

二疊紀－三疊紀境界部石灰岩の
古生物学、堆積岩学的研究

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Permian and Triassic Boundary in the Limestone
at Taho and Kamura, Southwest Japan

Toshio Koike*, Makoto Arima*, and Hisaharu Igo**

Introduction

It has been emphasized that there was a global mass extinction of the Paleozoic marine invertebrates and land plants at the period boundary between the Permian and Triassic. There are several different opinions concerning the cause of the mass extinction.

It is known that there occurred a remarkable sea level drop at the end of the Permian, which caused serious erosion in vast areas of shallow water depositional environment on continental shelves. Therefore, the boundary between the Permian and Triassic is usually unconformable and the section showing continuous stratigraphic sequences across the Permian-Triassic boundary is remarkably restricted, i.e., hitherto known in the Southern Alps, Iran, Himalayan region, South China, and Greenland.

In Japan the Upper Permian and Lower Triassic sequence of shelf facies exposes in some areas, i.e., Southern Kitakami Terrain, Northeastern Japan and Mairuru Belt, Inner Side of Southwestern Japan. However, the Permian-Triassic boundary is unconformity and the upper Changxingian of the Permian and the Induan of the Triassic are probably lacking in both areas.

On the other hand, the chert sequence includes the Permian-Triassic boundary horizons in some areas of the Mino Belt, Southwest Japan (Yamakita, 1987 and others). The chert sequence is of deep sea pelagic origin and occurs in a Jurassic accretionary complex. The sequence is mainly composed of bedded radiolarian cherts. The Permian-Triassic boundary unit consists of gray or black siliceous claystone attaining to about 30 m in thickness and yields Late Permian radiolarians in the lower part and Early Triassic conodonts in the upper part. However, the Induan fossils have not been obtained from the boundary unit.

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The carbonate sequence of oceanic facies including the Upper Permian and Lower Triassic strata distributes in Takachiho, Kyushu (central part of Chichibu Belt). All workers concluded that the sequence lacks the upper Changxingian and the Induan.

We investigated the carbonate sequence in Taho and Kamura sections and found out the Permian-Triassic boundary. The lithologic character of the carbonate rocks and microfossils obtained are discussed in this paper.

The Permian-Triassic boundary and conodont faunas in the Tethys Realm

Recent active study on conodont biostratigraphy have revealed significance of conodonts for recognition of the Permian-Triassic boundary. Conodonts of latest Permian and earliest Triassic age have been known from sections in the southern Alps (Italy), the Salt Range and Trans-Indus Range of Pakistan; from the Vihi District of Kashmir; from the Spiti District of northern India; from sections at Kuh-e-Ali Bashi in the Julfa District of northwest Iran; from the Abadeh region of central Iran; from the Permian-Triassic sequence exposed on Cape Stosch, central East Greenland; from western United States; from several sections on the Yangtze platform, South China.

Southern Alps

The Upper Permian Bellerophon Formation of the Dolomites and Carnia, Italy ranges in thickness from 400-500 m to zero and consists of marl, dolomite, sabkha, gypsum, and marly dolomitic limestone. The topmost segment of the Bellerophon Formation is composed of a sequence, 0.5 to 2 m thick, of dark marls and limestones with fusulinids (Nankinella) and other foraminifers, calcareous algae, and brachiopods (Comellicarina, Ombinia, and Orthotetina), fungus Typanocysta. This facies records the spread of shallow-marine conditions over a very wide area of the Southern Alps (Fig. 1).

Representatives of Comellicania from the Southern Alps belong in Comericania and Alatothyris. A characteristic comellicaniid assemblage (C. megalotis, C. ladinina) seems to support a latest Drashamian age for the uppermost part of the Bellerophon Formation. Extensive research emphasizes the peculiarity of the Bellerophon Formation's microfauna by comparison with those reported from other Tethyan areas, and the Southern Alps is thought to represent a distinct bioprovince, which lacks the common index microfossils but has similarities with associations from Changxingian sequences in South China (Broglia et al., 1986, 1988).

The Bellerophon Formation is overlain, with no evidence of a stratigraphic gap, by the Lower Triassic oolitic unit of the Tesero Horizon of the Werfen Formation.

The Lower Triassic Werfen Formation is an interbedded sequence of carbonate and terrigenous deposits that ranges in thickness from about 150 to 700 m and, in the Dolomites, includes nine lithostratigraphic units. The Werfen Formation was deposited in a shallow-shelf setting that was generally below fair-weather wave-base but was frequently affected by storm waves (Broglia and Cassinis, 1992).

The basal oolitic unit, the Tesero Horizon yields the Ombonia-?Crurithyris Assemblage in the 10-20 cm thick layer. The assemblage includes smooth pectinid bivalves, and brachiopods and foraminifers of Permian aspect.

In marly intercalation 0.5 to 2 m above the formational boundary there are sculptured aviculopectinid bivalves, 'Bellerophon' voceki Bittner, Polygirina gracilior (Schauroth), ?Crurithyris extima Grant, Ombonia sp. cf. O. canevai Merla, ?Spinomarginifera sp. and foraminifers of Permian type (i.e. Nankinella, Globivalvulina, Hemigordius, Geinitzina). Gymnocodium and Mizzia are rarely present.

'Bellerophon' vaceki is a Triassic species whose first occurrence is in the basal oolitic layers of the Tesero Horizon. The morphology of this species is very different from that of Paleozoic Bellerophon and it ranges from the base of the Tesero to the Claraia aurita Subzone (Lower Nammalian). This species considered the haralder of the Early Triassic in the mixed fauna occurred 1-2 m above the formational boundary, which is correlated with that of the Otoceras woodwardi Zone

The conodont Hindeodus latidentatus is represented 2 m above the Bellerophon-Werfen contact. The highest occurrence of a palynomorph assemblage with dominant fungal remains coincides with the highest record of Late Permian elements.

Next above the Ombonia-?Crurithyris Assemblage, in the lower Mazzin Member, is the Unionites-Lingula Assemblage, which is of lower taxonomic diversity and quite different composition than assemblages in the Tesero Horizon and Bellerophon Formation. Lingula sp., Unionites fassaensis (Wissmann), Unionites sp. cf. U. camalensis (Catullo), and Bellerophon vaceki are the most characteristic fossils. Articulate brachiopods, algae, and foraminifers of Permian aspect appear to be absent. The conodont Isarcicella parva has been reported from the lower Mazzin Member (Brander et al., 1986).

The palynofacies appears to be dramatically changed from the lower part of the Mazzin Member. The index bivalves Claraia appears 15 to 20 m above the base of the Werfen, at a level roughly equivalent to that at which the conodont Isarcicella isarcica makes its debut.

Sedimentologic research emphasizes a gradual transition from the Bellerophon to the Werfen Formation. Bioclastic packstones and grainstones with the Comelicania-Nankinella assemblage coarsen and grade into oolitic grainstones of overlying Tesero Horizon, basal unit of the Werfen, in which the Ombonia-Crurithyras Assemblage occurs. Evidence of erosion and clear indications of emergence supporting a gap occur only in the middle part of the Southern Alps.

Carbon-isotope profiles through the Tesero section also indicate the Bellerophon-Werfen boundary is transitional (Magaritz et al., 1988).

Broglia and Cassinis (1992) concluded that the systemic (and erathemic) boundary would coincide with the contact between the Bellerophon and Werfen formations because the contact coincides with the essentially simultaneous drop in taxonomic diversity, the flourishing of fungi, and the alteration in pattern of sedimentation. Fossils of Permian aspect in the Tesero Horizon record the last attempt by survivors of the biologic revolution to adapt to a new ecosystem, which was very different from the one to which they were adapted in earlier times.

Iran

In the Abadeh region, Iran the latest Permian Hambast Formation consists of thin bedded limestone. The lower unit yields fusulinids and ammonoids. The upper unit includes uppermost Dorashamian ammonoids such as Shevyrevites and Paratiro-lites and conodonts referable to Hindeodus julfensis (= H. minutus) and Neogondolella subcarinata orientalis (Fig. 2).

The strata of the formation was deposited under calm, possibly lagoonal conditions (Iran-Japanese Research Group, 1981). After a short interval of emergence the depositional area was rapidly submerged and Early Triassic sediments were deposited under infralittoral to littoral conditions.

The basal part of the Lower Triassic (Unit a) is composed of yellowish green clay (boundary clay, 10-30 cm thick), Stromarite limestone (130-180 cm), alternation of limestone and shale (8.7 m), in ascending order. The boundary clay yields Claraia sp. The Stromarite limestone contains Hindeodus parvus with Xenodiscus sp. The alternation of limestone and shale includes Hindeodus parvus and

Isarcicella isarcica and ammonoids referable to Ophiceras, Acanthophiceras, Lytophyceras, and Vishnuites.

Salt Range

Upper Permian Chhidru Formation is 190 ~280 feet in thickness and consists of pale gray to dark gray shale in the basal 20 ~45 feet and calcareous sandstone with a few sandy limestone beds in the remainder of the formation (Fig.3).

The white sandstone unit (Kummel and Teichert, 1970) of the topmost Chhidru Formation varies considerably in thickness ranging from over 5 m to almost zero and yields brachiopods, foraminifers, and acritarchs. The unit is fine- to medium-grained white to yellowish-gray sandstone and has varying amount of interbeds of dark shale of 6 to 18 cm thick. The sandstone is predominantly quartz and feldspar and a small amount of biotite. The groundmass consists of generally finely crystallized calcite which is partly dolomitized. The sandstone is thinly laminated and, in places, faintly cross-bedded. Symmetrical ripple marks are rarely present. This suggests considerable shallowness of the water. However, rarity of this kind of ripple marks indicates that sediment-water interface for the most part must have been below the zone of wave turbulence (Kummel and Teichert, 1970).

Furnish and Glenister (1970), on the basis of ammonoids, recognized the absence of the uppermost Permian stage Changhsingian in the Chhidru Formation.

Pakistan-Japanese Research Group (PJRG) (1985) also concluded that the Chhidru Formation is most probably late Dzhulfian because there is no paleontological evidence to indicate the latest Permian Dorashamian or Changhsingian.

The Lower Triassic Kathwai Member of the Mianwali Formation is subdivided into a lower dolomite unit (5.2 to 14 feet thick) and an upper limestone unit (0.5 to 7 feet thick) (Kummel and Teichert, 1970)

The dolomite unit differs sharply from the white sandstone unit of the Chhidru Formation on which it rests with apparent conformity. The unit consists entirely of fine to coarse - grained dolomite, containing calcite, minor amount of detrital mineral grains of quartz, feldspar, mica, and glauconite. The original rock, before dolomitization, is essentially a bioclastic limestone, consisting mostly of huge number of fragments of echinodermal skeletons and of comminuted shell fragments, frequently not more than 1 mm in size. The dolomite is grayish orange in color and medium-bedded and, in places, laminated and cross-bedded. Mudcracks and capped interference ripples are observed in some levels.

Kummel and Teichert (1970) considered that the dolomitized limestone deposited in intertidal zone.

The upper limestone unit consists of bioclastic limestone with large amount of minute shell fragments and minor amount of echinoderm fragments and glauconite grains. The limestone is dolomitized in small extent.

The dolomite unit contains cephalopods, presumably Ophiceras connectens Schindewolf in the upper part. The limestone unit yields rich brachiopods, echinoderms, cephalopods, and palynomorphs. Ophiceras connectens, Glyptophyceras himalayanum (Griesbach) are present with Permian type brachiopods and nautiloids, and Paleozoic type ostracods.

Kummel and Teichert (1970) concluded that the Permian-Triassic boundary in the Salt Range is a paraconformity reflecting a recession of the sea and an emargent condition in latest Permian time followed by a transgression in the earliest Triassic as defined by the first appearance of Ophioceras.

PJRG (1985) divided the Kathwai Member into three units, the Lower, the Middle, and the Upper instead of two-fold division of Kummel and Teichert (1970).

The Lower Unit corresponds to the basal part of the dolomite unit of Kummel and Teichert (1970). The unit ranges from 160 cm to zero in thickness and composed of dolostone, dolomitic limestone, and more or less calcareous sandstone.

The Middle unit is 80 to 150 cm in thickness and consists of massive or faintly bedded dolostone. Parallel and cross lamination are rarely discernible. The mudcracks reported by Kummel and Teichert (1970) was regarded as secondary weathering product.

The Upper Unit considerably varies the lithofacies and thickness. At Chhidru it is 360 cm in thickness and alternating dolomite and shale in the lower part and thin-bedded alternation of sandstone and shale with limestone interbeds in the upper part. At Narmia it is about 70 cm in thickness and represent by bedded limestone. In the other localities the lower part is dolostone and the upper part is limestone. Parallel and cross lamination are locally developed. Ripple marks are observed in some localities.

The Lower Unit yields foraminifers as Reichelina sp., Globivalvulina cf. vonderhumitti, Nodosaria cf. minuta, Pachyphloia sp. and so on. Grant (1970) reported Permian type brachiopods from this unit.

The Middle Unit contains Eumorphotis waageni, Entolium cf. discites, and ophyceratid ammonoids from the basal part.

PJRG (1985) correlated the Lower Unit with the highest Permian as Grant and Cooper (1973) considered and drew the Permian- Triassic boundary at the boundary of the Lower Unit and the Middle Unit.

Triassic conodonts were studied for the first time by Sweet (1970). Sweet (1970) established the Hindeodus typicalis and Neogondolella carinata zones in the lowermost part of the Kathwai Member. However, Sweet and Bergstrom (1986) and Sweet (1988) revised Sweet's Lower Triassic zonal scheme and recognized the Isarcicella isarcica Zone in the interval of the H. typicalis and N. carinata Zones. Sweet (in Ziegler, 1977) regarded that I. parva is synonymous with I. isarcica. Thus the I. isarcica Zone (Sweet and Bergstrom, 1986, Sweet, 1988) includes the

According to PJRG (1985), the Lower Unit yields very few conodonts, only Hindeodus minutus (H. typicalis of Sweet). This unit was distinguished as H. minutus Zone (Nakazawa, 1993). The Middle Unit has the association of H. minutus, Isarcicella parva, I. isarcica, and N. carinata and two conodont zones, I. parva-H. minutus Zone and I. isarcica-I. parva Zone, were settled in ascending order. The I. parva-H. minutus Zone was correlated with the upper part of Otoceras woodwardi Zone and I. isarcica-I. parva Zone was included in Ophiceras tibeticum Zone. PJRG (1985) concluded that the lower part of Otoceras woodwardi Zone is most probably missing in the Salt Range region.

