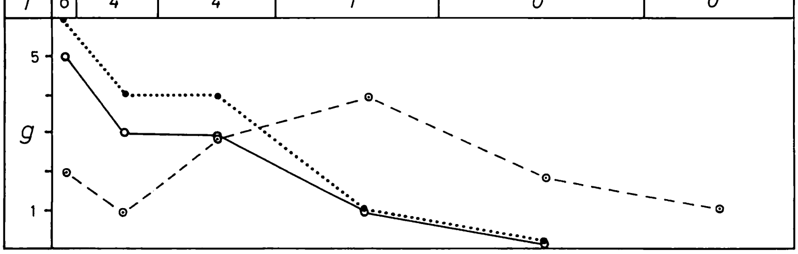
Rate of origination, the newly appeared generic numbers during one millon years, is 0.85 and rate of disappearance, the disappeared generic numbers during one million years, is 0.24 i. e. both are much lower than those of Carnivora, in Miocene. Mean survivorship of genera is 8.78×10^{6} years in Desmostylia which is longer than that of land Carnivora (6.5×10^{6} years). The taxa of Desmostylia were richest in middle Miocene (F_3), next in late early Miocene (F_2) and became rather poor in early- and late Miocene (F_1, G). The taxonomic rate of Desmostylia is very low. The potential coefficient of genera is 5 in E, then 3 in F_1, 1 in F_3 and becomes O in G. Those of species is 6 in E, then 4 in F_1, 1 in F_3 and O in G. Thus their coefficient gradually decreased as stages become new, and the curve of potential coefficient more acute early than later. The specific potential coefficent curve crosses the curve of specific numbers on the point in F_2 which corresponds with the explosive development of individual numbers of Desmostylia.

There is no evolution from species to species as seen in the equine phylogeny. In the case of Desmostylia, there is seen no distinct morphological or numerical differences. About individual variation or vertical changing of anatomical elements of *Desmostylus*, we have no sufficient materials except isolated teeth. Here it should be kept in mind that *Desmostylus hesperus japonicus* had a fully developed cheek teeth in size and shape from its first appearance as shown by the Obirashibetsu tooth of the Tappu shale (E). There was seen no remarkable accelation of adaptation in the adaptive zone of *Desmostylus*. It is very difficult to do a statistical or numerical researches on the morphological rate of Desmostylia.

What caused Desmostylia to become extinct in the early Pliocene ? It may be assumed that its adaptive zone was closed by some abrupt change in oceanographical conditions (for instance, change in thermocline, surface water temperature, salinity and extinction of the food of Desmostylia, etc.) because Desmostylia had no powerful enemy or survival competitors. Of course long survivorship and much decreased potential energy of gen might be principal factors against its extinction.

Table 31. Generic numbers of Desmostylia in each geologic stages and potential decreasing curve of genera and species.

a	Miocene					Pliocene
		Early		Middle	Late	Early
	E	F_1	F_2	F_3	G	H_1
b	25.1 25.6	23.0	19.8	15.4	10.0	6.0
c	2+0	0 + 1	2 + 1	1 + 3	0 + 2	0 + 1
d	2+0	0 + 1	3 + 1	1 + 4	0 + 3	0 + 1
e	5	3	3	1	0	0
f	6	4	4	1	0	0



●···● Dotted line: Potential decreasing curve of species
○—○ Solid line: Ditto of genera
⊙ - ⊙ Broken line indicating numbers of genera
a: Geologic age. b: Absolute time. c: Generic number. (already appeared on left, newly appeared on right). d: Specific number. e: Potential coefficient of genera. f: Ditto of species. g: Decreasing curve.

XI. CONCLUSION

The Keton desmostylid which was found in 1933 by NAGAO, OISHI and others from Keton, South Saghalien, mounted provisionally and named as *Desmostylus mirabilis* by NAGAO and is now kept in the Department of Geology and Mineralogy, Hokkaido University (UHR no 18466) belongs, the writer thinks, to *Desmostylus hesperus japonicus* TOKUNAGA & IWASAKI. The Izumi desmostylid which was found in 1950 by TOMATSU and AZUMA from Inkyoyama hill, Izumi-machi, Gihu Prefecture, and is now kept in the National Science Museum in Tokyo (NSMT-P-5601) has been selected here by the writer as the neotype of *Paleoparadoqia tabatai* (TOKUNAGA). The postcranial skeleton except vertebrae, costae, scapula and pelvis of them is described here. The Keton *Desmostylus* occurred from the Naihoro coal bearing formation of early Miocene (F_2) and the Izumi *Paleoparadoxia* from the Yamanouchi bed of Akeyo formation of the same horizon.

1. The Keton skeleton was preserved in a nodule of hard calcareous shale. Larger parts of vertebrae, costae, pelvis, sternum and hind limbs were procured from a large block (A). Left scapula, left fore limb, a part of right manus and anterior part of costae were gained from another block (B) and posterior part of skull was gained from block C. Of 194 bones of full skeleton, 112 bones are known, indicating 58% preservation, when all bones composing skull are calculate as one. Fossil bones are all very hard but much deformed by pressure in preservation.

2. The Izumi skeleton was preserved in massive sandstone and some bones were tolerably detached from each other except vertebral column, pelvis and costae. The cadabel was tolerably decomposed, separated in several parts of putrefied body, settled to depositing sands by its lumbar portion; firstly sacral, caudal and lumbar portions were buried together with hind limbs. The orientation of each bone shifted from their original position, shows some kind of rotation, which may indicate the direction of running water or a kind of turbidity current. Teeth of *Galeocerdo* are associated with the bones. Of 222 bones of full skeleton, 124 bones are known, indicating 56% preservation. Bones are not deformed but rather fragile.

3. Desmostylid represented by *Paleoparadoxia* and *Desmostylus* is a rather large sized animal like *Tapirus* or *Hippopotamus*. It is a graviportal quadriped, terrestrial and semiplantigrade animal and amphibious in habit, not aquatic like Sirenia but often semiaquatic in its life. Probably it had not claws but primitive hoofs. In body stoutness it is more powerful than Hyracoidea or archaic Ungulata such as *Coryphodon*, *Astrapotherium* or *Anthracotherium*, and poorer than pachydermate Ungulata such as *Barylambda*, *Uintatherium*, Titanothere, *Hippopopotamus*, *Toxodon* or Proboscidea. Advanced Ungulata has more slender and specialized limbs. Proboscidea and Sirenia are much different in limbs. Body style is like those of tapir, *Amynodon* or archaic Titanothere such as *Dolichorhinus*. Shoulder is not high compared with body length.

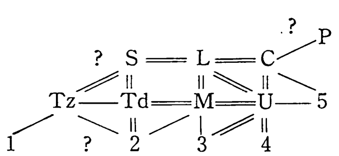
4. Fore and aft digits are five anatomically and four functionally; their length and stoutness are almost undifferentiated. Manus is directed outward while pes is

inward; their planes are parallel with the axis of body. Metatarsus is 0.26 to 0.56 long of metacarpus in *Paleoparadoxia*. Metacarpus and metatarsus are accompanying sesamoid bones which are in contact with their posterior distal portion. Phalanges are stout and flat.

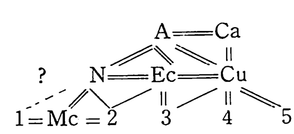
5. Humerus is straight with deltoid ridge unexpanded outward. Ulna and radius are short with distinct distal expansion. Distal portion of ulna is unreduced and olecranon is large. In Keton it is eminently oblique to axis of shaft. Femur is straight with flat condyle; ectocondyle is unprojected anteriorly and third trochanter disappears. Tibia is long, unslender and with flat distal end. Fibula is also long, twisted and narrow; proximal end is expanded and distal end is unreduced.

6. Carpus and tarsus are relatively weak and low; alternate jointing exists between carpus and metacarpus and between tarsus and metatarsus. Reduction or confluency as seen in the advanced Artiodactyla does not occur in carpus, metacarpus, tarsus or metatarsus except in first digit. Carpus and tarsus lack centrum and entocuneiform respectively. Trapezium and pisiform are unpreserved and precisely unknown. Astragalus is not high and without well developed median longitudinal groove of upper surface. In the Izumi skeleton, astragalus restored is almost like in anterior view that of Keton. Calcaneum is relatively long and well developed in *Desmostylus*. Astragalus joints with ectocuneiform and cuboid. Scaphoid does not articulate with magnum while lunar closely associates with unciform. Navicular does not articulate with cuboid, but with second metatarsus in *Paleoparadoxia*. Carpal and tarsal formula are as follows:

Carpal formula



Tarsal formula



7. Sternum consists of four paired platy bones and an unpaired platy bone (second xiphisternum).

8. Each bone of the Keton skeleton is a little larger than the corresponding bone of the Izumi. Phalanges and sternum are better developed in Keton than the Izumi. Epiphysis is fully fused with the shaft of bones in Keton, but insufficiently confluent in Izumi; the latter is linked with the teeth of the Izumi skull which are not so much worn. The Izumi animal is of young individual, while the Keton animal is fully adult.

9. Desmostylid was not skillful in locomotion on land. The animal often put its ventral side of thoracic portion directly on land, pushed the body forward kicking land with hind limb, using fore limb as paddle, rudeer or supporter. During this motion the animal used its eminent lowere jaw of stoutly expanded symphysis as a kind of shovel, hardly moving its upper rostrum in vertical direction, scooped mud looking for its food plants and animal such as mollusca, annelida and crustacea, etc. Desmotylid slided on sea bottom near coast as *Phacochoerus* does on land.

10. In the West Pacific Territory, desmostylid is found in association with littoral to shallow neritic benthonic faunae of warm-temperate water like Kadono-

sawa or Togari faunae, or with deep neritic or bathyal benthonic fauna of temperate or cool-temperate waters such as Shikonai, Yamanouchi, Yama, Poronai and Kamenoo faunae. There are many cases in which an isolated tooth dropped from surface water to the deep sea bottom of an inland sea or a long bay. Probably it was derived from putrefied cadabel floating on surface water. In the East Pacific Territory, desmostylid is also associated with subtropical molluscan fauna such as Temblor. Desmostylid is a coast dweller of neither pure boreal nor tropical but of warm-temperate.