Sweet (in Ziegler, 1977) regarded that Hindeodus parvus is synonymous with I. isarcica. Thus the I. isarcica Zone (Sweet and Bergstrom, 1986: Sweet, 1988) includes the H. parvus Zone which marks the lowermost Triassic.

Kashimir

Upper Permian and Lower Triassic strata in the Guryul Ravine, Vihi District of Kashmir, India have been divided into two formations, the Zewan and conformably overlying Khunamuh Formations (Nakazawa et al., 1975) (Fig. 4). The uppermost part (18.2 m in thickness) of the Zewan Formation (Member D of Nakazawa et al., 1975) is characterized by a development of thick-bedded sandy limestone (biomicrudite) intercalating laminated muddy sandstone and calcareous sandstone. The lowermost part (18.6 m in thickness) of the Khunamuh Formation (Member E of Nakazawa et al., 1975) is constituted by dark gray to black shale intercalating limestone layers of 10 to 30 cm in thickness. The Member E of the Khunamuh Formation was further subdivided into three units, E₁ to E₃ in ascending order.

Member D of the Zewan Formation corresponds to the Cyclolobus walkeri Zone and Unit E₁ to the Hypophyceras? Zone. Unit E₂ to the Otoceras woodwardi Zone.

and Unit E₃ to the Ophyceras Zone, respectively (Nakazawa et al., 1975, Nakazawa, 1993).

The conodont faunas of the Upper Permian and Lower Permian sequence in this area have been studied by Sweet (1970) and four conodont zones were established: Hindeodus typicalis, Neogondolella carinata, Neospathodus dieneri, and N. cristagalli zones in ascending order. The Hindeodus typicalis Zone straddles the boundary of the Zewan and Khunamuh Formation. Three conodont zones were established in the E member by Nakazawa et al. (1975): Hindeodus typicalis, Neogondolella carinata, and Neospathodus cristagalli zones. However, Nakazawa et al. (1980) and Matsuda (1981), and Nakazawa (1993) proposed another conodont zonation of Unit E based on detailed conodont sampling by Matsuda, namely, Hindeodus minutus, Isarcicella isarcica, Neogondolella carinata, Neospathodus kumeli, and Neospathodus cristagalli zones.

Unit E₁ includes Permian brachiopods, bivalves, bryozoas, and Triassic type bivalves, Claraia. The greatest faunal change takes place in the lowermost Khunamuh, namely, between Unit E₁ and E₂ and almost characteristic Permian species disappear at the end of Unit E₁. Teichert et al. (1976) draw the Permian-Triassic boundary at the base of Unit E₁. Nakazawa et al. (1975) proposed the boundary at the base of Unit E₂ but Nakazawa (1993) draw it at the base of Unit E₁.

The sedimentary environment was estimated by sedimentological study of Nakazawa et al. (1975). In the last Zewan stage, there was uplift of the land and shallowing of the sea but not emergence above sea-level. In the earliest Khunamuh stage, the basin was rapidly deepened to probably bathyal environment.

Permian-Triassic Boundary Working Group (1993) candidate Guryul ravin section as a stratotype of the Permian - Triassic boundary because Hindeodus parvus and Otoceras are both represented. Wang (1990) noticed the shortcomings, i.e., the turbiditic nature of the Khunamuh Formation, metamorphism (> 300 c) judged by the black color of conodonts; the lack of chrono-, chemo- and magnetostratigraphic data, and the lack of ammonoids in E₁. Moreover, the Changxingian age of Zewan and /or Khunamuh E₁ is not confirmed. The discontinuity between Zewan and Khunamuh at 2.6 m below the suggested Permian-Triassic boundary between Khunamuh E₁ and E₂, poses another problem that the Permian-Triassic boundary must be placed in a section where discontinuity has already been recognized within such short distance from the Permian-Triassic boundary, and that a considerable thickness of a continuous sequence above and below the Permian-Triassic boundary

needed for security.

Selong section

According to Geldsetzer et al., (at the Guiyang workshop) the 7 cm thick 'Changxingian' is reworked band with a matrix derived from the underlying 'Pre-Changxingian' crinoidal grainstones. Jin and Shen (at the workshop) reported that 80% of the brachiopods are fragmented, but that the species composition is the same as that in the 'Prechangxingian'. No typical Changxingian conodonts or ammonoids have been reported yet. The negative excursion of carbon and oxygen isotopes occurs at 1.5 cm from the base of the 'Chanxingian'. The contact with the overlying *Otoceras* level is an uneven surface. The coexistence of *Hindeodus parvus* and *Otoceras* at this level is reconfirmed by Orchard (1994), although he reported that *Isarcicella isarcica* occurred slightly higher in the same bed, not on the same specimens with *Otoceras* as was reported by Rao and Zhang (1985). Previous works reported *Neogondorella* (or *Clarkina*) *changxingensis* and *N. deflecta* from the same level, but this was not confirmed by Orchard.

It is now clear that there is no confirmed Changxingian in this section. The 'Changxingian' may consist of reworked sediments deposited in the earliest Triassic, judging from the position of the carbon excursion. The *Otoceras* level may be reworked or condensed and discontinuities exist close to or even right below it (Fig. 5).

South China

In South China more than 30 fairly continuous marine Permian-Triassic sections have been studied in detail.

In the Meishan section in Changxing the Upper Permian Changxing Formation is divided into the lower Baoqing Member and the upper Meishan Member (Fig. 6).

The Baoqing Member is about 27 m in thickness and consists of bioclastic limestone intercalated with shale. The basal part of the limestone yields rich ammonoids

(*Tapashanites-Shevyrevites* Assemblage), brachiopods (*Peltichia zigzag*-*Preliossorhynchia triplication* Assemblage), and fusulinids (*Palaeofusulina minima* and *Nankinella simplex*).

The Meishan Member is about 12 m in thickness and composed of partly dolomitized bioclastic micritic limestone. White montmorillonite clayrock is present in the uppermost part. The member contains ammonoids (*Rotodicoceras-Pseudotiro-lites* Assemblage), and fusulinids (*Palaeofusulina sinensis*, *P. nana*, *Reichelina*

changxingensis).

The Lower Triassic Yinkeng Formation conformably overlies the Changxing Formation. The lower part of the Yinkeng Formation consists of calcareous mudstone, bedded silty limestone, clay rock, bedded marl with clay rock, and fine grained quartz sandstone.

The lowermost dark brown calcareous mudstone (bed 26, 0.07 m thick) yields Permian-type brachiopods (Cathaysia chonetoides (Chao), Crurithyris flabelliformis Lio, Neochonetes convexa Lio, Paryphella orbicularis (Lio), P. triquetra Lio, Waagenites barusiensis (Davidson), W. wongiana (Chao)), bivalves (Claraia sp.), and Permian-type conodonts (Neogondolella changxingensis Wang and Wang, N. deflecta Wang and Wang).

The upper bed (bed 27, 0.15 m) composed of greyish white, medium bedded, silty limestone bears Permian-type brachiopods (Acosarina sp. cf. A. minuta (Abich), Crurithyris flabelliformis Liao, Fusichonetes pigmae Liao, Waagenites barusiensis (Davidson), Paryphella orbicularis (Liao), P. triquetra (Liao)) and conodonts such as Isarcicella parva (Kozur and Pjatakova), Hindeodus typicalis (Sweet).

The bed 29 (grey, medium-bedded argillaceous limestone, 0.26 m thick) bears Permian-type brachiopod Paryphella orbicularia with bivalve Pseudoclararaia wangi (Pette) and ammonoid Ophyceras sp.

The bed 30 (grey, medium-bedded marl with grey clayrock, 0.52 m thick) yields Pseudoclararaia wangi, Claraia griesbachi (Bittner).

The bed 31 (greenish grey, fine-grained quartz sandstone, 1.00 m thick) bears ammonoids (Ophyceras sp.), bivalves (Claraia griesbachi, Pseudoclararaia wangi).

The biostratigraphic sequence of Upper Permian and Lower Triassic conodont faunas in South China was established by Wang, C. and Wang, Z. (1981, 1983), Zao et al. (1981), Yang Zunyi et al. (1987), and Ding (1992).

The Uppermost Permian Changxingian Stage includes two conodont zones, Neogondolella subcarinata and N. changxingensis Zone in ascending order. Neogondolella changxingensis Zone begins at the middle part of the Changxiang Formation and ends at the uppermost of the formation. Conodont fauna in this zone is composed of Neogondolella orientalis, N. subcarinata, N. deflecta, N. changxingensis, N. carinata, and Hindeodus typicalis.

Three conodont zones were established in the lowermost Triassic Induan formation: Hindeodus parvus, Isarcicella isarcica, and Neogondolella carinata zones.

The base of the Hindeodus parvus Zone is marked by the first occurrence of H. parvus and this zone is characterized by abundant specimens of H. parvus and H. typicalis. In Changxing section H. parvus occurs first in bed 27 (0.15 m thick) above the occurrence of N. changxingensis and N. deflecta in bed 26 (0.07 m thick). In the Yanjing section H. parvus also occurs just above the limestone bearing N. changxingensis and N. deflecta.

In the Isarcicella isarcica Zone I. isarcica occurs in common and is associated with H. typicalis, H. parvus, and N. carinata.

Yin et al. (1994) made a comprehensive review and recommended the D section of Meishan and the first appearance of Hindeodus parvus at the base of Bed 27 c as the global stratotype section and point of the Permian-Triassic boundary. However, the find of Otoceras is not confirmed. The Meishan sections are so far the only sections of the Permian-Triassic boundary candidates where integrative stratigraphy has been investigated. Chrono-chemo, and event stratigraphic results have been extensively reported.

Lower Triassic biostratigraphy in carbonate rocks in Japan

Lower Triassic carbonate rocks distribute at Tahokamigumi in Ehime Prefecture, Kamura in Miyazaki Prefecture, Kurotaki in Kochi Prefecture, Shionosawa in Gumma Prefecture, Iwai in Tokyo District.

The carbonate rocks occur as exotic blocks in Jurassic clastic rocks formed as a result of accretion during Jurassic. Carbonate rock blocks expose at Kurotaki, Sionosawa, and Iwai yield Olenekian (Smithian and Spathian) ammonoids, mollusks, and conodonts (Ichikawa, 1951, Bando, 1964, Nakazawa 1971, Koike et al. 1985). These blocks are very small and 20-30cm to a few meters in thickness. They have been almost collected out or unexposed at present.

The Taho section

The carbonate rock block of the Taho section in Tahokamigumi, Siro-kawa-cho, Higashi-uwa-gun, Ehime Prefecture attains 54 meters in total thickness and the exposure is about 5,000 square meters at the type section. The limestone generally dips 10 to 20 degrees toward north and the uppermost part is bounded by Jurassic conglomeratic sandstone and the lower limit is unexposed.

The limestone yields abundant conodonts in whole stratigraphic levels and corresponds to the lower Olenekian to middle Anisian and late Carnian to Norian. The Ladinian to lower Carnian formations are absent due to a fault (Koike, 1981, 1994).

The lower Olenekian (Smithian) carbonate rock is composed of massive biomicrite of lower part (10 m thick) and thin-to medium bedded or massive partly dolomitized biomicrite of upper part (6 m thick). The biomicrite includes small thin-shelled bivalves probably of Halobia, Daonella, Bositra and other monotids, radiolarians and subordinate echinoderm spines and crusts.

Anasibirites kingianus inaequicostatus (Waagen), Meekoceras japonicus (Shimizu and Jimbo) and other ammonoids and bivalves Anodontophora sp. and Eumorphotis sp. occur from the uppermost level of the upper part (Shimizu and Jimbo, 1933, Bando, 1964). Conodonts Neospathodus dieneri Sweet and Ellisonia triasica Muller occurs throughout the levels and N. waageni Sweet and N. conservativus (Muller) occur in the upper part (Koike, 1981, 1990).

Kamura section

The Permian-Triassic limestone exposed in Kamura, Takachiho-cho, Nishiusuki-gun, Miyazaki Prefecture is about 50 meters in maximum thickness and ex-

tends about 200 meters in NE-SW direction with nearly vertical dip. The upper and the lower limit of the limestone bounds with mudstone of Jurassic or chert block of Permian or Triassic.

The Permian carbonate rock was divided into two formations, the Iwato and Mitai Formations in ascending order by Kanmera and Nakazawa (1973) and Working Group on Permian-Triassic Systems [W.G.P.T.S.] (1975).

The Iwato Formation yields Neoschwagerina megaspherica Deprat, Yabeina cf. katoi (Ozawa) and other fusulinids which indicate the Guadalupian of Middle Permian (Saito, Kanbe, Katada, 1958).

The Mitai Formation (43 m thick) includes Palaeofusulina sp. - Reichelina changhsingensis assemblage in the lower 15 m and Nankinella sp. B - Staffella sp. B assemblage in the upper 28 m. Palaeofusulina sp. - Reichelina changhsingensis assemblage contains Palaeofusulina sp., Reichelina changhsingensis (Sheng and Chang), Codonofusiella kueichoensis Sheng. The assemblage was correlated with the lower Changxingian in South China. Nankinella sp. B. - Staffella sp. B assemblage is composed of Nankinella sp. B, Staffella sp. A, S. sp. B, Codonofusiella sp., Dunbarula? sp. The assemblage was correlated with middle to upper Changxingian in South China (Kanmera and Nakazawa, 1973, W.G.P.T.S., 1975).

The Triassic Kamura Formation yields conodonts throughout the levels and bivalves and ammonoids in part. A detailed study on conodonts by Watanabe et al. (1979) revealed that the limestone is of the Smithian to Norian.

The Lower Triassic limestone is composed of massive or thin- to medium bedded biomicritic limestone or dolomitized biomicrite including thin-shelled bivalves and ammonoids.

Kambe (1963) described following molusks in the interval of 6 m to 20 m above the base of the Kamura Formation, Eumorphotis multiformis (Bittner), E. multiformis shionosawensis Ichikawa and Yabe, Pteria ussurica yabei Nakazawa, Gervilla cf. exporrecta (Lepsius) [Bakevella? sp.], Entolium discites (v. Shlotheim) ["Steblochondria" sp.], Eupecten minimus (Kiparisova) [Leptochondria cf. minima (Kiparissova)], Anodontophora canalensis Catullo [Unionites canalensis Catullo], and A. fassaensis (Wissmann) [Unionites fassaensis] (name in [] was offered by Nakazawa 1971). Following ammonites was reported by Kambe (1963) and Bando (1975) in the same interval, Clypites japonicus Kambe, Aspenites kamurensis Kambe, Parahedenstroemia sp., Meekoceras cf. gracilitatus White, and Koninckites sp. Kambe (1963), W.G.P.T.S. (1975), and Nakazawa et al. (1994) refer-

ed this fauna of bivalves and ammonoids to lower Owenitan (Smithian).

Neospathodus dieneri Sweet, N. sp.A and other conodonts have been reported from the same location by Watanabe et al., (1979).

The boundary between the Upper Permian Mitai Formation and the Lower Triassic Kamura Formation was regarded as disconformity and Griesbachian and Dienerian strata are absent in the Kamura section (Kanmera and Nakazawa, 1973; Watanabe et al., 1979).

The Permian-Triassic boundary in the Taho section

A drilling was performed for the purpose of getting an information about the Permian-Triassic boundary in the Taho Limestone in 1994. The drilling point is shown in the figure 7. The diameter of the drilling core is 70 mm and the well was bored 50 m from the ground surface.

The columnar section obtained from the core is shown in the figures 8, 9. The true thickness was calculated as the general dip of 20 degrees. The lithologic character and fossils occurred are as follows in descending order.

The Taho Formation (Triassic)

Dienerian

Light gray to dark gray, massive, slightly dolomitized biomicritic limestone. Intrusive structure of mudstone. conodonts, Neospathodus dieneri Sweet, N. cf. pakistanensis Sweet 0.70-13.15 m

Thin alternation of limestone and dark colored mudstone indicating grading. conodonts, N. dieneri. 15-13.48 m

Light gray, massive, slightly dolomitized biomicritic limestone. conodonts, N. dieneri. 13.48-15.65 m

Light gray, massive, dolomitic limestone. conodonts, N. dieneri. 15.65-16.80 m

Light gray, massive, dolomitic limestone bearing undeterminable micro fossils. conodonts, N. dieneri, ?N. kummeli. 16.80-17.70 m

cave 17.70-18.15 m

Light gray, massive, dolomitic limestone bearing abundant bivalves and small amount of small gastropods, small ammonoids. 18.15-22.30 m

Light gray, massive, dolomitic limestone. unfossiliferous. 22.30-22.60 m

Griesbachian

Dark gray, massive, dolomitic limestone with small gastropods and undetermi-

minable microfossils. 22.60-23.45 m
 conodonts, Hindeodus parvus (Kozur and Pjatakova), H. minutus (Ellison) obtained at the level of 22.80-23.35 m. ? Isarcicella isarcica (Huckriede) obtained at the level of 22.80-22.90 m.

conformity

The Shirokawa Formation (Upper Permian)

Light gray to white, massive, dolomitic limestone to dolostone bearing fusulinids, Staffella sp. and other foraminifers, calcareous algae, Mizzia and stratified algae, ostracods. 23.45-36.00 m

Light gray to white dolostone to dolomitic limestone with stratified algae. 36.00-42.25 m

Dark gray to black, massive, slightly dolomitezed micritic limestone with ?algae. 42.25-44.44 m

Light gray to white, massive, dolostone. thin shelled bivalves. 44.44-48.60 m

Light gray, massive, slightly dolomitized limestone with algae. 48.60-50.00 m

Biostratigraphic correlation

The Shirokawa Formation of the Permian is slightly to strongly dolomitized and occurrence of fossils is restricted. Foraminifers including fusulinids and algae, Mizzia and Tubiphytes are recognized. Fusulinids, Staffella sp. occurring near the top of the Shirokawa Formation is only one species determined (Fig.10). It is difficult to decide the geological age of the Shirokawa Formation. This is the same feature with the uppermost Mitai Formation in which fusulinid species is restricted in occurrence of Staffella sp. although Changxingian Palaeofusulina sp. occurs in the lower part of the formation. The Upper Changxingian fusulinid assemblage in South China is not characterized by Staffella but Palaeofusulina. The Changxingian Palaeofusulina assemblage usually occurs in sparitic limestone characterizing deposition in high energy open sea environment (W.G.P.T.S.,1975). On the other hand, Staffella assemblage in the upper Mitai Formation occurs in dolomitic micritic limestone representing deposition in low energy hypersaline environment. Thus the difference of sedimentary environment might have provided the different fusulinid assemblage.

The basal part of the Taho Formation characterized by dark gray dolomitic

limestone yields Hindeodus minutus, H. parvus, and ?Isarcicella isarcica (Fig. 11). The presence of these conodont species represents the Griesbachian of the basal part.

?Neospathodus kummeli, N. dieneri appears about 6 m above the base of the Taho Formation. Coexistence of the former two species represents the Dienerian.

Feature of the boundary between the Shirokawa and Taho Formation

The Upper Permian Shirokawa Formation and the Lower Triassic Taho Formation can be distinguished at a glance because of the contrast in color of the limestones, light gray to white in the Shirokawa and dark gray in the Taho Formation. The basal part of the Taho Formation is strongly dolomitized as well as the uppermost part of the Shirokawa Formation and undolomitized dark colored micritic limestone sporadically scatters within gray colored dolostone in irregular shaped ramps or breccias which ranges in size from 0.1 mm to 5 mm. Very thin calcite veins or stylorite showing pressure solution are formed along the boundary in most part but there is a portion without such structure in which the boundary is smooth. There is no sign of unconformity as far as observed (Fig.12)

The Permian-Triassic boundary in the Kamura section

The boundary between the upper Permian Mitai Formation and the Triassic Kamura Formation was studied in detail at the Section I, II, and III of Watanabe et al. (1979).

Section I

In Section I (Fig.13) the Mitai Formation is strongly dolomitized in the uppermost part and fossils are quite rare but foraminifers including fusulinids and algae, Mizzia are observed in some levels (Fig. 14). At the level of about 10 m beneath the top of the Mitai Formation, Dunbarula sp., ?Leella sp., and Staffella sp. (Fig. 10). These fusulinids are the characteristics of Nankinella sp. B - Staffella sp. A assemblage proposed by W.G.R.T.S. (1975).

The basal 3 m of the Kamura Formation is characterized by dark gray dolomitic micritic limestone (Fig.15). Hindeodus minutus, H. parvus, Isarcicella isarcica, Neogondolella carinata occurs in the basal part (Fig. 11). The biostratigraphic order in appearance of these conodonts, H. minutus - H. parvus - I. isarcica is known in several areas (South China, Himalaya) in the Tethyan Realms. This conodont assemblage represents the Griesbachian (Orchard, 1994; Yin et al., 1994;

Wang 1994).

The limestone in the interval of 3 m to 6 m above the base is light gray dolomitic micrite partly intercalated with dark gray micrite which is similar in lithology to the dark gray micrite in basal part. The light gray micrite includes small bivalves and algae. Conodonts have not been collected in this part.

The limestone in the interval of 6 m to 12 m above the base is light gray micrite with rich large bivalves, gastropods, and ammonoids (Fig. 15). Conodonts have not been found in this part. However, bivalves Eumorphotis multiformis, Unionites canalensis, U. fassaensis, ammonoids Clypites japonicus and Aspenites kamurensis has been reported from this limestone by Kambe (1963) and others. The bivalves and ammonoids are thought to represent the Smithian (Kambe, 1963; Nakazawa et al., 1974).

Section II

In this section the uppermost part of the Mitai Formation consists of dolostone or dolomitic light gray micrite. The dolomitic limestone yields calcareous algae and foraminifers but has not yielded index fossils such as fusulinids.

The basal 3 m of the Kamura Formation is composed of dark gray micrite with small gastropods and ostracods (Fig. 16). Griesbachian conodonts Hindeodus minutus and H. parvus, Neogondolella sp. occur in this limestone.

The limestone in the interval of 3 m to 6 m above the boundary of the Mitai and Kamura Formation is light gray micritic limestone which includes small bivalves.

The large mollusks (Eumorphotis multiformis, Unionites canalensis and others) bearing micrite overlies the light gray micritic limestone.

Section III

The upper Mitai Formation in Section III (Fig. 17) is composed of dolomitic light gray micrite or dolostone. Fusulinids and other foraminifers and algae occur in weakly dolomitized micrite. Staffella sp. is present near the uppermost part of the formation.

The basal 3 m of the Kamura Formation consists of dark gray micritic limestone with small gastropods and ostracods. Griesbachian conodont Hindeodus minutus, H. parvus, and Neogondolella carinata occur near the base of the limestone.

The Griesbachian conodont bearing limestone is cut by a fault and contacts with the light gray dolomitic micrite with bivalves such as Eumorphotis multi-

formis, Unionites canalensis and others. Neospathodus dieneri is present at the level of 7 m and 9.5 m above the base of the formation.

Feature of the boundary between the Mitai and Kamura Formation

The boundary between the Upper Permian Mitai and Lower Triassic Kamura Formation can be easily distinguished in the field by the contrast of the color of the limestones, namely, light gray to white dolomitic micrite of the Mitai and dark gray micrite of the Kamura Formation. Under the microscope there occurs stylorite at the boundary in many parts but no stylorite in some parts. There is no evidence of disconformity such as erosional surface or cave on the Mitai Formation, occurrence of limestone breccias or conglomerates in the boundary (Fig. 18).

Systematic Paleontology

Order CONODONTOPHORIDA Eichenberg, 1930

Genus HINDEODUS Rexroad and Furnish, 1964

Hindeodus minutus (Ellison, 1941)

Figure 11- 1.2.

Spathognathodus minutus Ellison, 1941, p. 120, figs. 50-52.

Anchignathodus minutus (Ellison), von Bitter, 1972, p. 65-66, pl. 6, figs.

2a-i: Zhao et al., 1981, pl. 1, 3.

Ellisonia teichertii Sweet, 1970a, p. 8, pl. 1, fig. 3, 4, 7, 8, 12; Zhao et al., 1981, pl. 7, figs. 4, 14, 22-24.

Ozarkodina minutus (Ellison), Baesemann, 1973, p. 704-706, pl. 2, figs. 1, 4-15, 19, 20.

Hindeodus ex. gr. Hindeodus minutus (Ellison), Bender, 1980, p. 10, pl. 4, fig. 22.

Anchignathodus typicalis Sweet, 1970a, p. 7-8, pl. 1, figs. 13, 22.

Hindeodus typicalis (Sweet), Sweet in Ziegler, p. 223-224, Hindeodus pl. 2, figs. 1-6, Perri and Andraghetti, 1987, p. 308-309, pl. 32, figs. 1-5; Kozur, 1992, p. 102-103, fig. 19.

Remarks: A detailed synonymy was given by Matsuda (1981). Multielement species Hindeodus minutus is composed of six elements, Pa, Pb, M, Sa, Sb, and Sc

elements. Among the elements the Pa element has been treated as unimembrate species Spathognathodus minutus since Ellioson (1941) described the form. On the other hand, the Pb, M, Sa, Sb, and Sc elements of H. parvus were referred to quinquimembrate skeletal apparatuses of Ellisonia teichertii by Sweet (1970_a). Sweet (1970_a) proposed a unimembrate species Anchignathodus typicalis composed of single element of the Pa. Baesmann (1973) regarded "S." minutus as one element of multielement species "Ozarkodina" minutus. Since then most workers have followed Baesmann's opinion. However, there was strong confusion in naming of genus and species.

Sweet (1977) proposed a seximembrate genus Hindeodus and included "S." minutus and "A." typicalis as different species in the genus. Sweet (1977) distinguished two species on the basis of value of ratio of length to width, denticulation, lateral profile of upper margin of blade. On the other hand, Matsuda (1981) referred "A." typicalis is synonym of "S." minutus because several morphologic characters of the former fall within variation of the latter.

Hindeodus parvus (Kozur and Pjatakova, 1975)

Figure 11- 3-15.

Spathognathodus isarcicus Huckriede, Staesche, 1964, p. 288-289, figs. 60-61.

Anchignathodus isarcicus (Huckriede), Sweet in Teichert et al., 1973, p.424, 426, pl.11, fig. 5.

Anchignathodus parvus Kozur and Pjatakova, Kozur, 1975, p. 7-9, pl. 1, figs. 17, 22; Kozur, Mostler, and Rahimi-Yazd, 1975, p. 4, pl. 1, figs. 6, 12-15, pl. 7, figs.7, 9; Kozur and Pjatakova, p. 123-125, figs. 1a, 1b, 14, 15, pl. 7, fig. 7; Kozur, 1977, p. 1120-1121, figs.17, 19, 20; Jiang, 1988, pl.2, fig. 8; Beyers and Orchard, 1991, pl.4, Figs. 2-3.

Isarcicella isarcica (Huckriede), Sweet in Ziegler, 1977, p. 229-230, morphotype 1 in text-fig. "Terminology of Isarcicella Kozur, 1975" at p. 225; Perri and Andraghetti, 1987: p. 309-311, pl. 32, figs. 6, 7.

Hindeodus parvus (Kozur and Pjatakova), Matsuda, 1981, p. 91-93, pl. 5, figs. 1-3; Matsuda, 1985, pl. 1, fig. 2; Wang, Z. and Cao, 1993, p. 253-254, pl. 55, figs. 1-3; Wang, C.Y., 1994, pl. 1, figs. 1-2 (Morphotype 1), figs. 3-5 (Morphotype 2).

Description

Pa element

The antero posterior process ranges 0.32 to 0.58 mm in length, 0.16 to 0.32 mm in width, 0.22 to 0.46 mm in height and 1.1 to 1.5 in length to height ratio. The process slightly bows inward and fairly expands on the inner side and carries 5 to 9 denticles which are nearly equal in height in anterior half and gradually or rapidly decrease in height posteriorly. The cusp at the anterior end of the process usually attains as twice in height as the highest denticle. The basal cavity is subelliptical to subcircular in shape and occupies posterior two-thirds to three-fourths of the process and a narrow groove extends toward anterior.

Remarks:- Pa element of Hindeodus parvus is closely similar to H. minutus which has large and high cusp. However, the cusp of H. parvus is higher and bowed posteriorly and that of H. minutus stands in perpendicular.

Kozur and Pjatakova (1976) regarded Ellisonia teichertii multielement as the elements of H. parvus and illustrated neoprioniodiniform (M) element and hindeodelliform (Sc) element with spathognathodiform (Pa) element. E. teichertii was established by Sweet on the basis of statistically reconstructed apparatus of a quinquimembrate with the LD (M), U(Sa), LE(Sb), U (Sc), and LA (Pb) elements. Sweet(1977) treated that Ellisonia teichertii of a quinquimembrate is a part of the skeletal apparatus of H. typicalis (Sweet). On the other hand, Matsuda (1981) regarded that E. teichertii is a part of the apparatus of H. minutus. The M and Sc elements figured by Kozur and Pjatakova (1976) coincide with those of H. minutus (= H. typicalis).