11. In the extremely developed paired platy bones of sternum, pecurious direction of manus and pes, unique combination of tarsal bones, desmostylid is clearly separated from any order of mammals. Proboscidea and Sirenia may be near in teeth pattern; Sirenia, archaic Perissodactyla and archaic Artiodactyla may be near in many characters of skull, while archaic Perissodactyla, archaic Artiodactyla, some Protoungulata such as Astrapotheria or Notoungulata may be near in limb bones. Proboscidea and Sirenia are far distant in the last characteristics just mentioned. When we compare desmostylid by elements of teeth, skull, body style, scapula, pelvis, sternum, vertebrae, costae, limb bones, carpus, tarsus and digits, with fourteen orders of Protoungulata, Paenungulata, Perissodactyla and Artiodactyla, the degree of intimateness can be arranged as follows: Perissodactyla (15), Proboscidea and Artiodactyla (13), Sirenia (9), Astrapotheria and Notoungulata (8), Embrithopoda and Dinocerata (7), Pantodonta and Condylarthra (6), Litopterna (3), Hyracoidea (2). That is to say the desmostylid stands as an order Desmostylia, among Proboscidea, Sirenia, Perissodactyla and Artiodactyla.

12. Order Desmostylia REINHART, 1953 are classified as follows:

1. Family Cornwalliidae SHIKAMA, 1957
   Genus *Paleoparadoxia* REINHART, 1959
      Paleoparadoxia tabatai (TOKUNAGA, 1939)
   Genus *Cornwallius* HAY, 1923
      Cornwallius sookensis (CORNWALL, 1922)
2. Family Desmostylidae OSBORN, 1905
   Genus *Desmostylus* MARSH, 1888
      Desmostylus hesperus MARSH, 1888
      D. hesperus japonicus TOKUNAGA & IWASAKI, 1914
   Genus *Vanderhoofius* REINHART, 1959
      Vanderhoofius coalingensis REINHART, 1959
   Genus *Kronotherium* PRONINA, 1957
      Kronotherium brevimaxillare PRONINA, 1957

13. Dental formula is 3·1·3·3/3·1·4·3 in the first family and 0·1·3·3/1·1·3·3 in the second family. Cusp formula is $\left(\mathrm{P1}=\frac{0}{1}, \mathrm{P2}=\frac{?}{?}, \mathrm{P3}=\frac{3+0}{3+0}, \mathrm{P4}=\frac{3+2}{4+0}, \mathrm{M1}=\frac{?}{?}, \mathrm{M2}=\frac{5+4}{6+(1-2)}, \mathrm{M3}=\frac{5+4}{5+(3-4)}\right)$ in the former and $\left(\mathrm{P4}=\frac{4}{7}, \mathrm{M1}=\frac{4-5}{6-(6+1)}, \mathrm{M2}=\frac{8-9}{6+1}, \mathrm{M3}=\frac{8-10\ ?}{6-8\ ?}\right)$ in the latter. Canine of the latter is cylindrical tusk like and larger than incisors, while that of the former is small sized. Cheek teeth

are brachydont, bunodont, small sized and have a long root in the former, while that of the latter is hypsodont, large sized, consisting of closely appressed cylindrical columns; also basal cingulum and accessory tubercles are obsolete or absent in the latter. Median cranial crest of parietal is distinct in the former and obsolete in the latter. Humerus has an eminent inner tubercle in the former but an obsolete one in the latter, no supratrochlea foramen and a large major tubercle in the former, while a supratrochlea foramen and a small major tubercle in the latter. Femur of the former has a small distinct trochanter but that of the latter has an obsolete one. Scaphoid is relatively low and outer surface of magnum carries no median groove in the former, while in the latter scaphoid is relatively high and outer surface of magnum has a median groove.

14. *Cornwallius* is known only from the upper Oligocene formations of Unalaska Island, Vancouver Island and Baja California in the East Pacific Territory. *Paleoparadoxia* is known from the Burdigalian Vaqueros formation to the Santa Margarita formation (Mio-Pliocene) of California, also from Takinouean (F_2) to Kuromatsunaian (G) in Japan, and it may be said that it appeared in almost the same horizon in the Vaqueros to the Clarendonian in California and Oregon, most abundant in the Temblor formation (Hemingfordian or Vindovonian). *Desmostylus hesperus japonicus* is known from Poronaian (E) to Kuromatsunaian (G) in Japan, explosively appears and attains its acme in late F_2, abruptly decreases in number in F_3 and becomes extinct in the end of G stage. Hence it may be said *Desmostylus* appeared earlier in the West Pacific than in the East Pacific Territory. *Vanderhoofius* is only known from the Temblor formation and *Kronotherium* from the Tyusheoskaya — upper Vayampolskaya formations.