The Permian-Triassic Boundary Working Group (PTBWG) (1994), emphasized that H. parvus is a seximembrate. However, the elements has not been figured and described. More than 100 specimens of the Pa element of H. parvus have been collected in association with 12 Pa elements of H. minutus from the basal part of the Kamura Formation. The occurrence of ramiform elements is considerably small compared with the Pa element and the M, Sa, Sb, Sc, and Pb elements are 10, 3, 6, 15, 4, in number, respectively. These elements seem to belong to E. minutus. According to Matsuda (1981), ramiform elements of H. parvus has not been confirmed in the sample from Guryul Ravine section in Kashmir. It is probable that H. parvus is a unimembrate.

Sweet in Ziegler (1977) also suggested that H. parvus belongs to unimembrate

type whereas genus Hindeodus to seximembrate. On the basis of the morphological affinity and close stratigraphic range, Sweet (1977) first referred H. parvus as "morphotype 1" of Isarcicella isarcica as Staesche (1964) classified this form as one of morphotypes of "Spathognathodus" isarcicus Huckriede, but later recognized the species 'parvus' and included it tentatively to Isarcicella (1992). Isarcicella was proposed by Kozur (1975) for the form with one or two denticles on one or either sides of the blade among "Spathognathodus" isarcicus described by Staesche (1964). Sweet in (1977) referred Isarcicella to unimembrate.

As mentioned previously, H. parvus is probably a unimembrate. Therefore, this form does not belong to typical Hindeodus with seximembrate apparatus. However, as Sweet (1977) and Matsuda (1981) already pointed out H. parvus is morphologically related to the Pa element of H. minutus. On the other hand, H. parvus is not a typical Isarcicella proposed by Kozur (1975) although it represents morphological relation to Isarcicella isarcica in the denticulation on the blade and carina. It is not adequate to propose a new genus for H. Parvus in this paper because it will cause another confusion. I treat 'parvus' as Hindeodus because proposal of genus Isarcicella by Kozur (1975) is earlier than that of multielement Hindeodus by Sweet (1977).

Genus Isarcicella Kozur, 1975
Isarcicella isarcica (Huckriede)

Figure 11- 16. 17.

Spathognathodus isarsicus Huckriede, 1958, p. 162, pl. 10, figs. 6, 7a-7c: Staesche, 1964, p. 288-289, figs. 62-64: Hirsch and Sussli, 1973, p. 528, Pl. 1, figs. 1-2.

Anchignathodus isarcicus (Huckriede), Sweet, 1970b, p. 223-224, pl. 1, figs. 18, 19: Sweet in Ziegler, 1973, p. 13-14, Anchignathodus pl. 1, fig. 1: Sweet in Teichert et. al., 1973, p. 424, 426, pl. 11, figs. 6, 7: Clark et al., 1979, pl. 1, fig. 19.

Isarcicella isarcicus (Huckriede), Kozur, Mostler, and Rahimi-Yazd, 1975, p. 6-7, pl. 7, figs. 3-6.

Isarcicella isarcica (Huckriede), Sweet in Ziegler, 1977, p. 229-230: Kozur, 1978, pl. 8, figs. 23, 28: Matsuda, 1981, p. 93-94, pl. 5, figs 4-7: Paull, 1982,

fig. 5. 14, 16-19: Matzuda, 1985. pl. 1, fig. 3: Jiang, 1988. pl. 2, fig. 9a-b:
Wang. Z. and Cao. 1993. p. 254, pl. 55, figs. 8, 9.

Description

The anteroposterior process is 0.37 to 0.52 mm in length, 0.21 to 0.40mm in width and 0.23 to 0.37 mm in height. The process slightly bows inward and carries 4 to 7 denticles which are nearly equal in height or highest in anterior or central part. The inner side of the process strongly expands and bears one or two denticles which are almost equal in height with the denticles on the process. The cusp at the anterior end of the process is about twice as high and large as the largest denticle on the process. The basal cavity occupies posterior three-fourths of the process and a narrow groove extends toward anterior.

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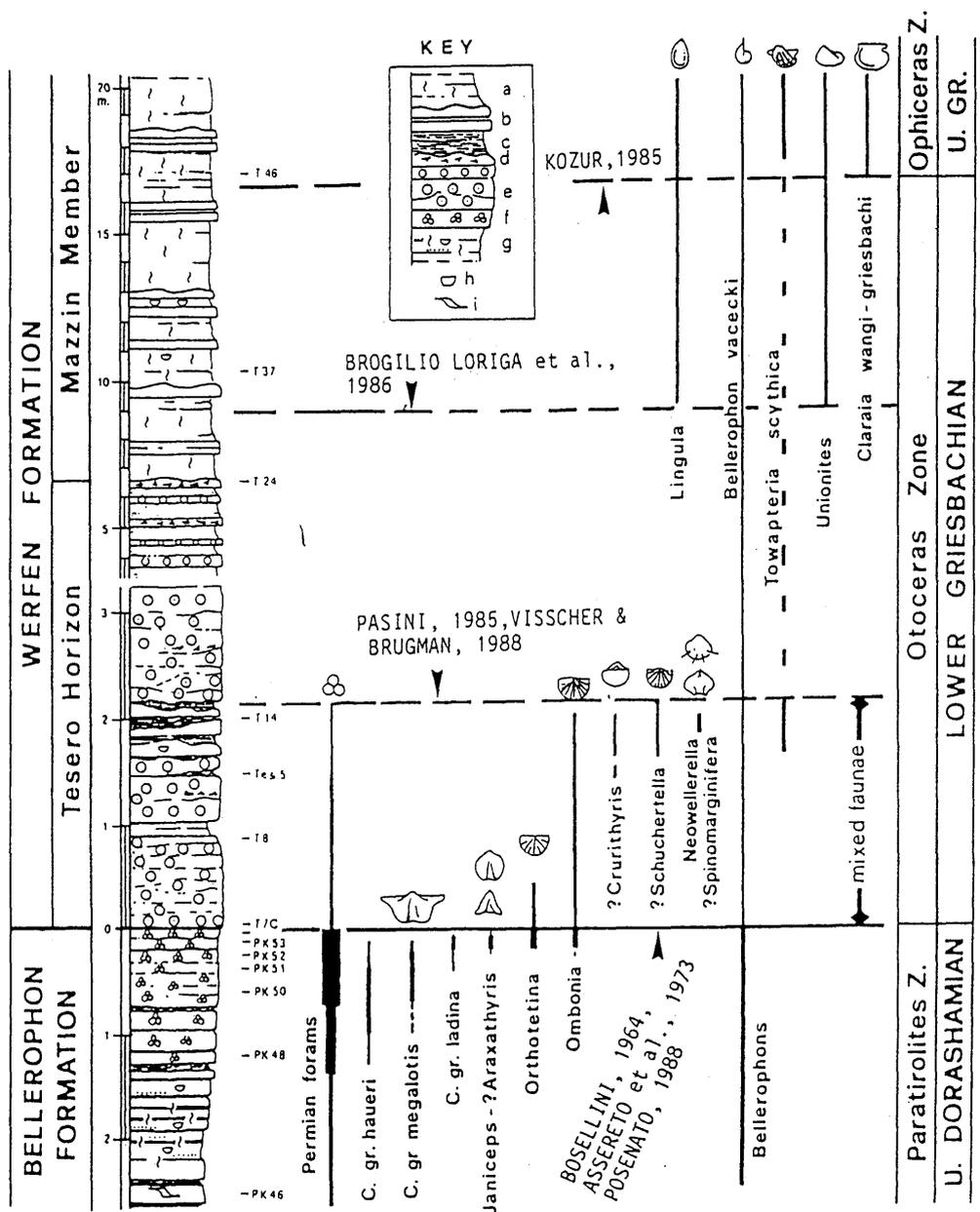


Fig. 1 Composite sequence of the uppermost Bellerophon Formation and lower Werfen Formation-Tesero section. Reproduced from Fig.3 of Posenato (1988) with the addition of Permian-Triassic boundary position of various authors based on his Fig.2. a: bioturbated marly limestone, b:limestone, c:marl, d:intraclastic limestone, e:oolitic limestone, f:bioclastic limestone, g:silty and arenaceous bioturbated dolomitic limestone. by Nakazawa, 1993

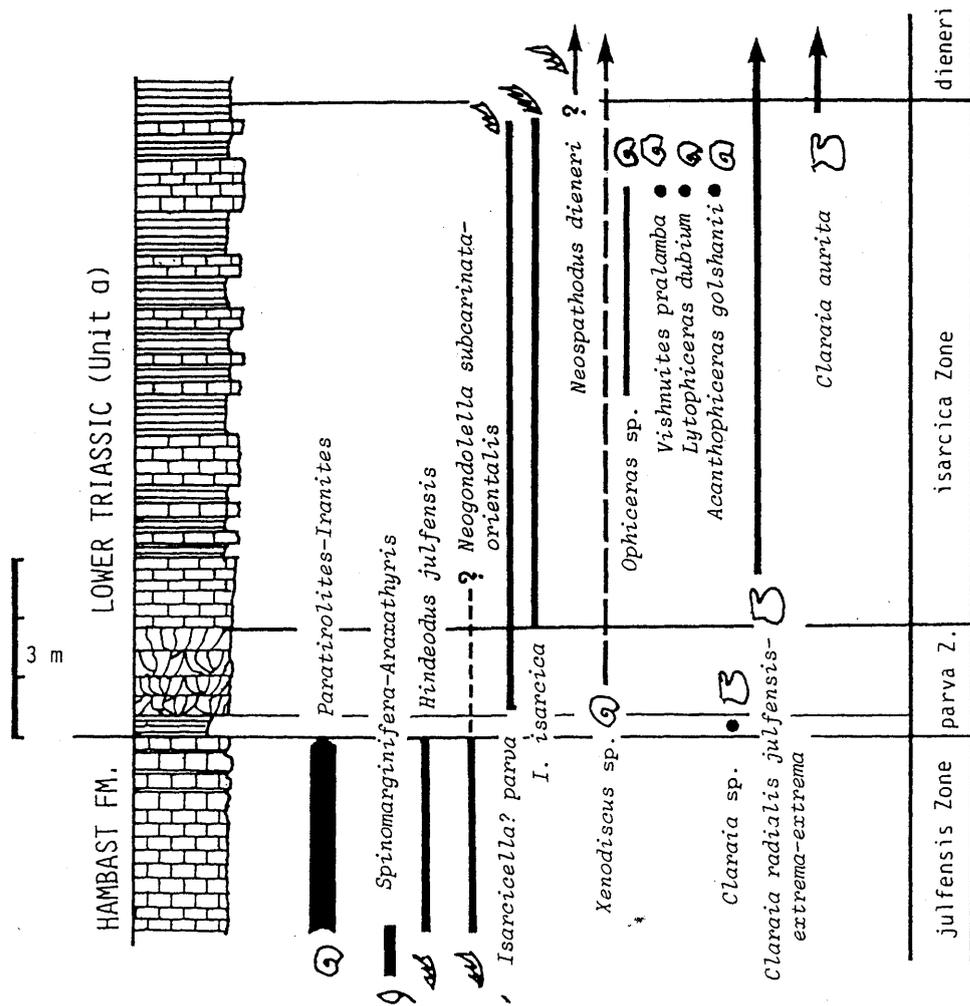


Fig. 2 Uppermost Permian and Lower Triassic sequence in Abadeh region, Central Iran, showing range chart of significant fossils (adapted from Iranian-Japanese Research Group, 1981). by Nakazawa, 1993

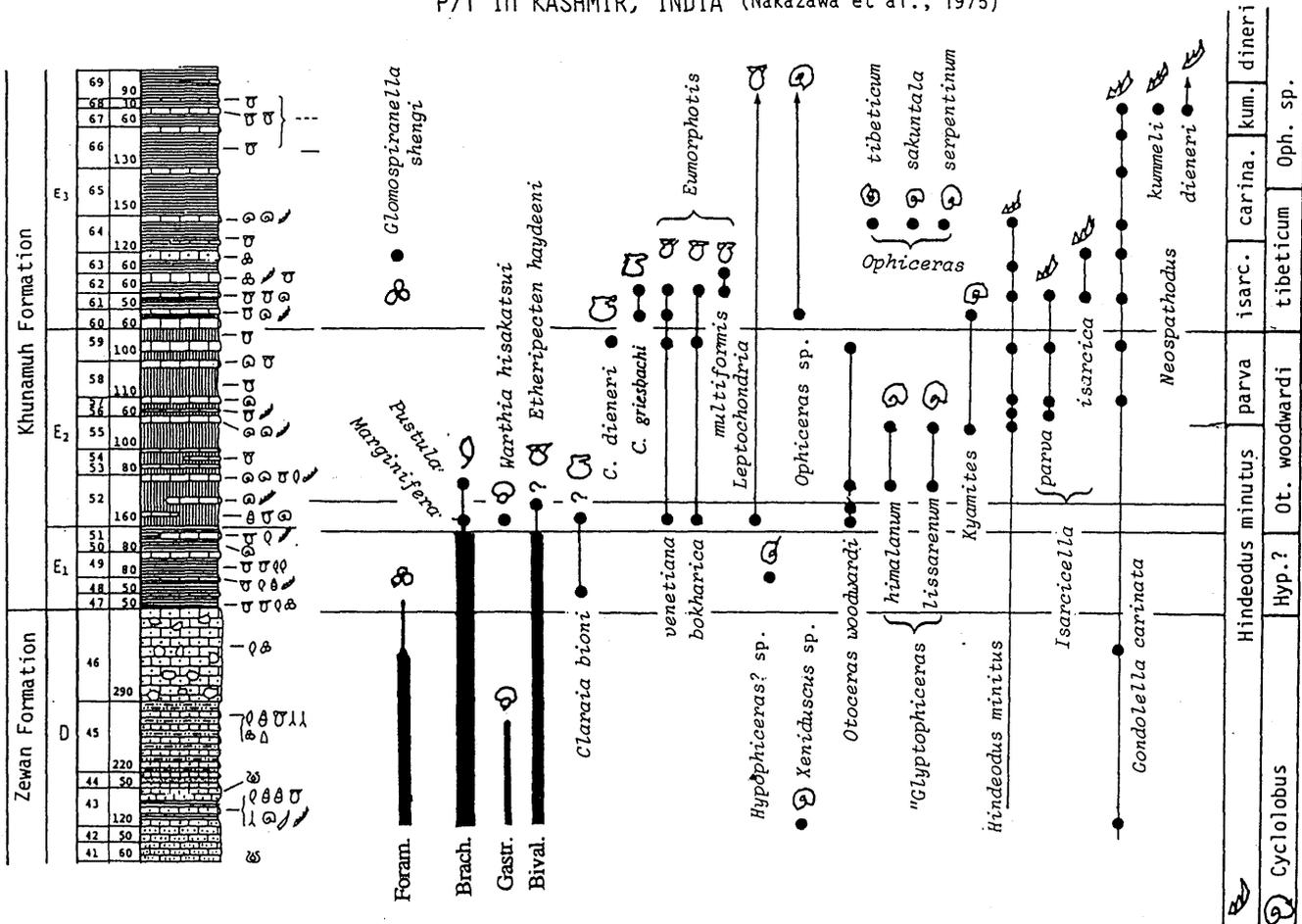


Fig. 4 Columnar section and range chart of fossils of uppermost Zewan Formation and lower part of Khunamuh Formation in Kashmir, India (adapted from Nakazawa et al., 1975). by Nakazawa, 1993

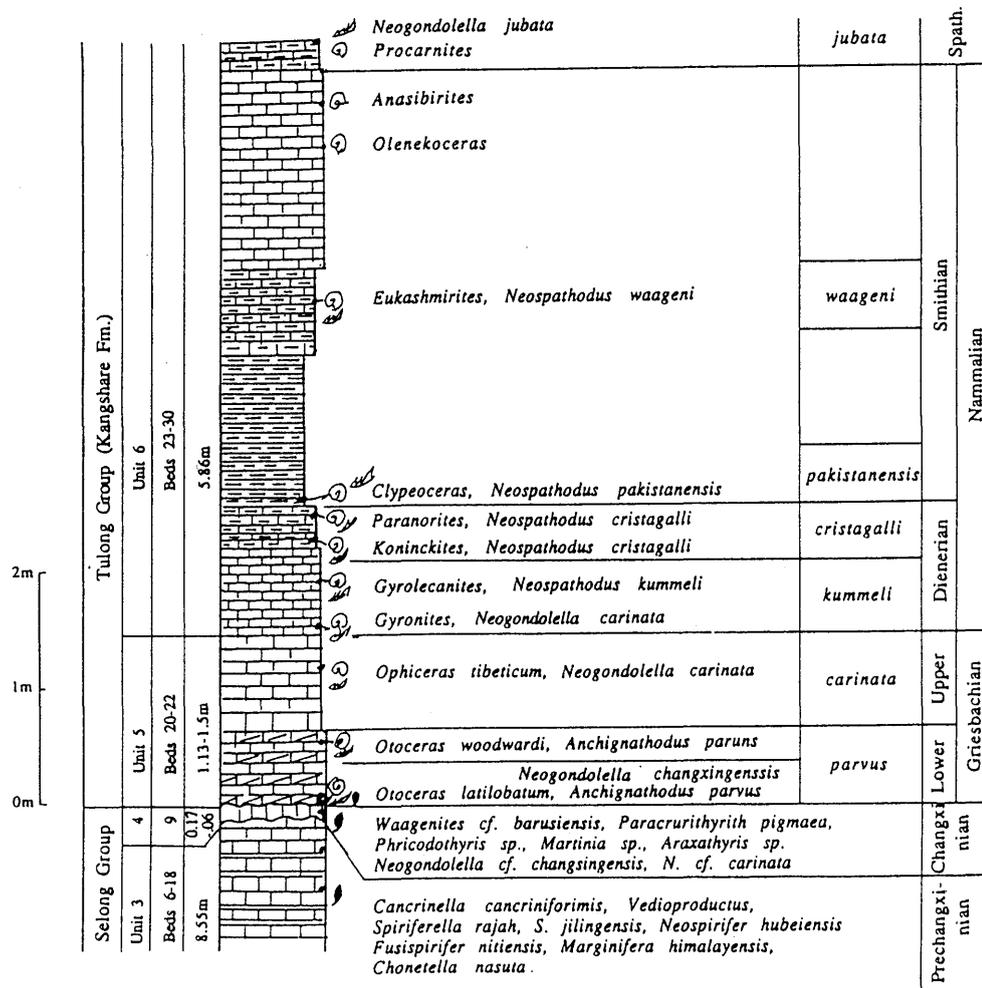


Fig. 5 Columnar section of Permian-Triassic transition beds in Selong-Xishan area, South Tibet (made from Wang *et al.*, 1989). by Nakazawa, 1993

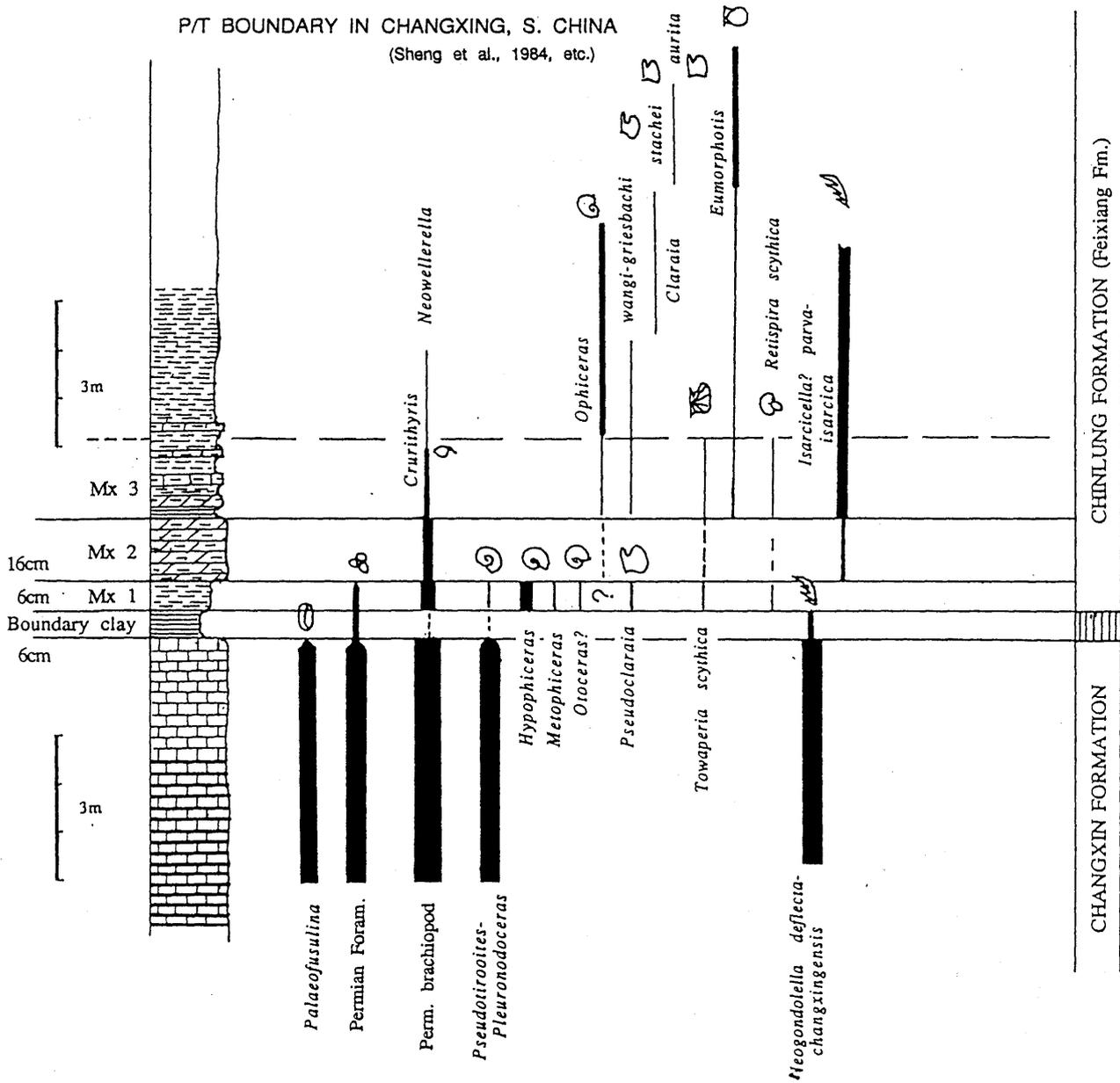


Fig. 6 Columnar section and range chart of representative fossils or fossil groups of Uppermost Changxing Formation and lowermost Chinlung Formation at Meishan in Changxing area, South China (made from Sheng *et al.*, 1984) by Nakazawa, 1993

調査地点位置図 (2)



機械ボーリング
(オールコア: φ86)



コアドリル

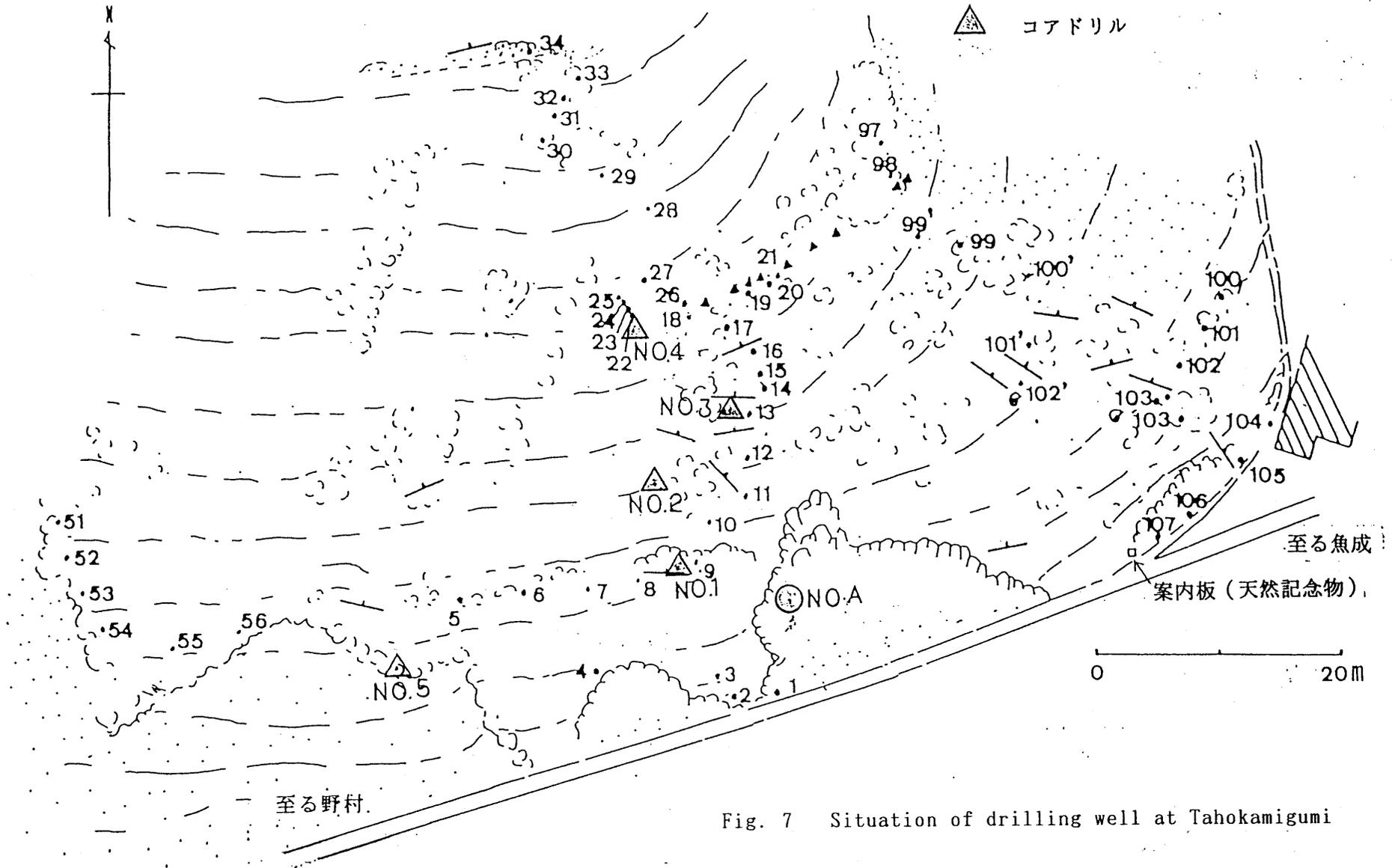
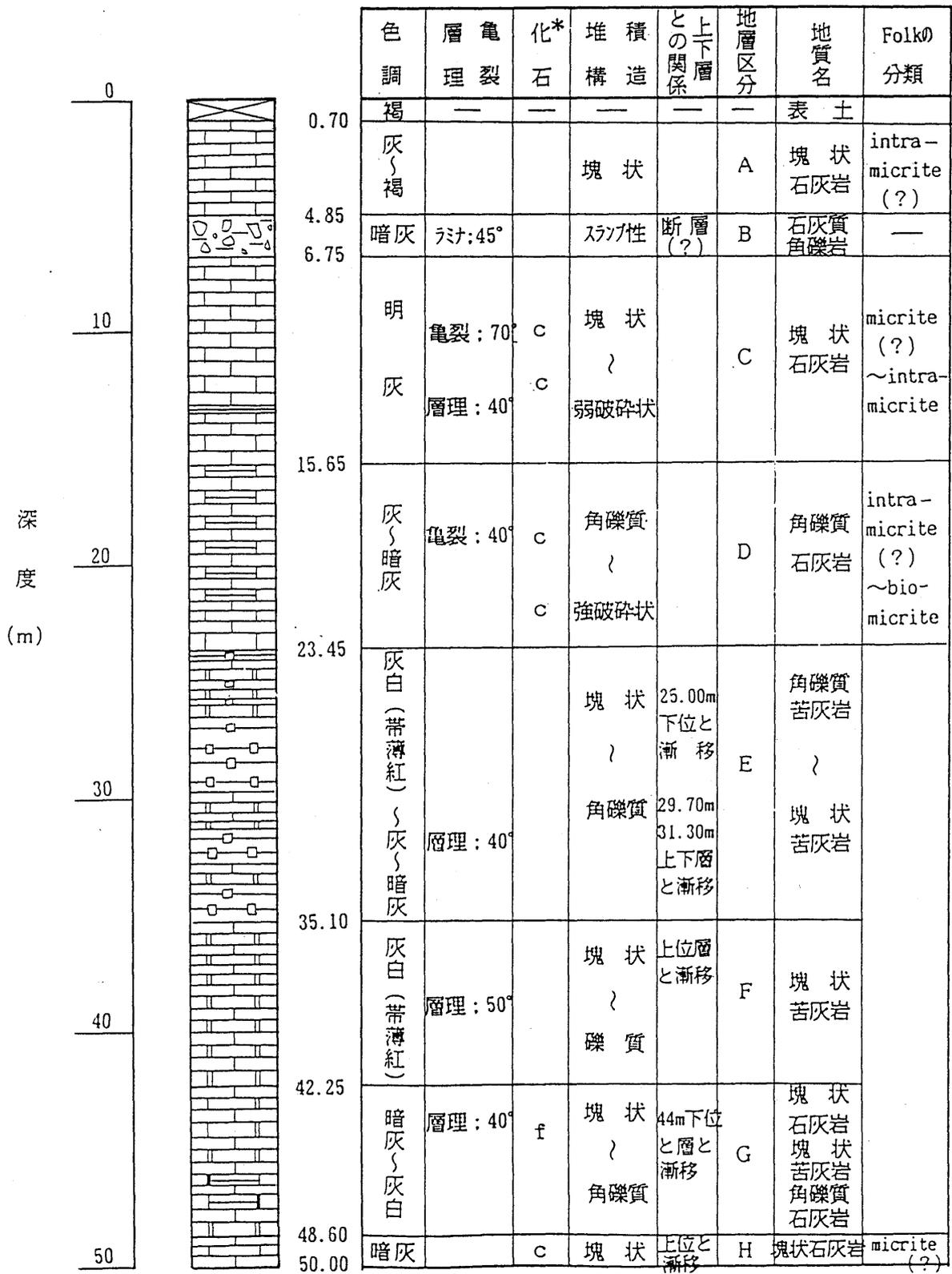


Fig. 7 Situation of drilling well at Tahokamigumi



* c: コノドント
f: 有孔虫(?)