15. *Desmostylus hesperus japonicus* is distributed between Lat. 52°25′N and Lat. 35°21′45″N, occurs more commonly in the area of northern Honshu to Saghalien. *Paleoparadoxia* is more restricted. *Desmostylus hesperus* is distributed between Lat. 46°26′24″N and Lat. 33°42′N. It is most common in the San Francisco—Temblor area between Lat. 36°-38°N. *Cornwallius* is wider in distribution than *Desmostylus*. *Desmostylus* was mainly distributed in the desmostylid belt which runs between Lat. 52°N-Lat. 35°N in the West Pacific and between Lat. 46°N-Lat. 25°N in the East Pacific Territory. These areas during Miocene were transgressed by warm—temperate to subtropic sea. Desmostylid was neither a pure boreal nor a tropic animal.

16. Desmostylid was at least closely associated with the subtropic Daijima geoflora, but on the other hand associated even with cold Aniai or temperate Mitoku geoflorae. It lived independently of the composition of geoflora and its main food plant was not land plant. It also associated with more different geoflora of Temblor. It is not known from such a land formation with mammalina fauna as Hiramaki. Desmostylid is not a pure terrestrial animal, but a coast dweller of amphibious to semiaquatic habit as seen in Pinnipedia.

17. The phylogeny of Desmostylid is shown in Textfig. 116. Archaic *Cornwallius* and more advanced *Desmostylus* were coeval in the stage E (Aquitanian). *Desmostylus* may be a mother lineage of Desmostylia which sprung out in basal Eocene or Palaeocene of Afro-Europe. The stage of F_2-F_3 is the acme and mature stage

of *Desmostylus*. The developing stages of desmostylid may be embryonal (Palaeogene), young (Oligo-Miocene to basal Miocene, E-F_1), mature (late early to middle Miocene, F_2-F_3) and old stages (late Miocene to basal Pliocene, G-H).

18. Desmostylid may have migrated from Afro-Europe to North Pacific via the northern coast of the Tethys Sea. It was isolated in a special adaptive zone of desmostylid belt of the Northern Pacific area. The oceanographical condition of this area was special; warm-temperate surface water and cold deep water produced a thermocline very near the sea surface. Desmostylid food plant and animal were influenced by this thermocline and stenohaline and a little stenothermal desmostylid could not migrate southward beyond the southern limit of the desmostylid belt. Adaptive zone of desmostylid was in contact with that of Sirenia in the East Pacific but isolated in the West Pacific area. The zone was divided into *Paleoparadoxia* subzone of browsing—omnivorous peak and *Desmostylus* subzone of shifted peak for grazing. There was seen no remarkable accelaration of adaptation in the adaptive zone of desmostylid. Mean survivorship of genera is 8.78×10^6 years. The order desmostylia are a very scanty and unpowerful taxon.

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Plates 1–12

Paleoparadoxia tabatai (TOKUNAGA)

All figures illustrated in the Plates 1—12 are of the specimen (NSMT-P-5601) from Inkyo-yama, Izumi-machi, Doki City.

Plate 1

Explanation of Plate 1

(All figures are $\times 0.25$ natural size, unless mentioned)

Page

Figs. 1-5. Left humerus (NSMT-P-5601-4). 26
1, Anterior Side. 2, Outer side. 3, Posterior side. 4, Inner side. 5, Distal side. $\times 0.33$.

Figs. 6-12. Right humerus (NSMT-P-5601-3). 26
6, Posterior side of distal portion. 7, Anterior side of ditto. 8, Outer side of ditto. 9, Inner side of ditto. 10, Posterior side of posterior inner corner of head. 11, Outer side of ditto. 12, Inner side of ditto.

Figs. 13-18. Left ulna (NSMT-P-5601-6) and radius (NSMT-P-5601-8). 30
13, Outer side of ulna and radius jointed to each other. 14, Anterior side of ditto. 15, Inner side of ditto. 16, Outer side of ulna. 17, Posterior side of ditto. 18, Anterior side of ditto.


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Plate 2

Explanation of Plate 2

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Fig. 1. Left ulna (NSMT-P5601-6), inner side, ×0.28. 30

Figs. 2-6. Left radius (NSMT-P-5601-8). 32
2, Inner side, ×0.25. 3, Anterior side, ×0.25. 4, Posterior side, ×0.25. 5, Outer side, ×0.25. 6, Proximal side, ×0.28.

Figs. 7, 8. Right ulna (NSMT-P-5601-5). 30
5, Outer side of a part of shaft, ×0.25. 6, Inner side of ditto, ×0.25.

Figs. 9-13. Right radius (NSMT-P-5601-7). 32
9, Inner side of proximal part, ×0.18. 10, Outer side of ditto, ×0.18. 11, Posterior side of distal part, ×0.18. 12, Anterior side of ditto, ×0.18. 13, Inner side of ditto, ×0.18.

Figs. 14-19. Right femur (NSMT-P-5601-40). 74
14, Anterior side of shaft, ×0.25. 15, Posterior side of ditto, ×0.25. 16, Inner side of ditto, ×0.25. 17, Outer side of ditto, ×0.25. 18, Distal side of condyle, ×0.32. 19, Proximal side of head, ×0.32.