Fig. 8 Columnar section of drilling core (by Umezawa, 1993)

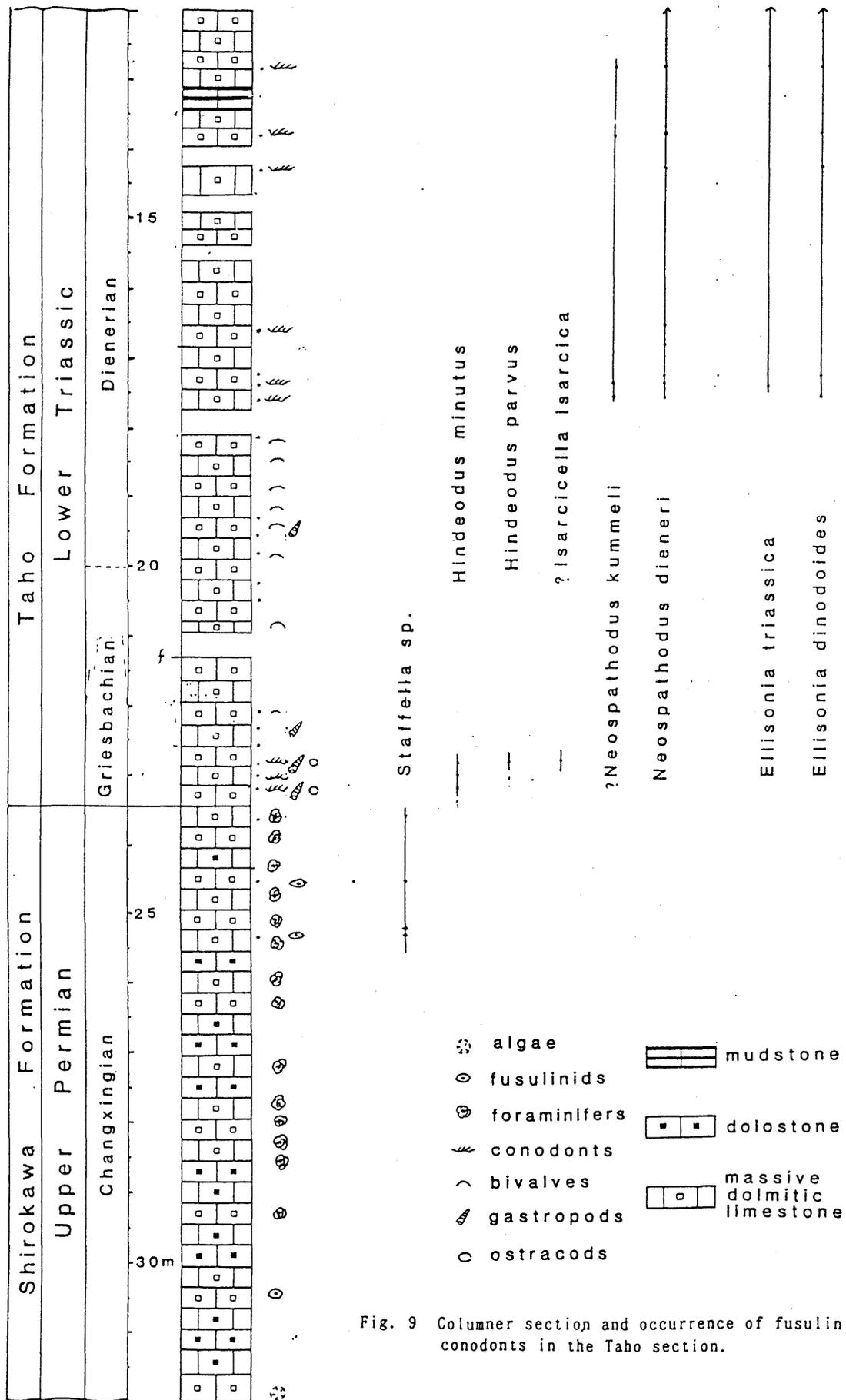


Fig. 9 Columnar section and occurrence of fusulinids and conodonts in the Tahoe section.

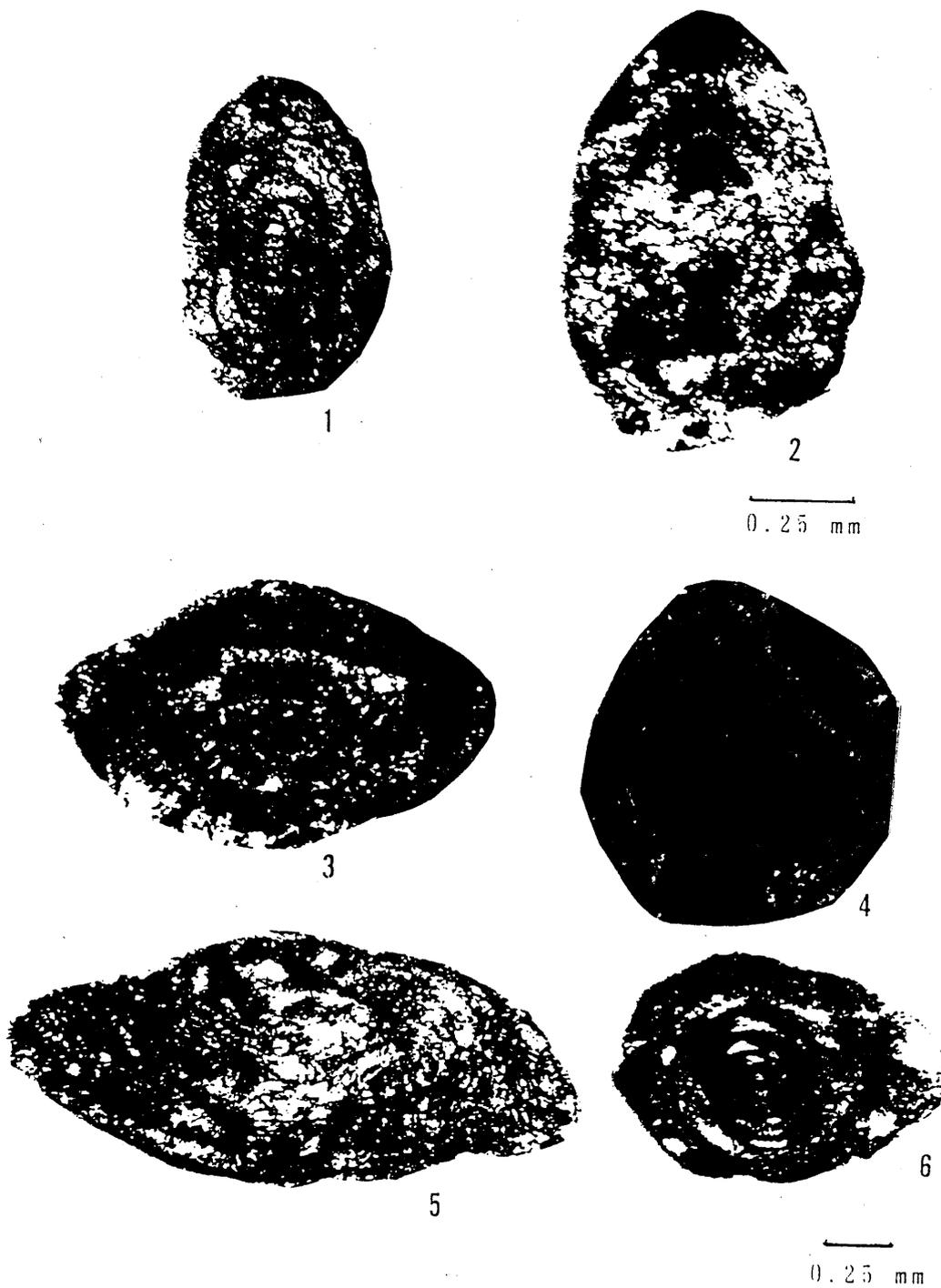
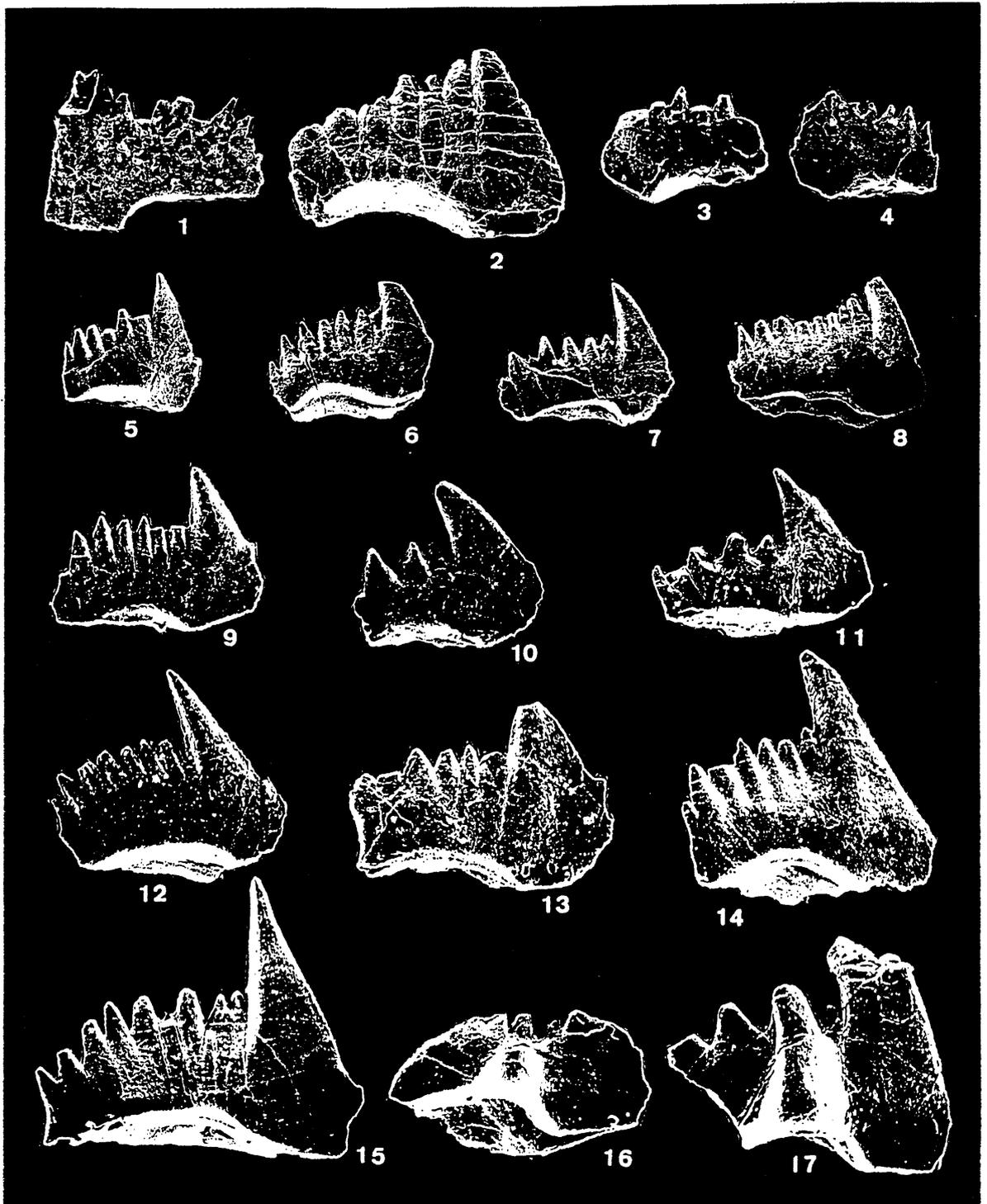
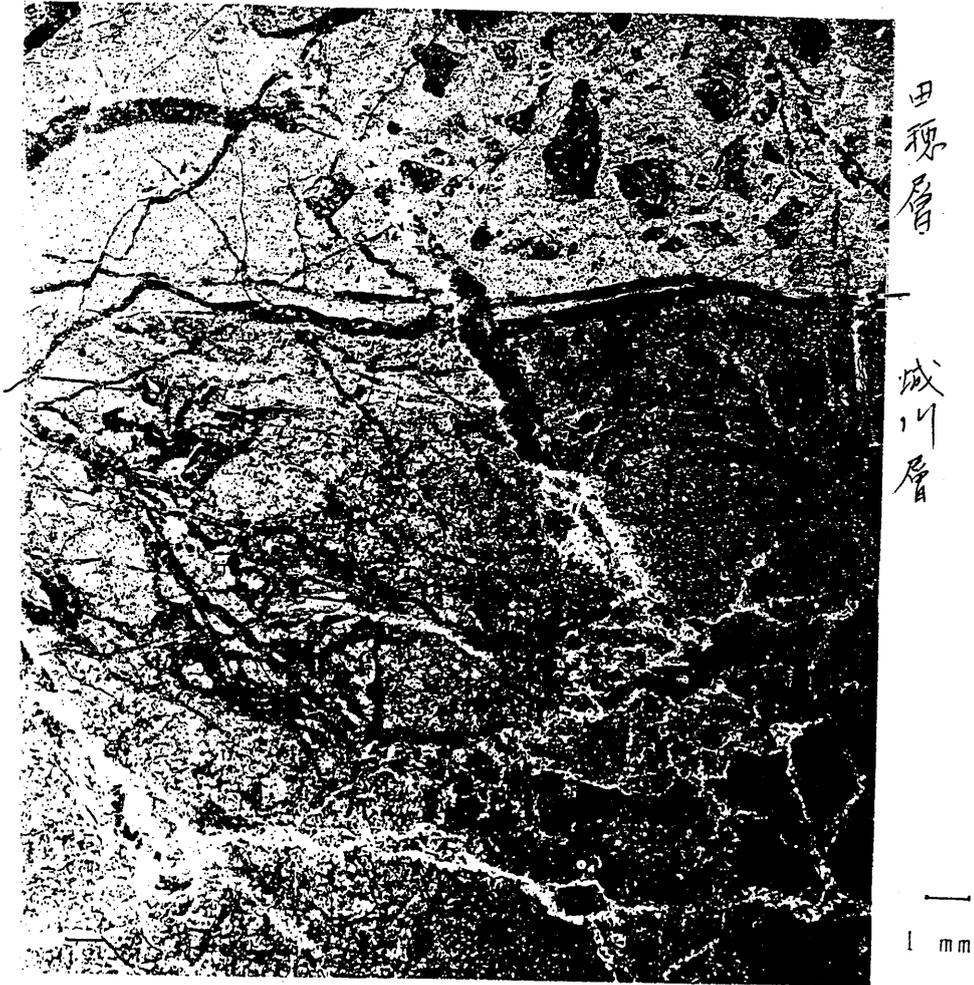


Fig. 10 Fusulinids from the Taho and Kamura section.
1, 2. *Staffella* sp. from the Shirokawa Formation,
3-5, *Dunbarula* sp. 6. ?*Leella* sp. from the Mitai Formation.