Fig. 20. Left femur (NSMT-P-5601-41). 74
Anterior side of shaft, ×0.25.


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Plate 3

Explanation of Plate 3


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Plate 4

Explanation of Plate 4

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Figs. 1-4. Left fibula (NSMT-P-5601-44). 82
1, Outer side of shaft, ×0.21. 2, Posterior side of ditto, ×0.21. 3, Inner side of ditto, ×0.21. 4, Anterior side of ditto, ×0.21.

Figs. 5-8. Left unciform (Bone C, NSMT-P-5601-14). 46
5, Distal side, ×0.52. 6, Proximal side, ×0.52. 7, Anterior side, ×0.52. 8, Posterior side, ×0.52.

Figs. 9-13. Left cuneiform (Bone A, NSMT-P-5601-10). 40
9, Outer side, ×0.48. 10, Anterior side, ×0.48. 11, Posterior side, ×0.48. 12, Distal side, ×0.48. 13, Proximal side, ×0.48.

Figs. 14-19. Left magnum (Bone D, NSMT-P-5601-13). 44
14, Inner side, ×0.47 (right margin of the figure proximal). 15, Outer side, ×0.47 (left margin of the figure proximal). 16, Anterior side, ×0.47. 17, Posterior side, ×0.47. 18, Distal side, ×0.47 (left margin of the figure anterior). 19, Proximal side, ×0.47 (right margin of the figure anterior).

Figs. 20-25. Left lunar (Bone B, NSMT-P-5601-9). 36
20, Anterior side, ×0.46. 21, Posterior side, ×0.46. 22, Proximal side, ×0.65. 23, Distal side, ×0.65. 24, Outer side, ×0.65. 25, Inner side, ×0.65.

Figs. 26-30. Left trapezoid (Bone E, NSMT-P-5601-12). 42
26, Distal side, ×0.48. 27, Inner side, ×0.48. 28, Proximal side, ×0.48. 29, Outer side, ×0.48. 30, Anterior side, ×0.48.

Figs. 31-33. Left first metacarpus (NSMT-P-5601-15). 51
31, Posterior side, ×0.48. 32, Anterior side, ×0.48. 33, Proximal side, ×0.48.

Figs. 34-37. Left fifth metacarpus (NSMT-P-5601-23). 54
34, Anterior side, ×0.38. 35, Outer side, ×0.38. 36, Posterior side, ×0.38. 37, Inner side, ×0.38.

Fig. 38. Right fifth metacarpus (NSMT-P-5601-22). 54
Anterior side, ×0.38.


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Plate 5

Explanation of Plate 5

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Figs. 1–3. Right fifth metacarpus (NSMT-P-5601-22). 54
1, Outer side, ×0.38. 2, Inner side, ×0.38. 3, Posterior side, ×0.38.

Figs. 4–8. Left fourth metacarpus (NSMT-P-5601-21). 53
4, Anterior side, ×0.46. 5, Posterior side, ×0.46. 6, Outer side, ×0.46. 7, Inner side, ×0.46. 8, Proximal side, ×0.46.

Figs. 9–12. Right fourth metacarpus (NSMT-P-5601-20). 53
9, Anterior side, ×0.5. 10, Posterior side, ×0.5. 11, Inner side, ×0.5. 12, Outer side, ×0.5.

Figs. 13–16. Left third metacarpus (NSMT-P-5601-19). 52
13, Anterior side, ×0.54. 14, Posterior side, ×0.54. 15, Outer side, ×0.54. 16, Inner side, ×0.54.


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Plate 6

Explanation of Plate 6


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Plate 7

Explauation of Plate 7

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Figs. 1-7. Right calcaneum (Bone D, NSMT-P-5601-45). 88
1, Anterio-inner side of proximal part, ×0.5. 2, Anterior outer side of ditto, ×0.5. 3, Anterior side of ditto, ×0.5. 4, Outer side of ditto, ×0.5. 5, Inner side of ditto, ×05. 6, Distal view of ditto, ×0.5. 7, Posterior side of ditto (broken surface), ×0.5.

Figs. 8-10. Right navicular (Bone B, NSMT-P-5601-46). 90
8, Posterior side, ×0.5. 9, Proximal side, ×0.5. 10, Ditto restored, ×0.5.

Figs. 11-15. Right ectocuneiform (Bone C, NSMT-P-5601-48). 93
11, Anterior side, ×0.5. 12, Proximal side, ×0.5. 13, Distal side, ×0.5. 14, Inner side, ×0.5. 15, Outer side, ×0.5.

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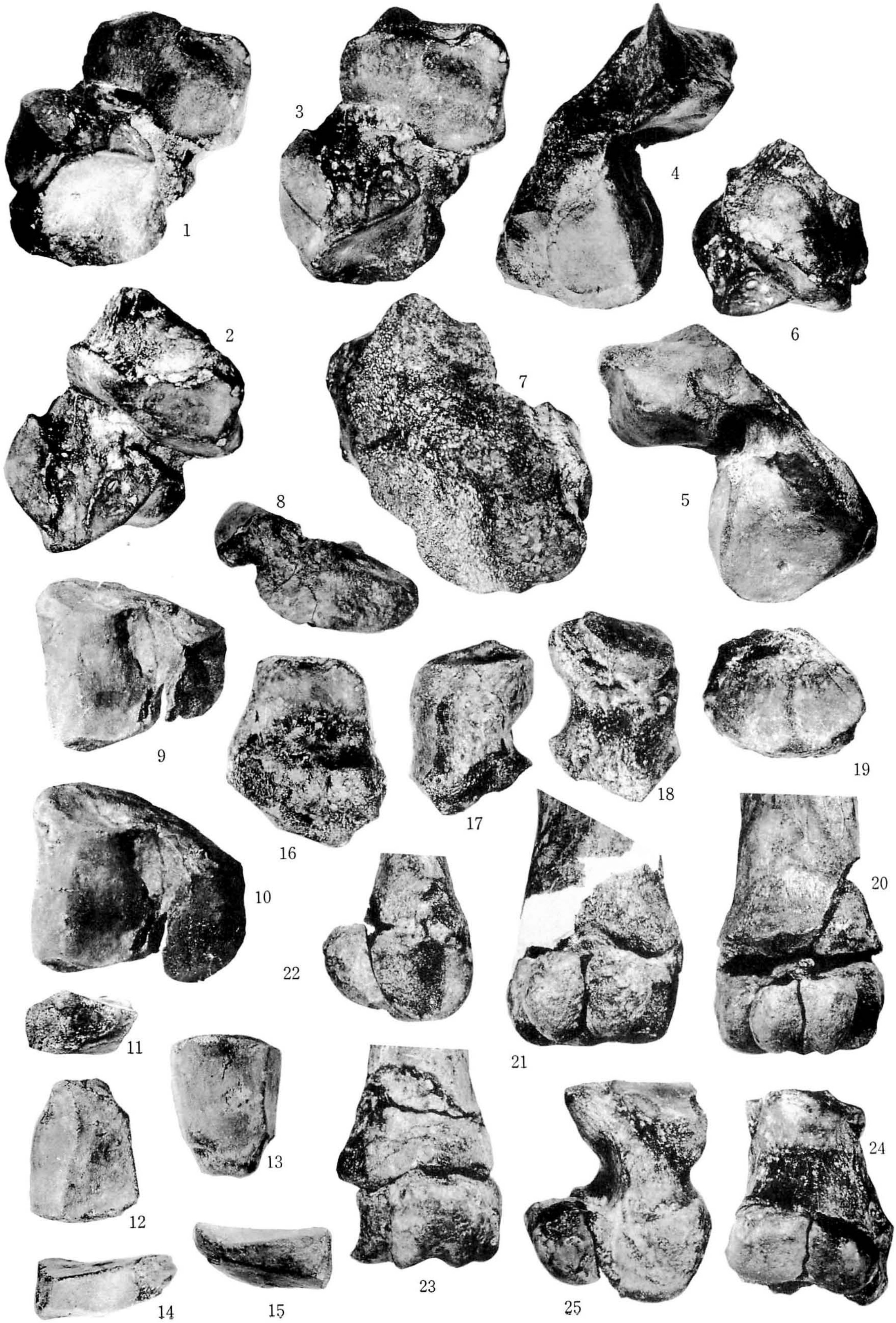
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Explanation of Plate 8

(All figures $\times 0.5$ natural size, unless mentioned)