0.1 mm

Fig. 11 Conodonts from the Tahoe and Kamura section. 1,2. *Hindeodus minutus*, 1. from the Tahoe Formation, 2. from the Kamura Formation. 3-15. *Hindeodus parvus* 3, 4. from the Tahoe Formation. 5-15. from the Kamura Formation. 16-17. *Isarcicella isarcica* from the Kamura Formation.



Boundary between Permian dolostone and Triassic dolomitic limestone with breccia of dolostone -23.45 m

Fig. 12 Photomicrographs of boundary of the Shirokawa and Taho Formations at Tahokamigumi

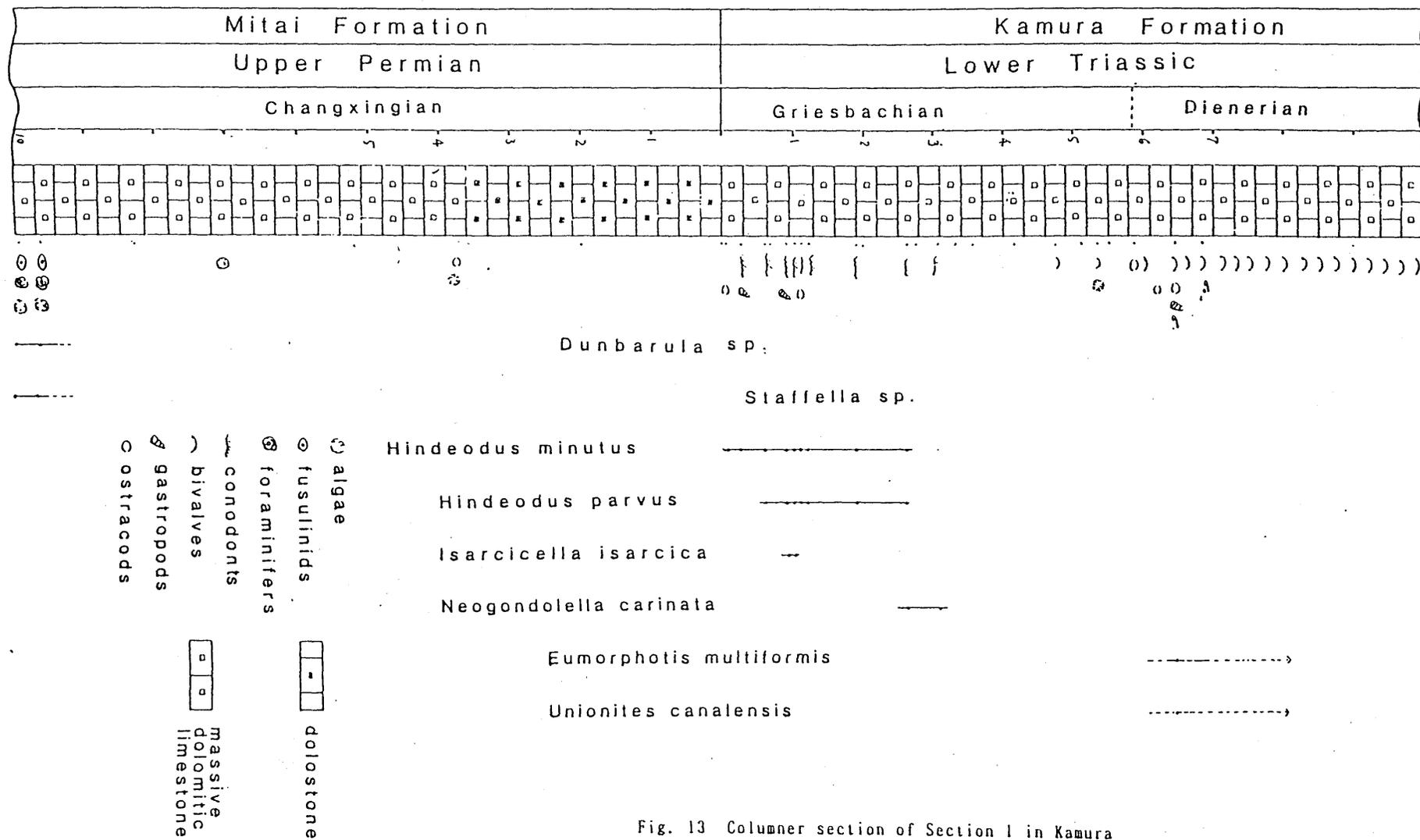
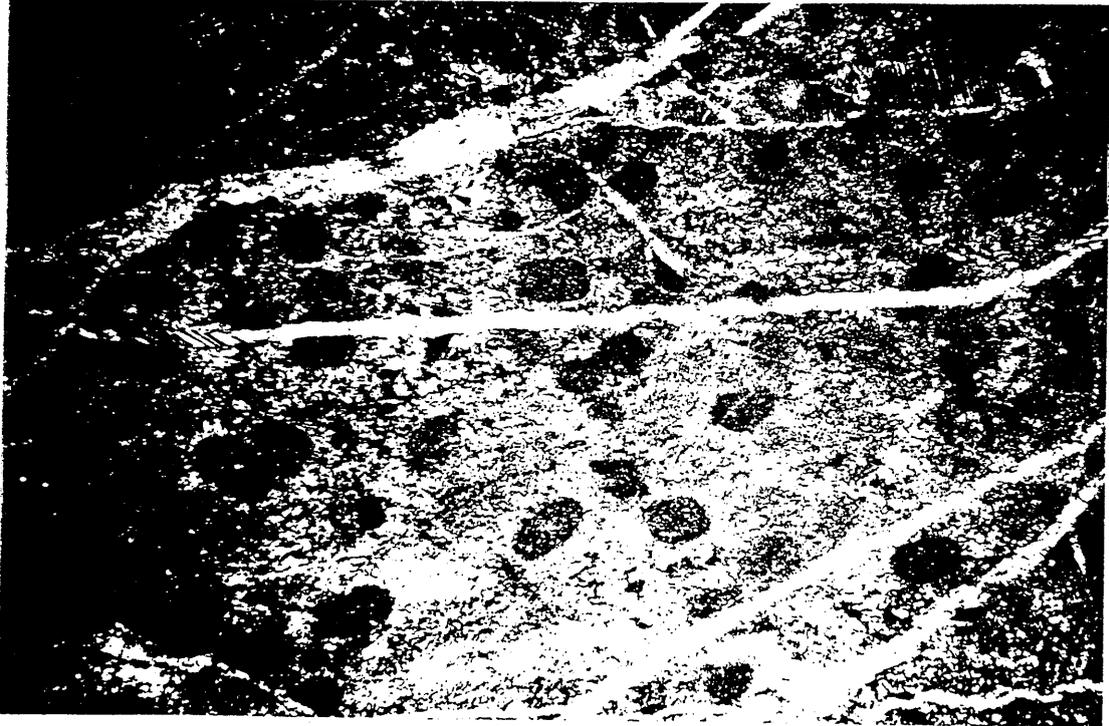
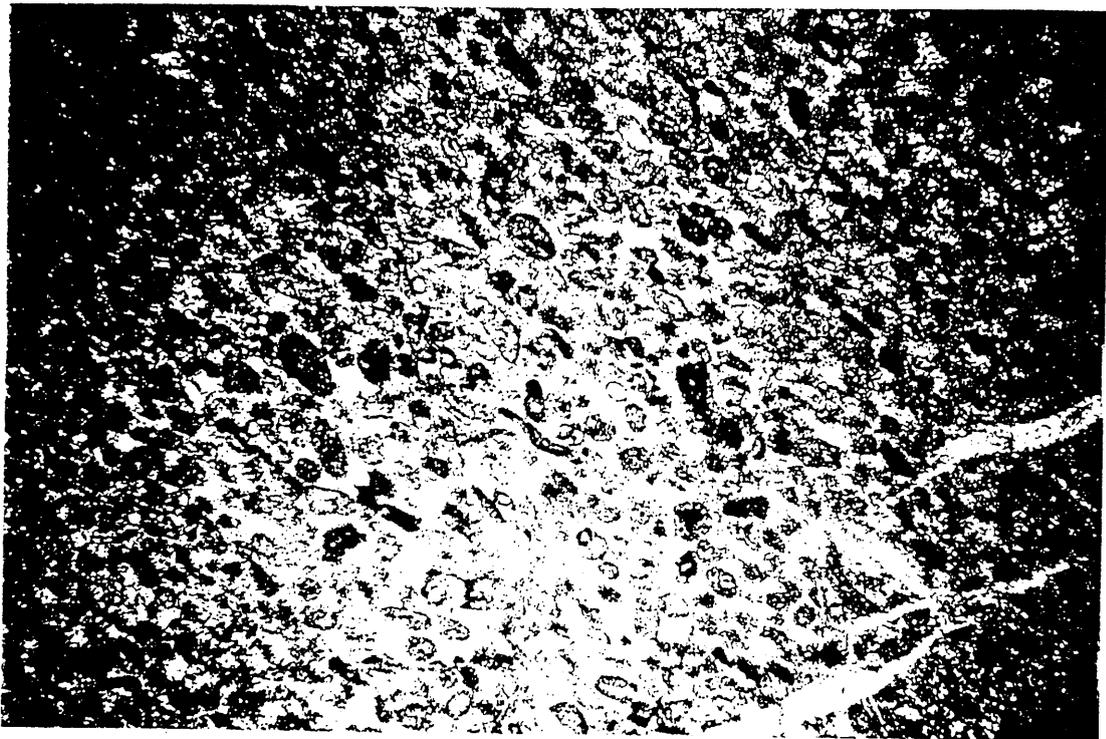


Fig. 13 Columnar section of Section 1 in Kamura



micritic limestone with pellet Loc.617

1 mm



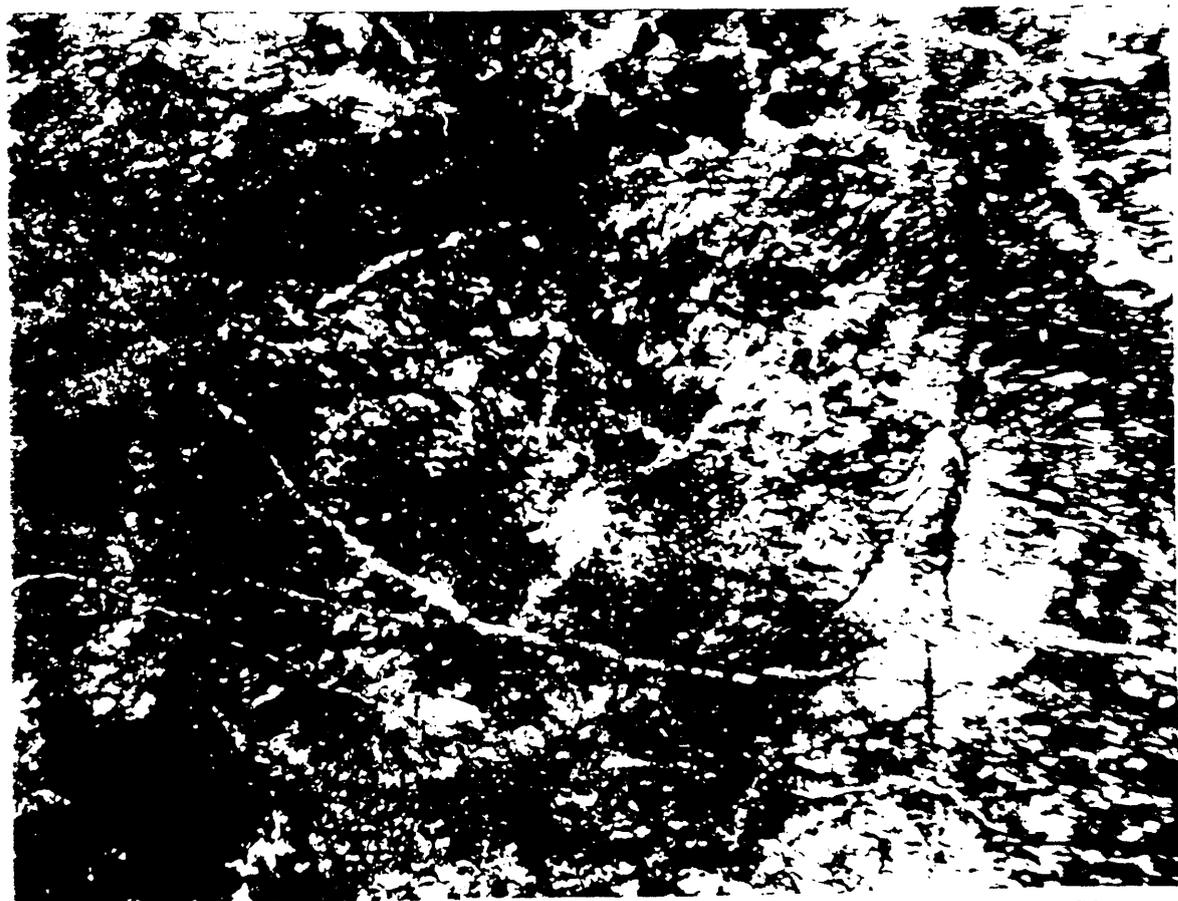
micritic limestone with algae and pellet Loc.300