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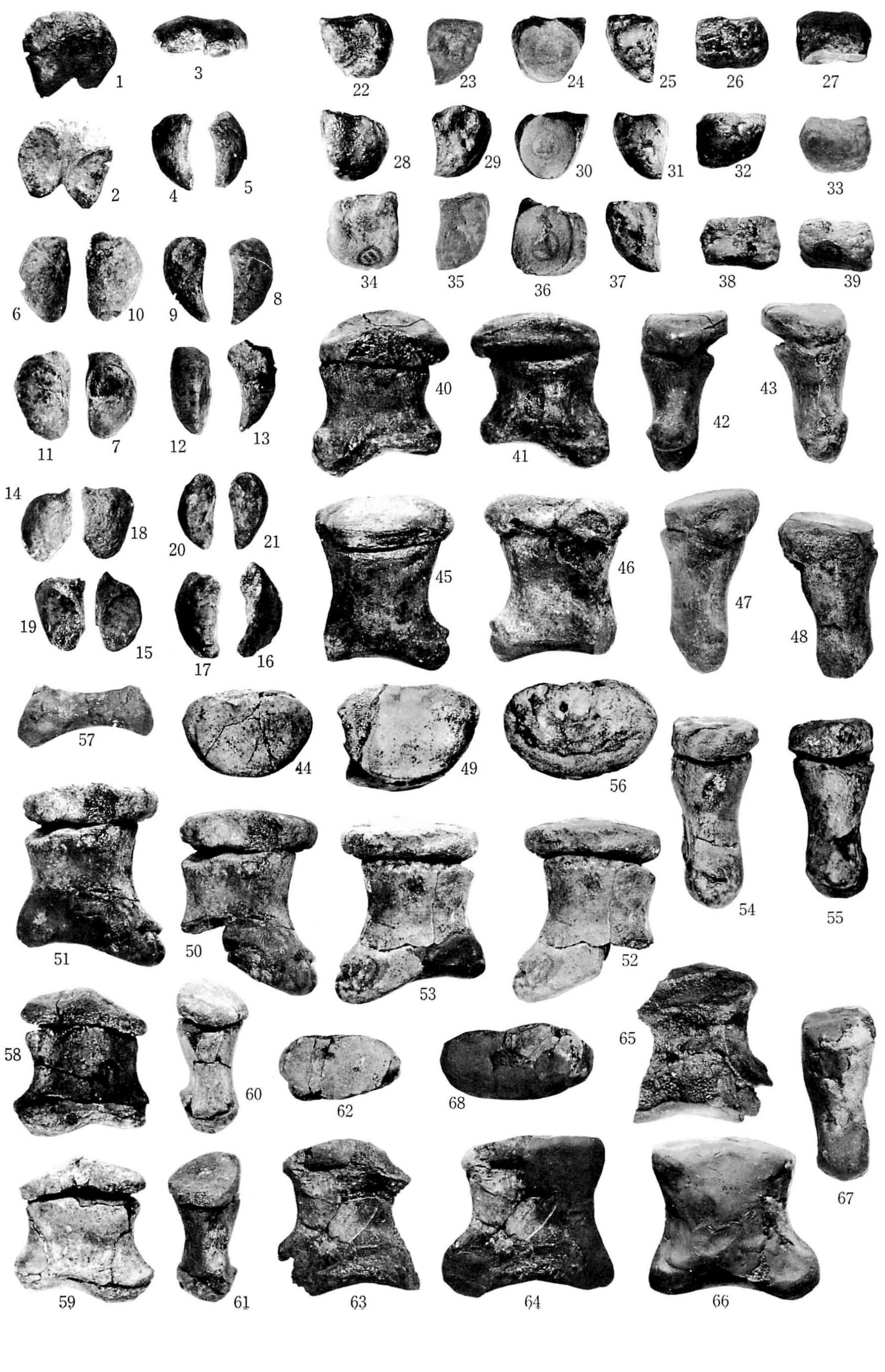
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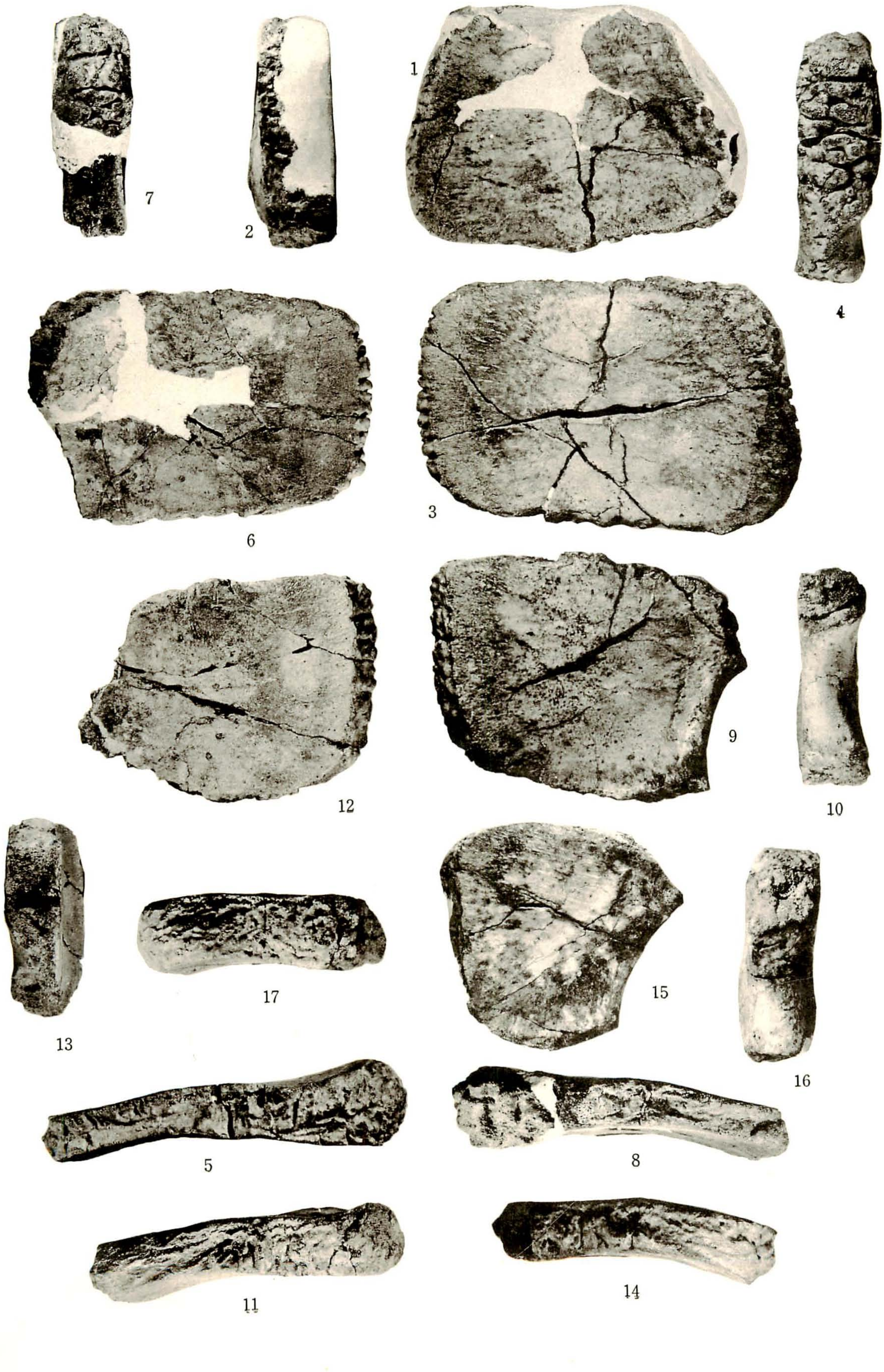