1mm

Fig. 14 Photomicrographs of limestone of the Mitai Formation
at Shioinousou



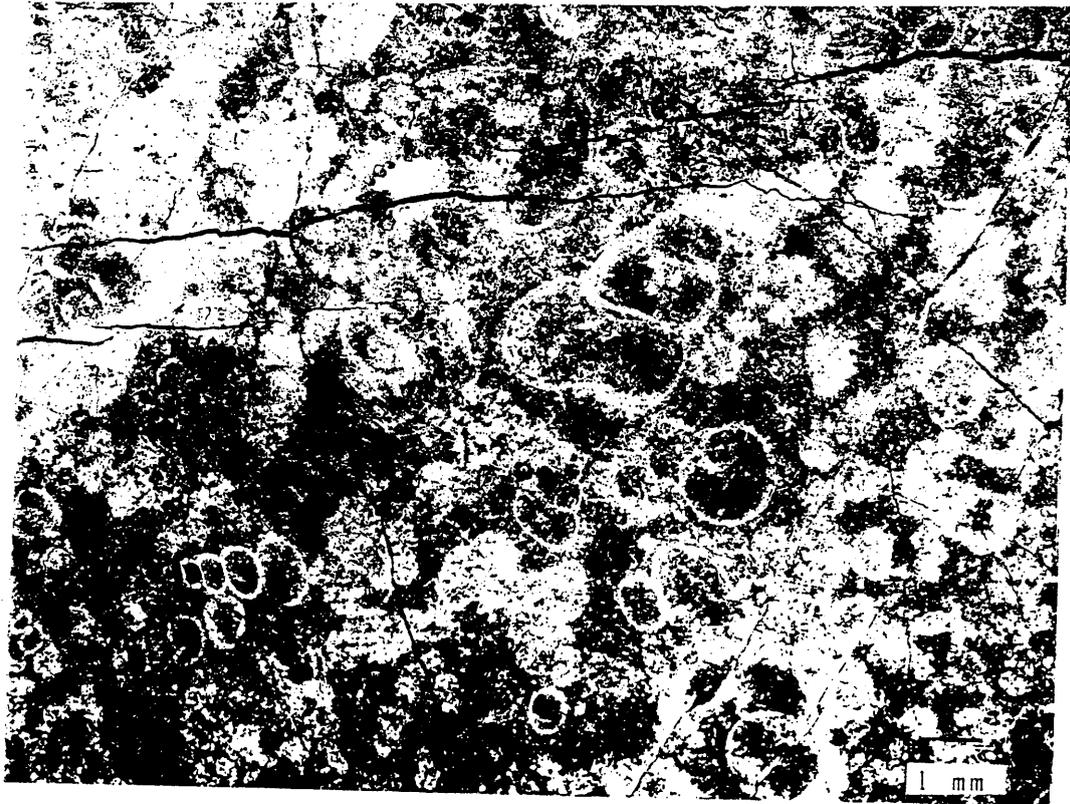
micritic limestone with gastropods, bivalves, and ostracods Loc. 600



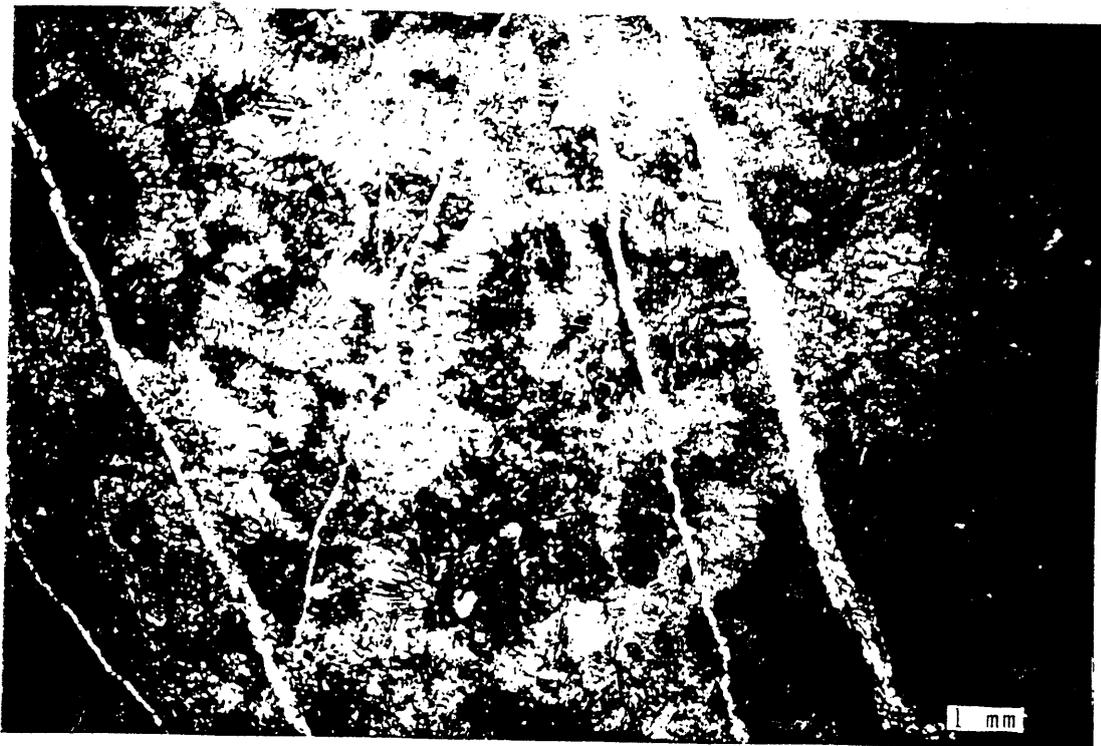
dolomitic limestone with algae Loc. 602

1 mm

Fig. 15 Photomicrographs of limestone at basal part of the
Kamura Formation at Shoinousou



dolomitic limestone with gastropods Loc. 441-8 up G



Loc. 441-8 up G

Fig. 16 Photomicrographs of limestone at basal part of the
Kamura Formation

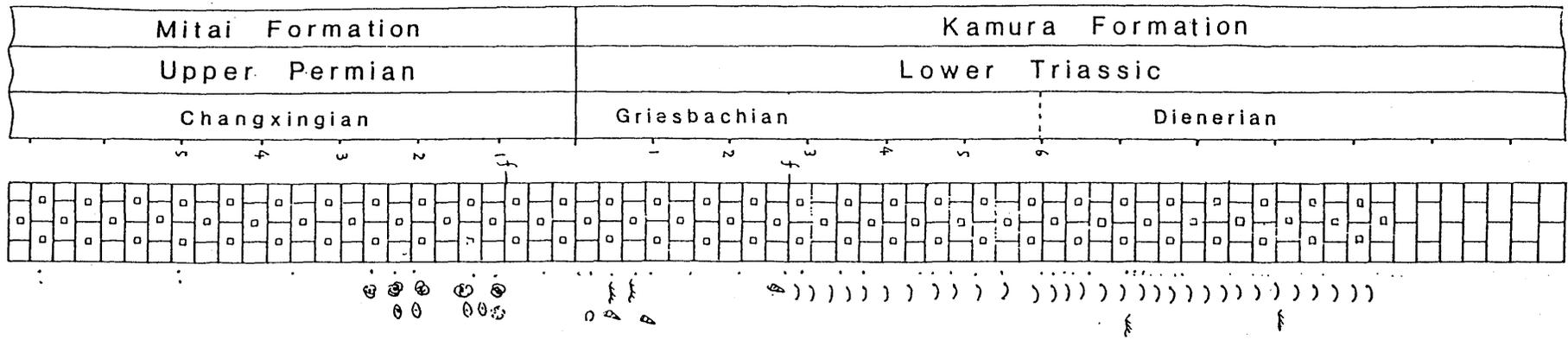
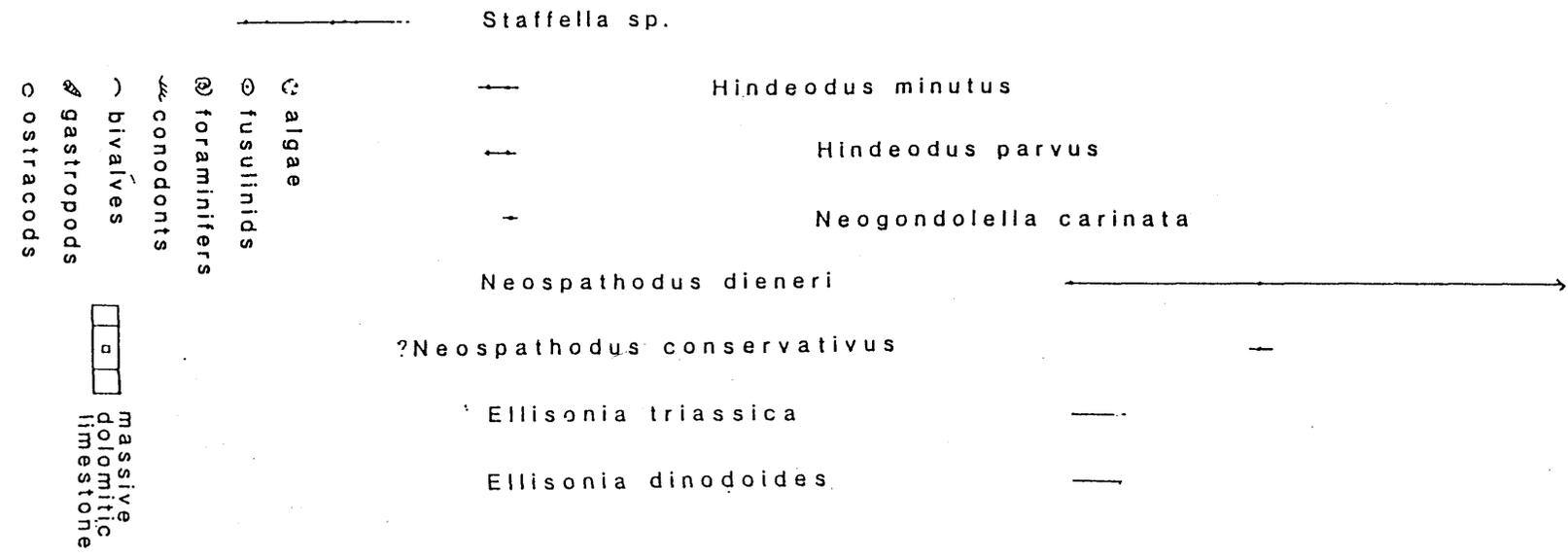


Fig. 17 Columnar section of Section III in Kamura

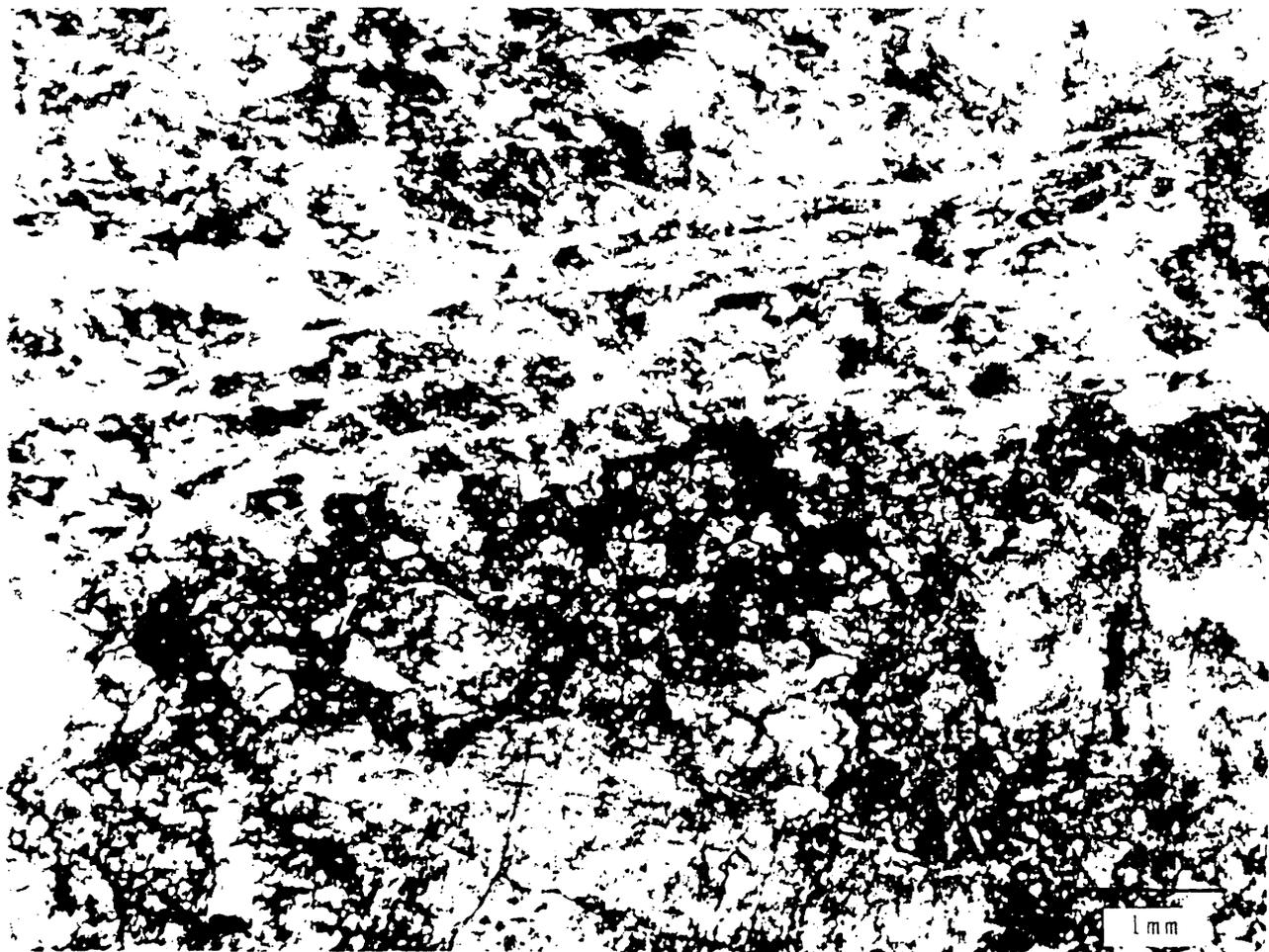




上村層

三田井層

1 mm



上村層

三田井層

1 mm

Boundary between Permian dolostone and Triassic dolomitic limestone

Fig. 18 Photomicrographs of boundary of the Mitai and Kamura Formations (Loc. 612)

Formations