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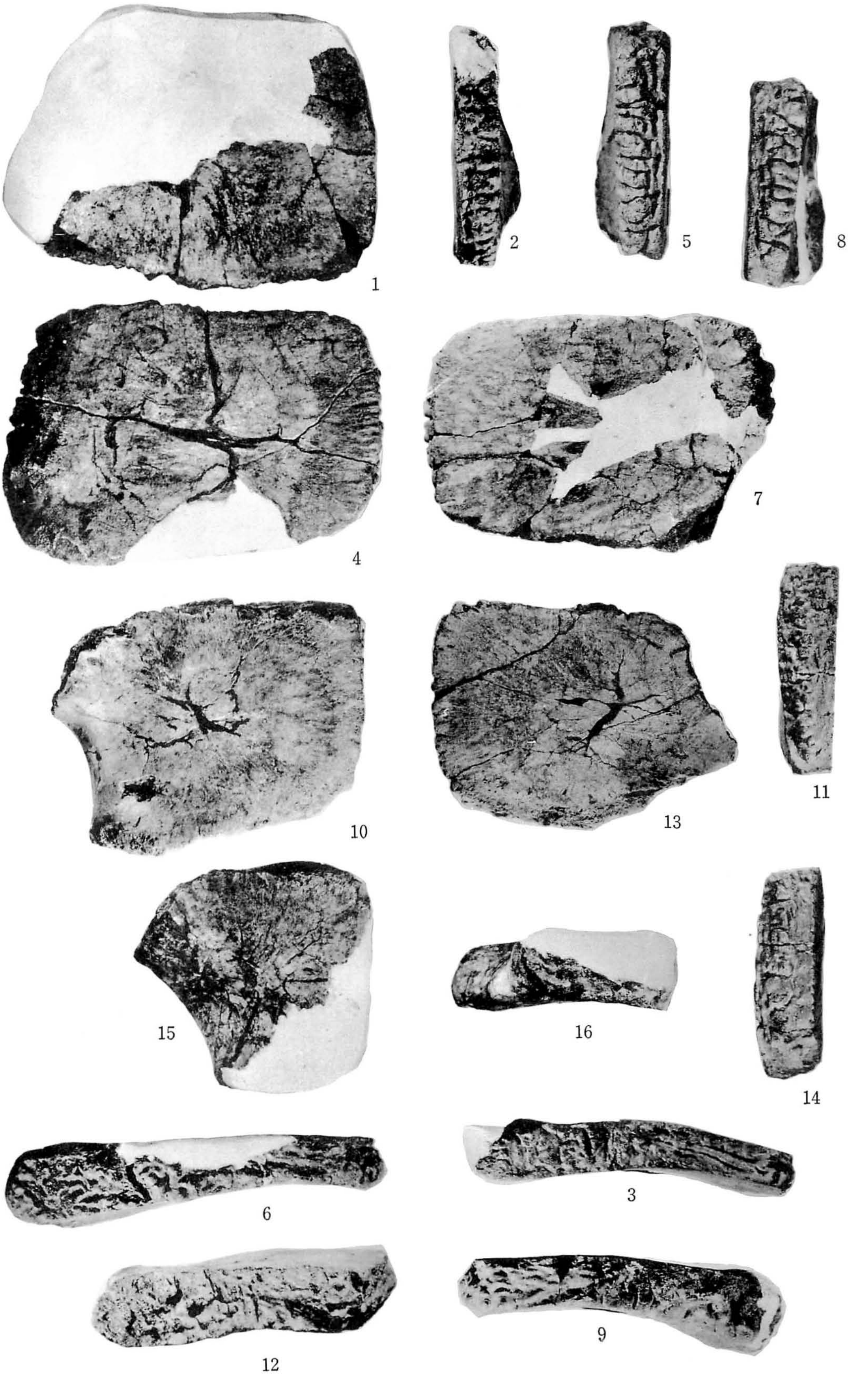
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